

**QUANTIFYING THE ENVIRONMENTAL AND  
ECONOMIC BENEFITS OF INCREASED  
DEPLOYMENT OF COMBINED HEAT AND  
POWER TECHNOLOGIES IN NEW YORK  
STATE AND THE IMPACTS OF  
VARIOUS REGULATORY SCENARIOS**

**FINAL REPORT 09-03  
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**NEW YORK STATE  
ENERGY RESEARCH AND  
DEVELOPMENT AUTHORITY**





**NYSERDA**

**New York State Energy Research  
and Development Authority**

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NYSERDA works with businesses, schools, and municipalities to identify existing technologies and equipment to reduce their energy costs. Its responsibilities include:

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Final Report

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**NEW YORK STATE  
ENERGY RESEARCH AND  
DEVELOPMENT AUTHORITY**  
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## ABSTRACT

Small-scale generation facilities such as distributed generation (“DG”) systems operating in combined heat and power (“CHP”) applications may provide benefits to all energy customers throughout New York State (“NYS”). However, full realization of these benefits may require changes to environmental regulations that encourage increased CHP development. CHP resources are an efficient use of otherwise wasted energy, and new CHP resources are more efficient (and more likely be fueled by natural gas) than their older counterparts. Benefits include reductions in energy market prices and congestion costs as well as reduced environmental emissions. Specifically, this report explores how CHP facilities may affect the hourly dispatch of energy resources, change the clearing price of the wholesale energy market, and reduce the emissions of nitrogen oxide (“NO<sub>x</sub>”), sulfur dioxide (“SO<sub>2</sub>”), and carbon dioxide (“CO<sub>2</sub>”) for NYS and other electric markets within the eastern United States. Three specific scenarios, each with different levels of CHP emission regulations, were simulated and analyzed.

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## SUMMARY

The deployment of small-scale generation facilities such as distributed generation (“DG”) systems operating in combined heat and power (“CHP”) applications throughout New York State (“NYS”) may provide significant benefits to the energy industry, transmission grid, electric customers, and the public. However, these benefits may not be fully realized without changes to environmental regulations that encourage the development of CHP resources. The purpose of this report is to quantify the benefits of CHP usage over several environmental regulatory scenarios on wholesale energy prices, transmission congestion costs, and environmental emissions.

Three specific scenarios were developed and analyzed, each with different emission reductions regulations that directly affect CHP resources. There is a Base Case and two alternative CHP scenarios - each assumes changes to air emission regulations that encourage the replacement of older, less efficient and less environmentally beneficial resources with new, more efficient resources fueled with natural gas that have desirable emission characteristics. There is also a Reference Case to establish a baseline of the energy market prior to the introduction of CHP resources. These cases are summarized as follows:

- A Reference Case without the addition of CHP;
- A Base Case scenario that incorporates a supportive institutional environment for CHP, and a nitrogen oxide (“NO<sub>x</sub>”) emissions limit for CHP systems of 1.6 lb/MWh (Scenario 1);
- A second scenario that maintains the supportive institutional environment and lowers the NO<sub>x</sub> emissions limit for CHP systems to 1.0 lb/MWh by 2012 and 0.6 lb/MWh by 2020 (Scenario 2); and
- A third scenario that maintains the supportive institutional environment, incorporates the 1.0 lb/MWh by 2012 and 0.6 lb/MWh by 2020 NO<sub>x</sub> limits, but also includes a CHP thermal credit based on displacing on-site boiler fuel with assumed NO<sub>x</sub> emissions rates of 0.2 lb/MMBtu (Scenario 3).

The report provides a forecast of the penetration of various technology types of CHP in each of the New York Independent System Operator (“NYISO”) load zones. The forecast was prepared based on a portfolio of resources selected using a market diffusion model. The diffusion model includes delivered electric and natural gas prices, technology capital costs, and other factors related to the geographical area.

For each of the three scenarios, there was a comparison of wholesale energy prices, transmission congestion costs, and air emissions for NO<sub>x</sub>, sulfur dioxide (“SO<sub>2</sub>”), and carbon dioxide (“CO<sub>2</sub>”). New York State was analyzed in detail, considering each of the load zones within the bulk electric market. In addition, the New York State wholesale energy market and other, interconnected wholesale markets contained within the North American Electric Reliability Council (“NERC”) Eastern Interconnection were

reviewed. Results show multiple benefits from additional CHP utilization through regulatory incentives. A significant conclusion resulting from this study is that increased amounts of CHP would both reduce energy prices and have a positive impact on environmental considerations.

# 1 Introduction

## 1.1 Purpose of Study

The New York State Research and Development Authority (“NYSERDA”) commissioned this comprehensive assessment of the New York wholesale electric market to analyze and quantify how the widespread use of distributed generation (“DG”) systems operating in combined heat and power (“CHP”) applications throughout New York State (“NYS”) would affect emissions of criteria air pollutants and wholesale electricity market prices. The increased development of CHP systems could positively affect the New York energy infrastructure because they make use of heat that is normally a wasted byproduct of power generation to supply the heating and or cooling needs of an industrial process or commercial building. According to the October 2002 NYSERDA report, “Combined Heat and Power Market Potential for New York State,” CHP can reach overall efficiencies of 70% to 80%. The total efficiency of separate generation of heat and power is typically only 40 to 50%. There is no question that a CHP system, when measured in terms of total energy use, is more efficient than an equivalent power generating plant plus an onsite boiler or chiller.

New questions now emerge:

- What effects will the widespread use of CHP systems have on the New York electric system?
- Could the widespread deployment of CHP throughout New York introduce enough system-wide efficiencies that other dirtier (but lower cost) forms of generation, such as coal, are displaced?
- If that happens, what are the attendant environmental benefits and economic consequences?
- To what extent could imports of coal-generated electricity from western Pennsylvania and the Midwest also be reduced?
- What are the environmental and economic consequences if more efficient CHP resources merely displace resources that are only marginally less efficient but essentially equivalent in terms of environmental attributes, such as combined cycle natural gas plants?
- What impact would the environmental regulations have on the development of CHP and what market impact would CHP have?

These are some of the issues that NYSERDA sought to have explored through this assessment.

The objective of this analysis was to introduce varying amounts of CHP resources and model the impacts on the environment, electric market prices, and congestion costs in NYS and the individual zones that comprise the New York Independent System Operator (“NYISO”). A Reference Case was established as a baseline prior to the introduction of CHP resources; a Base Case and two additional scenarios were also created. The project team analyzed emissions for three pollutants: nitrogen oxide (“NOx”), sulfur dioxide

("SO<sub>2</sub>"), and carbon dioxide ("CO<sub>2</sub>"). Economic impacts on the electricity market were gauged by measuring the differences in wholesale market electricity prices.

## **1.2 Definition of Scenarios**

The 2002 NYSERDA study performed by Energy Nexus Group (now Energy and Environmental Analysis, Inc.) and Pace Energy Project reviewed the technical potential for CHP in New York State. The central questions were how much CHP could economically be installed over the next decade, what benefits would the installation of that CHP yield, and what actions could policymakers take to promote CHP growth. The technical market potential, it estimated, was constrained only by technological limits, or the ability of then-existing CHP systems to fit customer applications. Results showed that, in addition to an existing base of approximately 5,000 MW of CHP, there was a technical market potential for nearly 8,500 MW of CHP spread over approximately 26,000 sites. The study evaluated various CHP technologies, classified them according to application (industrial/commercial), and grouped them by size. It then considered the economics of each size range and assessed the impediments to greater market penetration in each size range and application. The study provided three major conclusions: 1) standby charges in utility service areas had a major impact on the competitiveness of CHP; 2) technology improvements increased CHP competitiveness in all size categories; and 3) in the absence of standby charges, CHP would be cost competitive in all size ranges, both upstate and downstate.

Using the 2002 study as a starting point, the current effort developed a new projection of CHP penetration, adding several updates. First, the technical potential was revised, including applications for CHP where the primary thermal output is cooling. Second, the standby rate tariffs were included in the economic analyses, with relevant exemptions that were approved by the New York State Public Service Commission ("NYPSC"). These standby rates essentially removed a penalty for CHP units that were built into utility rates. Third, natural gas prices were updated based on the latest US DOE and EIA short and long-term forecasts. The previous study relied on a 2002 natural gas price forecast; this study was updated to a 2006 natural gas price forecast as used by the Regional Greenhouse Gas Initiative ("RGGI") in its base case modeling. Finally, natural gas utilities have been directed to implement special delivery rates for non-residential customers who own and operate DG/CHP. These rates were also incorporated into this study.

These updates combined formed a positive regulatory environment for CHP. Scenario 1, the Base Case, was built on this supportive economic environment. Assumptions included initial emission rate limits for DG/CHP that remained constant through 2020 (the analysis period), based on early indications of intent by NYSDEC. The NO<sub>x</sub> limits in this scenario were 1.6 lb/MWh.

Scenario 2 include a more aggressive "environmental forcing" strategy. The favorable economic conditions of the base case scenario were retained, but DG/CHP emission rate limits were reduced every five years in discrete steps. The discrete steps aligned with periodic technology reviews, but did constrain

the use of certain CHP technologies, particularly in the near-term time frame of the analysis period. Specific assumptions regarding the technological advancement/improvements that were included in this scenario can be found in Section 2 of this report. NO<sub>x</sub> limits in this scenario were 1.0 lb/MWh by 2012 and 0.6 lb/MWh by 2020.

Scenario 3 included the phased in approach to more stringent emissions limits from Scenario 2, but has an added CHP thermal credit based on displacing on-site boiler emissions. This scenario also has NO<sub>x</sub> emission rate limits of 1.0 lb/MWh by 2012 and 0.6 lb/MWh by 2020.

In addition to these three scenarios, a Reference Case was modeled to establish a baseline without the introduction of CHP in order to draw further comparisons and gauge the total magnitude of the CHP impact.

### **1.3 Analytical Methods Applied**

The analysis of CHP impacts in NYS began with the development of cost and performance profiles of CHP technologies. This assessment is explained in detail in Section 2, but the technologies considered included fuel cells, reciprocating engines, microturbines, gas turbines, and back-pressure steam turbines. The cost and performance projections that were developed also included expected technology advancements related to equipment costs and emissions profiles. Emissions performance included carbon monoxide, particulate matter, volatile organic compounds, nitrogen oxides, mercury, sulfur oxides, and carbon dioxide.

Similar to the 2002 CHP study, the second step in the analysis was to develop market penetration rates for each scenario. The assessment of market penetration included factors such as the base level of CHP penetration in each particular application, the maximum achievable growth rate in each application, the economic benefit to customers (considering fuel prices and retail electric rates), and the size of the remaining market. It is not possible to achieve 100% installation due to site restrictions, customer risk preferences, and other factors that inhibit CHP adoption. Accordingly, penetration of CHP in NYS followed an “S” shape curve pattern, where penetration rates slow as the penetration levels reach the technical potential levels for CHP. Finally, as the technology and costs were changed to reflect the assumptions of the different scenarios, the relative economics among the technologies also changed. This yielded different mixes of costs, sizes, and deployed CHP technologies across the different scenarios.

Next, computer simulations of the New York electric system were completed. CHP plants were added to the New York electric system in each scenario, and the economic dispatch of the system was then simulated on an hourly basis (similar to how the system is actually operated by the NYISO). CHP plants were essentially “forced” into the system according to the penetration analysis done in the earlier stages, creating the effect of reduced load, which, in turn, affected the dispatch of the other plants in the system. The CHP were added according to the type of technology, size of plant, and with the environmental and cost characteristics specified by the penetration analysis. When the CHP were modeled together with the

other electric supply resources in New York, it was possible to calculate its impact by comparing the scenarios. The impact of the CHP was measured as the difference in the emissions generated by the generating resources as a whole, and the difference in the electric market prices compared to the Reference Case. This deterministic analysis was designed to measure the impact of various levels of CHP penetration on several key energy market attributes, such as changes to prices, congestion costs, and environmental emissions.

The electric system modeling encompassed the entire Eastern Interconnection, which includes a geographic area covering roughly the central and eastern portions of the U.S., and Canada from the foot of the Rockies to the Atlantic Ocean (excluding most of Texas). The simulation was performed in five-year increments, consistent with the timing of technological reassessments. Intermediate years were estimated through interpolation. The simulation of the electric system allowed us to capture the changes in fuel consumed, electric wholesale market prices, pollutant emissions, and generation by various central station and technology types. The results were assessed by season, consistent with the NO<sub>x</sub> ozone periods, and broken down by each zone in New York.

## **1.4 Organization of Report**

This report is organized into seven sections, beginning with this introduction. Estimates of the technical potential of CHP for New York are developed in Section 2. Section 3 characterizes the amount of CHP that can economically enter the New York market under each of the three scenarios. Section 4 lays out the market modeling approach and describes the simulation model and post processing of the results. Section 5 describes the assumptions used in the modeling that are common to all three scenarios, and Section 6 presents the results of the market modeling. Finally, Section 7 presents the study conclusions. Following the conclusion are the appendices containing major study assumptions.

## 2 CHP Technical Potential Estimate

### 2.1 Project objectives

The overall project objectives were to analyze the air emissions and electric market impacts that could result from an increase in CHP units in New York State. This section of the report summarizes the CHP market potential analyses – an assessment of CHP market penetration under a Reference Case and three market/regulatory scenario – and the update of the CHP technical market potential estimate. The market penetration scenarios were defined with input from NYSERDA staff and a stakeholder advisory board as follows:

- A Reference Case without the introduction of CHP;
- A Base Case scenario that incorporated a supportive institutional environment for CHP, and a NO<sub>x</sub> emissions limit for CHP systems of 1.6 lb/MWh;
- A second scenario that lowered the NO<sub>x</sub> emissions limit for CHP systems to 1.0 lb/MWh by 2012 and 0.6 lb/MWh by 2020; and
- A third scenario that incorporated the 1.0 lb/MWh by 2012 and 0.6 lb/MWh by 2020 NO<sub>x</sub> limits, but also included a CHP thermal credit based on displacing onsite boiler fuel with assumed emissions rates of 0.2 lb/MMBtu.

The market penetration results were used as input into an electricity production simulation model to evaluate the air emissions impacts associated with each scenario. This analysis provided insight into the dynamic relationship between emissions regulatory control and CHP penetration. It also provided NYSERDA with a reliable quantification of the potential environmental impacts, as well as system/market benefits, of increased CHP deployment.

The first scenario, aka the Base Case, was designed to examine *the expected market penetration of CHP technologies, and resulting system effects (e.g., air emissions impacts, wholesale market price effects) under a regulatory and market climate that is favorable to clean onsite generation*. This scenario offered an update of the 2002 New York State CHP Market Assessment prepared jointly by Energy Nexus (now Energy and Environmental Analysis, Inc.) and the Pace Energy Project for NYSERDA. Additionally, it incorporated an early DEC proposal for NO<sub>x</sub> emissions standards for small distributed generation sources.

The second scenario was designed to simulate the impacts of *reducing the DG/CHP emissions rate limit pursuant to a technology review requirement*. Emissions limits were “technology forcing” in nature; i.e., regulatory limits were expressly intended to drive prime mover and after-treatment technology to higher standards of performance. However, more optimistic economic regulatory and market conditions were retained to isolate the market penetration (overall, and technology market share), environmental and electricity system effects of stricter environmental standards.

The third scenario was intended to examine *DG emissions regulatory regimes that included a CHP thermal credit for displaced boiler emissions*. The purpose of this scenario was to determine whether a thermal credit enables DG technologies that would have otherwise been out of compliance to retain market share when operated in a combined heat and power mode, as well as to assess the concomitant environmental and market impacts. In this scenario, we held constant both the optimistic economic regulatory and market conditions from Scenario 1 and the more stringent emissions conditions from Scenario 2.

## **2.2 Summary of the Market Penetration Analysis**

The technical approach used for the market penetration estimates was based on the approach used by EEA and Pace Energy Project in the original 2002 CHP market assessment study.<sup>1</sup> However, the underlying data used in this approach was updated and several enhancements to the approach were incorporated. There are four basic components to the analytical framework used to estimate CHP market penetration:

1. Technical Market Potential – The output of this analysis was an estimate of the technically suitable CHP applications by size and by application. This estimate was derived from the screening of market databases based on application and size characteristics that are used to estimate groups of facilities with appropriate electric and thermal load characteristics.
2. Energy Price Projection – Present and future fuel prices were estimated to provide inputs into the CHP net power cost calculation.
3. Technology Characterization – For each size range, a set of applicable CHP technologies was selected for evaluation. These technologies were characterized in terms of their capital cost, heat rate, non-fuel operating and maintenance costs, emissions and available thermal energy for process use onsite.
4. Market Penetration – Within each market size, the competition among applicable technologies was evaluated. Based on this competition, the economic market potential was estimated and shared among competing CHP technologies. The rate of market penetration by technology was then estimated using a market diffusion model.

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<sup>1</sup> *Combined Heat and Power Market Potential for New York State*, Energy Nexus Group (now EEA, Inc.) and Pace Energy Project, NYSERDA, October 2002.

This section of the report summarizes the estimates of technical potential and market penetration for each of the scenarios. Detailed explanations of the methodologies and assumptions are presented in the appendices.

### **2.2.1 Technical Market Potential**

The purpose of the initial market characterization was to identify the number and size of facilities in New York State that provide the physical operating characteristics that are most likely to support an economic CHP system. These target applications, called technical market potential, provided the input to the economic competition and market penetration models that follow. The technical market potential defined for the previous study was used as the starting point for this analysis. The original estimates for technical potential were reviewed and updated to reflect current conditions, and viable CHP targets were increased to include applications incorporating cooling as a thermal output.

To effectively utilize CHP, a commercial building or industrial facility must have at least a portion of its electric and thermal load that coincides with the ratios of thermal to electric energy available from CHP systems. For best economic performance, this coincident thermal and electric load should be fairly steady for as many hours per year as possible. A continuous process industry with a nearly constant steam demand and electric load is an excellent target - a hospital with steady electric and hot water demands is a good example. Facilities with intermittent electric and thermal loads are progressively less attractive as the number of hours of coincident load diminishes.

Two market categories were considered in developing the technical potential:

- High load factor applications – This market provides for continuous or nearly continuous operation. It includes all industrial applications and round-the-clock commercial/institutional operations such as colleges, hospitals, hotels, and prisons; and
- Low load factor applications – Some commercial and institutional markets provide an opportunity for coincident electric/thermal loads for a period of 3,500 to 5,000 hours per year. This sector includes applications such as office buildings, schools, and laundries.

The technical market potential in these categories was calculated for existing commercial and industrial facilities in New York (Table 1) and for new facilities expected from market sector growth during the forecast period (Table 2) based on the sector growth rates contained in Appendix A. As shown, the total technical market potential for CHP in New York equals almost 14,300 MW at existing commercial and industrial facilities, and an additional 5,700 MW from expected new facilities during the forecast period. The tables provide a breakdown of the technical potential in high load (>7000 hours per year) and low load (<5000 hours per year) applications, and a geographical breakdown between upstate and downstate.

**Table 1. CHP Technical Potential in Existing Commercial and Industrial Facilities**

High Load Applications (&gt;7000 hours/year)

| Region      | 50-500 kW | 0.5-1 MW | 1-5 MW | 5-20 MW | >20 MW | Total MW |
|-------------|-----------|----------|--------|---------|--------|----------|
| Downstate   | 470       | 871      | 2,082  | 1,027   | 1,073  | 5,523    |
| Upstate     | 246       | 589      | 1,368  | 1,124   | 819    | 4,146    |
| State Total | 717       | 1,460    | 3,450  | 2,152   | 1,891  | 9,669    |

Low Load Applications (4000 to 5000 hours/year)

| Region      | 50-500 kW | 0.5-1 MW | 1-5 MW | 5-20 MW | >20 MW | Total MW |
|-------------|-----------|----------|--------|---------|--------|----------|
| Downstate   | 739       | 930      | 1,208  | 16      | 0      | 2,893    |
| Upstate     | 484       | 549      | 683    | 9       | 0      | 1,726    |
| State Total | 1,224     | 1,479    | 1,891  | 25      | 0      | 4,618    |

All Applications

| Region      | 50-500 kW | 0.5-1 MW | 1-5 MW | 5-20 MW | >20 MW | Total MW |
|-------------|-----------|----------|--------|---------|--------|----------|
| Downstate   | 1,210     | 1,802    | 3,289  | 1,043   | 1,073  | 8,416    |
| Upstate     | 730       | 1,137    | 2,051  | 1,134   | 819    | 5,871    |
| State Total | 1,940     | 2,939    | 5,340  | 2,177   | 1,891  | 14,287   |

**Table 2. CHP Technical Potential in New Commercial and Industrial Facilities**

High Load Applications (&gt;7000 hours/year)

| Region      | 50-500 kW | 0.5-1 MW | 1-5 MW | 5-20 MW | >20 MW | Total MW |
|-------------|-----------|----------|--------|---------|--------|----------|
| Downstate   | 68        | 217      | 817    | 310     | 438    | 1,849    |
| Upstate     | 71        | 230      | 484    | 279     | 200    | 1,263    |
| State Total | 139       | 447      | 1,300  | 588     | 638    | 3,112    |

Low Load Applications (4000 to 5000 hours/year)

| Region      | 50-500 kW | 0.5-1 MW | 1-5 MW | 5-20 MW | >20 MW | Total MW |
|-------------|-----------|----------|--------|---------|--------|----------|
| Downstate   | 410       | 458      | 723    | 3       | 0      | 1,594    |
| Upstate     | 253       | 310      | 419    | 0       | 0      | 982      |
| State Total | 663       | 768      | 1,143  | 3       | 0      | 2,576    |

All Applications

| Region      | 50-500 kW | 0.5-1 MW | 1-5 MW | 5-20 MW | >20 MW | Total MW |
|-------------|-----------|----------|--------|---------|--------|----------|
| Downstate   | 478       | 675      | 1,540  | 313     | 438    | 3,443    |
| Upstate     | 323       | 540      | 903    | 279     | 200    | 2,245    |
| State Total | 801       | 1,215    | 2,443  | 591     | 638    | 5,688    |

*It is important to point out that technical potential is not in any sense a market forecast for CHP under current or any reasonable set of assumptions.* The technical market potential is intended to represent the universe of potential applications upon which the economic screening and market penetration analysis is conducted. These markets represent the primary sales targets for CHP developers. However, if a developer were to approach one of these target facilities, any number of reasons might stand in the way of a CHP system ever being installed, such as:

- Actual facility electric and thermal loads might vary from the typical industry or application profile;
- The economics might not work out due to site-specific costs or the customer's investment criteria might be highly restrictive;
- There might be site limitations such as lack of fuel availability or environmental restrictions; and
- The customer may be unable or unwilling to consider CHP.

These factors were considered in the economic competition and market penetration model.

### 3 CHP Market Penetration Results

The economic market potential was determined based on a comparison of the net power costs from the competing CHP technologies with the delivered electric and natural gas prices within that market size and geographical area. Within each market category (size and region), the competition among applicable technologies was evaluated. Based on this competition, the economic market potential was estimated and shared among competing CHP technologies. The rate of market penetration by technology under each scenario was then estimated using a market diffusion model (see Appendix D). Only “within the fence” CHP systems were considered in the analysis. All thermal energy and power generated by the CHP systems was assumed to be used onsite; no power export market was considered for any of the size categories.

Table 3 presents the market penetration results for each state region (upstate and downstate) for each of the three scenarios by year (2010, 2015, and 2020). By 2020, CHP penetration is estimated to range from 10.9% (Scenario 2) to 11.4% (Scenario 3) of the total technical, potential presented in the previous section. The absolute increase is 310 MW, which is 15% greater capacity for Scenario 3 than the total Scenario 2 penetration of 2170 MW.

**Table 3. CHP Market Penetration Estimates (MW)**

Base Case

|           | 2010 | 2015  | 2020  |
|-----------|------|-------|-------|
| Downstate | 255  | 958   | 1,342 |
| Upstate   | 239  | 775   | 1,067 |
| Total     | 494  | 1,733 | 2,409 |

Scenario 2

|           | 2010 | 2015  | 2020  |
|-----------|------|-------|-------|
| Downstate | 249  | 857   | 1,199 |
| Upstate   | 232  | 704   | 971   |
| Total     | 481  | 1,561 | 2,170 |

Scenario 3

|           | 2010 | 2015  | 2020  |
|-----------|------|-------|-------|
| Downstate | 297  | 1,000 | 1,385 |
| Upstate   | 267  | 803   | 1,095 |
| Total     | 564  | 1,803 | 2,480 |

The more restrictive NOx emissions standards of Scenario 2 (1.0 lb/MWh vs. 1.6 lb/MWh for the Base Case) reduce total CHP penetration by 239 MW (about 10% of the Base Case penetration). Allowing a

CHP thermal credit (Scenario 3) increases CHP penetration slightly compared to the Base Case (71 MW or 3% of the Base Case penetration) even considering the stricter NO<sub>x</sub> standard of 1.0 lb/MWh.

The impact of the different scenarios is more apparent when individual CHP technology penetration was considered as shown in Table 4.

**Table 4. CHP Market Penetration Results by Technology – Year 2020 (MW)**

Recip Engine

| Size Range    | Base | Scenario 2 | Scenario 3 |
|---------------|------|------------|------------|
| 50-500 kW     | 155  | 155        | 155        |
| 500kW-1,000kW | 389  | 355        | 392        |
| 1-5 MW        | 912  | 551        | 971        |
| 5-20 MW       | 244  | 114        | 244        |
| >20 MW        | 0    | 0          | 0          |
| All Sizes     | 1699 | 1174       | 1762       |

Microturbine

| Size Range    | Base | Scenario 2 | Scenario 3 |
|---------------|------|------------|------------|
| 50-500 kW     | 17   | 17         | 17         |
| 500kW-1,000kW | 24   | 32         | 23         |
| 1-5 MW        | 0    | 0          | 0          |
| 5-20 MW       | 0    | 0          | 0          |
| >20 MW        | 0    | 0          | 0          |
| All Sizes     | 40   | 49         | 40         |

Gas Turbine

| Size Range    | Base | Scenario 2 | Scenario 3 |
|---------------|------|------------|------------|
| 50-500 kW     | 0    | 0          | 0          |
| 500kW-1,000kW | 0    | 0          | 0          |
| 1-5 MW        | 186  | 358        | 194        |
| 5-20 MW       | 159  | 257        | 159        |
| >20 MW        | 310  | 310        | 310        |
| All Sizes     | 656  | 926        | 663        |

Fuel Cell

| Size Range    | Base | Scenario 2 | Scenario 3 |
|---------------|------|------------|------------|
| 50-500 kW     | 4    | 4          | 4          |
| 500kW-1,000kW | 3    | 5          | 3          |
| 1-5 MW        | 7    | 13         | 7          |
| 5-20 MW       | 0    | 0          | 0          |
| >20 MW        | 0    | 0          | 0          |
| All Sizes     | 14   | 21         | 14         |

As shown in Table 4, the stricter NOx standards of Scenario 2 restrict the deployment of reciprocating engine CHP. Much of this is replaced by gas turbine CHP in the larger size categories, but only a small fraction is replaced by other technologies (microturbines and fuel cells) in the smaller size categories. Table 5 presents the market penetration estimates by size, year, and region for each scenario.

**Table 5. CHP Market Penetration by Size, Year, and Region**

**Base Case Cumulative Market Penetration 2010, 2015, and 2020**

| Year | Region    | 50-500 kW | 0.5-1 MW | 1-5 MW | 5-20 MW | >20 MW | Total MW |
|------|-----------|-----------|----------|--------|---------|--------|----------|
| 2010 | Downstate | 13        | 42       | 96     | 63      | 41     | 255      |
|      | Upstate   | 8         | 27       | 56     | 62      | 86     | 239      |
|      | NY Total  | 21        | 69       | 152    | 126     | 127    | 494      |
| 2015 | Downstate | 57        | 156      | 503    | 159     | 82     | 958      |
|      | Upstate   | 37        | 107      | 269    | 174     | 188    | 775      |
|      | NY Total  | 94        | 263      | 772    | 334     | 270    | 1,733    |
| 2025 | Downstate | 105       | 243      | 708    | 193     | 93     | 1,342    |
|      | Upstate   | 69        | 173      | 397    | 210     | 217    | 1,067    |
|      | NY Total  | 175       | 416      | 1,105  | 403     | 310    | 2,409    |

**Scenario 2 Cumulative Market Penetration 2010, 2015, and 2020**

| Year | Region    | 50-500 kW | 0.5-1 MW | 1-5 MW | 5-20 MW | >20 MW | Total MW |
|------|-----------|-----------|----------|--------|---------|--------|----------|
| 2010 | Downstate | 13        | 42       | 96     | 58      | 41     | 249      |
|      | Upstate   | 8         | 29       | 56     | 53      | 86     | 232      |
|      | NY Total  | 21        | 70       | 152    | 111     | 127    | 481      |
| 2015 | Downstate | 57        | 146      | 424    | 148     | 82     | 857      |
|      | Upstate   | 37        | 105      | 218    | 157     | 188    | 704      |
|      | NY Total  | 94        | 251      | 642    | 304     | 270    | 1,561    |
| 2025 | Downstate | 105       | 224      | 596    | 181     | 93     | 1,199    |
|      | Upstate   | 69        | 168      | 326    | 191     | 217    | 971      |
|      | NY Total  | 175       | 392      | 922    | 371     | 310    | 2,170    |

**Scenario 3 Cumulative Market Penetration 2010, 2015, and 2020**

| Year | Region    | 50-500 kW | 0.5-1 MW | 1-5 MW | 5-20 MW | >20 MW | Total MW |
|------|-----------|-----------|----------|--------|---------|--------|----------|
| 2010 | Downstate | 13        | 44       | 136    | 63      | 41     | 297      |
|      | Upstate   | 8         | 28       | 83     | 62      | 86     | 267      |
|      | NY Total  | 21        | 72       | 219    | 126     | 127    | 564      |
| 2015 | Downstate | 57        | 158      | 544    | 159     | 82     | 1,001    |
|      | Upstate   | 37        | 108      | 295    | 174     | 188    | 803      |
|      | NY Total  | 94        | 266      | 839    | 334     | 270    | 1,803    |
| 2025 | Downstate | 105       | 245      | 749    | 193     | 93     | 1,385    |
|      | Upstate   | 69        | 174      | 424    | 210     | 217    | 1,094    |
|      | NY Total  | 175       | 419      | 1,172  | 403     | 310    | 2,479    |

The market penetration results were used in the remaining analysis as follows: Using the MW of CHP capacity estimated to be installed in each county, the hours of operation (low load and high load), and hourly and seasonal load shapes by customer groups, the reduction of electricity purchases from the grid was calculated for each county on a seasonal and daily basis. This reduction in “demand” was factored into the production simulation model that captures the hour-by-hour dynamics of electric power markets and determines the impacts on central station dispatch and the need for new capacity over time. The emissions impacts of CHP at the site (i.e., displacing existing thermal sources with the CHP systems) were compared to the emissions impacts at the power plant level (i.e., comparing net incremental emissions at the sites with displaced emissions from the grid) to determine the overall environmental impact of CHP deployment for each scenario.

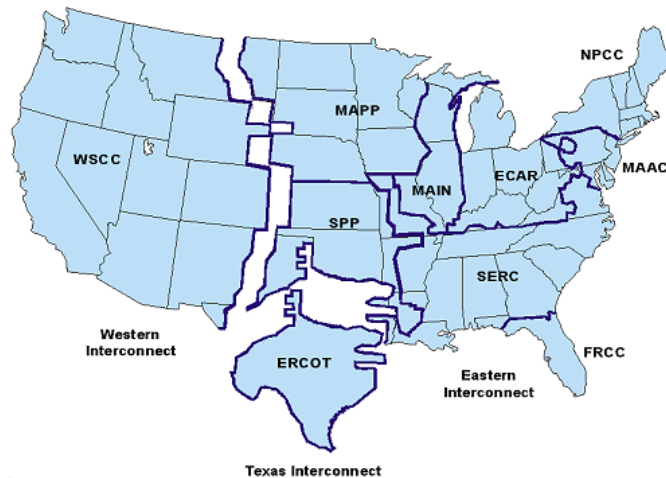
## 4 Modeling Approach

### 4.1 Market Simulation

In order to develop reasonable estimations of the environmental and economic impacts of CHP under the three scenarios, it was necessary to simulate operation of these plants in the NYS competitive marketplace. New York operates a competitive wholesale market for power sales where generation plants and demand side resources compete to provide the most cost effective means to meet demand. The CHP plants were introduced into the modeling in such a way to perform as though they were being self-scheduled, their operation being controlled by the steam host. Thus, their electrical output directly offset a portion of system load according to our calculated schedule (peak/off-peak) and caused a reordering of the dispatch of the central station plants compared to the Reference Case. In this way, we were able to simulate the economic dispatch of generators in the market and measure the changes in pollutant levels and wholesale market costs.

NCI used Prosym to develop its wholesale energy market price and plant performance forecast simulation. Prosym is a detailed energy production cost model that simulates hourly operation of generation and transmission resources. Prosym dispatches generating resources to match hourly electricity demand, dispatching the least expensive generation first. The choice of generation is determined by the generator's offer to the market operator, including technical factors such as ramp rates (for fossil resources) or water availability (for hydraulic resources), and transmission constraints. The supply offer of the marginally dispatched unit in each hour sets the hourly market-clearing price. All generators in the same market area whose supply offers are accepted receive the same hourly market-clearing price regardless of actual offer price. The NCI Prosym model specification included the entire Eastern Interconnect, which covers the electrically interconnected areas of the United States and Canada roughly east of the Rocky Mountains, excluding Texas.

**Figure 1. Map of Interconnected Electric Systems in U.S.**



Within Prosym, production costs were calculated based upon heat rate, fuel, and other operating costs, expressed as a function of output. Physical operating limits related to expected maintenance and forced outages, start-up, unit ramping, minimum up and down time, and other characteristics were also factored into the simulation. Supply offer prices were developed for each unit within the Prosym construct and correspond to the minimum price the unit owner is willing to accept to operate the unit. For most generation resources, offer prices were composed primarily of incremental production costs. The incremental production cost was calculated as each generating unit's fuel price multiplied by its incremental heat rate, plus unit emissions costs and variable operations and maintenance costs. Unit emissions costs were derived from historic unit specific emission rates and forecasts of allowance prices.

Where relevant (primarily for thermal units), the unit offer price also incorporated the unit's start-up and no-load costs, which are costs that aren't directly incurred with the output of a plant, but do get factored into a generator's offer to sell into the market. The start-up cost component included fuel and other operating costs encountered in starting the generating unit, beyond those reflected in the heat rate and variable operating cost assumptions. The no-load cost reflected the difference between average and incremental fuel costs for generating stations that are dispatched at less than full output.

The offer price can also include a markup factor that increases the offer price above the variable production cost. We applied such a factor, where appropriate, to reflect observed market behavior, particularly during times when supply margins are tight or when we observe shadow pricing. We may assign price markups to individual generators depending upon the underlying fuel efficiency, production cost, and technology type. The specific markups were designed to increase offer prices above the cost of production as less efficient resources were called upon for power production and as the intersection of supply and demand occurred at higher points on the supply curve. The level of price markups was determined through a benchmarking of the Prosym market price forecast against recent actual wholesale energy prices and observable energy prices in the forward market. Energy market clearing prices reflect the offer of the last generating resource used to meet the next increment (megawatt) of demand. Station revenues were based on these market-clearing prices within the market area in which the plant is located. The net results were simulations that closely reflect observed market behavior and market outcomes.

CHP plants were entered in the modeling with zero cost and zero emissions. They were divided into two groups of resources, based on the penetration of different technologies under the assumptions in the different scenarios according to the EEA analysis. The technologies were categorized into high load factor CHP resources and low load factor CHP resources. The high load factor CHP resources were assumed to operate around the clock, albeit at varying levels depending on the scenario, time of day (peak/off-peak) and season. The low load factor CHP resources were assumed to operate only during "day-time" (peak) hours, also varying their output based on the scenario and season. These resources were essentially modeled as "energy limited" resources, or resources that would produce energy according to a schedule

that was determined by factors outside of the energy market. Run-of-river hydro plants are an example of a resource that falls into this category-- they produce energy when water is available and flowing. In the case of CHP projects, their production schedule is dictated by the host - energy production is a byproduct, and not the primary determinant of when a CHP plant operates. While it was necessary to model the plants in this manner, in reality, the CHP plants would not be dispatched by the system operator and their energy would not be delivered to the grid. The energy they produced would offset their own host's energy needs, thereby reducing system demand and causing a different dispatch order than would occur in their absence.

## **4.2 Post-Processing of Results**

While the Prosym model was able to simulate the competitive dispatch of generators in New York, further analysis and processing of the results was required to quantify the total impacts of the CHP on the New York electric market in terms of both environmental impacts and economic impacts.

As an output from Prosym, we obtained the emissions of SO<sub>2</sub>, NO<sub>x</sub>, and CO<sub>2</sub> based on calculations of plant fuel consumed from generating power and their emission rates (lbs per MMBtu). Total emissions of these pollutants were then calculated over a given geographical region and time period. Generating plants that use fuels containing high levels of sulfur will have high rates of SO<sub>2</sub> emissions unless those plants also employ control technology to capture those emissions. The same is true for NO<sub>x</sub> and CO<sub>2</sub>. Because the Prosym model contains actual, historical emissions rates, it captures the impacts of the control technologies already being employed at the generating plants in the database. For modeling purposes, NCI assumed that the cost of emissions rate limits would be captured through the trading of allowances.

NO<sub>x</sub> emissions results were disaggregated into seasons. Season 1 extends from May through September in the presentation (ozone season), and Season 2 extends from October through April (non-ozone season). This allowed for the differentiation of summer, winter, and annual NO<sub>x</sub> impacts.

Economic impacts were calculated as the change in the average wholesale market price of electricity in each scenario compared to the base case (in \$/MWh) for each scenario for the state of New York as well as for each zone within the state.

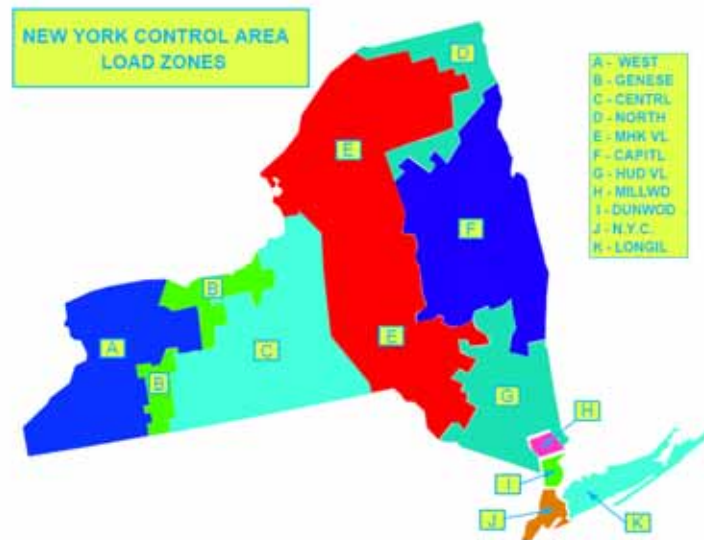
## 5 Assumptions Used in the Analysis

### 5.1 Scope of Simulation and Level of Detail for the New York Market

As stated above, we simulated the economic dispatch of the entire Eastern Interconnected electric system, which included the central and eastern portions of the U.S. and Canada, roughly from the foot of the Rocky Mountains to the Atlantic Ocean (excluding most of Texas). Within this area, the transmission topography was represented to take into account major transmission interfaces and bottlenecks where energy pricing differences normally occur. Within New York, the topography was broken down into eight zones. While the NYISO recognizes 11 zones, A through K, we aggregated A through D. This is because there are rarely transmission constraints causing congestion between these zones, and therefore, there is rarely any electric price separation. Zone A is located in the Niagara Falls region of the state; the zones are named roughly west to east, with Zone K corresponding to Long Island.

