Pennsylvania RGGI Modeling Report

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Introduction

Historically, the electricity generation sector has been the leading source of Carbon Dioxide (CO_2) emissions in Pennsylvania. Based upon data contained in the Department of Environmental Protections (DEP or Department) 2020 GHG Inventory, 29% of Pennsylvania's total GHG emissions are produced by the electricity generation sector. In recent years, Pennsylvania has seen a shift in the electricity generation portfolio mix, resulting from market forces and the establishment of alternative energy goals, and energy efficiency targets. Since 2005, Pennsylvania's electricity generation has shifted from higher carbon-emitting electricity generation sources, such as coal, to lower and zero emission generation sources, such as natural gas, wind and solar. At the same time, overall energy use in the residential, commercial, transportation, and electric power sectors has decreased.

However, looking forward, the Department projects CO_2 emissions from the electricity generating sector will increase due to reduced fuel switching from coal to natural gas, the potential closure of zero carbon emitting nuclear power plants, and most significantly the addition of fossil-fuel fired capacity in Pennsylvania.

The Department's Climate Action Plan[1] predicts that total and net GHG emissions (including emissions sinks) will increase by 4% and 5%, respectively, from 2015 to 2050. Additionally, the most recent GHG Inventory[2] indicates that after years of declines, in 2017 GHG emissions in Pennsylvania increased, widening the gap between current emissions and reductions necessary to avoid the worst impacts of climate change.

It is for these reasons that on October 3, 2019, Governor Wolf signed Executive Order 2019-07, *Commonwealth Leadership in Addressing Climate Change through Electric Sector Emissions Reductions,* which directed the Department to use its existing authority to develop a rulemaking to abate, control or limit CO_2 emissions from fossil fuel-fired electric power generators. As directed by the Executive Order, the Department is proceeding to establish a program that includes a CO_2 budget consistent in stringency to that established by the states participating in the Regional Greenhouse Gas Initiative (RGGI), provides for the annual or more frequent auction of CO_2 emissions allowances through a market-based mechanism, and is sufficiently consistent with the RGGI Model Rule such that allowances may be traded with holders of allowances from other states.

RGGI is a cooperative regional market-based cap-and-trade program designed to reduce CO_2 emissions from fossil fuel-fired power plants. RGGI is currently composed of ten northeastern states, including Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island and Vermont, with Virginia expected to join in January 2021. Since its inception on January 1, 2009, RGGI has utilized a market-based mechanism to cap and cost-effectively reduce CO_2 emissions that cause climate change. Because CO_2 from large fossil fuel-fired power plants is a major contributor to regional

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[1] Pennsylvania Department of Environmental Protection, 2018 Pennsylvania Climate Action Plan: Strategies and actions to reduce and adapt to climate change, April 29, 2019, http://www.depgreenport.state.pa.us/elibrary/GetDocument?docId=1454161&DocName=2018%20PA%20CLIMATE%20ACTION%20PLAN.PDF%20%20%20%3cspan%20style%3D%22color:blue%3b%22%3e%28NEW%29%3c/span%3e

[2] Pennsylvania Department of Environmental Protection, 2019 Pennsylvania Greenhouse Gas Inventory Report, December 2019, http://files.dep.state.pa.us/Energy/Office%20of%20Energy%20and%20Technology/OETDPortalFiles/Climate%20Change%20Advisory%20Committee/2019/12-20-19/FINAL%20Inventory%20-%202019_2019-12-20.pdf.

climate change, the participating states developed a regional approach to address CO_2 emissions. This regional approach resulted in a Model Rule applicable to fossil fuel-fired power plants with a nameplate capacity equal to or greater than 25 Megawatts. RGGI is implemented in the participating states through each state's independent CO_2 Budget Trading Program regulations, based on the Model Rule, which link together.

RGGI is a "cap and trade" program that sets a regulatory limit on CO_2 emissions from fossil fuel-fired power plants and permits trading of CO_2 allowances to effect cost efficient compliance with the regulatory limit. RGGI is also referred to as a "cap and invest" program, because unlike traditional cap and trade programs, RGGI provides a "two-prong" approach to reducing CO_2 emissions from fossil fuel-fired power plants. The first prong involves a declining CO_2 emissions budget and the second prong is investment of the proceeds resulting from the auction of CO_2 allowances to further reduce CO_2 emissions.

Developing a cap and invest program is necessary to ensure CO_2 emissions continue to decrease and at a rate that shields Pennsylvania from the worst impacts of climate change. RGGI plays an important role in providing a platform whereby Pennsylvania can reduce CO_2 emissions using a market-based approach. As the electricity generation sector remains one of the leading sources of CO_2 in Pennsylvania, it is imperative that emissions continue to decrease from that sector.

In order to analyze the full extent of CO_2 emission reductions due to Pennsylvania's participation in RGGI, the Department hired an expert modeling consultant, ICF International, Inc., to determine potential impacts to both the power sector and Pennsylvania's overall economy.

The following report provides a detailed explanation of modeling processes, assumptions, inputs, and outputs to provide a broad understanding of the results. In addition to this summary report, the Department has posted all of the modeling results and two public webinars providing further explanation of key results on the Department's RGGI webpage located at www.dep.pa.gov/RGGI.

Approach

This section provides an overview of the scenarios (including the Reference, Policy, and revenue recycling cases (Policy + Investments), as well as a description of the IPM and REMI models, process, and assumptions.

Overview

The analytical approach used to model the impacts of Pennsylvania participation in the Regional Greenhouse Gas Initiative on the Commonwealth consisted of two steps. First, DEP modeled the effects of the cap-and-invest program on the power sector using the Integrated Planning Model (IPM®). IPM is a multi-region model that determines capacity expansion plans, unit dispatch and compliance decisions, as well as power, coal and allowance price forecasts, all of which are based on power market fundamentals. IPM is a proprietary model developed by ICF for power sector analysis. IPM is also the same platform used by Environmental Protection Agency's (EPA's) Clean Air Markets Division for analyzing air policy scenarios. The results have been used in EPA's as the basis for several EPA regulatory initiatives. ICF has used the IPM platform for several other clients including Edison Electric Institute which is the association that represents all U.S. investor-owned electric companies.

Once the outputs from IPM were received, along with other economic data, DEP modeled the macroeconomic impacts of those power sector changes on the overall state economy using a customized version of the REMI Policy Insight Plus model. The REMI Policy Insight Plus model is used by government agencies (including most U.S. state governments), consulting firms, nonprofit institutions, universities, and public utilities to forecast economic impacts of policy decisions.

Model simulations estimate comprehensive economic and demographic effects in wide-ranging initiatives, such as: economic impact analysis; policies and programs for economic development, infrastructure, environment, energy and natural resources; and state and local tax changes. Articles about the model equations and research findings have been published in professional national journals, including the American Economic Review, The Review of Economic Statistics, the Journal of Regional Science, and the International Regional Science Review. The sections below describe the approaches used for both the IPM and REMI modeling.

Scenario Overview

This section describes the scenarios developed for modeling purposes both in IPM (power sector) and REMI (macroeconomic). The time horizon for the IPM analysis was 2019-2030, with reporting years of 2020, 2022, 2025, 2028, and 2030.

IPM Reference Case

The Reference Case represents a business-as-usual case in which Pennsylvania does not join RGGI. In the Reference Case, RGGI was modeled as an 11-state program including Massachusetts, Connecticut, Maine, New Hampshire, Rhode Island, Vermont, New York, Delaware, and Maryland. New Jersey and Virginia were modeled to join the program in 2020 and 2021, respectively. New Jersey's starting allowance budget was input at 18 million short tons, and Virginia joins with an allowance budget of 27.16 million short tons.

IPM Policy Case

The IPM Policy Case uses similar assumptions as the Reference Case with the key difference that it assumes that Pennsylvania begins participation in RGGI beginning on January 1, 2022. As shown in Table 1, the allowance budget for Pennsylvania's entrance in 2022 is 78 million short tons of CO_2 which declines by 25.5% to just over 58 million tons by 2030. In the Policy Case, Pennsylvania's allowance budget is added to the allowance budgets of the other RGGI states to calculate the RGGI program cap. Pennsylvania's allowance budget includes a 9.3-million-ton allowance set-aside for generators burning waste coal.

TABLE 1. PENNSYLVANIA ALLOWANCE BUDGET

Year	Budget (Short Tons CO_2)
2022	78,000,000
2023	75,510,630
2024	73,021,260
2025	70,531,890
2026	68,042,520
2027	65,553,150
2028	63,063,780
2029	60,574,410
2030	58,085,040

IPM Policy + Investment Case

The third modeling case includes the Policy Case parameters and also includes the investments of allowance revenue, called the Policy + Investments case (or Adjusted Policy case). Three allowance revenue recycling scenarios were considered for the analysis: the balanced scenario where the allowance revenues were split roughly equally amongst the three main categories of investments (see Table 2), recycling of investments in similar proportion to Maryland's historical revenue allocation (called Bill Assistance in Table 2); and a scenario with a majority of revenue going to Pennsylvania's General Fund. For each scenario, it was assumed that 6% of revenues would be set-aside for programmatic costs. Since the beginning of RGGI, the participating states have averaged approximately 5% for administering the programs and provided 1% to RGGI Inc. for administrative and technical support including auction management and market monitoring. Additional revenue categories are described below with more detail on each category in Section 4.3. These scenarios were outlined as potential investment options strictly for the purposes of modeling and do not reflect a commitment for funding from allowance auction proceeds. Those general categories are as follows :

- Energy Efficiency – investments in electric and fossil fuel energy efficiency
- Clean and Renewable Energy – investments in utility scale solar, wind, low-impact hydro, distributed solar, and biogas digesters
- Greenhouse Gas (GHG) Abatement – investments in electric vehicles and research and development for carbon capture, utilization, and storage (CCUS)
- Direct Bill Assistance – discounts on low-income household electric bills
- General Fund – payments used by the Pennsylvania general fund to reduce service payments on financed debt

It is important to note that the investment scenarios modeled in this case are not spending commitments by the Department. These scenarios were selected to provide a reasonably wide range of potential impacts of different investment scenarios that could result from this regulation. There will be a widespread stakeholder engagement effort to develop a comprehensive investment plan prior to implementation of the regulation.

TABLE 2. REVENUE ALLOCATION BY SCENARIO

Scenarios	Admin	Efficiency	Renewables	GHG Abatement	Bill Assistance	General Fund
Proportional Allocation						
Balanced Approach	6%	31%	32%	31%	-----	-----
Bill Assistance	6%	30%	8%	7%	49%	-----
General Fund	6%	10%	5%	10%	-----	69%
*Monetary Allocation (Million 2017$)**						
Balanced Approach	$15.65	$80.87	$83.48	$80.87	-----	-----
Bill Assistance	$15.65	$78.26	$20.87	$18.26	$127.83	-----
General Fund	$15.65	$26.09	$13.04	$26.09	-----	$180.00

Based on average annual allowance revenue of $261 million from 2022-2030.

Investments from revenue recycling have feedbacks with the electricity market. Using assumptions discussed in Section 4.3 annual electricity savings from investments in electric energy efficiency, distributed solar, and biogas digesters were modeled as reduced load in a

Policy + Investments case scenario in IPM. Investments in the clean and renewable energy category were used to incentivize additional utility scale generation sources for solar, wind, and low-impact hydro. Additional capacity additions stemming from these investments were also used in the Policy + Investments case IPM scenario. The resulting 9-year cumulative electricity demand reductions and capacity additions are presented below in Table 3. The Policy + Investments case IPM scenario was run once using the Balanced Approach scenario values and used to extrapolate results for other revenue recycling scenarios.

TABLE 3. SCENARIO COMPARISONS

Scenario Comparisons (Based on 2022-2030)	Balanced Approach	Bill Assistance	General Fund
Total 9-year Energy Efficiency (EE) Savings (GWh)*	10,940	10,588	3,529
Total 9-year Distributed Generation (DG) Solar Savings (GWh)	11,029	2,757	1,723
Total 9-year Biogas Saving (GWh)	5,852	1,463	914
Total Demand Reduction (GWh)	**27,822**	**14,808**	**6,167**
Total Utility Scale Solar Capacity (MW)	7,605	1,896	1,185
Total Wind Capacity (MW)	932	232	145
Total Low-impact Hydro Capacity (MW)	255	64	40
Total Renewable Capacity Additions (MW)	**8,792**	**2,192**	**1,370**

*Electricity load reductions displayed as EE savings.

IPM

This section describes the IPM model and discusses the modeling process used including various assumptions developed by DEP for modeling purposes.

Model Overview

IPM is a dynamic linear programming model that generates optimal decisions under the assumption of perfect foresight. It determines the least-cost method of meeting energy and peak demand requirements over a specified period. In its solution, the model considers several key operating or regulatory constraints that are placed on the power, emissions, and fuel markets. The constraints include, but are not limited to, emission limits, transmission capabilities, renewable generation requirements, and fuel market constraints. The model is designed to accommodate complex treatment of emission regulations involving trading, banking, and special provisions affecting emission allowances, as well as traditional command-and-control emission policies.

