Exhibit 36

NERA
ECONOMIC CONSULTING

SOCIOECONOMIC GAINS TO MARYLAND OF THE CONOWINGO HYDROELECTRIC PROJECT AND THE MUDDY RUN PUMPED STORAGE PROJECT

Prepared for Exelon Generation Company, LLC

November 2012

Project Team

David Harrison, Jr., Ph.D., Project Director
Noah Kaufman, Ph.D., Project Manager
Jonathan Falk
Eugene Meehan
Nicholas Hodges
Marta Łuczyńska

This report was commissioned by Exelon Generation. It reflects the research, opinions and conclusions of its authors and does not necessarily reflect those of National Economic Research Associates, Inc. (NERA) or any of its clients.

Public information and industry and statistical data are from sources we deem to be reliable; however, we make no representation as to the accuracy or completeness of such information and have accepted the information without further verification.

The findings contained in this report may contain predictions based on current data and historical trends. Any such predictions are subject to inherent risks and uncertainties. In particular, actual results could be impacted by future events that cannot be predicted or controlled, including, without limitation, changes in business strategies, changes in market and industry conditions, and changes in law or regulations. NERA accepts no responsibility for actual results or future events.

The opinions expressed in this report are valid only for the purpose stated herein and as of the date of this report. No responsibility is taken for changes in market conditions or laws and regulations, and no obligation is assumed to revise this report to reflect changes, events or conditions, which occur subsequent to the date hereof. This report is intended to be read as a whole. Separation or alteration of any section or page is forbidden and would invalidate the report.

This report does not represent investment advice nor does it provide an opinion regarding the fairness of any transaction to any and all parties. There are no third party beneficiaries with respect to this report, and NERA does not accept any liability to any third party. In particular, NERA shall not have any liability to any third party in respect of the contents of this report or any actions taken or decisions made as a consequence of the results, advice or recommendations set forth herein.

NERA Economic Consulting
200 Clarendon Street, 11th Floor
Boston, Massachusetts 02116
Tel: +1 617 927 4500
Fax: +1 617 927 4501
www.nera.com

Contents

List of Figures

List of Tables

Executive Summary

This study estimates the socioeconomic contributions to Maryland of the Conowingo Hydroelectric Project (“Conowingo”) and the Muddy Run Pumped Storage Project (“Muddy Run”). Both Conowingo and Muddy Run (“the Projects”) are hydroelectric facilities owned and operated by Exelon Generation Company, LLC (“Exelon”) and are currently in the relicensing process with the Federal Energy Regulatory Commission (FERC).

A. Overview of the Projects

Conowingo is a large hydroelectric power plant located on the Susquehanna River in northern Maryland. Conowingo has eleven turbines that generate electricity as the water flows through the dam. In 2011, Conowingo supplied over 2.5 million megawatt hours (“MWh”) of clean electricity generation to the regional electricity system.

Muddy Run is a large pumped storage hydroelectric facility located in southern Pennsylvania, also on the Susquehanna River. Muddy Run purchases electricity from the power grid during off-peak hours to pump water from the lower-elevation Conowingo Pond to the higher-elevation Muddy Run Reservoir in order to store energy. During peak-hour periods of high electricity demand, water is released from the Muddy Run Reservoir and returned back to the Conowingo Pond, powering eight turbines that generate electricity. Muddy Run thus provides electricity generation to the regional electricity system during peak hours when electricity is particularly valuable.

The Projects lead to gains to the electricity system as well as gains to the economy. These economic gains include increased jobs as well as increased economic output, population, personal income and government taxes. Because hydroelectric generation means that some fossil-fueled generation is not needed, the Projects may also lead to lower emissions of air pollutants and greenhouse gases. In addition to these quantified effects, the Projects have other effects that cannot be quantified but for which we have developed some qualitative information.

B. Contributions of the Projects to the Electricity System

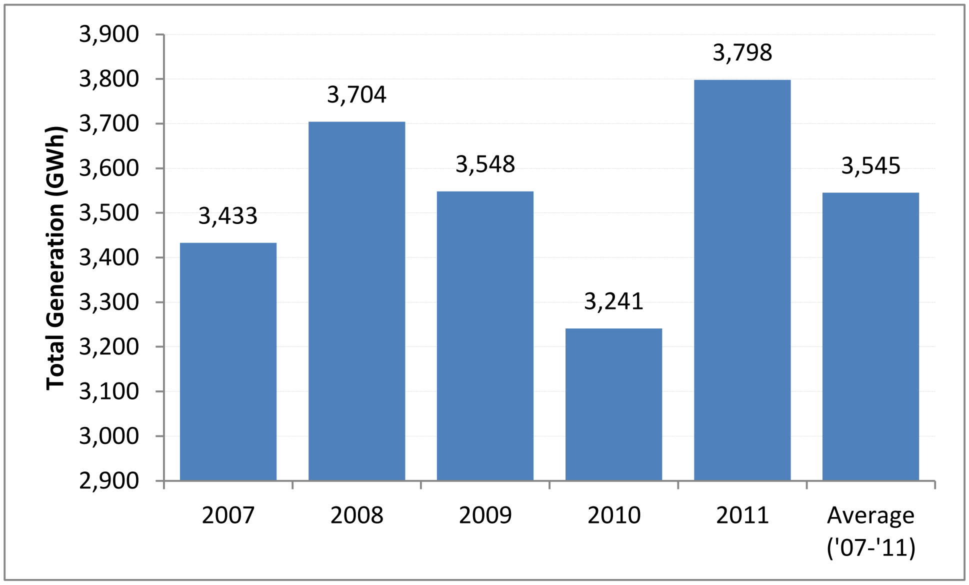
The Projects provide important contributions to the electricity system through the electricity generation and capacity they provide. These contributions in turn lead to electricity prices in Maryland and elsewhere that are lower than they would be if these facilities were not available. In addition to electricity generation and capacity, there are other contributions to the electricity system that are not quantified but are nonetheless important.

1. Contributions to Electricity Generation

Conowingo and Muddy Run are large facilities that supply substantial generation and capacity to the PJM Interconnection electricity grid.[1] Moreover, as discussed below, Muddy Run shifts generation to hours when it is most needed to meet demand.

Figure ES-1 displays the combined annual generation of the Projects from 2007 to 2011 (not including the electricity purchases of Muddy Run). The variation by year in annual generation over this time period is primarily due to differences in weather conditions that have led to changes in the water available for use at Conowingo. With regard to the variation in generation by time of day, the generation from the Projects is typically largest during the late afternoons and early evenings when electricity demand is relatively high (although the time profile of generation varies to some extent by season reflecting differences in peak usage hours).

Figure ES-1. Total Annual Generation of the Projects (2007-2011)



Source: Exelon and NERA Calculations
Note: Does not include electricity purchases at Muddy Run.

As noted above, Muddy Run purchases electricity from the power grid to re-fill its upper-reservoir so that electricity can be generated during peak hours when it is most needed by customers. Indeed, the amount of megawatt hours of electricity purchased by Muddy Run is greater than the amount of its generation. The principal purpose of a pumped storage facility is to provide for a shift in electricity generation from off-peak to peak hours to meet customer demand.

---

[1] PJM Interconnection is a regional transmission organization that coordinates wholesale electricity movement in all or parts of 13 states and the District of Columbia, a region that includes more than 60 million people. See http://www.pjm.com/about-pjm.aspx.

2. Contributions to Electricity Capacity

In addition to their contributions to electricity generation, the Projects provide significant contributions to the wholesale electricity market through their substantial capacity. Because of the difficulties of storing electricity, service reliability and price stability are largely contingent upon the amount of capacity available to the grid operators. Sufficient capacity is needed to ensure that the demand for electricity can be continually met, including during occasional periods of extremely high demand (i.e., the hottest summer days).

The rated capacities of Conowingo and Muddy Run are 572 megawatts (MW) and 1070 MW, respectively, which make them among the largest 25 percent of generators within PJM.[2] The Projects' capacity provides grid operators with reliable and flexible sources of power. Because water at Muddy Run and Conowingo can be stored for the periods when it is most needed, the Projects are relied upon most heavily when demand is high, thus eliminating the need for costly additional capacity to be added to the electricity system.

The Projects can also ramp up generation very rapidly when demand or supply change unexpectedly, and therefore ensure service reliability and lower costs of electricity for all customers. The benefits of facilities such as Conowingo and Muddy Run have often been noted by policymakers and grid operators, including the president and CEO of PJM, who recently discussed the need for a more flexible grid and stressed the reliability contributions to the grid of energy storage technologies such as pumped storage facilities.[3]

3. Contributions to Reduced Wholesale Electricity Prices

We estimated the reductions in electricity rates attributable to the Projects by simulating the removal of the two facilities and determining likely impacts on prices in various parts of the electricity system. The price effects are estimated on an hourly basis using historical data from 2009 to 2011, and we report the average impacts across all hours of the day and year (and thus across peak and off-peak demand periods).

Figure ES-2 summarizes the estimated annual reductions in wholesale electricity prices in the regions within the PJM system due to the Projects. (All dollar values are reported in 2012 dollars in this report). These price effects include both capacity market effects, which are assumed to be constant across PJM, and PJM energy market[4] effects (due to generation of the Projects), which differ by geographic region. The regions are based primarily on the service territories of electricity distribution companies.

---

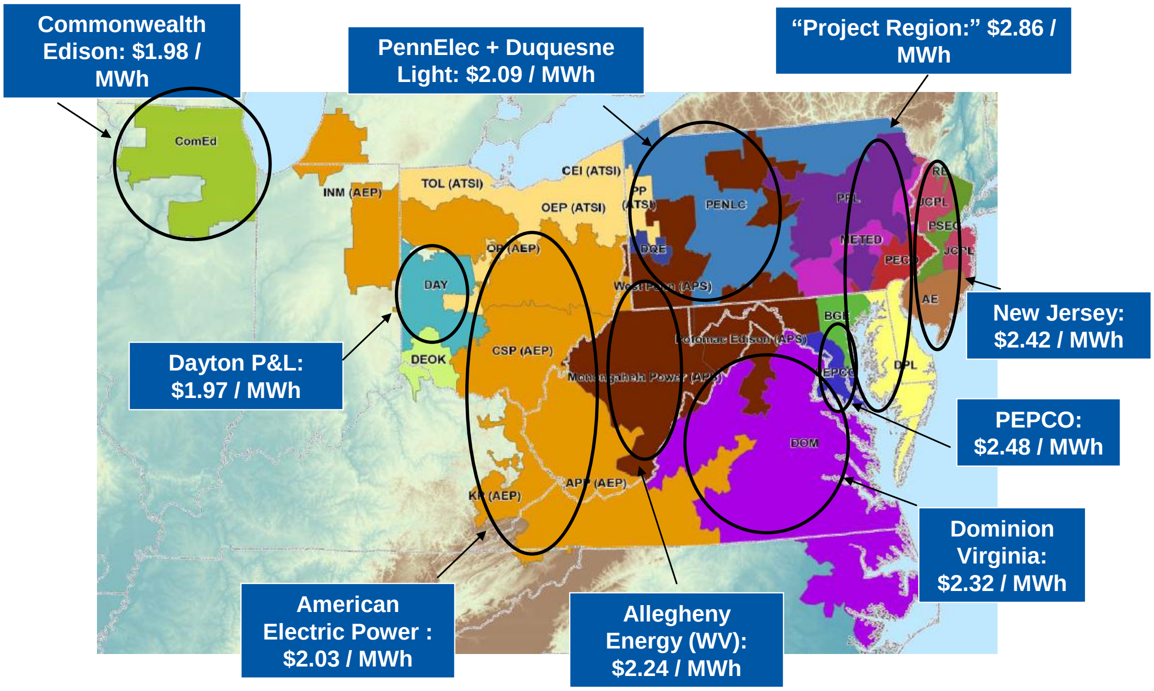
[2] Based on the facilities' summer capacities as of January 1, 2010 (www.pjm.com).

[3] See http://www.pjm.com/about-pjm/newsroom/newsletter-notices/state-lines/2011/december.aspx.

[4] The PJM Energy Market is where the continuous buying, selling and delivery of wholesale electricity takes place. The market uses "locational marginal pricing" that reflects the value of the energy at the specific location and time it is delivered (www.pjm.com).

The price reductions are the largest in the "Project Region" that surrounds the Conowingo and Muddy Run facilities.[5] In this region, the average reductions due to the generation and capacity of the Projects are $1.21 per MWh and $1.65 per MWh, respectively, for a total reduction of $2.86 per MWh on the wholesale electricity price. The average wholesale electricity price in PJM from 2009 to 2011 was roughly $61 per MWh, so the effect in the Project Region corresponds to nearly a 5 percent price reduction. As shown in Figure ES-2, the price reductions in the wholesale market due to the Projects are significant across the entire PJM region.

Figure ES-2. Reductions in Wholesale Electricity Prices in PJM Regions due to the Projects



Commonwealth Edison: $1.98 / MWh

PennElec + Duquesne Light: $2.09 / MWh

"Project Region:" $2.86 / MWh

New Jersey: $2.42 / MWh

Dayton P&L: $1.97 / MWh

PEPCO: $2.48 / MWh

Dominion Virginia: $2.32 / MWh

American Electric Power : $2.03 / MWh

Allegheny Energy (WV): $2.24 / MWh

Notes: Wholesale electricity price effects include PJM Energy Market effects, which vary by geographic region, and capacity market effects, which are equal to $1.65 per MWh in all regions.
The "Project Region" consists of the service territories of PECO, Delmarva Power & Light (DPL), Baltimore Gas & Electric (BGE), PPL Electric Utilities (PPL) and Metropolitan Edison Company (MetEd).
The prices displayed are average impacts across all hours of the day.
Source: NERA calculations as explained in text.

These wholesale electricity price effects can be translated into estimates of the percentage reductions in retail prices for residential, commercial and industrial electricity customers. Retail prices include charges for electricity transmission and distribution services, which typically account for about one-half of the average retail price. Estimates of the changes in retail electricity rates due to the Projects are provided below in the context of our assessment of the economic contributions of the Projects to local and state economies.

---

[5] The "Project Region" is comprised of the service territories of the following electric utilities: PECO, Metropolitan Edison Company, PPL Electric Utilities, Baltimore Gas & Electric and Delmarva Power & Light Company.

4. Other Contributions to Wholesale Electricity Markets

The Projects provide additional important contributions to the electricity grid that are not quantified in this study, including ancillary services that are essential for the proper functioning of a regional electricity grid. These ancillary services provided by the Projects include the following:[6]

- *Regulation service.* The Projects provide important corrections for short-term changes in electricity use that might otherwise affect the stability of the power system;
- *Spinning and non-spinning reserve:* The Projects supply a reliable source of electricity to the grid in situations when there is an unexpected need for more power on short notice;
- *Black-start services.* The Projects provide an important capability to restore electricity to the grid in the event of a large-scale power outage without using an external electrical supply; and
- *Voltage control:* The Projects provide for the injection into the grid and absorption from the grid of power in order to maintain voltages throughout the transmission system.

C. Contributions of the Projects to the Local and State Economies

The Projects provide important economic gains to the counties in which they operate as well as to other areas of Pennsylvania, Maryland, and the country as a whole. These gains reflect the direct employment and other expenditures at the facilities, the effects of lower electricity prices, and the multiplier effects of increased spending. We have developed estimates of the complete economic gains using a state-of-the-art economic impact model (Regional Economic Models, Inc., or REMI).

1. Direct Employment and Expenditure Contributions

The direct economic contributions of the Projects include the jobs at Conowingo and Muddy Run as well as the expenditures on various other goods and services to run the facilities. The Projects employ 56 full-time workers at the two facilities and hire roughly 100 additional part-time workers each year. In 2011, the operations and maintenance expenditures of the Projects were $22.8 million and capital costs were $26.1 million, based on information provided by Exelon. In addition, Exelon spent an estimated $53.7 million on electricity to pump water into the Muddy Run Reservoir for storage. The Projects also contributed significantly to public sector finances with a combined $78.5 million in income and property taxes in 2011.

---

[6] Information is compiled from the PJM website (www.pjm.com).

2. Direct Retail Electricity Price Reductions

As noted above, the estimates of wholesale electricity price reductions due to the Projects can be translated into estimates of the percentage reductions in retail prices, which differ from wholesale prices primarily because they include transmission and distribution costs.

Table ES-1 displays the estimated percentage reductions in retail electricity prices for residential, commercial and industrial consumers in the counties surrounding the facilities (Lancaster and York Counties in Pennsylvania, and Cecil and Harford Counties in Maryland), the rest of Pennsylvania and Maryland, and the rest of the United States. The Projects are estimated to lower retail electricity prices by about 1.8 to 3.4 percent in Maryland and Pennsylvania. The percentage reductions in retail prices are largest for industrial customers because they pay the lowest transmission and distribution charges (and thus the wholesale price change is a larger percentage gain).

Table ES-1. Summary of Retail Electricity Price Reductions by Geographic Region

	Electricity Price Effects		
	Residential	Commercial	Industrial
Lancaster/York Counties	2.1%	2.5%	3.4%
Cecil/Harford Counties	2.0%	2.3%	3.3%
Rest of Pennsylvania	2.0%	2.4%	3.3%
Rest of Maryland	1.8%	2.2%	3.0%
Rest of United States	0.2%	0.2%	0.2%

Source: NERA calculations as described in Chapter II of this report.

The reductions in retail electricity rates due to the Projects result in direct gains for local and state residents who pay less for electricity and thus have more money to spend on other goods and services. The reductions also provide direct gains to businesses that pay less for electricity and thus are more competitive than they otherwise would be. While the benefits due to the jobs and expenditures of the Projects are focused on the counties that surround the Conowingo and Muddy Run facilities, the effects of lower electricity prices are experienced across the entire PJM region.

3. Total Economic Impact Gains

We used the state-of-the-art REMI model to develop estimates of the overall gains due to the Projects for local, state and national economies. The REMI model provides estimates of the indirect and induced (often referred to as “multiplier”) effects of increased spending and lower electricity rates due to the Projects. The REMI model incorporates various important market effects, including effects on local wage rates, prices and other economic variables.

Table ES-2 summarizes the estimated annual contributions of the Projects to employment, gross regional/domestic product, disposable personal income and population at the local and state levels. Relative to the size of the economy, the gains are larger at the local level. The local economy is affected primarily by the increased jobs and expenditures and to a lesser extent by the reduced electricity prices. In contrast, the state and U.S. gains are to a much greater degree due to the reduced electricity rates.

Table ES-2. Annual Economic Contributions of the Projects to the Maryland Economy

Region	Employment (jobs)	Gross Regional Product (million 2012$)	Disposable Personal Income (million 2012$)	Population (people)
Cecil & Harford	298	46	26	366
Maryland	2,060	273	228	2,764
United States	20,857	2,372	1,987	-

Source: REMI Model and NERA calculations as described in Chapter III of this report.
State-level contributions include the local contributions, and nationwide contributions include the state contributions.

D. Air Emissions and Non-quantified Socioeconomic Impacts of the Project

In addition to the electricity and economic contributions, the Projects have other important socioeconomic impacts that provide important societal benefits. This report provides estimates of the impacts of the Projects on air emissions as well as discussions of other non-quantified socioeconomic impacts.

1. Reductions in Air Emissions

As a renewable electricity source, hydroelectric facilities avoid the need to rely upon fossil-fuel generation. In the PJM system, electricity generation from the Projects displaces generation from fossil fuel sources such as coal and natural gas, which leads to reduced emissions of pollutants including carbon dioxide, sulfur dioxide, and nitrogen oxide. These pollutants are linked to global climate change as well as a host of other health and welfare effects (EPA 2010, IPCC 2007).

We estimated the potential impacts of the Projects on air emissions based on the assumption that the net generation of the Projects would be replaced by generation from the marginal fuel in each hour on the PJM grid, which is generally either coal or natural gas.[7] Table ES-3 summarizes our estimates of the reductions in emissions of carbon dioxide, sulfur dioxide, and nitrogen oxide due to the Projects over the period 2009 through 2011. These results imply that the Projects lead to annual reductions in carbon dioxide emissions of about one million metric tons.

---

[7] PJM provides data on the percentage of each hour that a given fuel served as the marginal source of electricity generation on the grid. These data can be found at the following website: http://www.monitoringanalytics.com/data/marginal_fuel.shtml.

Table ES-3. Avoided Air Emissions due to Electricity Generation of the Projects

Year	Projects' Net Generation (GWh)	CO_2 (metric tons)	SO_2 (short tons)	NOx (short tons)
2009	1,380	960,284	6,619	1,211
2010	1,204	800,966	5,708	1,036
2011	2,158	1,380,567	9,841	1,784
Total ('09-'11)	**4,742**	**3,141,818**	**22,168**	**4,031**
Average ('09-'11)	**1,581**	**1,047,273**	**7,389**	**1,344**

Note The assumed replacement generation is from the marginal fuel source in PJM in each hour; in 2011, coal and natural gas were the marginal fuel sources 61 and 33 percent of all hours, respectively.
The net generation of the Projects includes electricity purchases of Muddy Run.

Source: Exelon Corporation; U.S. EPA; PJM; Monitoring Analytics; NERA calculations as described in Chapter IV of this report.

These changes do not necessarily translate into net emissions changes for pollutants that are covered by cap-and-trade programs, such as those for sulfur dioxide and nitrogen oxide.[8] If the emissions cap is binding, an increase (or decrease) in emissions from one source will lead to an equivalent decrease (or increase) in emissions from other sources. Note, however, that in these circumstances the Projects provide important gains by lowering the cost of meeting the emissions caps. The Projects decrease the demand for emissions allowances (i.e., the right to emit a ton of the pollutant) and thus lower the market prices; the lower market prices translate into electricity prices that are lower than they otherwise would be without the Projects. These gains are not quantified in this study.

The Projects also lead to reductions in emissions of pollutants that are not covered by cap-and-trade programs, such as mercury and particulate matter from coal-fired generating units. These reductions lead to additional benefits of the Projects. These benefits have not been quantified in this study.

2. Other Socioeconomic Impacts

The Projects will lead to various additional socioeconomic impacts that are not quantified in this study, including impacts on water supply, recreational facilities and fish populations.

a. Water Supply

The roughly 14 mile stretch of the Susquehanna River between the Muddy Run and Conowingo facilities is known as the Conowingo Pond ("the Pond"). The Pond and the surrounding land—including the Conowingo Dam and the recreational areas and natural habitat on the banks of the

---

[8] The situation is complicated for carbon dioxide; although emissions are capped for power plants in the ten states in the Regional Greenhouse Gas Initiative ("RGGI")—including Maryland—trade in electricity with non-RGGI states (such as Pennsylvania) can lead to net emissions reductions and not just reduced costs of meeting the emissions cap.

Susquehanna River—are primarily preserved by Exelon. The water in the Pond is a water supply for various municipalities (including the City of Baltimore) and is used as cooling water by industrial facilities in the area, including Peach Bottom Atomic Power Station.

b. Recreational Facilities

Popular recreational activities in the areas surrounding Conowingo and Muddy Run include hiking, bird watching and boating. The broad expanse of water at the southern portion of the Pond is used for waterskiing, sailing, and motor boating. The northern portion of the Pond is narrower, includes islands, and is ideal for use by canoes and small boats.

Good fishing areas are accessible along the shoreline or by boat. There is also fishing access to streams feeding into the pond and to a lake at Muddy Run Park, which is just east of the Pond. Stocking programs and fishing tournaments help attract anglers to the pond. Exelon recently invested $4.5 million in a fish wharf at the Conowingo dam that allows visitors increased access to the river for fishing, bird-watching, picnics and photography[9]. According to its License Applications for the Projects, Exelon plans to invest over $7 million (in 2014 dollars) in recreation management at the Pond over the upcoming 50 years (Exelon 2012a, 2012b).

The Pond and surrounding areas are also utilized by visitors for camping, hunting, swimming, nature observation, and educational facilities (SRBC 2006).

c. Fishery Impacts

The existence of the Conowingo Dam and the operations of the Conowingo and Muddy Run Projects result in certain unavoidable impacts on the local ecosystem. Dams can serve as barriers to fish migration, and the plant's intake structures (in particular, the turbines) can result in fish losses of both migratory and resident fish species. As part of the relicensing process for Muddy Run, Exelon has conducted a number of resource studies to assess the impact of the operations of the Projects on migratory and resident fish. The studies have been submitted to the Federal Energy Regulatory Commission and made available to relicensing stakeholders.

---

[9] http://www.exeloncorp.com/energy/generation/hydro.aspx.

I. Introduction

Exelon Generation Company, LLC ("Exelon") has applied for new licenses with the Federal Energy Regulatory Commission (FERC) for the Conowingo Hydroelectric Project and the Muddy Run Pumped Storage Project ("the Projects"). This report evaluates various key socioeconomic impacts of the Projects, including gains to the electricity system, environmental impacts and potential impacts on the local, state and national economies.

The remainder of this chapter provides background information on Exelon, the Projects and the re-licensing process. It then describes the organization of the remainder of the report.