In the presented results, Upstate New York refers to Zones A-D and E. Downstate New York refers to Zones F through K. See Figure 2 below for a geographical depiction of the zones in New York State.

Figure 2. New York Control Area Zone Reference



## **5.2 New Capacity Resources**

Long-range market price simulations require assumptions regarding future generating plant additions and retirements. We included actual plants in the model that are under active development and have a high probability of successful development. In consultation with NYSERDA and consistent with assumptions used in RGGI policy analysis, NCI introduced capacity into the model that could reasonably be expected to be developed over time due to build economics, reliability requirements, or policy initiatives. These additions included a variety of capacity types, such as conventional gas-fired combined cycle (“CC”) and renewable technologies. In New York State, the majority of new capacity additions were combined cycle (see Table 6 below). Of the total capacity additions (5,691 MW by 2020), new renewable capacity accounted for 1,196 MW and were made up of wind as well as landfill gas projects. The combined cycle gas plants that were added were the SCS Astoria plant in NYC and other generic CC units in downstate NY.

In addition, a total of 685 MW of oil and coal capacity were retired over the forecast period. The retired coal plants included Greenidge and Russell, and the retired oil-fired plants included units at East Hampton, East River, Montauk, and Waterside.

**Table 6: Assumed Resource Changes in New York State for the Energy Dispatch Model****New York State cumulative capacity changes**

|                                    | <b>2006</b> | <b>2010</b> | <b>2015</b>  | <b>2020</b>  |
|------------------------------------|-------------|-------------|--------------|--------------|
| Repower to CC                      | -           | -           | -            | -            |
| CC                                 | -           | 995         | 2,495        | 4,495        |
| CT                                 | -           | -           | -            | -            |
| Coal                               | -           | -           | -            | -            |
| Repower to IGCC                    | -           | -           | -            | -            |
| Oil/Gas                            | -           | -           | -            | -            |
| Nuclear                            | -           | -           | -            | -            |
| Nuclear Uprate                     | -           | -           | -            | -            |
| <b>Total Conventional Capacity</b> | -           | <b>995</b>  | <b>2,495</b> | <b>4,495</b> |
| Biomass                            | -           | -           | -            | -            |
| Fuel Cell                          | -           | -           | -            | -            |
| Hydro                              | -           | -           | -            | -            |
| Landfill Gas                       | 48          | 145         | 266          | 378          |
| Solar                              | -           | -           | -            | -            |
| Wind                               | 102         | 307         | 562          | 818          |
| <b>Total Renewable Capacity</b>    | <b>151</b>  | <b>452</b>  | <b>828</b>   | <b>1,196</b> |
| Mothballed Oil/Gas                 | -           | -           | -            | -            |
| Return to Service Oil/Gas          | -           | -           | -            | -            |
| Retire Oil/Gas                     | -           | 276         | 276          | 286          |
| Retire Coal                        | -           | 399         | 399          | 399          |
| <b>Net Capacity Added</b>          | <b>151</b>  | <b>772</b>  | <b>2,648</b> | <b>5,006</b> |

Source: Navigant Consulting Analysis

Additions of CHP resources were included in the model as zero price resources with energy delivery shapes corresponding to whether they were high or low load factor resources. Low load factor resources were set to deliver energy during on peak periods, while high load factor resources were set to deliver energy during all hours. This modeling approach reproduced the effect of having plants on the system that self-schedule their energy production according to their own needs, rather than the system needs. Thus, we were able to control the CHP energy production in a realistic manner.

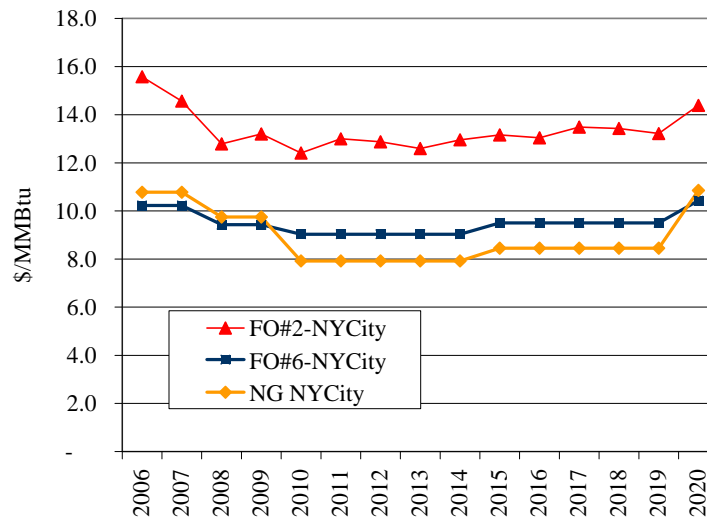
### 5.3 Time Periods

For the purposes of modeling, the on-peak period was defined as 0700 to 2300 Monday to Friday (excluding holidays) and the off-peak period was defined as all other periods. Two seasonal periods were also defined within the year - summer and winter. The summer period extended from May through October, and the winter period extended from November through April.

## 5.4 Fuel Prices

The price of natural gas is a major input variable for any power price forecast. As previously illustrated, natural gas-fired generation is the marginal unit for many hours in each of the markets. Consequently, power prices are highly correlated with natural gas prices. Our intention was to coordinate the input assumptions as closely as possible with those used as part of the RGGI policy analysis in order to facilitate the work of policy makers as they attempt to evaluate various future power development objectives. Accordingly, NCI used the fuel forecasts for natural gas, distillate and residual fuel oil (“FO#2” and “FO#6”, respectively), coal, and emissions allowances that were used in the RGGI base case. The fuel prices used in the market simulation analyses were also consistent with the fuel prices used in the CHP penetration analysis. Shown in Figure 3 below are the forecasts used for FO#6, FO#2, and Natural gas in New York City<sup>2</sup>. FO#6 and FO#2 track each other fairly closely with FO#2 demonstrating a bit more annual price volatility. FO#6 is not projected to decline in price as much as natural gas beyond 2010. This will put natural gas into a position of relative value compared to FO#6 around 2010. It is not expected to return to price parity with FO#6 until the end of the forecast period in 2020.

**Figure 3. Oil and gas price forecasts for New York City**



<sup>2</sup> As thermal capacity additions are concentrated in downstate New York, only New York City prices are shown. All fuel prices can be found in the detailed Appendices.

## 5.5 Allowance Prices

Emission allowance prices were derived in coordination with NYSERDA and the RGGI policy analysis. SO<sub>2</sub> and CO<sub>2</sub> do not have seasonal differentiation in their markets (or anticipated markets). Therefore, their prices are annual in nature and do not vary within the year. SO<sub>2</sub> allowance prices were expected to begin at just over \$1,000/ton and rise to over \$2,600/ton by 2020. While SO<sub>2</sub> are no longer at the levels predicted at the time of the modeling, we do not believe that substituting current, lower SO<sub>2</sub> allowance prices would have a material impact on the study outcomes. The CO<sub>2</sub> price was expected to start at \$3/ton in 2010 (the first modeled year after the start of RGGI), and rise to \$6/ton by 2020. While there are annual NO<sub>x</sub> regulations, NO<sub>x</sub> prices did vary by season as NO<sub>x</sub> is a contributor to ground level ozone in the summer and there are stricter summertime environmental restrictions on the NO<sub>x</sub> emissions. By 2015, it was expected that seasonal prices differences would disappear and the NO<sub>x</sub> allowance prices would remain consistent throughout the year. The full price forecasts for all three pollutants can be seen in Table 7 below.

**Table 7. Emissions Allowance Prices in New York (\$/ton)**

|                                | New York              |                        |                       |                        |                       |                        |                       |                        |
|--------------------------------|-----------------------|------------------------|-----------------------|------------------------|-----------------------|------------------------|-----------------------|------------------------|
|                                | 2006                  |                        | 2010                  |                        | 2015                  |                        | 2020                  |                        |
|                                | Season 1:<br>May-Oct. | Season 2:<br>Nov-April | Season 1:<br>May-Oct. | Season 2:<br>Nov-April | Season 1:<br>May-Oct. | Season 2:<br>Nov-April | Season 1:<br>May-Oct. | Season 2:<br>Nov-April |
| SO <sub>2</sub> Price (\$/ton) | \$1,035               | \$1,035                | \$1,266               | \$1,266                | \$1,513               | \$1,513                | \$2,610               | \$2,610                |
| NO <sub>x</sub> Price (\$/ton) | \$3,001               | \$1,600                | \$2,244               | \$2,818                | \$2,446               | \$2,446                | \$3,409               | \$3,409                |
| CO <sub>2</sub> Price (\$/ton) | \$0                   | \$0                    | \$3                   | \$3                    | \$4                   | \$4                    | \$6                   | \$6                    |

## 5.6 Emissions Rates

Emission rates for each plant in the Eastern Interconnect were input based on the Continuous Emissions Monitoring System (“CEMS”) data as reported to the EPA. This data was entered into Prosym as emission rates for SO<sub>2</sub>, NO<sub>x</sub> and CO<sub>2</sub>, in terms of pounds of each pollutant emitted per unit of fuel consumed (MMBtu). Prosym calculates plant emissions from fuel consumed in start-up and in operation. Presented in Table 8 below are the average emission rates resulting from plant operations over the study period. These emission rates represent the average of the plants’ emissions in each technology/ fuel class for each study year, by emission type. Emission changes over time were primarily the result of variations in the individual plants’ operations vis-à-vis each other. This is true whether analyzing within or between categories. That is, if the model dispatches lower emission rate plants rather than higher emission rate plants within the same category, then the overall emission rate for that plant category will decline. If the model displaces higher emission rate plants in one category with lower emission rate plants in another category, the higher emission plants will run less and the overall emission rate for their category will, again, decline. The emission rates shown below are for the Reference case - before the introduction of CHP.

**Table 8. Average Emission Rates by Technology/ Fuel Class, Year and Emission Type of Existing Plants in New York**

|               | SO <sub>2</sub> Rates (lbs/MMBtu) |       |       |       | NO <sub>x</sub> Rates (lbs/MMBtu) |       |       |       | CO <sub>2</sub> Rates (lbs/MMBtu) |      |      |      |
|---------------|-----------------------------------|-------|-------|-------|-----------------------------------|-------|-------|-------|-----------------------------------|------|------|------|
|               | 2006                              | 2010  | 2015  | 2020  | 2006                              | 2010  | 2015  | 2020  | 2006                              | 2010 | 2015 | 2020 |
| New CC        |                                   | 0.001 | 0.001 | 0.001 |                                   | 0.013 | 0.013 | 0.013 |                                   | 119  | 119  | 119  |
| Existing CC   | 0.294                             | 0.199 | 0.190 | 0.191 | 0.056                             | 0.049 | 0.046 | 0.043 | 97                                | 95   | 95   | 95   |
| Gas CT        | 0.001                             | 0.001 | 0.001 | 0.001 | 0.008                             | 0.010 | 0.012 | 0.013 | 124                               | 124  | 124  | 125  |
| Oil CT and IC | 0.294                             | 0.199 | 0.190 | 0.191 | 0.056                             | 0.049 | 0.046 | 0.043 | 97                                | 95   | 95   | 95   |
| Jet Engine    | 0.656                             | 0.673 | 0.670 | 0.672 | 0.211                             | 0.217 | 0.305 | 0.278 | 163                               | 165  | 164  | 164  |
| Steam Coal    | 1.193                             | 0.972 | 0.962 | 0.955 | 0.187                             | 0.179 | 0.179 | 0.178 | 203                               | 203  | 203  | 203  |
| Steam Gas     | 0.147                             | 0.084 | 0.073 | 0.126 | 0.119                             | 0.104 | 0.116 | 0.139 | 125                               | 126  | 125  | 125  |
| Steam Oil     | 0.294                             | 0.199 | 0.190 | 0.191 | 0.056                             | 0.049 | 0.046 | 0.043 | 97                                | 95   | 95   | 95   |

## **6 Modeling Results**

### **6.1 Air Impacts Resulting from DG/CHP**

As noted above, each Scenario was designed to introduce specific amounts of CHP into the New York market. Some of these resources were high load factor, or baseload, while others were low load factor, or peaking. Whether baseload or peaking, all of the CHP introduced to the modeling would have the effect of shifting the supply curve to the right and displacing higher cost, less efficient resources. To see the impact of the CHP in full, we modeled a Reference Case that simulated the economic dispatch of the electric system prior to the introduction of CHP. Numerically, the results of the Reference Case are given in Table 9 below. As stated earlier, the Reference Case provides a basis for comparison a “worldview” prior to the introduction of policies that encourage the adoption of CHP resources to the Scenarios with pro-CHP policies. As CHP policies in New York will also have effects on electric market operation and dispatch in other parts of the country, Table 9 shows generation, fuel consumption and cost, emission quantities and costs, and CHP generation for each region of the country. The CHP generation was limited to New York for purposes of this study.

**Table 9. Modeling Results for the Reference Case**

| Reference Case - Real 2006\$ |                          |                   |                     |              |                   |                     |              |                   |                     |              |                   |                     |              |
|------------------------------|--------------------------|-------------------|---------------------|--------------|-------------------|---------------------|--------------|-------------------|---------------------|--------------|-------------------|---------------------|--------------|
| Market Area                  | Data                     | 2006              |                     |              | 2010              |                     |              | 2015              |                     |              | 2020              |                     |              |
|                              |                          | Season 1: May-Oct | Season 2: Nov-April | Annual Total | Season 1: May-Oct | Season 2: Nov-April | Annual Total | Season 1: May-Oct | Season 2: Nov-April | Annual Total | Season 1: May-Oct | Season 2: Nov-April | Annual Total |
| New York                     | Generation (GWh)         | 73,586            | 73,788              | 153,374      | 85,669            | 78,398              | 164,068      | 91,917            | 84,168              | 176,084      | 97,354            | 83,604              | 185,957      |
|                              | Fuel Consumption (GBtu)  | 630,906           | 559,740             | 1,190,646    | 676,423           | 587,472             | 1,263,894    | 722,191           | 629,667             | 1,351,858    | 756,165           | 658,350             | 1,414,515    |
|                              | Fuel Cost (\$000)        | \$3,434,681       | \$2,960,579         | \$6,395,259  | \$2,806,603       | \$2,358,328         | \$5,164,931  | \$2,928,650       | \$2,500,987         | \$5,429,637  | \$3,340,690       | \$2,859,502         | \$6,200,193  |
|                              | SO2 Emissions (000 tons) | 93                | 87                  | 181          | 67                | 64                  | 131          | 66                | 62                  | 128          | 68                | 63                  | 131          |
|                              | NOx Emissions (000 tons) | 20                | 18                  | 38           | 19                | 16                  | 35           | 16                | 16                  | 34           | 18                | 15                  | 33           |
|                              | CO2 Emissions (000 tons) | 31,454            | 27,190              | 58,644       | 32,830            | 27,502              | 60,332       | 34,407            | 28,909              | 63,317       | 35,407            | 29,681              | 65,088       |
|                              | SO2 Cost (\$000)         | \$96,657          | \$90,538            | \$187,195    | \$84,938          | \$80,413            | \$165,351    | \$89,310          | \$84,120            | \$173,430    | \$127,828         | \$118,061           | \$245,890    |
|                              | NOx Cost (\$000)         | \$56,440          | \$28,454            | \$84,894     | \$39,682          | \$41,338            | \$81,019     | \$36,274          | \$31,708            | \$67,981     | \$43,956          | \$37,353            | \$81,309     |
|                              | CO2 Cost (\$000)         | \$0               | \$0                 | \$0          | \$89,568          | \$75,034            | \$164,602    | \$111,179         | \$93,413            | \$204,592    | \$152,425         | \$127,777           | \$280,201    |
|                              | CHP Generation (GWh)     |                   |                     |              |                   |                     |              |                   |                     |              |                   |                     |              |
| New England                  | Generation (GWh)         | 76,260            | 77,910              | 154,170      | 82,850            | 84,879              | 167,729      | 90,671            | 92,217              | 182,888      | 97,942            | 99,290              | 197,232      |
|                              | Fuel Consumption (GBtu)  | 649,222           | 656,528             | 1,305,750    | 702,603           | 703,826             | 1,406,430    | 774,825           | 770,872             | 1,545,697    | 835,861           | 830,968             | 1,666,829    |
|                              | Fuel Cost (\$000)        | \$3,171,002       | \$3,435,071         | \$6,606,073  | \$2,583,576       | \$2,942,013         | \$5,525,588  | \$2,896,570       | \$3,138,203         | \$6,036,773  | \$3,517,962       | \$3,794,177         | \$7,312,138  |
|                              | SO2 Emissions (000 tons) | 109               | 112                 | 222          | 94                | 100                 | 194          | 82                | 83                  | 164          | 92                | 93                  | 184          |
|                              | NOx Emissions (000 tons) | 19                | 20                  | 39           | 17                | 18                  | 35           | 19                | 18                  | 37           | 20                | 20                  | 39           |
|                              | CO2 Emissions (000 tons) | 37,229            | 37,563              | 74,792       | 37,649            | 39,073              | 76,722       | 42,040            | 42,074              | 84,113       | 45,520            | 45,587              | 91,107       |
|                              | SO2 Cost (\$000)         | \$68,047          | \$71,949            | \$139,996    | \$65,147          | \$72,259            | \$137,406    | \$56,167          | \$56,424            | \$114,592    | \$84,092          | \$87,528            | \$171,620    |
|                              | NOx Cost (\$000)         | \$20,588          | \$625               | \$21,213     | \$3,093           | \$805               | \$3,897      | \$859             | \$871               | \$1,729      | \$798             | \$816               | \$1,614      |
|                              | CO2 Cost (\$000)         | \$0               | \$0                 | \$0          | \$7,681           | \$8,688             | \$16,369     | \$14,123          | \$14,408            | \$28,531     | \$19,121          | \$19,878            | \$39,000     |
|                              | CHP Generation (GWh)     |                   |                     |              |                   |                     |              |                   |                     |              |                   |                     |              |
| PJM                          | Generation (GWh)         | 172,729           | 163,023             | 335,752      | 185,850           | 178,186             | 364,035      | 203,116           | 192,990             | 396,106      | 232,565           | 216,959             | 449,524      |
|                              | Fuel Consumption (GBtu)  | 1,664,623         | 1,565,904           | 3,230,527    | 1,771,805         | 1,682,297           | 3,454,101    | 1,910,445         | 1,797,157           | 3,707,602    | 2,142,347         | 1,995,113           | 4,137,460    |
|                              | Fuel Cost (\$000)        | \$3,946,052       | \$3,604,258         | \$7,550,310  | \$3,826,772       | \$3,611,129         | \$7,437,900  | \$4,717,131       | \$4,408,281         | \$9,125,412  | \$5,998,186       | \$5,502,811         | \$11,500,997 |
|                              | SO2 Emissions (000 tons) | 728               | 691                 | 1,419        | 538               | 521                 | 1,062        | 292               | 287                 | 578          | 199               | 196                 | 395          |
|                              | NOx Emissions (000 tons) | 76                | 75                  | 151          | 74                | 71                  | 145          | 62                | 60                  | 122          | 67                | 64                  | 131          |
|                              | CO2 Emissions (000 tons) | 106,587           | 100,120             | 206,707      | 112,404           | 106,869             | 219,273      | 120,253           | 113,145             | 233,398      | 138,428           | 129,141             | 267,569      |
|                              | SO2 Cost (\$000)         | \$753,676         | \$715,116           | \$1,468,792  | \$680,645         | \$664,216           | \$1,344,661  | \$441,359         | \$433,600           | \$874,960    | \$372,078         | \$366,771           | \$738,858    |
|                              | NOx Cost (\$000)         | \$194,727         | \$0                 | \$194,727    | \$115,012         | \$88,576            | \$203,589    | \$89,981          | \$87,772            | \$177,753    | \$120,130         | \$115,915           | \$236,045    |
|                              | CO2 Cost (\$000)         | \$0               | \$0                 | \$0          | \$0               | \$0                 | \$0          | \$376,728         | \$358,302           | \$735,030    | \$770,912         | \$721,700           | \$1,492,612  |
|                              | CHP Generation (GWh)     |                   |                     |              |                   |                     |              |                   |                     |              |                   |                     |              |
| ECAR                         | Generation (GWh)         | 292,161           | 282,340             | 574,501      | 304,693           | 288,576             | 593,268      | 315,411           | 299,380             | 614,791      | 325,479           | 309,269             | 634,748      |
|                              | Fuel Consumption (GBtu)  | 2,133,092         | 1,987,358           | 4,120,451    | 2,240,909         | 2,097,115           | 4,338,024    | 2,333,491         | 2,178,714           | 4,512,205    | 2,418,022         | 2,269,802           | 4,687,825    |
|                              | Fuel Cost (\$000)        | \$5,025,935       | \$4,609,301         | \$9,634,897  | \$5,182,209       | \$4,749,011         | \$9,911,219  | \$6,264,418       | \$5,840,275         | \$12,104,693 | \$7,007,812       | \$6,588,585         | \$13,598,387 |
|                              | SO2 Emissions (000 tons) | 1,692             | 1,694               | 3,386        | 1,305             | 1,310               | 2,615        | 1,034             | 1,030               | 2,063        | 943               | 939                 | 1,882        |
|                              | NOx Emissions (000 tons) | 288               | 303                 | 591          | 279               | 279                 | 558          | 246               | 244                 | 490          | 238               | 235                 | 473          |
|                              | CO2 Emissions (000 tons) | 258,618           | 252,444             | 511,062      | 265,109           | 253,983             | 519,091      | 270,594           | 258,489             | 529,083      | 279,470           | 266,832             | 546,302      |
|                              | SO2 Cost (\$000)         | \$1,751,558       | \$1,753,240         | \$3,504,798  | \$1,629,767       | \$1,635,333         | \$3,265,100  | \$1,497,047       | \$1,487,211         | \$2,984,257  | \$1,634,247       | \$1,622,841         | \$3,257,689  |
|                              | NOx Cost (\$000)         | \$720,407         | \$0                 | \$720,407    | \$552,214         | \$460,891           | \$1,013,105  | \$478,174         | \$474,323           | \$952,497    | \$563,791         | \$555,892           | \$1,119,683  |
|                              | CO2 Cost (\$000)         | \$0               | \$0                 | \$0          | \$0               | \$0                 | \$0          | \$1,092,921       | \$1,044,027         | \$2,136,948  | \$2,003,814       | \$1,913,110         | \$3,916,924  |
|                              | CHP Generation (GWh)     |                   |                     |              |                   |                     |              |                   |                     |              |                   |                     |              |
| SERC                         | Generation (GWh)         | 472,636           | 424,603             | 897,239      | 509,256           | 459,062             | 968,318      | 548,132           | 491,705             | 1,039,837    | 598,993           | 533,165             | 1,132,158    |
|                              | Fuel Consumption (GBtu)  | 3,385,570         | 2,988,387           | 6,373,956    | 3,630,218         | 3,236,366           | 6,866,585    | 3,886,144         | 3,457,562           | 7,343,706    | 4,223,938         | 3,709,398           | 7,933,337    |
|                              | Fuel Cost (\$000)        | \$10,676,078      | \$8,757,757         | \$19,433,836 | \$10,217,762      | \$8,699,670         | \$18,917,432 | \$12,582,836      | \$10,738,493        | \$23,321,329 | \$16,010,832      | \$13,633,725        | \$29,644,557 |
|                              | SO2 Emissions (000 tons) | 1,748             | 1,610               | 3,357        | 1,456             | 1,355               | 2,811        | 1,275             | 1,178               | 2,455        | 1,080             | 995                 | 2,075        |
|                              | NOx Emissions (000 tons) | 274               | 259                 | 533          | 283               | 258                 | 541          | 247               | 218                 | 465          | 257               | 229                 | 485          |
|                              | CO2 Emissions (000 tons) | 300,650           | 269,381             | 570,031      | 316,494           | 284,526             | 601,020      | 336,969           | 300,580             | 637,549      | 368,863           | 327,830             | 696,692      |
|                              | SO2 Cost (\$000)         | \$1,808,874       | \$1,665,864         | \$3,474,738  | \$1,830,383       | \$1,701,909         | \$3,532,292  | \$1,901,547       | \$1,755,117         | \$3,656,664  | \$1,977,873       | \$1,819,240         | \$3,797,114  |
|                              | NOx Cost (\$000)         | \$536,935         | \$0                 | \$536,935    | \$546,776         | \$426,458           | \$973,234    | \$482,901         | \$427,945           | \$910,846    | \$616,708         | \$550,462           | \$1,167,170  |
|                              | CO2 Cost (\$000)         | \$0               | \$0                 | \$0          | \$0               | \$0                 | \$0          | \$699,225         | \$654,006           | \$1,353,231  | \$1,347,907       | \$1,250,731         | \$2,598,637  |
|                              | CHP Generation (GWh)     |                   |                     |              |                   |                     |              |                   |                     |              |                   |                     |              |
| Midwest                      | Generation (GWh)         | 373,709           | 343,601             | 717,310      | 398,191           | 366,398             | 764,589      | 433,874           | 402,480             | 836,354      | 471,984           | 437,824             | 909,808      |
|                              | Fuel Consumption (GBtu)  | 2,820,938         | 2,605,984           | 5,426,922    | 3,085,127         | 2,831,262           | 5,896,389    | 3,395,798         | 3,152,199           | 6,548,189    | 3,722,807         | 3,457,592           | 7,180,499    |
|                              | Fuel Cost (\$000)        | \$5,626,031       | \$4,661,324         | \$10,287,355 | \$5,609,081       | \$4,912,250         | \$10,521,331 | \$6,962,075       | \$6,258,614         | \$13,220,689 | \$9,541,846       | \$7,737,112         | \$16,278,958 |
|                              | SO2 Emissions (000 tons) | 985               | 936                 | 1,921        | 991               | 938                 | 1,929        | 857               | 812                 | 1,668        | 835               | 787                 | 1,622        |
|                              | NOx Emissions (000 tons) | 324               | 306                 | 630          | 313               | 292                 | 605          | 266               | 249                 | 515          | 261               | 243                 | 504          |
|                              | CO2 Emissions (000 tons) | 280,199           | 259,505             | 539,703      | 292,924           | 270,215             | 563,140      | 312,557           | 289,977             | 602,534      | 338,007           | 313,651             | 651,658      |
|                              | SO2 Cost (\$000)         | \$1,019,562       | \$968,295           | \$1,987,857  | \$1,243,665       | \$1,177,455         | \$2,421,120  | \$1,262,757       | \$1,195,908         | \$2,458,665  | \$1,504,407       | \$1,416,309         | \$2,920,716  |
|                              | NOx Cost (\$000)         | \$271,894         | \$0                 | \$271,894    | \$357,081         | \$300,513           | \$657,595    | \$274,730         | \$264,128           | \$538,858    | \$326,341         | \$312,035           | \$638,377    |
|                              | CO2 Cost (\$000)         | \$0               | \$0                 | \$0          | \$0               | \$0                 | \$0          | \$377,132         | \$353,451           | \$730,583    | \$692,648         | \$648,339           | \$1,340,987  |
|                              | CHP Generation (GWh)     |                   |                     |              |                   |                     |              |                   |                     |              |                   |                     |              |
| Florida                      | Generation (GWh)         | 129,863           | 106,497             | 236,360      | 145,982           | 122,312             | 268,294      | 174,146           | 147,362             | 321,508      | 203,400           | 169,764             | 373,164      |
|                              | Fuel Consumption (GBtu)  | 773,990           | 622,776             | 1,396,765    | 904,877           | 735,138             | 1,640,015    | 1,148,396         | 963,700             | 2,112,096    | 1,367,071         | 1,157,058           | 2,524,129    |
|                              | Fuel Cost (\$000)        | \$7,444,973       | \$5,775,626         | \$13,220,599 | \$5,791,524       | \$4,773,526         | \$10,565,050 | \$6,568,765       | \$5,519,382         | \$12,088,147 | \$8,654,304       | \$7,147,099         | \$15,801,403 |
|                              | SO2 Emissions (000 tons) | 167               | 133                 | 300          | 157               | 129                 | 286          | 162               | 130                 | 292          | 159               | 122                 | 282          |
|                              | NOx Emissions (000 tons) | 54                | 43                  | 97           | 41                | 31                  | 67           | 28                | 26                  | 55           | 28                | 21                  | 47           |
|                              | CO2 Emissions (000 tons) | 80,899            | 66,354              | 147,252      | 89,212            | 74,210              | 163,422      | 106,726           | 90,044              | 196,770      | 124,182           | 103,982             | 228,164      |
|                              | SO2 Cost (\$000)         | \$172,869         | \$137,559           | \$310,429    | \$198,762         | \$163,900           | \$362,662    | \$245,147         | \$196,162           | \$441,310    | \$297,303         | \$228,806           | \$526,109    |
|                              | NOx Cost (\$000)         | \$0               | \$0                 | \$0          | \$100,986         | \$67,096            | \$168,082    | \$73,474          | \$55,778            | \$129,252    | \$97,654          | \$71,102            | \$168,756    |
|                              | CO2 Cost (\$000)         | \$0               | \$0                 | \$0          | \$0               | \$0                 | \$0          | \$0               | \$0                 | \$0          | \$0               | \$0                 | \$0          |
|                              | CHP Generation (GWh)     |                   |                     |              |                   |                     |              |                   |                     |              |                   |                     |              |
| Canada                       | Generation (GWh)         | 172,424           | 203,654             | 376,077      | 172,511           | 205,392             | 377,903      | 184,883           | 219,150             | 404,013      | 193,990           | 229,636             | 423,625      |
|                              | Fuel Consumption (GBtu)  | 524,644           | 583,226             | 1,107,870    | 504,100           | 594,783             | 1,088,884    | 515,194           | 598,332             | 1,113,516    | 577,143           | 666,337             | 1,243,481    |
|                              | Fuel Cost (\$000)        | \$1,699,697       | \$1,993,078         | \$3,692,776  | \$1,716,192       | \$1,957,380         | \$3,673,572  | \$1,874,923       | \$2,112,711         | \$3,987,634  | \$2,386,319       | \$2,692,042         | \$5,078,360  |
|                              | SO2 Emissions (000 tons) | 68                | 74                  | 142          | 70                | 76                  | 146          | 73                | 77                  | 151          | 75                | 80                  | 155          |
|                              | NOx Emissions (000 tons) | 11                | 12                  | 23           | 11                | 12                  | 23           | 11                | 12                  | 23           | 12                | 13                  | 25           |
|                              | CO2 Emissions (000 tons) | 26,714            | 29,067              | 55,781       | 28,777            | 30,751              | 59,528       | 30,406            | 32,362              | 62,768       | 34,386            | 36,920              | 71,306       |
|                              | SO2 Cost (\$000)         | \$1               |                     |              |                   |                     |              |                   |                     |              |                   |                     |              |

capacity in New York was being dispatched in the model to reduce peak hours and fill off-peak hours in the hourly load profile. The changes in CHP penetration across the various scenarios have slightly altered the way in which the pumped storage and thermal resources have been dispatched. This, in turn, caused greater fuel consumption in New York. However, the change in dispatch of plants toward a cleaner overall mix led to a reduction of emissions SO<sub>2</sub>, and CO<sub>2</sub> for New York, and the system as a whole. There was also a system-wide reduction in NO<sub>x</sub> emissions even though there were slight increases in Scenarios 1 and 3 compared to the Reference Case.