IPM represents power markets through model regions that are geographical entities with distinct operational characteristics. The model regions are largely consistent with the North American Electric Reliability Council (NERC) assessment regions, and with the organizational structures of the Regional Transmission Organizations (RTOs), and the Independent System Operators (ISOs) that handle dispatch on most of the U.S. electricity grid. Figure 1 below illustrates the key components of IPM.

FIGURE 1. IPM MODELING STRUCTURE

IPM represents the least-cost arrangement of electricity supply (capacity and generation) within each model region to meet assumed future load (electricity demand) while constrained by a transmission network of bulk transfer limitations on interregional power flows. All utility-owned existing electric generating units, including renewable resources, as well as independent power producers and cogeneration facilities selling electricity to the grid, are modeled.

IPM provides a detailed representation of new and existing resource options. These include fossil, nuclear, renewable, and non-conventional options. Fossil options include coal steam, oil/gas steam, combined cycles, and gas-fired simple cycle combustion turbines. Renewable options include wind, landfill gas, geothermal, low-impact hydropower, solar thermal, solar photovoltaic, and biomass. Non-conventional options include fuel cell and pump storage. IPM provides estimates of air emission changes, regional wholesale energy and capacity prices, incremental electric power system costs, changes in fuel use, and capacity and dispatch projections.

Another important structural feature of IPM is the use of model 'run years' to represent the full planning horizon being modeled. Although IPM can represent an individual year in an analysis time horizon, mapping each year in the planning horizon into a representative model run year enables IPM to perform multiple year analyses while keeping the model size manageable. IPM takes into account the costs in all years in the planning horizon while reporting results only for model run years.

For this analysis, the following run years were used: 2020, 2022, 2025, 2028, and 2030.

Process

ICF has supported several analyses of the RGGI program for RGGI Inc. and the member states over the past 15 years, and recently for Rutgers University (with analysis of New Jersey's participation) and the Georgetown Climate Center (with analysis of Virginia's participation). The analytical process for this Pennsylvania analysis was similar to those used to support that previous work using Pennsylvania specific assumptions. That process begins with the development of assumptions for a number of inputs that drive the projections from IPM, including electricity load and peak demand, fuel prices, cost and performance for generating capacity types, and policy assumptions, such as the representation of the RGGI cap and trade program and state renewable portfolio standards (RPS). Typical assumptions also include firm build and retirement assumptions, which are units specified in IPM to either build or retire. For this analysis, DEP specified the sources for these assumptions, as detailed in the following section, based on publicly available information and sources adopted for previous RGGI analyses.

Following specification of the assumptions, ICF inputs the assumptions in IPM and uses the model to generate projections. The results provided include changes in generation capacity and generation mix; energy, capacity, and firm (energy plus capacity) power prices; renewable energy credit (REC) prices for relevant RPS programs; CO_2, SO_2, and NOx emissions; fuel consumption; and zonal transmission flows. IPM also provides projections of RGGI program behavior, including emissions from affected sources, the amount of ECR or CCR allowances used in a year, allowance banking and withdrawals, and the projected allowance price.

As described earlier, ICF performed analysis of both a Reference Case, which did not include Pennsylvania in the RGGI program, and a Policy Case, which added Pennsylvania as a participating state starting in 2022. Previous RGGI studies have relied on a similar approach.

Assumptions Overview

The representation of the electric markets and the policies that impact them require specification of a range of assumptions, as noted above. Figure 2 summarizes the sources specified by the state for this analysis. Previous analyses of the RGGI program conducted by ICF have used similar sources, such as the U.S. Energy Information Administration’s Annual Energy Outlook, ISOs, and the National Renewable Energy Laboratory (NREL), a U.S. Department of Energy national laboratory, at the direction RGGI, Inc. and/or the other client organizations. In some cases, such as for firmly planned capacity additions or retirements, ICF provided an initial list of assumptions based on public announcements and other public sources, such as ISO queues, which are then reviewed and adopted by the State. In this case, the Department further refined that list based on whether projects met two out of three criteria including, fully funded, fully permitted, or had a power purchase agreement in place for the majority of the generation. Additionally, there are some issues that were not factored into the model as assumptions. Key examples of these include FERC’s Minimum Offer Price Rule (MOPR), the implementation of Phase IV of the Act 129 Energy Efficiency Program, and the sale and continued operation of the Colver Waste Coal Power Plant were not finalized at the time of modeling and not included in the assumptions.

FIGURE 2. ASSUMPTIONS OVERVIEW

Category	Source/Approach for Assumptions
Demand - Load and Peak Growth	ISO-NE - 2019 CELT Net PDR. Demand falls 0.63% from 2020 to 2030. NYISO – Includes adjustments for EE, PV, ZEV, HP, and Non-PV Behind the Meter DG. Demand falls 1.66% from 2020 to 2030. PJM - PJM 2020 Load Forecast with incremental EE adjustments in VA and NJ to account for state legislative mandates. Incremental BTM Solar adjustments were also made in NJ. PJM 2020 Load Forecast demand

Category	Source/Approach for Assumptions
	increases 2.81% from 2020 to 2030. Rest of US: ISO (as available) or EIA AEO 2020 regional growth rates.
Gas Prices at Henry Hub	Average of 2020 AEO Reference and High Gas Resource Cases
Build Costs - Renewables	EPA v6 adoption of NREL (2019 Annual Technology Baseline Study) capital costs; regionalized to account for cost differences by zone/state
Minimum Generation - NY	Assume minimum run time and oil burn for dual-fuel units in Zones J and K based on input from NYSERDA. The total MWhs of minimum generation declines over time consistent with the decline in load for each of the respective zones, maintaining the share of minimum generation as a percentage of load.
Minimum Generation - PJM (DE and MD)	DE - Minimum coal generation of 279 GWh in 2020
Minimum Generation - ISONE	NH - Minimum coal generation of 660 GWh in 2020 MA - Minimum coal generation of 393 GWh in 2020
Firm Capacity - NYISO	Latest information from NYISO and ICF
Firm Capacity – PJM (DE, MD, NJ and VA)	Latest information from PJM ISO and ICF
Firm Capacity – ISO-NE	Latest information from ISO-NE and ICF
Nuclear Lifetime	80 years, or as planned by owners
Renewable Portfolio Standards	RPS targets met in New England and PJM with state-level RPS implementation Fulfillment of NY 70-by-30 requirement RPS, including imports from Quebec
Offshore Wind Requirements	Based on input from the States and expectations based on state policies/announcements NY: 9,000 MW by 2035 MA: 3,200 MW; 2,400 by 2030 modeled CT: 2,000 MW by 2030 RI: 400 MW by 2030 MD: 1,568 MW by 2030 NJ: 3,500 MW by 2030 VA: 5,200 MW by 2034
Storage	Based on publicly announced storage targets as well as input from the RGGI states
Firm Transmission	New England Clean Energy Connect – 1200 MW from Quebec to New England in 2022

REMI

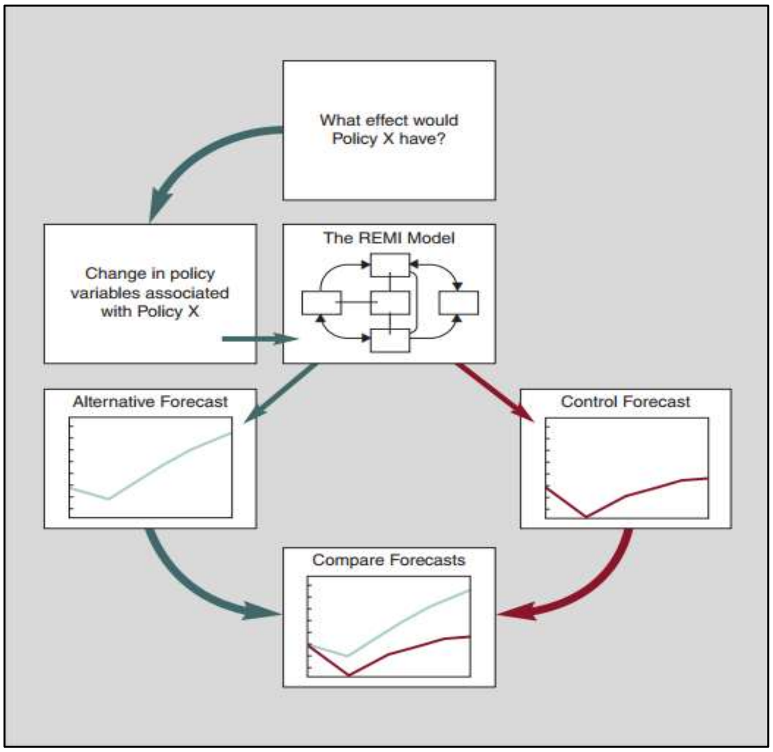
The economic impact modeling for the revenue recycling scenarios was conducted with a customized version of the REMI model. This section provides a brief background on the REMI model.

Model Overview

REMI's PI+ model is a structural economic forecasting and policy analysis model that integrates several analytic techniques including input-output (I-O), computable general equilibrium (CGE), econometric, and economic geography methodologies. REMI is a dynamic model, with forecasts and simulations to include behavioral responses to wage, price, and other economic factors. It can be used for estimating national, regional, and state-level impacts of policy changes. The dynamic modeling framework supports the option to forecast how changes in the economy, and adjustments to those changes, will occur on an annual basis.

REMI functions by forecasting two states of the world. The first is the state of the regional economy under some standard assumptions of employment and population changes. This first forecast is referred to as the control forecast. The second forecast, in which the model user incorporates the desired policy changes, is referred to as the alternative forecast or the simulation. A sample REMI workflow can be seen in Figure 3, with the policy changes reflected in policy variables, also called levers, in the alternate forecast and compared to the control forecast in the final stage. The difference between the two forecasts would be the estimated effect of the policy.

FIGURE 3. REMI WORKFLOW

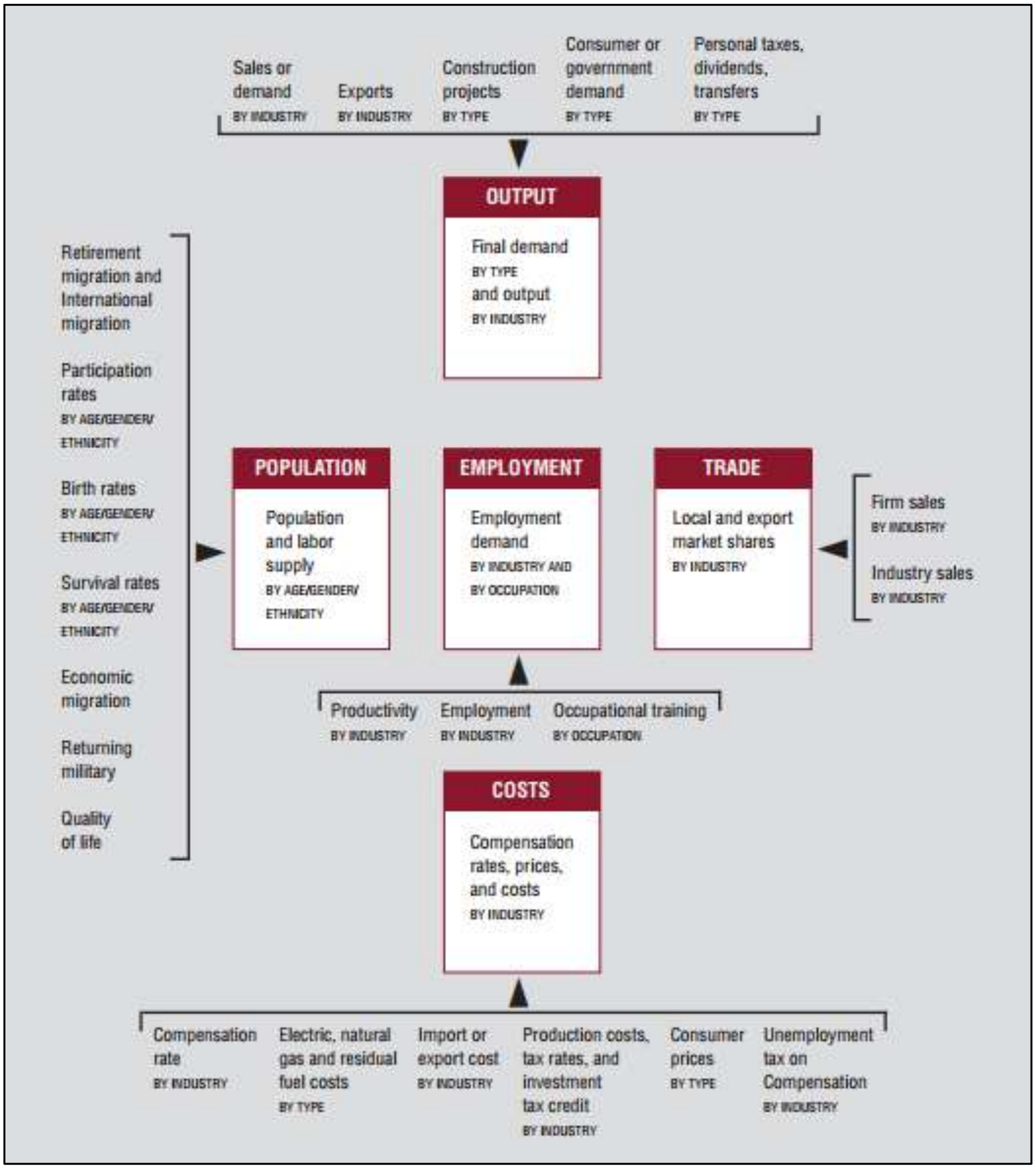


Source: REMI (2015).[3]

[3] REMI PI+ Brochure. http://ledsgp.org/wp-content/uploads/2015/10/REMI-Brochure.pdf

The REMI model projects the total economic effects of policy initiatives, as defined by changes in key policy variables such as change in output or prices (e.g., electricity or natural gas production and prices), investments (e.g., in energy efficiency or new capacity), and changes in production costs, among other variables. Figure 4 presents the broad policy variable categories that can be adjusted (often at the industry level) to reflect policy changes.

