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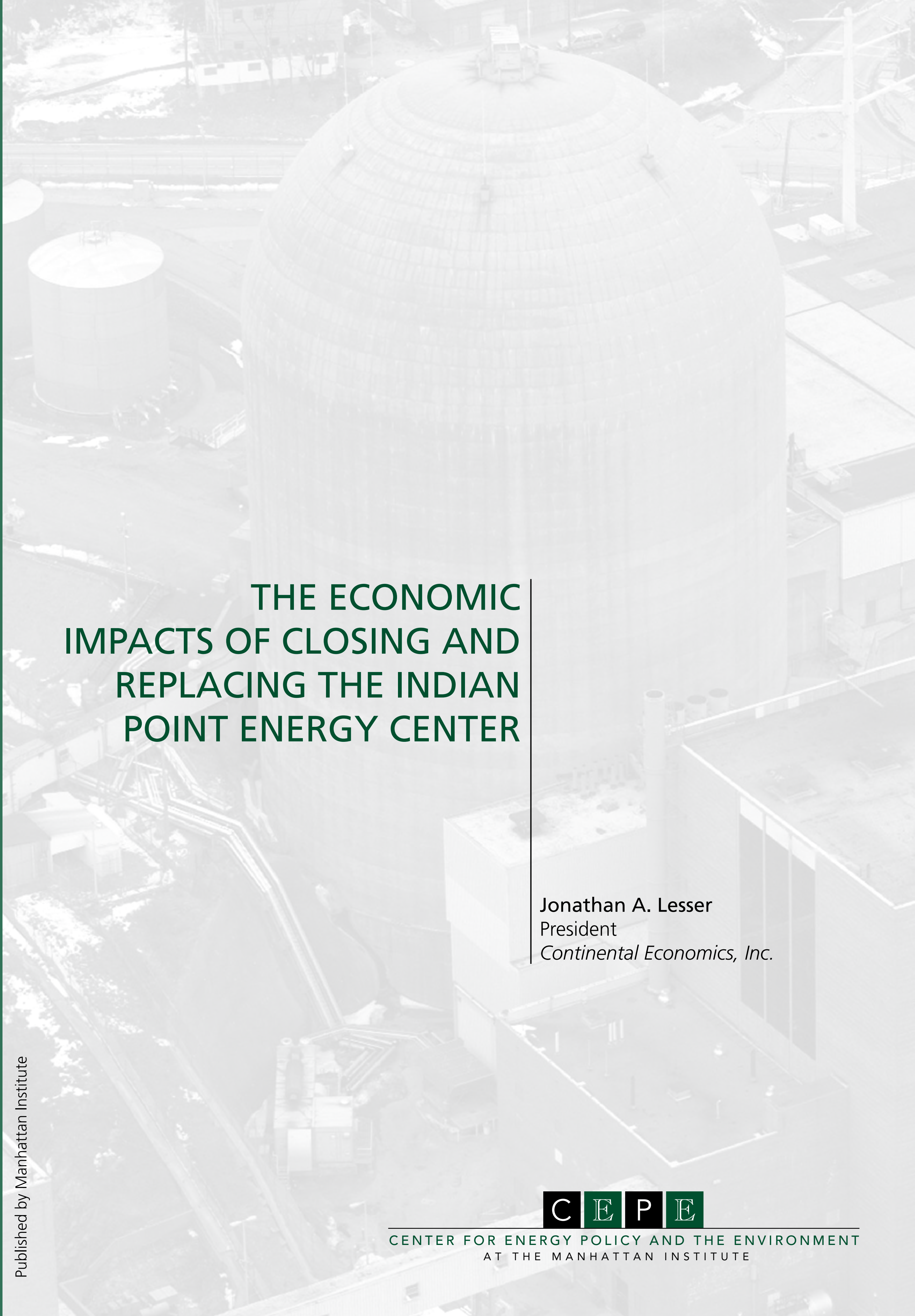

THE ECONOMIC IMPACTS OF CLOSING AND REPLACING THE INDIAN POINT ENERGY CENTER

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Executive Summary

Located some 40 miles north of New York City, in Westchester County, the Indian Point Energy Center (IPEC) consists of two operating nuclear reactors, with a combined generating capacity of over 2,000 MW, and one long-retired reactor. IPEC's size and location are the key factors in both the power it provides and the decades-long fight to shutter the plant permanently.

Although antinuclear sentiment is not new, opposition to IPEC's continued operation was galvanized by the September 11, 2001, attacks on the World Trade Center. More recently, the March 2011 earthquake and subsequent tsunami that destroyed Japan's Fukushima Dai-ichi nuclear plant complex has reinvigorated the debate over IPEC's safety and its environmental impacts.

Because IPEC provides significant quantities of round-the-clock electricity to the New York City area and because of long-standing constraints that limit how much electricity can be imported from upstate New York, New England, New Jersey, and elsewhere, closing IPEC would require the development of higher-cost alternatives. These alternatives include: building new natural gas–fired generating plants in southeastern New York (SENY); building additional high-voltage transmission lines into SENY to increase the quantities of electricity that can be imported into the area; building renewable generation, such as wind and solar resources; implementing more aggressive energy-conservation measures; or combinations of all four approaches.

This paper examines the economic consequences of closing IPEC. Specifically, we consider the broader economic impacts of shutting down the plant and replacing its electricity-generating capacity. We evaluate how the resulting higher electric costs will manifest themselves in reduced economic growth and job losses throughout the state.

We conclude that closing IPEC would increase average annual electric expenditures in New York State by $1.5 billion–$2.2 billion over the 15-year period 2016–30. For a typical residential customer, this would mean an increase in the household electric bill of $76–$112 each year. The average increase for a commercial customer would be $772–$1,132 per year. The average increase in industrial customers' electric bills would be $16,716–$24,517. The largest increase would be for transportation customers, such as the subway system, which would see increases of $1.26–$1.85 million per year.

The effects of these higher electricity costs absorbed by customers would ripple through the New York economy, leading to estimated reductions in output of $1.8 billion–$2.7 billion per year over the 15-year period 2016–30. The resulting loss of jobs in the state could range from 26,000 to 40,000 per year, depending on the alternative chosen to replace IPEC.

About the Author

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INTRODUCTION

Located some 40 miles north of New York City, the Indian Point Energy Center (IPEC) consists of two operating nuclear reactors, with a combined generating capacity of over 2,000 megawatts (MW), and one long-retired reactor. IPEC generates about 20 million megawatt-hours (MWh) of electricity each year—enough to power almost 3 million homes.[1] That generation, along with the plant's location, explains the role that IPEC plays in ensuring adequate and reliable electric supplies for the southeast New York (SENY) region. However, the plant's reactors and its placement have also spurred a decades-long effort to shutter the plant permanently.

Of course, antinuclear sentiment is not new. Events such as the accidents at the Three Mile Island nuclear plant in 1979 and Chernobyl in 1986, along with concerns about storage of high-level nuclear waste, have contributed to calls to shutter IPEC. Additionally, the September 11, 2001, attacks heightened concerns about the plant's vulnerability to a terrorist attack. More recently, the March 2011 earthquake and subsequent tsunami that destroyed Japan's Fukushima Dai-ichi nuclear plant complex brought more attention to questions about the potential risks.[2]

The safety of IPEC and its environmental impacts have been addressed thoroughly over the past few years by independent studies performed as part of the plant's relicensing process (one reactor's license expires in 2013 and the other in 2015; Entergy Nuclear, the owner of IPEC, has applied for 20-year extensions for both).[3] These studies have addressed numerous scenarios, including catastrophic possibilities such as earthquakes or terrorists crashing commercial airliners into the reactor vessels, as well as more mundane concerns, such as the environmental impact of cooling water discharged into the Hudson River. Whether these studies are accurate and have adequately addressed all relevant factors (environmental "justice," appropriate risk avoidance, etc.) are political issues outside the scope of this report. Any decision to close IPEC would have inevitable economic consequences and would require changes in current practices in electricity generation and use. Those economic impacts are the subject of this paper.

The plant's two operating reactors, IPEC-2 and IPEC-3, each have a rated generating capacity of about 1,020 MW. By generating some 2,000 MW around the clock, IPEC provides up to 30 percent of the New York City area's base-load electricity (base-load power is defined as the minimum necessary at any given time to sustain normal activities). The plant's location is crucial to its importance, especially in the dog days of summer, when electricity demand peaks. The city, Long Island, and the Hudson Valley region to its north (collectively designated "southeastern New York," or SENY, on the electricity grid) need local sources of power because there are limits on the amount of electricity that they can import from outside. It is a fact of life that IPEC, if shut down, would have to be replaced. Moreover, there would not be much time to find substitute sources of power. If license extensions are denied for both reactors, alternatives—with a capacity of about 2,000 MW—would therefore have to be online by 2016.

Those possible alternatives are: (1) building new natural gas–fired generating plants in SENY; (2) raising the region's electricity-importing capacity by building additional high-voltage transmission lines into SENY; (3) building renewable generation, such as wind and solar resources; (4) implementing more aggressive energy-conservation measures (thus "generating" power by cutting consumption); or (most likely) combining all four of these strategies in some way.

All these alternatives would increase the price that businesses and individuals pay for electricity. If IPEC's contribution could be replaced by lower-cost electricity, we suspect that the plant would already be closed. IPEC remains open, and its attendant controversies rage on, precisely because there is no way to replace the plant without creating an economic burden. This report maps the scope of that burden as precisely as possible.

Report Organization

Section II of this report provides a nontechnical overview of how New York's electric system works, the challenges of ensuring reliable electricity service to the region, and IPEC's role in ensuring reliable power. Section II also details why electric-system reliability standards effectively mandate that IPEC be replaced by other sources if the plant is shut.

In Section III, we examine the alternatives to IPEC: new generating plants within the region, reduced demand through conservation, or increased ability to import power from elsewhere.

Each alternative presents its own set of challenges. For example, importing more electricity requires adding high-voltage transmission capacity—a far from trivial engineering project, rather like adding new interstate highways or additional lanes onto existing highways. On the other hand, replacing IPEC with 2,000 MW of new gas-fired generating plants would require building new gas pipelines because the existing pipeline infrastructure is insufficient to transport that much more natural gas. Building natural gas pipelines through heavily populated areas must be done within a complex regulatory framework and, if past experience is any guide, is likely to spark opposition.[4] Similarly, attempts to build new high-voltage transmission lines into SENY have met with tremendous resistance.

Renewable power does not offer an escape from these requirements because renewable sources (wind and solar photovoltaics) are inherently intermittent generators of electricity. On a dark, windless, hot, humid July evening, demand will spike, and some *nonrenewable* alternative must be standing ready to meet it. Because of this need for reliability, a commitment to wind and solar power is also a commitment to new gas- or oil-fired generating plants and their associated pipelines, which will serve that essential standby function.

Nor can energy conservation alone replace 2,000 MW of generating capacity. There are two different forms of energy conservation: one, "demand response," addresses an acute, immediate problem. It involves paying industrial and commercial users to turn off power-consuming equipment when directed by the New York Independent System Operator (NYISO), which coordinates the state's electric grid; the other form of conservation is the more familiar notion of using less electricity to obtain the same services (for example, using compact fluorescent lightbulbs instead of incandescent ones or installing more attic insulation to reduce heat loss in winter and keep homes cooler in summer; or replacing inefficient air conditioners). Although both types of energy-conservation measures are useful, they do not constitute a magic bullet: they are unlikely to make up for IPEC's closure and cannot be relied upon to do so.

Section IV quantifies the costs of various IPEC replacement strategies and examines how these costs would affect New York's economy. We have found that all alternatives would create higher costs that would reverberate throughout society, increasing the price of goods and services to consumers, businesses, and industry.

II. HOW NEW YORK'S ELECTRIC SYSTEM WORKS … AND HOW IPEC FITS IN

A. Why Reliability Standards Were Developed: A Brief History

Reliability standards, which are the underlying reason that IPEC would have to be replaced with other generating capacity, were developed in the wake of a power catastrophe. On November 9, 1965, a blackout left 30 million people—in New York, New Jersey, most of New England, and Ontario—without power for up to 12 hours. The cause was a blown safety relay on a transmission line that delivered electricity from a dam north of Niagara Falls. The relay, not unlike a circuit breaker in a typical home, was set to switch off in the event of an overflow of current, preventing damage to the system. Unfortunately, it had been wrongly set to "blow" at too low a level.[5]

On that cold November day, demand for electricity was quite high. Though its line was not overloaded, the relay tripped. With its line shut off, electricity flowed into other transmission lines, which became genuinely overloaded and shut down in their turn. In short order, a cascading set of failures left much of the Northeast in darkness.

This massive failure prompted the formation of the North American Electric Reliability Council (NERC) in 1968, as well as ten regional reliability councils whose mission is to coordinate the activities of independent electric utilities.[6] NERC also designed voluntary reliability standards and operating policies so as to reduce the risk of future blackouts. Some regions, including New York State, use integrated power pools, in which the operation of all electric generators is centrally coordinated.

Despite NERC's many safeguards to improve reliability, another major blackout struck the region in August 2003. This one affected significant portions of the Midwest, Ontario, and the Northeast, including, once again, New York City.[7] In the wake of this new crisis, new reliability standards were developed—and this time, they were made mandatory. Today, NERC is responsible for developing reliability standards, and the Federal Energy Regulatory Commission (FERC) enforces them.[8]

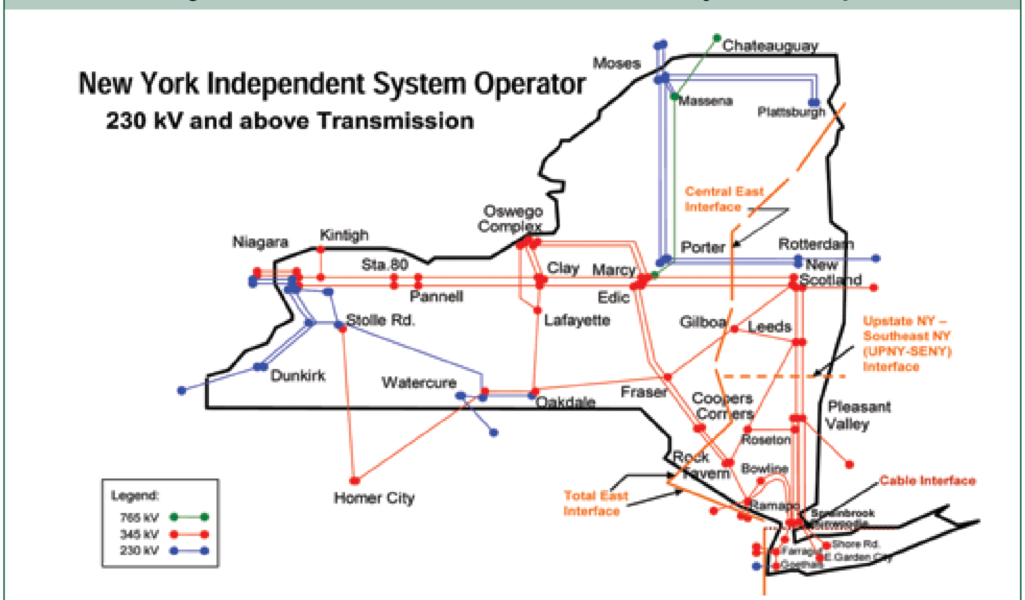
NYISO coordinates the operation of all electric generators in the state and oversees the operation of the high-voltage transmission system. Another state agency, the New York State Reliability Council (NYSRC), forecasts future electricity demand and, given transmission system constraints, how much electric generation must be provided from "local" sources.