A. Background on Exelon

Exelon is a competitive energy provider headquartered in Chicago, Illinois. It participates in every stage of energy production and sales, including generation, transmission and distribution. Following its merger with Constellation Energy in 2012, Exelon Corporation has operations and business activities in 47 states, the District of Columbia and Canada and serves over six million customers in the United States. Exelon Generation—a subsidiary of Exelon Corporation— is the largest competitive power generator in the United States, owning approximately 35,000 megawatts ("MW") of capacity, including nuclear, natural gas, oil, coal, hydroelectric and other renewable facilities.

Three of these hydroelectric power facilities are on the Lower Susquehanna River in Maryland and Pennsylvania. Exelon has a two-thirds ownership stake in the Safe Harbor Hydroelectric Station, which is the northernmost of the three facilities. This facility has a generating capacity of 416.5 MW.

Exelon fully owns and operates the other two hydroelectric facilities—the Conowingo Hydroelectric Project ("Conowingo") and the Muddy Run Pumped Storage Project ("Muddy Run")—which are both located in the Conowingo Pond and are the focus of this report.

B. Conowingo Pond

The Conowingo Pond ("the Pond") is a 14-mile stretch of the Susquehanna River formed by the Conowingo Dam, which is located between Cecil and Harford counties in northern Maryland (see Figure 1). The lower six miles of the Pond forms the border between Cecil and Harford counties, whereas the uppermost eight miles of the Pond serve as the border between Lancaster and York counties in southern Pennsylvania.

The Pond is utilized for a variety of purposes, which include various public recreational activities. Exelon recently invested $4.5 million in a fish wharf that provides access to the Pond for fishing and bird-watching, among other activities.[10] According to the License Applications for Conowingo and Muddy Run, Exelon plans to invest over $7 million (in 2014 dollars) in

---

[10] http://www.exeloncorp.com/energy/generation/hydro.aspx.

recreation management at the Pond over the upcoming 50 years (Exelon 2012a, 2012b). Visitors also use the Pond area for boating, camping, hunting, hiking, swimming, nature observation and educational facilities (SRBC 2006).

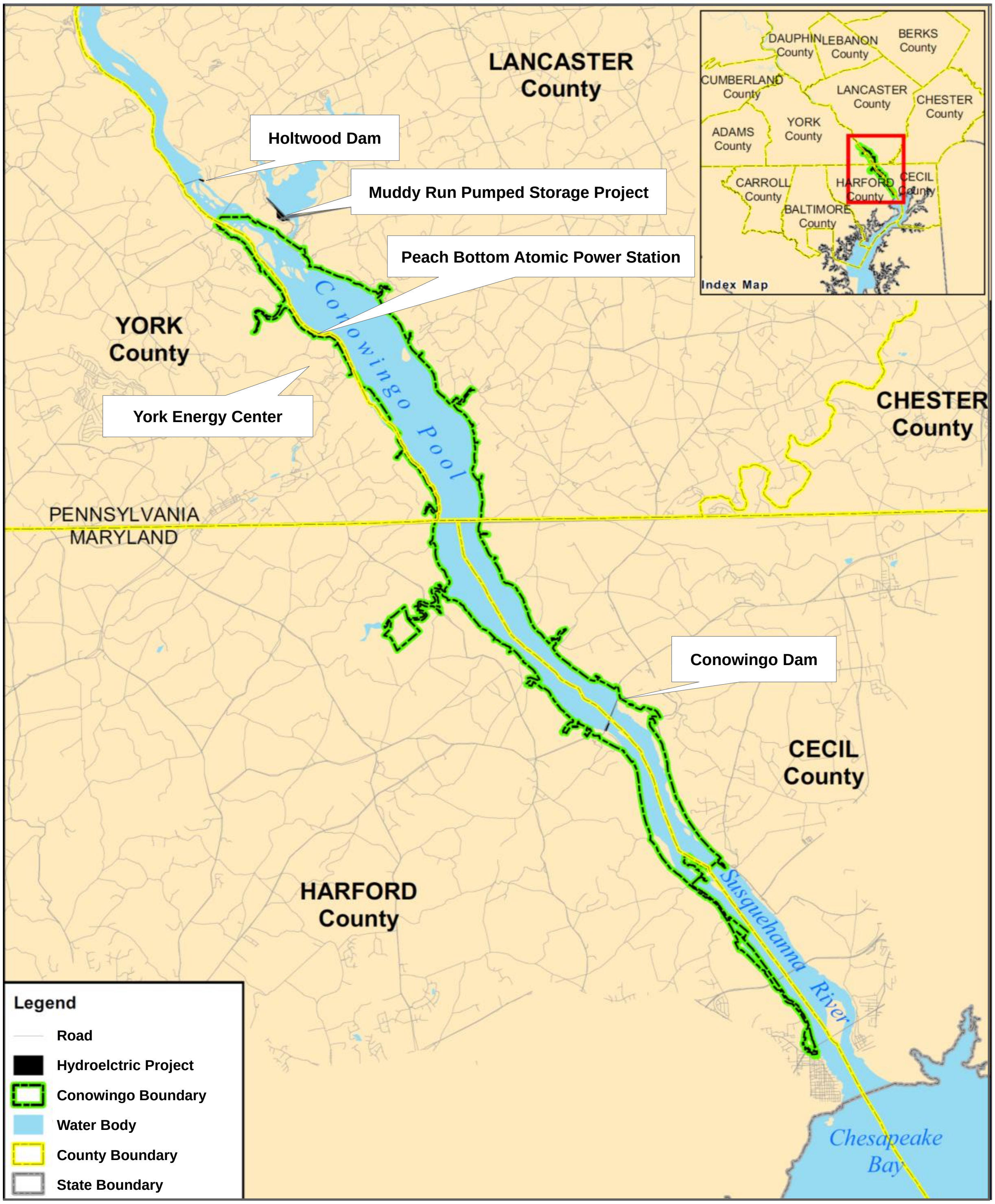
The Pond is also used as a public water supply source for nearby areas. The City of Baltimore and the Chester Water Authority (which provides water to southeastern Pennsylvania and northern Delaware) have permits to withdraw water from the Pond (Exelon 2012b).

The Pond plays an essential role in providing electricity to customers in the region, and not just from Conowingo and Muddy Run. At the north end of the Pond is the Holtwood Dam, which is the location of a hydroelectric facility owned by Pennsylvania Power and Light (PPL). The Holtwood Hydroelectric Plant currently has a rated capacity of 109 MW, and was recently granted a license amendment by FERC to expand its capacity to 196 MW and extend its license expiration date to 2030 (Exelon 2012b).

Two additional generating facilities are located near the banks of the Pond and use the water for industrial cooling purposes. First, the Peach Bottom Atomic Power Station is co-owned by Exelon and Public Service Electric and Gas of New Jersey and operated by Exelon. It is located on the west bank of the Pond in York County, Pennsylvania. It is a two-unit nuclear generating facility capable of generating over 2,000 MW of electricity.

The second facility that uses the Pond water for cooling purposes is the York Energy Center. This facility is a combined-cycle power plant in York County that is owned by Calpine and withdraws cooling water approximately seven miles upstream from the Conowingo Dam (Exelon 2012b). It began operations in 2011 and has a maximum capacity of 565 MW (Calpine 2010, p. 8).

Figure 1. Conowingo Pond



Source: Exelon Generation and NERA

1. Conowingo Hydroelectric Project

Construction of the Conowingo Dam began in 1926, roughly ten miles northwest of the mouth of the Susquehanna River at the Chesapeake Bay. When completed in 1928, the Conowingo Hydroelectric Project had the largest turbines and generators of any power plant built to date. With roughly 250 MW of capacity at the time, Conowingo also became the second largest hydroelectric project in the United States, behind Niagara Falls.

Conowingo is a large conventional hydroelectric power plant. The water flow of the Susquehanna River provides the fuel to spin its turbines and generate electricity. In 1964, four additional turbines were added to the original seven, and these eleven turbines now have a rated capacity of 572 MW. Conowingo is the most downstream of five hydroelectric projects located on the Lower Susquehanna River.

In 2011, Conowingo supplied over 2.5 million megawatt hours ("MWh") of generation to the regional grid. Unlike electricity produced by fossil fuel generation, the electricity produced at Conowingo does not produce harmful emissions of greenhouse gases or other pollutants such as sulfur dioxide, nitrogen oxide and mercury. In additional to its generation and capacity, Conowingo provides other valuable services (such as "black-start" capability in the case of a widespread electricity outage) to the local electricity grid that will be discussed in detail in the next chapter.

Conowingo has an operating license issued by FERC that expires on September 1, 2014. On March 12, 2009, Exelon filed a Notification of Intent (NOI) with FERC to relicense the Conowingo facility.

2. Muddy Run Pumped Storage Project

The Muddy Run Pumped Storage Project began commercial operations in 1966 when a dam was built across the Muddy Run ravine. Located in Pennsylvania just north of the Maryland border (see Figure 1 above), it was the largest pumped storage hydroelectric power plant in the world when built.

Muddy Run utilizes relatively cheap electricity from the power grid during off-peak hours to move water from the lower-elevation Conowingo Pond to the higher-elevation Muddy Run Reservoir in order to store energy. The Muddy Run Reservoir is located on the eastern shoreline of the Pond in Lancaster County, PA, and is approximately 411 feet above the normal elevation of the Pond.

During periods of high electricity demand (peak-hours), water is released from the upper reservoir and discharged back into the Pond, powering eight turbines that have a combined rated capacity of 1,070 MW of electricity. This electricity is sold at relatively higher prices compared to when the water was pumped.

Electricity is generally not a storable commodity and thus changes in demand usually have to be matched by simultaneous changes in supply. Pumped storage is an exception and, indeed, pumped storage is currently the only widely adopted large-scale electricity storage technology (Yang and Jackson, 2011), and is therefore valuable to the electricity grid in periods of high demand. The output of Muddy Run is particularly critical for meeting the electricity needs of the region on hot summer afternoons when electricity demand and the marginal costs of electricity generation are the highest[11]. Muddy Run also provides important ancillary services to the grid that enable grid operators to balance supply and demand.

Muddy Run has an operating license issued by FERC that expires on August 31, 2014. On March 12, 2009, Exelon filed an NOI with FERC to relicense the Muddy Run facility.

C. Importance of Hydroelectric Facilities

Hydropower provides roughly 8 percent of U.S. electricity generation in 2011 according to the U.S. Energy Information Administration (EIA).[12] There are immense benefits of the continued reliance on hydroelectric facilities such as Conowingo and Muddy Run, in addition to those already noted above. Hydroelectric power is a clean, efficient, reliable, flexible and domestically produced electricity source.

These benefits have long been recognized by policymakers and operators of electricity grids. For example, an official at the U.S. Department of Energy recently noted the great benefits of the use of hydroelectric power:

> "Modernizing and optimizing our nation's hydropower dams is one of the best opportunities to sustainably increase our supply of clean energy. Hydropower's ability to quickly ramp up power output makes it a natural fit with wind, solar and other renewable energy sources that supply variable power" (Beaudry-Losique, Director, EIA Wind & Water Program, 2010).[13]

At a recent meeting of grid stakeholders, the PJM president and CEO spoke about the benefits of pumped storage facilities such as Muddy Run. These remarks were described in a PJM newsletter:

> "Terry Boston, PJM president and CEO, discussed the need for a stronger, more flexible grid and emphasized the importance of innovation. Boston said PJM was focused on the grid reliability benefits of energy storage technologies as possible ways to integrate intermittent resources, including pumped storage, large-scale compressed air, mobile batteries and even water heaters" (*State Lines*, December 2011*)*.[14]

---

[11] http://www.exeloncorp.com/powerplants/muddyrun/Pages/profile.aspx.

[12] http://www.eia.gov/energy_in_brief/renewable_electricity.cfm .

[13] http://energy.gov/articles/boost-hydropower-and-economy.

[14] http://www.pjm.com/about-pjm/newsroom/newsletter-notices/state-lines/2011/december.aspx.

D. Report Objectives

The purpose of this report is to provide an assessment of the major socioeconomic contributions of the Projects. These contributions include the gains to the electricity system, including the potential for lower electricity prices. We develop quantitative impacts of the Projects on the local, state and federal economies, including the potential for additional jobs, gross regional/domestic product, personal income and taxes. The environmental impacts include the potential to reduce greenhouse gas emissions and other pollutants as well as gains to water supply and recreational opportunities. Although the primary emphasis of this report is on quantifiable impacts, we also provide qualitative discussions of various non-quantified socioeconomic impacts of the Projects.

E. Organization of the Report

The remainder of the report is divided into four chapters. Chapter II discusses the contributions of the Projects to the electricity system and presents estimates of the effects of the generation and capacity supply of the Projects on electricity rates.

Chapter III provides an overview of the economic contributions of the Projects, which includes both direct and overall impacts. The direct impacts of the Projects are the effects that can be identified as resulting directly from Project activities and are not dependent on subsequent economic interactions. These direct impacts include the employment and payroll of the Projects, the monetary outlays by Exelon for supplies and services related to the Projects and the direct contributions of the electricity the Projects provide to customers. Chapter III also presents the modeling results of the overall effects of the Projects, integrating the direct impacts into a modeling framework that also incorporates multiplier effects.

Chapter IV provides an overview of the environmental impacts of the Projects, focusing specifically on the impacts of the generation of the Projects on air emissions. Also discussed in this chapter are various other non-quantified socioeconomic impacts of the Projects and the surrounding areas, including recreational and water supply uses.

II. Contributions of the Projects to the Electricity System

This chapter discusses the contributions of the Conowingo Hydroelectric and Muddy Run Pumped Storage Projects to the electricity system. The primary purpose of the Projects is to supply electricity to customers in the region and across the PJM Interconnection electricity grid. This section first discusses the various important electricity contributions provided by the Conowingo and Muddy Run Projects. Then, we estimate the effects of the Projects on the electricity rates of residential, commercial and industrial customers.

A. Electricity Contributions of the Conowingo Hydroelectric Station

Conowingo is a hydroelectric facility owned and operated by Exelon. The water flow of the Susquehanna River provides the fuel to spin its turbines and generate electricity (see Figure 2). The Project is located in northern Maryland, and has been operating since 1928. Conowingo provides the local grid with electricity generation, capacity and other ancillary services. Conowingo is among the largest non-Federal hydroelectric facilities in the United States. It has 11 turbines and a rated capacity of 572 MW.

Figure 2. Conowingo Hydroelectric Project

Source: Exelon (2012b).

1. Conowingo Electricity Generation

The supply of electricity from Conowingo at any given time depends on a variety of factors, including the needs of the regional electricity grid, the flow of the river and the constraints imposed on the facility.

As a result of a 1988 settlement agreement, there exist minimum flow requirements and minimum downstream dissolved oxygen requirements to protect downstream aquatic resources. The FERC license for Conowingo does not allow the depth of the Pond to fall below 100.5 feet, and additional restrictions exist to promote recreational resources of the Conowingo Pond during summer weekends (SRBC 2006, p. 14).

Between 1996 and 2010, average annual generation at Conowingo was roughly 1.8 million MWh. In 2011, generation increased to over 2.5 million MWh, largely due to the increase in water flow caused by Tropical Storm Lee and Hurricane Irene. Table 1 displays the Conowingo generation by month from 2007 until 2011. The generation of Conowingo is used most heavily during the late afternoon hours of the day when electricity demand is the largest and thus the benefits to the grid are the largest.

Table 1. Conowingo Generation by Month (2007-2011)

	Conowingo Generation (GWh)					
Month	**2007**	**2008**	**2009**	**2010**	**2011**	**Avg**
January	264	221	151	189	68	178
February	74	285	153	131	149	158
March	298	311	207	268	338	285
April	282	246	198	187	318	246
May	149	220	177	152	326	205
June	55	69	160	77	150	102
July	33	57	95	43	59	57
August	49	40	127	42	82	68
September	25	39	64	31	214	75
October	46	40	140	173	297	139
November	121	67	145	139	211	137
December	235	250	227	211	307	246
Total	**1,630**	**1,844**	**1,844**	**1,645**	**2,518**	**1,896**

Source: Exelon data and NERA calculations.

The low-cost electricity generation and capacity from Conowingo boost the economy by lowering electricity prices. The following chapter provides estimates of the reductions in the wholesale and retail prices of electricity due to Conowingo.

In addition, a large conventional hydroelectric facility such as Conowingo provides economic value by increasing electricity price stability. Unlike gas or coal-fired generation, hydroelectric power is not subject to market fluctuations due to prices in the underlying fuel source. When the price of coal or natural gas sharply rises, the impact on the price of electricity is dampened due to the stabilizing effects of hydroelectric generation. The benefits of increased price stability are not quantified in this report but are nonetheless important to the electricity system.

2. Conowingo Capacity

Electricity is generally not a commodity that can be easily stored, so sufficient capacity is needed at all times to ensure that the demand for electricity can be continually met. The addition of capacity to an electricity system decreases the chances of a disruption of electricity supply to customers.

PJM defines the capacity of a generation resource as the number of megawatts of electric power which the unit can deliver to the grid.[15] In recent years, a capacity market has been developed to ensure that sufficient capacity is available across the PJM electricity system and to ensure that incentives are in place so that the long-term capacity needs of the grid are satisfied. PJM requires that electricity distributors obtain the capacity necessary to meet the forecasted demand of their customers plus a reserve margin to reflect uncertainty regarding forecasted demand.

This capacity can be obtained by distributors through the PJM capacity market auctions, which are described in detail in Appendix C. Electricity generators in PJM receive payments for their supply of capacity, either through the capacity market auctions or bilateral contracts. The capacity prices received by generators represent the value of supplying capacity to the grid that is in addition to the value placed on the generation.

Conowingo’s 572 MW of capacity provides substantial value to the PJM electricity system grid, and thus to local residents and businesses in the form of lower electricity prices and increased service reliability. If Conowingo were not able to supply capacity at its current level, costly replacement capacity would likely be needed so that peak demand could be met on the grid without service interruptions.

3. Ancillary Services Provided by Conowingo

In addition to the electricity generation and capacity it provides, Conowingo also provides ancillary services within PJM. These ancillary services are additional services that support the reliable operation of the transmission system as electricity is moved from generating sources to retail customers.[16] These services include “spinning reserve” and “black-start capability.” Spinning reserve and black start capabilities provide real additional value to the grid and

---

[15] PJM Manual 18 (PJM Capacity Market Operations, 2012) defines the net capability of a resource (which forms the basis of the definition of installed capacity) and specifies that all capacity resources in PJM need to submit verification tests for their summer and winter net capabilities.

[16] See www.pjm.com.

therefore to the economy. Exelon earns roughly $115,000 annually for providing these services (Exelon 2012b).

a. Spinning Reserve Contributions

Hydroelectric power can generally be injected into the electricity system faster than other energy sources.[17] "Spinning reserve" is extra capacity from generators already connected to the grid[18] that is made available to grid operators in case there is an unexpected need for power on short notice. The power output of generators supplying spinning reserve can be increased quickly (within 10 minutes in PJM) to supply the needed energy to balance supply and demand on the grid and thus ensure system reliability.[19] Spinning reserve is especially valuable to grid operators during periods of outages and when there are large and unanticipated swings in load.

b. Black Start Contributions

To begin operations, nearly all power generators need a supply of electricity. In the event of a widespread power outage (or "blackout"), when a large portion of the power system is out of service, this electricity may be unavailable from the local grid. Such situations are of course uncommon, but the consequences can be catastrophic.

In the event of a large-scale blackout, it is useful for certain generators within the grid to have "black start" capability, meaning they can start themselves without an external electricity source. These units can then be used to restart other generating units, and ultimately restore service to customers (Denholm *et al.* 2010, p. 13).

Large conventional hydroelectric facilities such as Conowingo are particularly well suited to provide black start capabilities. They require little initial power to start up and can quickly provide a large amount of power to the grid, which can enable the resumed operations of other facilities that do not have such capabilities.

Conowingo is a designated black start facility in the event of a system failure of the PJM Interconnection. The necessary equipment and communications therefore exist at Conowingo to provide this important service. In addition to the eleven turbines used to supply generation, two house turbines have also been installed to provide black-start capability (one of these turbines is also used to provide station service under normal conditions).

B. Electricity Contributions of the Muddy Run Pumped Storage Hydroelectric Plant

Muddy Run is a pumped storage hydroelectric plant owned and operated by Exelon in southern Pennsylvania that uses the water from the Muddy Run Power Reservoir and the Conowingo

---

[17] See U.S. Geological Survey website at: http://ga.water.usgs.gov/edu/hydroadvantages.html.

[18] By contrast, non-spinning reserve is extra capacity from generators that are not already connected to the grid.

[19] See PJM website at: http://www.pjm.com/markets-and-operations/ancillary-services/synchronized-service.aspx.

Pond (see Figure 3). Muddy Run began operations in 1966, at which point it was the largest pumped storage power plant in the world[20]. Muddy Run electricity contributions include valuable supplies of capacity and peak generation, as well as ancillary services.

The eight turbines at Muddy Run provide a rated capacity of 1070 MW, making it the largest hydroelectric facility in the region. In order to fill the Muddy Run Power Reservoir, water is pumped from the lower Conowingo Pond during off peak hours. The capacity of Muddy Run is utilized primarily during peak hours when electricity demand is highest (and higher priced generation would otherwise need to be relied upon).

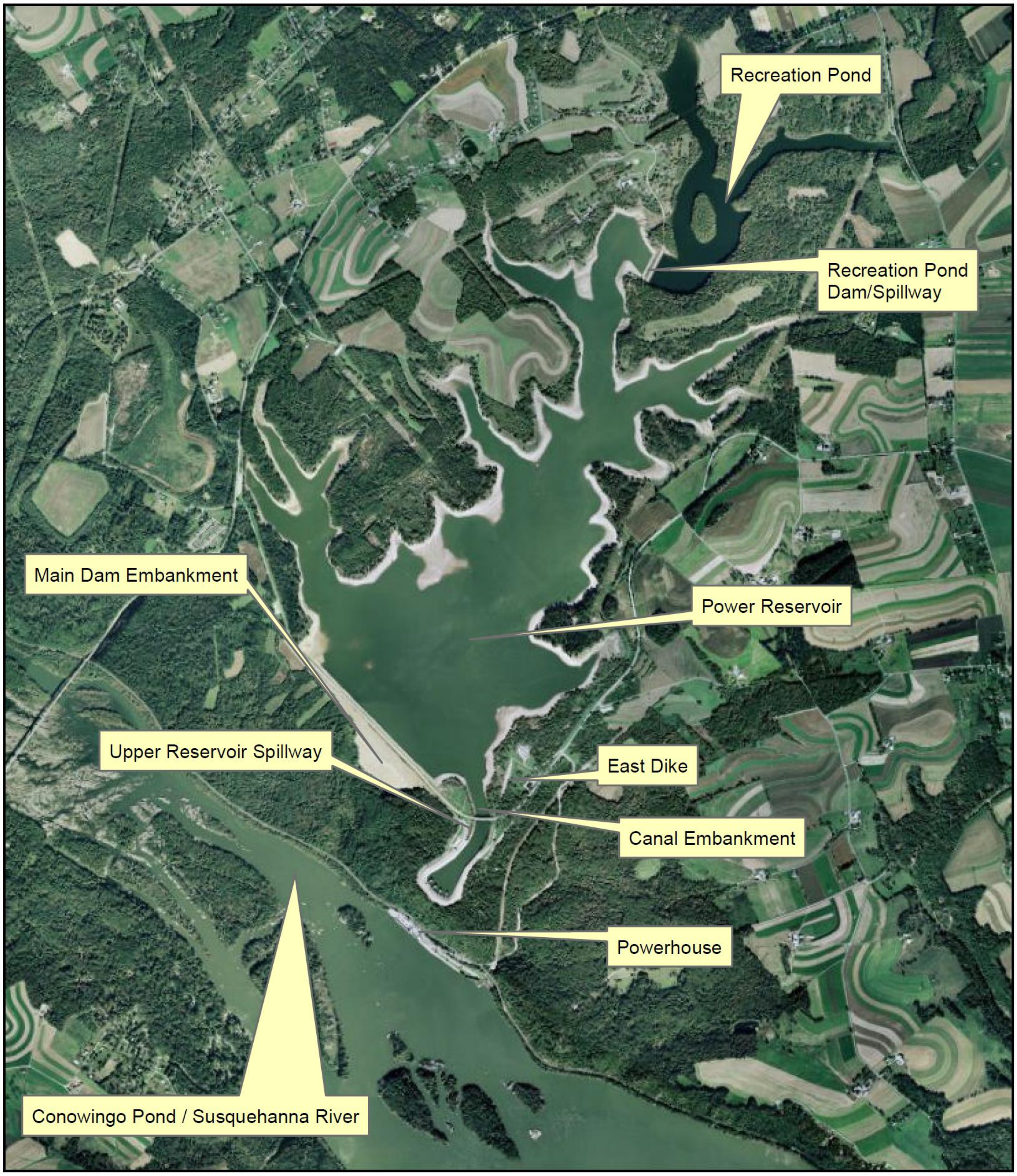
The flexible capacity offered by pumped storage facilities is useful in supporting the use of less predictable energy sources such as wind or solar power. A major concern related to the increased use of these renewable energy sources is that when the wind is not blowing or the sun is not shining, no electricity is produced. However, various states in PJM—including Maryland and Pennsylvania—have renewable portfolio standards that require the increased use of renewable electricity in the near future.[21] The ability to store electricity at pumped storage facilities such as Muddy Run and then provide generation when needed helps to achieve renewable electricity goals.