FIGURE 4. ADJUSTABLE POLICY VARIABLES IN REMI



Source: REMI (2015).[4]

The REMI models separate industry categories according to the North American Industry Classification System (NAICS). NAICS is the standard classification system for business establishments used by Federal agencies. When selecting a REMI model, the end user identifies the level of granularity required for the analysis. A 23-sector model would contain the

[4] REMI PI+ Brochure. http://ledsgp.org/wp-content/uploads/2015/10/REMI-Brochure.pdf.

industries separated at the 2-digit NAICS, while a 70-sector model would contain industries mapping to 3-digit NAICS (providing more granularity).

Key outputs include gross state product (GSP), disposable personal income, and employment impacts.

This analysis uses a one region (PA), 70-sector model of REMI PI+ version 2.3.5 to estimate the macroeconomic impacts.

Process

ICF used a variety of data sources in conducting this analysis. These sources included state-specific data provided by PADEP, supplemented with data from other sources, where required. Sources included the U.S. Energy Information Administration (EIA), the National Renewable Energy Laboratory (NREL), the Integrated Planning Model (IPM), the U.S. Census Bureau, and REMI.

The overall process for REMI modeling involves three broad set of inputs to the REMI model: investment changes from IPM, ratepayer impacts from IPM, and impacts from revenue recycling expenditures. Outputs of IPM consist of investments in new generation, retirements, and changes to variable and fixed operating and maintenance costs, fuel inputs, and price impacts. Ratepayer impacts from IPM are associated with changes in wholesale electricity prices due to the RGGI program (allowance price impact) and revenue recycling expenditures (e.g., price changes from load reductions).

For revenue recycling each category has associated investments that are funded by the costs associated with the RGGI allowance price (i.e., impacts to electricity prices from IPM that occur due to RGGI). In addition, the modeling team (ICF & DEP) assume leverage ratios whereby public (i.e., RGGI) funding incentivizes additional private dollars for investment. This private funding has associated opportunity costs that are modeled in REMI. Private (e.g., households and business) budgets are assumed to be fixed and modeling investment in one category (e.g., energy efficiency) requires giving up investments in business as usual activities.

Analysis

The REMI analysis of revenue recycling scenarios requires developing inputs to REMI associated with investments made under each of the revenue categories. To develop these inputs ICF worked with PA DEP and leveraged other data sources to make assumptions for development of REMI inputs.

Programmatic Costs

Programmatic spending is assumed to involve state governmental support to administer the RGGI program and programs associated with revenue recycling. In addition, some of the revenue for programmatic spending is used to support RGGI, Inc. The amount modeled for programmatic costs is for modeling purposes only based on past RGGI averages, and is not a spending commitment by the Department.

Energy Efficiency

The energy efficiency category of revenue recycling consists of the same inputs for each scenario with differing proportions depending on the amount of revenue recycling spent on energy efficiency under each scenario. REMI inputs follow the general process described in section 4.2 where there are RGGI program funded investments (public) that leverage private investment with associated opportunity costs. The electric energy efficiency investments have associated reductions in electricity demand which is modeled in IPM and produces a variety of ratepayer impacts including bill savings, price suppression from lower load, and revenue decoupling whereby utilities are assumed to petition the Public Utility Commission (PUC) to raise electricity rates to recoup fixed costs from lower demand (i.e., less kWh paying for fixed costs). Table 4 provides a summary of this modeling with more discussion of assumptions and generation of inputs below.

TABLE 4: ENERGY EFFICIENCY MODELING SUMMARY

Revenue Source			REMI Inputs
RGGI Revenue	Energy Efficiency	Electric Energy Efficiency	Investments (Private + Public)
			Opportunity Cost (Private)
			Ratepayer impacts (IPM)
		Fossil Energy Efficiency	Investments (Private + Public)
			Opportunity Cost (Private)
			Bill Savings
			Lost fossil revenue

Energy efficiency consists of investments in electric energy efficiency and fossil energy efficiency. For the purposes of this modeling effort, PA DEP assumed that due to a likely design of revenue investment in energy efficiency, 75% of investments would be made in a manner that resulted in electric energy efficiency and 25% of investments would be made in fossil energy efficiency (Table 5).

TABLE 5. ENERGY EFFICIENCY ALLOCATION ASSUMPTIONS

Type	% of EE Proceeds
Electric Energy Efficiency	75%
Fossil Energy Efficiency	25%

Source: PA DEP

Electric Energy Efficiency

Revenue for electric energy efficiency is assumed to be invested in residential, commercial, and industrial electric energy efficiency in the proportions presented in Table 6 below. Based on PA experience it was assumed that every dollar of RGGI revenue invested would result in an additional $2.52 of private investment in electric energy efficiency. Therefore, total investments made in electric energy efficiency amount to the revenue allocated to each customer class as the RGGI revenue invested in electric energy efficiency plus 2.52 times that amount (Private Investment = 2.52* Public; Total Investment = Public + Private). To estimate the annual electricity savings produced by investments in electric energy efficiency a savings ratio of 3.57 kwh per $ revenue was assumed which represents the electricity savings produced from a dollar of revenue spending (i.e., before applying the leverage ratio). This savings ratio was used to develop an annual series of electricity savings based on each year of revenue. An equipment lifetime of 20-years was assumed to develop a cumulative series of electricity savings extending beyond the program's final year of 2030, to 2050. Annual electricity savings were monetized as using retail electricity rates derived from IPM's wholesale electricity prices with a transmission and distribution adder.

TABLE 6. ELECTRIC ENERGY EFFICIENCY SECTORAL ASSUMPTIONS

Customer Class	% of EE Proceeds	Leverage Ratio	Savings (kWh / $ Revenue)
Residential	50%	2.52	3.57
Commercial	35%	2.52	3.57
Industrial	15%	2.52	3.57

Source: 2017 RGGI Program data and consultation with PA DEP

Investments in electric energy efficiency are assumed to generate final demand for sectors in REMI associated with purchasing, installation, and other aspects of energy efficiency equipment. These are assumed to go in proportion to residential, commercial, and industrial sectors based on the allocations in Table 7.

TABLE 7. ELECTRIC ENERGY EFFICIENCY INDUSTRY ALLOCATION BY SECTOR

Industry	Residential	Commercial	Industrial
Wood product mfg.	1%	1%	0%
Nonmetallic mineral product mfg.	1%	1%	0%
Paper product mfg.	1%	0%	0%
Machinery mfg.	3%	8%	15%
Computer and electronic product mfg.	1%	3%	3%
Electrical equipment mfg.	5%	10%	15%
Plastics, rubber product mfg.	2%	2%	0%
Wholesale trade	1%	2%	2%
Construction	60%	53%	45%
Retail trade	15%	0%	0%
Professional Services	5%	15%	15%
Utilities	5%	5%	5%

Source: Acadia Center report on energy efficiency[5]

Investments in electric energy efficiency within the industrial and commercial sectors are assumed to be made by the largest and most electric energy intensive sectors in Pennsylvania. Using REMI data, ICF estimated proportions for these based on the size of the sector (output) and electric intensity (energy use per dollar) with estimated proportions presented below.

[5]Jamie Howland et al. (1999). Energy Efficient: Engine of Economic Growth: A Macroeconomic Modeling Assessment. Acadia Center (Environment Northeast).

TABLE 8. TOP 10 COMMERCIAL ELECTRICITY INTENSIVE SECTORS

Sector	Proportion
Real estate	55%
Educational services	12%
Retail trade	7%
Hospitals	7%
Management of companies and enterprises	5%
Food services and drinking places	4%
Wholesale trade	3%
Nursing and residential care facilities	3%
Professional, scientific, and technical services	2%
Telecommunications	2%

Source: REMI

TABLE 9. TOP 10 INDUSTRIAL ELECTRICITY INTENSIVE SECTORS

Sector	Proportion
Chemical manufacturing	26%
Food manufacturing	17%
Paper manufacturing	16%
Primary metal manufacturing	15%
Fabricated metal product manufacturing	7%
Plastics and rubber product manufacturing	6%
Nonmetallic mineral product manufacturing	5%
Construction	4%
Machinery manufacturing	3%
Mining	2%

Source: REMI

Fossil Energy Efficiency

Revenue for fossil energy efficiency is assumed to be invested in residential and commercial fossil energy efficiency in proportions presented in Table 9 below. Based on PA experience it was assumed that every dollar of RGGI revenue invested would result in an additional $2.52 of private investment in fossil energy efficiency. The same methodology as electric energy efficiency is used to calculate total investments (Private Investment = 2.52* Public; Total Investment = Public + Private). To estimate the annual fossil fuel savings produced by investments in fossil energy efficiency a savings ratio of 0.006 million British Thermal Units (MMBtu) per $ Revenue was assumed by PA DEP which represents the fuel savings produced from a dollar of revenue spending (i.e., before applying the leverage ratio). This savings ratio was used to develop an annual series of fuel savings based on each year of revenue. Fuel savings are assumed to occur for a mixture of natural gas, fuel oil, and coal in proportions consistent with their observed heating consumption for each sector according to EIA State Energy Data System (SEDS) data. An equipment lifetime of 20-years was assumed to develop a cumulative series of fuel savings extending beyond the program's final year of 2030, to 2050.

Annual fuel savings were monetized as using retail fuel prices from EIA's Annual Energy Outlook.

TABLE 10. FOSSIL ENERGY EFFICIENCY SECTORAL ASSUMPTIONS

Customer Class	% of EE Proceeds	Leverage Ratio	Savings (MMBtu / $ Revenue)
Residential	50%	2.52	0.006
Commercial	50%	2.52	0.006
Industrial	0%	NA	NA

Source: 2017 RGGI Program data and consultation with DEP

The same methodology as electric energy efficiency was used to determine how investments in fossil energy efficiency generate final demand for sectors in REMI associated with purchasing, installation, and other aspects of energy efficiency equipment. These are assumed to go in proportion to sectors for residential and commercial investments based on the allocations in Table 11.

TABLE 11. ELECTRIC ENERGY EFFICIENCY INDUSTRY ALLOCATION BY SECTOR

Industry	Residential	Commercial	Industrial
Wood product mfg.	1%	0%	NA
Nonmetallic mineral product mfg.	1%	1%	NA
Paper product mfg.	1%	0%	NA
Machinery mfg.	5%	15%	NA
Computer and electronic product mfg.	1%	2%	NA
Electrical equipment mfg.	5%	5%	NA
Plastics, rubber product mfg.	2%	1%	NA
Wholesale trade	1%	1%	NA
Construction	65%	55%	NA
Retail trade	8%	0%	NA
Professional Services	5%	15%	NA
Utilities	5%	5%	NA

Source: Acadia Center report on energy efficiency[6]

Investments in fossil energy efficiency within the commercial sectors are assumed to be made by the largest and most energy intensive (by natural gas and other liquid fuel consumption) sectors in Pennsylvania. Using REMI data, ICF estimated proportions for these based on the size of the sector (output) and energy intensity (natural gas / other liquid fuel use per dollar) with estimated proportions presented below.

[6] Jamie Howland et al. (1999). Energy Efficient: Engine of Economic Growth: A Macroeconomic Modeling Assessment. Acadia Center (Environment Northeast).

TABLE 12. TOP 10 COMMERCIAL FOSSIL FUEL INTENSIVE SECTORS

Sector	Proportion
Real estate	40%
Management of companies and enterprises	10%
Professional, scientific, and technical services	10%
Hospitals	10%
Food services and drinking places	8%
Administrative and support services	7%
Retail trade	5%
Wholesale trade	4%
Rental and leasing services	4%
Ambulatory health care services	3%

Source: REMI

Clean and Renewable Energy

The clean and renewable energy category of revenue recycling accounts for investments made in distributed generation (solar and biogas digesters) and utility scale generation (solar, wind, and low-impact hydropower) (Table 13).

TABLE 13: CLEAN AND RENEWABLE ENERGY MODELING SUMMARY

Revenue Source			REMI Inputs
RGGI Revenue	Clean and Renewable Energy	Distributed Solar and Biogas	Investments (Private + Public)
			Opportunity Cost (Private)
			Ratepayer impacts (IPM)
		Utility Scale Solar, Wind, and Low-impact Hydro	Investments (Private + Public)
			Ratepayer impacts (IPM)

For the purposes of this modeling effort, PA DEP assumed that a likely design of revenue investment in clean and renewable energy would result in the investments identified in the proportions presented in Table 14.