B. Why IPEC's Generating Capacity Would Have to Be Replaced

An electric transmission system operates like a set of roads and highways. In and around New York State, most of the "traffic" leads to SENY, especially to New York City. However, there are too few electrical "roads" to handle all these electrons, so not enough electricity flows to the region—especially when demand is greatest.

Transmission congestion is most likely to take place in two specific areas: between upstate and SENY, called the "UPNY-SENY interface"; and the region between western New York and eastern New York, called the "Total East interface." These interfaces act like tollgates, allowing only so many electrons to pass through at a time. Their locations are shown in Figure 1.

Figure 1: New York Bulk Transmission System Map



Source: NYISO

Figure 2: SENY Transmission System and IPEC

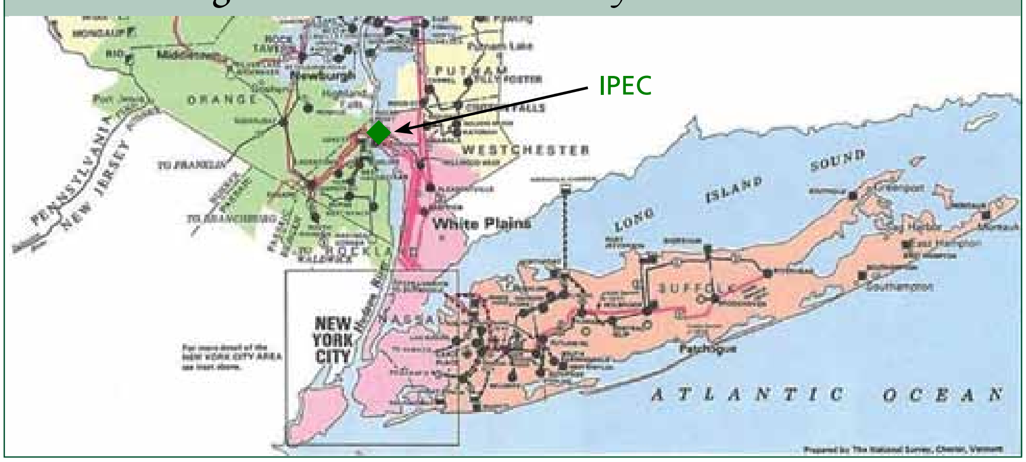
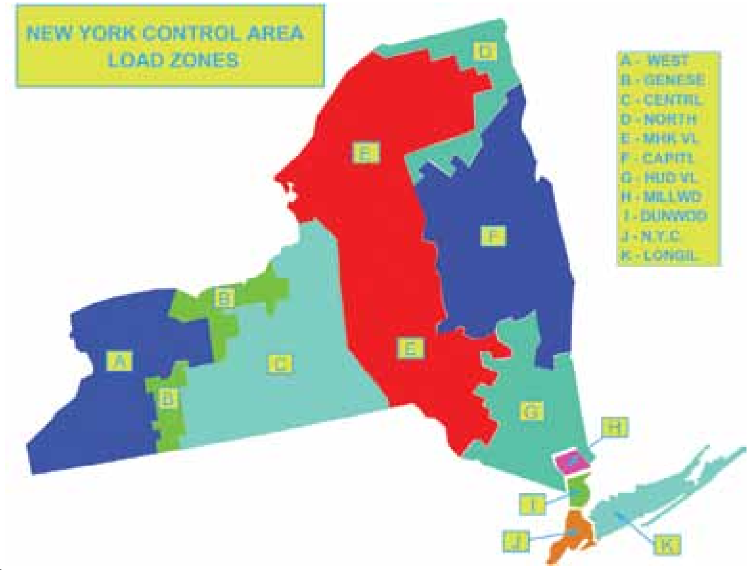


Figure 3: New York Load Zones



Source: NYISO

Because transmission east and south of these interfaces is constrained, the region requires local generating plants (including IPEC), whose energy does not need to move along these highways from outside the region. Figure 2 shows the location of IPEC, which is the largest single generating plant in SENY.

The NYISO system is divided into 11 load zones, A–K, as shown in Figure 3. Collectively, Zones G–K make up what NYISO considers to be the SENY region. IPEC is located in Zone H. Just south of Zone H is Zone I, which incorporates the southern half of Westchester County, including White Plains. The New York City zone, which includes the western half of Nassau County, lies south of that. To the east is Zone K, which incorporates the bulk of Long Island.

The New York City and Long Island zones have the greatest electric demand and are the most constrained of these 11 load zones. This is why generating facilities must be located in the SENY region, in New York City, and on Long Island.

Each January, NYISO publishes the amount of local generating capacity required in the New York City and Long Island load zones for the following 12 months to ensure that reliability standards are met.[9] For the upcoming 2012–13 planning year, NYISO determined that the amount of local generating capacity in the New York City zone must be at least 83 percent of the forecast peak load. For Long Island, NYISO determined that the amount of generating capacity must be 99 percent of the forecast peak load.

Although IPEC is not physically located in either of these zones, it is "downstream" of the electricity-transmission bottlenecks shown on Figure 1. Therefore, if IPEC were shut down and the capacity it provides were not somehow replaced, NYISO could not maintain electric-system reliability at the required level.[10]

IPEC provides up to 30 percent of New York City's total demand for electricity.[11] If IPEC's output were not replaced, the resulting decrease in system reliability would impose significant costs on consumers. Recent studies estimate that the total cost borne just by New York City's power consumers would be over $5 billion in electric-bill increases over a 15-year period.[12] Adding to these direct costs would be the indirect costs of increased potential for rolling blackouts.

Thus, to maintain system reliability if IPEC's operating license were not renewed and the plant shut down permanently, the equivalent base-load capacity would have to be available to New York City or the demand for electricity would have to be reduced.

C. How New York's Electricity Markets Work

NYISO oversees two key electricity markets: one for installed generating capacity; and the other for energy.

The market for capacity ensures that there is sufficient power to meet peak summer demand at any given instant. A power plant may not be operating at full capacity at a given moment, but it must be capable of reaching that capacity when demand requires it to do so. The market for energy involves the trade of electricity among distributors as needed (distributors sell unneeded kilowatt-hours or buy from others when they need more). This market ensures that there is enough electricity to meet demand over time. Because of the bottlenecks on transmission into SENY, there is an overall New York state capacity market and separate markets for the New York City and Long Island load zones shown in Figure 3.

Local electric distribution utilities such as Consolidated Edison (ConEd) are required to have sufficient capacity to meet their forecast peak demands each year, plus a reserve. They meet this requirement in part with generators that they own (for example, ConEd's East River Generating Station) plus capacity that is purchased from the NYISO capacity market. Because of the transmission constraints into SENY that we have already noted, much of that capacity must be located within the New York City and Long Island zones.

Capacity requirements can also be met with demand-response resources. These are essentially promises by companies to reduce power consumption when NYISO tells them to do so.[13] Thus, meeting peak electric demand can be met by having enough generating capacity (the supply side) or by reducing peak use (the demand side).

The NYISO installed capacity (ICAP) market includes several thousand MW of demand-response resources—a cost-effective source of "capacity" that is created by cutting demand rather than increasing supply. This approach is not cost-free. Consider a manufacturer that reduces its demand for electricity by shutting down a production line when asked by NYISO. The electric system gains capacity; but the manufacturer loses revenue, and the local economy loses the benefits of its production.

The other market, for energy, allows local electric distribution utilities to purchase the actual kilowatt-hours they need to meet customers' electric consumption requirements each day, or sell unneeded kilowatt-hours that they may have generated or purchased from other suppliers.

In SENY, the capacity and energy markets will face increased demand in the next ten years. The current NYISO forecast projects an additional 2,500 MW of peak-load growth in the state between 2011 and 2021, 1,800 MW of which stems from projected growth in the NYC and LI zones, as shown in Figure 4.

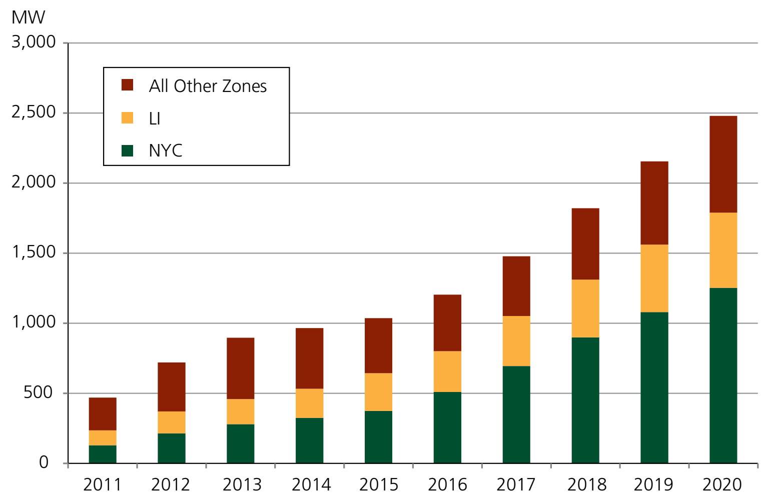
NYISO anticipates that peak load will increase by about 500 MW in the NYC and LI zones by 2014, after IPEC-2's operating license expires (barring license extension), and about 650 MW by 2016, after IPEC-3's operating license expires. The region will need even more locally produced electricity in the future.

III. CLOSING IPEC: THE ALTERNATIVES[14]

If IPEC were closed, replacements could certainly be found to supply the electricity that it generates. But not for free. Every possible means of making up for IPEC's 2,000 MW of electrical generation would require large and expensive alterations in today's status quo.

The job might require, for instance, the construction of a significant number of electric generating plants, relatively close to New York City, and their attendant infrastructure (for example, extra gas lines for new gas plants). Alternatively, it might require adding high-voltage electric transmission lines to bring power to the region from afar. Or it might demand stringent new

Figure 4: Projected NYISO Summer Peak-Load Growth (2011–21)



Source: 2011 NYISO Gold Book

conservation measures. As we have already explained, any solution would likely involve some combination of all these alternatives, and therefore entail some combination of their negative economic effects.[15]

This paper will first describe the available alternatives, noting those which seem most practical. It will then discuss the costs, according to the best estimates available for each strategy. We will then turn to the main original findings of this paper: the effects of these costs on New York metropolitan employment and overall economic activity.

Each of the alternatives to IPEC would be costly. An independent study commissioned by NYISO estimated that the cost to construct a new 100-megawatt (MW) gas-fired combined-cycle generating unit in New York City would be almost $190 million.[16] At that price, replacing all of IPEC with new combined-cycle units in NYC would require almost $4 billion. In addition, replacing IPEC with 2,000 MW of gas-fired generation would require adding new natural gas pipeline capacity into SENY, over and above what is already going to be added in an already expensive and controversial process.

Constructing new generating resources upstate is significantly less costly than building in New York City. However, bringing the electricity to SENY would require new transmission lines. Transmission lines are multibillion-dollar projects. For example, the proposed Champlain-Hudson Power Express (CHPE) line, which would extend from the New York–Quebec border to New York City, has an estimated price tag of $2 billion. The West Point Transmission project is another alternative that would run from Albany south to Buchanan, where IPEC is located. Although no cost estimates have been published, the project is similar in design to the Neptune Transmission project (and would be developed by the same group of investors), which extended an undersea transmission cable between New Jersey and Long Island. The cost of constructing that project is estimated to have been $600 million.[17]

Moreover, proposed new transmission lines have faced significant opposition in the past. For example, the developers of the proposed New York Regional Interconnect (NYRI), which would have delivered power from upstate New York into SENY, were opposed by local groups funded by the New York state legislature itself, as well as opposed by the New York State Department of Public Service (NYDPS), which recommended the development of new gas-fired generating units in SENY rather than building a new transmission line. Thus, while sufficient new transmission capacity could be built, the process of siting, permitting, and constructing new transmission lines is complex, costly, and far from guaranteed.

In evaluating alternatives to IPEC, one also needs to consider the age distribution of existing generating facilities in the NYC and LI zones. Today, there is about 9,100 MW of installed generating capacity in the New York City zone and an additional 5,500 MW installed in the Long Island zone. However, as shown in Figure 5, much of this generation is quite old. In the NYC zone, for example, 60 percent of the generating plants are over 40 years old. In the Long Island zone, almost 70 percent of the generating plants are over 30 years old. These plants are typically combustion turbines that burn natural gas and fuel oil.[18]

The additional maintenance expenses of older plants, combined with increasingly stringent environmental regulations, will likely accelerate retirements, as did New York Power Authority's oil-fired Poletti Generating Station in January 2010. NYISO regularly assesses the retirement risk of existing plants that may fail to meet environmental standards. NYISO's most recent *Reliability Needs Assessment* identified over 6,000 MW of capacity in the NYC and LI zones that falls into the so-called Category 3 risk assessment.[19]

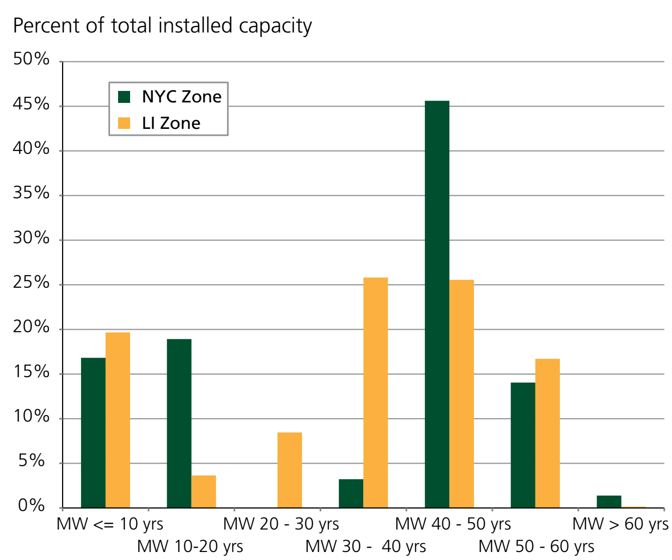
In short, demand for electricity in southeastern New York is rising fast, and generating capacity in the region could well diminish as older plants are accelerated into retirement. Given this context, it is vital to understand in detail how IPEC's 2,000 MW of electricity might be replaced if the facility were to lose its licenses.