---

[20] http://www.exeloncorp.com/powerplants/muddyrun/Pages/profile.aspx.

[21] Maryland's "Renewable Portfolio Standard" requires 20 percent of its electricity to be generated by renewable energy sources by 2022 and Pennsylvania's "Alternative Energy Portfolio Standard" requires 18 percent of electricity produced by renewables by 2020-2021 (U.S. DOE).

Figure 3. Muddy Run Pumped Storage Project



Source: Exelon (2012a).

1. Muddy Run Electricity Generation

Table 2 displays the Muddy Run generation by month from 2007 until 2011. Electricity is primarily generated during the day and early evenings, with the highest levels of generation occurring in the peak electricity demand hours from 4 PM until 9 PM.

Table 2. Muddy Run Generation by Month (2007-2011)

	Muddy Run Generation (GWh)					
Month	**2007**	**2008**	**2009**	**2010**	**2011**	**Avg**
January	149	166	136	157	135	149
February	125	153	127	146	108	132
March	145	162	91	104	97	120
April	70	145	144	136	104	120
May	162	172	152	157	113	151
June	157	174	154	158	131	155
July	154	152	163	120	129	144
August	170	143	172	80	125	138
September	164	157	146	151	119	147
October	181	154	144	129	84	138
November	159	133	129	124	75	124
December	167	149	146	135	59	131
Total	**1,803**	**1,860**	**1,704**	**1,596**	**1,280**	**1,649**

Note: Values do not include electricity purchases for pumping.
Source: Exelon data and NERA calculations.

As a pumped storage facility, Muddy Run purchases electricity from the grid in order to pump water into its upper reservoir. Indeed, net generation is negative at Muddy Run, in that more electricity is purchased than generated. However, the value of the electricity generated is significantly larger than the value of electricity purchased, because electricity is purchased during off-peak periods when it is relatively inexpensive and generated during peak demand periods when electricity is relatively expensive.

Table 3 displays the monthly value of net generation at Muddy Run from 2007 until 2011. The value of generation is equal to the revenues from electricity generation minus the cost of electricity purchases. The value of the net generation is significantly positive, averaging roughly $40 million annually.

Table 3. Monthly Value of Muddy Run Net Generation (2007-2011)

	Value of Generation at Muddy Run ($000)					
Month	**2007**	**2008**	**2009**	**2010**	**2011**	**Avg**
January	$3,119	$4,467	$1,935	$1,783	$1,840	$2,629
February	$1,841	$3,102	$1,009	$1,035	$1,889	$1,775
March	$3,090	$2,752	$959	$749	$1,499	$1,810
April	$1,320	$4,041	$1,058	$1,529	$1,047	$1,799
May	$6,551	$8,707	$1,196	$2,739	$3,531	$4,545
June	$6,497	$13,302	$1,961	$4,406	$6,442	$6,522
July	$6,204	$9,487	$2,290	$6,392	$8,589	$6,592
August	$8,252	$4,497	$2,815	$2,830	$3,713	$4,421
September	$5,669	$4,323	$1,686	$3,935	$1,881	$3,499
October	$4,761	$2,139	$1,540	$721	$668	$1,966
November	$3,164	$2,289	$883	$1,123	$646	$1,621
December	$3,614	$2,795	$1,983	$2,973	$529	$2,379
Total	**$54,084**	**$61,899**	**$19,314**	**$30,216**	**$32,273**	**$39,557**

Notes: Values are in thousands of nominal dollars.
The value of net generation is the net result of revenues from the sale of generation minus the costs of purchased generation. Revenues and costs are calculated using the average day-ahead and real-time locational marginal price at the Muddy Run facility.

Source: Exelon data and NERA calculations.

2. Muddy Run Capacity

As described previously in the context of Conowingo, PJM defines the capacity of a generation resource as the number of megawatts of electric power which the unit can deliver to the grid. Generators in PJM must submit to periodic verification tests to confirm their summer and winter capacity levels.

Electricity generators in PJM are paid for their supply of capacity, either through PJM capacity market auctions or bilateral contracts. Capacity payments represent the value of supplying capacity to grid, which is in excess of the value of electricity generation. Such payments are necessary because electricity is generally not a storable good, so sufficient capacity is needed at all times to ensure that the demand for electricity can be continually met, even in periods when demand is at its peak. The capacity market ensures that incentives exist for generators in PJM to provide sufficient supply to meet the demand of its customers in the foreseeable future. The PJM capacity market is described in more detail below and in Appendix C.

Muddy Run is valuable to the electricity grid because water (and thus the potential to generate electricity) can be stored in the upper reservoir and then released whenever it is most needed. With a rated capacity of 1070 MW, Muddy Run is the largest hydroelectric facility in the region. As noted above, in order to fill the upper reservoir, water is pumped from the lower Conowingo Pond during off-peak hours. The capacity of Muddy Run is utilized primarily during peak hours, when electricity is most valuable.

Muddy Run's capacity is therefore valuable in providing lower wholesale and retail electricity prices and increased service reliability. If Muddy Run were not able to supply capacity at its current level, costly replacement capacity would likely be needed so that peak demand could be met on the grid without service interruptions.

3. Ancillary Services Provided by Muddy Run

Muddy Run provides ancillary services that are essential in ensuring the proper functioning of the electricity grid. These include spinning reserve and black start capability, which are also provided by Conowingo, and described above (Exelon 2012a). The ancillary services provided at Muddy Run lead to real economic value, even though this value is not quantified in this study. Exelon earns roughly $10.8 million annually for providing ancillary services at Muddy Run (Exelon 2012a). The following subsections provide information on additional ancillary services provided at Muddy Run, so-called regulation service and voltage control.

a. Regulation Service

Muddy Run provides regulation service to the grid, which is the correction for short-term changes in electricity use that might affect the stability of the power system. Regulation service helps match generation and load and adjusts generation output to maintain the desired frequency.[22]

As noted above, because of the inherent volatility of demand in the electricity market, grid operators need a reliable source of supply to balance minute-to-minute fluctuations. A major advantage of pumped storage facilities is that they offer incomparable flexibility to immediately respond to these fluctuations in the generation or demand for electricity. Muddy Run thus enables the PJM grid to function more efficiently. As additional intermittent electricity sources (e.g., wind power) are added to the grid, regulation services increase in importance.

b. Voltage Control

Muddy Run also supplies the electricity grid with voltage control, which can be provided through adjustments in generator reactive output and transformer taps, and by switching capacitors and inductors on the transmission and distribution systems. This service involves the injection into the grid and absorption from the grid of power in order to maintain voltages in the transmission system (Kirby and Hirst, 1997).

C. Contributions of the Projects to Reduced Electricity Rates

Basic economic theory asserts that increases in supply of a commodity will, all else equal, lead to decreases in its price. The Projects add to the supply of both electricity generation and capacity in the region and therefore should lead to decreases in electricity prices.

---

[22] See www.pjm.com.

This section first provides a brief overview of the wholesale electricity market in PJM and the methodologies we use to estimate the impacts of the projects on this market (full descriptions of the methodologies are provided in Appendices C and D). Then, estimates are provided of the impacts of the Projects on the energy and capacity markets in PJM.

1. Background on PJM Wholesale Electricity Market

Deregulation of wholesale electricity markets in the United States in the 1990s gave rise to the development of independent system operators (ISOs) and regional transmission organizations (RTOs) as means of administering transmission grids on a regional basis[23]. In 1996, the Federal Energy Regulatory Commission (FERC) issued Order No. 888 requiring that all transmission line operators provide non-discriminatory transmission access to all electricity suppliers; the FERC suggested that RTOs or ISOs could be implemented as independent entities tasked with ensuring competitiveness in wholesale markets.

PJM Interconnection had already been in existence as a power pool for Pennsylvania, New Jersey, and Maryland for many decades, but PJM was designated an RTO by FERC in 2001. PJM takes bids to supply electricity from wholesale suppliers. Based on the bids from wholesale suppliers (which generally reflect the marginal cost of generating electricity—i.e., the cost to a wholesale supplier of producing one additional unit of electricity), PJM dispatches generating units and other resources to meet electricity demand in the most cost-effective way, subject to transmission and other constraints. In this system, which is referred to as the PJM Energy Market, a “locational marginal price” (LMP) indicates the day-ahead or real-time price of wholesale electricity at a specific location. The LMP is based on the wholesale market bids accepted by the ISO, the transmission costs and other constraints specific to that location, and the demand[24] for power.

PJM also administers a capacity market known as the Reliability Pricing Model (RPM), in which wholesale electricity suppliers bid to make their electricity generation capacity available in the future to meet the electric grid needs. The objective of the RPM is to ensure that sufficient resources will be available to PJM to meet electricity demand.

2. Price Effects in the PJM Energy Market

Our approach to estimating the electricity rate effects relies on a statistical model of electricity generation in PJM. Using regression analysis, we estimate the effects of various cost drivers on the hourly LMPs in the day-ahead market from 2009 to 2011. We then simulate the removal of the generation of the Projects from the Energy Market (assuming no replacement capacity is added to the grid[25]) and re-calculate the hourly LMPs. The Projects’ Energy Market price impacts are then calculated as the average difference between these two LMPs over all hours of

---

[23] This section draws on information from EIA (1998), FERC (2007) and the PJM website.

[24] Day-ahead demand is the sum of demand bids from load servers which are matched with generation offers. Real-time demand is the actual demand for generation.

[25] The assumption of no replacement capacity is likely reasonable in the short run, given the long periods of time required for the permitting and construction of new power plants.

the three years between 2009 and 2011. The following subsections provide a brief overview of the steps involved in calculating electricity price effects, and detailed information on this methodology can be found in Appendix B.

a. Geographic Regions Analyzed

We use a statistical model of electricity generation to estimate the Projects' price impacts on LMPs in geographic regions across PJM. The selection of regional boundaries for this analysis is determined primarily by the service territories of the electricity distribution companies within PJM. Because the Conowingo and Muddy Run facilities are located very near the borders of a number of distribution companies, the "Project Region" is defined as the service territories of PECO, Delmarva Power & Light (DPL), Baltimore Gas & Electric (BGE), PPL Electric Utilities (PPL) and Metropolitan Edison Company (MetEd).[26]

Table 4 displays the geographic regions for which we calculate price effects. These regions comprise the entirety of PJM's territory between 2009 and 2011, with the exception of American Transmission Systems, Inc. (in Northern Ohio) which joined PJM in 2011.

Table 4. Regions for which Electricity Price Effects are Calculated

Regions	PJM Load Zones	Description of Geography
Project Region	Delmarva Power & Light (DP&L) Baltimore Gas & Electric (BG&E) Metropolitan Edison (MetEd) PECO Energy (PECO) PPL Electric Utilities (PPL)	Southeastern Pennsylvania / Northeastern Maryland / Delaware (The five load zones in close proximity to Conowingo and Muddy Run)
Pennsylvania	Pennsylvania Electric Co. (PENLC) Duquesne Light (DQE)	Pittsburgh Area / Central and Northern Pennsylvania (Proxy for the areas of Pennsylvania not included in the Project Region)
Maryland	Potomic Electric Power Co. (PEPCO)	Southern Maryland / Washington D.C. and suburbs (Proxy for the areas of Maryland not included in the Project Region)
New Jersey	Public Service Electric & Gas Co. (PSEG) Jersey Central Power & Light Co. (JCPL) Atlantic Electric Co. (AE) Rockland Electric Co. (RECO)	All of New Jersey
American Electric Power	American Electric Power (AEP)	Areas of Virginia, West Virginia, and Ohio
Dayton	Dayton Power & Light (DAY)	Western Ohio
Dominion	Dominion Virginia (DOM)	Eastern Virginia, Coastal North Carolina
Allegheny Power Systems	Allegheny Power Systems in WV (APS)	Eastern West Virginia / Western Maryland
Commonwealth Edison	Commonwealth Edison (ComEd)	Northeastern Illinois

b. Methodology

The statistical model allows us to conceptually vary any causal variable to create an estimate of LMPs in each region between 2009 and 2011 under different conditions with respect to that

---

[26] Note that Cecil, Harford, Lancaster and York Counties are all subsets of the "Project Region."

variable, including changes in the supply of electricity from facilities such as Conowingo and Muddy Run. We are effectively using statistical analysis to answer the question "what would the electricity prices have been without the generation of Conowingo and Muddy Run?"

The following factors are assumed to impact the hourly LMPs in each region:

- Hourly electricity demand ("load") in each PJM region;
- Daily natural gas and coal prices[27] in the region;
- Daily high and low temperatures in the local region; and
- Attributes of the hour (time of day, day of week, date of year).

The supply curve of electricity is largely fixed, but moves somewhat from hour-to-hour as transmission conditions change, the availability of units change, and other transient factors (such as temperature) change. If, as a first approximation, we regard the supply curve of electricity as fixed, a statistical regression of electricity price on electricity demand will "trace out" the electricity supply curve. Thus, our estimation strategy is to use the demand to identify the supply curve while varying the supply curve from hour-to-hour to reflect underlying technical supply differentials.

With the supply curve identified, we estimate the changes in hourly LMPs when the net generation of the Projects is removed from the supply of electricity in the Project Region[28]. The average hourly price change over the period 2009 and 2011 is our estimate of the price effect in any geographic region.

c. Results

Table 5 displays the energy market price effects in each region. As expected, the largest price effect is in the Project Region (subsets of which are Lancaster, York, Cecil and Harford Counties), where the removal of the generation of the Projects leads to an average wholesale price increase of $1.21 per MWh, or 2.6 percent of the hourly LMP.

Table 5 indicates that the Projects, on average, are estimated to be responsible for reducing wholesale electricity prices in PJM by between $0.33 and $1.21 per MWh (0.88 to 2.63 percent). The price effects are generally smaller the further is the geographic region from Conowingo and Muddy Run. The smallest price effect is in Western Ohio.

---

[27] Natural gas and coal-fired power plants are most often the marginal source of electricity generation (or the "price setting" units) within PJM.

[28] This is accomplished by increasing the load in the Project Region by the amount of the hourly net generation of the Projects. Please see Appendix C for an explanation of this methodology.

The PJM electricity grid is also interconnected with the grids of the surrounding states and regions. It is therefore likely that there are small price effects in areas of the country not displayed in Table 5. These estimated price effects are not included in our analysis.

Table 5. PJM Wholesale Energy Market Price Impacts

	Price Effect	
	$/MWh	% Change
Project Region	$1.21	2.63%
Pennsylvania (PENLC+DUQ)	$0.44	1.13%
Maryland (PEPCO)	$0.83	1.74%
New Jersey	$0.77	1.65%
American Electric Power	$0.38	1.01%
Dayton Power & Light	$0.32	1.03%
Dominion Virginia	$0.67	1.47%
Allegheny Energy	$0.59	1.42%
Commonwealth Edison	$0.33	0.88%

Note: Results do not include capacity market impacts.
Percentage impacts are calculated as the average hourly price effect (in $/MWh) divided by the average hourly LMP in the region.
Source: NERA calculations as explained in text.

3. Price Effects in the PJM Capacity Market

We estimate the effects of the Projects on capacity prices by comparing the market clearing prices in recent PJM capacity auctions to the clearing prices in hypothetical auctions in which the Projects' capacity has been removed. The following subsections provide a brief overview of this methodology and the results. Detailed information on the methodology is provided in Appendix C.

a. Overview of Methodology

The market clearing capacity price is given by the intersection of the supply and demand curves. The supply curve is determined by the bids of electricity generators, whereas the demand curve is defined in advance by PJM administrators based on forecasts of peak load, desired reserve margins, and the costs of building new capacity.

We use data gathered from PJM on the annual capacity auctions at the RTO (PJM-wide) level[29], and we assume that the capacity price reductions due to the Projects are equal across PJM. We

---

[29] Capacity auctions are also sometimes held for particularly "constrained" sub-regions within PJM. In certain years the capacity prices in the Mid-Atlantic region of PJM (MAAC) have been significantly higher due to transmission constraints. Because the capacity of the Conowingo and Muddy Run facilities are in the MAAC region, this implies their capacity was more valuable in these years. Thus, our focus on RTO capacity prices will lead to conservative estimates of capacity price impacts.

estimate the price impacts from 2007/2008 to 2013/2014 using the following steps (each is explained in detail in Appendix C):

1. Recreate the administratively-defined demand curves in annual capacity auctions;

2. Using graphical depictions of the supply curve for each annual capacity auction, create linear approximations of the curves around the auction clearing price and quantity;

3. Estimate the hypothetical auction clearing prices with the capacity of the Projects removed:

    a. Shift the linearly approximated supply curve in by the combined capacity of the Muddy Run and Conowingo facilities;

    b. Determine the intersection point between this shifted-in supply curve and the original administratively-defined demand curve;

    c. Using this intersection point, calculate the differences in capacity price and total capacity payments compared to the original market clearing price and quantity;

4. Convert the change in total capacity payments to generators into a change in capacity charges to electricity customers in PJM, using data on average capacity charges from PJM and the assumption that the percent change in capacity payments to generators equals the percent change in capacity charges to customers.

This methodology for estimating capacity market price effects relies on the assumption that there is no substitute for the capacity of the Projects in PJM, which is likely a reasonable assumption in the short-term. In the long-term, new capacity could be built to replace the generation of the Projects.

b. Results

Using the methodology described above, the Projects' effects on the PJM annual capacity auctions for the 2007/2008 to 2013/2014 delivery years are displayed in Table 6. Because the administratively-defined demand curve is designed to be relatively steeply sloped, small changes in capacity can lead to significant swings in capacity prices. Table 6 shows that the price of capacity ranged from $16.46 per MW-day to $174.29 per MW-day. The estimated changes in prices due to the removal of the Projects' capacity range from 9.4 to 35.5 percent.

Table 6. Contributions of the Projects to Reduced Capacity Payments in PJM

	Auction Results			Removal of Projects' Capacity			Change in Capacity Payments
Delivery Year	Capacity Price ($/MW-day)	Cleared Capacity (MW, UCAP)	Total Payments ($/day)	Capacity Price ($/MW-day)	Cleared Capacity (MW, UCAP)	Total Payments ($/day)	(%)
2007/2008	$40.80	129,409	5,279,895	$55.48	128,942	7,154,152	35.5%
2008/2009	$111.92	129,598	14,504,563	$143.29	128,583	18,424,161	27.0%
2009/2010	$102.04	132,232	13,492,933	$119.72	131,651	15,761,047	16.8%
2010/2011	$174.29	132,190	23,039,465	$191.99	131,256	25,200,136	9.4%
2011/2012	$110.00	132,222	14,544,365	$124.54	131,743	16,407,168	12.8%
2012/2013	$16.46	136,144	2,240,922	$18.92	136,144	2,576,256	15.0%
2013/2014	$27.73	152,743	4,235,572	$33.89	152,743	5,176,089	22.2%

Source: PJM BRA Auction Results; NERA calculations.

In Table 7, the Projects' effects on capacity payments to generators are converted to effects on capacity charges to electricity customers. The annual average charge to customers for capacity ranged from $6.25 to $12.15 per MWh. Applying the annualized percentage change in capacity payments to generators to these capacity charges results in changes in capacity charges that range from $0.87 to $2.60 per MWh.

The Projects' average contribution to reduced capacity prices over the six years is roughly $1.65 per MWh. The impact on wholesale electricity prices is estimated to be larger due to the capacity contributions of the Projects (displayed in Table 7) than due to the contributions of electricity generation of the Projects (which were displayed in Table 5).

Table 7. Contributions of the Projects to Reduced Capacity Charges in PJM

Calendar Year	Capacity Charge to Customers[1] ($/MWh)	Change in Capacity Charge[2] (%)	Change in Capacity Charge ($/MWh)
2008	$8.33	31.3%	$2.60
2009	$11.02	21.9%	$2.42
2010	$12.15	13.1%	$1.59
2011	$9.72	11.1%	$1.08
2012	$6.25	13.9%	$0.87
2013	$7.16	18.6%	$1.33
Average			$1.65

Notes: [1] In 2012 and 2013, the annual percent change in capacity charges is assumed to equal the annual percent change in the weighted average capacity price paid to generators in PJM.

[2] Average of the percent change in total capacity payments for the related delivery years.

Source: PJM Capacity Market auction results; NERA calculations.

4. Electricity Rate Contributions by Customer Group

The total effects on retail electricity prices are the sum of the PJM energy market and PJM capacity market price effects in each geographic region of PJM. These price effects may understate the actual contributions to electricity prices of the Projects because of our conservative modeling assumptions and because the significant contributions of the Projects to ancillary services are not quantified.

Capacity and energy market prices are both components of the wholesale price of electricity. These wholesale prices are passed on to consumers of electricity, so the price effects of the Projects are assumed to be equal for electricity customers of all types.

The next step in our methodology is to convert these price effects into percentage impacts on electricity rates for residential, commercial and industrial customers. Because residential, commercial and industrial customers pay substantially different amounts in transmission and distribution fees (which typically comprise roughly half of retail electricity rates), the percentage impacts on retail electricity prices will differ by customer type. We estimate the percentage change in retail electricity price in a given region by dividing the price effect of the Projects by the average retail price of electricity for each customer type in that region.

To develop average retail electricity prices for residential, commercial, and industrial customers, we use data from the U.S. Energy Information Administration (2012) on zonal electricity sales and revenues by customer type. We then add together the electricity price impacts and capacity price impacts described in the preceding sections, arriving at overall price impact levels. Finally, we translate these price impact levels into price impact percentages by dividing the price impact levels by the average retail prices[30].

Table 8 displays our calculations of the Projects' contributions to reduced electricity rates by customer type and geographic region. Note that the "Project Region" has been divided into two sub-regions for Maryland and Pennsylvania because average electricity rates differ in Maryland and Pennsylvania.

Table 8. Contributions to Reduced Electricity Rates by Customer Type and PJM Region

	Price Effects[1]	Average Retail Prices ($/MWh)[2]			Impacts on Average Retail Price[3]		
Electricity Modeling Region	($/MWh)	Residential	Commercial	Industrial	Residential	Commercial	Industrial
Project Region in PA (PECO+PPL+METED)	2.86	135.32	116.57	84.71	2.1%	2.5%	3.4%
Project Region in MD (BGE)	2.86	146.50	127.16	86.49	2.0%	2.2%	3.3%
Pennsylvania (PENLC + DUQ)	2.09	127.12	92.21	73.73	1.6%	2.3%	2.8%
Maryland (PEPCO)	2.48	151.96	117.06	102.50	1.6%	2.1%	2.4%
Project Region in DE (DPL)	2.86	138.81	113.22	93.40	2.1%	2.5%	3.1%
New Jersey	2.42	163.78	137.40	116.42	1.5%	1.8%	2.1%
American Electric Power	2.03	94.69	81.08	55.25	2.1%	2.5%	3.7%
Dayton Power & Light Co.	1.97	122.15	101.03	82.15	1.6%	1.9%	2.4%
Dominion Virginia	2.32	104.37	76.86	61.21	2.2%	3.0%	3.8%
Allegheny Energy	2.24	92.99	77.18	60.62	2.4%	2.9%	3.7%
Commonwealth Edison	1.98	121.65	99.70	63.79	1.6%	2.0%	3.1%

Notes: [1]Price effects are the sum of the PJM Energy Market price impacts for each region and the PJM Capacity Market price impact of $1.65 per MWh for all regions.
[2]Average of 2009, 2010 and 2011 average retail prices by customer type from EIA (2012).
[3]Impacts on average retail prices are the price effects as percentages of average retail prices for each customer type.

---

[30] For example, assume that the LMP price impact is $1 per MWh, the capacity price impact is $1.50 per MWh, and the average retail electricity price for consumers is $100 per MWh. In this case, the price impact to consumers in percentage terms would be ($1 + $1.50)/$100 = 2.5 percent.

There are various uncertainties associated with these estimates of electricity rate contributions. The methodology uses historical economic conditions, which of course are subject to change. For example, environmental regulations recently proposed or finalized by the U.S. Environmental Protection Agency are expected to affect electricity prices and could thus affect the electricity price reductions due to the Projects.

III. Contributions of the Projects to the Economy

This chapter develops estimates of the contributions of the Projects to the economy. We first describe our methodology, which includes the use of a state-of-the-art economic impact model (Regional Economic Models, Inc., or REMI) to estimate regional economic impacts. We describe the process for developing the inputs to the REMI model using data provided by Exelon and other public sources. Finally, we present the results of the REMI modeling for various economic impact categories including jobs, income and population.

A. Overview of Economic Impact Methodology

This section provides background on the methods economists have developed to assess the economic impacts of business activities—such as the operations of hydroelectric facilities—on local or regional economies. The section begins with an overview of the types of economic impacts that typically are distinguished in regional economic assessments. We then provide an overview of the REMI model that was developed specifically for this study.