TABLE 14: CLEAN AND RENEWABLE ENERGY ALLOCATION ASSUMPTIONS

Type	% of RE Proceeds
Distributed Solar	25%
Utility Scale Solar	45%
Low-impact Hydropower	10%
Wind	10%
Biogas	10%

Inputs for distributed generation: biogas and solar, are estimated based on the assumption that they will need to be financed by entities installing them. Similar to energy efficiency, investments in all categories include a leverage ratio accounting for private investments incentivized by RGGI revenue investments. For distributed solar and biogas, a project lifetime assumption of 20 and 15 years respectively was used to develop an energy savings estimate based on the expected lifetime energy generation. The opportunity cost of private spending on distributed generation is assumed to occur over time based on paying back loans taken out with the fiscal assumptions for interest rate, loan length, and down payment presented in Table 15, below.

Utility solar, low-impact capacity changes are derived for IPM based on total investments (i.e., the total amount of dollars invested including leveraged private investment). These are input into IPM to estimate ensuing ratepayer impacts from added clean generation including impacts to the allowance price due to reduced emissions.

TABLE 15. FISCAL ASSUMPTIONS

Component	Unit	DG Solar	Biogas	Utility Solar	Hydropower	Utility Wind
Leverage Ratio	Ratio	14	14	20	16	16
Lifetime	Years	20	15	N/A	N/A	N/A
Loan Interest Rate	%	4%	4%	N/A	N/A	N/A
Loan Length	Years	15	15	N/A	N/A	N/A
Down Payment	%	1%	1%	N/A	N/A	N/A
Savings Ratio	(kWh / $ Revenue)	10.73	0.93	N/A	N/A	N/A

Source: PA DEP

To enter all generation investments into REMI, the investments are disaggregated into sectoral impacts. To do this, ICF consulted NREL's JEDI models. These models provide insights into project cost data for installed capacity, and designate the various costs associated with energy projects. The modeling team used these NREL JEDI models to proportion the investments, Fixed operating and maintenance (FOM), Variable operating and maintenance (VOM), and fuel costs into sectors using proportions specific to PA. Distributed generation investments are assumed to occur in proportion to electric energy intensity for the commercial sector and for biogas. For the purposes of this modeling effort, the modeling team assumed a likely design of revenue investment would result in the proportions presented in based on the proportions in Table 16.

TABLE 16. BIOGAS OPPORTUNITY COST ASSUMPTIONS

Industry	Proportion
Utilities	1/3
Agriculture and forestry support services	1/3
Waste Management Services	1/3

Source: PA DEP.

GHG Abatement

The GHG abatement category of revenue recycling accounts for investments made in transportation and research and development (R&D) (see Table 17). Historically, GHG abatement has been used as a broad category encompassing other ways to reduce greenhouse gases, apart from energy efficiency and clean and renewable energy. For the purposes of modeling, this category only includes transportation and R&D, but could include many other type of programs and initiatives.

Table 17: GHG Abatement Modeling Summary

<table>
<tr><th colspan="3">Revenue Source</th><th>REMI Inputs</th></tr>
<tr><td rowspan="11">RGGI Revenue</td><td rowspan="11">Clean and Renewable Energy</td><td rowspan="10">Transportation</td><td>EV Investments (Private + Public)</td></tr>
<tr><td>Opportunity Cost of EV (Private)</td></tr>
<tr><td>Charging Infrastructure Investments (Private + Public)</td></tr>
<tr><td>Opportunity Cost of Charging Infrastructure (Private)</td></tr>
<tr><td>Public Transportation (Public)</td></tr>
<tr><td>Public Transit Benefits</td></tr>
<tr><td>Bill savings (from lower fueling cost and reduced maintenance)</td></tr>
<tr><td>Increased electricity demand</td></tr>
<tr><td>Decreased fuel demand</td></tr>
<tr><td>Decreases maintenance demand</td></tr>
<tr><td>R&D</td><td>Investments (Public)</td></tr>
</table>

For the purposes of this modeling, the revenue for the GHG abatement is assumed to be invested in each transportation and R&D according to the proportions presented in Table 18.

Table 18. GHG Abatement Program Allocation Assumptions

Program Type	% of GHG Proceeds
Transportation	75%
Research and Development	25%

Source: PA DEP

Investments made in transportation are assumed to be made for electric vehicles, electric vehicle chargers, and public transportation (e.g., increasing use of public transit). Electric vehicles investments and public transportation investments are assumed to result in fuel savings calculated using the savings ratio presented in Table 19, along with the allocation of transportation revenue to each category. Savings ratio assumptions are from prior work on Pennsylvania's Climate Action Plan.

Table 19. Transportation Program Allocation Assumptions

Program Type	Allocation	Savings (MMBtu / $ Revenue)
Electric Vehicles	25%	42
Electric Vehicle Chargers	25%	NA
Public Transportation	50%	119

Source: PA Climate Action Plan Update

Investments in electric vehicles occur by class of vehicle in the proportions presented below in Table 20, along with assumptions for leverage ratio derived from the assumed cost of each class of electric vehicle and an assumed incentive payment. It is assumed that incentives are successful and result in purchase of vehicles so that the total spending on EVs of each category is the amount of revenue invested plus the leverage ratio multiplied by that investment.

TABLE 20. TRANSPORTATION PROGRAM ASSUMPTIONS

Program Category	Allocation	Vehicle Cost (2020)	Incentive	Leverage Ratio	Vehicle Lifetime
Class 1 & 2	34%	$48,300	$5,000	8.66	12
Class 3-7	33%	$175,000	$25,000	6	12
Class 8 and Buses	33%	$300,000	$50,000	5	12

Source: PA DEP assumptions, and vehicle costs from AEO (2020) and NREL

Additional inputs are derived estimating the change in fuel demand from EV investments. These are based on the savings ratio and lifetime assumptions in the above tables. The result is lower annual spending on fuel for users of the electric vehicles, as well as reduced maintenance spending. The impacts on supply side businesses is also modeled in REMI (e.g., reduced spending on gasoline reduces demand for gas stations and reduced maintenance requirements results in less demand for garages).

Research and development investments are assumed to be made in support of advancing carbon capture, storage, and utilization (CCUS) technologies. These investments are therefore direct towards research institutions in the private sector and higher education.

Direct Bill Assistance

The Bill Assistance scenario includes directing RGGI revenue towards low-income households, defined as 200% and below of federal poverty income guidelines. This involves allocating money to households with the assumption that they spend that money on the goods typically purchased by low-income households. Those consumption increases are assumed to occur in the proportions presented in Table 21, below.

TABLE 21. BILL ASSISTANCE EXPENDITURE CATEGORIES

Category	Proportion
Housing	30%
Food	15%
Utilities	10%
Transportation	10%
Health care	10%
Technology	5%
Apparel	4%
Education	3%
Savings	3%
Insurance	3%
Other (Personal Care, Miscellaneous)	7%

Source: ALICE and Consumer Expenditure Survey

General Fund

The general fund scenario assumes that a portion of RGGI revenues are allocated to reducing Pennsylvania’s government debt obligations. It is assumed that the government issues bonds in the Reference case to fund spending. These bonds have assumed terms (lengths) and interest rates associated. It is assumed that the bond is paid out at the end of the term and that the interest rate is paid each year until that payment. Therefore, in the Policy case, it is assumed that the bonds do not need to be issued as the spending they were funding, is funded by RGGI revenue. Therefore, the interest payments no longer need to be made, freeing up a small amount of money annually for additional spending. These term and interest rate assumptions are presented in Table 22.

TABLE 22. GENERAL FUND MODELING ASSUMPTIONS

Category	Value	Unit
Term	30	Years
Interest Rate	3%	Percent

Results

This section presents the results of the IPM and REMI modeling. The first section discusses the power sector results, from IPM, for Pennsylvania, RGGI, and PJM. The next section discusses the REMI results, including the macroeconomic impacts, detailed economic impacts, and sectoral impacts.

IPM

As noted, IPM produces projections of electricity sector activity, including generation, capacity expansion, and emissions, as well as RGGI program compliance, including allowance prices. This section provides an overview of the electricity sector and RGGI program impacts for Pennsylvania and for PJM as a whole.

Electricity Sector Impacts in Pennsylvania

Adding Pennsylvania to the RGGI program impacts the state's generation mix, emissions, and power prices, as shown in the Figures below. Overall, the Reference (or Business as Usual) case and the Policy Case (or RGGI) do not have significant differences in generation mix by 2030. When comparing the Policy + Investment (or RGGI + Investment) scenario, there is a notable increase in solar, hydro, and wind generation while coal generation declines from 2022-2030 in response to low gas prices and increased renewable penetration, seen in Figure 5 and 6 below.

FIGURE 5. PA GENERATION MIX IN 2030

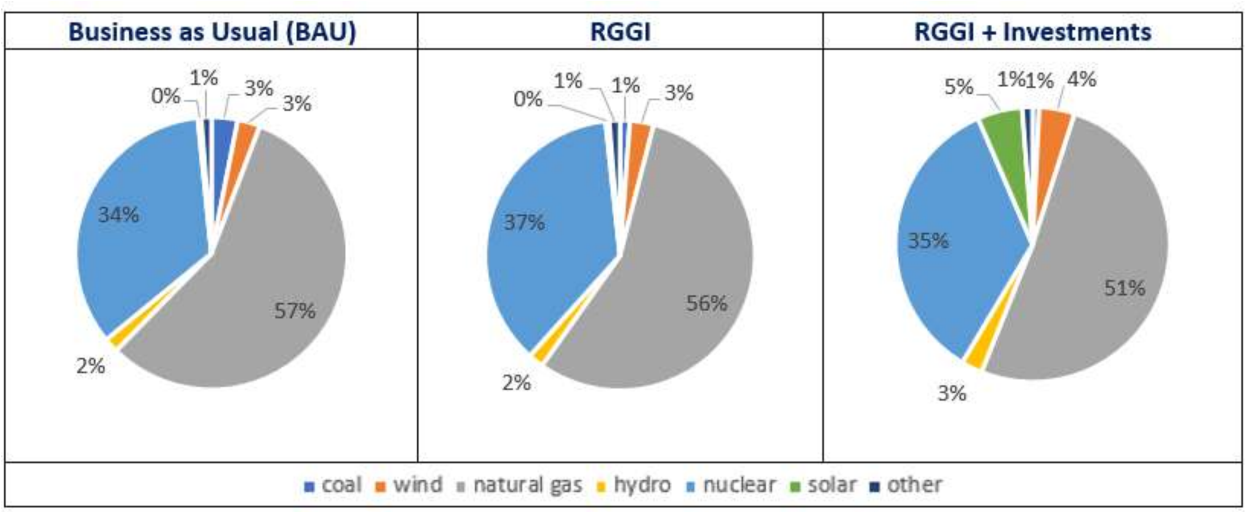
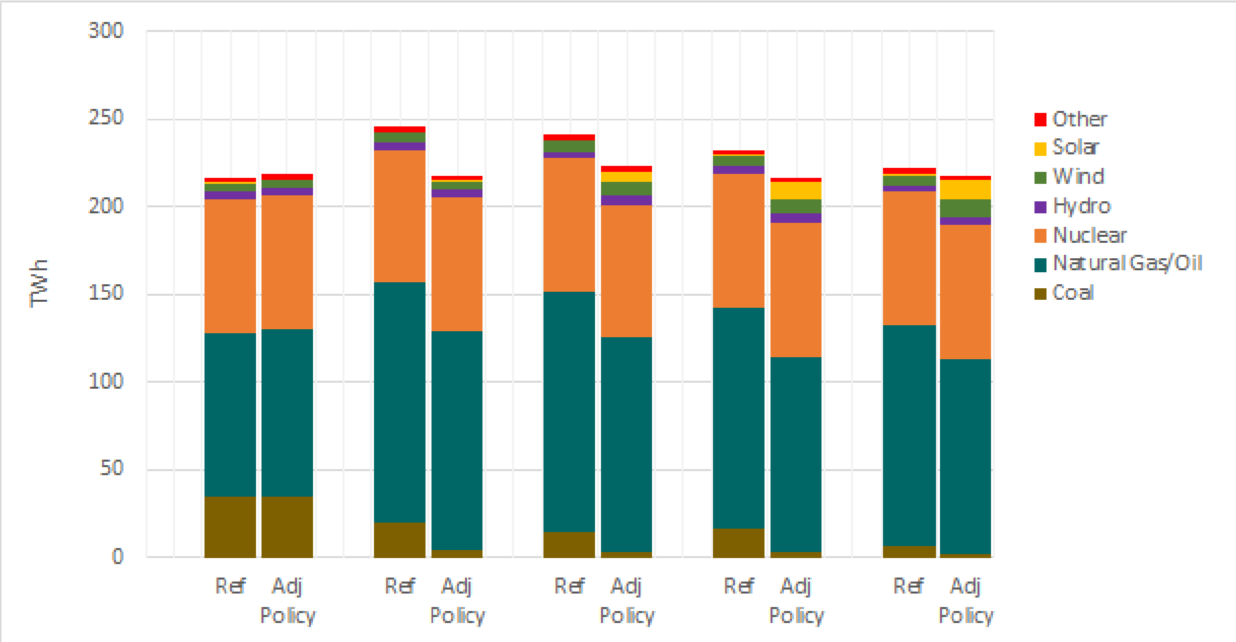
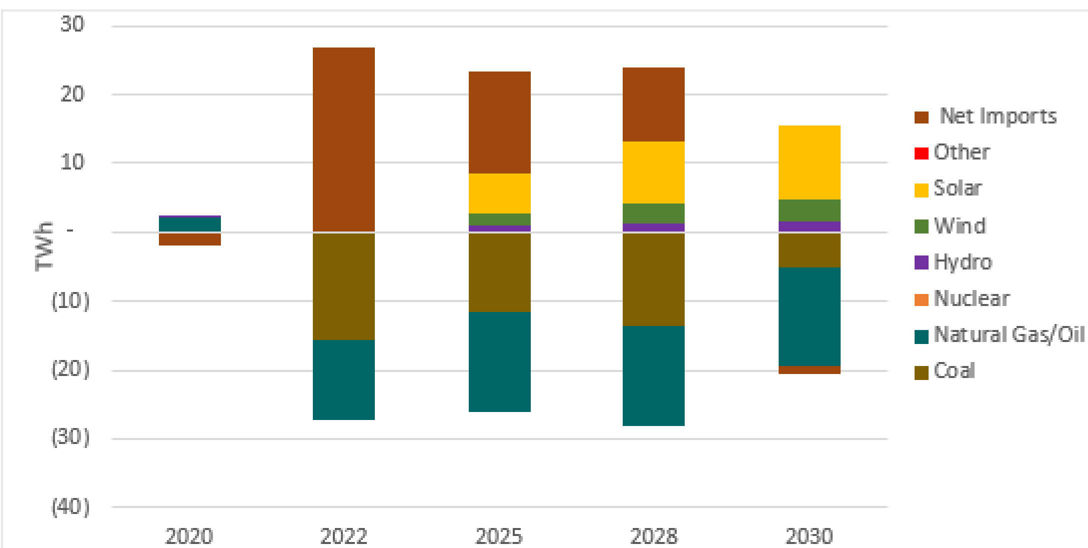