A. Option I: Replace IPEC with New Gas-Fired Generating Plants

New natural gas–fired generating units have been built in SENY, including the NYC and LI zones. The Astoria Energy II generating facility, for example, began operation in July 2011. And natural gas is currently the fuel of choice for electric generating plants, in part because of a significant decline in wellhead natural gas prices stemming from rapid growth in shale gas production. However, building more such plants to replace the output of IPEC is not a simple swap.

First, all those additional MW of gas-fired generation will require constructing new gas pipelines into SENY. This is because the existing pipeline system is already at capacity on peak-usage days.[22] Adding gas infrastructure is always costly and is accompanied

Figure 5: Age Distribution of Installed Generation in the NYC and LI Zones



The NYISO Queue

Before any construction can begin, any proposed generating or transmission facility must be evaluated by NYISO to determine its impacts on the electric system.[20] After all, any new facility affects the entire NYISO grid and thus could compromise reliability. Anyone proposing to develop a new facility must have NYISO (or a third party) conduct a detailed System Reliability Impact Study (SRIS).

Often, a new plant will require upgrades to the transmission facilities to which it connects. In its annual Facility Study, NYISO examines all new additions to its grid and determines whether they will entail transmission upgrades and, if so, what these will cost and how the developers and affected companies will divide up those costs.[21]

The resulting queue of upcoming additions includes many proposed facilities that are never actually developed. These projects nonetheless remain in the queue unless specifically withdrawn. For example, in 2001, TransGas Energy LLC proposed building a 1,100-MW combined-cycle cogeneration plant along the East River. Although TransGas was denied a siting permit in 2008, the project is still shown in the NYISO queue with an expected online date of the third quarter of this year.

by environmental and political controversies.[23] In fact, new gas pipeline capacity will be required even if IPEC is *not* retired. Therefore, having to add even more infrastructure to make up for the nuclear plant would make an already difficult situation even more daunting.

Second, while NYISO lists thousands of MW of new generating capacity in its queue of upcoming additions (see box above), not all of that capacity actually will be built. So the amount of gas-fired generation required to replace IPEC is very likely even greater than 2,000 MW.

SENY's Natural Gas Pipeline Infrastructure

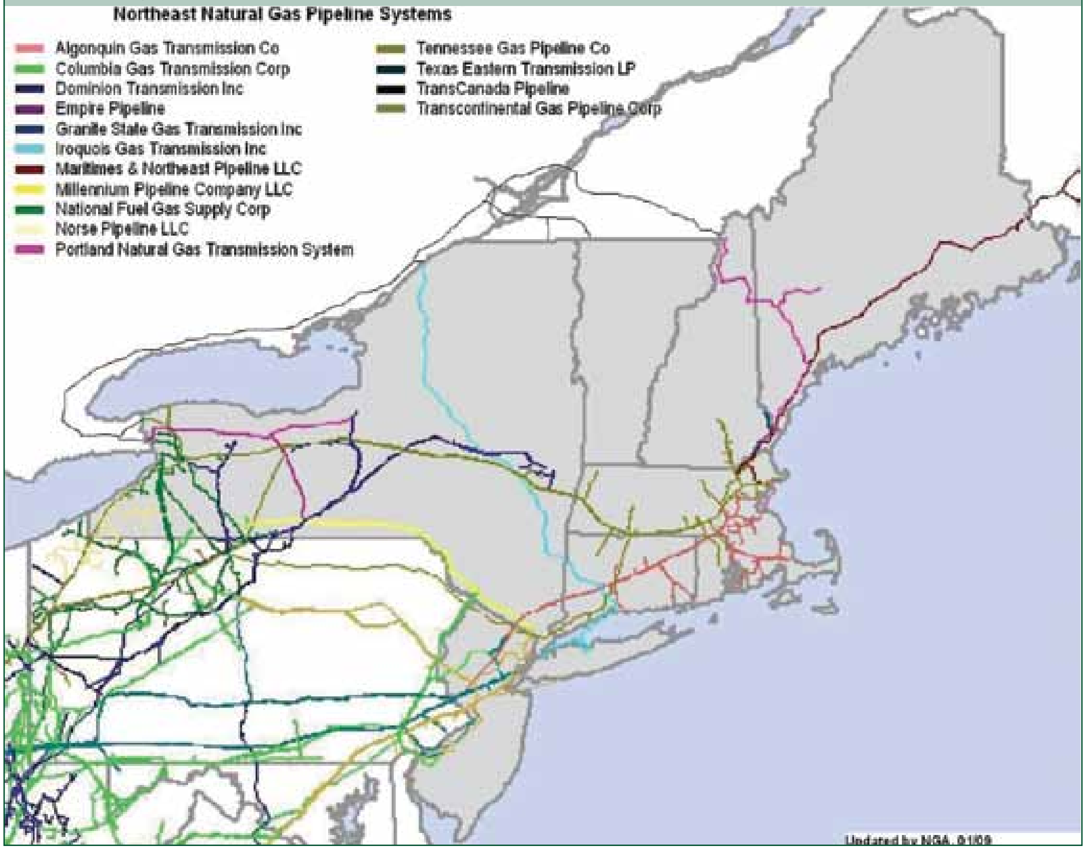
Natural gas–fired generating units require an adequate gas pipeline infrastructure that is capable of providing adequate and reliable supplies, not only to meet the needs for generating plants but also for consumers and businesses who use natural gas directly. In the past, meeting the demand for natural gas has been a challenge, especially in extremely cold weather, when direct natural gas demand has been greatest. Years ago, at times of peak demand, natural gas would be diverted from generating plants to direct-use consumers, and the generating plants instead burned fuel oil. Because of today's more stringent regulations against particulate air pollution, this stopgap use of fuel oil is severely limited.

Figure 6 shows the natural gas pipeline infrastructure in the Northeast. The New York City greater metropolitan area (northern New Jersey, New York City, Long Island, the NY counties of Westchester, Orange, and Rockland, and southeastern Connecticut) is served by six interstate natural gas pipeline companies, with a combined import capacity of about 4,600 million cubic feet (MMcf) per day.[24] These are: Algonquin, Iroquois, Millennium, Tennessee, Texas Eastern, and Transcontinental. Of these six pipelines, Iroquois provides service to Long Island, including natural gas for three generating plants. Table 1 provides a short discussion of each of the six pipelines.

Not all of the capacity on these pipelines is available to the SENY area. For example, although the Algonquin pipeline has an overall capacity of 2,400 MMcf/day, only 1,500 can be delivered into the SENY region.[25]

According to the 2009 New York State Energy Plan (NYSEP), three of these six pipelines—Algonquin, Texas Eastern, and Transcontinental—were already at capacity in 2009 on peak days.[29] By 2018, all but

Figure 6: Natural Gas Pipelines in the Northeast United States



Iroquois are expected to be at capacity, and unmet capacity is projected to be between 40 and 375 MMcf/day on peak days.

By 2020, annual gas demand in the state is expected to grow by 66 billion cubic feet, with 80 percent of this growth projected to be in the downstate New York region, owing in large part to the addition of new gas-fired electric generating facilities.[31] (These projections, of course, assume that IPEC will stay open and continue to contribute its electricity to the mix.)

The existing pipeline infrastructure will be unable to meet regional demand by 2018.[32] In response, new pipelines are planned. But these plans do not include any gas-fired replacement for IPEC. According to the NYSEP, if natural gas is used to replace all of IPEC's generating capacity, the need for additional pipeline capacity into SENY will double.[33]

Pipeline Infrastructure Costs and Issues

The U.S. Department of Energy (USDOE) classifies populated areas where natural gas pipelines exist as "high consequence areas."[34] Building new pipeline infrastructure through such areas is expensive because of the additional safety measures that must be undertaken. Moreover, residents in such areas seldom support new pipelines running beneath them.[35]

Additionally, the geology of certain areas, including parts of Westchester County, is not conducive to building underground pipelines. Specifically, the bedrock in many parts of Westchester County extends to the surface, making an underground pipeline prohibitively expensive to build. In other areas, building new underground pipelines would require excavation of old industrial sites that contain hazardous wastes. Though the costs would depend on the exact routes of these new pipelines (and thus

Table I: Natural Gas Pipelines Serving SENY

Pipeline	Notes
Algonquin (Spectra Energy)	Gas flows from New England southward. Interconnects with new Tennessee 300 line at Mahwah, New Jersey, and Texas Eastern, as well as Iroquois. Proposed NJ-NY expansion of Algonquin and Texas Eastern to serve Manhattan, including new pipeline underneath the Hudson River under review, with in-service date of November 2013.[26]
Iroquois	Gas currently flows from Canada, although now has approval to reverse flow and deliver gas to Canada. Currently serves Long Island and three existing generating plants.
Millennium[27]	Began service in 2008. Delivers gas into Rockland County near Ramapo (southwest of IPEC) and interconnects with Algonquin at Ramapo.
Tennessee[28]	Gas flows from the Gulf Coast. Transverses upstate New York, including connection from Canada. Tennessee 300 expansion in-service November 2011. Connects to existing facilities in White Plains but is fully subscribed. Recent approval to export natural gas to Canada.
Texas Eastern (Spectra Energy)	Gas flows from the Gulf Coast. Interconnects with Algonquin in New Jersey. Proposed NJ-NY expansion into Manhattan.
Transcontinental	Gas flows from the Gulf Coast. Provides service into New York City. Interconnects with Tennessee 300 at River Vale, New Jersey.

the precise industrial sites involved), it is safe to say that cleaning up such sites will add to the already high cost of high-consequence area gas pipelines.

The amount of gas required to generate at least 2,000 MW of new generation is significant. Assuming that all these new generating facilities were high-efficiency, combined-cycle units, we estimate that this generation would require an additional 330–400 MMcf per day of natural gas.[36] By way of comparison, the Portland Natural Gas Transmission System, a major interstate pipeline extending from northern New Hampshire to southern Maine, has a capacity of 200 MMcf per day. The amount of natural gas required by generators that replaced IPEC would require a relatively large pipeline, at least 30 inches in diameter, delivering gas at pressures of about 850 pounds per square inch (psi).[37]

How can we reckon the costs of a pipeline of these dimensions, given the extra expenses imposed by the region's population density, geology, and industrial history? A 2009 study prepared by ICF International[38] forecast average U.S. pipeline construction costs increasing to $60,000 per inch-mile in 2011, escalating about 2.5 percent per year, with costs in the Northeast 29 percent higher than average, or about $80,000 per inch-mile.[39] Given the high cost of constructing in SENY, including the need to construct in high-consequence areas, we believe that a lower-bound construction cost estimate is at least $100,000 per inch-mile. Thus, a 30-inch pipe would cost $3 million per mile to construct, plus the cost of the compressors needed to deliver natural gas at pressures of 850 psi, assuming that it could be sited successfully.[40]

B. Option 2: Build New High-Voltage Transmission Lines to Increase Imports of Electricity into Southeastern New York and New York City

Given that the need for local generating capacity is created by bottlenecks in the system that carries electricity to SENY, a logical alternative to more local electric generation is more transmission capacity to bring energy from elsewhere. More hydroelectric energy might be imported this way from Quebec, for example (an idea that the provincial government there has welcomed). This option would require siting and constructing new transmission lines into SENY, which is problematic given the history of proposed lines in New York. Moreover, current transmission-line discussions do not propose to import only hydroelectric energy. Instead, the most developed and viable proposals rely on a mix of hydroelectric generation, windmills, and solar collectors. Non-hydroelectric renewables are the most costly of all sources of electricity, largely because neither sun nor wind is a 24/7 resource; as we mentioned in this report's introduction, these sources must always be backed up with gas-fired generators.

Transmission lines are expensive to build, not least because they typically face significant siting opposition. For example, the proposed New York Regional Interconnect (NYRI), a 190-mile-long, direct-current transmission project from the Edic substation near Marcy, New York, to Rock Tavern (see Figure 1), would have increased import capacity into SENY by 1,200 MW.[41] NYRI was opposed by the New York Department of Public Service and the state legislature. In fact, the state legislature appropriated several million dollars to fund an opposition group, Communities Against the Regional Interconnect. Some SENY utilities also opposed development of NYRI because the project would have reduced prevailing market prices for electricity in SENY. A 2007 study prepared by Charles River Associates estimated that NYRI would have reduced average wholesale electric prices in all of New York State by almost 6 percent, saving consumers $536 million in 2015 alone and a total of $3.6 billion over the ten-year period of 2015–25.[42] Despite the estimated savings for New York's retail electric customers, NYRI's application was rejected by the New York Department of Public Service in 2009.

Of the other major proposed transmission lines, the 355-mile-long Champlain-Hudson Power Express (CHPE) is furthest along in the NYISO queue.[43] CHPE would deliver up to 1,000 MW of hydroelectric and wind power from Quebec into the SENY region. Its planners have sought solutions to the financial as well as the political challenges of transmission-line building: they expect to cover $1.5 billion of its estimated $2 billion construction cost through federal Department of Energy loans, and the line would be entirely underground or underwater, thus removing visual impacts. However, the project's dependence on wind sources for some of its electricity will require gas-fired capacity as a backup for days when the wind doesn't blow. If it is built, it will entail the expense and controversy involved in building new gas-fired generating plants. And if the project is approved, the current schedule calls for construction starting in 2013 and an in-service date of fall 2016; that is almost a year after IPEC-3's operating license expires.[44] For all these reasons, CHPE cannot be counted on as a replacement for electricity lost in the shuttering of IPEC.

C. Option 3: Replace IPEC with Wind, Solar Photovoltaic, and Hydroelectric Renewable Generation

Wind generation is the most prominent renewable generation option commonly discussed as an alternative to IPEC. The other is solar photovoltaic (PV) energy. In addition to these two renewable resource alternatives, hydroelectric generation and biomass are possibilities, although in-state development of these last two resources is limited.

Under a 2004 order issued by the New York Public Service Commission (NYPSC), electric utilities in the state already are required to meet 25 percent of their electric needs with renewable resources.[45] Replacing all or part of IPEC's installed capacity and annual generation with renewable resources would raise issues of cost (renewables are more expensive sources, especially in light of decreases in natural gas prices and the cost of gas-fired generation); transmission capacity (because wind resources are more likely to be developed upstate and need to be transported to the region); and the need to backstop wind and solar energy with additional gas-fired generating resources.

As a possible replacement for IPEC, wind-based generation consists of three types of energy source: (1) windmills built within SENY that would not require additional transmission capacity to be developed; (2) upstate wind generation, which would require those additional transmission lines; and (3) offshore wind generation that takes advantage of steadier wind speeds but that would, again, require new transmission capacity to be built.[46]

1. SENY Wind Generation

Currently, 1,261 MW of local (SENY) wind energy projects are in the NYISO interconnection queue.[47] The earliest that any of these projects could be completed is 2016, and the current online dates all reflect multiyear delays from their originally proposed online dates; these projects' ability to replace the output of IPEC in a timely fashion is questionable, at best. Moreover, local wind generation will require additional gas-fired generating capacity to account for the inherent output variability and maintain reliability standards in SENY. Thus, this source, in addition to the challenges involved in solar power, brings the difficulties associated with building more gas-fired plants.