**Table 10. Comparison of the Reference Case and Scenario 1**

| Comparison Reference Case & Scenario 1 (2006\$) |                                      |           |           |              |            |            |              |             |             |              |             |             |              |
|---|--------------------------------------|-----------|-----------|--------------|------------|------------|--------------|-------------|-------------|--------------|-------------|-------------|--------------|
| Market Area                                     | Data                                 | 2006      |           |              | 2010       |            |              | 2015        |             |              | 2020        |             |              |
|   |                                      | Season 1: | Season 2: | Annual Total | Season 1:  | Season 2:  | Annual Total | Season 1:   | Season 2:   | Annual Total | Season 1:   | Season 2:   | Annual Total |
|   |                                      | May-Oct.  | Nov-April |              | May-Oct.   | Nov-April  |              | May-Oct.    | Nov-April   |              | May-Oct.    | Nov-April   |              |
| New York  | Generation (GWh)                     | 0         | 0         | 0            | 546        | 437        | 983          | 1,793       | 1,413       | 3,202        | 1,889       | 1,259       | 3,148        |
|   | Fuel Consumption (GBtu)              | 0         | 0         | 0            | 5,108      | 5,368      | 10,464       | 18,879      | 17,903      | 36,782       | 22,777      | 22,777      | 45,689       |
|   | Fuel Cost (\$000)                    | \$0       | \$0       | \$0          | (\$85,896) | (\$82,541) | (\$168,437)  | (\$261,568) | (\$271,209) | (\$532,777)  | (\$407,611) | (\$422,737) | (\$830,347)  |
|   | SO <sub>2</sub> Emissions (000 tons) | 0         | 0         | 0            | (1)        | (1)        | (1)          | (3)         | (2)         | (4)          | (5)         | (3)         | (8)          |
|   | NO <sub>x</sub> Emissions (000 tons) | 0         | 0         | 0            | 0          | 0          | 0            | 0           | 0           | 1            | (0)         | 0           | (0)          |
|   | CO <sub>2</sub> Emissions (000 tons) | 0         | 0         | 0            | (210)      | (150)      | (360)        | (593)       | (556)       | (1,149)      | (969)       | (836)       | (1,805)      |
|   | SO <sub>2</sub> Cost (\$000)         | \$0       | \$0       | \$0          | (\$1,058)  | (\$907)    | (\$1,866)    | (\$3,985)   | (\$2,705)   | (\$6,690)    | (\$8,733)   | (\$6,155)   | (\$14,888)   |
|   | NO <sub>x</sub> Cost (\$000)         | \$0       | \$0       | \$0          | \$27       | \$193      | \$220        | \$119       | \$949       | \$1,968      | (\$305)     | \$650       | \$345        |
|   | CO <sub>2</sub> Cost (\$000)         | \$0       | \$0       | \$0          | (\$272)    | (\$410)    | (\$982)      | (\$1,917)   | (\$1,797)   | (\$3,713)    | (\$4,171)   | (\$3,598)   | (\$7,770)    |
|   | CHP Generation (GWh)                 | 0         | 0         | 0            | 1,704      | 1,662      | 3,367        | 5,820       | 5,669       | 11,489       | 7,971       | 7,760       | 15,731       |
| New England                                     | Generation (GWh)                     | 0         | 0         | 0            | (143)      | (122)      | (265)        | (431)       | (350)       | (781)        | (455)       | (213)       | (668)        |
|   | Fuel Consumption (GBtu)              | 0         | 0         | 0            | (986)      | (920)      | (1,906)      | (3,616)     | (2,635)     | (6,251)      | (3,615)     | (1,556)     | (5,171)      |
|   | Fuel Cost (\$000)                    | \$0       | \$0       | \$0          | (\$6,749)  | (\$6,367)  | (\$13,116)   | (\$23,176)  | (\$18,297)  | (\$41,473)   | (\$25,407)  | (\$11,055)  | (\$36,462)   |
|   | SO <sub>2</sub> Emissions (000 tons) | 0         | 0         | 0            | 0          | 0          | 0            | (0)         | (0)         | (0)          | (0)         | (0)         | (0)          |
|   | NO <sub>x</sub> Emissions (000 tons) | 0         | 0         | 0            | (0)        | (0)        | (0)          | (0)         | (0)         | (0)          | (0)         | (0)         | (0)          |
|   | CO <sub>2</sub> Emissions (000 tons) | 0         | 0         | 0            | (51)       | (63)       | (113)        | (240)       | (182)       | (422)        | (247)       | (109)       | (356)        |
|   | SO <sub>2</sub> Cost (\$000)         | \$0       | \$0       | \$0          | \$102      | (\$116)    | (\$14)       | (\$425)     | (\$518)     | (\$944)      | (\$568)     | (\$269)     | (\$837)      |
|   | NO <sub>x</sub> Cost (\$000)         | \$0       | \$0       | \$0          | (\$2)      | \$1        | (\$1)        | (\$3)       | (\$3)       | (\$6)        | (\$8)       | (\$2)       | (\$11)       |
|   | CO <sub>2</sub> Cost (\$000)         | \$0       | \$0       | \$0          | \$5        | \$7        | \$12         | (\$66)      | (\$69)      | (\$135)      | (\$179)     | (\$72)      | (\$251)      |
|   | CHP Generation (GWh)                 | 0         | 0         | 0            | 0          | 0          | 0            | 0           | 0           | 0            | 0           | 0           | 0            |
| PJM   | Generation (GWh)                     | 0         | 0         | 0            | (25)       | (118)      | (143)        | (289)       | (193)       | (482)        | (525)       | (382)       | (908)        |
|   | Fuel Consumption (GBtu)              | 0         | 0         | 0            | (99)       | (850)      | (949)        | (2,788)     | (1,799)     | (4,587)      | (4,185)     | (2,655)     | (6,840)      |
|   | Fuel Cost (\$000)                    | \$0       | \$0       | \$0          | \$319      | (\$4,586)  | (\$4,266)    | (\$15,584)  | (\$6,173)   | (\$21,757)   | (\$24,357)  | (\$16,935)  | (\$41,292)   |
|   | SO <sub>2</sub> Emissions (000 tons) | 0         | 0         | 0            | (0)        | (0)        | (0)          | (1)         | (1)         | (2)          | (1)         | (0)         | (1)          |
|   | NO <sub>x</sub> Emissions (000 tons) | 0         | 0         | 0            | (0)        | (0)        | (0)          | (0)         | (0)         | (0)          | (0)         | (0)         | (0)          |
|   | CO <sub>2</sub> Emissions (000 tons) | 0         | 0         | 0            | (9)        | (65)       | (74)         | (197)       | (168)       | (365)        | (302)       | (189)       | (490)        |
|   | SO <sub>2</sub> Cost (\$000)         | \$0       | \$0       | \$0          | (\$64)     | (\$344)    | (\$408)      | (\$797)     | (\$2,169)   | (\$2,966)    | (\$1,940)   | (\$307)     | (\$2,247)    |
|   | NO <sub>x</sub> Cost (\$000)         | \$0       | \$0       | \$0          | (\$20)     | (\$43)     | (\$63)       | (\$153)     | (\$68)      | (\$315)      | (\$50)      | (\$50)      | (\$570)      |
|   | CO <sub>2</sub> Cost (\$000)         | \$0       | \$0       | \$0          | \$0        | \$0        | \$0          | (\$478)     | (\$491)     | (\$969)      | (\$1,986)   | (\$1,516)   | (\$3,502)    |
|   | CHP Generation (GWh)                 | 0         | 0         | 0            | 0          | 0          | 0            | 0           | 0           | 0            | 0           | 0           | 0            |
| ECAR  | Generation (GWh)                     | 0         | 0         | 0            | (147)      | (119)      | (265)        | (533)       | (156)       | (689)        | (312)       | (564)       | (876)        |
|   | Fuel Consumption (GBtu)              | 0         | 0         | 0            | (429)      | 529        | 100          | (2,750)     | (1,092)     | (3,842)      | (2,569)     | (1,708)     | (4,277)      |
|   | Fuel Cost (\$000)                    | \$0       | \$0       | \$0          | (\$6,379)  | (\$8,762)  | (\$15,142)   | (\$26,301)  | (\$4,822)   | (\$31,124)   | (\$12,918)  | (\$26,464)  | (\$39,382)   |
|   | SO <sub>2</sub> Emissions (000 tons) | 0         | 0         | 0            | (0)        | (0)        | (0)          | (1)         | (1)         | (2)          | (0)         | (1)         | (2)          |
|   | NO <sub>x</sub> Emissions (000 tons) | 0         | 0         | 0            | (0)        | (0)        | (0)          | (0)         | (0)         | (1)          | (0)         | (0)         | (0)          |
|   | CO <sub>2</sub> Emissions (000 tons) | 0         | 0         | 0            | (81)       | (44)       | (124)        | (314)       | (143)       | (458)        | (261)       | (324)       | (585)        |
|   | SO <sub>2</sub> Cost (\$000)         | \$0       | \$0       | \$0          | (\$78)     | \$270      | \$192        | (\$833)     | (\$1,546)   | (\$2,380)    | (\$1,505)   | (\$1,648)   | (\$3,153)    |
|   | NO <sub>x</sub> Cost (\$000)         | \$0       | \$0       | \$0          | (\$79)     | \$174      | \$95         | (\$257)     | (\$832)     | (\$1,089)    | (\$422)     | (\$555)     | (\$977)      |
|   | CO <sub>2</sub> Cost (\$000)         | \$0       | \$0       | \$0          | \$0        | \$0        | \$0          | (\$1,270)   | (\$580)     | (\$1,850)    | (\$1,867)   | (\$2,322)   | (\$4,188)    |
|   | CHP Generation (GWh)                 | 0         | 0         | 0            | 0          | 0          | 0            | 0           | 0           | 0            | 0           | 0           | 0            |
| SERC  | Generation (GWh)                     | 0         | 0         | 0            | (184)      | 276        | 92           | 38          | (302)       | (264)        | (198)       | 319         | 120          |
|   | Fuel Consumption (GBtu)              | 0         | 0         | 0            | (1,710)    | 2,025      | 315          | (338)       | (4,302)     | (4,640)      | (4,640)     | 2,820       | (1,575)      |
|   | Fuel Cost (\$000)                    | \$0       | \$0       | \$0          | (\$8,796)  | \$14,243   | \$5,447      | \$689       | (\$2,342)   | (\$1,653)    | (\$3,689)   | \$23,882    | \$20,193     |
|   | SO <sub>2</sub> Emissions (000 tons) | 0         | 0         | 0            | 0          | 0          | 0            | 0           | 0           | 0            | (0)         | (0)         | (0)          |
|   | NO <sub>x</sub> Emissions (000 tons) | 0         | 0         | 0            | 0          | 0          | 0            | (0)         | 0           | (0)          | 0           | (1)         | (0)          |
|   | CO <sub>2</sub> Emissions (000 tons) | 0         | 0         | 0            | (91)       | 145        | 54           | (58)        | (21)        | (39)         | (35)        | 136         | 101          |
|   | SO <sub>2</sub> Cost (\$000)         | \$0       | \$0       | \$0          | \$39       | \$276      | \$315        | \$148       | \$301       | \$448        | (\$19)      | (\$312)     | (\$331)      |
|   | NO <sub>x</sub> Cost (\$000)         | \$0       | \$0       | \$0          | \$191      | \$41       | \$232        | (\$904)     | \$632       | (\$273)      | \$667       | (\$1,534)   | (\$867)      |
|   | CO <sub>2</sub> Cost (\$000)         | \$0       | \$0       | \$0          | \$0        | \$0        | \$0          | (\$1,777)   | (\$331)     | (\$508)      | \$327       | \$25        | \$352        |
|   | CHP Generation (GWh)                 | 0         | 0         | 0            | 0          | 0          | 0            | 0           | 0           | 0            | 0           | 0           | 0            |
| Midwest   | Generation (GWh)                     | 0         | 0         | 0            | (34)       | (208)      | (242)        | (447)       | (434)       | (881)        | (217)       | (75)        | (292)        |
|   | Fuel Consumption (GBtu)              | 0         | 0         | 0            | (485)      | (1,891)    | (2,376)      | (4,368)     | (1,094)     | (5,462)      | (1,486)     | (1,255)     | (2,741)      |
|   | Fuel Cost (\$000)                    | \$0       | \$0       | \$0          | (\$2,842)  | (\$6,908)  | (\$9,749)    | (\$20,525)  | (\$23,535)  | (\$44,061)   | (\$10,475)  | \$146       | (\$10,329)   |
|   | SO <sub>2</sub> Emissions (000 tons) | 0         | 0         | 0            | (0)        | (0)        | (0)          | (0)         | (0)         | (0)          | (0)         | (0)         | (0)          |
|   | NO <sub>x</sub> Emissions (000 tons) | 0         | 0         | 0            | (0)        | (0)        | (0)          | (0)         | (0)         | (0)          | (0)         | (0)         | (0)          |
|   | CO <sub>2</sub> Emissions (000 tons) | 0         | 0         | 0            | (13)       | (91)       | (104)        | (263)       | (281)       | (543)        | (116)       | (46)        | (162)        |
|   | SO <sub>2</sub> Cost (\$000)         | \$0       | \$0       | \$0          | \$80       | (\$137)    | (\$57)       | (\$365)     | (\$209)     | (\$574)      | (\$255)     | (\$434)     | (\$689)      |
|   | NO <sub>x</sub> Cost (\$000)         | \$0       | \$0       | \$0          | \$23       | (\$20)     | \$3          | \$109       | (\$5)       | \$105        | \$86        | \$22        | \$108        |
|   | CO <sub>2</sub> Cost (\$000)         | \$0       | \$0       | \$0          | \$0        | \$0        | \$0          | (\$1,311)   | (\$346)     | (\$1,659)    | (\$964)     | (\$859)     | (\$1,642)    |
|   | CHP Generation (GWh)                 | 0         | 0         | 0            | 0          | 0          | 0            | 0           | 0           | 0            | 0           | 0           | 0            |
| Florida   | Generation (GWh)                     | 0         | 0         | 0            | 17         | (96)       | (79)         | (7)         | (42)        | (49)         | (35)        | (185)       | (220)        |
|   | Fuel Consumption (GBtu)              | 0         | 0         | 0            | 197        | (719)      | (522)        | (194)       | (383)       | (577)        | (633)       | (1,423)     | (2,055)      |
|   | Fuel Cost (\$000)                    | \$0       | \$0       | \$0          | \$1,024    | (\$2,999)  | (\$1,976)    | (\$1,229)   | (\$3,059)   | (\$4,288)    | (\$3,445)   | (\$10,038)  | (\$13,484)   |
|   | SO <sub>2</sub> Emissions (000 tons) | 0         | 0         | 0            | (0)        | 0          | 0            | 0           | 0           | 0            | 0           | 0           | 0            |
|   | NO <sub>x</sub> Emissions (000 tons) | 0         | 0         | 0            | (0)        | 0          | 0            | 0           | (0)         | 0            | 0           | (0)         | 0            |
|   | CO <sub>2</sub> Emissions (000 tons) | 0         | 0         | 0            | 5          | (4)        | 1            | (4)         | (16)        | (20)         | (20)        | (84)        | (104)        |
|   | SO <sub>2</sub> Cost (\$000)         | \$0       | \$0       | \$0          | (\$72)     | \$257      | \$185        | \$93        | \$35        | \$128        | \$149       | \$25        | \$175        |
|   | NO <sub>x</sub> Cost (\$000)         | \$0       | \$0       | \$0          | (\$25)     | \$98       | \$73         | \$35        | (\$9)       | \$26         | \$28        | (\$12)      | \$16         |
|   | CO <sub>2</sub> Cost (\$000)         | \$0       | \$0       | \$0          | \$0        | \$0        | \$0          | \$0         | \$0         | \$0          | \$0         | \$0         | \$0          |
|   | CHP Generation (GWh)                 | 0         | 0         | 0            | 0          | 0          | 0            | 0           | 0           | 0            | 0           | 0           | 0            |
| Canada  | Generation (GWh)                     | 0         | 0         | 0            | (73)       | (77)       | (150)        | (184)       | (58)        | (243)        | (250)       | (237)       | (487)        |
|   | Fuel Consumption (GBtu)              | 0         | 0         | 0            | (418)      | (475)      | (893)        | (545)       | (185)       | (729)        | (1,291)     | (1,386)     | (2,678)      |
|   | Fuel Cost (\$000)                    | \$0       | \$0       | \$0          | (\$3,240)  | (\$3,417)  | (\$6,657)    | (\$11,236)  | (\$2,534)   | (\$13,771)   | (\$13,054)  | (\$11,981)  | (\$25,016)   |
|   | SO <sub>2</sub> Emissions (000 tons) | 0         | 0         | 0            | (0)        | (0)        | (0)          | (0)         | (0)         | (0)          | (0)         | (0)         | (0)          |
|   | NO <sub>x</sub> Emissions (000 tons) | 0         | 0         | 0            | (0)        | (0)        | (0)          | (0)         | (0)         | (0)          | (0)         | (0)         | (0)          |
|   | CO <sub>2</sub> Emissions (000 tons) | 0         | 0         | 0            | (32)       | (31)       | (63)         | (123)       | (29)        | (152)        | (123)       | (98)        | (221)        |
|   | SO <sub>2</sub> Cost (\$000)         | \$0       | \$0       | \$0          | (\$10)     | \$0        | (\$10)       | (\$78)      | (\$18)      | (\$95)       | (\$40)      | (\$10)      | (\$49)       |
|   | NO <sub>x</sub> Cost (\$000)         | \$0       | \$0       | \$0          | (\$3)      | \$0        | (\$3)        | (\$158)     | \$0         | (\$158)      | (\$47)      | \$0         | (\$47)       |
|   | CO <sub>2</sub> Cost (\$000)         | \$0       | \$0       | \$0          | \$0        | \$0        | \$0          | \$0         | \$0         | \$0          | \$0         | \$0         | \$0          |
|   | CHP Generation (GWh)                 | 0         | 0         | 0            | 0          | 0          | 0            | 0           | 0           | 0            | 0           | 0           | 0            |
| Total For Run                                   | Generation (GWh)                     | 0         | 0         | 0            | (42)       | (27)       | (69)         | (66)        | (122)       | (187)        | (102)       | (79)        | (182)        |
|   | Fuel Consumption (GBtu)              | 0         | 0         | 0            | 1,178      | 3,054      | 4,232        | 4,281       | 6,413       | 10,694       | 4,739       | 15,613      | 20,351       |
|   | Fuel Cost (\$000)                    | \$0       | \$0       | \$0          | (\$12,558) | (\$10,337) | (\$213,895)  | (\$358,932) | (\$331,972) | (\$690,904)  | (\$500,957) | (\$475,163) | (\$976,120)  |
|   | SO <sub>2</sub> Emissions (000 tons) | 0         | 0         | 0            | (1)        | (0)        | (1)          | (4)         | (5)         | (9)          | (7)         | (5)         | (12)         |
|   | NO <sub>x</sub> Emissions (000 tons) | 0         | 0         | 0            | 0          | 0          | 0            | 1           | (1)         | (0)          | (1)         | (1)         | (1)          |
|   | CO <sub>2</sub> Emissions (000 tons) | 0         | 0         | 0            | (482)      | (302)      | (784)        | (1,756)     | (1,412)     | (3,168)      | (2,073)     | (1,549)     | (3,622)      |
|   | SO <sub>2</sub> Cost (\$000)         | \$0       | \$0       | \$0          | (\$1,062)  | (\$601)    | (\$1,863)    | (\$6,244)   | (\$6,829)   | (\$13,073)   | (\$12,909)  | (\$9,109)   | (\$22,019)   |
|   | NO <sub>x</sub> Cost (\$000)         | \$0       | \$0       | \$0          | \$111      | \$445      | \$556        | (\$1,212)   | \$417       | (\$795)      | (\$521)     | (\$1,482)   | (\$2,003)    |
|   | CO <sub>2</sub> Cost (\$000)         | \$0       | \$0       | \$0          | (\$568)    | (\$402)    | (\$970)      | (\$5,218)   | (\$3,615)   | (\$8,833)    | (\$8,859)   | (\$8,342)   | (\$17,201)   |
|   | CHP Generation (GWh)                 | 0         | 0         | 0            | 1,704      | 1,662      | 3,367        | 5,820       | 5,669       | 11,489       | 7,971       | 7,760       | 15,731       |

**Table 11. Comparison of the Reference Case and Scenario 2**

**Comparison Reference Case & Scenario 2 (2006\$)**

|               |                          | 2006                  |                        |              | 2010                  |                        |              | 2015                  |                        |              | 2020                  |                        |              |
|---------------|--------------------------|-----------------------|------------------------|--------------|-----------------------|------------------------|--------------|-----------------------|------------------------|--------------|-----------------------|------------------------|--------------|
| Market Area   | Data                     | Season 1:<br>May-Oct. | Season 2:<br>Nov-April | Annual Total | Season 1:<br>May-Oct. | Season 2:<br>Nov-April | Annual Total | Season 1:<br>May-Oct. | Season 2:<br>Nov-April | Annual Total | Season 1:<br>May-Oct. | Season 2:<br>Nov-April | Annual Total |
| New York      | Generation(GWh)          | 0                     | 0                      | 0            | 544                   | 426                    | 970          | 1,672                 | 1,367                  | 3,039        | 1,525                 | 1,285                  | 2,810        |
|               | Fuel Consumption (GBtu)  | 0                     | 0                      | 0            | 5,196                 | 4,868                  | 10,064       | 17,235                | 17,194                 | 34,429       | 18,969                | 21,758                 | 40,727       |
|               | Fuel Cost (\$000)        | \$0                   | \$0                    | \$0          | (\$84,695)            | (\$85,040)             | (\$169,735)  | (\$241,764)           | (\$244,277)            | (\$486,040)  | (\$390,028)           | (\$379,304)            | (\$769,332)  |
|               | SO2 Emissions (000 tons) | 0                     | 0                      | 0            | (1)                   | (1)                    | (2)          | (1)                   | (4)                    | (4)          | (3)                   | (7)                    | (7)          |
|               | NOx Emissions (000 tons) | 0                     | 0                      | 0            | (0)                   | (0)                    | (0)          | (1)                   | (1)                    | (1)          | (1)                   | (1)                    | (3)          |
|               | CO2 Emissions (000 tons) | 0                     | 0                      | 0            | (179)                 | (165)                  | (344)        | (483)                 | (380)                  | (863)        | (909)                 | (621)                  | (1,530)      |
|               | SO2 Cost (\$000)         | \$0                   | \$0                    | \$0          | (\$1,138)             | (\$725)                | (\$1,863)    | (\$3,376)             | (\$2,266)              | (\$5,642)    | (\$7,848)             | (\$6,057)              | (\$13,906)   |
|               | NOx Cost (\$000)         | \$0                   | \$0                    | \$0          | (\$206)               | (\$130)                | (\$336)      | (\$1,692)             | (\$1,011)              | (\$2,703)    | (\$3,616)             | (\$2,699)              | (\$6,315)    |
|               | CO2 Cost (\$000)         | \$0                   | \$0                    | \$0          | (\$489)               | (\$450)                | (\$939)      | (\$1,561)             | (\$1,227)              | (\$2,788)    | (\$3,915)             | (\$2,673)              | (\$6,588)    |
|               | CHP Generation (GWh)     | 0                     | 0                      | 0            | 1,686                 | 1,645                  | 3,331        | 5,347                 | 5,210                  | 10,557       | 7,314                 | 7,121                  | 14,435       |
| New England   | Generation(GWh)          | 0                     | 0                      | 0            | (130)                 | (137)                  | (267)        | (363)                 | (279)                  | (642)        | (206)                 | (396)                  | (602)        |
|               | Fuel Consumption (GBtu)  | 0                     | 0                      | 0            | (962)                 | (1,069)                | (2,031)      | (3,047)               | (1,961)                | (5,008)      | (3,335)               | (1,496)                | (4,831)      |
|               | Fuel Cost (\$000)        | \$0                   | \$0                    | \$0          | (\$6,765)             | (\$7,119)              | (\$13,883)   | (\$19,329)            | (\$13,538)             | (\$32,866)   | (\$22,677)            | (\$10,769)             | (\$33,446)   |
|               | SO2 Emissions (000 tons) | 0                     | 0                      | 0            | (1)                   | (0)                    | (0)          | (0)                   | (0)                    | (1)          | (1)                   | (0)                    | (1)          |
|               | NOx Emissions (000 tons) | 0                     | 0                      | 0            | (0)                   | (0)                    | (0)          | (0)                   | (0)                    | (0)          | (0)                   | (0)                    | (0)          |
|               | CO2 Emissions (000 tons) | 0                     | 0                      | 0            | (57)                  | (71)                   | (128)        | (206)                 | (122)                  | (328)        | (246)                 | (101)                  | (348)        |
|               | SO2 Cost (\$000)         | \$0                   | \$0                    | \$0          | \$85                  | (\$181)                | (\$96)       | (\$478)               | (\$271)                | (\$749)      | (\$1,047)             | (\$176)                | (\$1,224)    |
|               | NOx Cost (\$000)         | \$0                   | \$0                    | \$0          | (\$4)                 | (\$2)                  | (\$6)        | (\$4)                 | (\$5)                  | (\$9)        | (\$4)                 | (\$1)                  | (\$10)       |
|               | CO2 Cost (\$000)         | \$0                   | \$0                    | \$0          | \$27                  | (\$44)                 | (\$17)       | (\$95)                | (\$66)                 | (\$160)      | (\$224)               | (\$33)                 | (\$257)      |
|               | CHP Generation (GWh)     | 0                     | 0                      | 0            | 0                     | 0                      | 0            | 0                     | 0                      | 0            | 0                     | 0                      | 0            |
| PJM           | Generation(GWh)          | 0                     | 0                      | 0            | (33)                  | (81)                   | (114)        | (252)                 | (492)                  | (233)        | (435)                 | (353)                  | (846)        |
|               | Fuel Consumption (GBtu)  | 0                     | 0                      | 0            | (171)                 | (497)                  | (668)        | (2,334)               | (1,962)                | (4,296)      | (3,844)               | (2,541)                | (6,384)      |
|               | Fuel Cost (\$000)        | \$0                   | \$0                    | \$0          | (\$106)               | (\$3,588)              | (\$3,694)    | (\$13,352)            | (\$7,808)              | (\$21,160)   | (\$23,161)            | (\$16,567)             | (\$39,728)   |
|               | SO2 Emissions (000 tons) | 0                     | 0                      | 0            | (0)                   | (0)                    | (0)          | (0)                   | (1)                    | (2)          | (1)                   | (0)                    | (1)          |
|               | NOx Emissions (000 tons) | 0                     | 0                      | 0            | (0)                   | (0)                    | (0)          | (0)                   | (0)                    | (0)          | (0)                   | (0)                    | (0)          |
|               | CO2 Emissions (000 tons) | 0                     | 0                      | 0            | (14)                  | (32)                   | (46)         | (166)                 | (174)                  | (340)        | (272)                 | (174)                  | (446)        |
|               | SO2 Cost (\$000)         | \$0                   | \$0                    | \$0          | (\$76)                | \$29                   | (\$46)       | (\$591)               | (\$1,949)              | (\$2,630)    | (\$1,650)             | (\$550)                | (\$2,201)    |
|               | NOx Cost (\$000)         | \$0                   | \$0                    | \$0          | (\$22)                | (\$23)                 | (\$45)       | (\$140)               | (\$272)                | (\$412)      | (\$460)               | (\$98)                 | (\$558)      |
|               | CO2 Cost (\$000)         | \$0                   | \$0                    | \$0          | \$0                   | \$0                    | \$0          | (\$356)               | (\$561)                | (\$917)      | (\$1,670)             | (\$1,242)              | (\$2,912)    |
|               | CHP Generation (GWh)     | 0                     | 0                      | 0            | 0                     | 0                      | 0            | 0                     | 0                      | 0            | 0                     | 0                      | 0            |
| ECAR          | Generation(GWh)          | 0                     | 0                      | 0            | (123)                 | (40)                   | (164)        | (600)                 | (228)                  | (829)        | (266)                 | (470)                  | (736)        |
|               | Fuel Consumption (GBtu)  | 0                     | 0                      | 0            | (272)                 | (199)                  | (470)        | (3,169)               | (1,247)                | (4,416)      | (2,556)               | (1,330)                | (3,886)      |
|               | Fuel Cost (\$000)        | \$0                   | \$0                    | \$0          | (\$5,212)             | (\$803)                | (\$6,115)    | (\$28,434)            | (\$8,217)              | (\$36,651)   | (\$10,044)            | (\$21,122)             | (\$31,166)   |
|               | SO2 Emissions (000 tons) | 0                     | 0                      | 0            | (0)                   | (1)                    | (1)          | (1)                   | (1)                    | (1)          | (1)                   | (1)                    | (2)          |
|               | NOx Emissions (000 tons) | 0                     | 0                      | 0            | (0)                   | (0)                    | (0)          | (0)                   | (0)                    | (1)          | (0)                   | (0)                    | (0)          |
|               | CO2 Emissions (000 tons) | 0                     | 0                      | 0            | (71)                  | (37)                   | (108)        | (352)                 | (154)                  | (506)        | (215)                 | (277)                  | (492)        |
|               | SO2 Cost (\$000)         | \$0                   | \$0                    | \$0          | (\$93)                | (\$642)                | (\$735)      | (\$1,145)             | (\$1,044)              | (\$2,189)    | (\$1,021)             | (\$1,783)              | (\$2,804)    |
|               | NOx Cost (\$000)         | \$0                   | \$0                    | \$0          | (\$88)                | (\$49)                 | (\$137)      | (\$346)               | (\$817)                | (\$1,163)    | (\$344)               | (\$467)                | (\$811)      |
|               | CO2 Cost (\$000)         | \$0                   | \$0                    | \$0          | \$0                   | \$0                    | \$0          | (\$1,422)             | (\$622)                | (\$2,044)    | (\$1,542)             | (\$1,987)              | (\$3,529)    |
|               | CHP Generation (GWh)     | 0                     | 0                      | 0            | 0                     | 0                      | 0            | 0                     | 0                      | 0            | 0                     | 0                      | 0            |
| SERC          | Generation(GWh)          | 0                     | 0                      | 0            | (166)                 | 135                    | (31)         | 12                    | (212)                  | (200)        | (166)                 | 281                    | 115          |
|               | Fuel Consumption (GBtu)  | 0                     | 0                      | 0            | (1,485)               | 1,025                  | (459)        | 1,278                 | (3,521)                | (2,243)      | (4,002)               | 2,875                  | (1,128)      |
|               | Fuel Cost (\$000)        | \$0                   | \$0                    | \$0          | (\$7,792)             | \$6,381                | (\$1,411)    | (\$5,066)             | \$1,074                | (\$3,992)    | (\$361)               | \$20,735               | \$20,374     |
|               | SO2 Emissions (000 tons) | 0                     | 0                      | 0            | 0                     | (0)                    | (0)          | 0                     | 0                      | 0            | (0)                   | (0)                    | (0)          |
|               | NOx Emissions (000 tons) | 0                     | 0                      | 0            | 0                     | 0                      | 0            | 0                     | 0                      | 0            | 0                     | 0                      | 0            |
|               | CO2 Emissions (000 tons) | 0                     | 0                      | 0            | (84)                  | 57                     | (26)         | (93)                  | 5                      | (88)         | (16)                  | 109                    | 93           |
|               | SO2 Cost (\$000)         | \$0                   | \$0                    | \$0          | \$33                  | (\$54)                 | (\$21)       | \$7                   | \$263                  | \$270        | (\$23)                | (\$406)                | (\$429)      |
|               | NOx Cost (\$000)         | \$0                   | \$0                    | \$0          | \$147                 | \$51                   | \$199        | (\$1,470)             | \$568                  | (\$902)      | \$670                 | (\$1,516)              | (\$846)      |
|               | CO2 Cost (\$000)         | \$0                   | \$0                    | \$0          | \$0                   | \$0                    | \$0          | (\$146)               | (\$370)                | (\$517)      | \$452                 | (\$3)                  | \$449        |
|               | CHP Generation (GWh)     | 0                     | 0                      | 0            | 0                     | 0                      | 0            | 0                     | 0                      | 0            | 0                     | 0                      | 0            |
| Midwest       | Generation(GWh)          | 0                     | 0                      | 0            | (46)                  | (258)                  | (305)        | (400)                 | (377)                  | (777)        | (58)                  | (136)                  | (194)        |
|               | Fuel Consumption (GBtu)  | 0                     | 0                      | 0            | (531)                 | (2,258)                | (2,789)      | (3,954)               | (4,417)                | (4,441)      | (884)                 | (1,883)                | (2,866)      |
|               | Fuel Cost (\$000)        | \$0                   | \$0                    | \$0          | (\$3,309)             | (\$8,656)              | (\$11,965)   | (\$19,711)            | (\$22,121)             | (\$41,832)   | (\$3,010)             | (\$374)                | (\$33,383)   |
|               | SO2 Emissions (000 tons) | 0                     | 0                      | 0            | (0)                   | (0)                    | (0)          | (0)                   | (0)                    | (0)          | (0)                   | (0)                    | (0)          |
|               | NOx Emissions (000 tons) | 0                     | 0                      | 0            | (0)                   | (0)                    | (0)          | 0                     | 0                      | 0            | 0                     | 0                      | 0            |
|               | CO2 Emissions (000 tons) | 0                     | 0                      | 0            | (18)                  | (134)                  | (152)        | (216)                 | (238)                  | (454)        | (12)                  | (108)                  | (121)        |
|               | SO2 Cost (\$000)         | \$0                   | \$0                    | \$0          | \$78                  | (\$361)                | (\$283)      | (\$140)               | (\$49)                 | (\$189)      | \$76                  | (\$855)                | (\$779)      |
|               | NOx Cost (\$000)         | \$0                   | \$0                    | \$0          | \$9                   | (\$155)                | (\$147)      | \$96                  | (\$19)                 | \$77         | \$76                  | \$45                   | \$121        |
|               | CO2 Cost (\$000)         | \$0                   | \$0                    | \$0          | \$0                   | \$0                    | \$0          | (\$1,074)             | (\$115)                | (\$1,189)    | (\$596)               | (\$1,226)              | (\$1,821)    |
|               | CHP Generation (GWh)     | 0                     | 0                      | 0            | 0                     | 0                      | 0            | 0                     | 0                      | 0            | 0                     | 0                      | 0            |
| Florida       | Generation(GWh)          | 0                     | 0                      | 0            | 1                     | (17)                   | (15)         | 19                    | (76)                   | (208)        | (27)                  | (208)                  | (235)        |
|               | Fuel Consumption (GBtu)  | 0                     | 0                      | 0            | 85                    | (157)                  | (72)         | 62                    | (624)                  | (562)        | (442)                 | (1,511)                | (1,953)      |
|               | Fuel Cost (\$000)        | \$0                   | \$0                    | \$0          | \$100                 | \$1,268                | \$1,368      | \$208                 | (\$4,210)              | (\$4,002)    | (\$2,155)             | (\$10,698)             | (\$12,854)   |
|               | SO2 Emissions (000 tons) | 0                     | 0                      | 0            | (0)                   | 0                      | 0            | 0                     | 0                      | 0            | 0                     | 0                      | 0            |
|               | NOx Emissions (000 tons) | 0                     | 0                      | 0            | (0)                   | 0                      | 0            | 0                     | 0                      | 0            | 0                     | 0                      | 0            |
|               | CO2 Emissions (000 tons) | 0                     | 0                      | 0            | (1)                   | 36                     | 35           | 5                     | (30)                   | (25)         | (11)                  | (90)                   | (101)        |
|               | SO2 Cost (\$000)         | \$0                   | \$0                    | \$0          | (\$51)                | \$241                  | \$190        | \$22                  | \$14                   | \$36         | \$142                 | (\$6)                  | \$135        |
|               | NOx Cost (\$000)         | \$0                   | \$0                    | \$0          | (\$24)                | \$117                  | \$93         | \$21                  | (\$13)                 | \$8          | \$21                  | (\$15)                 | \$6          |
|               | CO2 Cost (\$000)         | \$0                   | \$0                    | \$0          | \$0                   | \$0                    | \$0          | \$0                   | \$0                    | \$0          | \$0                   | \$0                    | \$0          |
|               | CHP Generation (GWh)     | 0                     | 0                      | 0            | 0                     | 0                      | 0            | 0                     | 0                      | 0            | 0                     | 0                      | 0            |
| Canada        | Generation(GWh)          | 0                     | 0                      | 0            | (84)                  | (58)                   | (141)        | (146)                 | (62)                   | (208)        | (194)                 | (270)                  | (464)        |
|               | Fuel Consumption (GBtu)  | 0                     | 0                      | 0            | (397)                 | (354)                  | (751)        | (570)                 | (329)                  | (899)        | (833)                 | (1,594)                | (2,456)      |
|               | Fuel Cost (\$000)        | \$0                   | \$0                    | \$0          | (\$4,193)             | (\$2,554)              | (\$6,747)    | (\$8,023)             | (\$2,056)              | (\$10,079)   | (\$9,912)             | (\$13,480)             | (\$23,392)   |
|               | SO2 Emissions (000 tons) | 0                     | 0                      | 0            | (0)                   | 0                      | 0            | (0)                   | (0)                    | (0)          | (0)                   | (0)                    | (0)          |
|               | NOx Emissions (000 tons) | 0                     | 0                      | 0            | (0)                   | 0                      | 0            | (0)                   | (0)                    | (0)          | (0)                   | (0)                    | (0)          |
|               | CO2 Emissions (000 tons) | 0                     | 0                      | 0            | (41)                  | (23)                   | (64)         | (85)                  | (23)                   | (107)        | (95)                  | (112)                  | (207)        |
|               | SO2 Cost (\$000)         | \$0                   | \$0                    | \$0          | (\$10)                | \$2                    | (\$8)        | (\$39)                | (\$4)                  | (\$43)       | (\$40)                | (\$13)                 | (\$52)       |
|               | NOx Cost (\$000)         | \$0                   | \$0                    | \$0          | (\$3)                 | \$0                    | (\$3)        | (\$82)                | \$0                    | (\$32)       | (\$32)                | \$0                    | (\$32)       |
|               | CO2 Cost (\$000)         | \$0                   | \$0                    | \$0          | \$0                   | \$0                    | \$0          | \$0                   | \$0                    | \$0          | \$0                   | \$0                    | \$0          |
|               | CHP Generation (GWh)     | 0                     | 0                      | 0            | 0                     | 0                      | 0            | 0                     | 0                      | 0            | 0                     | 0                      | 0            |
| Total For Run | Generation(GWh)          | 0                     | 0                      | 0            | (38)                  | (30)                   | (68)         | (57)                  | (103)                  | (159)        | (73)                  | (79)                   | (152)        |
|               | Fuel Consumption (GBtu)  | 0                     | 0                      | 0            | 1,464                 | 1,359                  | 2,823        | 5,501                 | 7,063                  | 12,564       | 2,944                 | 14,278                 | 17,221       |
|               | Fuel Cost (\$000)        | \$0                   | \$0                    | \$0          | (\$112,072)           | (\$100,111)            | (\$212,183)  | (\$335,470)           | (\$301,152)            | (\$636,622)  | (\$461,348)           | (\$431,579)            | (\$892,927)  |
|               | SO2 Emissions (000 tons) | 0                     | 0                      | 0            | (1)                   | (1)                    | (2)          | (4)                   | (6)                    | (6)          | (6)                   | (6)                    | (12)         |
|               | NOx Emissions (000 tons) | 0                     | 0                      | 0            | (0)                   | (0)                    | (0)          | (2)                   | (3)                    | (2)          | (2)                   | (2)                    | (4)          |
|               | CO2 Emissions (000 tons) | 0                     | 0                      | 0            | (465)                 | (368)                  | (833)        | (1,595)               | (1,116)                | (2,711)      | (1,777)               | (1,375)                | (3,152)      |
|               | SO2 Cost (\$000)         | \$0                   | \$0                    | \$0          | (\$1,170)             | (\$1,691)              | (\$2,861)    | (\$5,730)             | (\$5,305)              | (\$11,036)   | (\$11,412)            | (\$9,846)              | (\$21,258)   |
|               | NOx Cost (\$000)         | \$0                   | \$0                    | \$0          | (\$191)               | (\$192)                | (\$382)      | (\$3,617)             | (\$1,569)              | (\$5,186)    | (\$3,693)             | (\$4,752)              | (\$8,445)    |
|               | CO2 Cost (\$000)         | \$0                   | \$0                    | \$0          | (\$462)               | (\$494)                | (\$956)      | (\$4,654)             | (\$2,961)              | (\$7,614)    | (\$7,495)             | (\$7,164)              | (\$14,659)   |
|               | CHP Generation (GWh)     | 0                     | 0                      | 0            | 1,686                 | 1,645                  | 3,331        | 5,347                 | 5,210                  | 10,557       | 7,314                 | 7,121                  | 14,435       |