FIGURE 6. PA GENERATION MIX OVER TIME



While coal generation steadily declines in the Reference Case as firm gas-fired generation is added, it declines sharply in the Policy + Investments Case with the added dispatch cost added by the RGGI allowance price in 2022. In the Policy + Investments Case, coal and gas generation are both lower than in the Reference Case in response to the allowance price. As part of the revenue recycling, investment in solar and wind increases in the Policy + Investments Case, resulting in increased renewable generation that displaces fossil generation. These dynamics are further shown in Figure 7 below.

FIGURE 7. GENERATION CHANGE (POLICY + INVESTMENTS MINUS REFERENCE)

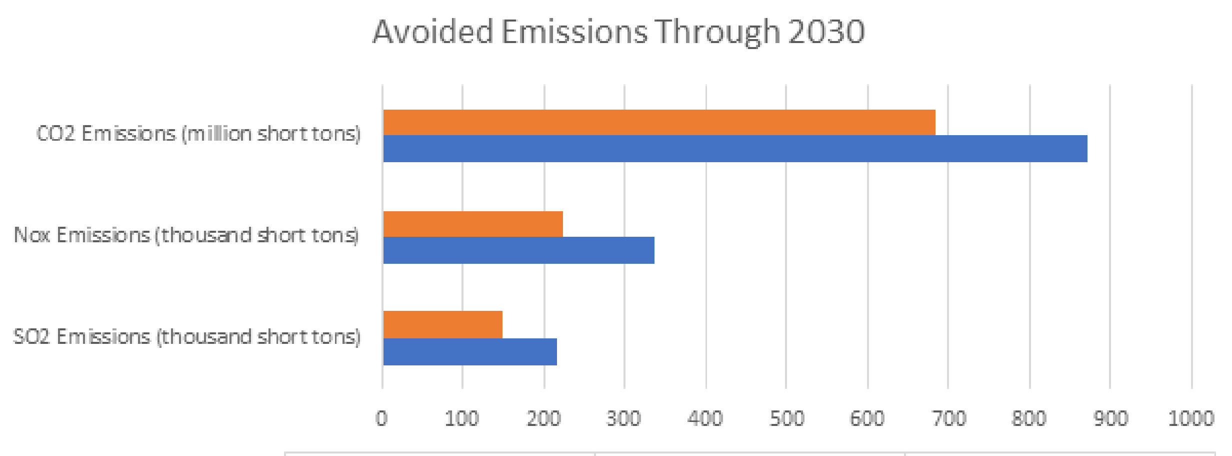


Incremental renewable generation in PA supported by the recycled allowance revenue displace some gas and coal in the Policy + Investments Case by 2030. Renewable generation is about 15 TWh higher by 2030 than the Reference Case. In addition to backing off fossil generation, the higher renewable generation decreases the need for imports. As such, compliance with

RGGI in the Policy + Investments Case entails increasing net imports in the mid-2020s but relies more heavily on in-state renewable generation by 2030.

As shown in Figure 8, RGGI compliance leads to changes in affected emissions in the state, as both renewable generation and imports do not contribute to the state's affected emissions.

FIGURE 8. CO2 EMISSIONS: PENNSYLVANIA

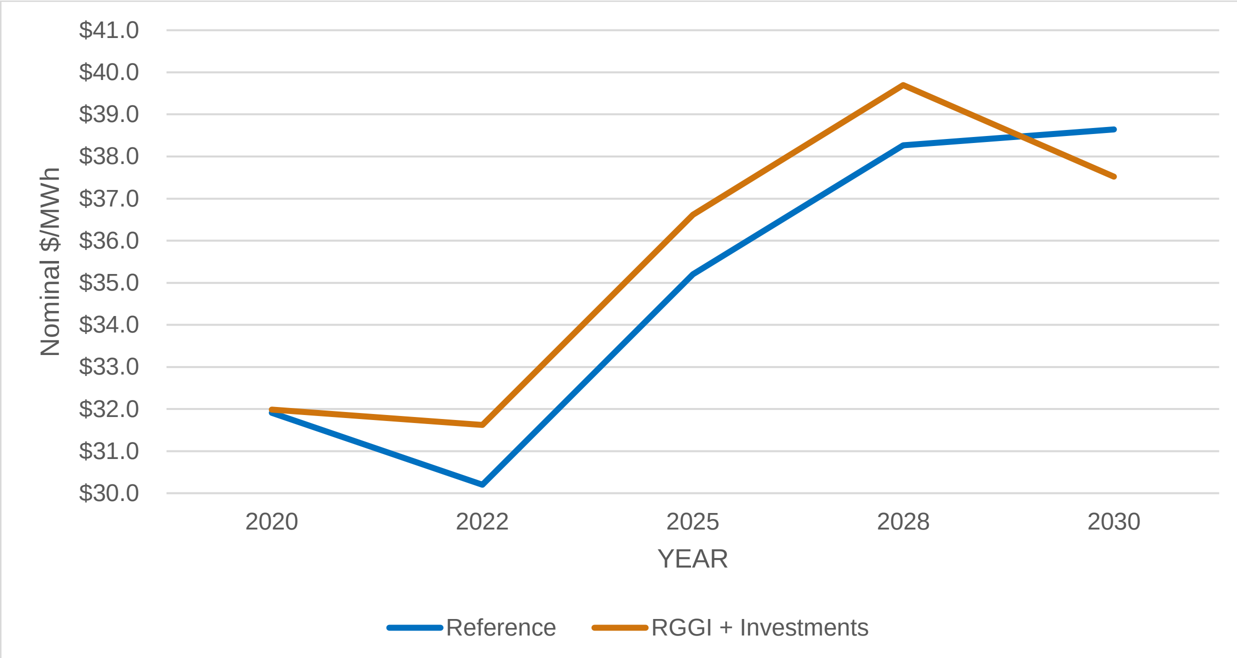


	SO2 Emissions (thousand short tons)	Nox Emissions (thousand short tons)	CO2 Emissions (million short tons)
RGGI + Investments	149	224	683
Business as Usual (BAU)	216	336	871

Reference (or Business as Usual) case CO_2 emissions increase somewhat in the near-term as firm gas generation is added, despite the decline in coal generation, but decline over time with the decrease in coal generation. In the Policy Case, emissions fall sharply with the reduction in gas and coal generation, and then in the Policy + Investments Case emissions are reduced further by additional renewable generation. Emissions are about 7% lower cumulatively in the Policy + Investments Case than in the Policy Case as a result of the renewable and energy efficiency investments.

Beyond CO_2 emissions reductions, the Policy and Policy + Investments Case would also provide public health benefits due to the expected reductions in ancillary emission reductions or co-benefits of SO_2 and NOx. The model projects cumulative emission reductions of 112,000 tons of NOx and around 67,000 tons of SO_2 over the decade.

FIGURE 9. FIRM POWER PRICES

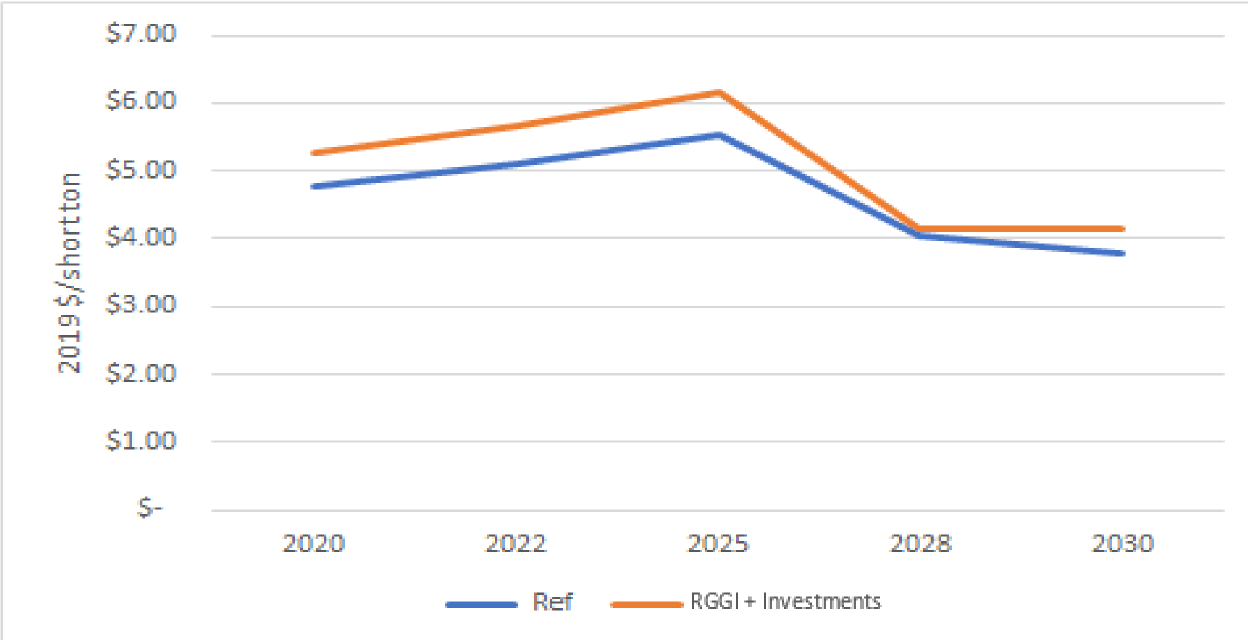


The Department's modeling estimates that over the next decade wholesale energy prices will stay in between a range of an increase of 3% in 2022 and ultimately a decrease of 3% by 2030 as a result of RGGI participation. The decline in 2030 is a function of lower capacity prices in PA given the incremental renewable additions and energy efficiency.

Impact on RGGI

The addition of PA to RGGI leads to slightly higher allowance prices in the Policy + Investments Case (Figure 10), but both scenarios remain well within the range of prices in past years. In fact, the difference in allowance price between the two scenarios stays below approximately 10% at the projected maximum.

FIGURE 10. ALLOWANCE PRICES



Impact on PJM

Overall, total PJM generation (Figure 11) stays relatively flat, with some decreases in PA made up for with increases elsewhere in PJM. On net, coal and gas generation decline in PJM in the Policy + Investments Case, leading to a decline in total PJM CO2 emissions (Figure 12). Total emissions in PJM decline by less than the fall in PA emissions, as some generation leakage results in higher emissions elsewhere in PJM. Specifically, 54% of the fall in PA emissions (2022-2030) are made up for by higher emissions elsewhere in PJM.