1. Categorization of Economic Impacts

The economic impacts of a hydroelectric facility on the regional economy can be classified in various ways, depending on the specific methodology used. One common approach is to group impacts into two broad categories:

1. *Direct impacts*. Direct impacts include the Projects' direct employment and expenditures in the relevant jurisdictions. In addition, direct impacts include the Projects' effects on electricity rates, taxes, tourism, and other categories.

2. *Indirect and induced (often referred to as "multiplier") impacts.* Multiplier impacts represent the subsequent rounds of economic activity that occur as the direct effects percolate through the economy. Key elements include effects of employee spending in the region as well as the subsequent rounds of spending for those receiving income from the expenditures of the Projects. Complex economic impact models also include the subsequent effects on local wage rates, prices, and other economic variables. The results of these subsequent multiplier effects are estimates of the additional effects of the Projects on overall economic activity including employment, gross regional product, population and income.

Direct effects are usually estimated through a detailed process of data gathering. As discussed below, multiplier effects can be estimated using a regional economic model such as REMI.

2. Overview of the REMI Model

We use the REMI Policy Insight Plus (PI+) model to develop estimates of the local, state and national economic contributions of the Projects. REMI is a state-of-the-art regional economic tool that has been developed and refined by researchers over more than twenty-five years. It is widely used by federal, state, and local agencies, as well as analysts in the private sector and academia, to estimate the effects of major projects and policies including forecasting and planning, economic development, transportation, energy and natural resources, taxation, budget and welfare, and environmental policies.

The core of the REMI model is a set of input/output ("I/O") relationships among different industries. These relationships show how industries are related to one another, in terms of both inputs and outputs. Thus, they allow one to estimate how changes in one industry will affect demand for other industries (those that provide inputs to the industry in question) or supply (those that purchase outputs from the industry). In addition, I/O models can be used to trace the effects that result from changes in the incomes of workers in the affected industries.

The REMI model, however, goes well beyond the standard I/O relationships to incorporate other important feedback effects. The model includes demographic components, because the population of an area over a long span of time depends in part on the available economic opportunities. Changes in population in turn have feedback effects on the local economy, affecting the demand for housing and other goods. Other feedback effects include changes in wages as the result of changes in economic activity. If employment increases, for example, wages will tend to rise, affecting the competitive position of the region relative to other areas.

REMI has been regularly updated both to include the newest empirical information and to integrate the most up-to-date theoretical framework. For example, REMI has incorporated a component known as the "new economic geography," which allows different sub-regions in the model to interact in a manner consistent with the most recent theory. These additions to the model provide even greater abilities to capture the complicated geographic interactions that influence the levels of economic activity in various regions.

The REMI model is based on forecasts of economic data that are of course highly uncertain. Actual future economic conditions may differ substantially from the predictions of these forecasts. The uncertainties in the forecasts could affect the estimates of the economic impacts of the Projects, although the changes are not likely to be significant since we are interested in the *change* in economic conditions—as opposed to the level of the conditions—and we have found that such changes are relatively consistent across relatively minor changes in the baseline forecast.

Appendix A contains a more detailed description of the REMI model.

a. REMI Model Developed for this Study

Each version of the REMI PI+ model is custom-built for the regions of interest, which can range from small areas to entire countries. The model custom-built for this project was compiled in March 2012 with version 1.3 of REMI's PI+ application and includes historical data through 2010 based upon the most recent U.S. Census (2010), recent reports of the Bureau of Economic Analysis and the Bureau of Labor Statistics, as well as various other sources.

The REMI model is available at the county or state levels. The model developed for this study is a nationwide model broken down by the following five model regions:

1. Harford and Cecil Counties, Maryland;
2. Lancaster and York Counties, Pennsylvania;
3. Rest of Maryland;
4. Rest of Pennsylvania; and
5. Rest of United States.

This regional breakdown allows for results to be presented at the regional level—including only the counties surrounding the Conowingo Pond—and at the state and national levels. The REMI model generates forecasts for each of these geographic regions, which we use to generate estimates of the "equilibrium" economic contributions of the Projects.

It is important to emphasize that this is a multi-region model rather than a model that disaggregates results from a larger region to sub-regions. The multi-region model takes into account interactions among the various regions. Thus, for example, if employment conditions change in Lancaster County, the REMI model accounts for the effects of these changes in all regions of the model.

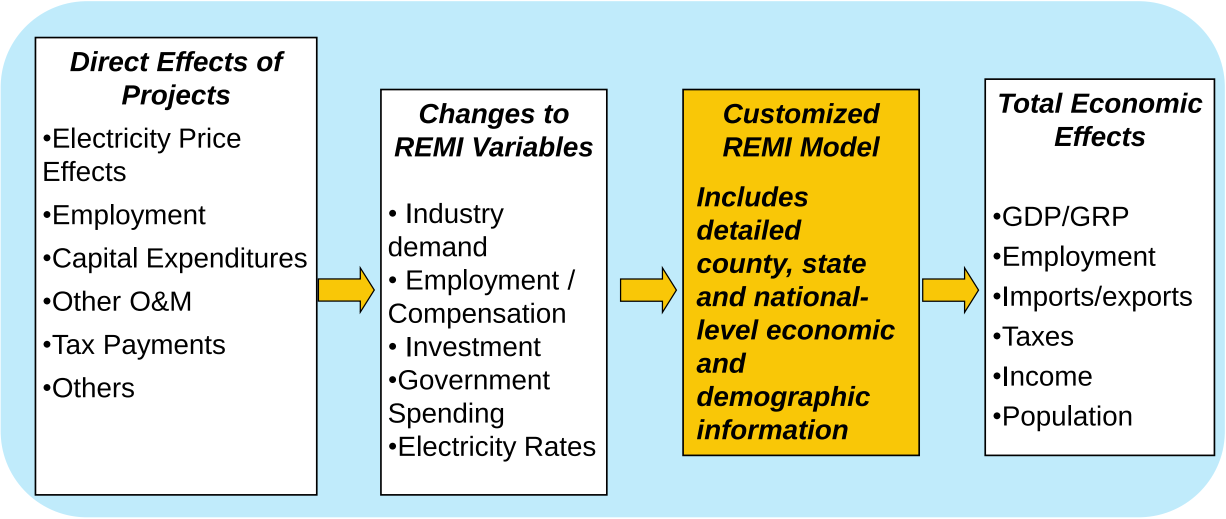
b. REMI Model Economic Impacts Estimates

The use of the REMI model to estimate the socioeconomic effects of the Projects can be viewed as a two-step process. The first step is a baseline simulation of the economy. This baseline simulation assumes that the Projects are in place, including the operations and economic activity related to the Projects. The baseline simulation includes values for the principal economic variables, including jobs, population, personal income, and gross regional product.

The second step is to develop an alternative simulation in which we change the economic variables in the REMI model to reflect the direct effects of the Projects. We then use the REMI model to simulate the economic activity for this alternative simulation. The difference in economic activity between that alternative simulative and the baseline simulation provides an estimate of the overall economic contributions of the Projects in any given year.

Figure 4 provides a visual depiction of how the direct effects of the Projects are translated into estimates of total impacts on the economic activity in a given model region.

Figure 4. REMI Model Flow Chart



c. Equilibrium Contributions of the Projects

There is, however, an additional complication involved in assessing the equilibrium contributions of the Projects. The direct effects of the Projects are entered into REMI on an annual basis, starting in 2012.

However, the simulation results in 2012 will not fully reflect the equilibrium (or long-term) contributions of the Projects. REMI is a dynamic model that allows firms and individuals to gradually change their behavior in response to changing economic conditions, as predicted by general equilibrium economic theory. It often takes years for economic effects to adjust to a long-term equilibrium. For example, if employment and expenditures in Lancaster and York Counties decrease, population would also decrease as residents seek opportunities elsewhere. But the full adjustment would take several years. It would thus be misleading to use the 2012 model results.

To account for these equilibrium effects, we input the current contributions of the Projects for each year starting in 2012, and we use the estimates from REMI of economic contributions in 2017, at which point the economy has largely adjusted to its new equilibrium. We cannot use the 2017 results directly, however, because they reflect growth in the economy and not just the adjustments to the changes in direct and indirect economic inputs. Thus, we use the following four-step procedure.

1. Develop a baseline REMI simulation from 2012 to 2017.

2. Develop an alternative REMI simulation using the various direct effects of the Projects as constant model inputs in each year from 2012 to 2017.

3. Calculate the percentage changes in various economic metrics of interest in 2017. In other words, we calculate the percentage difference between the alternative REMI simulation results for 2017 (from step 2) and the baseline simulation results for 2017 (from step 1).

4. Apply the 2017 percentage changes to the values from the 2012 baseline forecast. The result is an estimate of the annual equilibrium contributions of the Projects.

The last step removes the effects of growth in the economy and population by using the equilibrium (2017) percentage impact and applying it to the current (2012) values for each entity. For example, if the Projects' contributions to employment in Lancaster and York County were 5 percent in 2017 and Lancaster and York County had 100,000 jobs in 2012, the equilibrium effect of the Projects in 2012 would be to increase employment by 5,000 jobs. Such estimates of equilibrium contributions are presented for all of the socioeconomic categories considered in this study.

B. Direct Economic Contributions of the Projects

The Conowingo and Muddy Run Projects contribute to the economy not only by lowering electricity prices for consumers across the PJM electricity grid, but also by providing local jobs, increasing tax payments and raising the demand for local goods and services. This section provides an overview of these important economic contributions. In the final section of this chapter, these direct economic contributions are used (along with the contributions to reduced electricity prices) to estimate the overall economic contributions of the Projects using the REMI model.

1. Employment

The Projects are operated and maintained by 56 full-time employees. During periodic outage periods, employment at the facilities can increase substantially. Over the past three years, the Projects have employed an average of over 100 part-time workers per year. These jobs contribute to local employment, and the employees of the Projects spend their paychecks on a variety of goods and services in northern Maryland and southern Pennsylvania.

The total compensation of the Projects in 2011 was over $8 million. Compensation at Conowingo was roughly $6.6 million, which included $5.3 million in base wages and overtime, and $1.2 million in benefits and incentives. Total 2011 compensation at Muddy Run was roughly $1.5 million, which included $1.2 million in base wages and overtime and $300 thousand in benefits and incentives.

2. Demand for Local Goods and Services

The Projects also contribute to the local and regional economies by increasing the demands for various products and services. Expenditures of the Projects in 2011 were $7.4 million on contracting, $2.9 million in materials and supplies and roughly $3.8 million in other operating and maintenance expenditures (not including compensation).

As noted above, Muddy Run also purchases a significant amount of electricity from the local grid in order to operate its pumps. Electricity expenditures at Muddy Run were over $50 million in 2011 (based on the average day-ahead and real-time locational marginal prices at the facility).

3. Capital Expenditures

Exelon's ongoing capital expenditures maintain and enhance the Conowingo and Muddy Run facilities. Such investments contribute to the local economies by increasing the capital stock and raising the demands for local workers and materials that are used to carry out these improvements. Exelon estimates that average annual capital costs are roughly $16 million at Conowingo and $10 million at Muddy Run (Exelon 2012a; Exelon 2012b).

In addition, Exelon is proposing several new environmental measures at the facilities that would increase annual capital and operating expenditures. These measures include shoreline and recreation management, as well as additional safeguards to the local wildlife populations. Exelon estimates the average annual cost of these additional environmental measures to be roughly $1.3 million (Exelon 2012a, 2012b).

4. Tax Payments

Exelon pays a significant amount in taxes each year to the local, state and federal governments that are attributable to the operations of the Projects. These tax payments contribute to the economy by either funding additional local government services or by decreasing the tax burden on individuals and businesses.

Annual property taxes are roughly $3.8 million at Conowingo and $500,000 at Muddy Run (Exelon 2012a). Exelon estimates that the annual federal income taxes attributable to the Projects are approximately $63.1 million, and that the annual state income taxes are $4.5 million in Pennsylvania and $6.6 million in Maryland (Exelon 2012a; Exelon 2012b).

5. Expenditures of the Projects as Inputs to REMI

This section provides a brief overview of how certain direct economic contributions of the Projects are converted into inputs to the REMI model. Specifically, it covers the employment, expenditures and tax payments of the Projects. Contributions to electricity rates are covered in the following section. Appendix E provides more detailed descriptions of how these direct contributions are converted into the appropriate REMI model variables.

Table 9 displays the annual employment, expenditure and tax payments of the Projects.[31] As noted above, REMI estimates the contributions of the Projects by comparing a baseline simulation of the economy with an alternative simulation. The baseline economic data in REMI is assumed to include the contributions of the Projects. The alternative REMI simulation is

---

[31] These data are from the License Applications for Conowingo and Muddy Run (Exelon 2012a, 2012b) and from Exelon internal financial records.

therefore created by *removing* the expenditures and employment of the Projects (so the employment and expenditures in Table 9 are input in the model as negative values).

Table 9. Annual REMI Model Inputs for Employment, Expenditures and Tax Payments

	REMI Model Region	
	Cecil / Harford	**Lancaster / York**
Employment Inputs:		
Employment (total jobs)	100	63
Compensation	$9,086	$3,118
Expenditure Inputs:		
Capital	$16,177	$10,296
Electricity & Auxiliary Power	$20	$64,549
Contracting	$2,162	$843
Materials & Supplies	$1,543	$929
Travel & Entertainment	$166	$35
Licensing & Telecom	$28	$1
Other Opex	$1,299	$405
Tax Payment Inputs:		
Property Taxes	$3,819	$564
Federal Income Taxes	$37,255	$26,617
State Income Taxes	$6,644	$4,561

Notes: All dollar values in thousands of 2012 dollars.
Expenditures are the average of 2009, 2010 and 2011 data where available.
Compensation includes payments for base wages, overtime, benefits, incentives and pensions.
Capital costs are average values from the Conowingo and Muddy Run License Applications.
Employment refers to the total number of full-time and part-time jobs.
Electricity expenditures are primarily the power purchased to pump water into the upper reservoir of Muddy Run in off-peak periods (using the average of the real-time and day-ahead LMPs).
Source: Exelon Generation Company.

The contributions of the Projects to employment and compensation affect labor markets in REMI. These labor market effects are captured in the REMI results.

The operating and maintenance expenditures of the Projects are input into REMI as increases in demand for the goods and services in the appropriate sector of the economy. REMI then uses its built-in “regional purchase coefficients” to apportion the expenditures by model region, which is the mechanism by which the expenditures of the Projects affect economic activity across Maryland, Pennsylvania, and the rest of the region.

For example, the regional purchase coefficient for repair and maintenance in the Cecil/Harford region is 0.77, which means that 77 percent of every dollar spent at Conowingo on “Repair and

Maintenance" will directly contribute to the Cecil/Harford economy (in terms of employment, income, and so forth). The remaining "Repair and Maintenance" expenditures are assumed to occur outside of the Cecil/Harford region; this spending will only indirectly affect Cecil/Harford Counties.

The tax payments of the Projects can be thought of as either contributions to increased government spending or to a lower tax burden for the residents and businesses of the region. We assume that the Projects' property tax payments are in lieu of property tax payments of residents and businesses to support the activities of local governments. In contrast, we assume that federal and state income tax rates are not dependent on the tax payments of the Projects. We therefore assume the facility income tax payments lead to increases in government spending rather than reductions in income tax payments of others (see Appendix E for details on the REMI variables used for each of these inputs).

C. Electricity Rate Impacts as Inputs to REMI

As noted above, we enter price effects into REMI in terms of the percentage change in total retail electricity rates to residential, commercial and industrial customers[32]. We must also assign these price effects to appropriate REMI model regions, which differ from the geographic regions defined above.

The Cecil/Harford Counties region in the REMI model is a subset of the "Project Region in MD" in Table 8, so the price effects in these regions are assumed to be equal. Similarly, the Lancaster/York Counties region in REMI is a subset of the "Project Region in PA," so we assume the price effects for these regions are equal as well.

For the remaining three REMI model regions, we estimate weighted average price effects from various regions in Table 8 (and the price effect is assumed to be zero for all electricity customers outside of the PJM region). The weights are based on the relative size of the regions in terms of population and electricity load. Table 10 provides a summary of electricity price effects by REMI region and customer type.

---

[32] We use the REMI variable "Consumer Price of Electricity" for residential customers, "Electricity (Commercial Sectors) Fuel Cost" for commercial customers, and "Electricity (Industrial Sectors) Fuel Cost" for industrial customers.

Table 10. Summary of Electricity Price Inputs to REMI

	Price Effects		
	Residential	Commercial	Industrial
Lancaster/York Counties	2.1%	2.5%	3.4%
Cecil/Harford Counties	2.0%	2.3%	3.3%
Rest of PA	2.0%	2.4%	3.3%
Rest of MD	1.8%	2.2%	3.0%
Rest of US	0.2%	0.2%	0.2%

Source: NERA calculations are described in text.

D. Economic Contributions of the Projects

In this section we report the annual equilibrium economic contributions of the Projects, as estimated by REMI using the methodologies described above.

The results from REMI show that the Projects contribute significantly to the local and regional economies because of their contributions to jobs, the electricity grid and the demand for goods and services. Table 11 displays a summary of the annual contributions of the Projects to total jobs, gross regional/domestic product (the market value of all final goods and services produced with a region), disposable personal income and population. The following subsections provide further information on the economic contributions of the Projects to the local, state and national economies.

Table 11. Summary Equilibrium Annual Contributions of the Projects

Region	Employment (jobs)	Gross Regional Product (million 2012$)	Disposable Personal Income (million 2012$)	Population (people)
Cecil & Harford	298	46	26	366
Maryland	2,060	273	228	2,764
United States	20,857	2,372	1,987	-

Source: REMI Model simulations and NERA calculations
State-level contributions include local contributions, and nationwide contributions include the state-level contributions.

1. Contributions to Cecil and Harford Counties

The largest economic contributions of the Projects (relative to the total size of the economy) are to the local economies in Maryland's Cecil and Harford Counties and Pennsylvania's Lancaster and York Counties. The employees of Conowingo and Muddy Run largely live and spend their paychecks in the local regions, and much of the non-operating expenditures are on local goods and services.

As displayed in the previous section, the largest electricity rate contributions are also in the local counties. The PJM electricity grid consists of a much larger geographic area, but electricity customers benefit from having generation nearby due to transmission constraints on the grid that are confronted when electricity is transported over longer distances.

Table 11 shows the equilibrium annual contributions of the Projects to jobs, gross regional product (GRP), income and population in Cecil and Harford Counties. Table 12 and Table 13 display the contributions in Cecil and Harford Counties to gross regional product and total jobs, respectively, for the sectors that gain most from the Projects. With regard to the specific sectors that tend to gain from the Projects, gains are greatest for the Utilities sector, which is not surprising since the employment and many of the purchases are in that sector. Total annual contributions to gross regional product are about $46 million.

The Projects contribute approximately 300 (full time and part time) jobs to the Cecil and Harford Counties economy. The contributions to the Utilities sector are largest because the direct employment and expenditures of the Projects are focused on this sector.

Table 12. Equilibrium Annual Contributions to Gross Regional Product in Cecil/Harford Counties by Sector

Sector	**GRP Impact ($millions)**
Utilities	$34.7
Construction	$1.8
Real estate	$1.7
Retail trade	$1.6
Repair and maintenance	$1.4
All Sectors	**$46.1**

Notes: Impacts represent changes to the GRP of Cecil and Harford Counties due to the Projects.
All dollar amounts are millions of 2012 dollars.
Source: NERA calculations as explained in text.

Table 13. Equilibrium Annual Contributions to Total Jobs in Cecil/Harford Counties by Sector

Sector	**Employment Impact (total jobs)**
Utilities	99
Retail trade	26
Construction	25
Repair and maintenance	20
Professional and technical services	12
All Sectors	**298**

Notes: Impacts represent changes to the level of employment in Cecil and Harford Counties due to the Projects. All impacts are in estimated numbers of jobs.
Source: NERA calculations as explained in text.

The Projects also provide contributions to the public sector. As noted in the previous chapter, Exelon pays significant amounts in taxes attributable to the Projects. Annual property taxes for Conowingo are approximately $3.8 million (Exelon 2012b). These property tax payments provide local governments with a source of revenue that would otherwise need to come from higher taxes on local residents (or decreased government services).

In addition to these direct effects on the public sector, there are multiplier effects on local public revenues and expenditures. The increased population and economic activity in the region lead to increases in tax revenues for local jurisdictions, while the increased population linked to the Projects also generates additional demand for local public services. Overall, however, it is reasonable to expect that the effects on the government balance sheet may offset one another. That is, the increases in expenditures necessary to accommodate additional population may be approximately offset by increases in tax receipts from additional economic activity.

2. Contributions to the Maryland Economy

The Maryland economy benefits from the economic contributions of the Projects to Cecil/Harford Counties. There are also additional effects on the Maryland economy due to the increased economic activity in the rest of the state.

The Projects lead to reduced electricity rates for retail customers across the state. Although these contributions are smaller than those in the local counties on a per-customer basis, the aggregate contributions to the state economy are larger outside Cecil and Harford Counties because there are far more customers in the remainder of the State. In addition, certain expenditures of the Projects and their employees are on goods and services that are produced in the State but outside of Cecil/Harford Counties.

Table 11 showed the equilibrium annual contributions of the Projects to Maryland jobs, GRP, income and population. Annual GRP gains are about $270 million. Table 14 displays the gains to the state economy for the sectors most affected by the Projects. Table 15 displays the corresponding employment gains to the State, where there is an annual contribution of roughly 2,000 total jobs.

Unlike in the local economy, where the direct expenditures and employment are responsible for the majority of the economic contributions, the electricity rate effects are the largest driver of economic gains at the state level and thus the Utilities sector gains substantially. The gains are largest in the Real Estate sector, primarily because it is the largest sector in the state in terms of income. The Professional and Technical Services sector is another relatively large sector in Maryland, and it benefits not only from lower electricity rates but also from the significant annual contracting expenditures of the Projects.

Table 14. Equilibrium Annual Contributions to Gross Regional Product in Maryland by Sector

Sector	**GRP Impact ($millions)**
Real estate	$60.0
Utilities	$59.0
Construction	$22.6
Professional and technical services	$20.4
Retail trade	$14.4
All Sectors	**$272.6**

Notes: Impacts represent changes to the GRP of Maryland due to the Projects.
All dollar amounts are millions of 2012 dollars.
Source: NERA calculations as explained in text.

Table 15. Equilibrium Annual Contributions to Total Jobs in Maryland by Sector

Sector	**Employment Impact (total jobs)**
Construction	241
Retail trade	197
Professional and technical services	194
Real estate	168
Utilities	150
All Sectors	**2,060**

Notes: Impacts represent changes to the level of employment in Maryland due to the Projects.
All impacts are in estimated numbers of jobs.
Source: NERA calculations as explained in text.

The Projects also contribute to the state-level public sector finances. Exelon estimates $6.6 million in annual state income taxes are attributable to the Conowingo Project. The state government would otherwise need to either raise these funds from elsewhere or reduce government services.

3. Contributions to the National Economy

The Projects provide significant economic contributions outside of Maryland. The gains to the Pennsylvania economy are of course particularly large because the Muddy Run facility is located in the State.

As displayed in the previous section, the Projects lead to reduced electricity rates for customers across the various states that comprise the PJM electricity grid. Outside of Maryland (and Pennsylvania), the electricity rate effects are the primary driver of economic gains. The effects to each customer's electricity bill are small, but the total effects are substantial when aggregated across all residential, commercial and industrial customers in areas outside the State. In addition, the national economy is supported when the Projects, their employees, and their vendors purchase goods and services that are produced outside of Maryland but in the United States.

Table 11 displayed the overall equilibrium annual contributions of the Projects to U.S. jobs, GDP and income.[33] Table 16 displays the GDP gains to the national economy for the sectors most affected by the Projects, and Table 17 displays the employment gains to the national economy. As at the state level, the GDP contributions to the Utilities sector and Real Estate sectors are the largest. The Construction and Retail Trade sectors gain the most jobs at the national level.

Table 16. Equilibrium Annual Contributions to Gross Regional Product in the United States by Sector

Sector	**GRP Impact ($millions)**
Utilities	$297.0
Real estate	$190.0
Construction	$188.3
Professional and technical services	$156.7
Retail trade	$144.0
All Sectors	**$2,372.2**

Notes: Impacts represent changes to national GDP due to the Projects.
All dollar amounts are millions of 2012 dollars.
Source: NERA calculations as explained in text.

---

[33] The contributions of the Projects to the national economy assume that if the employment, expenditures and electricity supply of the Projects were removed from the economy, they would not be (immediately) replaced by other spending.

Table 17. Equilibrium Annual Contributions to Total Jobs in the United States by Sector

Sector	**Employment Impact (total jobs)**
Construction	2,510
Retail trade	2,056
Professional and technical services	1,627
Ambulatory health care services	1,136
Administrative and support services	921
All Sectors	**20,857**

Notes: Impacts represent changes to the level of national employment due to the Projects.
All impacts are in estimated numbers of jobs.
Source: NERA calculations as explained in text.