**Table 12. Comparison of the Reference Case and Scenario 3**

**Comparison Reference Case & Scenario 3 (2006\$)**

|               |                          | 2006                  |                        |              | 2010                  |                        |              | 2015                  |                        |              | 2020                  |                        |              |
|---------------|--------------------------|-----------------------|------------------------|--------------|-----------------------|------------------------|--------------|-----------------------|------------------------|--------------|-----------------------|------------------------|--------------|
| Market Area   | Data                     | Season 1:<br>May-Oct. | Season 2:<br>Nov-April | Annual Total | Season 1:<br>May-Oct. | Season 2:<br>Nov-April | Annual Total | Season 1:<br>May-Oct. | Season 2:<br>Nov-April | Annual Total | Season 1:<br>May-Oct. | Season 2:<br>Nov-April | Annual Total |
| New York      | Generation (GWh)         | 0                     | 0                      | 0            | 622                   | 478                    | 1,100        | 1,787                 | 1,470                  | 3,258        | 1,864                 | 1,358                  | 3,222        |
|               | Fuel Consumption (GBtu)  | 0                     | 0                      | 0            | 6,031                 | 5,515                  | 11,546       | 19,034                | 18,246                 | 37,280       | 23,105                | 23,915                 | 47,021       |
|               | Fuel Cost (\$000)        | \$0                   | \$0                    | \$0          | (\$95,030)            | (\$96,935)             | (\$191,965)  | (\$275,871)           | (\$283,665)            | (\$559,536)  | (\$422,918)           | (\$428,575)            | (\$851,493)  |
|               | SO2 Emissions (000 tons) | 0                     | 0                      | 0            | (1)                   | (1)                    | (2)          | (2)                   | (2)                    | (4)          | (5)                   | (4)                    | (8)          |
|               | NOx Emissions (000 tons) | 0                     | 0                      | 0            | 1                     | 1                      | 1            | 1                     | 1                      | 2            | 0                     | 1                      | 1            |
|               | CO2 Emissions (000 tons) | 0                     | 0                      | 0            | (202)                 | (208)                  | (410)        | (617)                 | (577)                  | (1,194)      | (983)                 | (817)                  | (1,800)      |
|               | SO2 Cost (\$000)         | \$0                   | \$0                    | \$0          | (\$1,206)             | (\$1,070)              | (\$2,276)    | (\$3,610)             | (\$2,796)              | (\$6,406)    | (\$8,494)             | (\$6,889)              | (\$15,183)   |
|               | NOx Cost (\$000)         | \$0                   | \$0                    | \$0          | \$1,082               | \$1,488                | \$2,570      | \$1,271               | \$1,941                | \$3,212      | \$886                 | \$1,756                | \$2,642      |
|               | CO2 Cost (\$000)         | \$0                   | \$0                    | \$0          | (\$550)               | (\$567)                | (\$1,117)    | (\$1,993)             | (\$1,864)              | (\$3,857)    | (\$4,275)             | (\$3,518)              | (\$7,793)    |
|               | CHP Generation (GWh)     | 0                     | 0                      | 0            | 1,929                 | 1,881                  | 3,810        | 6,041                 | 5,885                  | 11,926       | 8,191                 | 7,973                  | 16,164       |
| New England   | Generation (GWh)         | 0                     | 0                      | 0            | (98)                  | (157)                  | (255)        | (411)                 | (368)                  | (779)        | (491)                 | (238)                  | (729)        |
|               | Fuel Consumption (GBtu)  | 0                     | 0                      | 0            | (684)                 | (1,250)                | (1,933)      | (3,573)               | (2,688)                | (6,261)      | (4,003)               | (1,826)                | (5,829)      |
|               | Fuel Cost (\$000)        | \$0                   | \$0                    | \$0          | (\$3,870)             | (\$7,420)              | (\$11,290)   | (\$22,910)            | (\$18,487)             | (\$41,397)   | (\$27,864)            | (\$12,798)             | (\$40,683)   |
|               | SO2 Emissions (000 tons) | 0                     | 0                      | 0            | (0)                   | (0)                    | (0)          | (0)                   | (0)                    | (0)          | (0)                   | (0)                    | (0)          |
|               | NOx Emissions (000 tons) | 0                     | 0                      | 0            | (0)                   | (0)                    | (0)          | (0)                   | (0)                    | (0)          | (0)                   | (0)                    | (0)          |
|               | CO2 Emissions (000 tons) | 0                     | 0                      | 0            | (40)                  | (98)                   | (138)        | (242)                 | (175)                  | (418)        | (282)                 | (127)                  | (409)        |
|               | SO2 Cost (\$000)         | \$0                   | \$0                    | \$0          | (\$34)                | (\$500)                | (\$534)      | (\$466)               | (\$368)                | (\$834)      | (\$852)               | (\$525)                | (\$1,377)    |
|               | NOx Cost (\$000)         | \$0                   | \$0                    | \$0          | \$1                   | (\$9)                  | (\$8)        | (\$2)                 | (\$5)                  | (\$7)        | (\$10)                | (\$3)                  | (\$12)       |
|               | CO2 Cost (\$000)         | \$0                   | \$0                    | \$0          | \$10                  | (\$89)                 | (\$79)       | (\$39)                | (\$140)                | (\$179)      | (\$210)               | (\$45)                 | (\$255)      |
|               | CHP Generation (GWh)     | 0                     | 0                      | 0            | 0                     | 0                      | 0            | 0                     | 0                      | 0            | 0                     | 0                      | 0            |
| PJM           | Generation (GWh)         | 0                     | 0                      | 0            | (26)                  | (106)                  | (132)        | (276)                 | (266)                  | (542)        | (389)                 | (399)                  | (907)        |
|               | Fuel Consumption (GBtu)  | 0                     | 0                      | 0            | (146)                 | (678)                  | (824)        | (2,706)               | (2,315)                | (5,021)      | (4,197)               | (2,773)                | (6,970)      |
|               | Fuel Cost (\$000)        | \$0                   | \$0                    | \$0          | (\$324)               | (\$4,032)              | (\$3,708)    | (\$14,983)            | (\$10,101)             | (\$25,084)   | (\$22,934)            | (\$18,421)             | (\$41,355)   |
|               | SO2 Emissions (000 tons) | 0                     | 0                      | 0            | (0)                   | (0)                    | (0)          | (0)                   | (1)                    | (2)          | (1)                   | (0)                    | (2)          |
|               | NOx Emissions (000 tons) | 0                     | 0                      | 0            | (0)                   | (0)                    | (0)          | (0)                   | (0)                    | (0)          | (0)                   | (0)                    | (0)          |
|               | CO2 Emissions (000 tons) | 0                     | 0                      | 0            | (14)                  | (46)                   | (60)         | (196)                 | (196)                  | (316)        | (316)                 | (187)                  | (503)        |
|               | SO2 Cost (\$000)         | \$0                   | \$0                    | \$0          | (\$54)                | (\$167)                | (\$222)      | (\$751)               | (\$2,015)              | (\$2,766)    | (\$2,773)             | (\$607)                | (\$3,381)    |
|               | NOx Cost (\$000)         | \$0                   | \$0                    | \$0          | (\$23)                | (\$58)                 | (\$81)       | (\$167)               | (\$343)                | (\$510)      | (\$656)               | (\$66)                 | (\$722)      |
|               | CO2 Cost (\$000)         | \$0                   | \$0                    | \$0          | \$0                   | \$0                    | \$0          | (\$482)               | (\$484)                | (\$966)      | (\$2,235)             | (\$1,297)              | (\$3,532)    |
|               | CHP Generation (GWh)     | 0                     | 0                      | 0            | 0                     | 0                      | 0            | 0                     | 0                      | 0            | 0                     | 0                      | 0            |
| ECAR          | Generation (GWh)         | 0                     | 0                      | 0            | (167)                 | (38)                   | (205)        | (614)                 | (183)                  | (797)        | (274)                 | (529)                  | (803)        |
|               | Fuel Consumption (GBtu)  | 0                     | 0                      | 0            | (571)                 | (128)                  | (696)        | (3,232)               | (480)                  | (3,712)      | (2,129)               | (1,531)                | (3,661)      |
|               | Fuel Cost (\$000)        | \$0                   | \$0                    | \$0          | (\$7,980)             | (\$1,477)              | (\$9,457)    | (\$29,978)            | (\$7,501)              | (\$37,478)   | (\$11,444)            | (\$24,645)             | (\$36,088)   |
|               | SO2 Emissions (000 tons) | 0                     | 0                      | 0            | (0)                   | (0)                    | (0)          | (0)                   | (1)                    | (2)          | (1)                   | (1)                    | (2)          |
|               | NOx Emissions (000 tons) | 0                     | 0                      | 0            | (0)                   | (0)                    | (0)          | (0)                   | (0)                    | (1)          | (0)                   | (0)                    | (0)          |
|               | CO2 Emissions (000 tons) | 0                     | 0                      | 0            | (76)                  | (29)                   | (105)        | (357)                 | (140)                  | (497)        | (218)                 | (303)                  | (522)        |
|               | SO2 Cost (\$000)         | \$0                   | \$0                    | \$0          | \$723                 | (\$103)                | \$620        | (\$918)               | (\$1,560)              | (\$2,477)    | (\$1,266)             | (\$1,724)              | (\$2,990)    |
|               | NOx Cost (\$000)         | \$0                   | \$0                    | \$0          | \$45                  | (\$68)                 | (\$22)       | (\$296)               | (\$921)                | (\$1,217)    | (\$287)               | (\$484)                | (\$771)      |
|               | CO2 Cost (\$000)         | \$0                   | \$0                    | \$0          | \$0                   | \$0                    | \$0          | (\$1,442)             | (\$564)                | (\$2,006)    | (\$1,564)             | (\$2,174)              | (\$3,739)    |
|               | CHP Generation (GWh)     | 0                     | 0                      | 0            | 0                     | 0                      | 0            | 0                     | 0                      | 0            | 0                     | 0                      | 0            |
| SERC          | Generation (GWh)         | 0                     | 0                      | 0            | (261)                 | 168                    | (93)         | 19                    | (197)                  | (177)        | (186)                 | 290                    | 104          |
|               | Fuel Consumption (GBtu)  | 0                     | 0                      | 0            | (1,581)               | 1,517                  | (64)         | 1,270                 | (3,664)                | (2,393)      | (3,498)               | 2,716                  | (782)        |
|               | Fuel Cost (\$000)        | \$0                   | \$0                    | \$0          | (\$14,946)            | \$8,676                | (\$6,270)    | (\$5,639)             | \$1,292                | (\$4,347)    | (\$2,591)             | \$22,387               | \$19,797     |
|               | SO2 Emissions (000 tons) | 0                     | 0                      | 0            | (0)                   | (0)                    | (0)          | (0)                   | (0)                    | (0)          | (0)                   | (0)                    | (0)          |
|               | NOx Emissions (000 tons) | 0                     | 0                      | 0            | (0)                   | (0)                    | (0)          | (0)                   | (0)                    | (0)          | (0)                   | (0)                    | (0)          |
|               | CO2 Emissions (000 tons) | 0                     | 0                      | 0            | (159)                 | 93                     | (66)         | (109)                 | 8                      | (101)        | (35)                  | 122                    | 87           |
|               | SO2 Cost (\$000)         | \$0                   | \$0                    | \$0          | (\$19)                | \$211                  | \$192        | (\$176)               | \$254                  | \$78         | \$10                  | (\$366)                | (\$356)      |
|               | NOx Cost (\$000)         | \$0                   | \$0                    | \$0          | (\$99)                | (\$29)                 | (\$128)      | (\$1,535)             | \$616                  | (\$919)      | \$472                 | (\$1,601)              | (\$1,129)    |
|               | CO2 Cost (\$000)         | \$0                   | \$0                    | \$0          | \$0                   | \$0                    | \$0          | (\$269)               | (\$143)                | (\$411)      | \$223                 | (\$132)                | \$91         |
|               | CHP Generation (GWh)     | 0                     | 0                      | 0            | 0                     | 0                      | 0            | 0                     | 0                      | 0            | 0                     | 0                      | 0            |
| Midwest       | Generation (GWh)         | 0                     | 0                      | 0            | (53)                  | (217)                  | (270)        | (425)                 | (487)                  | (911)        | (219)                 | (123)                  | (342)        |
|               | Fuel Consumption (GBtu)  | 0                     | 0                      | 0            | (794)                 | (1,308)                | (2,092)      | (4,279)               | (1,599)                | (5,878)      | (2,022)               | (1,834)                | (3,856)      |
|               | Fuel Cost (\$000)        | \$0                   | \$0                    | \$0          | (\$2,971)             | (\$10,217)             | (\$13,188)   | (\$20,622)            | (\$26,183)             | (\$47,005)   | (\$9,508)             | (\$9,508)              | (\$8,700)    |
|               | SO2 Emissions (000 tons) | 0                     | 0                      | 0            | (0)                   | (0)                    | (0)          | (0)                   | (0)                    | (0)          | (0)                   | (1)                    | (1)          |
|               | NOx Emissions (000 tons) | 0                     | 0                      | 0            | (0)                   | (0)                    | (0)          | (0)                   | (0)                    | (0)          | (0)                   | (0)                    | (0)          |
|               | CO2 Emissions (000 tons) | 0                     | 0                      | 0            | (39)                  | (109)                  | (148)        | (234)                 | (302)                  | (536)        | (110)                 | (109)                  | (219)        |
|               | SO2 Cost (\$000)         | \$0                   | \$0                    | \$0          | (\$60)                | (\$93)                 | (\$154)      | (\$156)               | (\$179)                | (\$335)      | (\$245)               | (\$948)                | (\$1,193)    |
|               | NOx Cost (\$000)         | \$0                   | \$0                    | \$0          | (\$1)                 | (\$51)                 | (\$53)       | (\$53)                | \$88                   | \$14         | \$82                  | \$14                   | \$96         |
|               | CO2 Cost (\$000)         | \$0                   | \$0                    | \$0          | \$0                   | \$0                    | \$0          | (\$1,136)             | (\$337)                | (\$1,473)    | (\$1,011)             | (\$1,293)              | (\$2,304)    |
|               | CHP Generation (GWh)     | 0                     | 0                      | 0            | 0                     | 0                      | 0            | 0                     | 0                      | 0            | 0                     | 0                      | 0            |
| Florida       | Generation (GWh)         | 0                     | 0                      | 0            | 12                    | (97)                   | (86)         | (9)                   | (63)                   | (72)         | (17)                  | (195)                  | (213)        |
|               | Fuel Consumption (GBtu)  | 0                     | 0                      | 0            | 165                   | (740)                  | (575)        | (233)                 | (637)                  | (870)        | (376)                 | (1,493)                | (1,868)      |
|               | Fuel Cost (\$000)        | \$0                   | \$0                    | \$0          | \$298                 | (\$3,018)              | (\$2,720)    | (\$1,245)             | (\$2,403)              | (\$3,647)    | (\$1,985)             | (\$10,602)             | (\$12,587)   |
|               | SO2 Emissions (000 tons) | 0                     | 0                      | 0            | (0)                   | (0)                    | (0)          | (0)                   | (0)                    | (0)          | (0)                   | (0)                    | (0)          |
|               | NOx Emissions (000 tons) | 0                     | 0                      | 0            | (0)                   | (0)                    | (0)          | (0)                   | (0)                    | (0)          | (0)                   | (0)                    | (0)          |
|               | CO2 Emissions (000 tons) | 0                     | 0                      | 0            | 1                     | (7)                    | (6)          | (6)                   | (6)                    | (12)         | (11)                  | (88)                   | (99)         |
|               | SO2 Cost (\$000)         | \$0                   | \$0                    | \$0          | (\$74)                | \$249                  | \$175        | \$72                  | \$238                  | \$310        | \$104                 | \$40                   | \$144        |
|               | NOx Cost (\$000)         | \$0                   | \$0                    | \$0          | (\$37)                | \$90                   | \$53         | \$41                  | \$95                   | \$135        | \$6                   | \$0                    | (\$5)        |
|               | CO2 Cost (\$000)         | \$0                   | \$0                    | \$0          | \$0                   | \$0                    | \$0          | \$0                   | \$0                    | \$0          | \$0                   | \$0                    | \$0          |
|               | CHP Generation (GWh)     | 0                     | 0                      | 0            | 0                     | 0                      | 0            | 0                     | 0                      | 0            | 0                     | 0                      | 0            |
| Canada        | Generation (GWh)         | 0                     | 0                      | 0            | (71)                  | (70)                   | (142)        | (137)                 | (34)                   | (170)        | (258)                 | (258)                  | (526)        |
|               | Fuel Consumption (GBtu)  | 0                     | 0                      | 0            | (317)                 | (379)                  | (696)        | (237)                 | (38)                   | (275)        | (1,324)               | (1,506)                | (2,830)      |
|               | Fuel Cost (\$000)        | \$0                   | \$0                    | \$0          | (\$3,863)             | (\$3,129)              | (\$6,792)    | (\$9,074)             | (\$1,181)              | (\$10,255)   | (\$13,107)            | (\$13,603)             | (\$26,711)   |
|               | SO2 Emissions (000 tons) | 0                     | 0                      | 0            | (0)                   | (0)                    | (0)          | (0)                   | (0)                    | (0)          | (0)                   | (0)                    | (0)          |
|               | NOx Emissions (000 tons) | 0                     | 0                      | 0            | (0)                   | (0)                    | (0)          | (0)                   | (0)                    | (0)          | (0)                   | (0)                    | (0)          |
|               | CO2 Emissions (000 tons) | 0                     | 0                      | 0            | (36)                  | (30)                   | (66)         | (101)                 | (16)                   | (117)        | (123)                 | (114)                  | (237)        |
|               | SO2 Cost (\$000)         | \$0                   | \$0                    | \$0          | (\$11)                | (\$4)                  | (\$15)       | (\$73)                | (\$12)                 | (\$85)       | (\$40)                | (\$18)                 | (\$58)       |
|               | NOx Cost (\$000)         | \$0                   | \$0                    | \$0          | (\$3)                 | \$0                    | (\$3)        | (\$158)               | \$0                    | (\$158)      | (\$46)                | \$0                    | (\$46)       |
|               | CO2 Cost (\$000)         | \$0                   | \$0                    | \$0          | \$0                   | \$0                    | \$0          | \$0                   | \$0                    | \$0          | \$0                   | \$0                    | \$0          |
|               | CHP Generation (GWh)     | 0                     | 0                      | 0            | 0                     | 0                      | 0            | 0                     | 0                      | 0            | 0                     | 0                      | 0            |
| Total For Run | Generation (GWh)         | 0                     | 0                      | 0            | (43)                  | (40)                   | (83)         | (65)                  | (127)                  | (191)        | (101)                 | (93)                   | (194)        |
|               | Fuel Consumption (GBtu)  | 0                     | 0                      | 0            | 2,113                 | 2,553                  | 4,666        | 6,043                 | 6,826                  | 12,870       | 5,557                 | 15,668                 | 21,225       |
|               | Fuel Cost (\$000)        | \$0                   | \$0                    | \$0          | (\$127,840)           | (\$117,550)            | (\$245,390)  | (\$380,521)           | (\$348,230)            | (\$728,751)  | (\$512,371)           | (\$485,450)            | (\$997,821)  |
|               | SO2 Emissions (000 tons) | 0                     | 0                      | 0            | (1)                   | (1)                    | (2)          | (4)                   | (4)                    | (9)          | (7)                   | (6)                    | (13)         |
|               | NOx Emissions (000 tons) | 0                     | 0                      | 0            | 0                     | 1                      | 1            | 1                     | 0                      | 0            | 0                     | 0                      | 0            |
|               | CO2 Emissions (000 tons) | 0                     | 0                      | 0            | (565)                 | (433)                  | (998)        | (1,862)               | (1,403)                | (3,265)      | (2,087)               | (1,623)                | (3,710)      |
|               | SO2 Cost (\$000)         | \$0                   | \$0                    | \$0          | (\$735)               | (\$1,478)              | (\$2,213)    | (\$6,077)             | (\$6,437)              | (\$12,515)   | (\$13,566)            | (\$10,837)             | (\$24,393)   |
|               | NOx Cost (\$000)         | \$0                   | \$0                    | \$0          | \$966                 | \$1,363                | \$2,329      | (\$757)               | \$1,397                | \$641        | \$447                 | (\$393)                | \$54         |
|               | CO2 Cost (\$000)         | \$0                   | \$0                    | \$0          | (\$541)               | (\$656)                | (\$1,197)    | (\$5,361)             | (\$3,531)              | (\$8,892)    | (\$9,073)             | (\$8,459)              | (\$17,532)   |
|               | CHP Generation (GWh)     | 0                     | 0                      | 0            | 1,929                 | 1,881                  | 3,810        | 6,041                 | 5,885                  | 11,926       | 8,191                 | 7,973                  | 16,164       |

As illustrated above, the results of the study were all driven directly by and are correlated to the amount of CHP generation in a given year or scenario. As the quantity of CHP generation increased, the overall

market efficiency (Btu/kWh) also tended to increase<sup>3</sup>. In addition, as fuels were substituted, emissions of CO<sub>2</sub> and SO<sub>2</sub> tended to decline while emissions of NO<sub>x</sub> tended to increase. Figure 4 below shows the increase in CHP generation over the forecast period and the difference in levels of CHP generation between scenarios. CHP generation was zero in the Reference Case and in 2006, both of which represented cases and periods before the introduction of CHP from the policy programs studied under this analysis.

**Figure 4. CHP Generation in New York by Year and Scenario**

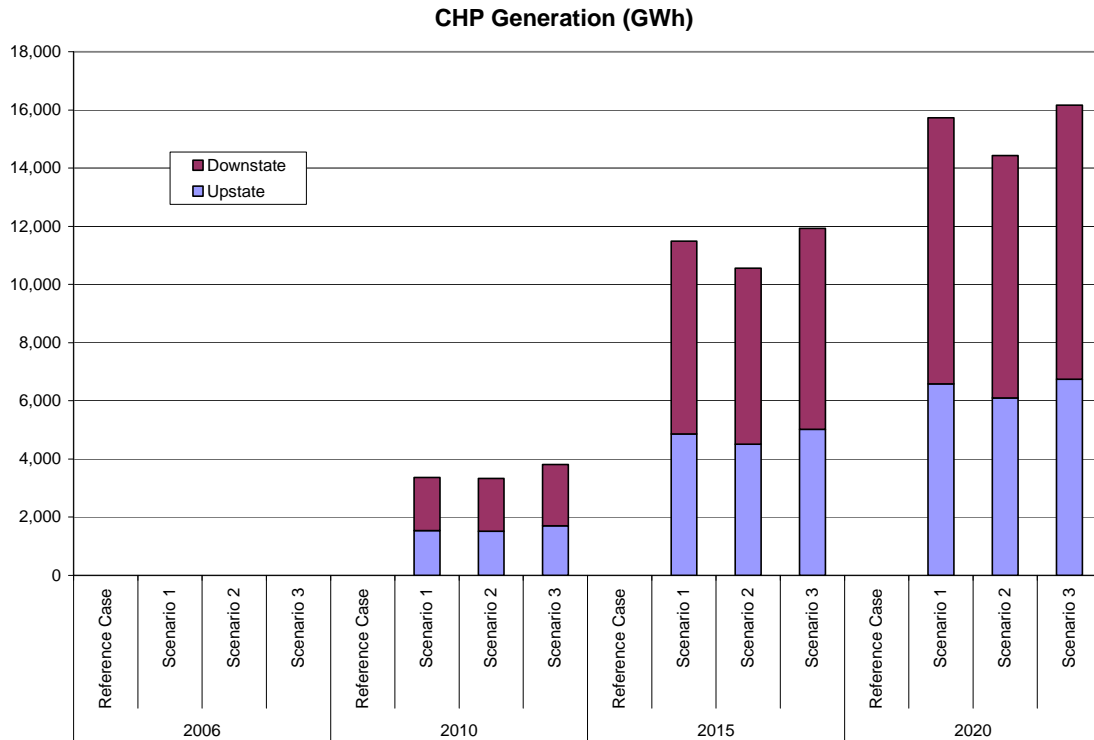
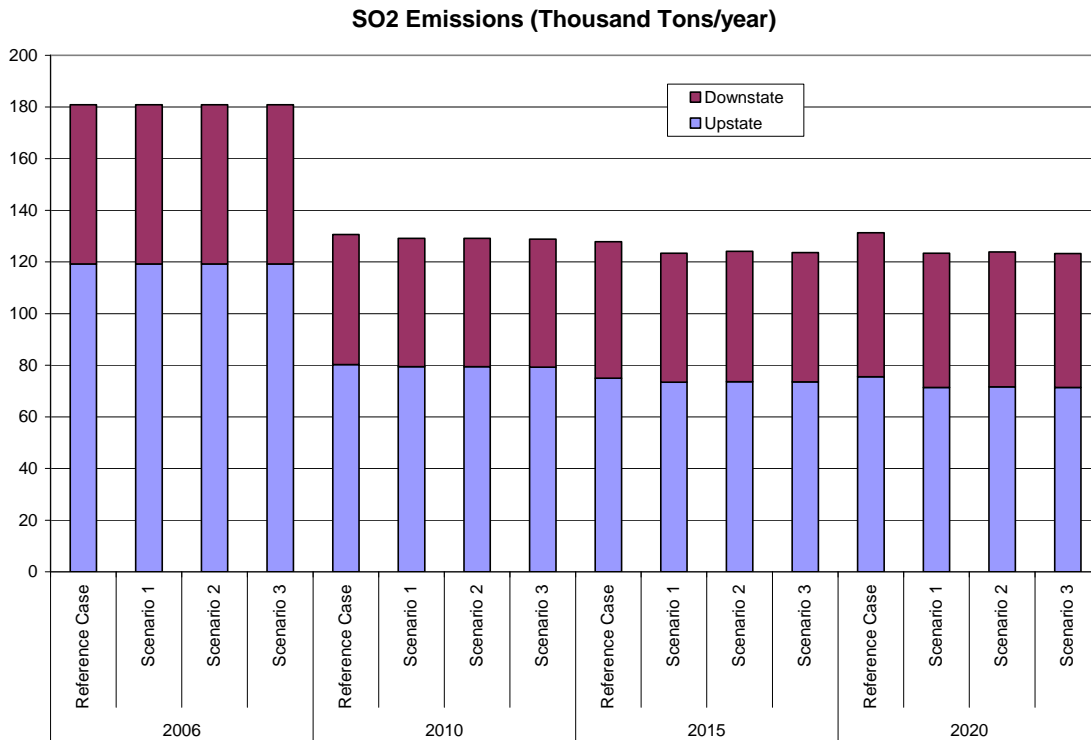


Figure 5 provides a comparison of SO<sub>2</sub> emissions for the Reference Case and the three scenarios over the forecast period. As illustrated in the figure, there was dramatic decline in SO<sub>2</sub> emissions after 2010. This was due to the planned retirement of coal capacity in upstate New York. CHP resources were projected to provide a significant reduction in SO<sub>2</sub> emission levels when compared to the Reference Case during the forecast period. Although the reductions between CHP scenarios were subtle, the reduction between the Reference Case and the CHP scenarios were approximately 1,500 tons in 2010, 4,000 tons in 2015, and

<sup>3</sup> Increased efficiency in this case would indicate that fewer BTUs were consumed for each kWh produced.

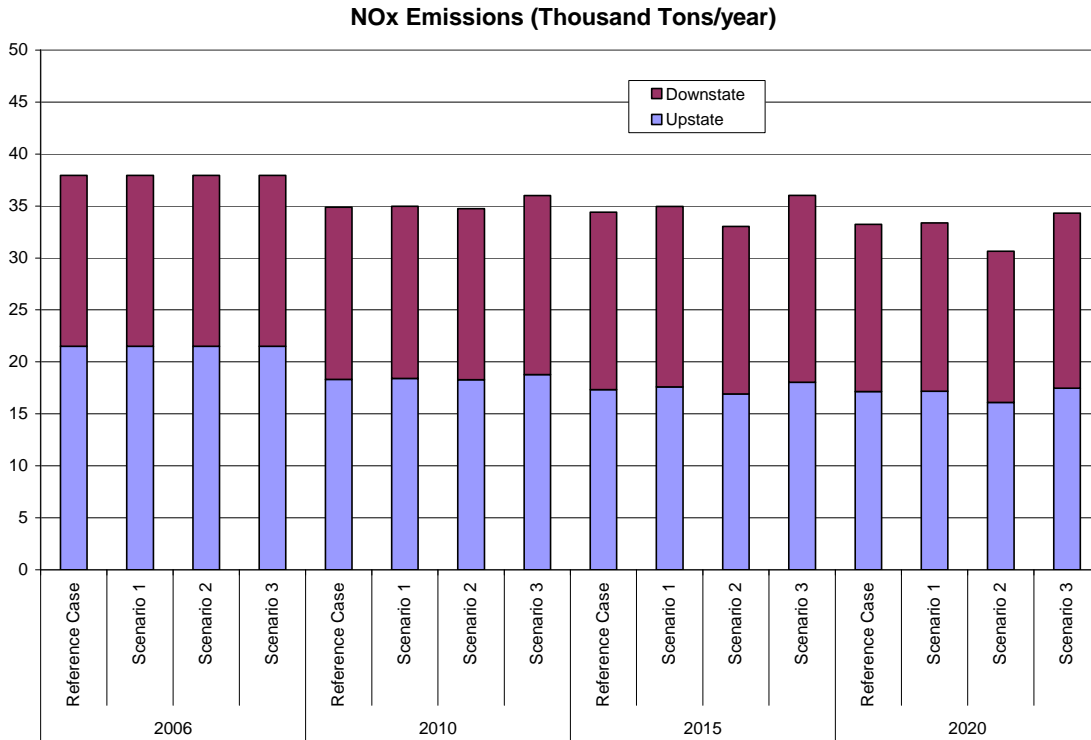
8,000 tons in 2020. As can be seen, the reduction in SO<sub>2</sub> emissions was most dramatic in downstate NY, where SO<sub>2</sub> was projected to decrease due to displacement of oil-fired capacity.

**Figure 5. SO<sub>2</sub> Emissions by Year and Scenario**



Similarly to the above, Figure 6 illustrates an overall decline in NO<sub>x</sub> emissions over the forecast period due to the planned retirement of coal capacity in upstate New York. As also can be seen from this figure, the projected amount of NO<sub>x</sub> emissions was proportional to the amount of CHP resources being included in the forecast beginning in 2010. In Scenario 1, the projected NO<sub>x</sub> emissions were similar to those in the Reference Case. In Scenario 2, which includes less CHP generation, the projected NO<sub>x</sub> emissions were less than Scenario 1. In Scenario 3, which includes more CHP generation than the Scenario 1, the projected NO<sub>x</sub> emissions were higher than Scenario 1. This indicates that the NO<sub>x</sub> emissions from CHP generation were, on average, higher than the energy that the CHP resources were displacing from central station plants. In terms of the magnitude of the NO<sub>x</sub> emissions from the introduction of CHP resources, in 2015 NO<sub>x</sub> emissions for Scenarios 1, 2, and 3 were approximately 35,000, 33,000, and 36,000 tons, respectively. Similarly, in 2020, NO<sub>x</sub> emissions for Scenarios 1, 2, and 3 were projected to be 33,400, 30,700, and 34,300 tons, respectively. The changes in NO<sub>x</sub> emissions between cases were projected to be minimal in 2010.

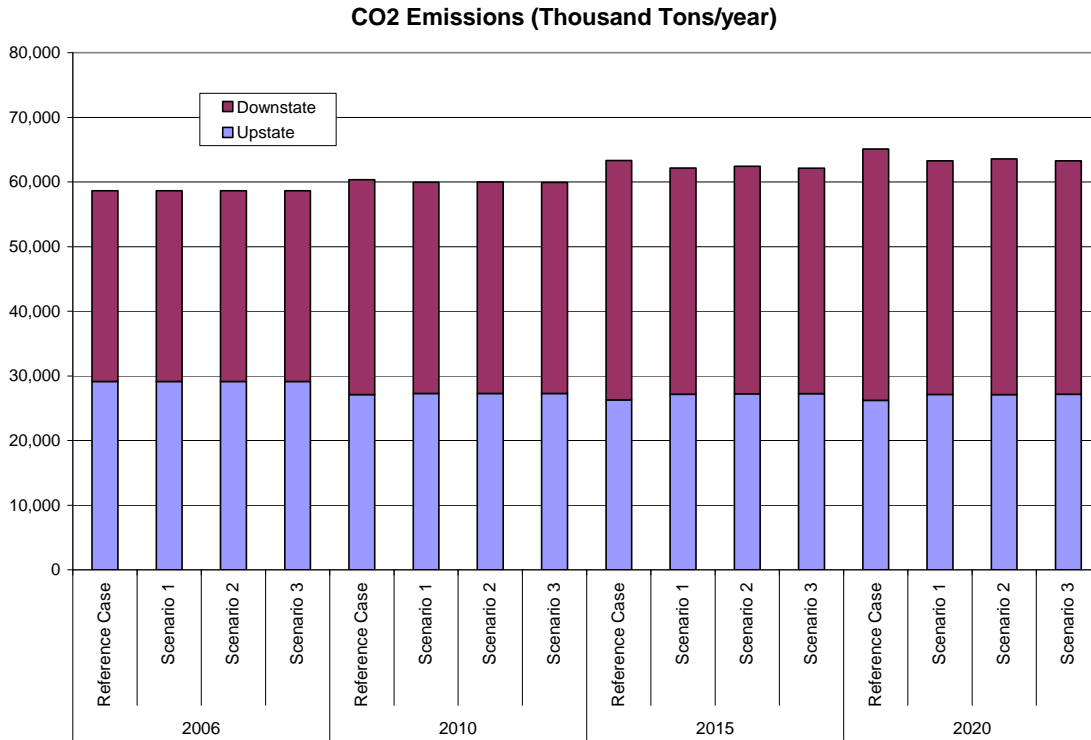
**Figure 6. NOx Emissions by Year and Scenario**



CO2 emissions were projected to increase over the forecast period in the Reference Case and in each of the three scenarios. However, the rate of increase in CO2 was different for each of the cases. Overall, the projected CO2 emissions for each of the scenarios were less than the Reference Case for each year of the forecast. However, difference between the reductions in CO2 emissions for each of the scenarios was projected to be minimal. In upstate New York, CO2 emissions were projected to decline over the forecast due to the retirement of coal-fired capacity. In downstate New York, CO2 emissions were projected to increase due to an increase in consumption and the increased operation of existing resources that have higher CO2 emission rates than the CHP resources. Figure 7 below shows the CO2 emissions by study year and scenario for New York State. As this chart illustrates, the total CO2 emissions were projected to increase over time with increases in load growth and the increased use of existing generation in downstate New York.

Since the New York electric grid is interconnected with neighboring regions, the impacts of CO2 emissions outside the state should also be considered in order to fully appreciate the potential impacts of CHP penetration. When these impacts are considered, the benefits of CHP installed in New York are significant. Table 10, Table 11, and Table 12 above show that across the entire Eastern Interconnect, the reduction in CO2 emissions resulting from CHP in New York ranges from 3.2 million tons/year to 3.7 million tons/year in 2020 when compared to the Reference Case.

**Figure 7. CO2 Emissions by Year and Scenario**



Scenario 1 established levels of generation, emissions of SO<sub>2</sub>, NO<sub>x</sub>, and CO<sub>2</sub>, and costs of fuels and emissions based on the emission rates established by NYSDEC and the CHP market penetration levels indicated in the October 2002 CHP study that were updated and revised to include a favorable market environment. These results are presented by region as well as the state as a whole in Table 13 below. Electric generation is shown in GWh by season and for each year studied. In addition, the fuel that was consumed in the production of electric energy is shown as well as the resulting emissions from SO<sub>2</sub>, NO<sub>x</sub>, and CO<sub>2</sub> and the costs of that fuel and those pollutants. The generation from CHP projects is also given.

As discussed earlier, generation increased over the forecast period as a result of the increased operation of pumped storage hydro plants in New York. This naturally caused increased fuel consumption, which in turn, led to higher emissions of SO<sub>2</sub>, NO<sub>x</sub>, and CO<sub>2</sub>. Comparing across zones, Zone A-D represents greater than 50% of New York generation in 2006, while Zones J and K (New York City and Long Island) account for 20%. Thus, the upstate and downstate distinction was concentrated in these two market areas. Roughly 30% of CHP generation is in Zone A-D while approximately 36% is concentrated in Zone J (New York City).