FIGURE 11. GENERATION MIX: PJM

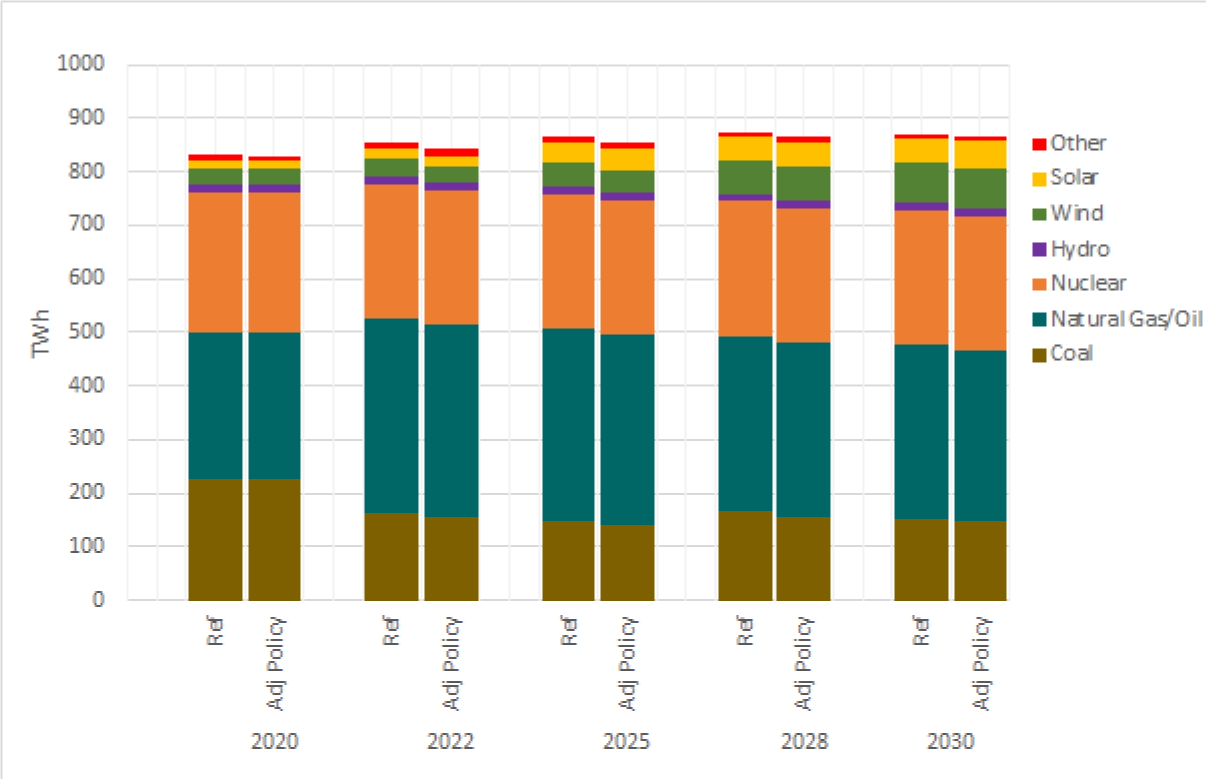
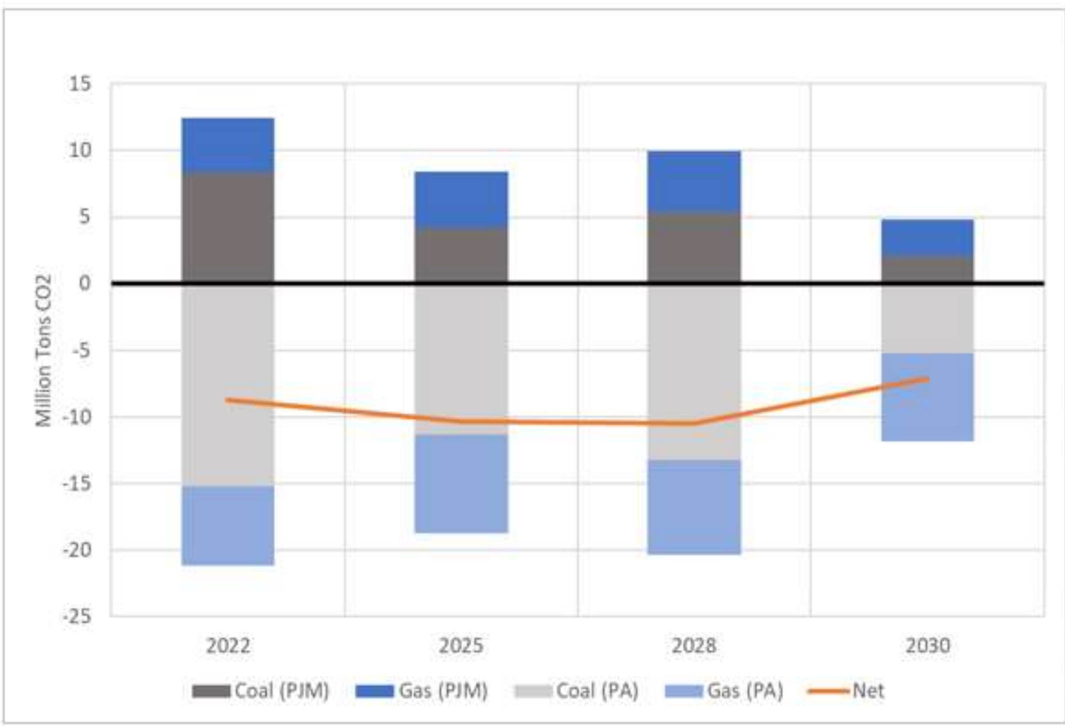


FIGURE 12. CHANGE IN CO2 EMISSIONS IN PA AND PJM (WITHOUT PA) (POLICY +I INVESTMENTS MINUS REFERENCE)



REMI

Inputs developed based on the REMI approach described in the Approach section above. These were run in REMI for each of the three scenarios modeled producing estimates of incremental job-years, gross state product (GSP), and disposable personal income. This section presents the high-level net results for each scenario and then more detailed results illustrating how the various components of the RGGI program (i.e., each revenue recycling category, price impacts) impact the economy.

Summary of Macroeconomic Impacts

Below in Table 23 through Table 25 are the annual results through 2030 for the three revenue recycling scenarios modeled and the cumulative results through 2030 and 2050 in Table 26 through Table 28.

Under the Balanced Approach, there is an increase in employment from the Reference Case in every year from 2022 through 2030 with a maximum increase in 2024 of over 6,600 jobs. Cumulatively the scenario results show an increase of 27,752 job-years through 2030 and 67,387 job-years through 2050. There are continued increases in employment beyond 2030 through 2050 due to lingering benefits of the RGGI program; primarily due to bill savings from energy efficiency and distributed generation installed with 20-year equipment lifetimes. The balanced approach also has an increase in Gross State Product (GSP) that trends similarly to employment. All impacts in the scenario are very small in the context of the entire Pennsylvania economy. Annual changes in employment range from -0.03% to 0.07%, GSP from -0.06% to 0.07%, and cumulatively both are less than a 0.05% increase in 2030 or 2050.

Disposable personal income results in the balanced approach scenario are slightly negative through 2030 but do increase between 2030 and 2050 as shown by the cumulative increase in undiscounted disposable income of $7,236 ($3,654 with a 3% discount rate) through 2050. It should be noted that the decrease in Disposable Income out to 2030 is overall very small, equal to approximately $8.50 per year for someone on a $50,000 salary. Up until 2030 there are two countervailing impacts to disposable income with positive pressure from the increase in economic activity in the economy as evidenced by the increased jobs and GSP as well as bill savings associated with energy efficiency and distributed generation. However, there are some short-term price impacts to ratepayers due to the RGGI program as well as from revenue decoupling though these trends reverse in the future.

Extrapolating those results to the average residential electric consumer sheds light on the actual impact to monthly electric bill. The average residential electric consumer spends from $97.04 to $136.60 per month depending on whether they heat their homes with electricity or another fuel source. Residential bills will increase by an estimated 1.5% in the short-term. This amounts to an additional $1.46 to $2.05 per month. However, the modeling shows that this minor increase is temporary. As a result of the revenue reinvestments from the auction proceeds, by 2030, energy prices will fall below business-as-usual prices resulting in future consumer electricity costs savings. This means electric consumers will see greater electric bill savings in the future under the Policy + Investments case. Results for the other two scenarios are both negative through 2030 with the Bill Assistance scenario having cumulative impacts through 2030 of -12,009 job-years, -$3.032 billion GSP (undiscounted), and -$4.417 billion in disposable personal income (undiscounted). In this scenario the primary difference is in revenue recycling where 49% of revenue is allocated to direct bill assistance. This allocation can be important to offset increases in low-income household electricity bills but results in less economic activity than investments made in the Balanced Approach. In addition, the bill savings generated from the balanced approach scenario accumulate to be larger than the direct bill assistance in the Bill Assistance scenario. Through 2050 the Bill Assistance scenario shows that there are cumulative employment benefits due to ongoing bill savings from some investments in energy efficiency and distributed generation.

The General Fund scenario shows the most negative impacts of the three scenarios. This is because the majority of the revenue (69%) is invested in the less productive activity of servicing state debts. As a result, there are not as many positive economic stimuli offsetting some of the negative economic impacts of the RGGI program such as increases in electricity prices from allowance prices and declines related to reduced fossil generation. This scenario sees consistent annual reductions in jobs of around -3,200 to -3,800 jobs annually, and cumulatively -30,067 job-years through 2030 and -9,865 job-years through 2050.

The last table, Table 29, presents results for disposable income per household. REMI is a dynamic model that includes population dynamics such as migration into the state when employment is increasing. As a result, the disposable income per household results have slightly different trend than the overall disposable income results presented in the cumulative tables. In the balanced approach, disposable income per household is almost unchanged with a cumulative impact from 2022-2050 of just $1.60 per household (undiscounted). With a discount rate taking into account the time value of money (i.e., money is preferred now rather than later), the balanced approach sees a small decline of -$3.19 per household (3% discount). The other two scenarios see small cumulative decreases both undiscounted and discounted, consistent with their overall disposable income results.

TABLE 23. BALANCED APPROACH SCENARIO SUMMARY RESULTS

Category		2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Cumulative
Employment	Jobs	224	-2,990	-2,150	6,048	6,518	6,401	2,249	2,131	2,068	2,981	4,272	**27,752**
	(% change)	0.003%	-0.04%	-0.03%	0.07%	0.08%	0.08%	0.03%	0.03%	0.03%	0.04%	0.05%	**0.03%**
Gross State Product	Million 2019$	34	-484	-427	573	634	619	98	92	91	284	464	**1,978**
	(% change)	0.00%	-0.06%	-0.05%	0.06%	0.07%	0.07%	0.01%	0.01%	0.01%	0.03%	0.05%	**0.02%**
Disposable Personal Income	Million 2019$	11	-344	-485	-13	1	-83	-295	-243	-226	-37	225	**-1,490**
	(% change)	0.00%	-0.05%	-0.07%	0.00%	0.00%	-0.01%	-0.04%	-0.03%	-0.03%	-0.01%	0.03%	**-0.02%**

Note: All tables have been updated with 2019 dollars, resulting in small differences compared to previously published modeling results that were in 2017 dollars.

Table 24. Bill Assistance Scenario Summary Results

Category		2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Cumulative
Employment	Jobs	229	-3,560	-2,085	-428	-369	-500	-1,716	-1,829	-1,901	-378	528	**-12,009**
	(% change)	0.003%	-0.05%	-0.03%	-0.01%	-0.01%	-0.01%	-0.02%	-0.02%	-0.02%	-0.01%	0.01%	**-0.01%**
Gross State Product	Million 2019$	34	-553	-405	-203	-202	-230	-395	-418	-435	-169	-56	**-3,032**
	(% change)	0.00%	-0.05%	-0.05%	-0.04%	-0.04%	-0.05%	-0.05%	-0.04%	-0.04%	-0.02%	-0.01%	**-0.03%**
Disposable Personal Income	Million 2019$	13	-395	-484	-407	-415	-486	-552	-546	-556	-373	-217	**-4,417**
	(% change)	0.00%	-0.06%	-0.07%	-0.06%	-0.06%	-0.06%	-0.07%	-0.07%	-0.07%	-0.05%	-0.03%	**-0.06%**

TABLE 25. GENERAL FUND SCENARIO SUMMARY RESULTS

Category		2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Cumulative
Employment	Jobs	233	-3,412	-3,848	-3,233	-3,247	-3,187	-3,710	-3,562	-3,412	-1,764	-925	**-30,067**
	(% change)	0.003%	-0.04%	-0.05%	-0.04%	-0.04%	-0.04%	-0.05%	-0.04%	-0.04%	-0.02%	-0.01%	**-0.04%**
Gross State Product	Million 2019$	35	-532	-604	-536	-546	-551	-634	-626	-618	-337	-237	**-5,185**
	(% change)	0.00%	-0.06%	-0.07%	-0.06%	-0.06%	-0.06%	-0.07%	-0.07%	-0.06%	-0.04%	-0.02%	**-0.06%**
Disposable Personal Income	Million 2019$	14	-386	-545	-532	-554	-593	-636	-635	-646	-466	-342	**-5,321**
	(% change)	0.00%	-0.06%	-0.08%	-0.07%	-0.07%	-0.08%	-0.08%	-0.08%	-0.08%	-0.06%	-0.04%	**-0.07%**

Table 26. Balanced Approach Cumulative Results

Category	Unit	Cumulative through 2030*	Cumulative through 2050*
Employment	Jobs	30,518	67,387
	%	0.042%	0.028%
Gross State Product (Million 2019$)	Undiscounted	$2,427	$8,596
	%	0.029%	0.027%
	3% Discounted	$2,010	$5,422
	7% Discounted	$1,585	$3,228
Disposable Personal Income (Million 2019$)	Undiscounted	-$1,199	$7,500
	%	-0.017%	0.027%
	3% Discounted	-$1,061	$3,787
	7% Discounted	-$910	$1,453