IV. Environmental and Other Effects of the Projects

The Projects impact the local, state and national communities in a variety of ways outside of their contributions to the electricity system and the economy. In this chapter we discuss the impacts of the projects on air emissions, water supply, local recreational activities, and fish populations.

A. Contributions of the Projects to Reduced Air Emissions

As a renewable electricity source, hydroelectric facilities play an important role in environmental protection. Specifically, electricity generation from hydroelectric facilities leads to reduced emissions of various pollutants.

The generation from Conowingo and Muddy Run displaces generation from other electricity generators that otherwise would be needed to meet the demand for electricity in PJM. The two most widely used sources of fuel to produce electricity for the PJM grid are coal and natural gas. Together, coal and natural gas generating units accounted for roughly 70 percent of installed generating capacity in PJM in December 2009 (FERC 2011, p. 2).

Coal and natural gas power plants are also the most common "marginal" sources of electricity generation (the source of fuel if one additional megawatt of electricity generation were required[34]) in the PJM grid at any given hour. According to FERC, coal is the marginal fuel type in PJM roughly 74 percent of the time, and natural gas is the marginal fuel type roughly 22 percent of the time.[35]

The burning of fossil fuels such as coal, natural gas and oil produces emissions of carbon dioxide and other pollutants that cause climate change and other adverse effects. Table 18 summarizes the air emissions from natural gas and coal units that have been identified by EPA in recent analyses of potential air emission regulations affecting electricity generation (not including any potential effects of facility construction).

---

[34] Ignoring transmission constraints, the "marginal" source of electricity generation would also have the highest variable cost of all generators supplying power.

[35] http://www.ferc.gov/market-oversight/mkt-electric/pjm.asp.

Table 18. Air Pollutants by Generation Plant Type

	Plant Type			
Air Pollutant	**Coal**	**Oil**	**Natural Gas**	**Hydro**
CO2 and other greenhosue gases	yes	yes	yes	-
Sulfur dioxide (SO2)	yes	yes	yes	-
Nitrogen Oxide (Nox)	yes	yes	yes	-
Particulate matter	yes	yes	yes	-
Mercury and other heavy metals	yes	yes	-	-
Carbon monoxide	yes	yes	yes	-
Volatile organic compounds	yes	yes	yes	-
Acid gases	yes	yes	-	-

Source: EPA (2005a), EPA (2010)

Table 19 shows average emission rates for three major pollutants—carbon dioxide (CO_2), sulfur dioxide (SO_2), and nitrogen oxides (NO_x)—from existing U.S. fossil-fired power plants from the EPA's eGRID database. These emissions rates are for coal, natural gas and oil power plants in eGRID's RFC East sub-region, which is (roughly) composed of the combined geographic areas of Maryland, Pennsylvania, and New Jersey.

Table 19. Average Emission Rates in eGRID RFC East Region

	Emissions Rates (lbs/MWh)		
	CO_2	**SO_2**	**NO_x**
Coal	2,027	16.80	2.88
Natural Gas	960	0.02	0.27
Oil	53	0.13	0.10

Source: NERA analysis based on eGRID (2010)

Generation from the Projects displaces generation from fossil fuel power plants that cause emissions of these and other pollutants. The following subsections note some of the health and other impacts associated with emissions of carbon dioxide, nitrogen oxides and sulfur dioxide[36]. The adverse effects of other air emissions (for example, mercury emissions) have been excluded from this analysis.

1. Impacts Associated with Carbon Dioxide and Other Greenhouse Gases

Emissions of carbon dioxide and other greenhouse gases contribute to global climate change. CO_2 levels in the atmosphere have risen substantially since pre-industrial times, and annual emissions grew about 80 percent between 1970 and 2004 according to the Intergovernmental Panel on Climate Change's Fourth Assessment Report (IPCC 2007, SPM, p. 5). Over the 100 years ending in 2005, the IPCC estimates that global temperatures have increased about 0.74°C. In the absence of additional policies to reduce emissions of CO_2 and other greenhouse gases, the

---

[36] The descriptions of emissions impacts are general, but the magnitude of the impacts often depend upon site-specific factors, including emission rates, meteorological conditions, population exposures, and background concentrations.

IPCC estimates that temperatures will rise by an additional 1.8 to 4.0°C by 2099 (IPCC 2007, SPM, p. 8).

In its Climate Change 2007 Synthesis Report, the IPCC concludes that climate change could have a wide range of adverse effects. These include coastal flooding due to a rise in global sea level, heat waves, increased cyclone frequency and intensity, droughts, and increased mortality due to heat waves, malnutrition, disease, and natural disasters (IPCC 2007, SPM, p. 13). Because CO_2 is a global pollutant, these effects depend upon global emissions (and concentrations) rather than emissions solely in the RFC East sub-region or in the United States.

2. Impacts Associated with Nitrogen Oxides and Sulfur Dioxide Emissions

Nitrogen oxide and sulfur dioxide emissions from fossil-fired power plants and other sources react in the atmosphere to form fine particles, which are associated with a wide range of adverse health and other effects, including reduced visibility (EPA 2010). NOx emissions also react with volatile organic compounds to form ground-level ozone, which has been linked to adverse impacts on health and welfare. Over the past decade, federal, regional, and state efforts to control ozone in the eastern United States have focused primarily on reducing emissions of NOx from power plants and other large stationary sources.

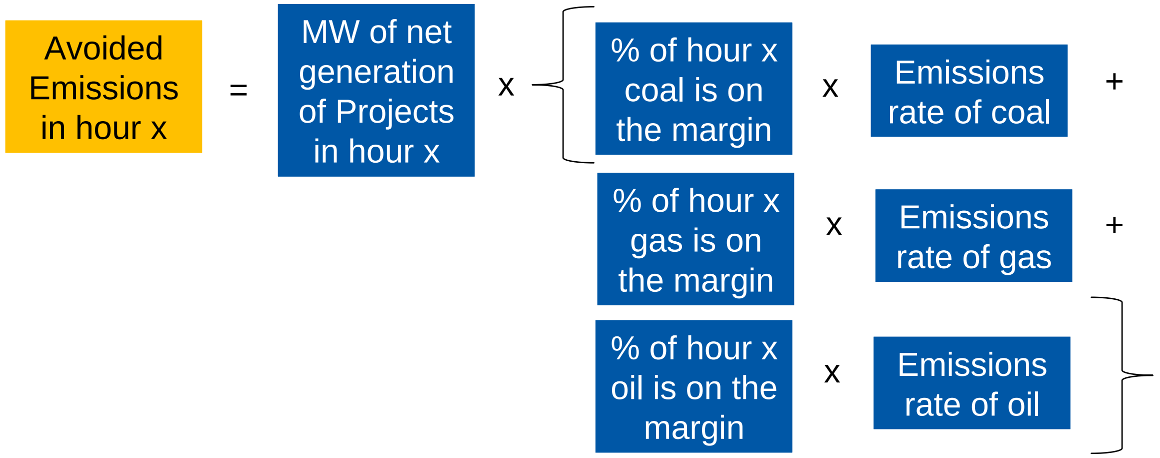
Emissions of NOx and SO_2 contribute to acid deposition (sometimes called "acid rain"). Acid rain can have adverse impacts of forests and lakes and can accelerate the decay of building materials and paints (EPA 2010).

3. Avoided Air Emissions from the Generation of the Projects

The electricity generation from the Conowingo and Muddy Run Projects decreases the generation needed from other sources in PJM. Of course, electricity purchases from Muddy Run increase the generation from these sources. In this subsection, we use hourly data on the net generation of the Projects (including the electricity purchases of Muddy Run), marginal fuel sources in PJM and emissions rates to estimate the annual avoided emissions of carbon dioxide, sulfur dioxide and nitrogen oxide.

Avoided emissions are calculated using the formula displayed in Figure 5.

Figure 5. Avoided Emissions Calculation



Hourly generation data for the Projects is provided by Exelon from 2009 to 2011. PJM's Independent Market Monitor provides historical data on the grid's marginal fuel source for any given hour, where the percentage provided is the portion of the hour that the given fuel type was on the margin (calculated at five minute intervals)[37]. As noted above, emissions rates in the region are from the EPA's eGRID database.

Table 20 displays the estimated annual avoided emissions for the Projects from 2009 to 2011. Over these three years, the generation of the Projects avoided roughly three million metric tons of carbon dioxide emissions. This is equivalent to avoiding the carbon dioxide emissions of roughly 200,000 passenger vehicles.[38] Using the range of social costs of carbon dioxide emissions estimated by the U.S. Government's Interagency Working Group on the Social Cost of Carbon (2010), [39] the implied global value of avoided emissions due to the generation of the Projects is between $5 million and $69 million per year.

---

[37] The independent market monitor is Monitoring Analytics. See www.monitoringanalytics.com for details.

[38] This assumes an average passenger vehicle travels 11,720 miles per year, gets 20.4 miles per gallon and burns 8.92×10^{-3} metric tons of CO_2 per gallon, based on 2007 data provided on the U.S. EPA website (http://www.epa.gov/cleanenergy/energy-resources/refs.html).

[39] The U.S. Government's Interagency Working Group on the Social Cost of Carbon (2010) estimated that the monetized global damages of carbon dioxide emissions in 2011 were in the range of $5 to $66 per metric ton in 2007 dollars.

Table 20. Avoided Air Emissions due to the Electricity Generation of the Projects

Year	Projects' Net Generation (GWh)	CO_2 (metric tons)	SO_2 (short tons)	NOx (short tons)
2009	1,380	960,284	6,619	1,211
2010	1,204	800,966	5,708	1,036
2011	2,158	1,380,567	9,841	1,784
Total ('09-'11)	**4,742**	**3,141,818**	**22,168**	**4,031**
Average ('09-'11)	**1,581**	**1,047,273**	**7,389**	**1,344**

Note We assume that replacement generation is from the marginal fuel source in PJM in each hour; in 2011, coal and natural gas were the marginal fuel sources 61 and 33 percent of all hours, respectively.
Net generation of the Projects includes electricity purchases of Muddy Run.

Sources: Exelon Corporation; EPA; PJM; NERA calculations.

These changes do not necessarily translate into net emissions changes for pollutants that are covered under cap-and-trade programs, such as sulfur dioxide and nitrogen oxides. (The situation is complicated for carbon dioxide, since emissions are capped for power plants in the ten states in the Regional Greenhouse Gas Initiative—including Maryland—but not in other affected states, which include Pennsylvania.) If the emissions cap is binding, an increase (or decrease) in emissions from one source will lead to an equivalent decrease (or increase) in emissions from other sources. Note, however, that in these circumstances the Projects provide important gains by lowering the cost of meeting the emissions caps. Moreover, the Projects decrease the demand for emissions allowances (i.e., the right to emit a ton of the pollutant) and thus lower the market prices; the lower market prices translate into electricity prices that are lower than they otherwise would be without the Projects. These gains are not quantified in this study.

The Projects also lead to reductions in emissions of pollutants that are not covered by cap-and-trade programs, such as emissions of mercury and particulate matter from coal-fired generating units. These reductions lead to additional benefits of the Projects. These benefits have not been quantified in this study.

B. Non-Quantified Socioeconomic Effects of the Projects

This section provides brief summaries of the socioeconomic impacts of the Conowingo Pond and the Projects that are not quantified in this report.

1. Water Supply to Municipalities

The Conowingo Pond is a public water supply source to local communities in Maryland, Pennsylvania, and Delaware. The Susquehanna River Basin Commission is responsible for determining how much water can be withdrawn by each municipality. The City of Baltimore currently has approval to withdraw up to 250 million gallons per day (MGD) from the Pond[40], but its pumping capacity limits it to withdrawals of roughly 137 MGD (Exelon 2012b).

Through water supply provided by the City of Baltimore's system, Harford County in Maryland also utilizes the Pond as a water source. The County currently relies on the Pond for withdrawals of 20 MGD, but anticipates needing up to 40 MGD in the future. Cecil County may also utilize water from the Susquehanna River to meet its growth objectives (SRBC 2006).

Finally, the Chester Water Authority serves areas in southeast Pennsylvania and northern Delaware. It has been approved for the withdrawal of up to 30 MGD (SRBC 2006).

If not for the existence of the Conowingo Dam, the water supply for municipalities would not be available. The municipalities would need to find alternative supplies of water that would likely be more expensive.

2. Supply of Industrial Cooling Water

The Peach Bottom Atomic Power Station is located on the west bank of the Conowingo Pond in York County, Pennsylvania. It is a nuclear generating facility with two units, capable of generating 1,093 MW each, that is co-owned by Exelon and Public Service Electric and Gas of New Jersey and operated by Exelon.

The Peach Bottom facility uses water from the Conowingo Pond for cooling purposes. Specifically, it evaporates up to 28 MGD through heat transfer via once-through cooling with water withdrawn from the Conowingo Pond (SRBC 2006).

In addition, a new combined cycle natural gas generating facility—the York Energy Center—has been built in York County, Pennsylvania. The plant is owned by Calpine—a Houston-based energy company—and it is capable of generating 565 MW of electricity. The plant began commercial operations in March 2011 (Calpine 2010, p. 8).

The York Energy Center is located inland approximately 2.5 miles from the Conowingo Pond, but the major water needs for the project are met by withdrawals from the Conowingo Pond. These withdrawals are used for cooling tower makeup water, blowdown makeup, process water for emissions control and fuel conditioning, and fire protection needs (SRBC 2006).

3. Recreational Activities

The Conowingo Pond and Muddy Run Reservoir offer a variety of outdoor recreational activities. Exelon has contributed substantially to the existence and maintenance of these recreational facilities. For example, Exelon recently constructed a $4.5 million fish wharf at the

---

[40] Authority to withdraw water from the Pond is automatically reduced during low flow conditions (Exelon 2012b).

Conowingo Dam that allows visitors access to the river for fishing, bird-watching, picnics and photography.[41]

Fishing is a popular recreational activity at the Conowingo Pond. Good fishing areas around the Pond are accessible along the shoreline or by boat. There is also fishing access to streams feeding into the pond and to a lake at Muddy Run Park, which is just east of the pond. Stocking programs and fishing tournaments help attract anglers to the pond (SRBC 2006).

Boating is another recreational activity for visitors to the Pond. The broad expanse of water at the southern portion of the Pond is used for waterskiing, sailing, and motor boating. The northern portion of the Pond is narrower, includes islands, and is ideal for use by canoes and small boats. Besides fishing and boating, the Pond is utilized by visitors for camping, hunting, hiking, swimming, nature observation, and educational facilities (SRBC 2006).

The Muddy Run Recreational Park contains a 100-acre lake surrounded by 700 acres of wood and field areas. The habitat is home to Eastern blue bird and other songbirds, bald eagles, ducks, geese and white-tailed deer, among many other creatures. This park also provides recreational activities, including camping, biking, hiking, boating and fishing. The park includes a campground and a boat launch with electric boats and rowboats available for use.[42]

4. Fish Populations

The existence of the Conowingo Dam and the operations of the Conowingo and Muddy Run Projects result in certain adverse impacts on the local ecosystem. Dams can serve as barriers to fish migration, and the plants' intake structures (in particular, the turbines) can result in fish losses of both migratory and resident fish species. As part of the relicensing process for Muddy Run, Exelon has conducted a number of resource studies to assess the impact of the operations of the Project on migratory and resident fish. The studies have been submitted FERC and made available to relicensing stakeholders.

---

[41] http://www.exeloncorp.com/energy/generation/hydro.aspx.

[42] http://www.exeloncorp.com/powerplants/muddyrun/Pages/profile.aspx.

References

Calpine 2010. “2010 Annual Report – A Generation Ahead, Today”. http://www.calpine.com/docs/CPN_Annual_Report.pdf

Denholm, P., E. Ela, B. Kirby, and M. Milligan 2010. “The Role of Energy Storage with Renewable Electricity Generation”. National Renewable Energy Laboratory Technical Report. NREL/TP-6A2-47187. January. http://www.nrel.gov/docs/fy10osti/47187.pdf

Energy Information Administration (“EIA”) 2012. *Form EIA-826 Data Monthly Electric Utility Sales and Revenue Data*. Data used is from 2009, 2010, and 2011. http://www.eia.gov/cneaf/electricity/page/eia826.html

Environmental Protection Agency (EPA). 2001. “Economic Analysis of the Final Regulations Addressing Cooling Water Intake Structures for New Facilities”. Chapter 11: CWIS EPA-821-R-01-035. November. http://water.epa.gov/lawsregs/lawsguidance/cwa/316b/phase1/upload/2009_04_02_316b_phase1_economics_ch11.pdf

Environmental Protection Agency (EPA). 2004. “Technical Development Document for the Final section 316(b) Phase II Existing Facilities Rule”. Chapter 4: Efficacy of Cooling Water Intake Structure Technologies. February. http://water.epa.gov/lawsregs/lawsguidance/cwa/316b/phase2/upload/2009_03_26_316b_phase2_devdoc_final_ch4.pdf

Environmental Protection Agency (EPA). 2005a. “Regulatory Impact Analysis for the Final Clean Air Interstate Rule”. EPA-452/R-05-002. March. http://www.epa.gov/cair/pdfs/finaltech08.pdf

Environmental Protection Agency (EPA). 2010. *Regulatory Impact Analysis for the Proposed Federal Transport Rule*. June. www.epa.gov/ttn/ecas/regdata/RIAs/proposaltrria_final.pdf.

Electric Power Research Institute (“EPRI”) 1997. “Turbine entrainment and survival database – field tests”. Prepared by Alden Research Laboratory, Inc., Holden, Massachusetts. EPRI Report No. TR-108630. October.

Exelon 2012a. “Application for New License for Major Water Power Project-Existing Dam”. Muddy Run Pumped Storage Project. FERC Project Number 2355. April.

Exelon 2012b. “Application for new License for Major Water Power Project-Existing Dam”. Conowingo Hydroelectric Project, FERC Project Number 405. April.

Federal Energy Regulatory Commission (“FERC”) 2011. “PJM Electric Market: Overview and Focal Points”. March. http://www.ferc.gov/market-oversight/mkt-electric/pjm/2011/03-2011-elec-pjm-archive.pdf

Franke, G.F., D.R. Webb, R.K. Fisher, Jr., D. Mathur, P.N. Hopping, P.A. March, M.R. Headrick, I.T. Laczo, Y. Ventikos, and F. Sotiropoulos 1997. "Development of Environmentally Advanced Hydropower Turbine System Design Concepts". Prepared for U.S. Department of Energy. Lockheed Idaho Technologies Co., Idaho Operations Office. Contract DE-AC07-94ID13223.

IPCC 2007. "Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change". [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, 104 pp. http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_synthesis_report.htm

Kirby, B. and Hirst, E. 1997. "Ancillary Service Details: Voltage Control." Sponsored by The National Regulatory Research Institute, Columbus, Ohio. December.

The National Council on Energy Policy 2009. "Updating the Electric Grid: An Introduction to Non-Transmission Alternatives for Policymakers". September. http://energy.gov/sites/prod/files/oeprod/DocumentsandMedia/Updating_the_Electric_Grid_Sept09.pdf

PJM Capacity Market Operations (2012). PJM Manual 18: PJM Capacity Market. Revision 15. June.

Susquehanna River Basin Commission ("SRBC") 2006. "Conowingo Pond Management Plan". Publication No. 242. June. http://www.srbc.net/pubinfo/techdocs/Publication_242%20%20Conowingo_Mngt_Plan/Conowingo%20Pond%20Mgmt%20Rpt%20-%20Pub.%20No.%20242.pdf

Yang, C. and R. B. Jackson 2011. "Opportunities and Barriers to Pumped-Hydro Energy Storage in the United States". *Renewable and Sustainable Energy Reviews*. 15. Pp. 839-844. http://www.biology.duke.edu/jackson/rser2010.pdf

Appendix A. Overview of the REMI Model

This overview is based on text prepared by Regional Economic Models, Inc. More detailed information is available from REMI PI+[43].

REMI PI+ is a structural economic forecasting and policy analysis model. It integrates input-output, computable general equilibrium, econometric, and economic geography methodologies. The model is dynamic, with forecasts and simulations generated on an annual basis and behavioral responses to compensation, price, and other economic factors.

The model consists of thousands of simultaneous equations with a structure that is relatively straightforward. The exact number of equations used varies depending on the extent of industry, demographic, demand, and other detail in the specific model being used. The overall structure of the model can be summarized in five major blocks: (1) Output and Demand, (2) Labor and Capital Demand, (3) Population and Labor Supply, (4) Compensation, Prices, and Costs, and (5) Market Shares.

The Output and Demand block consists of output, demand, consumption, investment, government spending, exports, and imports, as well as feedback from output change due to the change in the productivity of intermediate inputs. The Labor and Capital Demand block includes labor intensity and productivity as well as demand for labor and capital. Labor force participation rate and migration equations are in the Population and Labor Supply block. The Compensation, Prices, and Costs block includes composite prices, determinants of production costs, the consumption price deflator, housing prices, and the compensation equations. The proportion of local, inter-regional, and export markets captured by each region is included in the Market Shares block.

Models can be built as single region, multi-region, or multi-region national models. A region is defined broadly as a sub-national area, and could consist of a state, province, county, or city, or any combination of sub-national areas.

Single-region models consist of an individual region, called the home region. The rest of the nation is also represented in the model. However, since the home region is only a small part of the total nation, the changes in the region do not have an endogenous effect on the variables in the rest of the nation.

Multiregional national models also include a central bank monetary response that constrains labor markets. Models that only encompass a relatively small portion of a nation are not endogenously constrained by changes in exchange rates or monetary responses.

The following sub-sections describe the five blocks of the REMI PI+ model in more depth.

---

[43] See http://www.remi.com/index.php?page=documentation&hl=en_US.

A. Block 1: Output and Demand

This block includes output, demand, consumption, investment, government spending, import, commodity access, and export concepts. Output for each industry in the home region is determined by industry demand in all regions in the nation, the home region's share of each market, and international exports from the region.

For each industry, demand is determined by the amount of output, consumption, investment, and capital demand on that industry. Consumption depends on real disposable income per capita, relative prices, differential income elasticities, and population. Input productivity depends on access to inputs because a larger choice set of inputs means it is more likely that the input with the specific characteristics required for the job will be found. In the capital stock adjustment process, investment occurs to fill the difference between optimal and actual capital stock for residential, non-residential, and equipment investment. Government spending changes are determined by changes in the population.

B. Block 2: Labor and Capital Demand

The Labor and Capital Demand block includes the determination of labor productivity, labor intensity, and the optimal capital stocks. Industry-specific labor productivity depends on the availability of workers with differentiated skills for the occupations used in each industry. The occupational labor supply and commuting costs determine firms' access to a specialized labor force.

Labor intensity is determined by the cost of labor relative to the other factor inputs, capital and fuel. Demand for capital is driven by the optimal capital stock equation for both non-residential capital and equipment. Optimal capital stock for each industry depends on the relative cost of labor and capital, and the employment weighted by capital use for each industry. Employment in private industries is determined by the value added and employment per unit of value added in each industry.

C. Block 3: Population and Labor Supply

The Population and Labor Supply block includes detailed demographic information about the region. Population data is given for age, gender, and ethnic category, with birth and survival rates for each group. The size and labor force participation rate of each group determines the labor supply. These participation rates respond to changes in employment relative to the potential labor force and to changes in the real after-tax compensation rate. Migration includes retirement, military, international, and economic migration. Economic migration is determined by the relative real after-tax compensation rate, relative employment opportunity, and consumer access to variety.

D. Block 4: Compensation, Prices, and Costs

This block includes delivered prices, production costs, equipment cost, the consumption deflator, consumer prices, the price of housing, and the compensation equation. Economic geography concepts account for the productivity and price effects of access to specialized labor, goods, and services.

These prices measure the price of the industry output, taking into account the access to production locations. This access is important due to the specialization of production that takes place within each industry, and because transportation and transaction costs of distance are significant. Composite prices for each industry are then calculated based on the production costs of supplying regions, the effective distance to these regions, and the index of access to the variety of outputs in the industry relative to the access by other uses of the product.

The cost of production for each industry is determined by the cost of labor, capital, fuel, and intermediate inputs. Labor costs reflect a productivity adjustment to account for access to specialized labor, as well as underlying compensation rates. Capital costs include costs of non-residential structures and equipment, while fuel costs incorporate electricity, natural gas, and residual fuels.

The consumption deflator converts industry prices to prices for consumption commodities. For potential migrants, the consumer price is additionally calculated to include housing prices. Housing prices change from their initial level depending on changes in income and population density.

Compensation changes are due to changes in labor demand and supply conditions and changes in the national compensation rate. Changes in employment opportunities relative to the labor force and occupational demand change determine compensation rates by industry.

E. Block 5: Market Shares

The consumption deflator converts industry prices to prices for consumption commodities. For potential migrants, the consumer price is additionally calculated to include housing prices. Housing prices change from their initial level depending on changes in income and population density. Compensation changes are due to changes in labor demand and supply conditions and changes in the national compensation rate. Changes in employment opportunities relative to the labor force and occupational demand change determine compensation rates by industry.