2. Upstate Wind Generation

The NYISO interconnection queue lists 3,503 MW of wind capacity planned for regions outside of SENY. For this electricity to be made available to SENY (a bottlenecked region), additional transmission capacity must be constructed. However, the CHPE project is the only current upstate-to-SENY transmission line under development, and, because it is a DC line, no upstate wind generation will be able to interconnect with it except at the project's inception point at the Quebec–New York border.[48]

3. Offshore Wind Generation

Some proponents of wind generation have proposed offshore wind farms as a solution for replacing IPEC's capacity. Offshore facilities get stronger and more consistent wind speeds than do those based on land, which is a large part of their appeal. However, offshore wind farms require transmission lines to take their energy to consumers. Moreover, offshore is twice as expensive as onshore wind power. Finally, the economic lifetime of offshore wind generators is uncertain, owing to limited experience with long-term maintenance costs.[49]

There are also significant engineering hurdles to building offshore wind farms. A promising project (a joint venture between ConEd, the Long Island Power Authority, and the New York Power Authority) was recently withdrawn from the NYISO interconnection queue for being unable to meet its planned construction milestones.

As with any intermittent source of power, all three categories of wind generation will require nonrenewable generation as a backstop for days when the blades cannot turn. When the wind is not blowing, fossil fuel electricity is needed to ensure system reliability, which means more power plants and power lines.

Solar Photovoltaics

Some proponents of shuttering IPEC have recommended using solar PV as a replacement. The 2011 Synapse study discusses the potential for solar energy development under the New York State Solar Industry Development and Jobs Act, AB 5713-C. This bill, which has not been passed, would require New York retail electric suppliers to procure a minimum amount of solar energy to meet their loads each year, beginning in 2013. By 2025, the total amount of solar capacity would be about 5,000 MW.[50] However, capacity, as we have mentioned in Part II, Section C, is not the same as the actual output of a source at any given moment. Because the availability of solar power depends on both the day's weather and the season of the year, NYISO counts only 33 percent of solar capacity as available in summer, and 2 percent in winter. Therefore 5,000 MW of solar PV capacity can be counted on to replace, at best, only about one-third of IPEC's annual output.[51] Again, solar PV, like wind power, requires extensive backup generation from gas-fired plants. Therefore, installing solar PV would require some combination of additional gas-fired generation in SENY, plus new gas pipelines and additional high-voltage transmission capacity to import greater amounts of electricity from upstate.

It is important to remember that solar PV generation is not cost-competitive. Solar PV is far more expensive than even offshore wind. Additionally, solar PV currently accounts for only 32 MW in the NYISO interconnection queue. Recently, a 3.6-MW solar farm was constructed in Manalapan, New Jersey, costing $17.2 million, or about $4,800 per installed kilowatt.[52] The expected annual output from this plant is about 4,500 MWh, enough to power roughly 450 homes.[53]

Hydroelectric Generation

There is currently 16 MW of hydroelectric generating capacity in the NYISO interconnection queue, all of which increases generating capacity on the Saint Lawrence River. None of these projects is local to

SENY, so they cannot replace IPEC electricity without additional transmission lines being built. Aside from what is in the queue, there are no major plans to implement greater hydropowered generation. So hydropower will be unable to serve as a reliable replacement resource for IPEC, unless new hydroelectric dams are built in Quebec and their output transmitted into SENY.

In evaluating any renewable resource as replacements for IPEC, one more factor must be taken into account. To ensure long-term system stability, NYISO sets standards on the amount of Unforced Capacity (UCAP) that any resource can supply to the grid.[54] UCAP represents the amount of round-the-clock electricity generation that a source can be relied upon to provide. For land-based wind, UCAP is just 10 percent in the summer, meaning that 1,000 MW of installed wind-generating capacity provides 100 MW of UCAP. For solar, the highest possible UCAP is 43 percent in summer (and just 2 percent in winter), which would mean that installing 5,000 MW of solar PV capacity could provide no more than 2,150 MW of summer UCAP and just 100 MW in winter.[55]

D. Option 4: Replace IPEC with Demand-Response and Energy-Efficiency Resources

Yet another proposed alternative to IPEC consists of a combination of additional demand-response (DR) resources and energy-efficiency measures.[56] In essence, this alternative would address the loss of IPEC not by adding new resources but by reducing peak electric demand and overall electric consumption in SENY.

Demand-Response Resources

As we mentioned in Section II, DR resources "produce" energy by cutting demand at strategic times. NYISO currently has five DR programs.[57] The largest is the Installed Capacity/Special Case Resource (ICAP/SCR) program, in which electricity consumers enter bids in a kind of auction. If a DR resource's offer clears the market, the owner of the resource will be paid the market-clearing auction price. In exchange, the DR resource owner (typically, a manufacturer or other large-scale consumer) agrees to curtail the accepted quantity of load when called upon to do so by NYISO. At the end of 2010, 2,498 MW of DR resources were registered under the ICAP/SCR and Emergency Demand Response (EDRP) programs.[58] In 2010, there were a total of 2,239 MW of ICAP/SCR resources in New York State. Of that total, 773 MW were located in SENY load zones.[59] In 2011, the total quantity of these resources in New York State decreased to 2,173 MW. In SENY, the quantity decreased by 14 percent, to 663 MW.[60]

Other types of DR resources can be bid into the NYISO energy market but are not required to respond to NYISO's calls for load curtailment.[61] Because these resources are not required to curtail load when called upon by NYISO, their value for reliability purposes is far less than ICAP/SCR resources, which must curtail when called upon. These last forms of DR resources cannot be adequate replacements for IPEC.

Energy-Efficiency Resources

In 2008, the NYPSC issued an order requiring the state's investor-owned electric utilities to reduce forecast energy use 15 percent below forecast energy sales in 2015.[62] This requirement is known as the "15 by 15" program. At the time, the NYPSC projected the amount of required energy savings to be 6.4 million MWh in 2014 and 7.5 million MWh in 2015 for the entire state.[63] Projected savings from LIPA were 1.8 million MWh in 2014 and 2.2 million MWh by 2015.

Of the investor-owned utilities serving SENY, the vast majority of energy-efficiency savings are projected to derive from programs implemented by Consolidated Edison. This makes economic sense. ConEd not only has the largest loads; its higher retail rates mean that more of its customers' energy-efficiency measures are cost-effective. For ConEd, the NYPSC has projected cumulative savings of 2.4 million MWh by 2014 and 2.8 million MWh by 2015.[64] Thus, the proposed savings from electric energy-efficiency programs from both LIPA and ConEd have been estimated to be about 4.2 million MWh in 2014 and 5.0 million MWh in 2015, roughly one-fourth the annual energy generated by IPEC.

The NYDPS has also estimated actual savings through February 2011. (Energy-efficiency savings cannot be measured directly because many factors—e.g., weather and the economy—affect individual customers' and businesses' electricity consumption. It is therefore impossible, in evaluating energy-saving measures, to say precisely how much power a consumer would have used if those measures were not in place.) Through February 2011, the NYDPS estimated total electric savings by the state's investor-owned utilities in SENY at about 96,000 MWh, far short of the targeted savings they had expected, which were over 400,000 MWh.[65] Moreover, because energy-efficiency programs typically target the lowest-cost opportunities first, the cost to obtain additional MWh savings necessarily will increase over time.

Reducing Peak Demand Must Be the Focus of Energy-conservation Resources

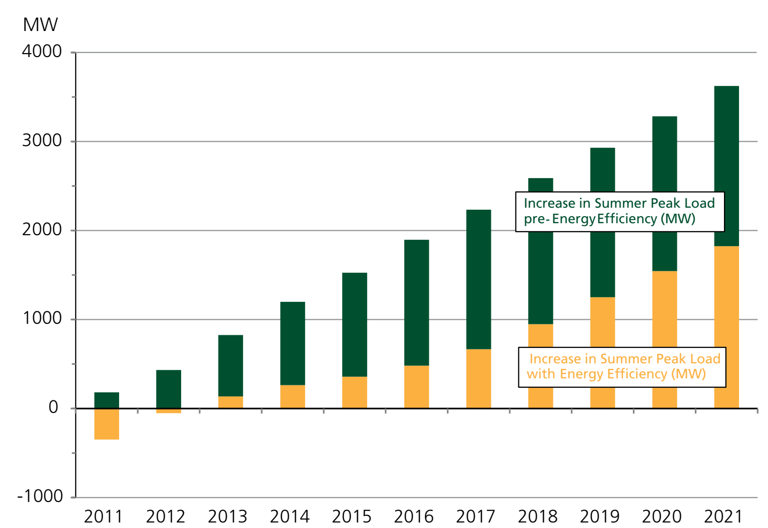
Whatever levels of overall electricity savings can be achieved, any discussion of replacing IPEC with savings must focus not on averages and overall figures but on peak demand. Electric-system reliability standards require that there always be enough power to meet the greatest demand possible, even if usage on a given day is below peak. In SENY, electricity demand peaks during the summer. Therefore, the crucial energy-saving measures are those that contribute to reducing summer peak demand.[66]

The NYISO 2011 Gold Book Report forecasts that, in the absence of additional energy-efficiency measures, SENY peak demand in summer 2016 would increase to 23,526 MW, an increase of about 1,900 MW from the observed peak in summer 2010. By 2021, NYISO forecasts summer peak demand to increase by over 3,600 MW, as shown in Figure 7.[67]

With the state's energy-efficiency programs, NYISO projects that energy-efficiency measures will reduce summer peak growth by 1,414 MW in 2016, resulting in a net increase over 2010 in peak demand of about 500 MW.[68] In 2021, NYISO estimates that peak loads will be lower by about 1,800 MW, resulting in a net increase in peak demand of just over 1,800 MW. These savings are summarized in Figure 7.

For all their merits, energy-efficiency programs can be problematic for maintaining system reliability because NYISO has no control over energy-efficiency savings. Moreover, the savings are all estimated, so NYISO cannot be sure that they actually exist. Setting aside those concerns and assuming a best-case scenario, replacing IPEC's full capacity would require energy-efficiency savings to increase from the currently estimated 1,414 MW in 2016 to over 3,400 MW—a rise of almost 150 percent. Given that actual energy-efficiency savings are already less than

Figure 7: SENY Forecast Summer Peak-Load Growth



Source: 2011 NYISO Gold Book

the targeted energy savings, it is unrealistic to expect these programs to make up for a shutdown at IPEC.[69]

E. Projected Costs of Replacing IPEC

We have reviewed some of the most important practical, political, and administrative difficulties posed by all possible methods of replacing IPEC's electrical generation capacity. Hovering over all of them is the issue that we will now examine: the cost of electricity. Replacing IPEC will impose extra expense on consumers—and not only in SENY. New York State's electrical system is a single, integrated unit, so the extra expense of living without IPEC would be borne by all the state's citizens.

As a practical matter, replacing IPEC would not involve choosing one option—new plants or transmission lines or energy efficiency; it would involve all three strategies in some combination. That makes it impossible to estimate the cost of every possible combination of replacement resources: there are simply too many. Moreover, costs will be site-specific. For example, replacing IPEC with gas-fired combined-cycle generating units at the IPEC site could have a significantly different cost from locating those units elsewhere in Westchester County or in New York City. Furthermore, the overall replacement cost for a given combination depends on how the entire NYISO system operates. So building new transmission lines to import power from upstate New York would change how upstate generators operated, requiring an analysis of the costs of specific generating units.

To model an integrated electric system, which links hundreds of generating plants in New York State and beyond, is a challenge; yet it can be done. The most accurate method available for estimating the projected costs of replacing IPEC is the use of comprehensive production-cost models.

Such models simulate the operation of the entire NYISO system, incorporating every generating facility in the state, as well as imports from Canada, New England, and the mid-Atlantic states. The models also account for the NYISO transmission system, including existing bottlenecks that limit the flow of lower-cost electricity into SENY. The models can simulate the effects of unexpected events, such as unplanned outages at generating units or individual transmission lines. Such modeling is critical because it is the basis for determining whether a given alternative to IPEC will meet reliability standards.

We are aware of only one study that has used a detailed production-simulation approach to evaluate the impacts of shuttering IPEC; it was performed by the Charles River Associates in 2011.[70] Although no simulation model can account for all possible contingencies, the CRA study is by far the most comprehensive analysis currently available.

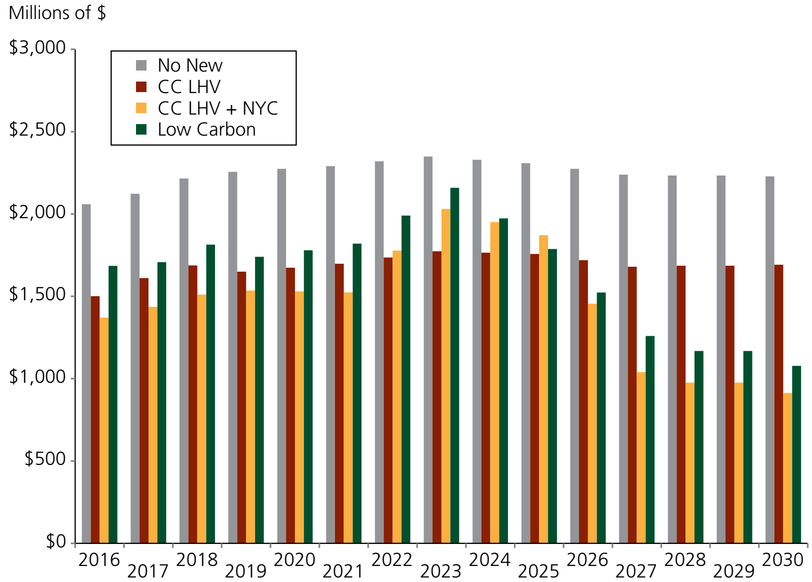
The CRA study clearly demonstrated that shutting IPEC without a replacement is not a realistic option. Not only would the increase in wholesale energy and capacity market prices increase the costs paid by retail electric customers throughout the state by over $2 billion per year; it would lead to unacceptable reductions in system reliability by 2016. Thus, IPEC must be replaced with a combination of resources that would provide the same quantities of energy and capacity: about 20 million MWh and 2,000 MW of installed capacity.[71] Moreover, if the plant is to be closed, a sufficient quantity of these alternative resources must be ready by the time IPEC-3's operating license expires in 2015 to ensure that system reliability standards are met.

The CRA study examined three alternative scenarios to replace IPEC, as well as estimated the additional costs of a "do nothing" option. Because the number of potential replacement scenarios is almost limitless, the CRA study selected these three scenarios to bracket the replacement cost estimates, based on the most likely possible combinations available:

1. CC LHV + NYC. Construction of two 500-MW high-efficiency gas-fired generators known as "combined-cycle units": one in NYC and the other in the Lower Hudson Valley (LHV);[72]

2. CC LHV. Construction of two 1,000-MW combined-cycle units replacing IPEC directly in the SENY area; and

Figure 8: Estimated Annual Increase in Wholesale Electric Costs—New York State



Source: CRA Study, Table 4, p. 25.