*Cumulative results begin in 2022

Table 27. Bill Assistance Cumulative Results

Category	Unit	Cumulative through 2030*	Cumulative through 2050*
Employment	Jobs	-8,678	15,879
	%	-0.012%	0.007%
Gross State Product (Million 2019$)	Undiscounted	-$2,513	$606
	%	-0.030%	0.002%
	3% Discounted	-$2,131	-$371
	7% Discounted	-$1,735	-$866
Disposable Personal Income (Million 2019$)	Undiscounted	-$4,036	-$1,091
	%	-0.057%	-0.004%
	3% Discounted	-$3,409	-$1,765
	7% Discounted	-$2,763	-$1,961

*Cumulative results begin in 2022

Table 28. General Fund Cumulative Results

Category	Unit	Cumulative through 2030*	Cumulative through 2050*
Employment	Jobs	-26,889	-9,965
	%	-0.037%	-0.004%
Gross State Product (Million 2019$)	Undiscounted	-$4,689	-$2,660
	%	-0.056%	-0.008%
	3% Discounted	-$3,982	-$2,802
	7% Discounted	-$3,250	-$2,646
Disposable Personal Income (Million 2019$)	Undiscounted	-$4,948	-$3,718
	%	-0.070%	-0.014%
	3% Discounted	-$4,175	-$3,478
	7% Discounted	-$3,378	-$3,034

*Cumulative results begin in 2022

TABLE 29. HOUSEHOLD LEVEL CUMULATIVE RESULTS (2022 – 2050)

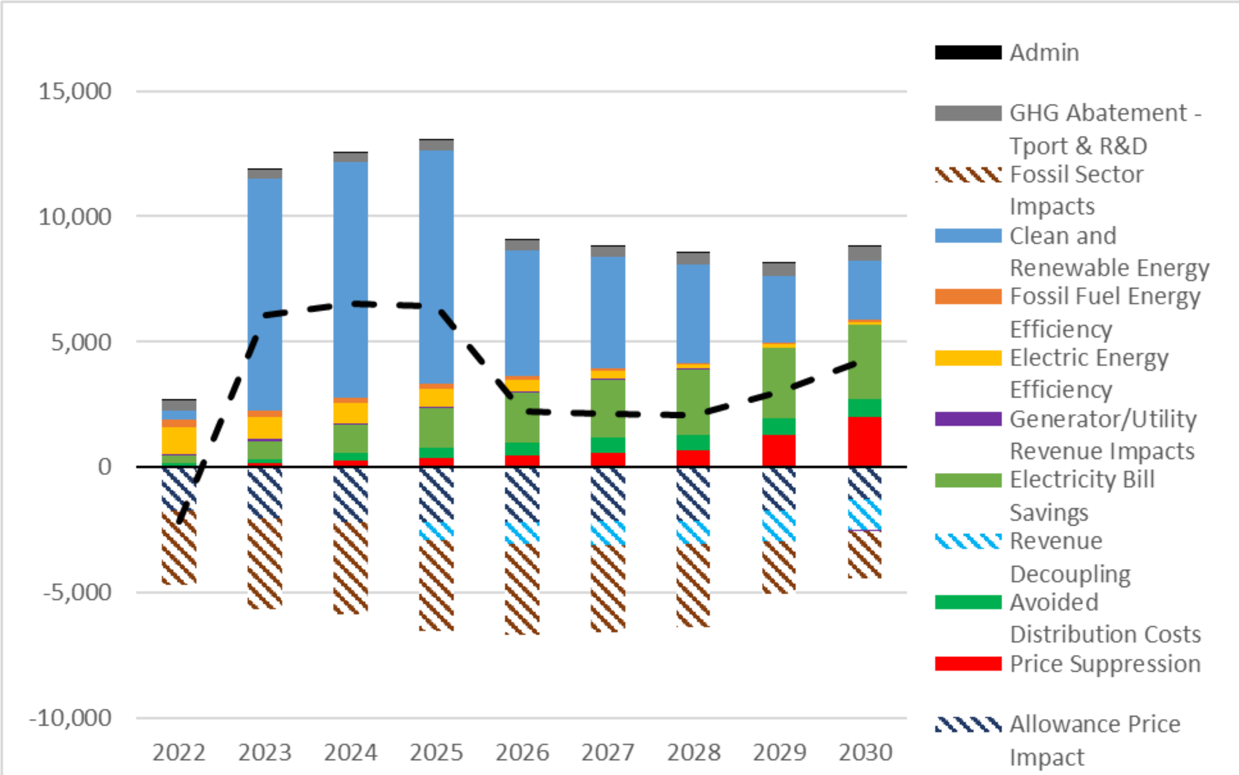
Category	Unit	Balanced Approach	Bill Assistance	General Fund
Disposable Personal Income per Household (2019$)	Annual Average (Undiscounted)	$1.60	-$10.25	-$11.14
	Annualized (3% Discount)	-$3.19	-$14.61	-$15.31
	Annualized (7% Discount)	-$10.02	-$20.95	-$21.54

Detailed Economic Impacts

In this section the detailed employment impacts that are driven by the various components of each scenario are discussed. The components are aligned with earlier discussions of inputs in the IV. Approach; 4.3 REMI Analysis section.

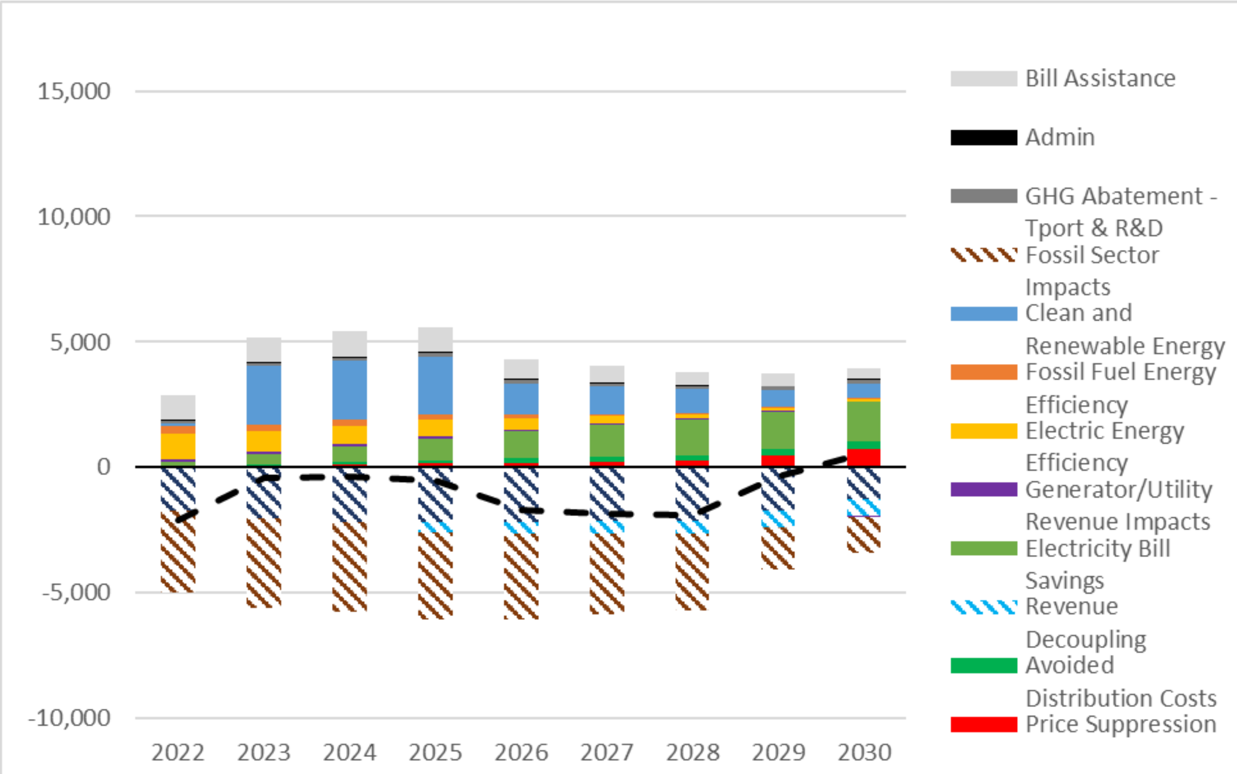
Detailed annual results for the balanced approach scenario are presented in Figure 13. The largest driver of the net increase in employment, until 2029, is the clean and renewable energy category. These are the jobs supporting revenue recycling investments made in utility scale solar, wind, low-impact hydro, biogas, and distributed generation. The second largest increase in jobs, and the largest in 2029 and beyond, is from electricity bill savings. This includes electricity bill savings from both electric energy efficiency and distributed generation. They accumulate over-time, reflected in the increasing size of the electricity bill savings bar. Similarly increasing over time are price suppression benefits which also increase in size overtime because it is a function of the load reductions (i.e., electricity savings; which increase in size) over time. On the negative impact side there are three primary drivers. The largest negative impact is to the fossil sector which consists of declines in natural gas and coal generation as described in the IPM results. The other two negative impacts are both associated with electricity price changes, the allowance price impact (i.e., increase in electricity prices due to the RGGI program) and revenue decoupling. Allowance price impacts decline in size over time reflecting price impacts discussed in the IPM results and the revenue decoupling impacts increase in size over time because of increasing electricity savings resulting in more T&D fixed costs needing to be recovered over less load.

FIGURE 13. BALANCED APPROACH DETAILED EMPLOYMENT RESULTS (JOBS)



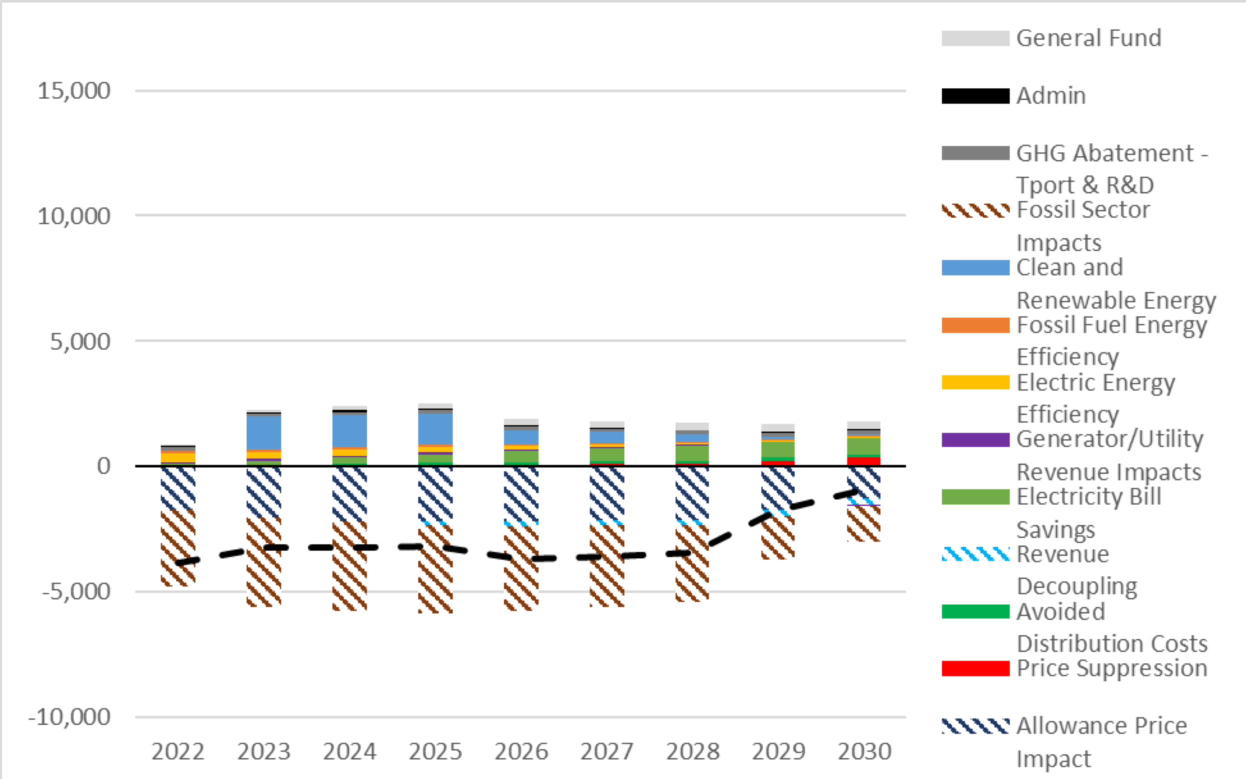
Detailed annual results for the Bill Assistance scenario are presented in Figure 14. The largest positive impact is from the clean and renewable energy category. These are the jobs supporting revenue recycling investments made in utility scale solar, wind, low-impact hydro, biogas, and distributed generation. The second largest increase in jobs is from electricity bill savings. This includes electricity bill savings from both electric energy efficiency and distributed generation. These impacts follow the same pattern as the balanced approach scenario but are smaller given the lower share of revenue spent on these categories. The Bill Assistance scenario also contains bill assistance impacts which slightly decrease over time, reflecting declining allowance revenue over time. The impacts are relatively important but even with less spending, electricity bill savings become larger than bill assistance relatively quickly. The negative side is approximately the same as the balanced approach scenario because most of the negative impacts (i.e., allowance price impact and fossil sector impacts) are because of the RGGI program itself and not the recycled revenues. Since the negative impacts are about the same size, and the positive impacts are lower as bill assistance is less economically simulative the net impact of this scenario is lower than the balanced approach.