Appendix B. Methodology for Estimating Energy Market Effects

This appendix provides a description of the methodology used to estimate the effects of the Projects on prices in the PJM Energy Market. Basic economic theory asserts that increases in supply of any commodity will, all else equal, lead to decreases in price. The Projects add to the supply of electricity in the region and therefore lead to decreased electricity rates. In the remainder of this appendix we estimate the contribution of the Projects to the LMPs in the PJM Energy Market using a statistical model. We first provide an overview of the PJM Energy Market and our methodology. We then present our estimates of the electricity price impacts of the facilities.

A. Background on PJM Energy Market

1. Overview of PJM Energy Market

PJM takes bids to supply electricity from wholesale suppliers. Based on the bids from these suppliers (which generally reflect the marginal cost of generating electricity—i.e., the cost to a wholesale supplier of producing one additional unit of electricity), PJM dispatches generating units and other resources to meet electricity demand in the most cost-effective way, subject to transmission and other constraints. In this system, which is referred to as the PJM Energy Market, a “locational marginal price” (LMP) indicates the day-ahead or real-time price of wholesale electricity at a specific location. The LMP is based on the wholesale market bids accepted by the ISO, the transmission costs and other constraints specific to that location, and the demand[44] for power.

2. Geographic Regions within PJM

We use a statistical model of electricity generation to estimate the Projects’ price impacts on LMPs in geographic regions across PJM. The regional boundaries for this analysis are determined primarily by the service territories of the electricity distribution companies within PJM. Because the Conowingo and Muddy Run facilities are located very near the borders of a number of distribution companies, the “Project Region” is defined as the service territories of PECO, Delmarva Power & Light (DPL), Baltimore Gas & Electric (BGE), PPL Electric Utilities (PPL) and Metropolitan Edison Company (MetEd).[45]

Table B-1 displays the geographic regions for which we calculate price effects. These regions comprise the entirety of PJM’s territory between 2009 and 2011, with the exception of American Transmission Systems, Inc. (in Northern Ohio) which joined PJM in 2011. These geographic regions are imperfect proxies for our modeling regions. For instance, if Cecil/Harford Counties are very different from other areas in the “Project Region” in Maryland, our estimates of the

---

[44] Day-ahead demand is the sum of demand bids from load servers which are matched with generation offers. Real-time demand is the actual demand for generation.

[45] Note that Cecil, Harford, Lancaster, and York counties are subsets of the “Project Region.”

electricity price effects in Cecil and Harford Counties will not be able to parse these differences and will include the characteristics of both regions.

B. Overview of Methodology for Estimating Electricity Rate Effects

Our approach to estimating the electricity rate effects relies on historical data related to LMPs in the regions within PJM. Using regression analysis, we estimate the effects of various cost drivers on the Day-Ahead LMPs in the regions displayed in Table B-1. (For regions in Table B-1 that comprise the service territories of several distribution companies in PJM, we calculate hourly load-weighted average LMPs).

Table B-1. Regional Units

Regions	PJM Load Zones	Description of Geography
Project Region	Delmarva Power & Light (DP&L) Baltimore Gas & Electric (BG&E) Metropolitan Edison (MetEd) PECO Energy (PECO) PPL Electric Utilities (PPL)	Southeastern Pennsylvania / Northeastern Maryland / Delaware (The five load zones in close proximity to Conowingo and Muddy Run)
Pennsylvania	Pennsylvania Electric Co. (PENLC) Duquesne Light (DQE)	Pittsburgh Area / Central and Northern Pennsylvania (Proxy for the areas of Pennsylvania not included in the Project Region)
Maryland	Potomic Electric Power Co. (PEPCO)	Southern Maryland / Washington D.C. and suburbs (Proxy for the areas of Maryland not included in the Project Region)
New Jersey	Public Service Electric & Gas Co. (PSEG) Jersey Central Power & Light Co. (JCPL) Atlantic Electric Co. (AE) Rockland Electric Co. (RECO)	All of New Jersey
American Electric Power	American Electric Power (AEP)	Areas of Virginia, West Virginia, and Ohio
Dayton	Dayton Power & Light (DAY)	Western Ohio
Dominion	Dominion Virginia (DOM)	Eastern Virginia, Coastal North Carolina
Allegheny Power Systems	Allegheny Power Systems in WV (APS)	Eastern West Virginia / Western Maryland
Commonwealth Edison	Commonwealth Edison (ComEd)	Northeastern Illinois

The statistical model allows us to vary any causal variable to create an estimate of price under different conditions with respect to that variable, including changes in the supply of electricity from facilities such as Conowingo and Muddy Run. We are effectively using econometrics to answer the question “what would the electricity prices have been had the grid been without the generation of Conowingo and Muddy Run?”

We use this statistical approach rather than the alternative approach, which is production cost modeling. There are two major concerns with production cost modeling. The first is that it may not mirror actual price experience, especially at peak loads under tight supply conditions, without undue effort devoted to calibration. Production cost models reflect a system which always behaves optimally, never has to adjust for unexpected contingencies in real time and may not reflect difficult-to-analyze costs such as the probability of damaging equipment by operating at high loading levels. These adjustments have real costs, and these costs are often substantial.

The second concern with production cost models is that for practical purposes, they must be run at expected conditions and cannot be run as a system actually runs, i.e., with widely varying gas prices, weather and demand conditions and transient transmission irregularities. The effects of these factors are not linear, particularly under peak conditions and thus do not average out.

These reasons contributed to our decision to use a statistical model and historical data to determine the contribution of the Projects to the PJM Energy Market. Of course, there are uncertainties related to the statistical modeling approach. The model and the modeling results are described in the following sections.

C. Data

We gathered data on Day-Ahead LMPs in PJM as well as the major determinants of these prices. Hourly Day-Ahead LMP prices and hourly loads are publicly available on the PJM website for the zones and subzones within PJM, as well as for PJM as a whole. Regional loads are simply aggregations of zonal loads, and regional prices are load-weighted averages.

Natural gas and coal are generally the marginal (or “price-setting”) fuels in PJM, so LMPs are affected by changes in the prices of these fuels. Natural gas price data are from Henry Hub in Louisiana. Daily coal prices are NYMEX Central Appalachian Coal forwards from Bloomberg.

Hourly generation data for Conowingo and Muddy Run is provided by Exelon. The hourly net generation of the Projects is calculated by summing the hourly generation of the two facilities (which includes the power purchases of Muddy Run).

Table B-2 displays summary statistics for these data.

Table B-2. Summary Statistics

	Units	Mean	Median	S.D.	Min	Max	Freq	N
Load								
PJM	MWh	81,301	79,529	15,630	49,613	158,071	hourly	26,276
Project Region	MWh	17,231	16,906	3,345	10,436	30,719	hourly	26,275
Pennsylvania (PENLC+DUQ)	MWh	3,708	3,713	595	2,310	6,131	hourly	26,275
Maryland (PEPCO)	MWh	3,680	3,569	794	1,967	7,023	hourly	26,275
New Jersey	MWh	9,374	9,047	2,212	5,684	20,911	hourly	26,275
American Electric Power	MWh	15,566	15,323	2,596	9,614	24,543	hourly	26,275
Dayton Power & Light	MWh	1,994	1,966	396	1,000	3,580	hourly	26,275
Dominion Virginia	MWh	10,949	10,503	2,458	5,516	20,085	hourly	26,275
Allegheny Energy	MWh	5,458	5,368	992	3,215	8,975	hourly	26,275
Commonwealth Edison	MWh	11,562	11,364	2,356	7,223	23,753	hourly	26,275
Day Ahead LMP								
Project Region	$/MWh	$46	$41	$23	$4	$421	hourly	26,275
Pennsylvania (PENLC+DUQ)	$/MWh	$39	$36	$15	$2	$332	hourly	26,275
Maryland (PEPCO)	$/MWh	$48	$42	$25	$0	$535	hourly	26,280
New Jersey	$/MWh	$47	$42	$23	$4	$420	hourly	26,275
American Electric Power	$/MWh	$37	$34	$14	$0	$300	hourly	26,280
Dayton Power & Light	$/MWh	$37	$34	$13	$0	$291	hourly	26,280
Dominion Virginia	$/MWh	$46	$41	$22	$0	$346	hourly	26,280
Allegheny Energy	$/MWh	$42	$38	$17	$0	$322	hourly	26,280
Commonwealth Edison	$/MWh	$32	$30	$14	-$8	$276	hourly	26,280
Generation								
Conowingo	MWh	229	196	192	-1	559	hourly	26,277
Muddy Run	MWh	-48	0	516	-977	991	hourly	26,277
Fuel Prices								
Natural Gas	$/MMBtu	$5	$4	$2	$2	$18	daily	1,095
Coal	$/Ton	$62	$62	$12	$42	$82	daily	1,095

Notes: Regional loads are aggregations of zonal loads. Regional prices are load weighted averages of zonal prices.
All data are for the years 2009, 2010, & 2011.
Between three and five data points are missing for some of the hourly data due to daylight savings issues.

Maximum and minimum daily temperatures are also included because the demand for electricity is highly dependent on weather conditions (e.g., people use their air conditioners on hot summer days). Temperature data are supplied by the National Climatic Data Center for each region that we include in our analysis. Table B-3 displays summary statistics for the minimum and maximum daily temperatures for each region in our analysis.

Table B-3. Summary of Temperature Data (Fahrenheit)

	Mean	Median	S.D.	Min	Max	N
Project Region						
Minimum	47	47	17	2	82	1,095
Maximum	66	68	19	18	106	1,095
Pennsylvania (PENLC+DUQ)						
Minimum	43	44	18	-10	77	1,095
Maximum	61	64	20	7	96	1,095
Maryland (PEPCO)						
Minimum	47	47	17	2	82	1,095
Maximum	66	68	19	18	106	1,095
New Jersey						
Minimum	48	48	17	5	86	1,095
Maximum	65	66	19	18	108	1,095
American Electric Power						
Minimum	46	47	17	-2	76	1,095
Maximum	66	69	19	15	98	1,095
Dayton Power & Light						
Minimum	43	44	18	-14	78	1,095
Maximum	62	64	21	4	98	1,095
Dominion Virginia						
Minimum	49	50	17	4	81	1,095
Maximum	70	72	18	23	105	1,095
Allegheny Energy						
Minimum	46	47	17	-2	76	1,095
Maximum	66	69	19	15	98	1,095
Commenwealth Edison						
Minimum	42	43	19	-18	80	1,095
Maximum	59	61	21	-1	99	1,095

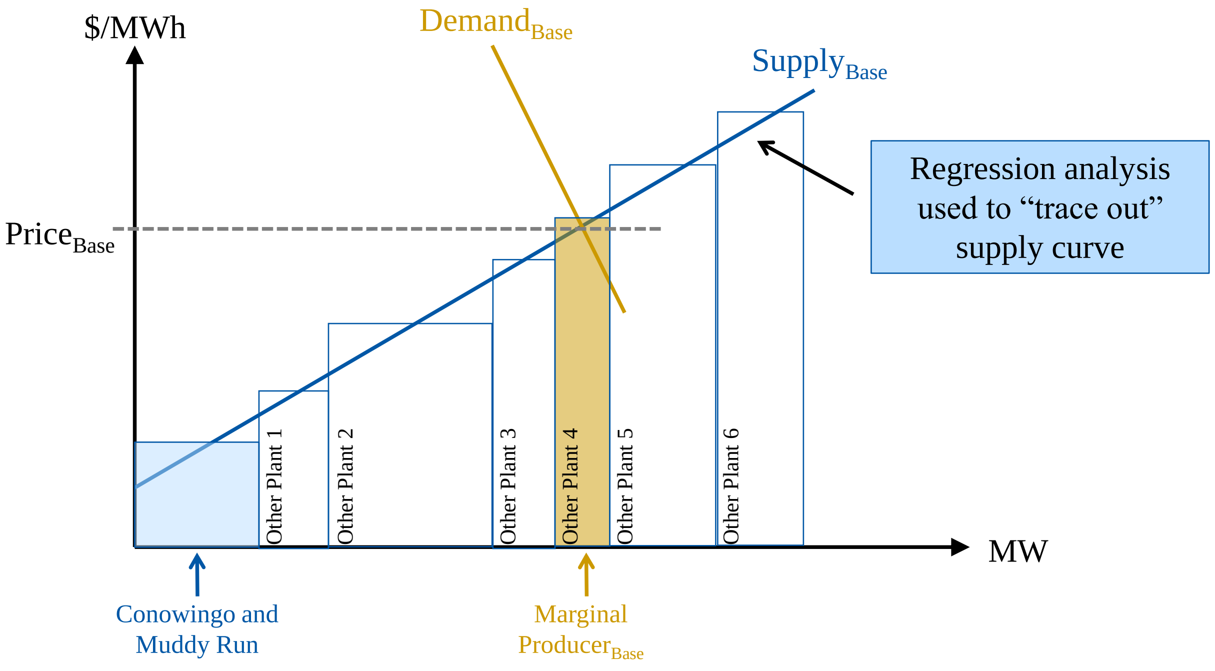
Source: National Climatic Data Center.

D. Estimating the Electricity Supply Curve

For each region and zone in our analysis, we run a regression of hourly electricity prices on the hourly demand for power in the same region or zone (and other variables listed above). Electricity price in any hour is determined by the intersection of offers to supply power and the estimated (Day Ahead) demand for power, adjusted for limitations, if any, of the transmission system to minimize total resource costs.

In general, a regression of the price of a commodity on the quantity sold of the same commodity would be subject to concerns of simultaneity because the supply and demand of the commodity are jointly determined in equilibrium. The supply curve of electricity is largely fixed, but moves somewhat from hour-to-hour as transmission conditions change, the availability of units change, and from other transient factors, e.g., temperature. If, as a first approximation, we regard the supply curve as fixed, then varying demand traces out the supply curve and avoids simultaneity bias in the estimation results. Thus, our estimation strategy is to use load to identify the supply curve while varying the supply curve from hour-to-hour to reflect underlying technical supply differentials. Figure B-1 provides an illustrative example of this process.

Figure B-1. Illustrative example of tracing out a supply curve by varying demand



We estimate the supply curves for each of the nine geographic regions with the following model (for region “r”):

$$\text{Log}(\text{LMP}_{rh}) = \beta_0 + \beta_1 \text{Load}_{1h} + \beta_2 \text{Load}_{2h} + \beta_3 \text{Load}_{3h} \ldots \beta_9 \text{Load}_{9h} + \beta_{10} (\text{Load}_{rh})^2 + \beta_{11} (\text{Load}_{rh})^3 + \beta_{12} (\text{Load}_{rh} \times \text{Net PJM load}_{rh}) + \beta_{13} \text{Controls}_{rh} + \varepsilon$$

LMP_h represents the wholesale electricity price for a given model region in hour “h”. We use the logarithm of LMP for several reasons. First, prices are normally thought of as behaving multiplicatively, and external drivers are generally expected to affect prices in percentage terms rather than absolute terms. Second, logarithmic specifications reduce inherent issues of heteroskedasticity in the observed data, in which large errors are far more likely at high prices than at low prices. Finally, logarithmic models prevent the estimation of prices below zero, which is a common problem with regressions on prices in levels. While the LMP can in theory fall below zero, this occurs very rarely.

$Load_{rh}$ represents the hour “h” and region “r”. Squared and cubed terms for load are included to capture non-linear elements of the supply curve. “Net PJM $Load_{rh}$” is the aggregate hourly load in the entire PJM region excluding region “r,” and it is included as an interaction with $Load_r$ to capture the relationship between the region under analysis and the rest of the PJM electricity market.

$Controls_{rh}$ is a vector of the remaining control variables for region “r” and hour “h,” including daily maximum and minimum temperatures, dummy variables for the day of the week, an interaction term for the hour-of-the-day and the month-of-the-year, and logged daily gas and coal prices interacted with time-of-day and month-of-year.

We follow the prevalent view of current literature (for example, see Angrist and Pischke 2010) in using ordinary least squares (“OLS”) and correcting the standard errors using the techniques of White (1980). Alternatively, to “correct” for heteroskedasticity, autocorrelation or correlation across observations in the estimates, we could have used Feasible Generalized Least Squares (“FGLS”) without a correction to the standard errors. The advantages of OLS are that unlike FGLS, OLS estimates are consistent when the explanatory variables are not strictly exogenous, and standards errors are not assumed to follow a specific AR(1) model as they are in most applications of FGLS (Wooldridge 2009).

Table B-4 displays key regression results for the statistical model of each region. The dependent variables are listed across the top row and the principle independent variables are listed in the first column of the table. “Local Load” refers to the megawatt-hours of electricity demand in the same region for which the prices are the dependent variables.

Table B-4. Partial Regression Results

	Dependent Variables (logged price)								
Independent Variables	Project Region	ComEd	New Jersey	AEP	DAY	AP	DOM	Marlyand	Pennsylvania
Local Load	0.000299***	0.00104***	0.000428***	0.000799***	0.00244***	0.00140***	7.48e-05***	0.000449***	0.00259***
	(2.07e-05)	(5.52e-05)	(1.93e-05)	(5.55e-05)	(0.000195)	(8.67e-05)	(2.65e-05)	(8.18e-05)	(0.000188)
Local Load^2	-1.50e-08***	-6.90e-08***	-4.29e-08***	-4.96e-08***	-1.22e-06***	-2.78e-07***	-2.53e-09	-1.46e-07***	-6.69e-07***
	(1.12e-09)	(3.84e-09)	(1.77e-09)	(3.35e-09)	(9.01e-08)	(1.51e-08)	(2.30e-09)	(2.12e-08)	(4.74e-08)
Local Load^3	3.08e-07***	1.51e-06***	1.11e-06***	1.02e-06***	0.000177***	1.73e-05***	3.28e-07***	9.93e-06***	5.38e-05***
	(1.90e-08)	(8.56e-08)	(4.61e-08)	(6.61e-08)	(1.33e-05)	(8.71e-07)	(6.29e-08)	(1.68e-06)	(3.93e-06)
Local Load * Net Agg Load	-1.66e-10	2.42e-10*	1.36e-09***	3.75e-10***	3.90e-09***	-1.35e-10	-1.20e-09***	2.84e-09***	3.12e-09***
	(1.40e-10)	(1.30e-10)	(1.18e-10)	(9.31e-11)	(5.18e-10)	(2.47e-10)	(1.20e-10)	(4.79e-10)	(4.36e-10)
Project Region Load		2.66e-05***	3.56e-05***	2.70e-05***	1.99e-05***	4.68e-05***	6.42e-05***	4.06e-05***	2.27e-05***
		(4.76e-06)	(3.24e-06)	(3.04e-06)	(2.82e-06)	(2.83e-06)	(3.41e-06)	(3.63e-06)	(2.93e-06)
ComEd Load	-1.43e-06		-2.12e-05***	1.51e-06	-7.10e-07	5.55e-06***	1.48e-05***	-1.98e-05***	-6.26e-06***
	(2.77e-06)		(1.74e-06)	(2.10e-06)	(1.71e-06)	(1.72e-06)	(1.89e-06)	(2.30e-06)	(1.96e-06)
New Jersey Load	-8.49e-06**	-2.05e-05***		-3.61e-05***	-3.35e-05***	-1.60e-05***	-6.74e-06**	-2.51e-05***	-2.36e-05***
	(3.42e-06)	(4.01e-06)		(2.71e-06)	(2.41e-06)	(2.80e-06)	(3.11e-06)	(3.74e-06)	(2.88e-06)
AEP Load	2.66e-05***	1.72e-05***	1.02e-05***		3.81e-05***	2.44e-05***	5.14e-05***	1.92e-05***	1.50e-05***
	(3.44e-06)	(4.61e-06)	(2.73e-06)		(2.59e-06)	(2.70e-06)	(3.15e-06)	(3.57e-06)	(2.77e-06)
DAY Load	7.40e-05***	0.000154***	6.46e-05***	8.40e-05***		7.53e-05***	8.13e-06	3.25e-05**	0.000101***
	(1.31e-05)	(2.21e-05)	(1.26e-05)	(1.20e-05)		(1.16e-05)	(1.36e-05)	(1.50e-05)	(1.18e-05)
AP Load	-8.21e-05***	-2.73e-05**	-8.14e-05***	-5.98e-05***	-6.36e-05***		-5.02e-05***	-7.01e-05***	-8.29e-05***
	(7.78e-06)	(1.12e-05)	(7.06e-06)	(5.57e-06)	(5.35e-06)		(7.35e-06)	(8.04e-06)	(5.70e-06)
DOM Load	4.43e-05***	2.94e-06	1.33e-05***	6.67e-06***	-1.58e-06	3.10e-05***		4.55e-05***	4.04e-06*
	(3.54e-06)	(3.95e-06)	(2.47e-06)	(2.23e-06)	(2.00e-06)	(2.27e-06)		(3.21e-06)	(2.37e-06)
Maryland Load	7.08e-06	-2.58e-05*	-1.39e-05*	8.89e-07	1.28e-06	-1.42e-05**	-1.24e-05		-2.52e-05***
	(8.63e-06)	(1.52e-05)	(8.21e-06)	(6.16e-06)	(6.07e-06)	(6.63e-06)	(8.05e-06)		(6.18e-06)
Pennsylvania Load	0.000112***	6.85e-05***	8.15e-05***	8.37e-05***	8.58e-05***	9.41e-05***	8.38e-05***	8.07e-05***	
	(9.69e-06)	(1.84e-05)	(9.15e-06)	(8.20e-06)	(8.16e-06)	(8.07e-06)	(9.45e-06)	(1.03e-05)	
	(Remainder of Independent Variables Omitted)								
Observations	26,275	26,227	26,275	26,275	26,275	26,275	26,275	26,275	26,275
R-squared	0.901	0.713	0.902	0.885	0.879	0.908	0.889	0.886	0.898

Note: Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$
Project Region = PECO + DPL + BGE + METED + PPL; New Jersey = AE + JCPL + PSEG + RE; Maryland = PEPCO; Pennsylvania = PENLC + DUQ

Source: NERA calculations as described in text.

E. The Price Effects of the Projects

The next step is to estimate the contribution to prices due to the generation of Conowingo and Muddy Run. A decrease in generation will produce a change in price equivalent to an increase in load of the same amount. Figure B-2 and Figure B-3 provide illustrative examples that help to graphically display this equivalence. Figure B-2 displays a shift inward of supply resulting from removing the generation of the Projects from the supply curve. Figure B-3 displays a shift outward in demand equivalent to the generation of Conowingo and Muddy Run. Whether supply decreases or demand increases, the same new marginal unit comes online, setting the same new price. In other words, the same segment of the supply curve determines the change in price in both Figure B-2 and Figure B-3.