3. Low Carbon. Construction of a 1,000-MW HVDC (high-voltage direct-current) line (similar to the Champlain-Hudson Power Express line) connecting into NYC, plus a 500-MW offshore wind farm.

Each option assumed that NYISO's projected energy-efficiency savings, as shown in Figure 7, would be obtained.

The CRA study estimated the cost impacts in the NYISO capacity and energy markets over a 15-year period between 2016 and 2030, as shown in Figure 8. Although these are wholesale cost impacts, they would eventually be paid by retail customers.

CRA estimated that doing nothing, in addition to violating reliability requirements, would increase wholesale electricity costs by over $2.2 billion per year. The study found that the least costly of the three options would be Option 1. Under this option, the average annual wholesale cost increase would be $1.46 billion per year for the 15-year period. Option 3, which CRA deemed a "low carbon" alternative, would increase costs by about $1.65 billion per year.

Over the entire 15-year period, CRA estimated the increase in wholesale energy and capacity costs to be $22 billion under Option 1. Option 3 would increase costs by $24.7 billion over the 15-year period.

Table 2 shows the estimated annual cost impact per customer, for each customer class, using published data on the number of customers and electricity usage per customer in 2010.

For a typical residential customer, this would mean an increase in the home's electric bill of $76–$112 each year. The average increase for a commercial customer would be $772–$1,132 per year. The average increase in industrial customers' electric bills would be $16,716–$24,517. The largest average increase would be for transportation customers, such as the subway system, which would see increases of $1.26–$1.85 million per year.

These estimates do not include the costs of additional natural gas pipelines, high-voltage transmission lines, or additional nonmarket subsidies that would need to be paid to developers for the projects.[73] These could add several billion dollars to the projected cost increases and, again, would be paid by all retail customers.

Table 2: IPEC Closure: Average Annual Cost per Customer

Customer Class	Total Sales (MWh)	Customers	Use per Customer (kWh)	Average Cost per Customer Low	Average Cost per Customer High
Residential	50,945,648	6,954,916	7,330	**$76**	**$112**
Commercial	77,275,676	1,038,260	74,430	**$772**	**$1,132**
Industrial	13,480,462	8,364	1,611,720	**$16,716**	**$24,517**
Transportation	2,921,787	24	121,741,130	**$1,262,669**	**$1,851,914**

Source: U.S. EIA

IV. ECONOMIC IMPACTS OF CLOSING IPEC

As previously described, IPEC plays a vital role in providing reliable electricity to the southeastern New York region, and therefore benefits all of New York State by helping to keep electricity prices down and contributing to the security of the state's electricity grid. The plant cannot be closed without finding some way to replace its 2,000 MW of generating capacity. And every possible replacement strategy—more power plants, more transmission lines, a turn to renewable resources, more energy-conservation efforts—would have a significant impact on the state's economy.

In this section, we will relate these various impacts to form a picture of the likely economic consequences for all New Yorkers of closing Indian Point. Some impacts of closing IPEC would be localized, while others would affect the entire New York economy. If the operating licenses at the two units are not renewed, more than 1,100 IPEC employees will lose their jobs by 2016. That would clearly affect the local economy of Westchester, Dutchess, and Orange Counties, where the majority of IPEC employees live. Some of these jobs would be replaced, depending on whether the plant was decommissioned immediately or put into what is called "SAFSTOR," a form of delayed decommissioning that allows radiation levels in the reactor to decrease over time, reducing the difficulty of decommissioning.[74]

Second, beginning in 2016, Entergy would no longer purchase goods and services in New York to maintain the plant. Those expenditures are estimated to be about $60 million per year.[75] Again, the reductions in purchases would be mitigated somewhat by purchases related to decommissioning the plant, depending on when decommissioning commenced.

Third, IPEC's closure would mean a loss of $25 million in property-tax payments to Westchester County, as well as lost income taxes paid to the state. There would be other local tax effects as well. For example, Entergy pays the overwhelming majority of the property taxes collected for the Hendrick Hudson Central Schools.

Fourth, depending on the alternative resources developed to replace IPEC, there would be local construction impacts and additional maintenance expenses. For example, if IPEC were replaced with a natural gas–fired, combined-cycle generating plant built at the same location, there would be several years of construction activity, ongoing maintenance expenditures, and so forth. There would also be construction activity associated with the new gas pipeline capacity that such a plant would need.

By far, the largest, longest-lasting, and most widespread economic impact of closing IPEC would arise from higher electricity prices because electricity is such a fundamental component of the U.S. economy. This is the impact that we focus on here.

According to data published by the U.S. Energy Information Administration, New York businesses and consumers spent over $21.7 billion for electricity in 2009.[76] Based on the CRA analysis, shuttering IPEC could increase electric costs by as much as 10 percent per year.

When businesses and consumers pay more for electricity, they have less money to spend on other goods and services and investments that increase economic output. Moreover, goods and services whose production requires electricity increase in cost. So businesses and consumers have less money to spend on goods and services, which cost more to produce. Closing IPEC, then, would impose the equivalent of a tax on consumers and producers that would, as tax increases do, reduce economic growth.

The adverse economic impacts of higher electric prices have been recognized by energy regulators. For example, in rejecting a proposed power purchase contract between Deepwater Wind (a small offshore wind development) and National Grid in April 2010, one reason cited by the Rhode Island Public Utilities Commission was the job-killing effects of higher electric prices: "It is basic economics to know that the more money a business spends on energy, whether it is renewable or fossil based, the less Rhode Island businesses can spend or invest, and the more likely existing jobs will be lost to pay for these higher costs."[77]

Of course, alternatives to IPEC will require new construction, which would create short-term economic lift. For example, building new combined-cycle generators would mean hiring construction workers, purchasing supplies, and so forth. However, these short-run economic impacts would not offset the long-run economic impacts of higher electric prices, which would reverberate throughout the New York State economy. Because the focus of this report is these long-run economic impacts, we did not model the economic impacts of one-time construction projects triggered by an IPEC closing.

A. Modeling Economic Impacts

Because the U.S. economy is complex, it is probably impossible to predict how specific policies will change output and employment in every industry over many years. (Some 20 years ago, for example, it would have been difficult to estimate the economic impacts of the Internet, which has created whole new industries.)

The challenges of modeling a constantly changing economy are so complex that many economic impact studies rely on so-called static models, which are based on a snapshot of the economy at a single moment in time. These models are called "input-output" models (I/O).[78]

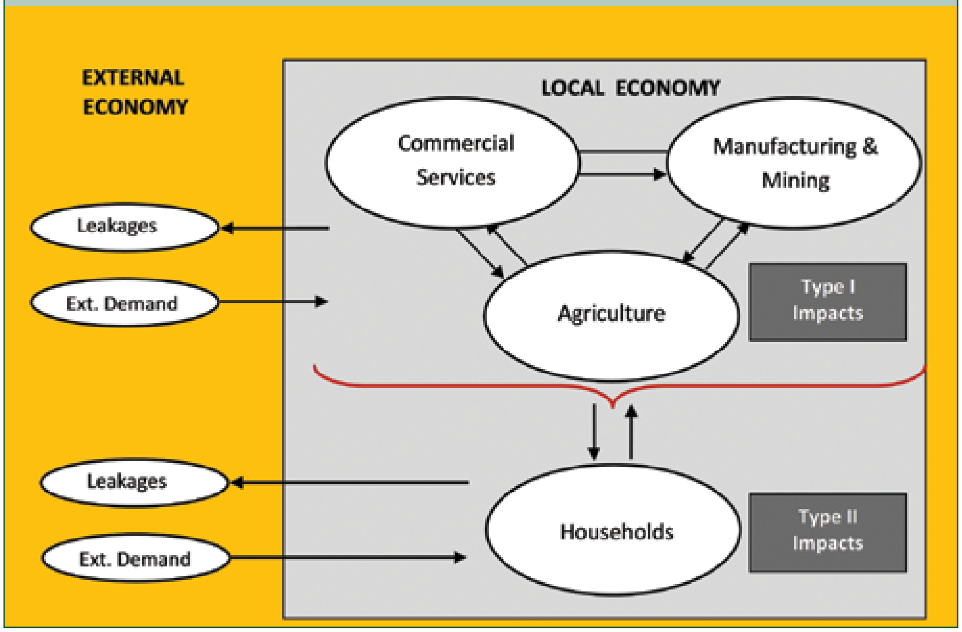
Often, I/O models are used to estimate the economic impacts of constructing and operating new facilities, including electric generating facilities.[79] For example, to estimate the economic impacts of building a new combined-cycle generator, an I/O model would allocate the expenditures for that construction to various sectors of the economy (cement, turbine manufacturing, wire, wages for construction workers, etc.) and then determine how those expenditures would ripple through the economy.

How an Input-Output Model Works

Input-output analysis traces the interdependencies of an economy—specifically, the sales and purchases of goods among all sectors of an economy.[80] For example, constructing a new high-voltage transmission line will require the purchase of concrete that will be used as foundations for transmission towers. But to manufacture that concrete, firms must purchase inputs including sand, gravel, and electricity. Similarly, transmission towers will be made of steel that is manufactured in steel mills that use iron ore, which is mined by other firms. Moreover, construction requires the use of many workers who then spend their wages on all varieties of goods and services. An input-output framework is designed to trace all those relationships. Figure 9 shows the general analytical framework for an I/O model.

In an I/O model, a local economy (which can be a county, state, or multicounty or multistate region) is broken down into manufacturing and mining, commercial services, and agriculture. There is also a household sector and, in some cases, a separate government sector. Purchases outside the local economy are considered "leakages." On the other hand, sales by business and industry of goods and services to outside the local economy are treated as external demand. External demand increases

Figure 9: I/O Model Structure



the level of economic activity within the local economy.

There are also household impacts. Households in the local economy purchase goods and services from local industries, as well as from the broader external economy. Moreover, households outside the area purchase goods and services from firms within the local economy. A model that does not include this household spending represents only impacts from activity among businesses and the government (these are designated "Type I impacts"). If households are included in the model, they represent "Type II impacts": all Type I impacts plus the effects of consumer spending. Type II impacts include changes in household spending that result from policy changes, such as changes in income-tax rates, as well as how changes in industrial output affect wages paid and expenditures that households make on goods and services.

For each sector of the economy, the I/O model traces employment and wages. Thus, concrete manufacturing within the local economy may require an average of, say, ten employees for every million dollars of concrete produced, while grocery stores may employ 30 people for every million dollars of retail sales.

The IMPLAN Model

We have adopted one of the most well-known economic impact models, the IMpact for PLANning (IMPLAN) model.[81] IMPLAN is the most widely used I/O model and is frequently employed by federal and state government agencies.

The IMPLAN model divides the U.S. economy into more than 500 separate economic sectors in agriculture, manufacturing, commercial services, and government. With these units of data, the model creates state- and county-level values by adjusting the national-level data to account for local conditions.

The model estimates imports and exports, using what are called "regional purchase coefficients" (RPCs). An RPC measures the proportion of the total supply of a commodity or service that is produced locally. The larger the RPC value, the higher the percentage of total regional demand that is met through local supplies and the fewer expenditures that "leak out" of the local economy. Naturally, the larger the local economy, the larger will be the RPC values. RPCs are important for estimating the economic impacts of higher electricity prices because the greater the

Table 3: Estimated Reductions in State Output, 2016–30 (2010$ Millions)				
		CRA Analysis Case		
Year	No New	CC LHV	CC LHV + NYC	Low Carbon
2016	($2,878)	($2,098)	($1,916)	($2,355)
2017	($2,911)	($2,209)	($1,969)	($2,341)
2018	($2,981)	($2,271)	($2,025)	($2,295)
2019	($2,976)	($2,177)	($2,025)	($2,295)
2020	($2,940)	($2,164)	($1,978)	($2,301)
2021	($2,903)	($2,152)	($1,931)	($2,306)
2022	($2,881)	($2,156)	($2,208)	($2,471)
2023	($2,859)	($2,159)	($2,472)	($2,627)
2024	($2,777)	($2,105)	($2,326)	($2,353)
2025	($2,699)	($2,053)	($2,187)	($2,088)
2026	($2,605)	($1,969)	($1,667)	($1,745)
2027	($2,515)	($1,887)	($1,168)	($1,414)
2028	($2,461)	($1,857)	($1,075)	($1,287)
2029	($2,414)	($1,822)	($1,055)	($1,262)
2030	($2,363)	($1,793)	($968)	($1,143)
Average	**($2,744)**	**($2,058)**	**($1,798)**	**($2,029)**

leakages out of the New York economy, the less the overall impacts will be in the state.

B. The Economic Impacts of Higher Electric Prices

We used IMPLAN, combined with the CRA analysis, to estimate the annual economic impacts to New York State from higher electric prices, as a consequence of a closure of IPEC, from 2016 to 2030.[82] Specifically, we estimated how higher prices will lead directly to reduction in overall output in the state and to reduction in state employment. Table 3 presents the estimated decreases in overall state economic output under the four CRA scenarios.

As Table 3 shows, the alternative in which combined-cycle units were built in the LHV near IPEC and in New York City would result in an average annual loss of economic output of $1.8 billion over the 15-year period. Failing to replace Indian Point, which would lead to higher electric prices and reliability-standard violations, would reduce state output by an average of $2.7 billion over the 15-year period. The low-carbon alternative would result in just over $2.0 billion per year in lost economic output.

Table 4 presents our estimate of consequent annual job losses throughout New York State.[83] As shown, under the alternative in which combined-cycle units are built in the Lower Hudson Valley and New York City, the average annual job loss due to IPEC closure in the region would be more than 26,500. If IPEC is not replaced with other generating capacity, job losses would average more than 40,000 per year. The low-carbon alternative would raise electric prices and lead to almost 30,000 lost jobs per year.