**Table 13. Scenario 1 - Baseline Results by Season and New York Zone (2006\$)**

|                |                                      | Scenario 1 Results    |                        |                 |                       |                        |                 |                       |                        |                 |                       |                        |                 |
|----------------|--------------------------------------|-----------------------|------------------------|-----------------|-----------------------|------------------------|-----------------|-----------------------|------------------------|-----------------|-----------------------|------------------------|-----------------|
|                |                                      | 2006                  |                        |                 | 2010                  |                        |                 | 2015                  |                        |                 | 2020                  |                        |                 |
| Market Area    | Data                                 | Season 1:<br>May-Oct. | Season 2:<br>Nov-April | Annual<br>Total | Season 1:<br>May-Oct. | Season 2:<br>Nov-April | Annual<br>Total | Season 1:<br>May-Oct. | Season 2:<br>Nov-April | Annual<br>Total | Season 1:<br>May-Oct. | Season 2:<br>Nov-April | Annual<br>Total |
| NY-A-D         | Generation (GWh)                     | 40,019                | 40,298                 | 80,317          | 40,860                | 41,081                 | 81,941          | 43,126                | 43,433                 | 86,559          | 45,221                | 45,503                 | 90,723          |
|                | Fuel Consumption (GBtu)              | 270,159               | 264,275                | 534,435         | 276,712               | 270,065                | 546,776         | 299,167               | 293,365                | 592,532         | 320,145               | 314,144                | 634,289         |
|                | Fuel Cost (\$000)                    | \$794,263             | \$862,244              | \$1,656,507     | \$627,408             | \$654,486              | \$1,281,894     | \$648,243             | \$673,199              | \$1,321,442     | \$706,342             | \$740,314              | \$1,446,656     |
|                | SO <sub>2</sub> Emissions (000 tons) | 60                    | 58                     | 118             | 39                    | 39                     | 78              | 36                    | 36                     | 72              | 35                    | 35                     | 70              |
|                | NO <sub>x</sub> Emissions (000 tons) | 11                    | 10                     | 21              | 9                     | 9                      | 18              | 8                     | 8                      | 17              | 8                     | 8                      | 17              |
|                | CO <sub>2</sub> Emissions (000 tons) | 12,599                | 12,376                 | 24,975          | 11,453                | 11,303                 | 22,755          | 11,252                | 11,259                 | 22,510          | 11,354                | 11,343                 | 22,697          |
|                | SO <sub>2</sub> Cost (\$000)         | \$62,395              | \$59,738               | \$122,133       | \$49,731              | \$49,225               | \$98,956        | \$54,061              | \$55,021               | \$109,082       | \$65,192              | \$65,999               | \$131,191       |
|                | NO <sub>x</sub> Cost (\$000)         | \$30,200              | \$16,459               | \$46,659        | \$19,238              | \$22,854               | \$42,092        | \$16,500              | \$17,057               | \$33,556        | \$20,237              | \$20,262               | \$40,499        |
|                | CO <sub>2</sub> Cost (\$000)         | \$0                   | \$0                    | \$0             | \$31,246              | \$30,837               | \$62,083        | \$36,357              | \$36,379               | \$72,736        | \$48,878              | \$48,833               | \$97,711        |
|                | CHP Generation (GWh)                 | 0                     | 0                      | 0               | 552                   | 539                    | 1,091           | 1,741                 | 1,697                  | 3,438           | 2,354                 | 2,293                  | 4,647           |
| NY-E           | Generation (GWh)                     | 2,348                 | 2,700                  | 5,049           | 2,420                 | 2,788                  | 5,209           | 2,612                 | 2,973                  | 5,584           | 2,721                 | 3,066                  | 5,788           |
|                | Fuel Consumption (GBtu)              | 12,820                | 13,364                 | 26,184          | 13,545                | 14,239                 | 27,784          | 15,451                | 16,078                 | 31,529          | 16,541                | 17,028                 | 33,569          |
|                | Fuel Cost (\$000)                    | \$91,264              | \$107,987              | \$199,251       | \$68,021              | \$80,150               | \$148,171       | \$65,651              | \$77,146               | \$142,797       | \$72,242              | \$84,798               | \$157,040       |
|                | SO <sub>2</sub> Emissions (000 tons) | 1                     | 1                      | 1               | 1                     | 1                      | 1               | 1                     | 1                      | 1               | 1                     | 1                      | 1               |
|                | NO <sub>x</sub> Emissions (000 tons) | 0                     | 0                      | 0               | 0                     | 0                      | 0               | 0                     | 0                      | 0               | 0                     | 0                      | 0               |
|                | CO <sub>2</sub> Emissions (000 tons) | 660                   | 692                    | 1,351           | 679                   | 726                    | 1,405           | 749                   | 792                    | 1,540           | 795                   | 827                    | 1,621           |
|                | SO <sub>2</sub> Cost (\$000)         | \$645                 | \$621                  | \$1,266         | \$760                 | \$780                  | \$1,541         | \$950                 | \$963                  | \$1,913         | \$1,239               | \$1,209                | \$2,447         |
|                | NO <sub>x</sub> Cost (\$000)         | \$299                 | \$166                  | \$464           | \$244                 | \$303                  | \$547           | \$310                 | \$309                  | \$619           | \$417                 | \$405                  | \$823           |
|                | CO <sub>2</sub> Cost (\$000)         | \$0                   | \$0                    | \$0             | \$1,851               | \$1,982                | \$3,833         | \$2,418               | \$2,559                | \$4,978         | \$3,421               | \$3,559                | \$6,980         |
|                | CHP Generation (GWh)                 | 0                     | 0                      | 0               | 82                    | 80                     | 162             | 261                   | 255                    | 516             | 355                   | 346                    | 702             |
| NY-F           | Generation (GWh)                     | 4,215                 | 3,914                  | 8,129           | 4,562                 | 4,461                  | 9,023           | 4,750                 | 4,484                  | 9,234           | 4,589                 | 4,001                  | 8,590           |
|                | Fuel Consumption (GBtu)              | 25,303                | 22,388                 | 47,691          | 27,706                | 26,306                 | 54,012          | 29,673                | 27,143                 | 56,816          | 28,802                | 24,070                 | 52,872          |
|                | Fuel Cost (\$000)                    | \$260,825             | \$256,231              | \$517,056       | \$182,666             | \$192,564              | \$375,229       | \$165,004             | \$166,702              | \$331,706       | \$169,289             | \$150,970              | \$320,259       |
|                | SO <sub>2</sub> Emissions (000 tons) | 0                     | 0                      | 0               | 0                     | 0                      | 0               | 0                     | 0                      | 0               | 0                     | 0                      | 0               |
|                | NO <sub>x</sub> Emissions (000 tons) | 0                     | 0                      | 0               | 0                     | 0                      | 0               | 0                     | 0                      | 0               | 0                     | 0                      | 0               |
|                | CO <sub>2</sub> Emissions (000 tons) | 1,494                 | 1,324                  | 2,818           | 1,602                 | 1,523                  | 3,125           | 1,638                 | 1,489                  | 3,127           | 1,552                 | 1,267                  | 2,820           |
|                | SO <sub>2</sub> Cost (\$000)         | \$10                  | \$9                    | \$20            | \$14                  | \$13                   | \$26            | \$16                  | \$15                   | \$31            | \$19                  | \$15                   | \$34            |
|                | NO <sub>x</sub> Cost (\$000)         | \$211                 | \$92                   | \$303           | \$216                 | \$239                  | \$455           | \$315                 | \$283                  | \$598           | \$388                 | \$310                  | \$698           |
|                | CO <sub>2</sub> Cost (\$000)         | \$0                   | \$0                    | \$0             | \$4,372               | \$4,155                | \$8,527         | \$5,291               | \$4,812                | \$10,104        | \$6,683               | \$5,455                | \$12,137        |
|                | CHP Generation (GWh)                 | 0                     | 0                      | 0               | 145                   | 142                    | 287             | 461                   | 449                    | 910             | 624                   | 608                    | 1,232           |
| NY-G           | Generation (GWh)                     | 7,078                 | 6,060                  | 13,138          | 8,833                 | 7,834                  | 16,667          | 9,083                 | 7,161                  | 16,245          | 7,642                 | 5,568                  | 13,210          |
|                | Fuel Consumption (GBtu)              | 66,730                | 55,140                 | 121,870         | 83,914                | 72,036                 | 155,949         | 84,714                | 63,448                 | 148,163         | 69,984                | 48,411                 | 118,395         |
|                | Fuel Cost (\$000)                    | \$476,472             | \$388,347              | \$864,818       | \$431,208             | \$380,280              | \$811,488       | \$392,924             | \$280,529              | \$673,452       | \$318,688             | \$177,743              | \$496,431       |
|                | SO <sub>2</sub> Emissions (000 tons) | 16                    | 16                     | 33              | 17                    | 17                     | 34              | 17                    | 17                     | 35              | 18                    | 17                     | 35              |
|                | NO <sub>x</sub> Emissions (000 tons) | 3                     | 3                      | 7               | 4                     | 4                      | 7               | 4                     | 4                      | 7               | 4                     | 3                      | 7               |
|                | CO <sub>2</sub> Emissions (000 tons) | 5,125                 | 4,338                  | 9,464           | 6,294                 | 5,483                  | 11,777          | 6,265                 | 4,790                  | 11,055          | 5,253                 | 3,843                  | 9,095           |
|                | SO <sub>2</sub> Cost (\$000)         | \$16,979              | \$16,819               | \$33,798        | \$21,506              | \$21,547               | \$43,054        | \$26,465              | \$25,882               | \$52,347        | \$32,950              | \$32,078               | \$65,029        |
|                | NO <sub>x</sub> Cost (\$000)         | \$9,470               | \$5,135                | \$14,605        | \$7,918               | \$9,162                | \$17,079        | \$7,639               | \$6,925                | \$14,565        | \$9,053               | \$8,223                | \$17,276        |
|                | CO <sub>2</sub> Cost (\$000)         | \$0                   | \$0                    | \$0             | \$17,173              | \$14,960               | \$32,133        | \$20,244              | \$15,476               | \$35,720        | \$22,611              | \$16,542               | \$39,153        |
|                | CHP Generation (GWh)                 | 0                     | 0                      | 0               | 111                   | 108                    | 219             | 379                   | 370                    | 749             | 521                   | 507                    | 1,028           |
| NY-H           | Generation (GWh)                     | 7,851                 | 7,564                  | 15,415          | 7,850                 | 7,561                  | 15,411          | 7,854                 | 7,571                  | 15,425          | 7,862                 | 7,574                  | 15,436          |
|                | Fuel Consumption (GBtu)              | 80,145                | 77,208                 | 157,353         | 80,137                | 77,176                 | 157,313         | 80,171                | 77,283                 | 157,454         | 80,253                | 77,309                 | 157,562         |
|                | Fuel Cost (\$000)                    | \$47,982              | \$46,244               | \$94,226        | \$45,392              | \$43,896               | \$89,288        | \$42,676              | \$41,454               | \$84,130        | \$40,300              | \$38,967               | \$79,267        |
|                | SO <sub>2</sub> Emissions (000 tons) | 0                     | 0                      | 0               | 0                     | 0                      | 0               | 0                     | 0                      | 0               | 0                     | 0                      | 0               |
|                | NO <sub>x</sub> Emissions (000 tons) | 0                     | 0                      | 0               | 0                     | 0                      | 0               | 0                     | 0                      | 0               | 0                     | 0                      | 0               |
|                | CO <sub>2</sub> Emissions (000 tons) | 153                   | 148                    | 301             | 149                   | 149                    | 299             | 154                   | 159                    | 312             | 162                   | 160                    | 322             |
|                | SO <sub>2</sub> Cost (\$000)         | \$336                 | \$325                  | \$660           | \$400                 | \$401                  | \$801           | \$493                 | \$506                  | \$999           | \$641                 | \$635                  | \$1,276         |
|                | NO <sub>x</sub> Cost (\$000)         | \$0                   | \$0                    | \$0             | \$0                   | \$0                    | \$0             | \$0                   | \$0                    | \$0             | \$0                   | \$0                    | \$0             |
|                | CO <sub>2</sub> Cost (\$000)         | \$0                   | \$0                    | \$0             | \$407                 | \$408                  | \$815           | \$497                 | \$510                  | \$1,007         | \$696                 | \$689                  | \$1,385         |
|                | CHP Generation (GWh)                 | 0                     | 0                      | 0               | 0                     | 0                      | 0               | 0                     | 0                      | 0               | 0                     | 0                      | 0               |
| NY-I           | Generation (GWh)                     | 7                     | 3                      | 9               | 108                   | 101                    | 209             | 370                   | 357                    | 727             | 505                   | 488                    | 992             |
|                | Fuel Consumption (GBtu)              | 0                     | 0                      | 0               | 1,011                 | 986                    | 1,997           | 3,632                 | 3,540                  | 7,172           | 4,979                 | 4,850                  | 9,829           |
|                | Fuel Cost (\$000)                    | \$42                  | \$15                   | \$57            | \$42                  | \$15                   | \$57            | \$41                  | \$15                   | \$57            | \$42                  | \$15                   | \$57            |
|                | SO <sub>2</sub> Emissions (000 tons) | 0                     | 0                      | 0               | 0                     | 0                      | 0               | 0                     | 0                      | 0               | 0                     | 0                      | 0               |
|                | NO <sub>x</sub> Emissions (000 tons) | 0                     | 0                      | 0               | 0                     | 0                      | 0               | 0                     | 0                      | 0               | 0                     | 0                      | 0               |
|                | CO <sub>2</sub> Emissions (000 tons) | 0                     | 0                      | 0               | 36                    | 36                     | 72              | 124                   | 121                    | 246             | 171                   | 167                    | 338             |
|                | SO <sub>2</sub> Cost (\$000)         | \$0                   | \$0                    | \$0             | \$0                   | \$0                    | \$0             | \$1                   | \$1                    | \$2             | \$2                   | \$2                    | \$3             |
|                | NO <sub>x</sub> Cost (\$000)         | \$0                   | \$0                    | \$0             | \$45                  | \$55                   | \$99            | \$204                 | \$198                  | \$402           | \$288                 | \$280                  | \$568           |
|                | CO <sub>2</sub> Cost (\$000)         | \$0                   | \$0                    | \$0             | \$100                 | \$87                   | \$197           | \$402                 | \$392                  | \$794           | \$736                 | \$717                  | \$1,453         |
|                | CHP Generation (GWh)                 | 0                     | 0                      | 0               | 101                   | 99                     | 200             | 353                   | 354                    | 717             | 498                   | 485                    | 983             |
| NY-J           | Generation (GWh)                     | 11,530                | 8,103                  | 19,633          | 16,654                | 11,549                 | 28,203          | 19,967                | 15,190                 | 35,157          | 23,174                | 17,970                 | 41,144          |
|                | Fuel Consumption (GBtu)              | 104,559               | 72,240                 | 176,799         | 145,080               | 95,511                 | 240,591         | 163,840               | 120,304                | 284,144         | 182,972               | 140,462                | 323,435         |
|                | Fuel Cost (\$000)                    | \$1,066,752           | \$766,802              | \$1,833,554     | \$991,766             | \$677,479              | \$1,669,245     | \$946,448             | \$712,246              | \$1,658,694     | \$1,139,072           | \$901,415              | \$2,040,487     |
|                | SO <sub>2</sub> Emissions (000 tons) | 5                     | 5                      | 10              | 4                     | 4                      | 6               | 3                     | 2                      | 4               | 3                     | 2                      | 4               |
|                | NO <sub>x</sub> Emissions (000 tons) | 3                     | 2                      | 5               | 3                     | 2                      | 5               | 3                     | 2                      | 5               | 3                     | 2                      | 5               |
|                | CO <sub>2</sub> Emissions (000 tons) | 6,475                 | 4,448                  | 10,923          | 8,850                 | 5,671                  | 14,521          | 9,446                 | 6,733                  | 16,179          | 10,295                | 7,751                  | 18,046          |
|                | SO <sub>2</sub> Cost (\$000)         | \$5,531               | \$4,768                | \$10,299        | \$5,067               | \$3,160                | \$8,228         | \$3,799               | \$2,586                | \$6,385         | \$5,092               | \$3,070                | \$8,162         |
|                | NO <sub>x</sub> Cost (\$000)         | \$7,905               | \$3,354                | \$11,259        | \$6,549               | \$4,671                | \$11,220        | \$5,730               | \$3,806                | \$9,536         | \$6,825               | \$4,540                | \$11,365        |
|                | CO <sub>2</sub> Cost (\$000)         | \$0                   | \$0                    | \$0             | \$24,143              | \$15,471               | \$39,614        | \$30,523              | \$21,756               | \$52,280        | \$44,320              | \$33,371               | \$77,691        |
|                | CHP Generation (GWh)                 | 0                     | 0                      | 0               | 575                   | 560                    | 1,135           | 2,091                 | 2,036                  | 4,127           | 2,882                 | 2,806                  | 5,688           |
| NY-K           | Generation (GWh)                     | 6,538                 | 5,146                  | 11,685          | 4,927                 | 3,460                  | 8,387           | 5,945                 | 4,410                  | 10,355          | 7,529                 | 5,694                  | 13,222          |
|                | Fuel Consumption (GBtu)              | 71,190                | 55,125                 | 126,315         | 53,426                | 36,520                 | 89,946          | 64,423                | 46,419                 | 110,841         | 75,403                | 54,850                 | 130,254         |
|                | Fuel Cost (\$000)                    | \$697,081             | \$532,708              | \$1,229,790     | \$374,205             | \$246,918              | \$621,123       | \$406,095             | \$278,486              | \$684,583       | \$487,104             | \$342,544              | \$829,648       |
|                | SO <sub>2</sub> Emissions (000 tons) | 10                    | 8                      | 18              | 5                     | 4                      | 9               | 6                     | 4                      | 11              | 7                     | 5                      | 12              |
|                | NO <sub>x</sub> Emissions (000 tons) | 3                     | 2                      | 5               | 3                     | 2                      | 4               | 3                     | 2                      | 5               | 3                     | 2                      | 4               |
|                | CO <sub>2</sub> Emissions (000 tons) | 4,949                 | 3,863                  | 8,812           | 3,557                 | 2,461                  | 6,017           | 4,187                 | 3,012                  | 7,199           | 4,857                 | 3,488                  | 8,345           |
|                | SO <sub>2</sub> Cost (\$000)         | \$10,762              | \$8,258                | \$19,019        | \$6,401               | \$4,479                | \$10,880        | \$9,540               | \$6,441                | \$15,981        | \$13,961              | \$8,898                | \$22,859        |
|                | NO <sub>x</sub> Cost (\$000)         | \$8,355               | \$3,247                | \$11,602        | \$5,499               | \$4,248                | \$9,747         | \$5,695               | \$4,078                | \$9,774         | \$6,443               | \$3,982                | \$10,425        |
|                | CO <sub>2</sub> Cost (\$000)         | \$0                   | \$0                    | \$0             | \$9,704               | \$6,714                | \$16,418        | \$13,528              | \$9,732                | \$23,260        | \$20,909              | \$15,013               | \$35,922        |
|                | CHP Generation (GWh)                 | 0                     | 0                      | 0               | 138                   | 134                    | 273             | 524                   | 508                    | 1,032           | 737                   | 715                    | 1,451           |
| Total NY State | Generation (GWh)                     | 79,586                | 73,788                 | 153,374         | 86,215                | 78,836                 | 165,051         | 93,706                | 85,579                 | 179,285         | 99,243                | 89,663                 | 189,106         |
|                | Fuel Consumption (GBtu)              | 630,906               | 559,740                | 1,190,646       | 681,531               | 592,827                | 1,274,358       | 741,071               | 647,569                | 1,388,640       | 779,077               | 681,126                | 1,460,204       |
|                | Fuel Cost (\$000)                    | \$3,434,681           | \$2,960,579            | \$6,395,260     | \$2,720,708           | \$2,275,787            | \$4,996,495     | \$2,667,082           | \$2,229,778            | \$4,896,860     | \$2,933,079           | \$2,436,7              |                 |

stations<sup>4</sup>. Comparing Scenario 1 to Scenario 2, as shown in Table 14, emissions of SO<sub>2</sub> and CO<sub>2</sub> were both lower in Scenario 1. This is because CHP generation in Scenario 1 was greater than in Scenario 2.

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<sup>4</sup> For modeling purposes, as discussed earlier, the energy production from CHP resources was simply scheduled into the system.

**Table 14. Comparison of Scenario 1 Results to Scenario 2 by Season and New York Zone (2006\$)**

|             |                          | Scenario 1 less Scenario 2 |                     |              |                    |                     |              |                    |                     |              |                    |                     |              |
|-------------|--------------------------|----------------------------|---------------------|--------------|--------------------|---------------------|--------------|--------------------|---------------------|--------------|--------------------|---------------------|--------------|
|             |                          | 2006                       |                     |              | 2010               |                     |              | 2015               |                     |              | 2020               |                     |              |
| Market Area | Data                     | Season 1: May-Oct.         | Season 2: Nov-April | Annual Total | Season 1: May-Oct. | Season 2: Nov-April | Annual Total | Season 1: May-Oct. | Season 2: Nov-April | Annual Total | Season 1: May-Oct. | Season 2: Nov-April | Annual Total |
| NY-A-D      | Generation (GWh)         | 0.0                        | 0.0                 | 0.0          | 16.0               | 12.8                | 28.7         | 91.7               | 89.4                | 181.1        | 139.4              | 137.3               | 276.7        |
|             | Fuel Consumption (GBtu)  | 0.0                        | 0.0                 | 0.0          | 155.0              | 112.7               | 267.7        | 853.5              | 895.9               | 1,739.4      | 1,421.5            | 1,381.6             | 2,803.1      |
|             | Fuel Cost (\$000)        | \$0.0                      | \$0.0               | \$0.0        | \$402.1            | (\$233.2)           | \$168.8      | (\$1,221.3)        | (\$1,443.5)         | (\$2,664.9)  | (\$860.5)          | (\$2,580.2)         | (\$3,240.7)  |
|             | SO2 Emissions (000 tons) | 0.00                       | 0.00                | 0.00         | (0.00)             | (0.00)              | (0.00)       | (0.14)             | (0.28)              | (0.28)       | (0.25)             | (0.24)              | (0.21)       |
|             | NOx Emissions (000 tons) | 0.00                       | 0.00                | 0.00         | 0.04               | 0.04                | 0.08         | 0.18               | 0.26                | 0.45         | 0.36               | 0.40                | 0.76         |
|             | CO2 Emissions (000 tons) | 0.00                       | 0.00                | 0.00         | 4.05               | 2.66                | 6.71         | (15.16)            | (7.40)              | (22.55)      | 1.82               | 12.20               | 14.03        |
|             | SO2 Cost (\$000)         | \$0.00                     | \$0.00              | \$0.00       | (\$1.16)           | (\$4.51)            | (\$5.67)     | (\$211.43)         | (\$218.11)          | (\$429.53)   | (\$461.39)         | \$68.76             | \$392.63     |
|             | NOx Cost (\$000)         | \$0.00                     | \$0.00              | \$0.00       | \$84.79            | \$99.02             | \$183.81     | \$363.66           | \$515.45            | \$879.11     | \$869.96           | \$977.62            | \$1,847.58   |
|             | CO2 Cost (\$000)         | \$0.00                     | \$0.00              | \$0.00       | \$11.27            | \$7.25              | \$18.52      | (\$48.97)          | (\$23.91)           | (\$72.88)    | \$7.92             | \$52.40             | \$60.32      |
|             | CHP Generation (GWh)     | 0.0                        | 0.0                 | 0.0          | 9.6                | 9.3                 | 18.8         | 126.8              | 123.5               | 250.3        | 171.9              | 167.1               | 339.0        |
| NY-E        | Generation (GWh)         | 0.0                        | 0.0                 | 0.0          | 1.4                | 3.1                 | 4.5          | 19.5               | 18.7                | 38.1         | 26.4               | 25.4                | 51.8         |
|             | Fuel Consumption (GBtu)  | 0.0                        | 0.0                 | 0.0          | 14.2               | 31.1                | 45.2         | 194.6              | 186.8               | 381.4        | 264.3              | 254.1               | 518.4        |
|             | Fuel Cost (\$000)        | \$0.0                      | \$0.0               | \$0.0        | \$4.1              | \$51.0              | \$55.1       | \$1.9              | (\$1.1)             | \$0.8        | \$3.5              | \$0.0               | \$3.5        |
|             | SO2 Emissions (000 tons) | 0.00                       | 0.00                | 0.00         | 0.00               | 0.01                | 0.01         | 0.00               | (0.00)              | 0.00         | 0.00               | 0.00                | 0.00         |
|             | NOx Emissions (000 tons) | 0.00                       | 0.00                | 0.00         | 0.01               | 0.01                | 0.01         | 0.05               | 0.04                | 0.09         | 0.06               | 0.06                | 0.12         |
|             | CO2 Emissions (000 tons) | 0.00                       | 0.00                | 0.00         | 0.12               | 1.91                | 2.03         | 3.72               | 3.39                | 7.11         | 4.97               | 4.67                | 9.64         |
|             | SO2 Cost (\$000)         | \$0.00                     | \$0.00              | \$0.00       | \$0.45             | \$6.18              | \$6.63       | \$0.65             | (\$0.12)            | \$0.53       | \$0.38             | \$0.05              | \$0.43       |
|             | NOx Cost (\$000)         | \$0.00                     | \$0.00              | \$0.00       | \$11.22            | \$16.34             | \$27.56      | \$89.94            | \$87.29             | \$177.23     | \$147.76           | \$143.89            | \$291.65     |
|             | CO2 Cost (\$000)         | \$0.00                     | \$0.00              | \$0.00       | \$0.34             | \$5.21              | \$5.55       | \$12.02            | \$10.95             | \$22.96      | \$21.40            | \$20.11             | \$41.50      |
|             | CHP Generation (GWh)     | 0.0                        | 0.0                 | 0.0          | 1.3                | 1.2                 | 2.5          | 19.4               | 18.7                | 38.1         | 26.3               | 25.4                | 51.7         |
| NY-F        | Generation (GWh)         | 0.0                        | 0.0                 | 0.0          | (5.9)              | 2.5                 | (3.3)        | 2.2                | (69.3)              | (67.0)       | 32.6               | (46.9)              | (35.6)       |
|             | Fuel Consumption (GBtu)  | 0.0                        | 0.0                 | 0.0          | (49.1)             | 51.4                | 2.3          | 186.9              | (373.9)             | (187.0)      | 86.0               | (133.5)             | 735.5        |
|             | Fuel Cost (\$000)        | \$0.0                      | \$0.0               | \$0.0        | (\$487.9)          | \$224.4             | (\$263.5)    | (\$974.4)          | (\$4,713.0)         | (\$5,687.4)  | \$2,995.6          | (\$5,180.3)         | (\$2,184.6)  |
|             | SO2 Emissions (000 tons) | 0.00                       | 0.00                | 0.00         | (0.00)             | (0.00)              | (0.00)       | (0.00)             | (0.00)              | (0.00)       | (0.00)             | (0.00)              | (0.00)       |
|             | NOx Emissions (000 tons) | 0.00                       | 0.00                | 0.00         | 0.01               | 0.01                | 0.02         | 0.08               | 0.07                | 0.15         | 0.11               | 0.10                | 0.21         |
|             | CO2 Emissions (000 tons) | 0.00                       | 0.00                | 0.00         | (4.63)             | 1.95                | (2.69)       | (2.03)             | (36.08)             | (38.11)      | 33.50              | (27.02)             | 6.48         |
|             | SO2 Cost (\$000)         | \$0.00                     | \$0.00              | \$0.00       | (\$0.04)           | \$0.02              | (\$0.02)     | (\$0.03)           | (\$0.37)            | (\$0.40)     | \$0.40             | (\$0.36)            | \$0.04       |
|             | NOx Cost (\$000)         | \$0.00                     | \$0.00              | \$0.00       | \$19.02            | \$24.79             | \$43.81      | \$156.50           | \$144.97            | \$301.47     | \$265.79           | \$243.26            | \$509.06     |
|             | CO2 Cost (\$000)         | \$0.00                     | \$0.00              | \$0.00       | (\$12.64)          | \$5.31              | (\$7.33)     | (\$6.57)           | (\$116.57)          | (\$123.14)   | \$144.22           | (\$116.31)          | \$27.91      |
|             | CHP Generation (GWh)     | 0.0                        | 0.0                 | 0.0          | 2.2                | 2.2                 | 4.4          | 33.5               | 32.6                | 66.1         | 46.1               | 44.8                | 90.9         |
| NY-G        | Generation (GWh)         | 0.0                        | 0.0                 | 0.0          | (13.4)             | 40.2                | 26.8         | (24.0)             | (157.8)             | (181.8)      | 3.5                | (46.5)              | (42.9)       |
|             | Fuel Consumption (GBtu)  | 0.0                        | 0.0                 | 0.0          | (163.6)            | 443.5               | 279.8        | (42.9)             | (1,582.6)           | (1,625.5)    | 216.5              | (299.9)             | (83.4)       |
|             | Fuel Cost (\$000)        | \$0.0                      | \$0.0               | \$0.0        | (\$1,181.4)        | \$4,285.9           | \$3,104.5    | (\$2,264.9)        | (\$13,258.5)        | (\$15,523.3) | (\$1,220.4)        | (\$5,479.2)         | (\$6,699.6)  |
|             | SO2 Emissions (000 tons) | 0.00                       | 0.00                | 0.00         | 0.00               | (0.03)              | (0.02)       | 0.00               | (0.01)              | (0.01)       | 0.00               | (0.00)              | (0.00)       |
|             | NOx Emissions (000 tons) | 0.00                       | 0.00                | 0.00         | 0.00               | 0.01                | 0.01         | 0.08               | 0.05                | 0.13         | 0.10               | 0.09                | 0.20         |
|             | CO2 Emissions (000 tons) | 0.00                       | 0.00                | 0.00         | (17.05)            | 23.57               | 6.52         | (6.56)             | (119.71)            | (126.26)     | (4.14)             | (38.10)             | (42.25)      |
|             | SO2 Cost (\$000)         | \$0.00                     | \$0.00              | \$0.00       | \$2.18             | (\$31.33)           | (\$29.16)    | \$4.83             | (\$18.41)           | (\$13.58)    | \$1.05             | (\$1.23)            | (\$0.17)     |
|             | NOx Cost (\$000)         | \$0.00                     | \$0.00              | \$0.00       | \$6.89             | \$18.92             | \$25.81      | \$161.69           | \$104.16            | \$255.85     | \$255.76           | \$230.60            | \$486.36     |
|             | CO2 Cost (\$000)         | \$0.00                     | \$0.00              | \$0.00       | (\$46.52)          | \$64.31             | \$17.79      | (\$1.93)           | (\$16.66)           | \$15.97      | \$32.62            | (\$17.84)           | (\$164.03)   |
|             | CHP Generation (GWh)     | 0.0                        | 0.0                 | 0.0          | 0.9                | 0.9                 | 1.8          | 30.6               | 30.0                | 60.6         | 42.7               | 41.6                | 84.3         |
| NY-H        | Generation (GWh)         | 0.0                        | 0.0                 | 0.0          | (0.1)              | (0.1)               | (0.2)        | 0.0                | 0.1                 | (0.1)        | (0.1)              | (0.0)               | (0.1)        |
|             | Fuel Consumption (GBtu)  | 0.0                        | 0.0                 | 0.0          | (1.2)              | (0.8)               | (2.0)        | 0.5                | 0.1                 | 0.6          | (1.2)              | (0.3)               | (1.5)        |
|             | Fuel Cost (\$000)        | \$0.0                      | \$0.0               | \$0.0        | (\$3.6)            | (\$2.5)             | (\$6.1)      | \$1.5              | \$0.3               | \$1.8        | (\$3.8)            | (\$0.8)             | (\$4.6)      |
|             | SO2 Emissions (000 tons) | 0.00                       | 0.00                | 0.00         | (0.00)             | (0.00)              | (0.00)       | 0.00               | 0.00                | 0.00         | (0.00)             | (0.00)              | (0.00)       |
|             | NOx Emissions (000 tons) | 0.00                       | 0.00                | 0.00         | 0.00               | 0.00                | 0.00         | 0.00               | 0.00                | 0.00         | 0.00               | 0.00                | 0.00         |
|             | CO2 Emissions (000 tons) | 0.00                       | 0.00                | 0.00         | (0.09)             | (0.06)              | (0.16)       | 0.04               | 0.01                | 0.05         | (0.10)             | (0.02)              | (0.12)       |
|             | SO2 Cost (\$000)         | \$0.00                     | \$0.00              | \$0.00       | (\$0.25)           | (\$0.17)            | (\$0.42)     | \$0.12             | \$0.02              | \$0.15       | (\$0.39)           | (\$0.08)            | (\$0.47)     |
|             | NOx Cost (\$000)         | \$0.00                     | \$0.00              | \$0.00       | \$0.00             | \$0.00              | \$0.00       | \$0.00             | \$0.00              | \$0.00       | \$0.00             | \$0.00              | \$0.00       |
|             | CO2 Cost (\$000)         | \$0.00                     | \$0.00              | \$0.00       | (\$0.26)           | (\$0.17)            | (\$0.43)     | \$0.12             | \$0.02              | \$0.15       | (\$0.42)           | (\$0.09)            | (\$0.51)     |
|             | CHP Generation (GWh)     | 0.0                        | 0.0                 | 0.0          | 0.0                | 0.0                 | 0.0          | 0.0                | 0.0                 | 0.0          | 0.0                | 0.0                 | 0.0          |
| NY-I        | Generation (GWh)         | 0.0                        | 0.0                 | 0.0          | 0.5                | 0.5                 | 0.9          | 31.2               | 30.2                | 61.4         | 43.7               | 42.5                | 86.2         |
|             | Fuel Consumption (GBtu)  | 0.0                        | 0.0                 | 0.0          | 4.4                | 4.3                 | 8.8          | 311.9              | 301.9               | 613.8        | 437.0              | 425.1               | 862.1        |
|             | Fuel Cost (\$000)        | \$0.0                      | \$0.0               | \$0.0        | \$0.0              | \$0.0               | \$0.0        | \$0.0              | \$0.0               | \$0.0        | \$0.0              | \$0.0               | \$0.0        |
|             | SO2 Emissions (000 tons) | 0.00                       | 0.00                | 0.00         | (0.00)             | (0.00)              | (0.00)       | 0.00               | 0.00                | 0.00         | 0.00               | 0.00                | 0.00         |
|             | NOx Emissions (000 tons) | 0.00                       | 0.00                | 0.00         | 0.01               | 0.01                | 0.01         | 0.08               | 0.07                | 0.15         | 0.10               | 0.10                | 0.19         |
|             | CO2 Emissions (000 tons) | 0.00                       | 0.00                | 0.00         | (0.36)             | (0.35)              | (0.71)       | 5.15               | 4.94                | 10.10        | 7.82               | 7.59                | 15.41        |
|             | SO2 Cost (\$000)         | \$0.00                     | \$0.00              | \$0.00       | (\$0.00)           | (\$0.00)            | (\$0.00)     | \$0.05             | \$0.05              | \$0.10       | \$0.08             | \$0.08              | \$0.16       |
|             | NOx Cost (\$000)         | \$0.00                     | \$0.00              | \$0.00       | \$11.85            | \$14.52             | \$26.37      | \$149.58           | \$145.76            | \$295.34     | \$240.10           | \$233.91            | \$474.00     |
|             | CO2 Cost (\$000)         | \$0.00                     | \$0.00              | \$0.00       | (\$0.98)           | (\$0.95)            | (\$1.93)     | \$16.66            | \$15.97             | \$32.62      | \$33.66            | \$33.66             | \$66.32      |
|             | CHP Generation (GWh)     | 0.0                        | 0.0                 | 0.0          | 0.5                | 0.5                 | 0.9          | 31.2               | 30.2                | 61.4         | 43.7               | 42.5                | 86.2         |
| NY-J        | Generation (GWh)         | 0.0                        | 0.0                 | 0.0          | 5.1                | (41.5)              | (36.4)       | (23.8)             | 136.8               | 113.0        | 51.6               | (134.8)             | (83.2)       |
|             | Fuel Consumption (GBtu)  | 0.0                        | 0.0                 | 0.0          | (44.2)             | (76.1)              | (120.2)      | (48.2)             | 1,357.7             | 1,309.6      | 599.8              | (561.4)             | 38.4         |
|             | Fuel Cost (\$000)        | \$0.0                      | \$0.0               | \$0.0        | \$113.9            | (\$1,302.1)         | (\$1,188.1)  | (\$13,206.1)       | (\$3,820.3)         | (\$17,026.4) | (\$14,377.6)       | (\$24,607.8)        | (\$38,985.4) |
|             | SO2 Emissions (000 tons) | 0.00                       | 0.00                | 0.00         | 0.06               | 0.04                | 0.10         | (0.25)             | (0.08)              | (0.33)       | (0.16)             | (0.04)              | (0.21)       |
|             | NOx Emissions (000 tons) | 0.00                       | 0.00                | 0.00         | 0.04               | 0.06                | 0.10         | 0.36               | 0.40                | 0.76         | 0.50               | 0.51                | 1.01         |
|             | CO2 Emissions (000 tons) | 0.00                       | 0.00                | 0.00         | (11.70)            | (4.58)              | (16.28)      | (85.46)            | 7.82                | (77.64)      | (80.42)            | (140.03)            | (220.44)     |
|             | SO2 Cost (\$000)         | \$0.00                     | \$0.00              | \$0.00       | \$72.63            | \$51.52             | \$124.15     | (\$376.69)         | (\$121.63)          | (\$498.32)   | (\$303.50)         | (\$80.14)           | (\$383.64)   |
|             | NOx Cost (\$000)         | \$0.00                     | \$0.00              | \$0.00       | \$85.56            | \$146.49            | \$232.04     | \$711.96           | \$786.60            | \$1,498.56   | \$1,234.37         | \$1,246.99          | \$2,481.97   |
|             | CO2 Cost (\$000)         | \$0.00                     | \$0.00              | \$0.00       | (\$31.93)          | (\$12.43)           | (\$44.35)    | (\$276.14)         | \$25.20             | (\$250.94)   | (\$346.17)         | (\$602.80)          | (\$948.97)   |
|             | CHP Generation (GWh)     | 0.0                        | 0.0                 | 0.0          | 3.1                | 2.9                 | 6.1          | 182.7              | 177.3               | 360.0        | 249.4              | 249.4               | 506.4        |
| NY-K        | Generation (GWh)         | 0.0                        | 0.0                 | 0.0          | (1.5)              | (6.6)               | (8.1)        | 19.6               | (1.9)               | 17.7         | 17.1               | (2.6)               | 14.5         |
|             | Fuel Consumption (GBtu)  | 0.0                        | 0.0                 | 0.0          | (3.4)              | (78.8)              | (82.2)       | 187.7              | (66.6)              | 136.4        | 136.4              | (46.9)              | 89.5         |
|             | Fuel Cost (\$000)        | \$0.0                      | \$0.0               | \$0.0        | (\$48.5)           | (\$524.2)           | (\$572.8)    | (\$2,140.9)        | (\$3,696.4)         | (\$5,837.3)  | (\$4,319.8)        | (\$5,583.8)         | (\$9,903.6)  |
|             | SO2 Emissions (000 tons) | 0.00                       | 0.00                | 0.00         | 0.00               | (0.08)              | (0.08)       | (0.02)             | (0.05)              | (0.07)       | (0.06)             | (0.05)              | (0.11)       |
|             | NOx Emissions (000 tons) | 0.00                       | 0.00                | 0.00         | 0.01               | 0.00                | 0.01         | 0.09               | 0.09                | 0.18         | 0.12               | 0.11                | 0.23         |
|             | CO2 Emissions (000 tons) | 0.00                       | 0.00                | 0.00         | (1.11)             | (10.39)             | (11.50)      | (9.77)             | (23.34)             | (39.11)      | (23.04)            | (34.21)             | (57.24)      |
|             | SO2 Cost (\$000)         | \$0.00                     | \$0.00              | \$0.00       | \$5.95             | (\$104.44)          | (\$98.49)    | (\$27.22)          | (\$80.05)           | (\$107.27)   | (\$120.89)         | (\$84.99)           | (\$205.88)   |
|             | NOx Cost (\$000)         | \$0.00                     | \$0.00              | \$0.00       | \$13.09            | \$3.33              | \$16.42      | \$177.22           | \$176.22            | \$353.44     | \$297.23           | \$272.82            | \$570.05     |
|             | CO2 Cost (\$000)         | \$0.00                     | \$0.00              | \$0.00       | (\$3.03)           | (\$28.35)           | (\$31.38)    | (\$31.56)          | (\$94.80)           | (\$126.36)   | (\$99.17)          | (\$147.26)          | (\$246.43)   |
|             | CHP Generation (GWh)     | 0.0                        | 0.0                 | 0.0          | 0.6                | 0.7                 | 1.3          | 48.8               | 47.2                | 96.1         | 69.8               | 67.4                | 137.2        |
| State       | Generation (GWh)         | 0.0                        | 0.0                 | 0.0          | 2.1                | 10.7                | 12.8         | 116.5              | 46.0                | 162.5        | 364.2              | (25.7)              | 338.5        |
|             | Fuel Consumption (GBtu)  | 0.0                        | 0.0                 | 0.0          | (87.9)             | 487.3               | 399.4        | 1,644.0            | 709.2               | 2,353.2      | 3,943.4            | 1,018.8             | 4,962.1      |
|             | Fuel Cost (\$000)        | \$0.0                      | \$0.0               | \$0.0        |                    |                     |              |                    |                     |              |                    |                     |              |

The greater energy output of the CHP plants in Scenario 1 displaced some generation from coal and oil plants in the state<sup>5</sup>, thereby causing fewer emissions of SO<sub>2</sub> and CO<sub>2</sub> in Scenario 1 than in Scenario 2. The higher level of CHP generation in Scenario 1 compared to Scenario 2 had the opposite impact on NO<sub>x</sub> emissions. These extra NO<sub>x</sub> emissions in Scenario 1 were simply due to the extra fuel that was burned by the CHP plants themselves compared to Scenario 2.

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<sup>5</sup> In the downstate New York region, particularly New York City and Long Island, there are some oil-fired plants that operate on a “must run” basis in order to provide system support. We did not, however, model these units as “must run” as it was determined inappropriate for this kind of a long-term study. New plants or transmission lines are likely to enter the market and alleviate the need for plants to receive out-of-market payments over time. In addition, the Prosym model is a zonal model and does not capture those local reliability issues. Nonetheless, those plants in New York City and Long Island burning heavy fuel oil operated on average at nearly 40% of capacity in 2006. Adding CHP reduced the capacity factors of those plants to an average of 21% to 26% in Scenario 1 between 2010 and 2020.