Figure B-2. Illustrative example of a shift in supply

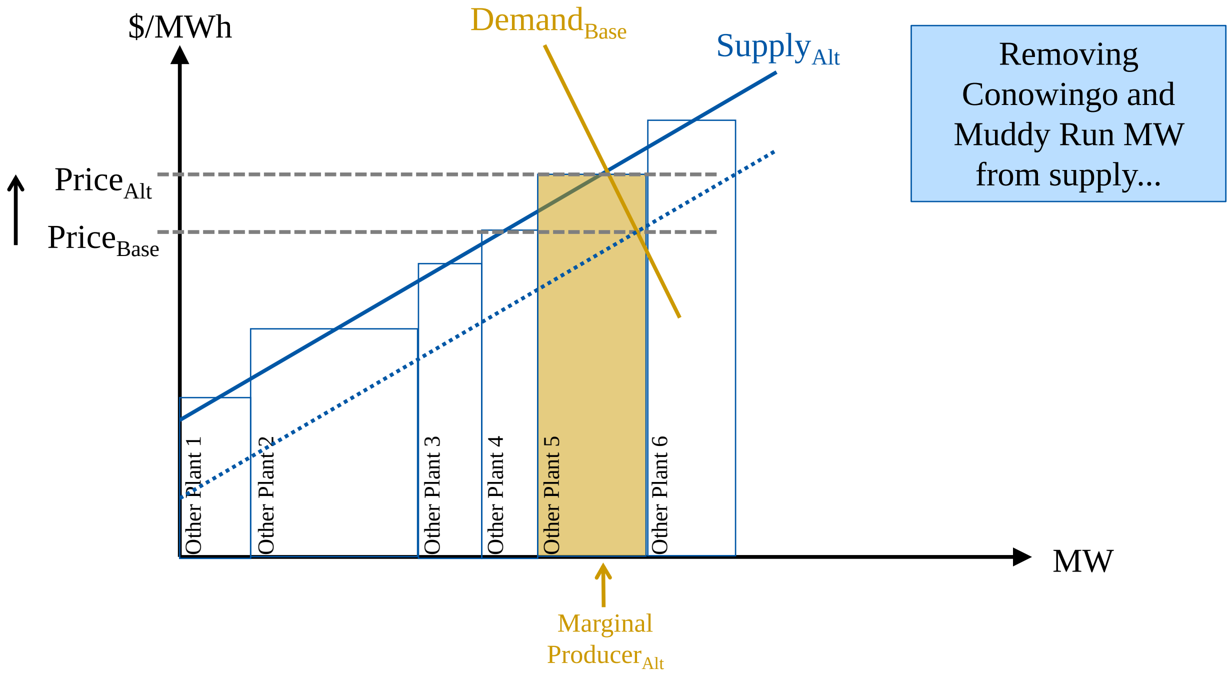
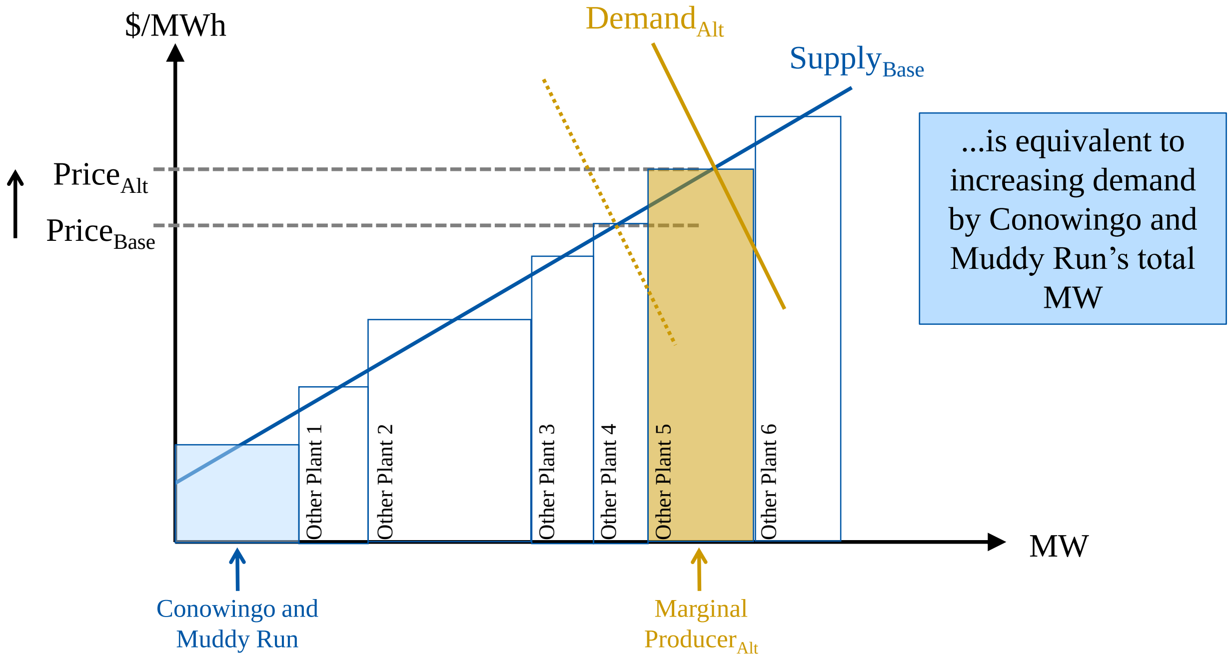


Figure B-3. Illustrative Example of a Shift in Demand



We thus recalculate hourly prices in each region after increasing the load in the "Project Region" by the amount of the hourly generation of Conowingo and Muddy Run, holding all else equal[46]. For all regions that are not the Project Region, this requires increasing the "Net PJM Load" by the same amount as well.

It is important to note that holding all other factors constant necessitates holding the unmeasured factors constant as well. Thus, we do not set the error terms (which reflect unmeasured factors) to their average level of zero, but allow them to take whatever value they actually took in the regression results.

Table B-5 displays our estimates of the average price effects of the facilities on the various regions in our analysis. It also provides summary information on the explanatory power of each of the regression analyses, displaying the correlation between the models' predicted prices and the actual prices as well as the R-squared of the regression, which is a measure (between zero and one) of how much of the variation of the dependent variables can be explained by the variation of the explanatory variables.

---

[46] During off-peak hours, Muddy Run uses electricity from the grid in order to pump water to refill its reservoir. This leads to increases in local load and thus increases off-peak prices, which are modeled in our analysis.

Table B-5. PJM Energy Market Price Effects of the Projects by Region

	Price Effect ($/MWh)	Fit[*]
Project Region	$1.21	0.91
Pennsylvania (PENLC+DUQ)	$0.44	0.93
Maryland (PEPCO)	$0.83	0.91
New Jersey	$0.77	0.92
American Electric Power	$0.38	0.88
Dayton Power & Light	$0.32	0.88
Dominion Virginia	$0.67	0.90
Allegheny Energy	$0.59	0.88
Commonwealth Edison	$0.33	0.91

Note: [*] Fit is the correlation between the model predicted prices and actual prices.

References

Angrist, J. and J-S. Pischke 2010. "The Credibility Revolution in Empirical Economics: How Better Research Design is Taking the Con out of Econometrics". *Journal of Economic Perspectives*, Vol 24, No 2, Spring.

Energy Information Administration ("EIA") 2012. "Form EIA-826 Data Monthly Electric Utility Sales and Revenue Data". Data used is from 2009, 2010, and 2011. http://www.eia.gov/cneaf/electricity/page/eia826.html

White, H. 1980. "A Heteroskedasticity-consistent Covariance Matrix Estimator and a Direct Test for Heteroskedasticity". *Econometrica* 48 (4): 817–838.

Wooldridge, J.M. 2009. "Introductory Econometrics: A Modern Approach", 2009, p. 428.

Appendix C. Methodology for Estimating Capacity Price Effects

This appendix provides background on the PJM capacity markets and describes the methodology and inputs that were used to model the impacts of the Muddy Run and Conowingo Projects on capacity prices in PJM.

A. Background on PJM's Capacity Markets

This section provides background on capacity markets organized and administered by PJM Interconnection.[47]

1. Rationale for Capacity Markets

The total amount of electricity generating capacity on the grid may be lower than its socially optimal level in the absence of capacity payments because capacity additions provide benefits to the electricity system that exceed the value that generating units receive for their generation alone. Disruptions in electricity supply can cause serious economic damage across large sections of the electricity system. As capacity is added in the electricity system, the probability of a disruption in electricity supply decreases and the expected losses associated with electrical system reliability are reduced. Under energy-only schemes, generators have to take large risks to add capacity and cannot capture the additional value for the broader electric system—because system reliability is a "public good"—unless the price they are paid includes the social cost of outages in times of scarcity. Since such payments are usually politically infeasible, virtually every organized power market in the United States exhibits a gap between net revenues from energy markets and the capital costs of investing in new capacity.

There are two main approaches to address the under-investment problem for generation capacity. System administrators can mandate a reserve capacity margin and let participants buy capacity from the least cost providers, or administrators can support capacity by making payments based on generators' installed capacity. As discussed below, PJM uses the second approach. Generators are paid for the capacity they make available whether it is dispatched or not. The capacity markets are designed so that capacity prices supplement energy-only revenues to allow investors to recoup the fixed capital costs of a new power plant.

2. Evolution of Capacity Markets in PJM

The level of installed capacity (ICAP) required to maintain reliability in PJM as a whole and its sub-regions for a delivery year (e.g., 2007/2008) is determined by PJM in accordance with the *PJM Reserve Requirements Manual (M-20)* (PJM 2012a, p. 7). This resource requirement is referred to as the installed reserve margin (IRM) and is expressed as a percentage of forecasted

---

[47] This section draws on Jaffe and Felder (1996) and Joskow (2006).

peak load.[48]. PJM ensures that each load-serving entity (LSE)[49] provides or pays for sufficient installed capacity to meet the IRM requirement.

Prior to the 2007/2008 delivery year, PJM’s capacity market construct was called the Capacity Credit Market (“CCM”). This was a voluntary mechanism in which LSEs could satisfy their installed capacity (“ICAP”) requirements on daily, monthly, and multi-monthly bases (Brattle Group 2011, p. 2). In the monthly ICAP auctions, the supply curve was defined via price offers from generation suppliers. The demand curve did not represent the buyer’s willingness to pay for capacity but instead represented demand set by an administrative rule, which was a vertical line that reflected the amount of installed capacity needed to meet a region’s target reserve margin (Chandley 2008, p. 11). There were various perceived problems with the system including high price volatility:

> “[P]rices could be very volatile from month to month. If the region had a slight surplus of capacity (e.g., slightly more than 15 percent reserve margins), then the price could be very low. Eastern ISOs often experienced months when the monthly capacity price was close to zero. In other months, a slight deficit in supplies would push capacity prices to a very high price cap, which might be some multiple of the capital costs of a new combustion turbine generating facility.” (Chandley 2008, p 11).

Finally, the vertical demand curve created incentives for suppliers to exercise market power:

> “Large suppliers could see that if they withheld only a small amount of their capacity from the monthly auctions, they could move the supply curve to the left just enough to force prices to leap from very low to very high levels. Capacity buyers would then be forced to pay very high capacity prices to the withholding supplier’s remaining capacity, more than compensating the supplier for the capacity it withheld from the market.” (Chandley 2008, p. 12).

To stabilize prices and address market power and other issues, PJM implemented a new capacity market construct called the Reliability Pricing Model (“RPM”), discussed in the next section.

3. Background on the Reliability Pricing Model

The RPM has a multi-auction structure that is designed to satisfy the region’s unforced capacity (“UCAP”) obligations through the following market mechanisms:

- Base residual auction (BRA): a forward-looking auction held three years prior to the start of the delivery year for which resources are needed, which allocates the costs of these

---

[48] The underlying criterion for the IRM is that the loss of load expectation (LOLE) is under 0.1, which implies a major outage does not occur more frequently that once in ten years (PJM 2012a, p.7).

[49] An LSE may be a competitive retailer or a utility that serves customers who are not served by competitive retailers.

commitments among the LSEs via a locational reliability charge. For the 2015/2016 delivery year, the IRM for this auction was set at 15.4 percent (PJM 2012c);

- Incremental auctions (IAs): up to three[50] are conducted after the BRA to produce additional capacity needed to satisfy any changes in market dynamics; and
- The bilateral market: a market created to provide resource providers with the possibility of covering any shortages in their auction commitments. (PJM 2012a, pp. 5-6).

RPM divides the PJM region into different locational deliverability areas ("LDAs") and conducts simultaneous auctions for each LDA (Chandley 2008, p. 4). This allows the capacity payments to differ in different regions of PJM and therefore reflect geographical transmission constraints through higher payments (and lower payments in locations where transmission is not as constrained). Presently, there are 25[51] LDAs as part of RPM, though only 8 LDAs are currently modeled in a manner such that capacity auctions could yield different clearing prices (Brattle Group 2011, p. 4).

The auction format in the RPM includes offer-based supply curves from generating entities that are cleared against administratively-defined demand curves. The demand and supply aspects of the RPM are discussed in the following section.

4. Demand and Supply in the RPM

For each auction in RPM, the demand curve is defined in advance of the auction and is either downward-sloping or a vertical line, depending on the purpose of the particular auction[52] (PJM 2012a, p. 16). For the BRA, the demand curve is downward-sloping and is based on the concept of a variable resource requirement ("VRR"), defining the price for a given level of capacity resource commitment relative to the applicable reliability requirement.

These VRR curves are defined for the PJM region as a whole and for each of the constrained[53] LDAs within the PJM region, based on the following parameters that are determined before the RPM auctions:

- A target level of reserve;
- Cost of new entry (CONE); and
- Net energy & ancillary services (E&AS) revenue offset. (PJM 2012a, p. 17).

---

[50] Effective the 2012/2013 delivery year, three incremental auctions are conducted and an additional conditional incremental auction may be conducted.

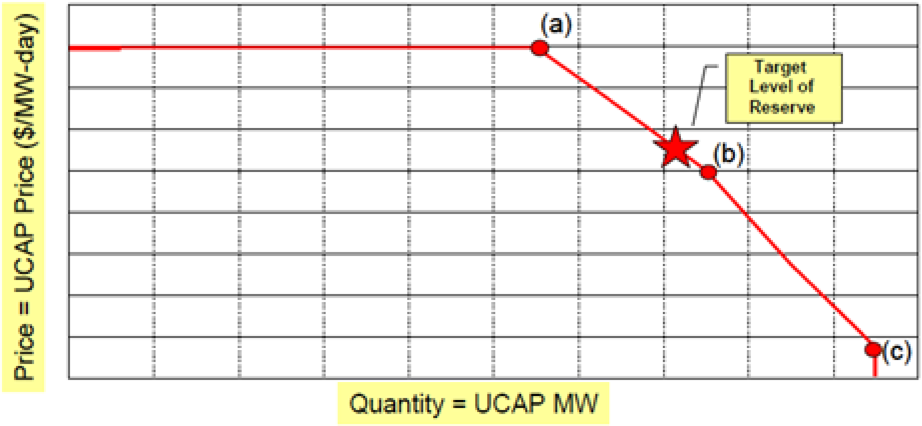
[51] Creation of new LDAs is possible when needed (PJM 2012a, p. 12).

[52] For example, in the second incremental auction, when the auction is cleared due to the increase in load forecast, the demand curve is a vertical line (PJM 2012a, p. 21).

[53] One of the criteria for modeling an LDA as constrained in RPM is if the LDA has a capacity emergency transfer limit (CETL) that is less than 1.15 times the capacity emergency transfer objective (CETO). See (PJM 2012a, pp. 9-10) for additional details.

The target level of reserve is defined by the IRM. The CONE is determined in accordance with the Open Access Transmission Tariff ("OATT")[54] and can vary by LDA. The E&AS revenue offsets for the entire PJM region and each modeled LDA are determined by PJM also in accordance with OATT[55] using the peak-hour dispatch (PJM 2012a, 18).

Figure C-1. Illustrative VRR Curve



Source: PJM (2012), p. 21.

Based on these and other parameters, a piece-wise linear demand curve is constructed, which has four connecting segments. An illustrative example of a VRR curve is shown in Figure C-1, with the three points of intersection marked as "(a)", "(b)", and "(c)"(for detailed formulas defining the demand curve, please see PJM 2012a, pp. 19-20):

- The price at point "(a)" reflects a cap on capacity payments;
- Point "(b)" can be understood as the "break even point" for new investments when the entire system just meets the reserve margin requirement;
- The kink in the curve defined by points "(a)", "(b)", and "(c)" is an inverted version of the kink proposed by the New England ISO, which is intended to balance encouraging investment when the amount of capacity is less than desired and reducing the risks of slight over-investment when capacity is close to the break-even point[56]; and
- Point "(c)" is a "zero crossing point." For levels of capacity beyond this point, capacity payments are zero (Chandley 2008, pp. 15-18).

---

[54] See PJM 2012b, Attachment DD, Section 5.10, (iv), (A).

[55] See PJM 2012b, Attachment DD, Section 5.10, (v).

[56] The New England curve had a steeper slope on the left side of the break even point and a shallower slope on the right hand-side, meaning the inversion of the kink could have effects opposite to those intended, but Chandley (2008, p. 17, Footnote 12) notes the effects are uncertain without more experience.

The PJM region and the LDAs can have different reliability requirements and this is reflected in the differing VRR curves for each constrained LDA. Because PJM performs a review of the shape of the VRR curve every few years, the methodology described above is subject to change (PJM 2012a, p. 21).

In terms of supply, in each auction, a supply curve is defined based on submitted offers from providers who have installed capacity resources (PJM 2012a, p. 24). A provider's resource portfolio may consist of existing generation, planned generation, bilateral contracts for unit-specific capacity resources, load management resources, energy efficiency resources, and qualifying transmission upgrades (PJM 2012a, pp. 24-25).

The BRA clears using an optimization software package, with the algorithm's objective function minimizing capacity procurement costs given the supply offers, VRR curves, and locational constraints[57] (PJM 2012a, p. 72).

Additional IAs are held following the BRA to allow additional resources to be procured as needed, e.g., due to adjustments in reliability requirements.

5. Historical Experience with RPM

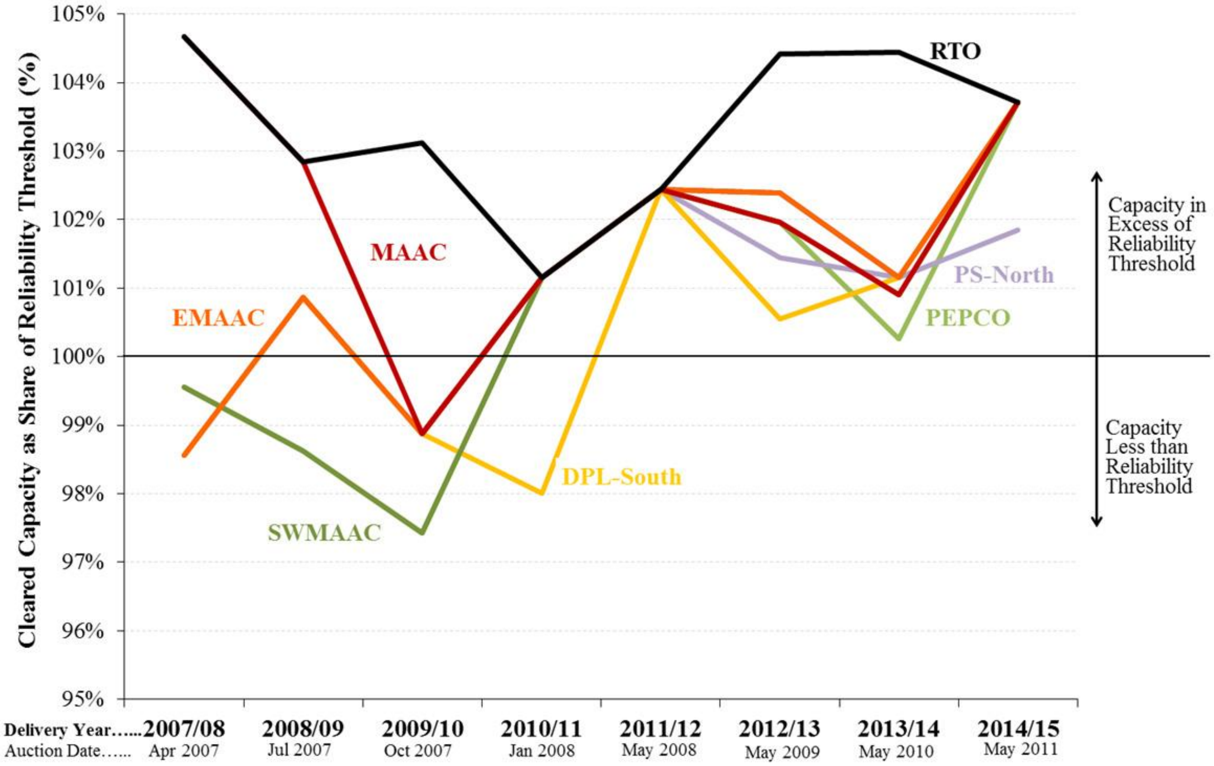
For the first eight BRAs conducted starting with the 2007/2008 delivery year, for the aggregate PJM region, the auctions have consistently cleared capacity above the target procurement level (Brattle Group 2011, p. 10). The 1.2 to 4.7 percent exceeding of the delivery year target of these eight auctions "reflect[s] the surplus supply conditions in the system overall" (The Brattle Group 2011, p. 10).

Figure C-2 shows the cleared capacity as a percentage of the target level for the PJM region as a whole (line "RTO") and for six LDAs – EMAAC, MAAC, SWMAAC, DPL-South, PEPCO, and PS-North. Cleared capacity percentages above 100 imply excess capacity, while percentages below 100 imply that capacity cleared at a level below the target one, i.e., there was a capacity deficit. As can be seen, although the PJM region as a whole consistently cleared above the target procurement level, the results in individual LDAs varied for the first four delivery years. After the first four BRAs, however, the LDAs universally exceeded their respective target procurement levels.

---

[57] Starting in June 1, 2014, the algorithm also optimizes with additional constraints of a minimum annual resource requirement and a minimum extended summer resource requirement (PJM 2012, p. 72).

Figure C-2. PJM Historical Capacity Supply Relative to Target Procurement Levels



Source: Brattle Group (2011), p. 11.

B. Overview of Methodology for Modeling Capacity Price Effects

In the BRA auctions, capacity prices are determined by the intersection of the demand and supply curves. We estimated capacity impacts by removing the capacity of the Conowingo and Muddy Run projects from the supply and calculating a revised clearing price.

We estimate capacity price impacts only at the RTO (PJM-wide) level, and not for any of the constrained LDAs. In certain years the capacity prices in the Mid-Atlantic region of PJM (MAAC) have been significantly higher due to transmission constraints. Because the capacity of the Conowingo and Muddy Run facilities are in the MAAC region, this implies their capacity was more valuable for these years. Thus, our focus on RTO capacity prices will lead to a conservative estimate of capacity price impacts.

This capacity price impact methodology for each BRA delivery year from 2007/2008 to 2013/2014 can be summarized as follows, and explained in more detail below:

1. Recreate the administratively-defined demand curves in annual capacity auction;

2. Using graphical depictions of the supply curve for each annual capacity auction, create linear approximations of the curves around the auction clearing price and quantity;

3. Estimate the hypothetical auction clearing prices with the capacity of the Projects removed:
    a. Shift the linearly approximated supply curve in by the combined capacity of the Muddy Run and Conowingo facilities;
    b. Determine the intersection point between this shifted-in supply curve and the original administratively-defined demand curve;
    c. Using this intersection point, calculate the differences in capacity price and total capacity payments compared to the original market clearing price and quantity;
4. Convert the change in total capacity payments to generators into a change in capacity charges to electricity customers in PJM, using data on average capacity charges from PJM and the assumption that the percent change in capacity payments to generators equals to percent change in capacity charges to customers.

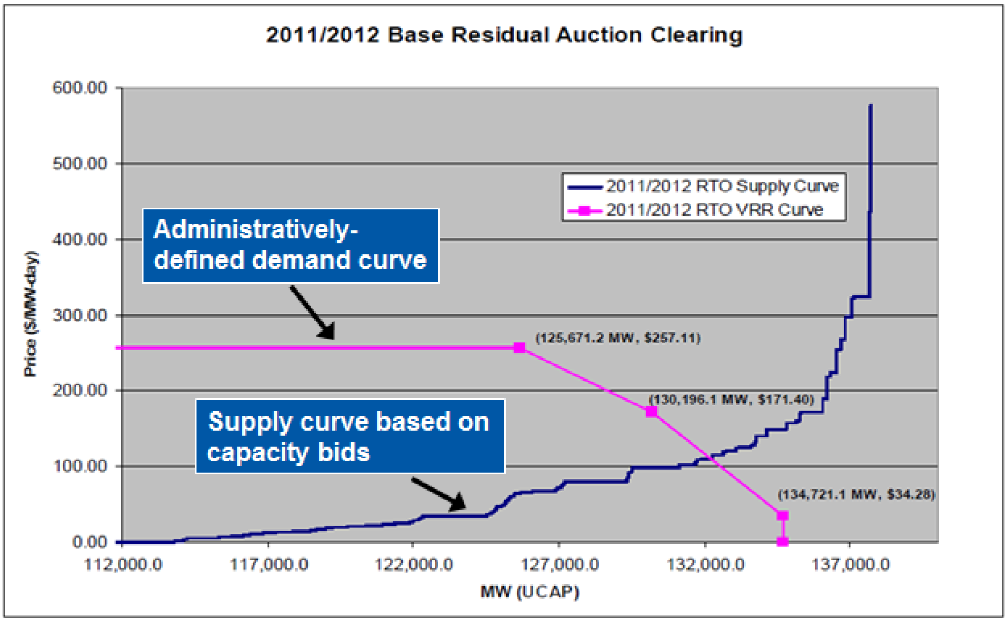
Step 1: Recreate the Capacity Demand Curves

PJM publishes the parameters defining the demand curve prior to each capacity auction[58]. As noted above, these parameters are based on peak load forecasts, desired reserve margins and the cost of building new capacity. We used this information to recreate the RTO piece-wise demand curves for the delivery years 2007/2008 to 2013/2014, as displayed in Figure C-3 for the 2011/2012 auction.

---

[58] http://pjm.com/markets-and-operations/rpm/rpm-auction-user-info.aspx.

Figure C-3. 2011/2012 Delivery Year PJM RTO BRA Clearing Results



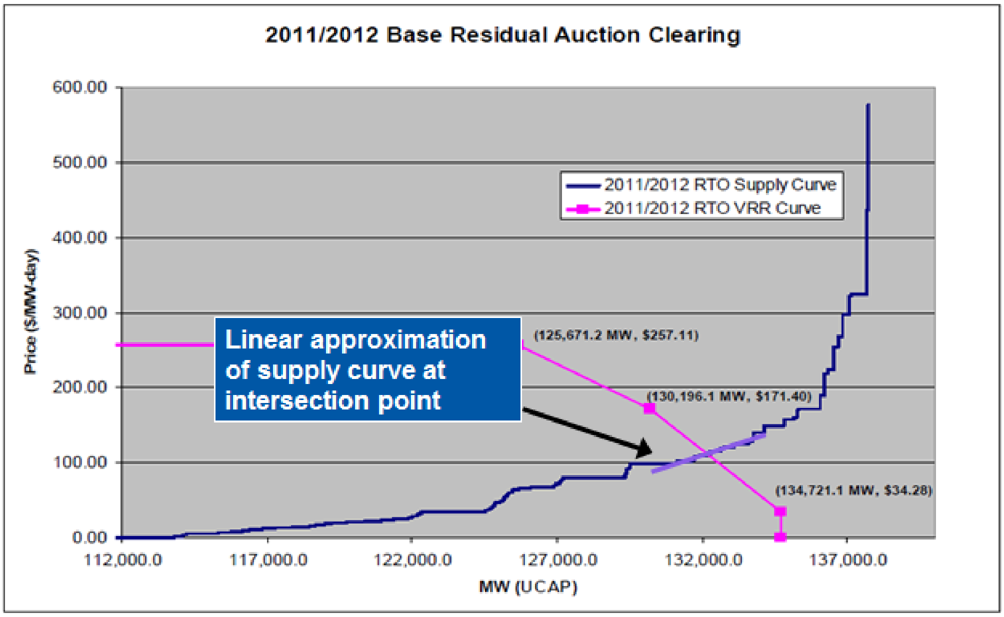
Source: PJM (2008), p. 13; NERA additions.