Some have criticized I/O modeling for failing to account for how consumers and businesses adjust to changing prices. If the price of electricity increases, a manufacturer is more likely to install higher-efficiency motors, while consumers may be more likely to purchase more energy-efficient appliances. Since I/O models use a static snapshot of economic activity on a particular date, they cannot, by definition, account for cascades of change as people respond to economic signals.[84]

This objection does not apply to our analysis. First, we have also used the CRA model, which does account for the impacts of changing electric prices and technologies over time, by incorporating the

Table 4: Estimated Reductions in State Employment, 2016–30

	CRA Analysis Case			
Year	No New	CC LHV	CC LHV + NYC	Low Carbon
2016	(42,466)	(30,958)	(28,277)	(34,753)
2017	(42,960)	(32,600)	(29,058)	(34,542)
2018	(43,992)	(33,510)	(29,977)	(36,012)
2019	(43,912)	(32,117)	(29,878)	(33,869)
2020	(43,379)	(31,933)	(29,186)	(33,955)
2021	(42,836)	(31,749)	(28,495)	(34,030)
2022	(42,507)	(31,807)	(32,577)	(36,461)
2023	(42,181)	(31,856)	(36,471)	(38,769)
2024	(40,978)	(31,055)	(34,327)	(34,714)
2025	(39,819)	(30,300)	(32,266)	(30,817)
2026	(38,438)	(29,056)	(24,594)	(25,743)
2027	(37,106)	(27,842)	(17,236)	(20,865)
2028	(36,312)	(27,404)	(15,864)	(18,985)
2029	(35,617)	(26,880)	(15,561)	(18,622)
2030	(34,862)	(26,464)	(14,280)	(16,860)
Average	**(40,491)**	**(30,369)**	**(26,536)**	**(29,933)**

energy-efficiency savings estimated by NYISO. Thus, over the 15-year modeling period, energy-efficiency improvements are already reflected in how goods and services are produced, including the amount of electricity required. Second, although the total dollar impacts are large in our model, the marginal increases in electricity prices are fairly small. Therefore, price-induced changes in electricity consumption would be small, as well.[85]

V. CONCLUSIONS

New York's electric system is highly complex, and IPEC is a critical component of that system. Not only does IPEC provide 30 percent of New York City's electricity; it helps ensure that the system operates safely and reliably.

If the plant is to be closed, New York must have alternative resources in place by the time IPEC-3's operating license expires in 2015. Doing nothing to replace IPEC would result in all New York electricity consumers—not just those in southeastern New York and New York City—spending over $30 billion more for electricity over the subsequent 15 years. It would also increase chances of blackouts, causing the state's system to violate its own standards for reliability.

All alternatives for replacing IPEC are limited and costly. Each comes with its own set of challenges and trade-offs. But each will result in higher electric prices for everyone in New York State. Those higher electric prices will have adverse impacts on the state's economy, resulting in the loss of thousands of jobs. Moreover, the alternatives—whether building new gas-fired generating plants or new transmission lines to bring in power from upstate New York and beyond—would all face major siting and infrastructure issues, as well as opposition from various constituencies.

Whether these trade-offs are greater than the benefits of closing IPEC is for New York politicians and policymakers to decide. But they should be under no illusions that closing IPEC will be painless. It will not be.

Appendix: Estimating the Economic Impacts of Increased Electric Costs

1. Mathematics of the Input-Output Framework[86]

An input-output framework begins with observed transaction data for a particular region. The IMPLAN model is constructed from data at the national, state, and county levels. The transactions are typically converted into dollar amounts, as that makes tracing economic flows much easier, since dollars are a uniform measure.

We assume that the economy is made up of numerous sectors—e.g., manufacturing, mining, agriculture, services, government, and foreign trade. To construct an input-output table, we record how the output produced (supplied) by a given sector, such as steel, is purchased (demanded) by the other industry sectors (which then use those purchased inputs to manufacture other goods), plus external sales to government and consumers. Thus, if the economy consists of N industries, the total output produced by an individual industry, X_k, will be purchased by the other N–1 industries, used by itself, and sold to final consumers. Thus,

$$X_k = z_{k,1} + z_{k,2} + z_{k,3} + \ldots + z_{k,N} + Y_k \qquad (1)$$

where the $z_{i,n}$ are sales to each industry n, and Y_k equals sales for final demand (i.e., to consumers, the government, and for export). Since we have N industries, we can write the entire set of flows as:

$$\begin{bmatrix} X_1 = z_{1,1} + z_{1,2} + \ldots + z_{1,k} + \ldots + z_{1,N} + Y_1 \\ X_2 = z_{2,1} + z_{2,2} + \ldots + z_{2,k} + \ldots + z_{2,N} + Y_2 \\ \vdots \\ X_k = z_{k,1} + z_{k,2} + \ldots + z_{k,k} + \ldots + z_{k,N} + Y_k \\ \vdots \\ X_N = z_{N,1} + z_{N,2} + \ldots + z_{N,k} + \ldots + z_{N,N} + Y_N \\ \end{bmatrix} \qquad (2)$$

Each column of coefficients on the right-hand side of equation (2), i.e.,

$$\begin{bmatrix} z_{1,k} \\ z_{2,k} \\ \vdots \\ z_{k,k} \\ \vdots \\ z_{N,k} \\ \end{bmatrix}$$

represents the purchases from industry sector k to the N–1 other industry sectors, and to itself ($z_{k,k}$). In other words, industry k purchases inputs from all the other industries to produce output X_k. When all the N different columns are combined, they create an *input-output table*, with each selling sector a different row and each purchasing sector a different column, as shown in Table 1.

Table I: An Input-Output Table								
		Purchasing Industry Sector						
		1	2	…	K	…	N
Selling Industry Sector	1	$Z_{1,1}$	$Z_{1,2}$	…	$Z_{1,k}$		$Z_{1,N}$
	2	$Z_{2,1}$	$Z_{2,2}$	…	$Z_{2,k}$		$Z_{2,N}$
	⋮	⋮	⋮		⋮		⋮
	k	$Z_{k,1}$	$Z_{2,k}$	…	$Z_{k,k}$		$Z_{N,k}$
	⋮	⋮	⋮		⋮		⋮
	N	$Z_{N,1}$	$Z_{N,2}$	…	$Z_{N,k}$		$Z_{N,N}$

Although the input-output table above incorporates all the interindustry sales and purchases, it does not account for the remainder of the economy. Final demand includes sales to consumers and to state, local, and federal government. It also includes investment and exports. Moreover, in addition to buying outputs from other industries, each industry pays wages to its employees (W), pays for government services (in the form of taxes), pays for capital (in the form of interest payments, I), and generates profits. Together, these components are called *value-added*. On top of that, each sector imports goods and services from outside the economy. For example, if building a new high-voltage transmission line requires buying substation equipment from Germany, the input-output model for the United States would consider that an import.

The input-output framework assumes that production coefficients are fixed. This means that specific quantities of inputs are required to produce a given output. Thus, building a car is assumed to take, say, 2,000 pounds of steel, 100 pounds of rubber, 200 pounds of glass, and so forth. Obviously, this assumption of fixed production coefficients does not match reality (it takes more materials to build a large pickup truck than a subcompact car). But for estimating short-run impacts, the overall assumption is reasonable: building more cars and trucks will clearly require more steel, producing more steel will require more iron ore, and so forth.

Because the input-output framework assumes fixed production coefficients (called a "Leontief production function"), the inputs needed to produce a unit of output are all constant. If we divide the purchases made by industry k from every other industry, i.e., the $z_{i,k}$, to produce output X_k, we derive the *technical coefficients*, $a_{i,k}$, for industry k, i.e.,

$$a_{i,k} = \frac{Z_{i,k}}{X_k} \qquad (3)$$

If we substitute equation (3) into equation (2), we obtain:

$$\begin{bmatrix} X_1 = a_{1,1}X_1 + a_{1,2}X_2 + \ldots + a_{1,k}X_k + \ldots + a_{1,N}X_N + Y_1 \\ X_2 = a_{2,1}X_1 + a_{2,2}X_2 + \ldots + a_{2,k}X_k + \ldots + a_{2,N}X_N + Y_2 \\ \vdots \\ X_k = a_{k,1}X_1 + a_{k,2}X_2 + \ldots + a_{k,k}X_k + \ldots + a_{k,N}X_N + Y_n \\ \vdots \\ X_N = a_{N,1}X_1 + a_{N,2} + \ldots + a_{N,k}X_k + \ldots + a_{N,N}X_N + Y_N \end{bmatrix} \qquad (4)$$

What equation (4) tells us is that some of the output produced by an industry is sold to all other industries and used in fixed quantities to produce those industries' outputs, and the remainder is sold as final demand to consumers, government, and as exports. As a final step, we isolate the final demands for the output from each industry, Y_k. Thus,

$$\begin{bmatrix} X_1 - a_{1,1}X_1 + a_{1,2}X_2 + \ldots + a_{1,k}X_k + \ldots + a_{1,N}X_N = Y_1 \\ X_2 - a_{2,1}X_1 + a_{2,2}X_2 + \ldots + a_{2,k}X_k + \ldots + a_{2,N}X_N = Y_2 \\ \vdots \\ X_k - a_{k,1}X_1 + a_{k,2}X_2 + \ldots + a_{k,k}X_k + \ldots + a_{k,N}X_N = Y_n \\ \vdots \\ X_N - a_{N,1}X_1 + a_{N,2} + \ldots + a_{N,k}X_k + \ldots + a_{N,N}X_N = Y_N \end{bmatrix} \tag{5}$$

Equation (5) lies at the heart of the economic impact analysis because it allows us to answer the question: If the demand for the output of industry k changes, by how much would the output of all the other industries change? For example, building a new high-voltage transmission line would increase the demand for concrete and steel, among other goods. How will these changes in demand ripple through a state's economy? And what will be the final changes in output levels in all other industries, as well as the change in total labor (i.e., jobs) and income?

To answer this sort of question, we solve equation (5) for each of the X_i. This requires a bit of matrix algebra. It turns out that the solution can be written as:

$$\mathbf{X} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{Y} \tag{6}$$

where

$$\mathbf{A} = \begin{bmatrix} a_{1,1} \cdots a_{1,N} \\ a_{2,1} \cdots a_{2,N} \\ \vdots \\ a_{k,1} \cdots a_{k,N} \\ \vdots \\ a_{N,1} \cdots a_{N,N} \end{bmatrix}, \qquad \mathbf{X} = \begin{bmatrix} X_1 \\ X_2 \\ \vdots \\ X_k \\ \vdots \\ X_N \end{bmatrix}, \qquad \mathbf{Y} = \begin{bmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_k \\ \vdots \\ Y_N \end{bmatrix}$$

The matrix $(\mathrm{I} - \mathrm{A})^{-1}$ is called the *Leontief inverse*. By changing the level of final demand in the output vector Y and knowing the technical coefficients $a_{i,k}$, we can determine the flows through the economy.

Three types of economic impacts are typically evaluated in an input-output study: *direct*, *indirect*, and *induced*. Direct effects result from an increase in demand for good k. For example, building a new high-voltage transmission line will require concrete for the tower foundations. A rise in demand for concrete is a *direct* impact of construction. Increasing the demand for concrete, however, will require concrete manufacturers to increase their purchases of all the inputs used to manufacture concrete, including sand, gravel, electricity, and so forth, thus increasing the demand for all those inputs. Thus, the *direct* increase in the demand for concrete *indirectly* increases the demand for all these other products. Finally, all these manufacturers pay wages to employees. Those employees, in turn, spend a portion of their wages on food, electricity, new cars, and so forth. As a result, we say that the resulting consumer spending from households *induces* further increases in demand and thus additional economic impacts.

Because of the interconnections among industries and between industries and households, an increased demand for just one good or service is said to cause *ripple effects* throughout the economy. These ripple effects lead to additional jobs and increased disposable income as workers are hired, equipment and supplies are purchased from other local businesses, wages are paid to employees, and taxes are paid to government entities. These impacts are called *multiplier* effects, or *multipliers*. For example, if the demand for concrete increases by $1 million and the overall impact on a state's economy is $2 million, the output multiplier equals $2 million/$1 million = 2.0. We can also calculate jobs and income multipliers. For example, if 100 workers are hired to construct a transmission line and the overall ripple effects result in the creation of 50 new jobs, the employment multiplier will equal 150/100 = 1.5.

2. Estimating Economic Impacts

Ripple effects act like waves bouncing off walls. Eventually, each subsequent round of impacts decreases in magnitude, just as a wave bouncing off walls eventually subsides. The speed at which these ripple effects diminish and the overall magnitude of multipliers depend on what are called *leakages* out of an economy. For example, not all the materials needed to build a transmission line will be purchased from in-state companies. Moreover, some of the workers hired to construct the project may be from outside the state. Furthermore, in-state workers who are hired will not spend all their wages within the state but will buy goods and services from neighboring states, too. As we discuss below, assumptions about *leakage rates*, i.e., what fraction of spending occurs outside the state, are crucial in estimating the overall economic impacts to the state.

Calculating multipliers[87]

Multipliers are calculated from the Leontief inverse matrix defined previously. Suppose we have an economy with just two industries, industry **X** and industry **Y**, with the following technical coefficients matrix:

$$\mathbf{A} = \begin{bmatrix} 0.15 & 0.25 \\ 0.20 & 0.05 \end{bmatrix} \tag{7}$$

What this means is that to produce $1 of additional output, industry **X** purchases $0.15 from itself and $0.20 from industry **Y**. The remaining $0.65 is accounted for through valued-added: wages and salaries paid to employees; taxes paid to federal, state, and local governments; and profits. Similarly, to produce $1 of additional output, industry **Y** purchases $0.25 from industry **X**, $0.05 from itself, and the remaining $0.70 is value-added. It turns out that the Leontief inverse matrix (ignoring the value-added impacts) is:

$$(\mathbf{I} - \mathbf{A})^{-1} = \begin{bmatrix} 1.254 & 0.33 \\ 0.264 & 1.122 \end{bmatrix} \tag{8}$$

The values in the Leontief inverse provide the output multipliers, by adding up each column. Specifically, if there is a $1 increase in final demand for the output of industry **X**, the total increase in demand for output of industry **X** is $1.254—$1 for the increase in final demand and $0.254 for interindustry and intra-industry use. There is also an *indirect* increase in demand of $0.264 of industry **Y** for interindustry and intra-industry use. Thus, if we sum down the first column, a $1 increase in demand for industry **X** leads to a total increase in output of $1.254 + $0.264 = $1.518. The output multiplier for industry **X** is thus $1.518/$1 = 1.518. Because we are not considering households in this example, this output multiplier is called a *Type I* multiplier.

Next, we consider household impacts, such as from wages paid to households. Suppose that industry **X** pays $0.30 in wages per dollar of output and that industry Y pays $0.25 in wages per dollar of output. By incorporating these payments into the technical coefficients matrix, we can determine the direct, indirect, and *induced* impacts from increased output. So we rewrite the technical coefficients matrix as follows:

$$\mathbf{A} = \begin{bmatrix} 0.15 & 0.25 & 0.05 \\ 0.20 & 0.05 & 0.40 \\ 0.30 & 0.25 & 0.05 \end{bmatrix} \quad (\mathbf{I}-\mathbf{A})^{-1} = \begin{bmatrix} 1.365 & 0.425 & 0.251 \\ 0.527 & 1.348 & 0.595 \\ 0.570 & 0.489 & 1.289 \end{bmatrix} \qquad (9)$$

The new technical coefficients matrix A now contains three rows and three columns. The 2x2 matrix of values in the top left-hand corner is the original matrix shown in equation (7). The third column represents households. So in the example, households spend \$0.05 per dollar buying items from industry X, \$0.40 per dollar buying items from industry Y, and \$0.05 buying items from within the household sector (the remainder is spent paying taxes and for investment). The third row shows that industry X spends \$0.30 per dollar on wages, while industry Y spends \$0.25 per dollar on wages.