FIGURE 14. BILL ASSISTANCE SCENARIO DETAILED EMPLOYMENT RESULTS (JOBS)



Detailed annual results for the General Fund scenario are presented in Figure 15. The positive impacts are the smallest of the three modeled scenarios because the revenues allocated to main revenue recycling categories are the smallest. Most of the revenue in the General Fund scenario is allocated to serviced Pennsylvania's government debt. As discussed in the analysis section this results in a small benefit as the revenue reduces the amount of bonds issued to finance state government spending, which in turns reduces the interest paid to those bonds. This results in a small increase in available funds for state government spending under the Policy scenario (the increase is the interest that would have been paid towards bonds in the Reference case). The negative impacts are approximately the same as the other scenarios because most of the negative impacts (i.e., allowance price impact and fossil sector impacts) are because of the RGGI program itself and not the recycled revenues. Since the negative impacts are about the same size, and the positive impacts are low the net impact of this scenario is the lowest amongst the modeled scenarios.

FIGURE 15. SCENARIO 3-GENERAL FUND DETAILED EMPLOYMENT RESULTS (JOBS)



Impact on Different Economic Sectors

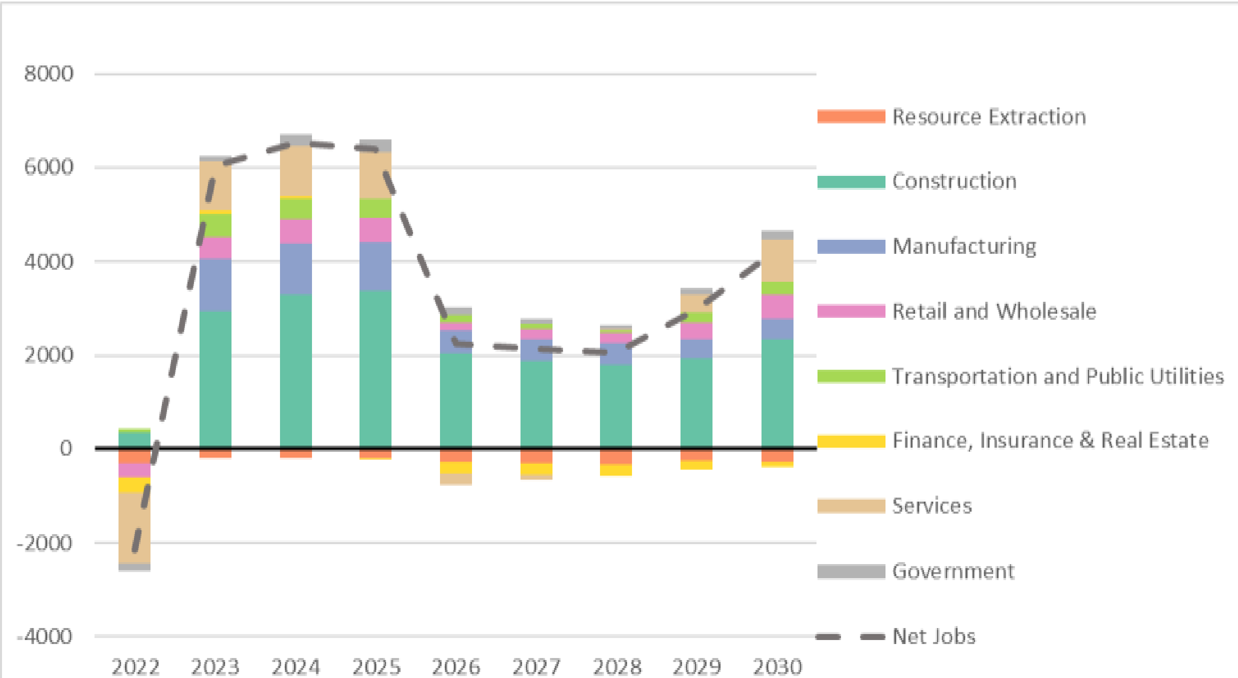
This final section of results focuses on the sectoral impacts of the three scenarios. There are detailed sectors embedded in the more aggregated sectors presented in each figure. The aggregated sector represents multiple NAICS codes as mapped in Table 30.

Table 30: Sectoral Mapping with NAICS Codes

Sector	NAICS Codes
Resource Extraction	113-115, 21
Construction	23
Manufacturing	31-33
Retail and Wholesale Trade	42, 44, 45
Transportation and Public Utilities	22, 48, 492-493
Finance, Insurance & Real Estate	52, 53
Services	51, 54-56, 61-62, 71-72, 81
Government	N/A

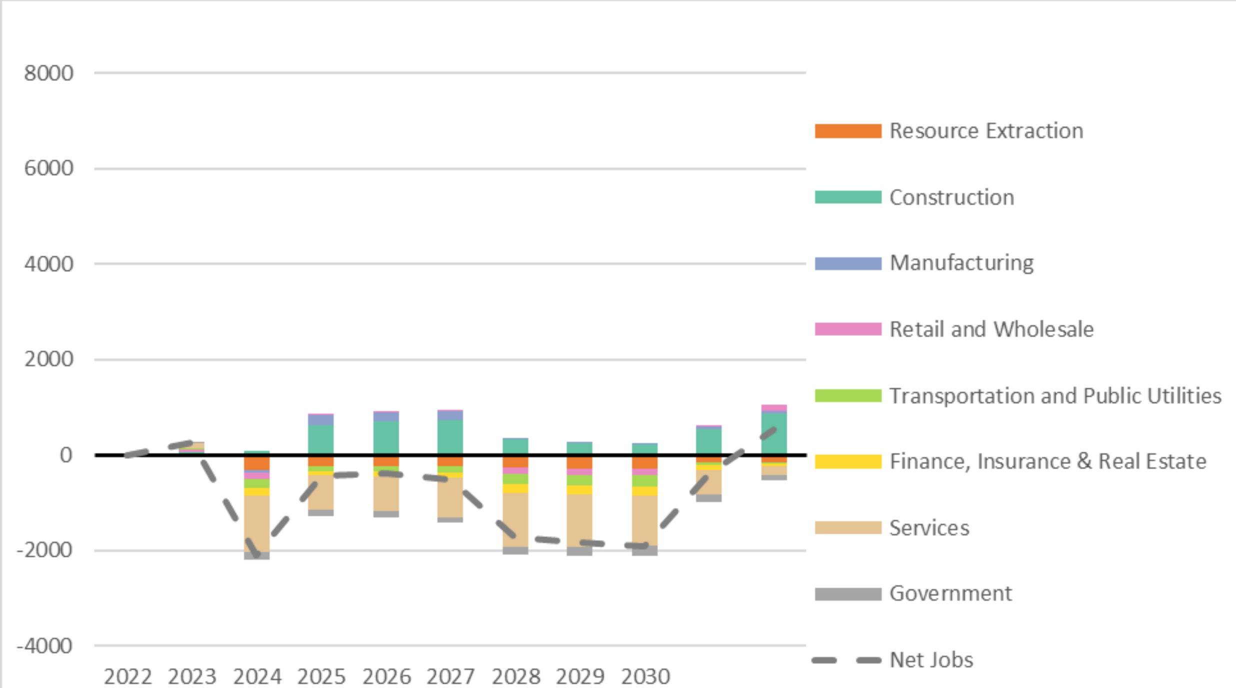
Sectoral results for the balanced approach scenario are presented in Figure 16. The sector with the largest gains is the construction sector which contains jobs associated with many of the investments being made. This includes actual construction of new clean and renewable generation as well as jobs associated with installation of energy efficiency or electric vehicle chargers (e.g., electricians). The manufacturing sector sees an increase in employment due to increased demand for materials supporting investments. Other sectors like the services sector provide engineering expertise and many service sectors benefit from commercial bill savings. Resource extraction is consistently negative through the time period as this sector contains most of the fossil sector impacts related to extraction of coal and natural gas, both which see declines in demand for with less generation burning those fossil fuels. However, the declines in these sectors are very small compared to gains in other sectors.

FIGURE 16. BALANCED APPROACH SECTORAL EMPLOYMENT RESULTS (JOBS)



Sectoral results for the Bill Assistance scenario are presented in Figure 17. In this scenario the construction sector is the only sector to be consistently positive in impacts, this is because it is associated with most of the investments being made as in the Balanced Approach (although at lower levels). Most other sectors see consistent negative impacts that primarily stem from electricity price impacts. From Figure 17 the negative impacts are largely driven by electricity price impacts and impacts to the fossil sector. The service sector is particularly impacted by both of these as the fossil fuel sector interacts with certain service sectors extensively (e.g., professional and scientific services). In addition, impacts to household consumption from the electricity price, which are not fully offset by bill assistance and other bill savings result in reduced consumption demand which primarily impacts service sectors. Resource extraction is consistently negative due to declines in demand for the extraction of coal and natural gas.

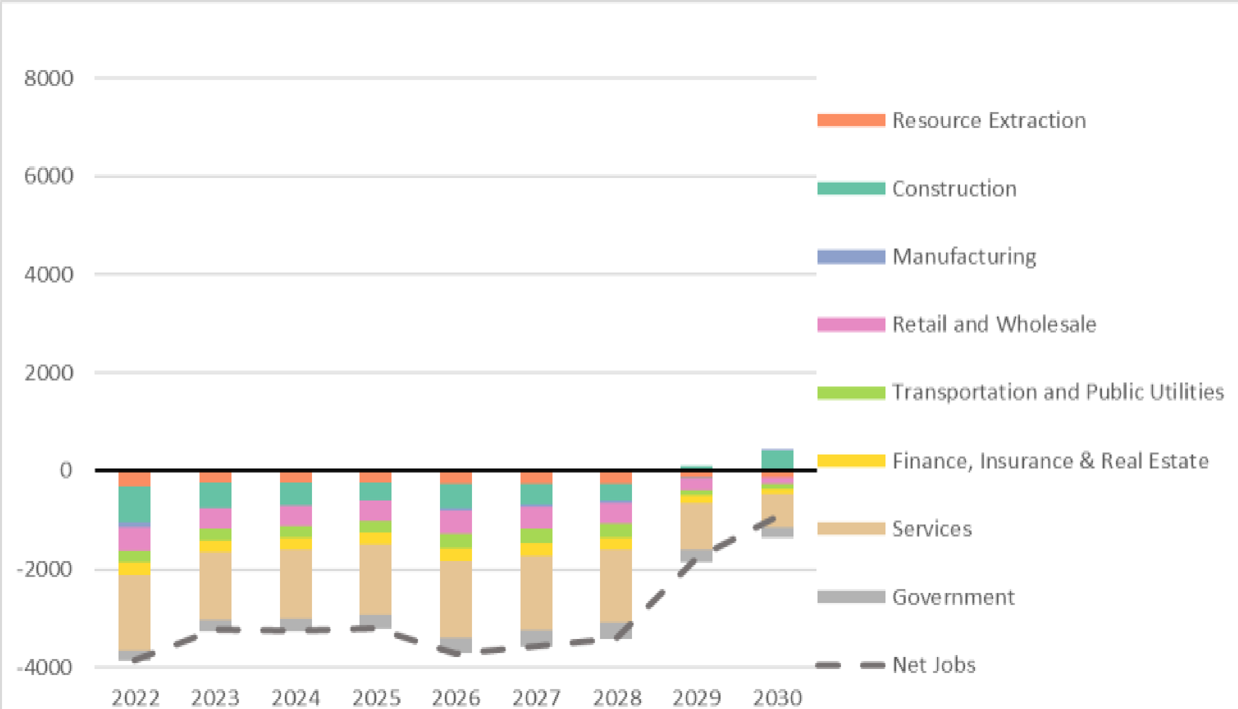
FIGURE 17. BILL ASSISTANCE SECTORAL EMPLOYMENT RESULTS (JOBS)



Sectoral results for the General Fund scenario are presented in Figure 18. In this scenario there is only one year where a sector sees positive impacts; the construction sector in 2030. Consistent with the prior economic impacts discussed for this scenario the positive impacts of limited revenue spending in productive areas are more than offset by increased electricity prices and declining demand for natural gas and coal. Since electricity price impacts percolate through the entire economy all sectors see declines in employment from the Reference case.

Despite spending associated with state administration of the RGGI program government and with a small increase in government spending associated with avoided debt service the government sector sees a decline in employment from the Reference case. This is due to several interactions occurring in the model, primarily sectors producing final demand require government services as an intermediate input. Since all sectors see declines under the general fund scenario, their demand for government services also declines.

FIGURE 18. GENERAL FUND SECTORAL EMPLOYMENT RESULTS (JOBS)



Conclusion

This modeling exercise was critical in understanding the potential impacts and benefits to Pennsylvania as the Department evaluates its participation in RGGI in 2022. It is important to note that these results do not address the entirety of RGGI participation impacts and benefits, such as the health benefits of reduced emissions. The intent of creating this report is to assist in fully understanding the inputs and outputs of the modeling the Department conducted. For additional information and understanding, all results and supplemental informational webinars can be viewed at the Department's RGGI website at www.dep.pa.gov/RGGI.