Step 2: Create Linear Approximations of the Capacity Supply Curves

The slope of the supply curve at capacity levels above the auction clearing amount are important in determining the impact of the Projects’ capacity on the market clearing price. The individual bids defining the curve are not publicly available. However, graphical representations of the generators’ bids are available for each auction year.

We used these figures to create a linear approximation of each supply curve based solely on points in close vicinity to the auction clearing price and quantity. These estimates should closely approximate the slope of the supply curve above the market clearing price and quantity. An example is shown in Figure C-4.

Figure C-4. 2011/2012 Delivery Year Supply Curve Linear Approximation



Source: PJM (2008), p. 13; NERA additions.

Step 3a: Shift the Linear Supply Curves Inward by Capacity of Projects

The rated capacity of Conowingo is 572 MW and the rated capacity of Muddy Run is 1070 MW. The combined capacity of the Projects is therefore 1642 MW. To simulate the impacts on the market of the Projects’ capacity, we shifted the linearly approximated supply curves inward by 1642 MW, as displayed in Figure C-5.

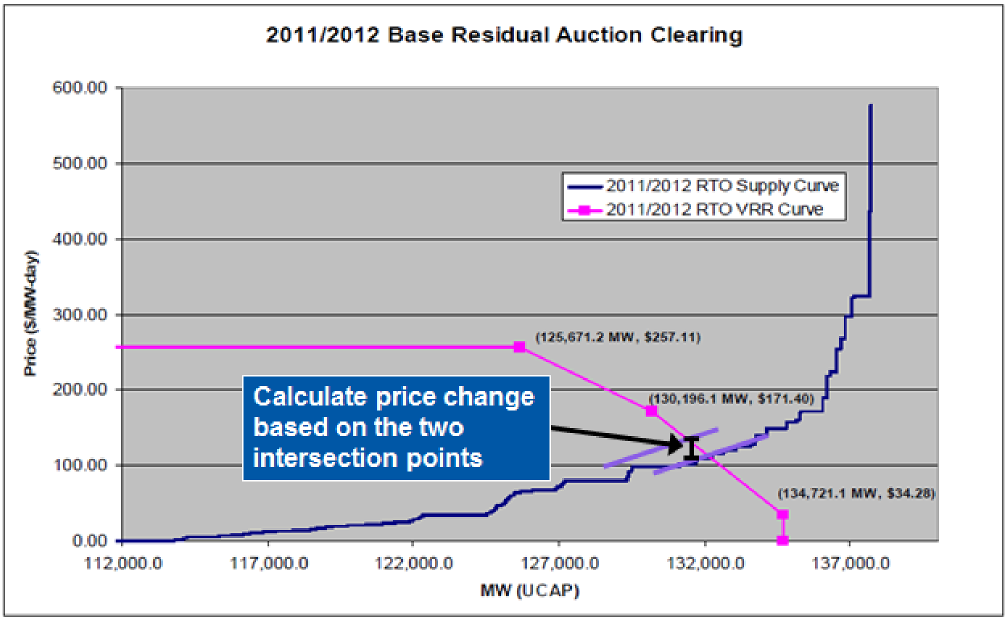
Step 3b: Determine the New Intersection Point

The new capacity price is determined based on the intersection of the shifted linear supply curve (from Step 3a) and the same administratively-defined demand curve (from Step 1).

Step 3c: Determine the Change in Capacity Price to Generators

The impact on the capacity price paid to generators is then calculated as the new capacity price minus the original market clearing capacity price. Figure C-5 shows that for the 2011/2012 year, the capacity price increased roughly $14.50 from $110 per MW-day to roughly $124.50 per MW-day.

Figure C-5. 2011/2012 Delivery Year Determination of the Resulting Price Change



Source: PJM (2008), p. 13; NERA additions.

Step 4: Convert to a Change in Consumer Capacity Charges

Using the results from Step 3, we calculate the percent change in total capacity payments to generators (capacity price multiplied by quantity) for each delivery year due the removal of the capacity of the Projects. For a given calendar year, the percent change in total capacity payments to generators is assumed to be the average of the two auctions related to that year's capacity. For example, the impact on capacity payments to generators is nine percent for the 2010/2011 auction and 13 percent for the 2011/2012 auction, so the 2011 impact on capacity payments generators is assumed to be 11 percent.

For the purpose of estimating the economic contributions of Projects' capacity, the impacts on capacity payments to generators must be converted into impacts on the capacity charge in electricity bills to customers. PJM publishes average electricity wholesale prices for each year, which are broken out into its component, including an average capacity charge per MWh of generation. In 2011, this charge was $9.72 per MWh. Of course, historical data on customer capacity charges is not yet available for 2012 or 2013. For these years it is assumed that the customer capacity charge will change by the percentage change in average PJM capacity prices[59].

For a given year, the percent increase in the capacity charge to consumers due to the Projects' capacity is assumed to equal the percent impact on capacity payments to generators due to the Projects' capacity. In 2011, the Projects' impact on capacity payments to generators was

---

[59] Annual weighted average capacity prices are published in the PJM State of the Market Reports.

calculated at 11 percent. Therefore, the capacity charge to customers is assumed to increase by 11 percent of $9.72 per MWh, or $1.07 per MWh.

C. Capacity Price Effects of the Projects

Using the methodology described above, the Projects' impacts on the PJM capacity auctions for the 2007/2008 to 2013/2014 delivery years are displayed in Table C-1.

Table C-1. Contributions of the Projects to Reduced Capacity Payments in PJM

	Auction Results			Removal of Projects' Capacity			Change in Capacity Payments
Delivery Year	Capacity Price ($/MW-day)	Cleared Capacity (MW, UCAP)	Total Payments ($/day)	Capacity Price ($/MW-day)	Cleared Capacity (MW, UCAP)	Total Payments ($/day)	(%)
2007/2008	$40.80	129,409	5,279,895	$55.48	128,942	7,154,152	35.5%
2008/2009	$111.92	129,598	14,504,563	$143.29	128,583	18,424,161	27.0%
2009/2010	$102.04	132,232	13,492,933	$119.72	131,651	15,761,047	16.8%
2010/2011	$174.29	132,190	23,039,465	$191.99	131,256	25,200,136	9.4%
2011/2012	$110.00	132,222	14,544,365	$124.54	131,743	16,407,168	12.8%
2012/2013	$16.46	136,144	2,240,922	$18.92	136,144	2,576,256	15.0%
2013/2014	$27.73	152,743	4,235,572	$33.89	152,743	5,176,089	22.2%

Notes: Prices are in 20YY dollars.
Source: PJM BRA Auction Results; NERA calculations.

The Projects' impacts on capacity payments to generators are then converted to impacts on capacity charges to customers, as displayed in Table C-2. The average impact over the six years is roughly $1.65 per MWh.

Table C-2. Contributions of the Projects to Reduced Capacity Charges in PJM

Calendar Year	Capacity Charge to Customers[1] ($/MWh)	Change in Capacity Charge[2] (%)	Change in Capacity Charge ($/MWh)
2008	$8.33	31.3%	$2.60
2009	$11.02	21.9%	$2.42
2010	$12.15	13.1%	$1.59
2011	$9.72	11.1%	$1.08
2012	$6.25	13.9%	$0.87
2013	$7.16	18.6%	$1.33
Average			$1.65

Notes: Prices are in 20YY dollars.
[1] For 2012 and 2013, the annual percent change in capacity charges is assumed to equal the annual percent change in the weighted average capacity price paid to generators in PJM.
[2] Average of the percent change in total capacity payments for the related delivery years.
Source: PJM BRA Auction Results; NERA calculations.

References

The Brattle Group ("Brattle Group"). 2011. "Second Performance Assessment of PJM's Reliability Pricing Model". August. http://pjm.com/~/media/committees-groups/committees/mrc/20110818/20110826-brattle-report-second-performance-assessment-of-pjm-reliability-pricing-model.ashx.

Chandley, John. 2008. "PJM's Reliability Pricing Mechanism: (Why It's Needed and How It Works). March. http://www.pjm.com/~/media/documents/reports/pjms-rpm-j-chandley.ashx.

Jaffe, Adam and Frank Felder. 1996. "Should Electricity Markets Have a Capacity Market? If So, How Should It Be Priced?" *Electricity Journal* (December): 52-60.

Joskow, Paul. 2006. *Competitive Electricity Markets and Investment in New Generation Capacity*. AEI-Brookings Joint Center for Regulatory Studies Working Paper 06-14. May. www.reg-markets.org/admin/authorpdfs/page.php?id=1276.

PJM 2008. "2011/2012 RPM Base Residual Auction Results". http://www.pjm.com/~/media/markets-ops/rpm/rpm-auction-info/20080515-2011-2012-bra-report.ashx

PJM. 2012a. "PJM Manual 18: PJM Capacity Market". Revision 14. Effective date: February 23, 2012. http://pjm.com/~/media/documents/manuals/m18.ashx.

PJM 2012b. "PJM Open Access Transmission Tariff". Effective Date: April 16, 2012. http://www.pjm.com/documents/~/media/documents/agreements/tariff.ashx.

PJM 2012c. "Planning Period Parameters". Posting Date: April 17, 2012. http://pjm.com/markets-and-operations/rpm/rpm-auction-user-info.aspx#Item09.

Appendix D. Electricity Price Effects of the Projects as Inputs to REMI Modeling

The REMI model regions differ geographically from the regions of the PJM electricity grid that we included in our statistical model of electricity price effects ("electricity market model"). This appendix explains the methodology for translating percentage changes in total retail electricity rates to residential, commercial and industrial customers[60] into price effects to the appropriate REMI model regions.

A. Overview of the REMI and Electricity Market Model Regions

Each REMI model region geographically corresponds to one or more electricity market model region. Table D-1 illustrates which electricity market model regions correspond to the various REMI regions.

Table D-1. Correspondence Between REMI Model Regions and Electricity Market Model Regions

REMI Regions	Corresponding Electricity Market Model Regions
Lancaster/York	Project Region
Cecil/Harford	Project Region
Rest of PA	Project Region, PENLC, and DUQ
Rest of MD	Project Region and PEPCO
Rest of U.S.	DPL, New Jersey, AEP, DAY, DOM, APS, ComEd, and non-PJM U.S. Regions

Note: The "Project Region" is made up of the PJM load zones which are in close proximity to Conowingo and Muddy Run (PPL, PECO, MetEd, BG&E, and DP&L).

B. Assumptions for Price Effects in REMI Regions

1. County-Level REMI Regions

As can be seen in Table D-1, the two county-level REMI regions ("Cecil/Harford" and "Lancaster/York") correspond to the "Project Region" in our electricity price effects model. In particular, the county-level REMI regions are sub-areas of the "Project Region." Thus, the price effects in the county-level REMI regions are assumed to be equal to the price effect in the "Project Region."

---

[60] We use the REMI variable "Consumer Price of Electricity" for residential customers, "Electricity (Commercial Sectors) Fuel Cost" for commercial customers, and "Electricity (Industrial Sectors) Fuel Cost" for industrial customers.

2. State- and National-Level REMI Regions

The state- and national-level REMI regions ("Rest of PA", "Rest of MD", and "Rest of U.S.") are composed of multiple electricity market model regions, so we assume that they are best represented by weighted averages of the price effects in the appropriate electricity market model regions.

a. Rest of Pennsylvania

Table D-2 displays our calculations of the electricity price impacts in the "Rest of Pennsylvania" region. They are estimated using the price impacts from the proportion of the "Project Region" that is in Pennsylvania ("Project Region in PA") and the other regions in our electricity market model that are in Pennsylvania (PENLC and DUQ). The weights are based on the relative size of the regions in terms of population and electricity load (which are assumed to be proportional across the state), except that Lancaster and York Counties are removed from the "Project Region in PA" because their price impacts have already been accounted for.

Table D-2. Electricity Price Effects in the "Rest of Pennsylvania" REMI Model Region

	Price Effects in Rest of PA			Percent of
	Residential	Commercial	Industrial	Total Region[1]
Project Region in PA	2.1%	2.5%	3.4%	72.6%
Pennsylvania (PENLC + DUQ)	1.7%	2.3%	2.9%	27.4%
Weighted Average Price Effect	2.0%	2.4%	3.3%	

Notes: [1] Calculated using estimates of population at the county and state levels and estimates of electricity load for the state of Pennsylvania and for PJM load zones.
Lancaster and York Counties are removed from the "Project Region in PA" region.
Load and population are assumed to be proportional across the state.

b. Rest of Maryland

Table D-3 displays our estimates of the electricity price impacts to the "Rest of Maryland" region. They are estimated using the price impacts from the proportion of the "Project Region" that is in Maryland ("Project Region in MD") and the other regions in our electricity market model that are in Maryland (PEPCO). As above, the weights are based on the relative size of the regions in terms of population and electricity load (which are assumed to be proportional across the state), except that Cecil and Harford Counties are removed from the "Project Region in MD" because their price impacts have already been accounted for.

Table D-3. Electricity Price Effects in the "Rest of Maryland" REMI Model Region

	Price Effects in Rest of MD			Percent of
	Residential	Commercial	Industrial	Total Region[1]
Project Region in MD	2.0%	2.3%	3.3%	52.3%
Maryland (PEPCO)	1.6%	2.1%	2.6%	47.7%
Weighted Average Price Effect	1.8%	2.2%	3.0%	

Notes: [1] Calculated using estimates of population and the county and state levels and estimates of electricity load for the state of Maryland and for PJM load zones.
Cecil and Harford Counties are removed from the "Project Region in MD" region.
Load and population are assumed to be proportional across the state.

c. Rest of U.S.

Table D-4 displays our estimates of the electricity price impacts to the "Rest of the United States" region. For each customer type, these impacts are load-weighted averages of the price effects in the PJM regions outside of Maryland and Pennsylvania. These price effects are small because the price effects are assumed to be zero for all electricity customers outside of the PJM territories (roughly 85 percent of the country).

Table D-4. Electricity Price Impact to "Rest of United States" REMI Model Region

	Price Effects			Load Weights			Weighted Average Price Effects		
Region	Res.	Comm.	Ind.	Res.	Comm.	Ind.	Res.	Comm.	Ind.
Delaware	2.1%	2.5%	3.1%	0.35%	0.34%	0.28%	0.007%	0.009%	0.009%
New Jersey	1.5%	1.8%	2.1%	2.19%	3.15%	0.86%	0.032%	0.055%	0.018%
American Electric Power	2.1%	2.5%	3.7%	2.54%	1.96%	4.19%	0.054%	0.049%	0.154%
Dayton Power & Light	1.6%	1.9%	2.4%	0.38%	0.15%	0.04%	0.006%	0.003%	0.001%
Dominion Virginia	2.2%	3.0%	3.8%	2.29%	3.18%	0.86%	0.051%	0.096%	0.033%
Allegheny Energy (WV)	2.4%	2.9%	3.7%	0.28%	0.22%	0.45%	0.007%	0.006%	0.017%
Commonwealth Edison	1.6%	2.0%	3.1%	2.05%	0.92%	0.09%	0.033%	0.018%	0.003%
Non-PJM Market Regions	0.0%	0.0%	0.0%	83.81%	84.11%	87.30%	0.000%	0.000%	0.000%
Total Rest of U.S.	-	-	-	93.89%	94.03%	94.07%	0.191%	0.237%	0.233%

Notes: Load weights are the 2011 loads as percentages of total "Rest of U.S." load using data from EIA (2012).
Adjusted price effects are calculated by multiplying price effects by load weights.

C. Summary of REMI Region Price Effects

The previous subsections have described how the results of our electricity market model are translated from electricity market regions to REMI regions. Table D-5 summarizes the results with the electricity price effects by REMI region and customer type.

Table D-5. Summary of Electricity Price Inputs to REMI

	Price Effects		
	Residential	Commercial	Industrial
Lancaster/York Counties	2.1%	2.5%	3.4%
Cecil/Harford Counties	2.0%	2.3%	3.3%
Rest of PA	2.0%	2.4%	3.3%
Rest of MD	1.8%	2.2%	3.0%
Rest of US	0.2%	0.2%	0.2%

Source: NERA calculations are described in text.

Appendix E. Expenditures of the Projects as Inputs to REMI

This appendix explains the methodology for estimating the economic contributions of certain direct effects of the Projects. Specifically, we describe how the employment, expenditures and tax payments of the Projects are converted into appropriate inputs to the REMI model.

A. Employment and Expenditures of the Projects

Table E-1 displays the annual employment, expenditure and tax payments of the Projects, as well as the corresponding REMI variables used to enter these direct effects into the model. These data are provided by Exelon, either from the License Applications for Conowingo and Muddy Run or from internal financial records from 2009 through 2011.

Table E-1. Annual REMI Model Inputs

	REMI Model Region		
	Cecil / Harford	**Lancaster / York**	**REMI Variable(s)**
Employment Inputs:			
Employment (jobs)	100	63	Utility Sector Employment; Nullify Intermediate Inputs Induced by Employment; Nullify Investment Induced by Employment
Compensation	$9,086	$3,118	Utility Sector Compensation (net of REMI assumptions)
Expenditure Inputs:			
Capital	$16,177	$10,296	Investment in Producers Durable Equipment
Electricity & Auxiliary Power	$20	$64,549	Exogenous Final Demand in Utilities Sector
Contracting	$2,162	$843	Exogenous Final Demand in Professional and Tech Services Sector
Materials & Supplies	$1,543	$929	Exogenous Final Demand in Repair and Maintenance Sector
Travel & Entertainment	$166	$35	Exogenous Final Demand in Accomodations Sector
Licensing & Telecom	$28	$1	Exogenous Final Demand in Telecommunications Sector
Other Opex	$1,299	$405	Exogenous Final Demand in Repair and Maintenance Sector
Tax Payment Inputs:			
Property Taxes	$3,819	$564	Consumer Housing Price (for residents); Capital Costs (for businesses)
Federal & State Income Taxes	$43,900	$31,178	Government Spending

Note: All dollar values in thousands of 2012 dollars
Expenditures are the average of 2009, 2010 and 2011 data where available
Source: Exelon Generation Company.

REMI estimates the contributions of the Projects by comparing a baseline simulation of the economy with an alternative simulation. The baseline economic data in REMI is assumed to include the contributions of the Projects. The alternative REMI simulation is therefore created by *removing* the expenditures and employment of the Projects (so the employment and expenditures in Table E-1 are input in the model as negative values).

The following subsections provide further detail on these inputs and the corresponding REMI variables.

B. Employment of the Projects as REMI Inputs

Exelon has provided us with the total number of full-time-equivalent employees of the Projects. Exelon has also provided historical data on the compensation of workers at the Conowingo and the Muddy Run facilities. We used the compensation data to apportion the current employees of the Projects by facility (i.e. because 76 percent of the total compensation was paid at Conowingo, we assume 76 percent of the employees work at Conowingo).

These workers add to local employment, and they also spend their paychecks on a variety of goods and services, leading to additional economic activity both locally and across the country. We input the number of employees working at the facilities into REMI as changes in "Utilities" industry employment.

REMI's default response to new employment is to assume increases in intermediate purchases and capital investment. Because we will explicitly input the expenses related to facility operations and intermediate purchases using data provided by Exelon, we make adjustments to the model to avoid the double counting of these expenditures. Specifically, we use the "Nullify Intermediate Inputs Induced by Employment" variable to avoid double-counting the purchases of materials, and the "Nullify Investment Induced by Employment" variable to avoid overstating the impacts on investment.

Compensation of these employees in REMI is based upon the industry- and region-specific average compensation levels. These assumptions differ from the employee compensation data provided to us by Exelon. To account for these differences, we adjust the REMI "Compensation" variable in the "Utilities" industry.

C. Expenditures of the Projects as REMI Inputs

The Projects contribute to the economy by increasing the demand for materials and services across a range of industries. Exelon has provided us with data on the current annual operating and non-operating expenditures of the Projects. Using these data, we categorized all expenditures of the Projects by REMI sector and region.

Expenditures of the Projects are input into REMI as increases in demand for the relevant industries in the relevant model regions. For example, contracting expenditures at Muddy Run are entered as increases in demand in the "Professional and Technical Services" sector in the Lancaster/York Counties region.

REMI then uses its built-in "regional purchase coefficients" to apportion the expenditures by model region. For example, the regional purchase coefficient for the "Repair and Maintenance" sector in the Lancaster/York region is 0.85, so the model assumes that 85 percent of every dollar spent at Muddy Run on "Repair and Maintenance" will directly contribute to the Lancaster/York economy (in terms of employment, income, and so forth). The remaining "Repair and Maintenance" expenditures are assumed to occur outside of the Lancaster/York region; this spending will only indirectly affect Lancaster/York.

Beside the typical operating and non-operating expenditures of an electricity generating facility on goods and services, Muddy Run also purchases a substantial amount of electricity from the local grid. As discussed in the previous section, Muddy Run is a pumped storage hydroelectricity facility that uses electricity to pump water in off-peak hours into its upper reservoir. We used data provided by Exelon to estimate the annual electricity expenditures at Muddy Run[61]. These expenditures were entered into REMI as changes in demand in the "Utilities" industry.

D. Capital Expenditures of the Projects as REMI Inputs

Exelon's ongoing capital expenditures maintain and enhance the Conowingo and Muddy Run facilities. These annual capital expenditures are entered into REMI as "Investment Spending" in "Producers Durable Equipment." They add to the capital stock of the region and increase the demands for local workers and materials.

According to Exelon, these capital expenditures are funded through a combination of equity and debt-financing. The impacts of the debt-financing on the economy will depend in part upon the extent to which the increased demand for capital leads to reductions in investment elsewhere in the economy, i.e., the extent to which the investments in the Projects crowd out other investments. The impacts of debt-financing also depend on how bondholders spend the interest payments in the economy, i.e., to what extent the interest payments lead to increased consumption, savings or investments.

We assume that the change in economic activity due to the Exelon interest payments on bonds is roughly equal to the change in economic activity due to the forgone investment and consumption of the bond purchasers. In other words, the annual effects of "crowding out" of investment and interest payments roughly cancel each other out.

E. Tax Payments of the Projects as REMI Inputs

Exelon pays state and federal income taxes as well as local property taxes related to the Projects. Exelon has provided us with data on the current annual tax expenditures attributable to each facility. These tax payments can be input into REMI either as changes in government spending or as changes in tax revenues.

We assumed that federal and state income tax rates are not affected by the tax payments of the Projects. We therefore entered facility income taxes in REMI as changes in "Government Spending." State income taxes are entered in the model based on the state in which the region is located, whereas federal income taxes are entered into the model based upon the percentage of the U.S. population in each model region (i.e., we assume 1.8 percent of federal tax payments lead to government spending in the "Rest of Maryland" region because this region has 1.8 percent of the total U.S. population).

---

[61] Exelon provided hourly electricity purchase data and the real-time and day-ahead "locational marginal prices" at the Muddy Run node. For each hour, we averaged the real-time and day-ahead prices and multiplied the result by the megawatts of electricity purchased as a proxy for the electricity expenditures at Muddy Run.

We assume that the Projects' property tax payments are in lieu of property tax payments of residents and businesses to support the activities of local governments. We therefore input the property tax payments into REMI as changes in the "Consumer Price" of "Owner-occupied Nonfarm Dwellings" for residents and as changes in "Capital Costs" for businesses[62]. To allocate these effects between residents and businesses, we used historical data on the assessable tax bases from the State Department of Assessment and Taxation for Maryland and the State Tax Equalization Board for Pennsylvania (Maryland 2011; Pennsylvania 2011).

References

Maryland 2011. "Real Property Taxable Assessable Base, County Level, by Class". Maryland State Department of Assessments and Taxation. July 1, 2011. http://www.dat.state.md.us/sdatweb/stats/11Aims2.pdf

Pennsylvania 2011. "Compatibility Report for 2010 SDPropertyBreakdown with Percent.xls". Pennsylvania State Tax Equalization Board. March 1, 2011. Emailed to NERA April 26, 2012.

---

[62] We used REMI's "spreader tool" to appropriately allocate these changes in "Capital Cost" among the various industries based on their percentage of total value added in the region.