When we calculate the new Leontief inverse **(I – A)**$^{-1}$, the first thing to notice is that the previous coefficients (the top-left 2x2 matrix) are all larger than they were in equation (8). This is because we are now including household demand impacts. Now, the output multiplier for industry X is the sum of the first column [1.365, 0.527, 0.570], or 2.462. Thus, for every \$1 increase in demand in industry X, total output in the local economy increases by \$2.462. The output multiplier for industry X is therefore 2.4262. In matrix notation, the output multiplier for industry i in our N-industry economy is:

$$M_{output,i} = \mathbf{i}_i \quad (\mathbf{I}-\mathbf{A})^{-1} \quad \mathbf{i}_i' \qquad (10)$$

where $\mathbf{i}_i = [\,0 \ \ldots \ 1_j \ \ldots 0]$.[88]

In our two-industry example, we can calculate the household income multiplier for industry X in several ways. The first is to treat household spending as outside our model and estimate impacts using the Type 1 multipliers. To do that, we go back to the initial Leontief inverse in equation (8) and multiply the household income coefficients in A for our two industries (the third row) by the first column in the Leontief inverse, and add the results, i.e.,

H_x = (0.30) (1.254) + (0.25) (0.264) = 0.442

What this means is that, for every \$1 increase in demand for the output of industry X, total household income increases by \$0.442 because of the direct and indirect economic impacts on output. Thus, the *Type 1 multiplier* is \$0.442/\$0.30 = 1.47.

If we include the economic impact caused by households also spending money in the economy, the result is called a *Type II multiplier*. To do this, we use the new A and **(I – A)**$^{-1}$ matrices shown above. For industry X, we calculate the total household income change, including the within-household sector impacts, and divide by the \$0.30 that industry X pays directly to households in the form of wages. Thus, we have

H'_x = (0.30) (1.365) + (0.25) (0.527) + (0.05) (0.57) = 0.570

and the multiplier is H_x/0.30 = \$0.57/\$0.30 = 1.9. Note that the overall household impact, \$0.57, is just the value in the last row of the Leontief inverse matrix for industry X.

Finally, we estimate *employment multipliers*, following the same approaches previously outlined. But this time, the multipliers do not reflect dollar changes but changes in employment. To do this, we determine the number of employees (in full-time equivalents) per dollar of output in each industry. Suppose that for each million dollars of output produced in industry X, 300 employees are required and that 400 employees are used per million dollars of output in industry Y. This translates to values of 0.003 and 0.004 employees per dollar in industries X and Y, respectively. Similarly, assume that the household sector requires 100 employees per million dollars of output, or 0.001 employees per dollar. Then, using the Leontief inverse matrix in equation (9), we calculate the total employment impact for industry X as

$$E'_x = (0.003)\,(1.365) + (0.004)\,(0.527) + (0.001)\,(0.570) = 0.000572$$

Using the same approach as for calculating the Type II income multipliers, we can calculate the Type II employment multiplier for industry 1 as $E'_x/0.0003 = 1.907$. Thus, for every job added in industry X, a total of 1.907 jobs are added in the entire economy.

3. The IMPLAN Model

IMPLAN was first developed in the 1970s by the U.S. Forest Service to analyze the economic impacts of various forestry policies. The current version of IMPLAN is maintained by the University of Minnesota IMPLAN group. IMPLAN provides a detailed breakdown of the U.S. economy, with more than 500 separate economic sectors. IMPLAN is widely used by numerous government agencies at the federal and state levels.

The IMPLAN model begins with the most current national transactions matrix developed by the National Bureau of Economic Analysis Benchmark Input-Output Model. Next, the model creates state- and county-level values by adjusting the national-level data, such as removing industries that are not present in a particular state or economy. The model also estimates imports using *regional purchase coefficients* (RPCs). RPCs measure the proportion of the total supply of a good or service required to meet a particular industry's intermediate and final demands that is produced locally. The larger the RPC value, the greater the percentage of total regional demand that is met through local supplies.

In addition to calculating standard Type I and Type II multipliers, IMPLAN can calculate "SAM multipliers" (Social Accounts Matrix), a more detailed breakdown of transactions within an economy. The typical input-output framework captures production and consumption but leaves out some income transactions, such as taxes, savings, and transfer payments. IMPLAN allows users to capture these components as well and thus derive SAM multipliers,[89] a form of Type II multiplier. Thus, SAM multipliers incorporate direct, indirect, and induced impacts, while accounting for the effects of savings, taxes, and transfer payments.

4. Estimating the Economic Impacts of Higher Electric Prices

To estimate the overall economic impacts of the higher wholesale electric prices and higher-capacity market costs, we assumed a short-run elasticity of zero, i.e., we assumed that consumers would not initially reduce their electric consumption in response to the slightly higher electric prices they faced. Since consumer income is assumed to be fixed in the short run, this implies that consumers must reduce their expenditures on all other goods and services (including savings and investment) by an equivalent amount.

Similarly, we assumed that instate businesses would react to the increased price of electricity by reducing their total output such that their aggregate production expenses remained unchanged. This assumption is consistent with the assumption of fixed production coefficients in the Leontief model. It also assumes that businesses would not be able to pass on the increased production costs to consumers.

a) Estimating the total impacts on individual state output

With these assumptions, we estimate the overall change in output as follows. First, we calculate a weighted-average *regional purchase coefficient* for output in a state's economy, excluding electric power. An RPC equals the fraction of local demand for a good or service that is satisfied from local production. For example, in New York, about 67 percent of all ready-mix concrete was purchased from in-state manufacturers, based on 2008 data. Thus, the weighted RPC, RPC_W, equals the sales-weighted average of the individual sector RPCs, excluding the electric generation sector (assumed to be sector *k*). Thus,

$$RPC_W = \frac{\sum_{i=1,i\neq k}^{N} Q_i \cdot RPC_i}{\sum_{i=1,i\neq k}^{N} Q_i} \tag{11}$$

Similarly, we calculate the weighted-average state SAM output multiplier, $\bar{M}_{State}^{output}$, using the output from each industry as the individual industry weights. Thus, using equation (10) for the output multiplier for industry *i*, we have:

$$\bar{M}_{State}^{output} = \sum_{i=1,j\neq k}^{N} Q_i \cdot \{\mathbf{i_i} \quad (\mathbf{I}-\mathbf{A})^{-1} \quad \mathbf{i_i}'\} / \Delta Q_{State}^{TOT} = \sum_{i=1,j\neq k}^{N} Q_i \cdot M_{output,i} / \Delta Q_{State}^{TOT} \tag{12}$$

The total impact on output in the state, ΔQ_{State}^{TOT} will equal the weighted RPC times the weighted output multiplier, times the estimated increase in total electric expenditures. Thus, if the total change in electric expenditures is ΔQ_{ELEC}, we have:

$$\Delta Q_{State}^{TOT} = \Delta Q_{ELEC} \cdot RPC_{State} \cdot \bar{M}_{State}^{output} \tag{13}$$

b) Estimating the total impact on state employment

We can follow a similar procedure to estimate the total impacts on state employment arising from the higher electric expenditures, with the additional step of estimating the weighted average employment per million dollars of output, using the employment multipliers calculated by IMPLAN. Thus, the weighted jobs per million dollars of output can be written as:

$$\bar{J}_{State} = \sum_{i=1,i\neq k}^{N} Q_i \cdot J_i / \Delta Q_{State}^{TOT} \tag{14}$$

where J_i is jobs per million dollars of output in industry *i*. Therefore, the overall weighted jobs multiplier is:[90]

$$\bar{M}_{State}^{jobs} = \sum_{i=1,i\neq k}^{N} Q_i \cdot J_i \{\mathbf{i_i} \quad (\mathbf{I}-\mathbf{A})^{-1} \quad \mathbf{i_i}'\} \tag{15}$$

So the total impact on jobs in the state from the increased expenditures on electricity will equal:

$$\Delta J_{State}^{TOT} = (\Delta Q_{ELEC} \cdot RPC_{State}) \cdot (\bar{J}_{State} \cdot \bar{M}_{State}^{jobs}) \tag{16}$$

Endnotes

1. Based on data published by the U.S. Energy Information Administration (EIA), average use per residential customer in the New York metropolitan area in 2010 was about 7,300 kWh.

2. In response to the Fukushima disaster, the U.S. Nuclear Regulatory Commission (NRC) released a new seismic study on January 31, 2012, to help nuclear plant owners assess the ability of their plants to withstand earthquakes. http://www.nrc.gov/reading-rm/doc-collections/news/2012/12-010.pdf.

3. See, e.g., ISE Panel, *Indian Point Independent Safety Evaluation*, July 31, 2008. See also NRC, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Supplement 38, Regarding Indian Point Nuclear Generating Unit Nos. 2 and 3, Final Report, Main Report and Comment Responses*, NUREG-1437, December 2010. See also http://www.nrc.gov/reactors/operating/licensing/renewal/applications/indian-point/ipec_lra_1_2.pdf.

4. See Mireya Navarro, "Pipeline Plan Stirs Debate on Both Sides of Hudson," *New York Times*, October 26, 2011.

5. E.g., a typical electric circuit in a home is rated at 20 amps, which means that it will not trip unless the current flow is greater than that. If a refrigerator draws, at most, 15 amps of power on such a circuit, all will be well. However, if a 10-amp circuit breaker is mistakenly installed on the circuit, the circuit breaker will trip when the refrigerator compressor switches on. In essence, this is the trouble that caused the 1965 blackout.

6. In 2006, NERC became the North American Electric Reliability Corporation.

7. For a discussion, see *Final Report on the August 12, 2003 Blackout in the United States and Canada: Causes and Recommendations, U.S.-Canada Outage Task Force*, April 2004. https://reports.energy.gov/BlackoutFinal-Web.pdf.

8. In 2006, FERC issued a Notice of Proposed Rulemaking (NOPR), accepting many of the reliability standards proposed by NERC. See *Mandatory Reliability Standards for the Bulk-Power System*, Docket No. RM06-16-000. The "bulk" power system refers to the system of generators and high-voltage transmission lines, which deliver electricity to local retail distribution systems that provide electricity to individual customers.

9. See NYISO, "Locational Minimum Installed Requirements Study," January 12, 2012. http://www.nyiso.com/public/webdocs/services/planning/resource_adequacy/LCR_OC_report_final.pdf

10. A recent study by Synapse Energy Economics downplays IPEC's need to maintain reliability because of additional generating capacity in New York City and Long Island. See "Indian Point Energy Center Nuclear Plant Retirement Analysis," October 17, 2011 (hereafter, "2011 Synapse study"). http://www.synapse-energy.com/Downloads/SynapseReport.2011-10.NRDC.Indian-Point-Analysis.11-041.pdf. The report fails to acknowledge generator retirements, such as the New York Power Authority's 926 MW Poletti unit, which was retired on January 31, 2010, as part of an agreement to address environmental concerns. NRG plans to retire its seven Astoria units at the end of 2014. See *NYISO 2011 Load & Capacity Data, Gold Book*, p. 63. http://www.nyiso.com/public/webdocs/services/planning/planning_data_reference_documents/2011_GoldBook_Public_Final.pdf.

11. PlaNYC 2011, p. 117. http://nytelecom.vo.llnwd.net/o15/agencies/planyc2030/pdf/planyc_2011_planyc_full_report.pdf.

12. CRA study, pp. 63–64, table 35. http://www.nyc.gov/html/dep/pdf/energy/final_report_d16322_2011-08-02.pdf.

13. For a discussion of demand-response resources, see Potomac Economics, *2010 State of the Market Report for the New York ISO Markets*, July 2011 (hereafter, "2010 SOTM report"). http://www.potomaceconomics.com/uploads/nyiso_reports/NYISO_2010_Final.pdf.

14. A number of potential legal issues are associated with closing IPEC, involving both state and federal jurisdictional issues and power system reliability. Discussion of these issues is beyond the scope of this report.

15. The 2011 Synapse study misleadingly concludes that, if IPEC is retired, "there is likely to be no need for new capacity to meet reserve margin requirements until 2020 at the earliest" (p. 26). This conclusion is based on a comparison of statewide reserve margins with and without IPEC (see, e.g., Figures 2.3 and 2.4, pp. 10–11, of the 2011 Synapse study). This comparison entirely ignores the transmission constraints into SENY, which is precisely why "doing nothing" is not an option if IPEC is shuttered.

16. NERA Economic Consulting, *Independent Study to Establish Parameters of the ICAP Demand Curve for the New York Independent System Operator*, July 1, 2010. http://www.nyiso.com/public/webdocs/committees/bic_icapwg/meeting_materials/2010-07-16/Demand_Curve_Study_Report_DRAFTV1_07_16_2010.pdf.

17. See http://www.eif.com/newsNeptune070207.html.

18. Natural gas is the primary fuel for most of these plants. However, many burn no. 2 fuel oil as a backup. A few plants, including Poletti, burn no. 6 fuel oil. Because of state and federal environmental regulations limiting particulate emissions, burning oil is severely restricted.

19. For Category 3 generating plants, the cost of capital improvements to comply with environmental standards is much higher than routine maintenance-related annual capital expenditures. See *NYISO 2010 Reliability Needs Assessment*, pp. 44–45.

20. See NYISO, "Steps in the NYISO Large Facility Interconnection Process," rev. 2010. (This process applies to new generating plants larger than 20 MW and all new merchant transmission lines.) http://www.nyiso.com/public/webdocs/services/planning/other_nyiso_interconnection_documents/steps_nyiso_large_facility_interconnection_process.pdf.

21. Because proposed facilities can interact, the additional transmission upgrades needed for a single facility can change, depending on what else is developed. Hence, NYISO examines all facilities proposed for a given year, and determines the upgrades that will be needed for all of them together.

22. See 2009 New York State Energy Plan, pp. 68–69. http://www.nysenergyplan.com/final/New_York_State_Energy_Plan_VolumeI.pdf.

23. Adding thousands of MW of new gas-fired generating capacity will further expose New York electric consumers to greater volatility from natural gas price swings. Although natural gas prices have dropped precipitously because of lower economic growth and the increase in shale gas supplies, New York policymakers have expressed concern about a too-heavy reliance on natural gas–fired generation. E.g., in 2009, NYSEP stated: "Based on the natural gas modeling runs, the natural gas system appeared to be strained with conditions such as: (1) *Indian Point being retired and replaced by a combined cycle natural gas plant*; (2) a significant amount of repowering of downstate dual fuel units that use residual oil as a backup; (3) a much colder than normal winter; and (4) and a combination of the three." (NYSEP, Energy Infrastructure Issue Brief, p. 2; italics added). http://www.nysenergyplan.com/final/Energy_Infrastructure_IB.pdf.

24. U.S. Energy Information Administration, "Natural Gas Pipeline Capacity & Utilization." http://www.eia.doe.gov/pub/oil_gas/natural_gas/analysis_publications/ngpipeline/usage.html and author calculations. Published EIA data reflect pipeline capacity through 2008. We have updated these data to incorporate subsequent pipeline capacity additions—notably, the expansions on the Algonquin and Tennessee systems, as well as the Millennium Pipeline, which commenced operation in late 2008.