**Table 15. Comparison of Scenario 1 Results to Scenario 3 by Season and New York Zone (2006\$)**

|             |                            | Scenario 1 less Scenario 3 |                     |              |                    |                     |              |                    |                     |              |                    |                     |              |
|-------------|----------------------------|----------------------------|---------------------|--------------|--------------------|---------------------|--------------|--------------------|---------------------|--------------|--------------------|---------------------|--------------|
|             |                            | 2006                       |                     |              | 2010               |                     |              | 2015               |                     |              | 2020               |                     |              |
| Market Area | Data                       | Season 1: May-Oct.         | Season 2: Nov-April | Annual Total | Season 1: May-Oct. | Season 2: Nov-April | Annual Total | Season 1: May-Oct. | Season 2: Nov-April | Annual Total | Season 1: May-Oct. | Season 2: Nov-April | Annual Total |
| NY-A-D      | Generation (GWh)           | 0.0                        | 0.0                 | 0.0          | (50.4)             | (29.8)              | (80.2)       | (62.4)             | (67.3)              | (129.8)      | (63.6)             | (15.6)              | (79.1)       |
|             | Fuel Consumption (GBtu)    | 0.0                        | 0.0                 | 0.0          | (548.8)            | (275.7)             | (824.6)      | (643.5)            | (694.6)             | (1,338.0)    | (629.9)            | (153.2)             | (783.1)      |
|             | Fuel Cost (\$000)          | \$0.0                      | \$0.0               | \$0.0        | (\$409.7)          | \$1,303.9           | \$894.2      | \$399.9            | (\$1,317.1)         | (\$917.2)    | \$2,021.3          | \$2,013.3           | \$1,966.0    |
|             | SO2 Emissions (000 tons)   | 0.00                       | 0.00                | 0.00         | (0.07)             | 0.15                | 0.08         | (0.13)             | (0.02)              | (0.14)       | (0.20)             | 0.19                | (0.02)       |
|             | NOx Emissions (000 tons)   | 0.00                       | 0.00                | 0.00         | 0.01               | 0.02                | 0.03         | (0.06)             | (0.00)              | (0.06)       | (0.00)             | 0.07                | 0.07         |
|             | CO2 Emissions (000 tons)   | 0.00                       | 0.00                | 0.00         | (1.79)             | 27.64               | 25.85        | (10.79)            | (9.62)              | (20.41)      | (7.09)             | 37.55               | 30.45        |
|             | SO2 Cost (\$000)           | \$0.00                     | \$0.00              | \$0.00       | (\$90.28)          | \$209.13            | \$118.85     | (\$236.64)         | (\$35.38)           | (\$272.02)   | (\$529.67)         | \$491.00            | (\$38.67)    |
|             | NOx Cost (\$000)           | \$0.00                     | \$0.00              | \$0.00       | \$16.76            | \$63.72             | \$80.48      | (\$145.87)         | \$1.09              | (\$144.79)   | (\$9.73)           | \$239.30            | \$229.57     |
|             | CO2 Cost (\$000)           | \$0.00                     | \$0.00              | \$0.00       | (\$5.28)           | \$82.94             | \$77.66      | (\$43.23)          | (\$38.63)           | (\$81.86)    | (\$42.48)          | \$225.25            | \$182.77     |
|             | CHP Generation (GWh)       | 0.0                        | 0.0                 | 0.0          | (8.3)              | (7.0)               | (15.3)       | (7.5)              | (5.9)               | (13.3)       | (5.9)              | (5.5)               | (11.5)       |
| NY-E        | Generation (GWh)           | 0.0                        | 0.0                 | 0.0          | (8.3)              | (8.2)               | (16.5)       | (6.7)              | (8.5)               | (17.2)       | (8.7)              | (8.7)               | (17.4)       |
|             | Fuel Consumption (GBtu)    | 0.0                        | 0.0                 | 0.0          | (83.0)             | (81.9)              | (164.9)      | (86.9)             | (84.8)              | (171.8)      | (87.6)             | (86.5)              | (174.1)      |
|             | Fuel Cost (\$000)          | \$0.0                      | \$0.0               | \$0.0        | \$20.9             | \$35.6              | \$56.5       | \$3.6              | \$8.4               | \$11.9       | \$1.4              | \$0.0               | \$1.4        |
|             | SO2 Emissions (000 tons)   | 0.00                       | 0.00                | 0.00         | 0.00               | 0.00                | 0.00         | 0.00               | 0.00                | 0.00         | 0.00               | 0.00                | 0.00         |
|             | NOx Emissions (000 tons)   | 0.00                       | 0.00                | 0.00         | 0.00               | 0.00                | 0.00         | 0.00               | 0.00                | 0.00         | 0.00               | 0.00                | 0.00         |
|             | CO2 Emissions (000 tons)   | 0.00                       | 0.00                | 0.00         | 0.68               | 0.60                | 1.27         | 0.10               | 0.16                | 0.26         | 0.02               | 0.00                | 0.02         |
|             | SO2 Cost (\$000)           | \$0.00                     | \$0.00              | \$0.00       | \$2.33             | \$1.08              | \$3.40       | \$0.44             | \$0.60              | \$1.04       | \$0.12             | \$0.00              | \$0.12       |
|             | NOx Cost (\$000)           | \$0.00                     | \$0.00              | \$0.00       | \$0.72             | \$0.50              | \$1.23       | \$0.09             | \$0.21              | \$0.30       | (\$0.02)           | \$0.00              | (\$0.02)     |
|             | CO2 Cost (\$000)           | \$0.00                     | \$0.00              | \$0.00       | \$2.03             | \$1.79              | \$3.82       | \$0.39             | \$0.64              | \$1.03       | \$0.14             | \$0.00              | \$0.14       |
|             | CHP Generation (GWh)       | 0.0                        | 0.0                 | 0.0          | (9.2)              | (9.9)               | (19.1)       | (9.2)              | (8.0)               | (17.5)       | (8.0)              | (8.6)               | (17.4)       |
| NY-F        | Generation (GWh)           | 0.0                        | 0.0                 | 0.0          | (0.6)              | 12.7                | 12.1         | 9.2                | (40.6)              | (31.4)       | (19.1)             | (19.1)              | (7.5)        |
|             | Fuel Consumption (GBtu)    | 0.0                        | 0.0                 | 0.0          | (35.3)             | 102.1               | 66.8         | 28.6               | (350.3)             | (321.7)      | 19.6               | (190.7)             | (171.1)      |
|             | Fuel Cost (\$000)          | \$0.0                      | \$0.0               | \$0.0        | \$894.0            | \$2,150.6           | \$3,044.7    | \$1,473.1          | (\$1,906.3)         | (\$433.2)    | \$1,717.3          | (\$715.8)           | \$1,001.6    |
|             | SO2 Emissions (000 tons)   | 0.00                       | 0.00                | 0.00         | 0.00               | (0.00)              | 0.00         | (0.00)             | (0.00)              | (0.00)       | (0.00)             | (0.00)              | (0.00)       |
|             | NOx Emissions (000 tons)   | 0.00                       | 0.00                | 0.00         | 0.00               | 0.00                | 0.00         | 0.00               | (0.00)              | (0.00)       | 0.00               | (0.00)              | 0.00         |
|             | CO2 Emissions (000 tons)   | 0.00                       | 0.00                | 0.00         | 6.97               | 15.98               | 22.95        | 11.03              | (14.12)             | (3.09)       | 10.66              | (2.14)              | 8.51         |
|             | SO2 Cost (\$000)           | \$0.00                     | \$0.00              | \$0.00       | \$0.07             | \$0.15              | \$0.22       | \$0.14             | (\$0.18)            | (\$0.04)     | \$0.19             | (\$0.04)            | \$0.15       |
|             | NOx Cost (\$000)           | \$0.00                     | \$0.00              | \$0.00       | \$1.71             | \$4.02              | \$5.73       | \$2.65             | (\$4.10)            | (\$1.45)     | \$3.08             | (\$0.97)            | \$2.11       |
|             | CO2 Cost (\$000)           | \$0.00                     | \$0.00              | \$0.00       | \$20.91            | \$47.94             | \$68.85      | \$44.11            | (\$56.49)           | (\$12.38)    | \$63.94            | (\$12.86)           | \$51.08      |
|             | CHP Generation (GWh)       | 0.0                        | 0.0                 | 0.0          | (15.7)             | (14.4)              | (31.1)       | (14.9)             | (14.9)              | (30.1)       | (15.1)             | (14.7)              | (28.8)       |
| NY-G        | Generation (GWh)           | 0.0                        | 0.0                 | 0.0          | 19.4               | 42.6                | 110.2        | 19.2               | 19.2                | 304.9        | 87.7               | (8.8)               | (8.8)        |
|             | Fuel Consumption (GBtu)    | 0.0                        | 0.0                 | 0.0          | 77.1               | 244.7               | 321.8        | 1,049.1            | 2,091.5             | 3,140.6      | 781.6              | (86.8)              | 694.8        |
|             | Fuel Cost (\$000)          | \$0.0                      | \$0.0               | \$0.0        | \$1,810.3          | \$3,748.5           | \$5,558.8    | \$9,711.1          | \$19,208.6          | \$28,919.7   | \$9,527.5          | \$644.6             | \$10,172.2   |
|             | SO2 Emissions (000 tons)   | 0.00                       | 0.00                | 0.00         | 0.00               | (0.01)              | 0.00         | 0.00               | 0.00                | 0.00         | 0.00               | (0.00)              | 0.00         |
|             | NOx Emissions (000 tons)   | 0.00                       | 0.00                | 0.00         | (0.00)             | 0.00                | 0.00         | 0.02               | 0.03                | 0.05         | 0.01               | 0.00                | 0.01         |
|             | CO2 Emissions (000 tons)   | 0.00                       | 0.00                | 0.00         | 7.39               | 24.12               | 31.51        | 74.78              | 138.44              | 213.22       | 56.60              | 3.96                | 60.56        |
|             | SO2 Cost (\$000)           | \$0.00                     | \$0.00              | \$0.00       | \$1.44             | (\$11.66)           | (\$10.23)    | \$3.76             | \$2.13              | \$5.89       | \$5.37             | (\$0.22)            | \$5.14       |
|             | NOx Cost (\$000)           | \$0.00                     | \$0.00              | \$0.00       | (\$0.45)           | \$13.82             | \$13.36      | \$38.36            | \$69.52             | \$107.89     | \$35.56            | \$0.48              | \$36.04      |
|             | CO2 Cost (\$000)           | \$0.00                     | \$0.00              | \$0.00       | \$22.18            | \$72.36             | \$94.54      | \$299.12           | \$553.75            | \$852.87     | \$339.61           | \$23.75             | \$363.36     |
|             | CHP Generation (GWh)       | 0.0                        | 0.0                 | 0.0          | (14.8)             | (14.5)              | (29.3)       | (14.6)             | (14.1)              | (28.7)       | (14.3)             | (13.8)              | (28.1)       |
| NY-H        | Generation (GWh)           | 0.0                        | 0.0                 | 0.0          | 0.2                | (0.1)               | 0.2          | 0.0                | 0.1                 | (0.1)        | 0.0                | 0.0                 | (0.0)        |
|             | Fuel Consumption (GBtu)    | 0.0                        | 0.0                 | 0.0          | 2.3                | (0.8)               | 1.6          | 0.1                | 0.8                 | 0.9          | (0.6)              | 0.0                 | (0.6)        |
|             | Fuel Cost (\$000)          | \$0.0                      | \$0.0               | \$0.0        | \$8.0              | (\$2.7)             | \$5.3        | \$0.2              | \$3.1               | \$3.4        | (\$2.6)            | \$0.0               | (\$2.6)      |
|             | SO2 Emissions (000 tons)   | 0.00                       | 0.00                | 0.00         | 0.00               | (0.00)              | 0.00         | 0.00               | 0.00                | 0.00         | (0.00)             | 0.00                | (0.00)       |
|             | NOx Emissions (000 tons)   | 0.00                       | 0.00                | 0.00         | 0.00               | 0.00                | 0.00         | 0.00               | 0.00                | 0.00         | 0.00               | 0.00                | 0.00         |
|             | CO2 Emissions (000 tons)   | 0.00                       | 0.00                | 0.00         | 0.19               | (0.06)              | 0.12         | 0.00               | 0.07                | 0.07         | (0.05)             | 0.00                | (0.05)       |
|             | SO2 Cost (\$000)           | \$0.00                     | \$0.00              | \$0.00       | \$0.55             | (\$0.19)            | \$0.37       | \$0.02             | \$0.26              | \$0.28       | (\$0.26)           | \$0.00              | (\$0.26)     |
|             | NOx Cost (\$000)           | \$0.00                     | \$0.00              | \$0.00       | \$0.00             | \$0.00              | \$0.00       | \$0.00             | \$0.00              | \$0.00       | \$0.00             | \$0.00              | \$0.00       |
|             | CO2 Cost (\$000)           | \$0.00                     | \$0.00              | \$0.00       | \$0.56             | (\$0.19)            | \$0.37       | \$0.02             | \$0.26              | \$0.28       | (\$0.29)           | \$0.00              | (\$0.29)     |
|             | CHP Generation (GWh)       | 0.0                        | 0.0                 | 0.0          | 0.0                | 0.0                 | 0.0          | 0.0                | 0.0                 | 0.0          | 0.0                | 0.0                 | 0.0          |
| NY-I        | Generation (GWh)           | 0.0                        | 0.0                 | 0.0          | (14.9)             | (14.7)              | (29.7)       | (15.0)             | (14.6)              | (29.6)       | (14.7)             | (14.3)              | (29.1)       |
|             | Fuel Consumption (GBtu)    | 0.0                        | 0.0                 | 0.0          | (149.6)            | (147.2)             | (296.7)      | (149.7)            | (145.7)             | (295.5)      | (147.3)            | (143.2)             | (290.5)      |
|             | Fuel Cost (\$000)          | \$0.0                      | \$0.0               | \$0.0        | \$0.0              | \$0.0               | \$0.0        | \$0.0              | \$0.0               | \$0.0        | \$0.0              | \$0.0               | \$0.0        |
|             | SO2 Emissions (000 tons)   | 0.00                       | 0.00                | 0.00         | 0.00               | 0.00                | 0.00         | 0.00               | 0.00                | 0.00         | 0.00               | 0.00                | 0.00         |
|             | NOx Emissions (000 tons)   | 0.00                       | 0.00                | 0.00         | 0.00               | 0.00                | 0.00         | 0.00               | 0.00                | 0.00         | 0.00               | 0.00                | 0.00         |
|             | CO2 Emissions (000 tons)   | 0.00                       | 0.00                | 0.00         | 0.00               | 0.00                | 0.00         | 0.00               | 0.00                | 0.00         | 0.00               | 0.00                | 0.00         |
|             | SO2 Cost (\$000)           | \$0.00                     | \$0.00              | \$0.00       | \$0.00             | \$0.00              | \$0.00       | \$0.00             | \$0.00              | \$0.00       | \$0.00             | \$0.00              | \$0.00       |
|             | NOx Cost (\$000)           | \$0.00                     | \$0.00              | \$0.00       | \$0.00             | \$0.00              | \$0.00       | \$0.00             | \$0.00              | \$0.00       | \$0.00             | \$0.00              | \$0.00       |
|             | CO2 Cost (\$000)           | \$0.00                     | \$0.00              | \$0.00       | \$0.00             | \$0.00              | \$0.00       | \$0.00             | \$0.00              | \$0.00       | \$0.00             | \$0.00              | \$0.00       |
|             | CHP Generation (GWh)       | 0.0                        | 0.0                 | 0.0          | (14.9)             | (14.7)              | (29.7)       | (15.0)             | (14.6)              | (29.6)       | (14.7)             | (14.3)              | (29.1)       |
| NY-J        | Generation (GWh)           | 0.0                        | 0.0                 | 0.0          | (24.2)             | (29.8)              | (53.9)       | (22.8)             | (14.7)              | (124.9)      | (14.7)             | (1.2)               | (8.0)        |
|             | Fuel Consumption (GBtu)    | 0.0                        | 0.0                 | 0.0          | (213.2)            | (164.5)             | (377.7)      | (293.5)            | (1,233.3)           | (1,526.8)    | (354.0)            | (202.2)             | (556.1)      |
|             | Fuel Cost (\$000)          | \$0.0                      | \$0.0               | \$0.0        | \$5,657.6          | \$5,390.2           | \$11,037.8   | \$4,654.1          | (\$3,166.2)         | \$1,488.0    | \$5,378.5          | \$6,861.1           | \$12,239.6   |
|             | SO2 Emissions (000 tons)   | 0.00                       | 0.00                | 0.00         | 0.12               | (0.00)              | 0.11         | (0.16)             | 0.03                | (0.12)       | 0.04               | 0.06                | 0.10         |
|             | NOx Emissions (000 tons)   | 0.00                       | 0.00                | 0.00         | 0.05               | 0.03                | 0.08         | (0.02)             | (0.02)              | (0.04)       | 0.01               | 0.02                | 0.03         |
|             | CO2 Emissions (000 tons)   | 0.00                       | 0.00                | 0.00         | 40.91              | 42.12               | 83.03        | 32.64              | (20.06)             | 12.58        | 29.96              | 37.93               | 67.89        |
|             | SO2 Cost (\$000)           | \$0.00                     | \$0.00              | \$0.00       | \$160.92           | (\$1.69)            | \$159.23     | (\$293.67)         | \$61.84             | (\$231.84)   | \$95.81            | \$167.87            | \$263.68     |
|             | NOx Cost (\$000)           | \$0.00                     | \$0.00              | \$0.00       | \$112.49           | \$84.93             | \$197.41     | (\$60.77)          | (\$49.28)           | (\$110.05)   | \$30.73            | \$63.05             | \$93.79      |
|             | CO2 Cost (\$000)           | \$0.00                     | \$0.00              | \$0.00       | \$122.72           | \$126.33            | \$249.05     | \$130.56           | (\$80.23)           | \$50.32      | \$179.84           | \$227.43            | \$407.27     |
|             | CHP Generation (GWh)       | 0.0                        | 0.0                 | 0.0          | (88.3)             | (85.9)              | (174.2)      | (87.0)             | (84.8)              | (171.9)      | (86.9)             | (84.3)              | (171.2)      |
| NY-K        | Generation (GWh)           | 0.0                        | 0.0                 | 0.0          | (1.0)              | 9.8                 | 8.8          | (8.9)              | 3.5                 | (5.3)        | 14.8               | (26.0)              | (11.2)       |
|             | Fuel Consumption (GBtu)    | 0.0                        | 0.0                 | 0.0          | 27.7               | 163.9               | 191.6        | (58.3)             | 72.8                | 144.4        | 224.9              | (276.2)             | (51.2)       |
|             | Fuel Cost (\$000)          | \$0.0                      | \$0.0               | \$0.0        | \$2,062.4          | \$3,210.1           | \$5,272.5    | \$1,464.2          | \$2,589.1           | \$4,053.3    | \$4,768.0          | (\$673.5)           | \$4,094.6    |
|             | SO2 Emissions (000 tons)   | 0.00                       | 0.00                | 0.00         | 0.06               | 0.07                | 0.13         | 0.03               | 0.04                | 0.08         | 0.04               | 0.03                | 0.07         |
|             | NOx Emissions (000 tons)   | 0.00                       | 0.00                | 0.00         | 0.01               | 0.01                | 0.02         | 0.02               | 0.01                | 0.03         | 0.03               | (0.02)              | 0.01         |
|             | CO2 Emissions (000 tons)   | 0.00                       | 0.00                | 0.00         | 17.36              | 24.88               | 42.24        | 11.82              | 19.72               | 31.54        | 29.49              | (2.94)              | 26.55        |
|             | SO2 Cost (\$000)           | \$0.00                     | \$0.00              | \$0.00       | \$87.73            | \$93.02             | \$180.75     | \$61.77            | \$84.59             | \$146.35     | \$97.39            | \$86.41             | \$183.79     |
|             | NOx Cost (\$000)           | \$0.00                     | \$0.00              | \$0.00       | \$25.97            | \$22.70             | \$48.68      | \$40.46            | \$22.50             | \$62.95      | \$98.41            | (\$74.60)           | \$23.81      |
|             | CO2 Cost (\$000)           | \$0.00                     | \$0.00              | \$0.00       | \$52.08            | \$74.64             | \$126.72     | \$47.28            | \$78.89             | \$126.17     | \$176.93           | (\$17.62)           | \$159.31     |
|             | CHP Generation (GWh)       | 0.0                        | 0.0                 | 0.0          | (23.2)             | (22.4)              | (45.6)       | (23.0)             | (22.5)              | (45.5)       | (22.8)             | (22.2)              | (44.3)       |
| State       | Generation (GWh)           | 0.0                        | 0.0                 | 0.0          | (76.0)             | (40.6)              | (116.6)      | 1.5                | (57.6)              | (56.1)       | 25.8               | (99.3)              | (73.4)       |
|             | Fuel Consumption (GBtu)    | 0.0                        | 0.0                 | 0.0          | (922.8)            | (159.4)             | (1,082.1)    | (154.2)            | (343.7)             | (497.8)      | (193.3)            | (1,138.8)           | (1,332.0)    |
|             | Fuel Cost (\$000)          | \$0.0                      | \$0.0               | \$0.0        | \$10,043.6         | \$15,826.2          | \$25,869.8   | \$17,706.3         | \$15,419.6          | \$33,125.9   | \$21,334.9         | \$8,137.8           | \$29,472.7   |
|             | SO2 Emissions (000 tons)</ |                            |                     |              |                    |                     |              |                    |                     |              |                    |                     |              |

## 6.2 Impact on wholesale electric prices resulting from DG/CHP by zone

Throughout all scenarios and all years, prices tend to be higher in the downstate zones than in the upstate zones. The upstate Zone A-D is characterized by a great deal of hydro, nuclear and coal capacity. Each of these capacity types has low variable costs of operation, which tends to depress electric prices during low and moderate demand periods. Downstate zones, by contrast, have gas and oil fired generation setting the market clearing price much of the time, leading to comparatively higher average prices.

**Table 16. New York LBMP by Year, Zone, Season, and Scenario**

| Market Area | Year | Scenario 1            |                        |                   | Scenario 2            |                        |                   | Scenario 3            |                        |                   |
|-------------|------|-----------------------|------------------------|-------------------|-----------------------|------------------------|-------------------|-----------------------|------------------------|-------------------|
|             |      | Season 1:<br>May-Oct. | Season 2:<br>Nov-April | Annual<br>Average | Season 1:<br>May-Oct. | Season 2:<br>Nov-April | Annual<br>Average | Season 1:<br>May-Oct. | Season 2:<br>Nov-April | Annual<br>Average |
| NY-A-D      | 2006 | \$63.54               | \$62.93                | \$63.24           | \$63.54               | \$62.93                | \$63.24           | \$63.54               | \$62.93                | \$63.24           |
| NY-E        | 2006 | \$63.87               | \$62.57                | \$63.22           | \$63.87               | \$62.57                | \$63.22           | \$63.87               | \$62.57                | \$63.22           |
| NY-F        | 2006 | \$69.60               | \$73.25                | \$71.42           | \$69.60               | \$73.25                | \$71.42           | \$69.60               | \$73.25                | \$71.42           |
| NY-G        | 2006 | \$71.46               | \$75.40                | \$73.43           | \$71.46               | \$75.40                | \$73.43           | \$71.46               | \$75.40                | \$73.43           |
| NY-H        | 2006 | \$70.56               | \$74.63                | \$72.59           | \$70.56               | \$74.63                | \$72.59           | \$70.56               | \$74.63                | \$72.59           |
| NY-I        | 2006 | \$71.15               | \$75.27                | \$73.21           | \$71.15               | \$75.27                | \$73.21           | \$71.15               | \$75.27                | \$73.21           |
| NY-J        | 2006 | \$92.55               | \$89.67                | \$91.11           | \$92.55               | \$89.67                | \$91.11           | \$92.55               | \$89.67                | \$91.11           |
| NY-K        | 2006 | \$118.01              | \$106.75               | \$112.38          | \$118.01              | \$106.75               | \$112.38          | \$118.01              | \$106.75               | \$112.38          |
| NY-A-D      | 2010 | \$61.25               | \$62.58                | \$61.91           | \$61.08               | \$62.34                | \$61.71           | \$61.28               | \$62.22                | \$61.75           |
| NY-E        | 2010 | \$61.53               | \$62.39                | \$61.96           | \$61.33               | \$62.09                | \$61.71           | \$61.62               | \$62.05                | \$61.83           |
| NY-F        | 2010 | \$62.96               | \$65.02                | \$63.99           | \$62.78               | \$64.49                | \$63.63           | \$62.88               | \$64.40                | \$63.64           |
| NY-G        | 2010 | \$64.09               | \$67.11                | \$65.60           | \$63.99               | \$66.77                | \$65.38           | \$63.95               | \$66.41                | \$65.18           |
| NY-H        | 2010 | \$64.00               | \$65.80                | \$64.90           | \$63.82               | \$65.44                | \$64.63           | \$63.99               | \$65.37                | \$64.68           |
| NY-I        | 2010 | \$64.60               | \$66.40                | \$65.50           | \$64.41               | \$66.05                | \$65.23           | \$64.58               | \$65.98                | \$65.28           |
| NY-J        | 2010 | \$85.37               | \$73.77                | \$79.57           | \$85.67               | \$73.62                | \$79.65           | \$85.86               | \$73.27                | \$79.56           |
| NY-K        | 2010 | \$94.93               | \$86.83                | \$90.88           | \$95.15               | \$86.60                | \$90.88           | \$94.54               | \$87.21                | \$90.87           |
| NY-A-D      | 2015 | \$71.44               | \$71.98                | \$71.71           | \$71.26               | \$71.89                | \$71.57           | \$71.11               | \$71.95                | \$71.53           |
| NY-E        | 2015 | \$71.88               | \$72.12                | \$72.00           | \$71.72               | \$71.98                | \$71.85           | \$71.59               | \$72.04                | \$71.82           |
| NY-F        | 2015 | \$73.38               | \$73.60                | \$73.49           | \$73.29               | \$73.37                | \$73.33           | \$73.04               | \$73.45                | \$73.25           |
| NY-G        | 2015 | \$74.23               | \$75.21                | \$74.72           | \$74.21               | \$74.69                | \$74.45           | \$73.87               | \$74.80                | \$74.34           |
| NY-H        | 2015 | \$74.59               | \$74.54                | \$74.56           | \$74.36               | \$74.31                | \$74.33           | \$74.26               | \$74.44                | \$74.35           |
| NY-I        | 2015 | \$75.29               | \$75.26                | \$75.28           | \$75.07               | \$75.03                | \$75.05           | \$74.96               | \$75.15                | \$75.05           |
| NY-J        | 2015 | \$88.75               | \$78.87                | \$83.81           | \$88.64               | \$78.57                | \$83.61           | \$88.49               | \$78.49                | \$83.49           |
| NY-K        | 2015 | \$107.22              | \$95.84                | \$101.53          | \$107.39              | \$96.04                | \$101.71          | \$107.10              | \$95.71                | \$101.41          |
| NY-A-D      | 2020 | \$90.99               | \$92.63                | \$91.81           | \$91.37               | \$92.44                | \$91.90           | \$91.20               | \$92.50                | \$91.85           |
| NY-E        | 2020 | \$91.78               | \$92.34                | \$92.06           | \$92.09               | \$92.08                | \$92.09           | \$91.93               | \$92.09                | \$92.01           |
| NY-F        | 2020 | \$93.68               | \$94.16                | \$93.92           | \$93.93               | \$94.14                | \$94.03           | \$93.92               | \$94.04                | \$93.98           |
| NY-G        | 2020 | \$95.14               | \$96.01                | \$95.57           | \$95.27               | \$95.91                | \$95.59           | \$95.27               | \$95.97                | \$95.62           |
| NY-H        | 2020 | \$95.46               | \$95.72                | \$95.59           | \$95.67               | \$95.51                | \$95.59           | \$95.56               | \$95.57                | \$95.56           |
| NY-I        | 2020 | \$96.41               | \$96.64                | \$96.52           | \$96.61               | \$96.43                | \$96.52           | \$96.49               | \$96.50                | \$96.49           |
| NY-J        | 2020 | \$103.87              | \$100.47               | \$102.17          | \$104.05              | \$100.49               | \$102.27          | \$104.17              | \$100.29               | \$102.23          |
| NY-K        | 2020 | \$122.24              | \$115.27               | \$118.76          | \$122.92              | \$115.54               | \$119.23          | \$122.05              | \$114.91               | \$118.48          |

The price impacts as a result of adding CHP when compared to the baseline Scenario 1 are largely driven by the amount of CHP added to the system. Beyond that, differences can be identified between upstate and downstate regions. In the upstate regions, with more low-cost generating capacity, the price effects of adding CHP were muted. In the downstate region, however, where there are more, higher-cost generating resources (fired by oil and gas) that could be displaced by CHP, the price impacts were more pronounced. The differences between the Reference Case and Scenarios 1, 2, and 3 are provided below in Table 17.

**Table 17. Summary of LBMP Price Differences between Scenarios<sup>6</sup>**

| Market Area | Year | Comparison Ref Case and Scenario 1 |                        |                   | Comparison Ref Case & Scenario 2 |                        |                   | Comparison Ref Case & Scenario 3 |                        |                   |
|-------------|------|------------------------------------|------------------------|-------------------|----------------------------------|------------------------|-------------------|----------------------------------|------------------------|-------------------|
|             |      | Season 1:<br>May-Oct.              | Season 2: Nov<br>April | Annual<br>Average | Season 1:<br>May-Oct.            | Season 2: Nov<br>April | Annual<br>Average | Season 1:<br>May-Oct.            | Season 2: Nov<br>April | Annual<br>Average |
| NY-A-D      | 2006 | \$0.00                             | \$0.00                 | \$0.00            | \$0.00                           | \$0.00                 | \$0.00            | \$0.00                           | \$0.00                 | \$0.00            |
| NY-E        | 2006 | \$0.00                             | \$0.00                 | \$0.00            | \$0.00                           | \$0.00                 | \$0.00            | \$0.00                           | \$0.00                 | \$0.00            |
| NY-F        | 2006 | \$0.00                             | \$0.00                 | \$0.00            | \$0.00                           | \$0.00                 | \$0.00            | \$0.00                           | \$0.00                 | \$0.00            |
| NY-G        | 2006 | \$0.00                             | \$0.00                 | \$0.00            | \$0.00                           | \$0.00                 | \$0.00            | \$0.00                           | \$0.00                 | \$0.00            |
| NY-H        | 2006 | \$0.00                             | \$0.00                 | \$0.00            | \$0.00                           | \$0.00                 | \$0.00            | \$0.00                           | \$0.00                 | \$0.00            |
| NY-I        | 2006 | \$0.00                             | \$0.00                 | \$0.00            | \$0.00                           | \$0.00                 | \$0.00            | \$0.00                           | \$0.00                 | \$0.00            |
| NY-J        | 2006 | \$0.00                             | \$0.00                 | \$0.00            | \$0.00                           | \$0.00                 | \$0.00            | \$0.00                           | \$0.00                 | \$0.00            |
| NY-K        | 2006 | \$0.00                             | \$0.00                 | \$0.00            | \$0.00                           | \$0.00                 | \$0.00            | \$0.00                           | \$0.00                 | \$0.00            |
| NY-A-D      | 2010 | (\$0.46)                           | (\$0.19)               | (\$0.32)          | (\$0.62)                         | (\$0.43)               | (\$0.53)          | (\$0.42)                         | (\$0.55)               | (\$0.49)          |
| NY-E        | 2010 | (\$0.32)                           | (\$0.08)               | (\$0.20)          | (\$0.51)                         | (\$0.38)               | (\$0.45)          | (\$0.23)                         | (\$0.42)               | (\$0.33)          |
| NY-F        | 2010 | (\$0.34)                           | \$0.12                 | (\$0.11)          | (\$0.52)                         | (\$0.42)               | (\$0.47)          | (\$0.42)                         | (\$0.50)               | (\$0.46)          |
| NY-G        | 2010 | (\$0.52)                           | \$0.36                 | (\$0.08)          | (\$0.62)                         | \$0.01                 | (\$0.30)          | (\$0.65)                         | (\$0.35)               | (\$0.50)          |
| NY-H        | 2010 | (\$0.36)                           | (\$0.10)               | (\$0.23)          | (\$0.55)                         | (\$0.47)               | (\$0.51)          | (\$0.38)                         | (\$0.54)               | (\$0.46)          |
| NY-I        | 2010 | (\$0.35)                           | (\$0.08)               | (\$0.21)          | (\$0.54)                         | (\$0.43)               | (\$0.48)          | (\$0.37)                         | (\$0.50)               | (\$0.44)          |
| NY-J        | 2010 | (\$1.84)                           | (\$0.38)               | (\$1.11)          | (\$1.54)                         | (\$0.52)               | (\$1.03)          | (\$1.36)                         | (\$0.87)               | (\$1.11)          |
| NY-K        | 2010 | (\$1.25)                           | (\$0.51)               | (\$0.88)          | (\$1.03)                         | (\$0.75)               | (\$0.89)          | (\$1.64)                         | (\$0.14)               | (\$0.89)          |
| NY-A-D      | 2015 | (\$0.98)                           | (\$1.18)               | (\$1.08)          | (\$1.16)                         | (\$1.28)               | (\$1.22)          | (\$1.31)                         | (\$1.22)               | (\$1.26)          |
| NY-E        | 2015 | (\$1.09)                           | (\$1.07)               | (\$1.08)          | (\$1.25)                         | (\$1.21)               | (\$1.23)          | (\$1.37)                         | (\$1.15)               | (\$1.26)          |
| NY-F        | 2015 | (\$1.08)                           | (\$0.90)               | (\$0.99)          | (\$1.16)                         | (\$1.13)               | (\$1.15)          | (\$1.42)                         | (\$1.05)               | (\$1.23)          |
| NY-G        | 2015 | (\$1.20)                           | (\$0.44)               | (\$0.82)          | (\$1.22)                         | (\$0.95)               | (\$1.09)          | (\$1.56)                         | (\$0.84)               | (\$1.20)          |
| NY-H        | 2015 | (\$0.91)                           | (\$0.81)               | (\$0.86)          | (\$1.14)                         | (\$1.04)               | (\$1.09)          | (\$1.24)                         | (\$0.90)               | (\$1.07)          |
| NY-I        | 2015 | (\$0.92)                           | (\$0.82)               | (\$0.87)          | (\$1.15)                         | (\$1.05)               | (\$1.10)          | (\$1.25)                         | (\$0.93)               | (\$1.09)          |
| NY-J        | 2015 | (\$1.01)                           | (\$0.80)               | (\$0.90)          | (\$1.11)                         | (\$1.09)               | (\$1.10)          | (\$1.17)                         | (\$1.17)               | (\$1.22)          |
| NY-K        | 2015 | (\$1.86)                           | (\$1.67)               | (\$1.76)          | (\$1.70)                         | (\$1.47)               | (\$1.58)          | (\$1.98)                         | (\$1.80)               | (\$1.89)          |
| NY-A-D      | 2020 | (\$2.29)                           | (\$0.94)               | (\$1.61)          | (\$1.91)                         | (\$1.13)               | (\$1.52)          | (\$2.08)                         | (\$1.07)               | (\$1.57)          |
| NY-E        | 2020 | (\$2.12)                           | (\$0.53)               | (\$1.32)          | (\$1.80)                         | (\$0.79)               | (\$1.29)          | (\$1.97)                         | (\$0.78)               | (\$1.38)          |
| NY-F        | 2020 | (\$2.05)                           | (\$0.47)               | (\$1.26)          | (\$1.81)                         | (\$0.49)               | (\$1.15)          | (\$1.82)                         | (\$0.59)               | (\$1.21)          |
| NY-G        | 2020 | (\$1.91)                           | (\$1.51)               | (\$1.71)          | (\$1.79)                         | (\$1.62)               | (\$1.70)          | (\$1.79)                         | (\$1.56)               | (\$1.67)          |
| NY-H        | 2020 | (\$1.72)                           | (\$0.27)               | (\$1.00)          | (\$1.51)                         | (\$0.48)               | (\$1.00)          | (\$1.62)                         | (\$0.42)               | (\$1.02)          |
| NY-I        | 2020 | (\$1.72)                           | (\$0.27)               | (\$1.00)          | (\$1.52)                         | (\$0.49)               | (\$1.00)          | (\$1.63)                         | (\$0.42)               | (\$1.03)          |
| NY-J        | 2020 | (\$2.33)                           | (\$0.80)               | (\$1.57)          | (\$2.15)                         | (\$0.77)               | (\$1.46)          | (\$2.03)                         | (\$0.98)               | (\$1.51)          |
| NY-K        | 2020 | (\$5.67)                           | (\$1.96)               | (\$3.81)          | (\$4.99)                         | (\$1.69)               | (\$3.34)          | (\$5.86)                         | (\$2.31)               | (\$4.08)          |

<sup>6</sup> Positive numbers indicate that Reference Case is more.

## 7 Conclusions

Due to its greater efficiency over traditional forms of generation, CHP has the potential to provide important environmental and economic benefits to New York State. However, many of these benefits may not be fully realized without the establishment of energy policies and environmental regulations that encourage the development of CHP resources. The purpose of this report is to quantify the benefits provided by deployment of CHP in terms of reduced wholesale energy prices, transmission congestion costs, and environmental emissions.

This study builds on a previous CHP market study conducted for NYSERDA in 2002. Using the 2002 study as a starting point, the current effort developed a new projection of CHP penetration, adding several important updates. First, the technical potential for CHP was revised, including applications for CHP where the primary thermal output is cooling. Second, the standby rate tariffs were included in the economic analyses, with relevant exemptions that were approved by the New York State Public Service Commission (NYPSC). These standby rates essentially removed a penalty for CHP units that were built into utility rates. Third, natural gas prices were updated based on the US DOE and EIA short and long-term forecasts. Finally, special delivery rates for natural gas offered by the natural gas utilities for non-residential customers who own and operate DG/CHP systems were incorporated into the study. These updates combined formed a positive regulatory environment for CHP.

Based on this supportive economic environment, CHP penetration was projected for three scenarios built around various approaches to NO<sub>x</sub> emissions regulations for CHP systems:

- Scenario 1, which was the Base Case scenario of this study, assumed an initial NO<sub>x</sub> emission rate limit of 1.6 lb/MWh for DG/CHP that remained constant through 2020 (the analysis period).
- Scenario 2 included a more aggressive “environmental forcing” strategy. It retained the favorable economic conditions of the base case scenario, but DG/CHP emission rate limits were reduced after five years to 1.0 lb/MWh and again in 2020 to 0.6 lb/MWh
- Scenario 3 included the phased in approach to more stringent emissions limits from Scenario 2, but also included a CHP thermal credit based on displacing on-site boiler emissions.

In addition to these three Scenarios, a Reference Case was modeled to establish a baseline without the introduction of new CHP in order to draw further comparisons and gauge the total magnitude of the CHP impact.

The economic market potential was determined for each scenario based on a comparison of the net power costs from the competing CHP technologies with the delivered electric and natural gas prices within that

market size and geographical area. Within each market category (size and region), the competition among applicable technologies was evaluated, and the rate of market penetration by technology under each scenario was then estimated using a market diffusion model. Only “within the fence” CHP systems were considered in the analysis. All thermal energy and power generated by the CHP systems was assumed to be used on-site; no power export market was considered for any of the size categories.

By 2020, CHP penetration ranged from 11% (Scenario 2 – 2,170 MW of installed CHP) to 12% (Scenario 3 – 2,480 MW) of the technical market potential. The more restrictive NO<sub>x</sub> emissions standards of Scenario 2 reduced total CHP penetration by about 10% from the Base Case penetration. Allowing a CHP thermal credit (Scenario 3) increased CHP penetration by about 3% over the Base Case, even considering the stricter initial NO<sub>x</sub> standard of 1.0 lb/MWh. The impact of the different scenarios is more apparent when individual CHP technology penetration is considered. The stricter NO<sub>x</sub> standards of Scenario 2 restrict the deployment of reciprocating engine CHP compared to both the Base Case and Scenario 3, which included a CHP thermal emissions credit. Much of the reciprocating engine capacity was replaced by gas turbine CHP in the larger size categories, but only a small fraction was replaced by other technologies (microturbines and fuel cells) in the smaller size categories.

The market penetration results were then used as the basis to evaluate the impact of CHP deployment on overall emissions and on electricity prices. The reduction of electricity purchases from the grid was calculated for each county in New York on a seasonal and daily basis using: 1) the amount of estimated CHP capacity installed in each county; 2) the hours of operation (low load and high load); and 3) hourly and seasonal load shapes by customer groups. This reduction in “demand” was then factored into a production simulation model that captured the hour-by-hour dynamics of electric power markets and determined the impacts on central station dispatch and the need for new capacity over time. The emissions impacts of CHP at the site (i.e., displacing existing thermal sources with the CHP systems) were compared to the emissions impacts at the power plant level (i.e., comparing net incremental emissions at the sites with displaced emissions from the grid) to determine the overall environmental impact of CHP deployment for each scenario. To see the impact of CHP deployment in full, a Reference Case was modeled that simulated the economic dispatch of the electric system prior to the introduction of any new CHP capacity.

The load reduction on the electric system resulting from the operation of the CHP plants reduced CO<sub>2</sub> emissions in each of the scenarios compared to the Reference Case, and did so across the entire Eastern Interconnect. In New York State alone, CO<sub>2</sub> emissions in each of the scenarios were approximately 3% below the CO<sub>2</sub> emission rate of the Reference Case in 2020. That reduction represents approximately *1.7 million tons of CO<sub>2</sub>*, on average, across scenarios when compared to the Reference Case. Across the entire Eastern interconnected electric markets, however, the addition of CHP projects in New York was responsible for a reduction of approximately *3.5 million tons of CO<sub>2</sub>* in 2020 for each of the scenarios compared to the Reference Case. By 2020, there were approximately 3.6 million tons of CO<sub>2</sub> emissions

reductions in Scenario 1, roughly 3.2 million tons of CO<sub>2</sub> emissions reductions in Scenario 2, and approximately 3.7 million tons of CO<sub>2</sub> emissions reductions in Scenario 3 resulting from the introduction of CHP. In each of these scenarios, roughly half of the CO<sub>2</sub> savings occurred in New York, with the other half distributed throughout the rest of the Eastern Interconnect.

Within New York, as stated in Section 6, the CO<sub>2</sub> reductions were not evenly distributed. In the upstate region, coal-fired generation was retired and displaced, which reduced CO<sub>2</sub> emissions relative to the Reference Case. In the downstate area, generation levels increased without displacing dirtier (more carbon intensive) forms of generation. This actually caused CO<sub>2</sub> emission levels to increase relative to the Reference Case. Nonetheless, on average across scenarios the introduction of CHP was responsible for a reduction of approximately 1.7 million tons of CO<sub>2</sub> emissions in NYS, and 3.5 million tons of CO<sub>2</sub> emissions in the Eastern Interconnected electric markets in 2020.

The introduction of CHP in all three scenarios reduced prices compared to the Reference Case across the entire New York State. Price reductions occurred throughout the year, but were greatest in the summer season. On average across the state in 2020, Scenario 1 saw a \$1.66/MWh (2006\$) price decrease due to the introduction of CHP compared to the Reference Case. The price decrease in Scenario 2 in 2020 compared to the Reference case was \$1.56/MWh (2006\$), and in Scenario 3 it was \$1.68/MWh (2006\$) on average across the state. These impacts are significant and represent strong potential economic benefits for all electric customers in the state, as all customers would benefit from lower prices and not only those who own CHP plants.

With respect to NO<sub>x</sub> emissions, there was very little change in Scenario 1 compared to the Reference Case. In fact, NO<sub>x</sub> emission increased slightly: 140 tons for the full year in 2020, which included a 120-ton decrease during the summer season and a 270-ton increase during the winter season. The NO<sub>x</sub> emission limits produced emissions reductions throughout the year. In Scenario 1, however, once the NO<sub>x</sub> emissions from the CHP plants were added to the NO<sub>x</sub> emissions from all the other plants, the combined emissions increased in the winter months but remained below Reference Case levels in the summer months. In Scenarios 2 and 3, however, where greater restrictions were placed on NO<sub>x</sub> emissions, greater emission reductions were realized. Scenario 2 saw a 2,583-ton reduction in NO<sub>x</sub> emissions compared to the Reference Case in 2020 for the full year, and Scenario 3 saw a 1,080 increase in NO<sub>x</sub> emissions compared to the Reference Case, after accounting for the NO<sub>x</sub> emissions from the CHP plants themselves. In Scenario 2, NO<sub>x</sub> emissions were reduced during the summer and winter periods, with greater reductions occurring during the summer.

Considering the impact of the CHP penetration scenarios, it is apparent that reductions in CO<sub>2</sub> emissions and electric prices are achievable. Reductions in NO<sub>x</sub> emissions however, were not realized by the introduction of CHP alone, but rather by the combination with stricter NO<sub>x</sub> limits. Therefore, while encouraging CHP development may further certain policy objectives, it is not likely to advance

improvement in policy goals that seek to reduce NOx emissions in the state unless NOx limits are written into the standards.

Finally, this study demonstrated that the introduction of CHP in New York State will provide benefits to electric consumers in the form of lower electric prices and reduced emissions of CO<sub>2</sub>, SO<sub>2</sub>, and NO<sub>x</sub> when combined with policies that limit NO<sub>x</sub> emissions. Because of the load reducing effects that CHP has on the system, the generation dispatch of central stations is affected. This study showed that, especially in the upstate New York region, dirtier types of generation such as coal were actually retired and displaced, resulting in some of the environmental benefits. The displacement of coal-fired generation was especially apparent, from an environmental perspective, in the reduction of SO<sub>2</sub> emissions. While there were modest SO<sub>2</sub> emission reductions in regions outside of New York, the majority occurred within the state. Given other constraints, such as the available transmission capability between regions and relative prices between regions, emissions reductions outside of New York through the introduction of CHP plants should be viewed as a peripheral benefit -- CHP projects in New York will not likely have a far-reaching impact on the reduction of coal usage in regions outside the state.

It has been demonstrated that CHP is effective at providing economic and environmental benefits within New York and beyond. From a carbon perspective, the benefits were demonstrated in nearly every region modeled. From an economic perspective, the benefits to New York electric customers would be significant: nearly \$1.70/MWh (2006\$) in 2020 on average across the state. CHP systems can enhance both the economic welfare of New York electric consumers and the environmental conditions within the state and across the modeling region.

## 8 Appendices

### 8.1 Appendix A: Technical Potential for CHP

This section provides an estimate of the technical market potential for combined heat and power (CHP) in the industrial, commercial/institutional, and multi-family residential market sectors. The estimation of technical market potential consists of the following elements:

- Identification of applications where CHP provides a reasonable fit to the electric and thermal needs of the user. Target applications were identified based on reviewing the electric and thermal energy consumption data for various building types and industrial facilities.
- Quantification of the number and size distribution of target applications. Several data sources were used to identify the number of applications by sector that meets the thermal and electric load requirements for CHP.
- Estimation of CHP potential in terms of megawatt (MW) capacity. Total CHP potential is then derived for each target application based on the number of target facilities in each size category and sizing criteria appropriate for each sector.
- Subtraction of existing CHP from the identified sites to determine the remaining technical market potential.

The technical market potential does not consider screening for economic rate of return, or other factors such as ability to retrofit, owner interest in applying CHP, capital availability, natural gas availability, and variation of energy consumption within customer application/size class. The technical potential as outlined is useful in understanding the potential size and size distribution of the target CHP markets in the state. Identifying technical market potential is a preliminary step in the assessment of market penetration.

The basic approach to developing the technical potential is described below:

- *Identify applications where CHP provides a reasonable fit to the electric and thermal needs of the user.* Target applications were identified based on reviewing the electric and thermal energy (heating and cooling) consumption data for various building types and industrial facilities. Data sources include the DOE EIA *Commercial Buildings Energy Consumption Survey (CBECS)*, the DOE *Manufacturing Energy Consumption Survey (MECS)* and various market summaries developed by DOE, Gas Technology Institute (GTI), and the American Gas Association. Existing CHP installations in the commercial/institutional and industrial sectors were also reviewed to understand the required profile for CHP applications and to identify target applications.

- *Quantify the number and size distribution of target applications.* Once applications that could technically support CHP were identified, the iMarket, Inc. *MarketPlace Database* and the *Major Industrial Plant Database (MIPD)* from IHI were utilized to identify potential CHP sites by SIC code or application, and location (county). The *MarketPlace Database* is based on the Dun and Bradstreet financial listings and includes information on economic activity (8 digit SIC), location (metropolitan area, county, electric utility service area, state) and size (employees) for commercial, institutional and industrial facilities. In addition, for select SICs limited energy consumption information (electric and gas consumption, electric and gas expenditures) is provided based on data from Wharton Econometric Forecasting (WEFA). MIPD has detailed energy and process data for 16,000 of the largest energy consuming industrial plants in the United States. The *MarketPlace Database* and MIPD were used to identify the number of facilities in target CHP applications and to group them into size categories based on average electric demand in kW.
- *Estimate CHP potential in terms of MW capacity.* Total CHP potential was then derived for each target application based on the number of target facilities in each size category. It was assumed that the CHP system would be sized to meet the average site electric demand for the target applications unless thermal loads (heating and cooling) limited electric capacity. **Table A-1** presents the specific target market sectors, and the assumed growth factors. Existing CHP capacity was subtracted from the technical potential in each specific size and market sector category.
- *Estimate the growth of new facilities in the target market sectors.* The technical potential included economic projections for growth through 2020 by target market sectors in New York State.

Two different types of CHP markets were included in the evaluation of technical potential:

- Traditional CHP – electric output is produced to meet all or a portion of the base load for a facility and the thermal energy is used to provide steam or hot water. Depending on the type of facility, the appropriate sizing could be either electric or thermal limited. Industrial facilities often have “excess” thermal load compared to their on-site electric load. Commercial facilities almost always have excess electric load compared to their thermal load. Two sub-categories were considered:
  - High load factor applications – This market provides for continuous or nearly continuous operation. It includes all industrial applications and round-the-clock commercial/institutional operations such colleges, hospitals, hotels, and prisons.
  - Low load factor applications – Some commercial and institutional markets provide an opportunity for coincident electric/thermal loads for a period of 3,500 to 5,000 hours per year. This sector includes applications such as office buildings, schools, and laundries.

- CHP with thermally activated cooling – All or a portion of the thermal output of a CHP system can be converted to air conditioning or refrigeration. This type of system can potentially open up the benefits of CHP to facilities that do not have the year-round thermal load to support a traditional CHP system. A typical system would provide the annual hot water load, a portion of the space-heating load in the winter months, and a portion of the cooling load in during the summer months. Two sub-categories were considered:
  - Low load factor applications – These represent markets that otherwise could not support CHP due to a lack of thermal load.
  - Incremental high load factor applications – These markets represent round-the-clock commercial/institutional facilities that could support traditional CHP, but with cooling, incremental capacity could be added while maintaining a high level of utilization of the thermal energy from the CHP system.

**Table A-1 – Target Market Sectors for CHP and Sector Growth Projections Through 2020**

| <b>SICs</b>                            | <b>Application</b>       | <b>Adj. Annual Growth</b> | <b>2005-2020 Growth</b> |
|--|--------------------------|---------------------------|-------------------------|
| 4581                                   | Airports                 | 5.00%                     | 107.89%                 |
| 6513                                   | Apartments               | 0.00%                     | 0.00%                   |
| 52,53,56,57                            | Big Box Retail           | 5.00%                     | 107.89%                 |
| 7542                                   | Carwashes                | 0.00%                     | 0.00%                   |
| 28                                     | Chemicals                | 5.00%                     | 107.89%                 |
| 8221, 8222                             | Colleges/Universities    | 0.95%                     | 15.27%                  |
| 34                                     | Fabricated Metals        | 0.00%                     | 0.00%                   |
| 20                                     | Food                     | 0.00%                     | 0.00%                   |
| 5411, 5421, 5451, 5461, 5499           | Food Sales               | 2.00%                     | 34.59%                  |
| 25                                     | Furniture                | 0.90%                     | 14.38%                  |
| 7992, 7997-9904, 7997-9906             | Golf/Country Clubs       | 0.93%                     | 14.91%                  |
| 7991, 00, 01                           | Health Clubs             | 0.93%                     | 14.91%                  |
| 8062, 8063, 8069                       | Hospitals                | 1.86%                     | 31.84%                  |
| 8062, 8063, 8069                       | Hospitals- Cooling       | 1.86%                     | 31.84%                  |
| 7011, 7041                             | Hotels                   | 1.24%                     | 20.33%                  |
| 7011, 7041                             | Hotels- Cooling          | 1.24%                     | 20.33%                  |
| 38                                     | Instruments              | 2.22%                     | 39.07%                  |
| 7211, 7213, 7218                       | Laundries                | 1.00%                     | 16.10%                  |
| 24                                     | Lumber and Wood          | 1.55%                     | 25.87%                  |
| 35                                     | Machinery/Computer Equip | 5.00%                     | 107.89%                 |
| 39                                     | Misc Manufacturing       | 0.00%                     | 0.00%                   |
| 7832                                   | Movie Theaters           | 0.93%                     | 14.91%                  |
| 8412                                   | Museums                  | 0.20%                     | 2.98%                   |
| 8051, 8052, 8059                       | Nursing Homes            | 3.81%                     | 75.31%                  |
| 8051, 8052, 8059                       | Nursing Homes- Cooling   | 3.81%                     | 75.31%                  |
| 6512                                   | Office Buildings         | 3.00%                     | 55.73%                  |
| 26                                     | Paper                    | 0.00%                     | 0.00%                   |
| 29                                     | Petroleum Refining       | 1.06%                     | 17.17%                  |
| 43                                     | Post Offices             | 0.00%                     | 0.00%                   |
| 33                                     | Primary Metals           | 4.97%                     | 107.01%                 |
| 27                                     | Printing/Publishing      | 0.00%                     | 0.00%                   |
| 9223, 9211 (Courts), 9224 (firehouses) | Prisons                  | 0.00%                     | 0.00%                   |
| 5812, 00, 01, 03, 05, 07, 08           | Restaurants              | 3.16%                     | 59.43%                  |
| 30                                     | Rubber/Misc Plastics     | 0.78%                     | 12.39%                  |
| 8211, 8243, 8249, 8299                 | Schools                  | 0.95%                     | 15.27%                  |
| 32                                     | Stone/Clay/Glass         | 0.00%                     | 0.00%                   |
| 22                                     | Textiles                 | 0.00%                     | 0.00%                   |
| 37                                     | Trasportation Equip.     | 1.87%                     | 32.08%                  |
| 4222, 5142                             | Warehouses               | 5.00%                     | 107.89%                 |
| 4941, 4952                             | Water Treatment/Sanitary | 1.23%                     | 20.18%                  |

## **8.2 Appendix B: Energy Price Projections**

The expected future relationship between purchased natural gas and electricity prices, called the “spark spread” in this context, is one major determinant of the ability of a facility with electric and thermal energy requirements to cost-effectively use CHP. A multilevel analysis of energy costs to customers was conducted for this study. The analysis consisted of the following:

- Detailed analysis of specific utility rate structures including standby and supplementary service to represent downstate and upstate costs
- Customer natural gas prices
- Long-term price trends

### **Electricity Prices**

Niagara Mohawk (NiMo), the largest electric utility in the upstate region of New York was selected as the basis for analysis of customer rates and specific charges related to customers with CHP or other on-site generating systems in the upstate market. Consolidated Edison Company (ConEd) was used as the basis for estimating economic competitiveness in the downstate market.

Under the restructured power markets in the state, utilities bill customers separately for delivery charges and supply charges. The delivery charges cover the utility costs for their local transmission, distribution, and customer service operations. Supply charges represent the costs for electricity generation and transmission; in the current market, the New York Independent System Operator (NYISO) sets these costs on a regional basis. These supply costs are passed through to the customer.

### **Tariffs Used in the Analysis**

For each of the five size categories in the CHP market assessment, the appropriate NiMo electric rate was selected for the upstate region and the ConEd rate selected for the downstate region. These rates are summarized below:

Niagara Mohawk (representing upstate region)

- 100-500 kW – SC3 – Large General Service
- 500-1,000 kW – SC3 – Large General Service
- 1-5 MW – SC3a – Large General Service Time of Use, Secondary
- 5-20 MW – SC3a – Large General Service TOU, Primary
- Greater than 20 MW – SC3a – Large General Service, Transmission voltage
- Standby Rates – SC7

Consolidated Edison (representing downstate region)

- Customers with demand between 10kW and 1,500 kW – SC9, Rate I – General, Large

- All customers with demand greater than 1,500kW – SC9, Rate II – General, Large, Time-of-use
- Supplementary Rate – SC10 – Supplementary Service
- Standby Rates – SC14A – Backup Service (replacing SC3 used in the 2002 New York CHP market study.)

Three usage rates were selected for each customer:

1. Constant usage – 8760 hours – based on the assumption that a nearly continuously operating CHP system would remove this slice from the annual energy bill, less downtime and standby.
2. Low load – 4500 hours – based on consumption patterns for a business that mostly shuts down at night and whose CHP system would be operating only on daytime basis.
3. AC load – 2000-2200 hours – to evaluate the avoided cost of electric chiller load that is taken over by a thermally activated technology using waste heat from the CHP system. Standby costs are not calculated for this usage because the CHP system itself is assumed to operate on one of the two schedules described above. Only the displaced electric chiller load is valued at this level.

Tariffs appropriate to the five customer sizes (50-500kW, 500-1000 kW, 1-5 MW, 5-20 MW, and >20 MW) were evaluated for each of these hourly usage levels and the standby charges were also calculated. The energy delivery costs were assumed to remain constant in real dollars over the forecast period. Half of the electricity supply costs were assumed to vary proportionally as a function of the natural gas price forecast, and the remaining half was assumed to be constant in real dollars.

The standby charges vary as a function of the annual hours of CHP operation with charges increasing as the load factor of the CHP system declines from continuous operation to 4500 hours/year. These charges were assumed to remain constant in real dollars over the forecast period.

The calculated average values were used in the market penetration model with the avoided purchased power cost equal to the average power cost at the appropriate load factor minus the standby costs. Table B-1 shows the average power costs for four sizes (5-20 MW and >20 MW size categories are assumed to use the same rates) and the three annual usage levels.

**Table B-1. Calculated Average Electric Rates Input to the Market Penetration Model**

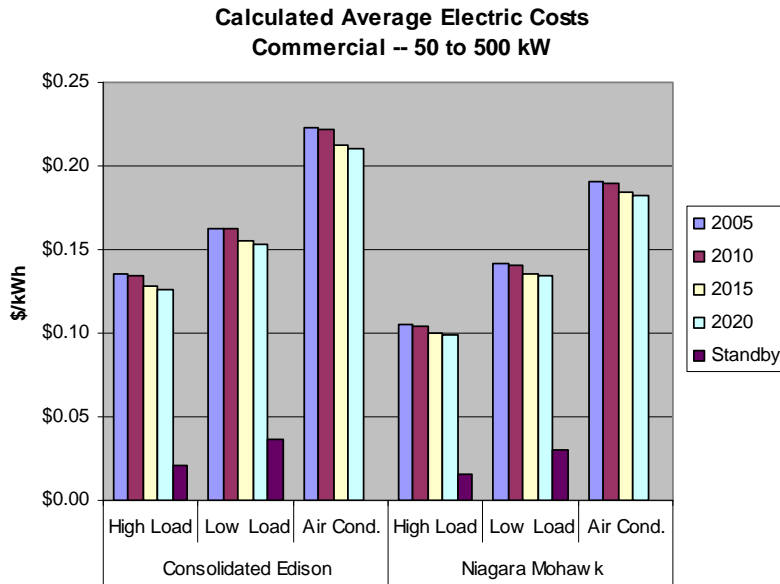
| Market and Year                                   | Consolidated Edison |          |           | Niagara Mohawk |          |           |
|---|---------------------|----------|-----------|----------------|----------|-----------|
|   | High Load           | Low Load | Air Cond. | High Load      | Low Load | Air Cond. |
| <b>Commercial 50 kW to 500 kW</b>                 |                     |          |           |                |          |           |
| 2005  | \$0.135             | \$0.163  | \$0.223   | \$0.105        | \$0.141  | \$0.190   |
| 2010  | \$0.135             | \$0.162  | \$0.222   | \$0.105        | \$0.141  | \$0.190   |
| 2015  | \$0.128             | \$0.155  | \$0.213   | \$0.100        | \$0.136  | \$0.184   |
| 2020  | \$0.126             | \$0.153  | \$0.210   | \$0.099        | \$0.134  | \$0.183   |
| Standby   | \$0.021             | \$0.037  | n.a.      | \$0.016        | \$0.031  | n.a.      |
| <b>Industrial -- 500 to 1,000 kW</b>              |                     |          |           |                |          |           |
| 2005  | \$0.131             | \$0.154  | \$0.205   | \$0.102        | \$0.136  | \$0.179   |
| 2010  | \$0.130             | \$0.154  | \$0.205   | \$0.102        | \$0.135  | \$0.179   |
| 2015  | \$0.124             | \$0.146  | \$0.196   | \$0.098        | \$0.130  | \$0.173   |
| 2020  | \$0.122             | \$0.144  | \$0.193   | \$0.097        | \$0.129  | \$0.172   |
| Standby   | \$0.020             | \$0.035  | n.a.      | \$0.013        | \$0.029  | n.a.      |
| <b>Large Industrial -- 1 to 5 MW</b>              |                     |          |           |                |          |           |
| 2005  | \$0.126             | \$0.169  | \$0.306   | \$0.097        | \$0.124  | \$0.159   |
| 2010  | \$0.125             | \$0.168  | \$0.305   | \$0.096        | \$0.124  | \$0.159   |
| 2015  | \$0.119             | \$0.161  | \$0.291   | \$0.092        | \$0.119  | \$0.154   |
| 2020  | \$0.118             | \$0.159  | \$0.288   | \$0.091        | \$0.117  | \$0.152   |
| Standby   | \$0.022             | \$0.044  | n.a.      | \$0.011        | \$0.015  | n.a.      |
| <b>Very Large Industrial -- Greater than 5 MW</b> |                     |          |           |                |          |           |
| 2005  | \$0.124             | \$0.161  | \$0.288   | \$0.088        | \$0.111  | \$0.138   |
| 2010  | \$0.124             | \$0.161  | \$0.287   | \$0.087        | \$0.110  | \$0.137   |
| 2015  | \$0.118             | \$0.153  | \$0.274   | \$0.083        | \$0.105  | \$0.132   |
| 2020  | \$0.116             | \$0.151  | \$0.270   | \$0.082        | \$0.104  | \$0.131   |
| Standby   | \$0.022             | \$0.043  | n.a.      | \$0.010        | \$0.013  | n.a.      |

These results are shown graphically for the smallest and largest sizes in Figure B-1 and Figure B-2.

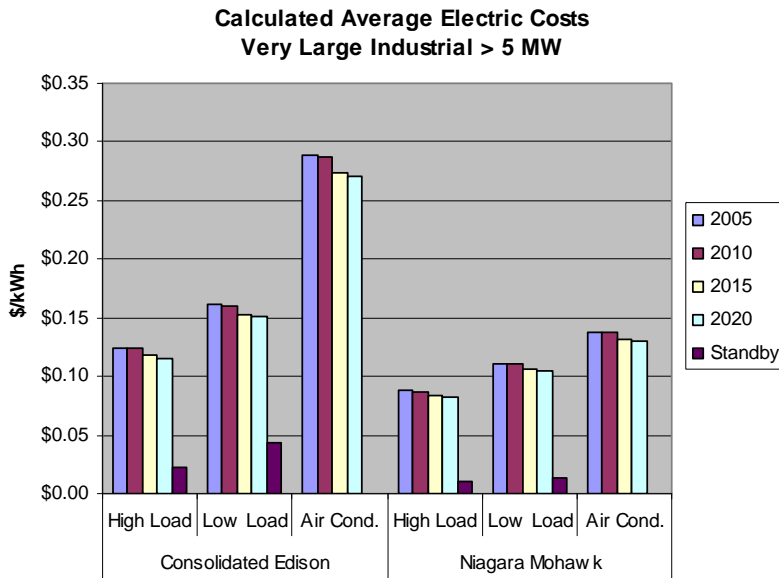
Notable aspects of the rate analysis are as follows:

- Downstate rates are higher than upstate rates with the difference becoming more significant as the customer size class increases.
- Electric rates decline slightly over the forecast period as a result of the declining gas price forecast used for the analysis (described in the next section.)
- Standby rates are more severe for low load factor CHP applications. Though the standby costs are high, the high power costs leave enough avoided purchased power costs to provide an economic market for CHP.
- The avoided air conditioning electric costs are the highest, peak period costs reaching as high as \$0.28/kWh.

**Figure B-1. Calculated Average Purchased Power Costs for Commercial Customers**



**Figure B-2. Calculated Average Purchased Power Costs for Very Large Industrial Customers**



**Natural Gas Prices**

The natural gas wellhead price forecast was specified by NYSERDA staff; the prices used as the basis for the analysis were from the update of the Regional Greenhouse Gas Initiative (RGGI.) The upstate and

downstate delivery markups were adapted from the RGGI output as well. The customer markups were based on evaluation of EIA pricing. The complete price forecast is shown in Table B-2. Figure B-3 shows the wellhead price trends in real dollars throughout the forecast period.

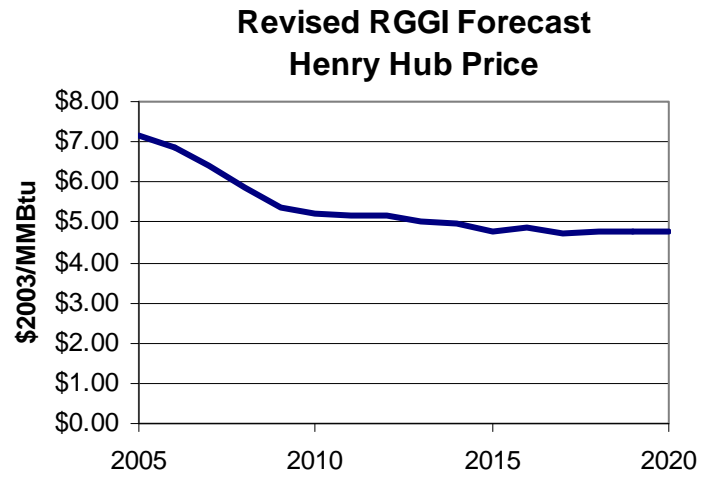
**Table B-2. Natural Gas Price Forecast**

| Year      | Henry Hub | Upstate          |            |        | Downstate          |            |        |
|-----------|-----------|------------------|------------|--------|--------------------|------------|--------|
|           |           | EG/CHP           | Industrial | Comm.  | EG/CHP             | Industrial | Comm.  |
| 2005      | \$7.14    | \$7.39           | \$7.54     | \$8.14 | \$7.96             | \$8.11     | \$8.71 |
| 2006      | \$6.86    | \$7.11           | \$7.26     | \$7.86 | \$7.68             | \$7.83     | \$8.43 |
| 2007      | \$6.43    | \$6.68           | \$6.83     | \$7.43 | \$7.25             | \$7.40     | \$8.00 |
| 2008      | \$5.86    | \$6.11           | \$6.26     | \$6.86 | \$6.68             | \$6.83     | \$7.43 |
| 2009      | \$5.39    | \$5.64           | \$5.79     | \$6.39 | \$6.21             | \$6.36     | \$6.96 |
| 2010      | \$5.22    | \$5.47           | \$5.62     | \$6.22 | \$6.04             | \$6.19     | \$6.79 |
| 2011      | \$5.16    | \$5.41           | \$5.56     | \$6.16 | \$5.98             | \$6.13     | \$6.73 |
| 2012      | \$5.19    | \$5.44           | \$5.59     | \$6.19 | \$6.01             | \$6.16     | \$6.76 |
| 2013      | \$5.02    | \$5.27           | \$5.42     | \$6.02 | \$5.84             | \$5.99     | \$6.59 |
| 2014      | \$4.96    | \$5.21           | \$5.36     | \$5.96 | \$5.78             | \$5.93     | \$6.53 |
| 2015      | \$4.79    | \$5.04           | \$5.19     | \$5.79 | \$5.61             | \$5.76     | \$6.36 |
| 2016      | \$4.87    | \$5.12           | \$5.27     | \$5.87 | \$5.69             | \$5.84     | \$6.44 |
| 2017      | \$4.71    | \$4.96           | \$5.11     | \$5.71 | \$5.53             | \$5.68     | \$6.28 |
| 2018      | \$4.76    | \$5.01           | \$5.16     | \$5.76 | \$5.58             | \$5.73     | \$6.33 |
| 2019      | \$4.76    | \$5.01           | \$5.16     | \$5.76 | \$5.58             | \$5.73     | \$6.33 |
| 2020      | \$4.77    | \$5.02           | \$5.17     | \$5.77 | \$5.59             | \$5.74     | \$6.34 |
| Henry Hub |           | \$0.25           | \$0.40     | \$1.00 | \$0.25             | \$0.40     | \$1.00 |
| Markups   |           | UpState Delivery |            | \$0.19 | Downstate Delivery |            | \$0.57 |

*Note: EG/CHP – Electric Generator/CHP rate*

The natural gas prices trend downward more strongly than the electric prices because only a portion of the supply related costs of electricity vary with the gas price, with the remaining supply costs and all of the delivery costs being fixed. This relationship tends to make CHP more competitive during the later years of the forecast period.

Figure B-3 Natural Gas Price Forecast Trends – RGGI



### 8.3 Appendix C: CHP Technology Cost and Performance

The CHP system itself is the engine that drives the economic savings. The cost and performance characteristics of CHP systems determine the economics of meeting the site's electric and thermal loads. A representative sample of commercially and emerging CHP systems was selected to profile performance and cost characteristics in combined heat and power (CHP) applications. The selected systems range in capacity from approximately 100 – 20,000 kW. The technologies include gas-fired reciprocating engines, gas turbines, microturbines, and fuel cells. The appropriate technologies were allowed to compete for market share in the penetration model. In the smaller market sizes, reciprocating engines competed with microturbines and fuel cells. In intermediate sizes (1 to 20 MW), reciprocating engines competed with gas turbines.

Cost and performance estimates for the CHP systems were based on work previously conducted for NYSERDA, on peer-reviewed technology characterizations that Energy and Environmental Analysis (EEA) developed for the National Renewable Energy Laboratory<sup>7</sup> and on follow-on work conducted by DE Solutions for Oak Ridge National Laboratory.<sup>8</sup> Additional emissions characteristics and cost and performance estimates for emissions control technologies were based on ongoing work EEA is conducting for EPRI.<sup>9</sup> Data is presented for a range of sizes that include basic electrical performance characteristics, CHP performance characteristics (power to heat ratio), equipment cost estimates, maintenance cost estimates, emission profiles with and without after-treatment control, and emissions control cost estimates. The technology characteristics are presented for three years: 2005, 2010, 2020. The 2005 estimates are based on current commercially available and emerging technologies. The cost and performance estimates for 2010 and 2020 reflect current technology development paths and currently planned government and industry funding. These projections were based on estimates included in the three references mentioned above. NO<sub>x</sub>, CO and VOC emissions estimates in lb/MWh are presented for each technology both with and without aftertreatment control (AT). NO<sub>x</sub> emissions are presented with and without a CHP thermal credit (using a displaced emissions approach and displaced boiler emissions of 0.2 lb/MMBtu for all technologies). Which system is applicable in any size category (e.g., with aftertreatment or without) is a function of the specific emissions requirements assumptions for each scenario. The installed costs in the

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<sup>7</sup> “Gas-Fired Distributed Energy Resource Technology Characterizations”, NREL, November 2003, <http://www.osti.gov/bridge>

<sup>8</sup> “Clean Distributed Generation Performance and Cost Analysis”, DE Solutions for ORNL. April 2004.

<sup>9</sup> “Assessment of Emerging Low-Emissions Technologies for Distributed Resource Generators”, EPRI, January 2005.

following technology performance summary tables are based on typical national averages. The installed costs used in the CHP penetration analysis were adjusted for upstate and downstate New York based on industry construction indices.

**Table C-1 - Reciprocating Engines**

| Size and Type                            | Characterization                      | 2005   | 2012   | 2020   |       |
|--|---------------------------------------|--------|--------|--------|-------|
| 100 kW Rich Burn<br>w/three way catalyst | Capacity, kW                          | 100    | 100    | 100    |       |
|  | Installed Costs, \$/kW                | 1,550  | 1,350  | 1,100  |       |
|  | Heat Rate, Btu/kWh                    | 11,500 | 10,830 | 10,500 |       |
|  | Electric Efficiency, %                | 29.7%  | 31.5%  | 32.5%  |       |
|  | Power to Heat Ratio                   | 0.61   | 0.67   | 0.7    |       |
|  | Thermal Output, Btu/kWh               | 5593   | 5093   | 4874   |       |
|  | O&M Costs, \$/kWh                     | 0.018  | 0.013  | 0.012  |       |
|  | NOx Emissions, lbs/MWh (no AT)        | 40     | 40     | 40     |       |
|  | NOx Emissions, lbs/MWh (w/ AT)        | 0.5    | 0.25   | 0.2    |       |
|  | NOx Emissions, lbs/MWh (W/ AT; w/CHP) | N/A    | N/A    | N/A    |       |
|  | CO Emissions, gm/bhp-hr               | 13.00  | 10.00  | 10.00  |       |
|  | CO Emissions w/AT, lb/MWh             | 1.87   | 0.60   | 0.30   |       |
|  | VOC Emissions w/AT, lb/MWh            | 0.47   | 0.09   | 0.05   |       |
|  | PMT 10 Emissions, lb/MWh              | 0.11   | 0.11   | 0.11   |       |
|  | SO2 Emissions, lb/MWh                 | 0.0068 | 0.0064 | 0.0062 |       |
| AT Cost, \$/kW                           | N/A                                   | N/A    | N/A    |        |       |
| 300 kW Rich Burn<br>w/three way catalyst | Capacity, kW                          | 300    | 300    | 300    |       |
|  | Installed Costs, \$/kW                | 1,250  | 1,150  | 1,050  |       |
|  | Heat Rate, Btu/kWh                    | 11,500 | 10,830 | 10,500 |       |
|  | Electric Efficiency, %                | 29.7%  | 31.5%  | 32.5%  |       |
|  | Power to Heat Ratio                   | 0.61   | 0.67   | 0.7    |       |
|  | Thermal Output, Btu/kWh               | 5593   | 5093   | 4874   |       |
|  | O&M Costs, \$/kWh                     | 0.013  | 0.012  | 0.01   |       |
|  | NOx Emissions, lbs/MWh (no AT)        | 40     | 40     | 40     |       |
|  | NOx Emissions, lbs/MWh (w/ AT)        | 0.5    | 0.25   | 0.2    |       |
|  | NOx Emissions, lbs/MWh (W/ AT; w/CHP) | N/A    | N/A    | N/A    |       |
|  | CO Emissions, gm/bhp-hr               | 13.00  | 10.00  | 10.00  |       |
|  | CO Emissions w/AT, lb/MWh             | 1.87   | 0.60   | 0.30   |       |
|  | VOC Emissions w/AT, lb/MWh            | 0.47   | 0.09   | 0.05   |       |
|  | PMT 10 Emissions, lb/MWh              | 0.10   | 0.10   | 0.10   |       |
|  | SO2 Emissions, lb/MWh                 | 0.0068 | 0.0064 | 0.0062 |       |
| AT Cost, \$/kW                           | 50                                    | 50     | 45     |        |       |
| 800 kW Lean Burn<br>AT is SCR            | Capacity, kW                          | 800    | 800    | 800    |       |
|  | Installed Costs, \$/kW                | 1,200  | 1,100  | 950    |       |
|  | Heat Rate, Btu/kWh                    | 10,650 | 9,750  | 9,225  |       |
|  | Electric Efficiency, %                | 32.0%  | 35.0%  | 37.0%  |       |
|  | Power to Heat Ratio                   | 0.8    | 0.9    | 1.05   |       |
|  | Thermal Output, Btu/kWh               | 4265   | 3791   | 3250   | 0.005 |
|  | O&M Costs, \$/kWh                     | 0.012  | 0.01   | 0.009  | 0.017 |
|  | NOx Emissions, gm/bhphr               | 0.8    | 0.4    | 0.3    |       |
|  | NOx Emissions, lbs/MWh (no AT)        | 2.48   | 1.24   | 0.93   |       |
|  | NOx Emissions, lbs/MWh (no AT; w/CHP) | 1.41   | 0.29   | 0.12   |       |
|  | NOx Emissions, lbs/MWh (w/ AT)        | 1.49   | 0.87   | 0.56   |       |
|  | NOx Emissions, lbs/MWh (W/ AT; w/CHP) | N/A    | N/A    | N/A    |       |
|  | CO Emissions, gm/bhp-hr               | 3      | 2.5    | 2      |       |
|  | CO Emissions w/AT, lb/MWh             | 0.87   | 0.45   | 0.31   |       |
|  | VOC Emissions w/AT, lb/MWh            | 0.38   | 0.05   | 0.05   |       |
| PMT 10 Emissions, lb/MWh                 | 0.01                                  | 0.01   | 0.01   |        |       |
| SO2 Emissions, lb/MWh                    | 0.0063                                | 0.0057 | 0.0054 |        |       |
| AT Cost, \$/kW                           | 300                                   | 190    | 140    |        |       |
| 3,000 kW Lean Burn<br>AT is SCR          | Capacity, kW                          | 3000   | 3000   | 3000   |       |
|  | Installed Costs, \$/kW                | 950    | 925    | 875    |       |
|  | Heat Rate, Btu/kWh                    | 9,700  | 8,750  | 8,325  |       |
|  | Electric Efficiency, %                | 35.2%  | 39.0%  | 41.0%  |       |
|  | Power to Heat Ratio                   | 1.04   | 1.07   | 1.18   |       |
|  | Thermal Output, Btu/kWh               | 3281   | 3189   | 2892   | 0.003 |
|  | O&M Costs, \$/kWh                     | 0.0085 | 0.0083 | 0.008  | 0.011 |
|  | NOx Emissions, gm/bhphr               | 0.7    | 0.4    | 0.25   |       |
|  | NOx Emissions, lbs/MWh (no AT)        | 2.17   | 1.24   | 0.775  |       |
|  | NOx Emissions, lbs/MWh (no AT; w/CHP) | 1.35   | 0.44   | 0.05   |       |
|  | NOx Emissions, lbs/MWh (w/ AT)        | 1.52   | 0.87   | 0.53   |       |
|  | NOx Emissions, lbs/MWh (W/ AT; w/CHP) | N/A    | N/A    | N/A    |       |
|  | CO Emissions, gm/bhp-hr               | 2.5    | 2      | 2      |       |
|  | CO Emissions w/AT, lb/MWh             | 0.78   | 0.31   | 0.31   |       |
|  | VOC Emissions w/AT, lb/MWh            | 0.34   | 0.10   | 0.10   |       |
| PMT 10 Emissions, lb/MWh                 | 0.01                                  | 0.01   | 0.01   |        |       |
| SO2 Emissions, lb/MWh                    | 0.0057                                | 0.0051 | 0.0049 |        |       |
| AT Cost, \$/kW                           | 200                                   | 130    | 100    |        |       |
| 5,000 kW Lean Burn<br>AT is SCR          | Capacity, kW                          | 5000   | 5000   | 5000   |       |
|  | Installed Costs, \$/kW                | 925    | 900    | 850    |       |
|  | Heat Rate, Btu/kWh                    | 9,213  | 8,325  | 7,935  |       |
|  | Electric Efficiency, %                | 37.0%  | 41.0%  | 43.0%  |       |
|  | Power to Heat Ratio                   | 1.02   | 1.22   | 1.31   |       |
|  | Thermal Output, Btu/kWh               | 3345   | 2797   | 2605   | 0.002 |
|  | O&M Costs, \$/kWh                     | 0.008  | 0.008  | 0.008  | 0.010 |
|  | NOx Emissions, gm/bhphr               | 0.5    | 0.4    | 0.25   |       |
|  | NOx Emissions, lbs/MWh (no AT)        | 1.55   | 1.24   | 0.775  |       |
|  | NOx Emissions, lbs/MWh (no AT; w/CHP) | 0.71   | 0.54   | 0.12   |       |
|  | NOx Emissions, lbs/MWh (w/ AT)        | 1.24   | 0.87   | 0.54   |       |
|  | NOx Emissions, lbs/MWh (W/ AT; w/CHP) | N/A    | N/A    | N/A    |       |
|  | CO Emissions, gm/bhp-hr               | 2.5    | 2      | 2      |       |
|  | CO Emissions w/AT, lb/MWh             | 0.75   | 0.31   | 0.31   |       |
|  | VOC Emissions w/AT, lb/MWh            | 0.22   | 0.1    | 0.1    |       |
| PMT 10 Emissions, lb/MWh                 | 0.01                                  | 0.01   | 0.01   |        |       |
| SO2 Emissions, lb/MWh                    | 0.0054                                | 0.0049 | 0.0047 |        |       |
| AT Cost, \$/kW                           | 150                                   | 115    | 80     |        |       |

| Additional O&M Costs for SCR |      |                                   |
|------------------------------|------|-----------------------------------|
| 2005                         | 2012 | 2020                              |
|                              |      | 0.002 SCR Adder, \$/kWh           |
|                              |      | 0.011 New total O&M w/SCR, \$/kWh |
|                              |      | 0.002 SCR Adder, \$/kWh           |
|                              |      | 0.009 New total O&M w/SCR, \$/kWh |

CHP thermal credit based on Displaced Boiler Emissions = 0.2 lbs/MMBtu  
 AT = Aftertreatment