25. See http://www.eia.gov/pub/oil_gas/natural_gas/analysis_publications/ngpipeline/northeast.html.

26. For a map of the proposed project, see http://www.spectraenergy.com/content/inline-images/Maps/map_NJ-NY_full.jpg. The project is designed to deliver Marcellus shale gas into New York City and is opposed by environmentalists and several New York City Council members.

27. Millennium replaced an existing 261,000 MMcf/day on the Columbia Pipeline.

28. Includes the Tennessee 300 expansion.

29. NYSEP, Natural Gas Assessment (2009), p. 33. http://www.nysenergyplan.com/final/Natural_Gas_Assessment.pdf.

30. Ibid. The "extreme cold" scenario models natural gas demand based on the weather conditions that prevailed in the winter of 1977–78. Under this scenario, unmet natural gas demand is lower than the "reference" scenario because the NYSEP model assumes that correspondingly high natural gas prices will reduce natural gas demand for electric generation. In light of greater environmental restrictions on burning fuel oil, retirements of coal-fired units in PJM, a Regional Transmission Organization (RTO), due to new EPA regulations governing mercury, and generally lower natural gas prices because of shale gas production, we expect that this assumption will no longer hold. Thus, we expect unmet demand to be greater than projected by NYSEP under an "extreme cold" scenario.

31. Ibid., p. 43.

32. With or without Indian Point, capacity will not be enough to meet demand. It is important to distinguish natural gas supply from natural gas capacity. While the natural gas may be there, pipelines need to be able to handle the increased volume of natural gas.

33. See NYSEP, Natural Gas Assessment (2009), p. 43. http://www.nysenergyplan.com/final/Natural_Gas_Assessment.pdf.

34. 49 C.F.R. § 192.903 provides the definition of a "high consequence area."

35. E.g., there is significant opposition to Spectra Energy's proposed NJ-NY expansion, which would be built under the Hudson River. There have been previous attempts to site pipelines under the Hudson; but because of environmental opposition, none has succeeded.

36. Combined-cycle generating units typically have heat rates (i.e., the number of Btus of energy input required to produce one kWh of electricity) of 7,000–8,000 Btus/kWh. (The actual operating efficiency depends on numerous factors, including outside air temperature and whether the plants are operating continuously or cycling on and off.) Assuming 7,000 Btus/kWh, 2,000 MW would require (2,000 MW) x (1,000 kW/MW) x (24 hours) x (7,000 Btus/kWh) = 336 billion Btus/day. Because one cubic foot of natural gas is approximately 1,030 Btus, that translates into about 330 MMCF per day.

37. Another issue that has arisen on very cold days, when the demand for natural gas is highest, is lack of sufficient pressure to operate gas-fired generators. Because so much gas is diverted for direct usage—such as for residential customers—that pipeline pressure drops below the level that the generators can operate.

38. ICF International, *Natural Gas Pipeline and Storage Infrastructure Projections Through 2030*, Report prepared for INGAA Foundation, October 20, 2009 (ICF 2009). http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=3&ved=0CDMQFjAC&url=http%3A%2F%2Fwww.ingaa.org%2FFile.aspx%3Fid%3D10509&ei=DJBCT5rrBuqkiQLbk-DxDg&usg=AFQjCNE0Fak_mTvwQHZb1Co-SvpOy-gfLg&sig2=EkeIOrFCkVKcJc3wQfLQ8g.

39. Ibid., p. 49. E.g., at $60,000 per inch-mile, a 30-inch pipeline would have a construction cost of $1.8 million per mile. In 2008, average costs were $100,000 per inch-mile, owing to the high cost of steel.

40. According to the U.S. Energy Information Administration, the average compressor motor was just over 14,000 horsepower (hp). At an average cost of $1,800 per hp (based on the ICF 2009 report for the Northeast), that implies

a cost of $25 million for a compressor. Typically, compressors are needed every 40–100 miles along a pipeline, depending on the pipeline pressure.

41. The author of this report testified on behalf of NYRI in a proceeding before the New York State Department of Public Service. A copy of that testimony can be found at http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId={5EDB6D60-3CD7-4F6E-9504-E706A6B3D07A}.

42. New York Department of Public Service, *In the Matter of New York Regional Interconnect, Inc.*, Case No. 06-T-0650. "New York Regional Interconnect: An Impact Analysis," Charles River Associates, December 6, 2008. http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId={63EA9E7A-22AE-4597-ACF6-5D583A108DC8}.

43. The other major projects are the Long Island Cable, which was originally scheduled to be energized in 2013 but now shows an in-service date of 2016. Moreover, LI Cable is listed as a wind project because it is designed to bring power from a proposed offshore wind development. Although a feasibility study for that project has been completed, none of the other required NYISO studies has been. Additionally, the Poseidon Transmission project is listed in the NYISO queue as having a scheduled in-service date of 2016. However, none of the required studies for that project has been completed.

44. Because the project is a DC line, wind resources located in upstate New York CHPE would not be able to interconnect to it, unless they were interconnected through the line's origination at the Quebec–New York border. CHPE is opposed by the Sierra Club, which regards the project as "greenwashing" and one that will undermine the renewable energy market in New York. http://newyork.sierraclub.org/SA/Vol40/CHPE_greenwashed.htm.

45. NYPSC, Proceeding on Motion of the Commission Regarding a Retail Renewable Portfolio Standard, Case 03-E-0188, order, September 24, 2004. http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId={B1830060-A43F-426D-8948-F60E6B754734}. In an order issued on January 8, 2010, the NYPSC revised its 2004 renewable portfolio standard (RPS) energy goals to 30 percent by 2015, or about 10.4 million MWh. See *Order Establishing New RPS Goal and Resolving Main Tier Issues*, January 8, 2010. http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId={30CFE590-E7E1-473B-A648-450A39E80F48}.

46. Integrating large amounts of new wind generation into the NYISO transmission system poses a number of operational challenges to ensure system reliability. For a discussion, see NYISO, "Integration of Wind into System Dispatch," white paper, October 2008. http://www.nyiso.com/public/webdocs/documents/white_papers/wind_management_whitepaper_11202008.pdf. See also New York State Energy Resource Development Agency, "The Effects of Integrating Wind Power on Transmission System Planning, Reliability, and Operations," March 4, 2005. www.uwig.org/nyserdaphase2.pdf.

47. 660 MW of this is the aforementioned LI Cable project, which is designed to connect offshore wind. The specific offshore wind project—a joint venture between the New York Power Authority, ConEd, and Long Island Power Authority—was in NYISO's queue but was withdrawn in 2011, citing an inability to meet milestones.

48. Several years ago, NYPA considered reconfiguring its Marcy South transmission line into a DC circuit. However, that project has never appeared in the NYISO queue.

49. See, e.g., S. Bolton, "Do Offshore Wind Farms Need a New Maintenance Model?," *Renewable Energy World* (November 28, 2011). http://www.renewableenergyworld.com/rea/news/article/2011/11/do-offshore-wind-farms-need-a-new-maintenance-model?page=1.

50. See 2011 Synapse study, p. 19. A full analysis of Assembly Bill 5713-C is beyond the scope of this report. The Synapse study states that this bill would lead to the development of 2,500 MW of solar resources in the SENY region because SENY accounts for 50 percent of total New York State retail electric loads. This is simply incorrect because AB 5713-C would not require solar generation to be procured by each retail utility from local sources.

51. 2010 SOTM report, pp. 167–68.

52. The U.S. Commerce Department has recently imposed countervailing duties on the import of photovoltaic cells from China, ranging from 2.9 percent to 4.73 percent, depending on the producer. The implication is that this would increase domestic (U.S.) cost of PV generation. See "Commerce Department Imposes Tariffs on Chinese Photovoltaic Cells," Ballard Spahr, March 20, 2012. http://www.ballardspahr.com/alertspublications/legalalerts/2012-03-20_commerce_department_imposes_tariffs_on_chinese_photovoltaic_cells.aspx.

53. See "$17.2M Solar Farm Constructed at the Village at Manalapan," *Manalapan Patch*, February 14, 2012. http://manalapan.patch.com/articles/17-2m-solar-farm-constructed-at-the-village-at-manalapan.

54. For a detailed explanation of UCAP calculations, see NYISO, *Installed Capacity Manual*, version 6.20, January 24, 2012. http://www.nyiso.com/public/webdocs/products/icap/icap_manual/icap_mnl.pdf.

55. UCAP for solar energy is based on the angle at which the panels are situated. Ibid., pp. 4-17–4-21. The maximum summer UCAP is 43 percent of ICAP. Maximum winter UCAP is 2 percent of ICAP.

56. See 2011 Synapse study, pp. 13–16.

57. See NYISO's summary of DR programs. http://www.nyiso.com/public/markets_operations/market_data/demand_response/index.jsp.

58. 2010 SOTM report, pp. 167–75. Unlike ICAP/SCR DR resources, EDRP resources are not required to curtail loads if called on by NYISO.

59. NYISO, *Supplement and Errata to Annual Report in Docket No. ER01-3001-000*, January 25, 2011, attachment III, p. 8. http://elibrary.ferc.gov/idmws/common/opennat.asp?fileID=12545228.

60. NYISO, *Errata to Annual Report in Docket No. ER01-3001-000*, January 25, 2012, attachment II, p. 7. http://elibrary.ferc.gov/idmws/common/opennat.asp?fileID=12875394.

61. These are resources acquired under the Targeted Demand Response Program (TDRP) and the Day-Ahead Demand Response Program (DADRP).

62. NYPSC, *Proceeding on Motion of the Commission Regarding an Energy Efficiency Portfolio Standard*, Case 07-M-0548, order, June 23, 2008.

63. Ibid., appendix 1, p. 5, table A-5. The savings figures are based on the "Jurisdictional Gap," i.e., electric utility programs that the NYPSC can oversee. Other programs, such as national appliance efficiency standards, are not controlled by the NYPSC.

64. Small portions of the SENY region are also served by Orange and Rockland, Central Hudson, and New York State Electric & Gas.

65. NYDPS, "Energy Efficiency Portfolio Standard Program Review White Paper," July 6, 2011. Corrected Table 2 (Staff Responses to O&R and Con Edison Corrections to EEPS White Paper Appendix Tables—July 13, 2011, table 2, p. 2). Includes all savings from ConEd, Orange and Rockland, Central Hudson, and New York State Electric & Gas. http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=BDD432F1-2C88-4375-A18D-A2047CCCAFF4.

66. This is one advantage that solar PV has over wind generation, as there is usually little wind on the hottest summer days.

67. See *2011 NYISO Gold Book*, p. 18, table I-3a: Econometric Forecast of Annual Energy & Peak Demand.

68. Ibid., p. 17, table I-2f: Energy Efficiency Savings.

69. The 2011 Synapse study (pp. 13–14) asserts that the state can reduce electric consumption by 1.5 percent per year. However, Synapse states that its estimate is based on a review of studies of energy-efficiency potential, not actual savings achieved. Moreover, Synapse focuses on statewide savings, not the SENY savings required to replace IPEC.

70. For a detailed description of the production simulation approach, see CRA study, pp. 31–36.

71. CRA study, p. 24, tables 2–3. Costs for NYC are also included in the total cost to NYS.

72. As discussed in the CRA study (p. 23, table 1), another option would involve only one 500 MW combined-cycle unit. However, this would result in violation failure to meet reliability standards in 2020.

73. CRA estimated that the subsidies needed would total nearly $700 million for the two-unit proposal and over $2 billion for the HVDC and offshore wind proposal. See CRA study, p. 26, table 6.

74. For a brief discussion of nuclear plant decommissioning, see Nuclear Regulatory Commission, "Fact Sheet on Decommissioning Nuclear Power Plants." http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/decommissioning.html.

75. Nuclear Energy Institute, *Economic Benefits of Indian Point Energy Center: An Economic Impact Study by the Nuclear Energy Institute*, April 1, 2004 (hereafter, "NEI study"). http://www.nei.org/filefolder/economic_benefits_indian_point.pdf.

76. U.S. EIA, State Energy Data System, table E9, 2009. http://www.eia.gov/state/seds/hf.jsp?incfile=sep_sum/html/sum_ex_tx.html.

77. *In Re: Review of New Shoreham Project Pursuant to R.I. Gen Laws § 39-26.1-7*, Docket No. 4111, report and order, April 2, 2010, p. 82. Subsequent to rejecting the proposed contract, the Rhode Island legislature passed a law that, in essence, mandated the Rhode Island Public Utilities Commission (PUC) to approve the contract.

78. The Appendix contains a mathematical introduction to I/O models.

79. E.g., the NEI study used an I/O framework to estimate the economic impacts stemming from annual operation of IPEC.

80. Nobel Prize–winning economist Wassily Leontief is generally considered to be the father of input-output analysis. For an introduction to I/O modeling, see his treatise *Input-Output Economics*, 2nd ed. (New York: Oxford University Press, 1986).

81. IMPLAN was first developed in the late 1970s by the U.S. Forest Service to analyze the economic impacts of various forestry policies. The current version of IMPLAN is maintained by MIG Inc., formerly known as the Minnesota IMPLAN Group.

82. A detailed description of the analytical methodology is provided in the Appendix.

83. I/O models estimate lost jobs in terms of "job-years." One job-year is one full-time equivalent for one year.

84. It is possible to change what are called the "production coefficients" in IMPLAN. However, doing so requires an analysis of how those coefficients should change, which requires complex econometric models of so-called production functions (i.e., the mix of resources used to produce a good or service). This type of modeling is far beyond the scope of this report.

85. Economists call this the “price elasticity” of electricity. Many studies have estimated price elasticity and found that electricity is “price inelastic,” i.e., a percentage change in the price of electricity leads to a smaller percentage change in consumption. See, e.g., L. Taylor, “The Demand for Electricity: A Survey,” *Bell Journal of Economics* 6, no. 1 (spring 1975): 74–110.

86. For a more detailed discussion, see Leontief, *Input-Output Economics*. See also R. Miller and P. Blair, *Input-Output Analysis: Foundations and Extensions* (Englewood Cliffs, N.J.: Prentice-Hall, 1985), chap. 2.

87. For a much more detailed discussion, see Miller and Blair, *Input-Output Analysis*, chap. 2, n. 1, from which these examples are drawn.

88. I.e., i_j is a 1xN unit vector having value 1 for industry j. The term i_j is called the *transpose* of i_i and is a Nx1 column vector.

89. For a complete discussion of how SAM multipliers are derived, see G. S. Alward and S. Lindall, “Deriving SAM Multipliers Using IMPLAN,” paper presented at the 1996 National IMPLAN Users Conference, Minneapolis, August 15–17, 1996. http://implan.com/v3/index.php?option=com_docman&task=doc_download&Itemid=138&gid=127.

90. The jobs multiplier is just the output multiplier weighted by jobs per million dollars of output.

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