**Table C-2 Gas Turbines**

| Size and Type                      | Characterization                      | 2005   | 2012   | 2020   |
|------------------------------------|---------------------------------------|--------|--------|--------|
| 1 MW Gas Turbine<br><br>AT is SCR  | Capacity, MW                          | 1      | 1      | 1      |
|                                    | Installed Costs, \$/kW                | 1,900  | 1,500  | 1,300  |
|                                    | Heat Rate, Btu/kWh                    | 15,580 | 14,500 | 13,500 |
|                                    | Electric Efficiency, %                | 21.9%  | 23.5%  | 25.3%  |
|                                    | Power to Heat Ratio                   | 0.51   | 0.61   | 0.7    |
|                                    | Thermal Output, Btu/kWh               | 6690   | 5593   | 4874   |
|                                    | O&M Costs, \$/kWh                     | 0.01   | 0.013  | 0.012  |
|                                    | NOx Emissions, ppm                    | 42.0   | 15.0   | 9.0    |
|                                    | NOx Emissions, lbs/MWh (no AT)        | 2.2    | 0.7    | 0.4    |
|                                    | NOx Emissions, lbs/MWh (no AT; w/CHP) | 0.53   | -0.70  | -0.82  |
|                                    | NOx Emissions, lbs/MWh (w/ AT)        | 0.22   | 0.07   | 0.04   |
|                                    | CO Emissions, ppm                     | 6      | 20     | 20     |
|                                    | CO Emissions, lb/MWh                  | 0.027  | 0.6    | 0.56   |
|                                    | VOC Emissions, lb/MWh                 | 0.027  | 0.025  | 0.023  |
|                                    | PMT 10 Emissions, lb/MWh              | 0.32   | 0.30   | 0.28   |
| SO2 Emissions, lb/MWh              | 0.0092                                | 0.0085 | 0.0079 |        |
| AT Cost, \$/kW                     | 300                                   | 250    | 150    |        |
| 3 MW Gas Turbine<br><br>AT is SCR  | Capacity, MW                          | 3      | 3      | 3      |
|                                    | Installed Costs, \$/kW                | 1,300  | 1,200  | 1,000  |
|                                    | Heat Rate, Btu/kWh                    | 13,100 | 12,650 | 11,200 |
|                                    | Electric Efficiency, %                | 26.0%  | 27.0%  | 30.5%  |
|                                    | Power to Heat Ratio                   | 0.68   | 0.76   | 0.84   |
|                                    | Thermal Output, Btu/kWh               | 5018   | 4489   | 4062   |
|                                    | O&M Costs, \$/kWh                     | 0.006  | 0.005  | 0.005  |
|                                    | NOx Emissions, ppm                    | 15.0   | 9.0    | 5.0    |
|                                    | NOx Emissions, lbs/MWh (no AT)        | 0.68   | 0.38   | 0.2    |
|                                    | NOx Emissions, lbs/MWh (no AT; w/CHP) | -0.57  | -0.74  | -0.82  |
|                                    | NOx Emissions, lbs/MWh (w/ AT)        | 0.068  | 0.038  | 0.02   |
|                                    | CO Emissions, ppm                     | 20     | 20     | 20     |
|                                    | CO Emissions, lb/MWh                  | 0.55   | 0.53   | 0.47   |
|                                    | VOC Emissions, lb/MWh                 | 0.027  | 0.025  | 0.023  |
|                                    | PMT 10 Emissions, lb/MWh              | 0.21   | 0.20   | 0.18   |
| SO2 Emissions, lb/MWh              | 0.007                                 | 0.0069 | 0.0069 |        |
| AT Cost, \$/kW                     | 210                                   | 175    | 150    |        |
| 5 MW Gas Turbine<br><br>AT is SCR  | Capacity, MW                          | 5      | 5      | 5      |
|                                    | Installed Costs, \$/kW                | 1,100  | 1,000  | 950    |
|                                    | Heat Rate, Btu/kWh                    | 12,590 | 11,375 | 10,500 |
|                                    | Electric Efficiency, %                | 27.1%  | 30.0%  | 32.5%  |
|                                    | Power to Heat Ratio                   | 0.68   | 0.76   | 0.84   |
|                                    | Thermal Output, Btu/kWh               | 5018   | 4489   | 4062   |
|                                    | O&M Costs, \$/kWh                     | 0.006  | 0.005  | 0.005  |
|                                    | NOx Emissions, ppm                    | 15.0   | 9.0    | 5.0    |
|                                    | NOx Emissions, lbs/MWh (no AT)        | 0.68   | 0.38   | 0.2    |
|                                    | NOx Emissions, lbs/MWh (no AT; w/CHP) | -0.57  | -0.74  | -0.82  |
|                                    | NOx Emissions, lbs/MWh (w/ AT)        | 0.068  | 0.038  | 0.02   |
|                                    | CO Emissions, ppm                     | 20     | 20     | 20     |
|                                    | CO Emissions, lb/MWh                  | 0.55   | 0.53   | 0.47   |
|                                    | VOC Emissions, lb/MWh                 | 0.027  | 0.025  | 0.023  |
|                                    | PMT 10 Emissions, lb/MWh              | 0.21   | 0.20   | 0.18   |
| SO2 Emissions, lb/MWh              | 0.007                                 | 0.0069 | 0.0069 |        |
| AT Cost, \$/kW                     | 210                                   | 175    | 150    |        |
| 10 MW Gas Turbine<br><br>AT is SCR | Capacity, MW                          | 10     | 10     | 10     |
|                                    | Installed Costs, \$/kW                | 965    | 950    | 850    |
|                                    | Heat Rate, Btu/kWh                    | 11,765 | 10,800 | 9,950  |
|                                    | Electric Efficiency, %                | 29.0%  | 31.6%  | 34.3%  |
|                                    | Power to Heat Ratio                   | 0.73   | 0.84   | 0.94   |
|                                    | Thermal Output, Btu/kWh               | 4674   | 4062   | 3630   |
|                                    | O&M Costs, \$/kWh                     | 0.006  | 0.005  | 0.005  |
|                                    | NOx Emissions, ppm                    | 15.0   | 9.0    | 5.0    |
|                                    | NOx Emissions, lbs/MWh (no AT)        | 0.67   | 0.37   | 0.2    |
|                                    | NOx Emissions, lbs/MWh (no AT; w/CHP) | -0.50  | -0.65  | -0.71  |
|                                    | NOx Emissions, lbs/MWh (w/ AT)        | 0.067  | 0.037  | 0.02   |
|                                    | CO Emissions, ppm                     | 20     | 20     | 20     |
|                                    | CO Emissions, lb/MWh                  | 0.5    | 0.46   | 0.42   |
|                                    | VOC Emissions, lb/MWh                 | 0.022  | 0.021  | 0.02   |
|                                    | PMT 10 Emissions, lb/MWh              | 0.2    | 0.18   | 0.17   |
| SO2 Emissions, lb/MWh              | 0.0069                                | 0.0064 | 0.0059 |        |
| AT Cost, \$/kW                     | 140                                   | 125    | 100    |        |
| 25 MW Gas Turbine<br><br>AT is SCR | Capacity, MW                          | 25     | 25     | 25     |
|                                    | Installed Costs, \$/kW                | 800    | 755    | 725    |
|                                    | Heat Rate, Btu/kWh                    | 9,945  | 9,225  | 8,865  |
|                                    | Electric Efficiency, %                | 34.3%  | 37.0%  | 38.5%  |
|                                    | Power to Heat Ratio                   | 0.95   | 1.04   | 1.1    |
|                                    | Thermal Output, Btu/kWh               | 3592   | 3281   | 3102   |
|                                    | O&M Costs, \$/kWh                     | 0.005  | 0.005  | 0.004  |
|                                    | NOx Emissions, ppm                    | 15.0   | 5.0    | 3.0    |
|                                    | NOx Emissions, lbs/MWh (no AT)        | 0.6    | 0.2    | 0.1    |
|                                    | NOx Emissions, lbs/MWh (no AT; w/CHP) | -0.30  | -0.62  | -0.68  |
|                                    | NOx Emissions, lbs/MWh (w/ AT)        | 0.06   | 0.02   | 0.01   |
|                                    | CO Emissions, ppm                     | 20     | 20     | 20     |
|                                    | CO Emissions w/AT, lb/MWh             | 0.05   | 0.05   | 0.04   |
|                                    | VOC Emissions w/AT, lb/MWh            | 0.01   | 0.01   | 0.01   |
|                                    | PMT 10 Emissions, lb/MWh              | 0.17   | 0.16   | 0.15   |
| SO2 Emissions, lb/MWh              | 0.0058                                | 0.0054 | 0.0052 |        |
| AT Cost, \$/kW                     | 100                                   | 80     | 50     |        |
| 40 MW Gas Turbine<br><br>AT is SCR | Capacity, MW                          | 40     | 40     | 40     |
|                                    | Installed Costs, \$/kW                | 700    | 680    | 660    |
|                                    | Heat Rate, Btu/kWh                    | 9,220  | 8,865  | 8,595  |
|                                    | Electric Efficiency, %                | 37.0%  | 38.5%  | 39.7%  |
|                                    | Power to Heat Ratio                   | 1.07   | 1.13   | 1.18   |
|                                    | Thermal Output, Btu/kWh               | 3189   | 3019   | 2892   |
|                                    | O&M Costs, \$/kWh                     | 0.004  | 0.004  | 0.004  |
|                                    | NOx Emissions, ppm                    | 15.0   | 5.0    | 3.0    |
|                                    | NOx Emissions, lbs/MWh (no AT)        | 0.55   | 0.2    | 0.1    |
|                                    | NOx Emissions, lbs/MWh (no AT; w/CHP) | -0.25  | -0.55  | -0.62  |
|                                    | NOx Emissions, lbs/MWh (w/ AT)        | 0.055  | 0.02   | 0.01   |
|                                    | CO Emissions, ppm                     | 20     | 20     | 20     |
|                                    | CO Emissions w/AT, lb/MWh             | 0.04   | 0.04   | 0.04   |
|                                    | VOC Emissions w/AT, lb/MWh            | 0.01   | 0.01   | 0.01   |
|                                    | PMT 10 Emissions, lb/MWh              | 0.157  | 0.15   | 0.15   |
| SO2 Emissions, lb/MWh              | 0.0054                                | 0.0052 | 0.0051 |        |
| AT Cost, \$/kW                     | 90                                    | 75     | 40     |        |

CHP Thermal credit based on Displaced Boiler Emissions = 0.2 lbs/MMBtu  
 AT = Aftertreatment

**Table C-3 Microturbines**

| Size and Type  | Characterization                      | 2005   | 2012   | 2020   |
|----------------|---------------------------------------|--------|--------|--------|
| 70-100 kW      | Capacity, kW                          | 70     | 70     | 70     |
|                | Installed Costs, \$/kW                | 2,200  | 1,800  | 1,400  |
|                | Heat Rate, Btu/kWh                    | 13,500 | 12,500 | 11,375 |
|                | Electric Efficiency, %                | 25.3%  | 27.3%  | 30.0%  |
|                | Power to Heat Ratio                   | 0.7    | 0.9    | 1.1    |
|                | Thermal Output, Btu/kWh               | 4874   | 3791   | 3102   |
|                | O&M Costs, \$/kWh                     | 0.017  | 0.016  | 0.012  |
|                | NOx Emissions, ppm                    | 3.0    | 3.0    | 3.0    |
|                | NOx Emissions, lbs/MWh (no AT)        | 0.15   | 0.14   | 0.13   |
|                | NOx Emissions, lbs/MWh (no AT; w/CHP) | -1.07  | -0.81  | -0.65  |
|                | NOx Emissions, lbs/MWh (w/ AT)        | N/A    | N/A    | N/A    |
|                | NOx Emissions, lbs/MWh (W/ AT; w/CHP) | N/A    | N/A    | N/A    |
|                | CO Emissions, ppm                     | 8      | 8      | 8      |
|                | CO Emissions, lb/MWh                  | 0.24   | 0.22   | 0.20   |
|                | VOC Emissions, lb/MWh                 | 0.027  | 0.025  | 0.023  |
|                | PMT 10 Emissions, lb/MWh              | 0.22   | 0.20   | 0.19   |
|                | SO2 Emissions, lb/MWh                 | 0.0079 | 0.0074 | 0.0067 |
| AT Cost, \$/kW | N/A                                   | N/A    | N/A    |        |
| 250 kW         | Capacity, kW                          | 250    | 250    | 250    |
|                | Installed Costs, \$/kW                | 2,000  | 1,600  | 1,200  |
|                | Heat Rate, Btu/kWh                    | 11,850 | 11,750 | 10,825 |
|                | Electric Efficiency, %                | 28.8%  | 29.0%  | 31.5%  |
|                | Power to Heat Ratio                   | 0.94   | 1      | 1.3    |
|                | Thermal Output, Btu/kWh               | 3630   | 3412   | 2625   |
|                | O&M Costs, \$/kWh                     | 0.016  | 0.015  | 0.012  |
|                | NOx Emissions, ppm                    | 9.0    | 5.0    | 3.0    |
|                | NOx Emissions, lbs/MWh (no AT)        | 0.43   | 0.24   | 0.13   |
|                | NOx Emissions, lbs/MWh (no AT; w/CHP) | -0.48  | -0.62  | -0.53  |
|                | NOx Emissions, lbs/MWh (w/ AT)        | N/A    | N/A    | N/A    |
|                | NOx Emissions, lbs/MWh (W/ AT; w/CHP) | N/A    | N/A    | N/A    |
|                | CO Emissions, ppm                     | 9      | 9      | 9      |
|                | CO Emissions, lb/MWh                  | 0.26   | 0.26   | 0.24   |
|                | VOC Emissions, lb/MWh                 | 0.027  | 0.025  | 0.023  |
|                | PMT 10 Emissions, lb/MWh              | 0.18   | 0.18   | 0.16   |
|                | SO2 Emissions, lb/MWh                 | 0.0070 | 0.0069 | 0.0064 |
| AT Cost, \$/kW | 500                                   | 200    | 90     |        |
| 500 kW         | Capacity, kW                          | -      | 500    | 500    |
|                | Installed Costs, \$/kW                | -      | 1,150  | 900    |
|                | Heat Rate, Btu/kWh                    | -      | 10,350 | 9,750  |
|                | Electric Efficiency, %                | -      | 33.0%  | 35.0%  |
|                | Power to Heat Ratio                   | -      | 1.3    | 1.38   |
|                | Thermal Output, Btu/kWh               | -      | 2625   | 2472   |
|                | O&M Costs, \$/kWh                     | -      | 0.015  | 0.012  |
|                | NOx Emissions, ppm                    | -      | 5.0    | 3.0    |
|                | NOx Emissions, lbs/MWh (no AT)        | -      | 0.2    | 0.11   |
|                | NOx Emissions, lbs/MWh (no AT; w/CHP) | -      | -0.46  | -0.51  |
|                | NOx Emissions, lbs/MWh (w/ AT)        | -      | N/A    | N/A    |
|                | NOx Emissions, lbs/MWh (W/ AT; w/CHP) | -      | N/A    | N/A    |
|                | CO Emissions, ppm                     | -      | 9      | 9      |
|                | CO Emissions, lb/MWh                  | -      | 0.24   | 0.23   |
|                | VOC Emissions, lb/MWh                 | -      | 0.025  | 0.023  |
|                | PMT 10 Emissions, lb/MWh              | -      | 0.0061 | 0.0057 |
|                | SO2 Emissions, lb/MWh                 | -      | 0.0056 | 0.0053 |
| AT Cost, \$/kW | -                                     | 200    | 90     |        |

CHP thermal credit based on Displaced Boiler Emissions =  
AT = Aftreatment

0.2 lbs/MMBtu

**Table C-4 Fuel Cells**

| Size and Type            | Characterization                      | 2005   | 2012   | 2020  |
|--------------------------|---------------------------------------|--------|--------|-------|
| 150 kW PEMFC             | Capacity, kW                          | 150    | 150    | 150   |
|                          | Installed Costs, \$/kW                | 3,800  | 3,600  | 2,700 |
|                          | Heat Rate, Btu/kWh                    | 9,750  | 9,480  | 8,980 |
|                          | Electric Efficiency, %                | 35.0%  | 36.0%  | 38.0% |
|                          | Power to Heat Ratio                   | 0.95   | 0.98   | 1.04  |
|                          | Thermal Output, Btu/kWh               | 3592   | 3482   | 3281  |
|                          | O&M Costs, \$/kWh                     | 0.023  | 0.017  | 0.015 |
|                          | NOx Emissions, ppm                    |        |        |       |
|                          | NOx Emissions, lbs/MWh (no AT)        | 0.10   | 0.07   | 0.05  |
|                          | NOx Emissions, lbs/MWh (no AT; w/CHP) | -0.80  | -0.80  | -0.77 |
|                          | CO Emissions, ppm                     | -      | -      | -     |
|                          | CO Emissions, lb/MWh                  | 0.07   | 0.07   | 0.07  |
|                          | VOC Emissions, lb/MWh                 | 0.01   | 0.01   | 0.01  |
|                          | PMT 10 Emissions, lb/MWh              | 0.001  | 0.001  | 0.001 |
| SO2 Emissions, lb/MWh    | 0.0057                                | 0.0056 | 0.0053 |       |
| 250 kW MCFC/SOFC         | Capacity, kW                          | 250    | 250    | 250   |
|                          | Installed Costs, \$/kW                | 5,000  | 3,200  | 2,500 |
|                          | Heat Rate, Btu/kWh                    | 7,930  | 7,125  | 6,920 |
|                          | Electric Efficiency, %                | 43.0%  | 47.9%  | 49.3% |
|                          | Power to Heat Ratio                   | 1.95   | 1.98   | 2.13  |
|                          | Thermal Output, Btu/kWh               | 1750   | 1723   | 1602  |
|                          | O&M Costs, \$/kWh                     | 0.032  | 0.02   | 0.015 |
|                          | NOx Emissions, ppm                    |        |        |       |
|                          | NOx Emissions, lbs/MWh (no AT)        | 0.06   | 0.05   | 0.04  |
|                          | NOx Emissions, lbs/MWh (no AT; w/CHP) | -0.38  | -0.38  | -0.36 |
|                          | NOx Emissions, lbs/MWh (w/ AT)        |        |        |       |
|                          | NOx Emissions, lbs/MWh (W/ AT; w/CHP) |        |        |       |
|                          | CO Emissions, ppm                     | -      | -      | -     |
|                          | CO Emissions, lb/MWh                  | 0.06   | 0.05   | 0.04  |
| VOC Emissions, lb/MWh    | 0.01                                  | 0.01   | 0.01   |       |
| PMT 10 Emissions, lb/MWh | 0.001                                 | 0.001  | 0.001  |       |
| SO2 Emissions, lb/MWh    | 0.0047                                | 0.0042 | 0.0041 |       |
| 2 MW MCFC                | Capacity, kW                          | 2,000  | 2,000  | 2,000 |
|                          | Installed Costs, \$/kW                | 3,250  | 2,800  | 2,200 |
|                          | Heat Rate, Btu/kWh                    | 7,420  | 7,110  | 6,820 |
|                          | Electric Efficiency, %                | 46.0%  | 48.0%  | 50.0% |
|                          | Power to Heat Ratio                   | 1.92   | 2      | 2.27  |
|                          | Thermal Output, Btu/kWh               | 1777   | 1706   | 1503  |
|                          | O&M Costs, \$/kWh                     | 0.033  | 0.019  | 0.015 |
|                          | NOx Emissions, ppm                    |        |        |       |
|                          | NOx Emissions, lbs/MWh (no AT)        | 0.05   | 0.05   | 0.04  |
|                          | NOx Emissions, lbs/MWh (no AT; w/CHP) | -0.39  | -0.38  | -0.34 |
|                          | NOx Emissions, lbs/MWh (w/ AT)        |        |        |       |
|                          | NOx Emissions, lbs/MWh (W/ AT; w/CHP) |        |        |       |
|                          | CO Emissions, ppm                     | -      | -      | -     |
|                          | CO Emissions, lb/MWh                  | 0.04   | 0.04   | 0.03  |
| VOC Emissions, lb/MWh    | 0.01                                  | 0.01   | 0.01   |       |
| PMT 10 Emissions, lb/MWh | 0.001                                 | 0.001  | 0.001  |       |
| SO2 Emissions, lb/MWh    | 0.0044                                | 0.0042 | 0.0040 |       |

CHP thermal credit based on Displaced Boiler Emissions =  
 AT = Aftertreatment

0.2 lbs/MMBtu

## 8.4 Appendix D: Market Penetration Analysis

The economic market potential was determined based on a comparison of the net power costs from the competing CHP technologies with the delivered electric and natural gas prices within that market size and geographical area. Within each market category (size and region), the competition among applicable technologies was evaluated. Based on this competition, the economic market potential was estimated and shared among competing CHP technologies. The rate of market penetration by technology under each scenario was then estimated using a market diffusion model.

The roughly 20,000 MW of technical market potential was identified by screening only with respect to the fact that the particular applications were likely to have the operating conditions necessary to support a high load factor CHP system. An additional screening factor was applied to reflect the share of each market size category (i.e., applications of 50 to 500 kW, applications of 500 to 1,000 kW, etc) within the technical potential that would be willing and able to consider CHP at all. These factors range from 32% in the smallest size bin (50-500 kW) to 64% in the largest size bin (more than 20 MW.) These factors were intended to take the place of a much more detailed screening that would eliminate customers that do not actually have appropriate electric and thermal loads in spite of being within the target markets, do not use gas or have access to gas, do not have the space to install a system, do not have the capital or credit worthiness to consider investment, or are otherwise unaware, indifferent, or hostile to the idea of adding CHP. The value for each size bin was established based on an evaluation of EIA facility survey data and gas use statistics from the iMarket database.

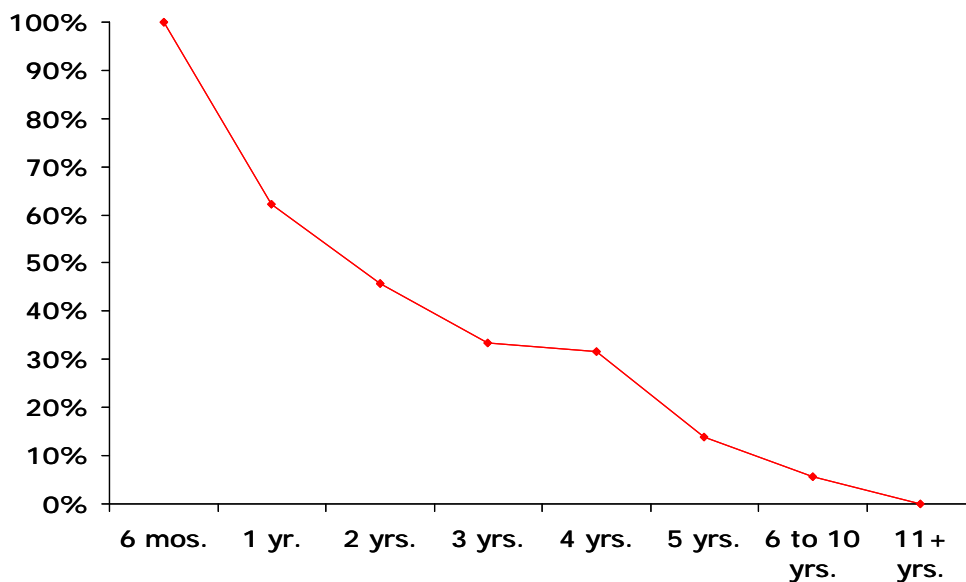
Among the customers that will consider CHP, the expected future fuel and electricity prices and the cost and performance of CHP technologies determined the economic competitiveness of CHP in each market. The economic figure-of-merit chosen to reflect this competition in the market penetration model was simple payback.<sup>10</sup> While not the most sophisticated measure of a project's performance, it is nevertheless widely understood by all classes of customers. In addition, all of the CHP projects have similar operating lives and cost structures making it likely that payback is very highly correlated with more detailed financial measures based on discounted cash flow analysis (net present value, return on investment, and return on equity).

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<sup>10</sup> Simple payback is the number of years that it takes for the annual operating savings to repay the initial capital investment.

Figure D-1 shows the response of a cross section of commercial and small industrial customers to a market survey concerning the payback that would be required for a distributed energy project to be accepted for investment<sup>11</sup>. As can be seen from the figure, more than 30% of customers would reject a project that promised to return their initial investments in just one year. A little more than half would reject a project with a payback of two years. This type of payback translates into a project with an ROI of between 49-100%. Potential explanations for rejecting a project with such high returns are that the average customer does not believe that the results are real and is protecting himself from this perceived risk by requiring very high projected returns before a project would be accepted; or that the facility is very capital limited and is rationing its capital-raising capability for higher-priority projects (market expansion, product improvement, etc.).

**Figure D-1 Customer Payback Acceptance Curve**



*Source: Primen's 2003 Distributed Energy Market Survey*

An approximation of this payback acceptance curve was used as the basis of determining the share of the market that would install CHP based on the calculated paybacks within each region/size market bin.

The technical potential was grouped into four separate categories (high load and low load factor traditional CHP, high and low load factor CHP with cooling,) based on their operating characteristics. Each category

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<sup>11</sup> "Assessment of California CHP Market and Policy Options for Increased Penetration", California Energy Commission, July 2005.

and each size bin within the category have specific assumptions about the annual hours of CHP operation, the share of recoverable thermal energy that is utilized, and the share of useful thermal energy that is used for cooling compared to traditional heating.

CHP technology and performance assumptions appropriate to each size category and region were selected to represent the competition in that size range (Table D-1). Within each of these size categories, the payback for each technology was estimated using appropriate gas and electric rates for the region, size, and load. The technology with the lowest payback was assumed to set the market acceptance share, which is a function of the percent of the market that will accept paybacks of different levels. The market acceptance share was based on this payback, using the payback acceptance curve that determines what share of the market will accept a given payback.

The market acceptance share was applied to the technical market potential constrained by a maximum market penetration (MMP) factor (from 32% to 64% depending on the size and scenario.) The resultant product equals the economic market for that region/size. The smaller the size bin, the greater the constraints on facilities considering CHP, so the smallest size bins are multiplied by the smallest MMP factors and the largest sizes have corresponding fewer constraints so a larger share of the market is considered receptive to CHP.

**Table D-1 Technology Competition Assumed within Each Size Category**

| <i>Market Size Bins</i> | <i>Competing Technologies</i>             |
|-------------------------|---|
| 50 - 500 kW             | 100 kW Reciprocal Engine                  |
|                         | 70 kW Microturbine                        |
|                         | 150 kW PEM Fuel Cell                      |
| 500 - 1,000 kW          | 300 kW Reciprocal Engine (multiple units) |
|                         | 70 kW Microturbine (multiple units)       |
|                         | 250 kW MC/SO Fuel Cell (multiple units)   |
| 1 - 5 MW                | 3 MW Reciprocal Engine                    |
|                         | 3 MW Gas Turbine                          |
|                         | 2 MW MC Fuel Cell                         |
| 5 - 20 MW               | 5 MW Reciprocal Engine                    |
|                         | 5 MW Gas Turbine                          |
| 20 - 100 MW             | 40 MW Gas Turbine                         |

The rate of market penetration was based on a *Bass diffusion curve* with allowance for growth in the maximum market. This determines cumulative market penetration for each 5-year period. Smaller size systems are assumed to take a longer time to reach maximum market penetration than larger systems. Cumulative market penetration using a Bass diffusion curve takes a typical S-shaped curve. In the generalized form used in this analysis, growth in the number of ultimate adopters is allowed. The curves shape is determined by an initial market penetration estimate, growth rate of the technical market potential, and two factors described as *internal market influence* and *external market influence*.

The market penetration was allocated by competing CHP technology with a size/utility bin based on a *logit function* calculated on the comparison of the system paybacks. The greatest market share went to the lowest cost technology, but more expensive technologies received some market share depending on how close they were to the technology with the lowest payback.

Additional assumptions were made for the competitive analysis. Technologies below 1 MW in electrical capacity were assumed to have an economic life of 10 years. Larger systems were assumed to have an economic life of 15 years. Capital-related amortization costs were based on a 10% discount rate. All applications less than 5 MW were assumed to have an electric load factor of 80% and an 80% utilization of

recoverable thermal energy. In the larger projects of 5 MW and larger, 90% electric load factor and 90% utilization of recoverable thermal energy were assumed.

For each scenario, the economic and dollar benefits for deployment of the mix of CHP technologies were calculated, and the environmental residuals were tracked for use in the comparison with the MAPS modeling system

## 8.5 Appendix E. Detailed Modeling Assumptions

**Table E 1. Peak Demand and Energy by Model Region**

| Model Region Group       | Peak Demand (MW) |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
|--------------------------|------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
|                          | 2006             | 2007   | 2008   | 2009   | 2010   | 2011   | 2012   | 2013   | 2014   | 2015   | 2016   | 2017   | 2018   | 2019   | 2020   |
| Upstate New York (A-E)   | 10,162           | 10,331 | 10,465 | 10,508 | 10,560 | 10,587 | 10,586 | 10,558 | 10,587 | 10,619 | 10,625 | 10,667 | 10,709 | 10,752 | 10,794 |
| NY Capital (F)           | 2,298            | 2,334  | 2,360  | 2,362  | 2,365  | 2,360  | 2,348  | 2,331  | 2,327  | 2,328  | 2,323  | 2,325  | 2,328  | 2,330  | 2,333  |
| Downstate New York (G-I) | 4,641            | 4,737  | 4,822  | 4,879  | 4,933  | 4,977  | 5,007  | 5,025  | 5,063  | 5,103  | 5,133  | 5,182  | 5,231  | 5,281  | 5,332  |
| New York City (J)        | 11,630           | 11,800 | 11,970 | 12,140 | 12,290 | 12,440 | 12,570 | 12,705 | 12,815 | 12,925 | 13,003 | 13,159 | 13,316 | 13,476 | 13,637 |
| Long Island (K)          | 5,469            | 5,549  | 5,628  | 5,738  | 5,840  | 5,936  | 6,037  | 6,141  | 6,249  | 6,372  | 6,511  | 6,584  | 6,658  | 6,733  | 6,809  |

Note: these are zonal peaks. They are not coincident

| Model Region Group       | Energy Demand (GWh) |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
|--------------------------|---------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
|                          | 2006                | 2007   | 2008   | 2009   | 2010   | 2011   | 2012   | 2013   | 2014   | 2015   | 2016   | 2017   | 2018   | 2019   | 2020   |
| Upstate New York (A-E)   | 60,103              | 61,426 | 62,311 | 62,478 | 62,486 | 62,253 | 61,880 | 61,641 | 61,507 | 62,073 | 62,446 | 62,693 | 62,941 | 63,190 | 63,440 |
| NY Capital (F)           | 12,069              | 12,287 | 12,415 | 12,399 | 12,352 | 12,257 | 12,136 | 12,041 | 11,967 | 12,029 | 12,053 | 12,066 | 12,079 | 12,092 | 12,104 |
| Downstate New York (G-I) | 19,936              | 20,400 | 20,799 | 21,040 | 21,263 | 21,440 | 21,569 | 21,727 | 21,887 | 22,185 | 22,449 | 22,663 | 22,880 | 23,098 | 23,319 |
| New York City (J)        | 52,276              | 53,230 | 54,275 | 55,179 | 56,158 | 57,136 | 57,993 | 58,863 | 59,628 | 60,403 | 61,188 | 61,921 | 62,662 | 63,412 | 64,171 |
| Long Island (K)          | 22,515              | 22,796 | 23,122 | 23,544 | 23,892 | 24,261 | 24,710 | 25,036 | 25,439 | 25,904 | 26,500 | 26,798 | 27,099 | 27,403 | 27,711 |

**Table E 2. Emission Allowance Costs (\$/ton)**

| EMISSION ALLOWANCE COSTS (\$/ton) |       |     |              |                   |
|-----------------------------------|-------|-----|--------------|-------------------|
| Date                              | SO2   | CO2 | NOx<br>Ozone | NOx Non-<br>Ozone |
| 1/1/2005                          | 1,500 | -   | 2,250        | 1,500             |
| 1/1/2006                          | 1,035 | -   | 3,001        | 1,600             |
| 1/1/2007                          | 1,035 | -   | 3,001        | 1,700             |
| 1/1/2008                          | 1,143 | -   | 3,051        | 1,750             |
| 1/1/2009                          | 1,143 | -   | 3,051        | 1,500             |
| 1/1/2010                          | 1,392 | 3   | 2,244        | 2,818             |
| 1/1/2011                          | 1,392 | 3   | 1,818        | 2,318             |
| 1/1/2012                          | 1,392 | 3   | 1,818        | 2,018             |
| 1/1/2013                          | 1,392 | 3   | 1,818        | 1,818             |
| 1/1/2014                          | 1,392 | 3   | 1,818        | 1,818             |
| 1/1/2015                          | 1,873 | 4   | 2,446        | 2,446             |
| 1/1/2016                          | 1,873 | 4   | 2,446        | 2,446             |
| 1/1/2017                          | 1,873 | 4   | 2,446        | 2,446             |
| 1/1/2018                          | 1,873 | 4   | 2,446        | 2,446             |
| 1/1/2019                          | 1,873 | 4   | 2,446        | 2,446             |
| 1/1/2020                          | 2,610 | 6   | 3,409        | 3,409             |
| 1/1/2021                          | 2,610 | 6   | 3,409        | 3,409             |
| 1/1/2022                          | 2,610 | 6   | 3,409        | 3,409             |
| 1/1/2023                          | 2,610 | 6   | 3,409        | 3,409             |
| 1/1/2024                          | 2,610 | 6   | 3,409        | 3,409             |
| 1/1/2025                          | 2,610 | 6   | 3,409        | 3,409             |

**Table E 3. Gas Price Forecast for Upstate and Downstate (\$/MMBtu)**

| <b>ANNUAL NATURAL GAS PRICES<br/>(\$/MMBtu)</b> |           |         |
|---|-----------|---------|
| Year  | NG NYCity | NG NYPP |
| 2006  | 10.780    | 10.791  |
| 2007  | 10.780    | 10.791  |
| 2008  | 9.750     | 9.773   |
| 2009  | 9.750     | 9.773   |
| 2010  | 7.922     | 7.957   |
| 2011  | 7.922     | 7.957   |
| 2012  | 7.922     | 7.957   |
| 2013  | 7.922     | 7.957   |
| 2014  | 7.922     | 7.957   |
| 2015  | 8.454     | 8.467   |
| 2016  | 8.454     | 8.467   |
| 2017  | 8.454     | 8.467   |
| 2018  | 8.454     | 8.467   |
| 2019  | 8.454     | 8.467   |
| 2020  | 10.850    | 10.880  |

**Table E 4. Oil Price Forecast for Upstate and Downstate (\$/MMBtu)**

| <b>ANNUAL FUEL OIL PRICES (\$/MMBtu)</b> |                |             |                |             |
|--|----------------|-------------|----------------|-------------|
| Year                                     | FO#2-NYUpstate | FO#2-NYCity | FO#6-NYUpstate | FO#6-NYCity |
| 2006                                     | 15.573         | 15.573      | 10.232         | 10.232      |
| 2007                                     | 14.563         | 14.563      | 10.232         | 10.232      |
| 2008                                     | 12.786         | 12.786      | 9.431          | 9.431       |
| 2009                                     | 13.203         | 13.203      | 9.431          | 9.431       |
| 2010                                     | 12.411         | 12.411      | 9.033          | 9.033       |
| 2011                                     | 12.999         | 12.999      | 9.033          | 9.033       |
| 2012                                     | 12.874         | 12.874      | 9.033          | 9.033       |
| 2013                                     | 12.599         | 12.599      | 9.033          | 9.033       |
| 2014                                     | 12.961         | 12.961      | 9.033          | 9.033       |
| 2015                                     | 13.156         | 13.156      | 9.505          | 9.505       |
| 2016                                     | 13.039         | 13.039      | 9.505          | 9.505       |
| 2017                                     | 13.484         | 13.484      | 9.505          | 9.505       |
| 2018                                     | 13.432         | 13.432      | 9.505          | 9.505       |
| 2019                                     | 13.220         | 13.220      | 9.505          | 9.505       |
| 2020                                     | 14.389         | 14.389      | 10.427         | 10.427      |

**Table E 5. Coal Price Forecast Delivered to Plants (\$/MMBtu)**

| COAL PRICES (\$/MMBtu) |         |             |               |             |            |              |              |                 |           |         |            |            |
|------------------------|---------|-------------|---------------|-------------|------------|--------------|--------------|-----------------|-----------|---------|------------|------------|
| Date                   | Huntley | Russell-Bit | Greenidge-Bit | Dunkirk-Bit | Goudey-Bit | Hickling-Bit | Milliken-Bit | Kintigh, AE-Bit | Coal-NPCC | Niagara | Danskammer | Lovett-Bit |
| 1/1/2006               | 1.011   | 2.600       | 1.011         | 1.011       | 1.011      | 1.700        | 1.011        | 1.011           | 2.800     | 1.493   | 1.114      | 1.150      |
| 1/1/2007               | 1.067   | 2.652       | 1.067         | 1.067       | 1.067      | 1.734        | 1.067        | 1.067           | 2.856     | 1.480   | 1.171      | 1.207      |
| 1/1/2008               | 1.176   | 2.705       | 1.176         | 1.176       | 1.176      | 1.769        | 1.176        | 1.176           | 2.913     | 1.596   | 1.281      | 1.317      |
| 1/1/2009               | 1.116   | 2.759       | 1.116         | 1.116       | 1.116      | 1.804        | 1.116        | 1.116           | 2.971     | 1.542   | 1.222      | 1.259      |
| 1/1/2010               | 1.038   | 2.814       | 1.038         | 1.038       | 1.038      | 1.840        | 1.038        | 1.038           | 3.031     | 1.471   | 1.145      | 1.182      |
| 1/1/2011               | 1.085   | 2.871       | 1.085         | 1.085       | 1.085      | 1.877        | 1.085        | 1.085           | 3.091     | 1.525   | 1.193      | 1.230      |
| 1/1/2012               | 1.135   | 2.928       | 1.135         | 1.135       | 1.135      | 1.914        | 1.135        | 1.135           | 3.153     | 1.582   | 1.244      | 1.283      |
| 1/1/2013               | 1.133   | 2.987       | 1.133         | 1.133       | 1.133      | 1.953        | 1.133        | 1.133           | 3.216     | 1.587   | 1.243      | 1.282      |
| 1/1/2014               | 1.267   | 3.046       | 1.267         | 1.267       | 1.267      | 1.992        | 1.267        | 1.267           | 3.281     | 1.728   | 1.378      | 1.417      |
| 1/1/2015               | 1.300   | 3.107       | 1.300         | 1.300       | 1.300      | 2.032        | 1.300        | 1.300           | 3.346     | 1.768   | 1.412      | 1.451      |
| 1/1/2016               | 1.243   | 3.169       | 1.243         | 1.243       | 1.243      | 2.072        | 1.243        | 1.243           | 3.413     | 1.718   | 1.356      | 1.396      |
| 1/1/2017               | 1.291   | 3.233       | 1.291         | 1.291       | 1.291      | 2.114        | 1.291        | 1.291           | 3.481     | 1.773   | 1.406      | 1.446      |
| 1/1/2018               | 1.411   | 3.297       | 1.411         | 1.411       | 1.411      | 2.156        | 1.411        | 1.411           | 3.551     | 1.900   | 1.526      | 1.567      |
| 1/1/2019               | 1.467   | 3.363       | 1.467         | 1.467       | 1.467      | 2.199        | 1.467        | 1.467           | 3.622     | 1.964   | 1.584      | 1.625      |
| 1/1/2020               | 1.516   | 3.431       | 1.516         | 1.516       | 1.516      | 2.243        | 1.516        | 1.516           | 3.695     | 2.021   | 1.634      | 1.675      |

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FINAL REPORT 09-03

STATE OF NEW YORK  
DAVID A PATERSON, GOVERNOR

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