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**Prepared For:**

Eastern Interconnection Planning Collaborative

# Working Draft of MRN-NEEM Modeling Assumptions and Data Sources for EIPC Capacity Expansion Modeling

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**Summary of Changes in this Version**

Key modifications and inserts to the October 26, 2010 version of this document have been shaded in yellow. Note that typo corrections/minor wording changes have not been shaded. A modified table will have the title of the table shaded in yellow. Because of the number of new tables/exhibits in this revision, all tables and exhibits have been renumbered from that of the prior draft.

Data previously based on AEO 2010 have been updated to the Early Release of AEO 2011, including gas prices, post-2020 load growth, and new capacity costs. This revision includes additional detail/information regarding previously distributed information (some items were provided to stakeholder working groups previously as supplemental information):

1. Canada modeling
2. EPA non-carbon regulations
3. New generation capital cost detail
4. Wind capacity factors and build potential by region
5. Load shapes by region
6. Wind shapes by region
7. Existing capacity by region and technology
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# 1. INTRODUCTION

This document focuses on the basic data inputs to the MRN-NEEM model to enable review and refinement by the Eastern Interconnection Planning Collaborative ("EIPC") The MRN-NEEM model combines two state-of-the-art economic models: the Multi-Region National (MRN) model and the North American Electricity and Environment Model (NEEM). This integrated modeling approach provides a robust framework for examining electricity sector specific impacts in detail while also understanding the economy-wide impacts of specific climate policies.

For the EIPC project, Charles River Associates ("CRA") will use the integrated MRN-NEEM model to maintain macro-economic consistency among futures and within a set of sensitivities for a given future. An MRN-NEEM solution is a general equilibrium solution, meaning that all markets in the economy are at equilibrium. The primary reason that a general equilibrium solution is desirable in assessing energy markets is that significant policies (e.g., carbon policies) can affect energy demand growth and relative fuel prices. Such policies can also affect the penetration of electric vehicles, increasing electricity demand and reducing gasoline demand. Because energy is an input to most products in the economy, a carbon policy ripples through the entire economy affecting relative prices. NEEM is strictly a model of the electric sector so it cannot assess these macroeconomic dynamics when run as a stand-alone model. However, there may be situations where CRA will run NEEM by itself, typically for the purpose of sensitivity analysis.

This document begins with an overview of the integrated MRN-NEEM model. We then discuss the NEEM portion of the integrated model and then the MRN portion of the integrated model. Since running the MRN-NEEM model involves running NEEM and MRN in succession (until convergence is achieved between the two models), it is helpful to conceptualize and discuss the models separately.

# 2. MRN-NEEM OVERVIEW

## 2.1. OVERVIEW OF THE MRN SUB-MODEL

The top-down component of the integrated MRN-NEEM model is tailored from CRA's Multi-Region National (MRN) model. MRN is a forward-looking, dynamic computable general equilibrium (CGE) model of the United States. It is based on the theoretical concept of an equilibrium in which macro-level outcomes are driven by the decisions of self-interested consumers and producers. The basic structure of CGE models, such as MRN, is built around a circular flow of goods and payments between households, firms, and the government, as illustrated in Figure 1.

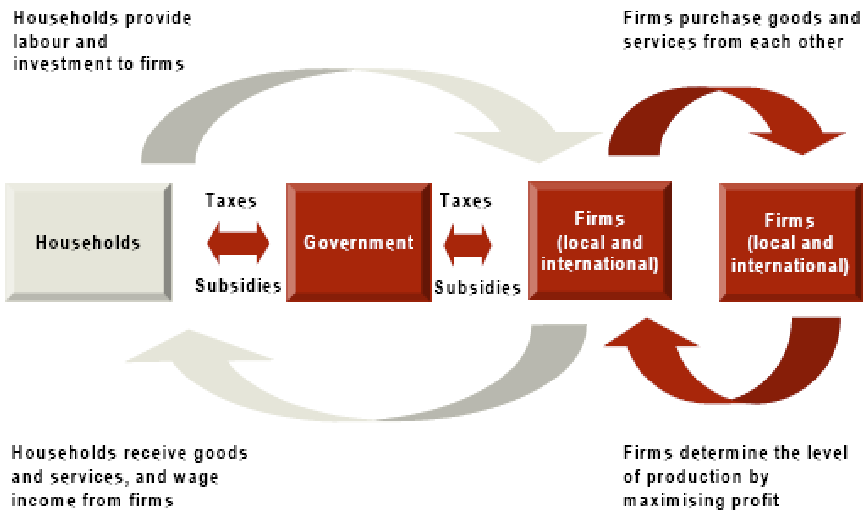



**Figure 1. Circular Flow of Goods and Services and Payment**

## 2.2. Overview of the NEEM Sub-model

The North American Electricity and Environment Model (NEEM) is a flexible, partial equilibrium model of the North American electricity sector that can simultaneously model both system expansion and environmental compliance over a 30- to 50-year timeframe.

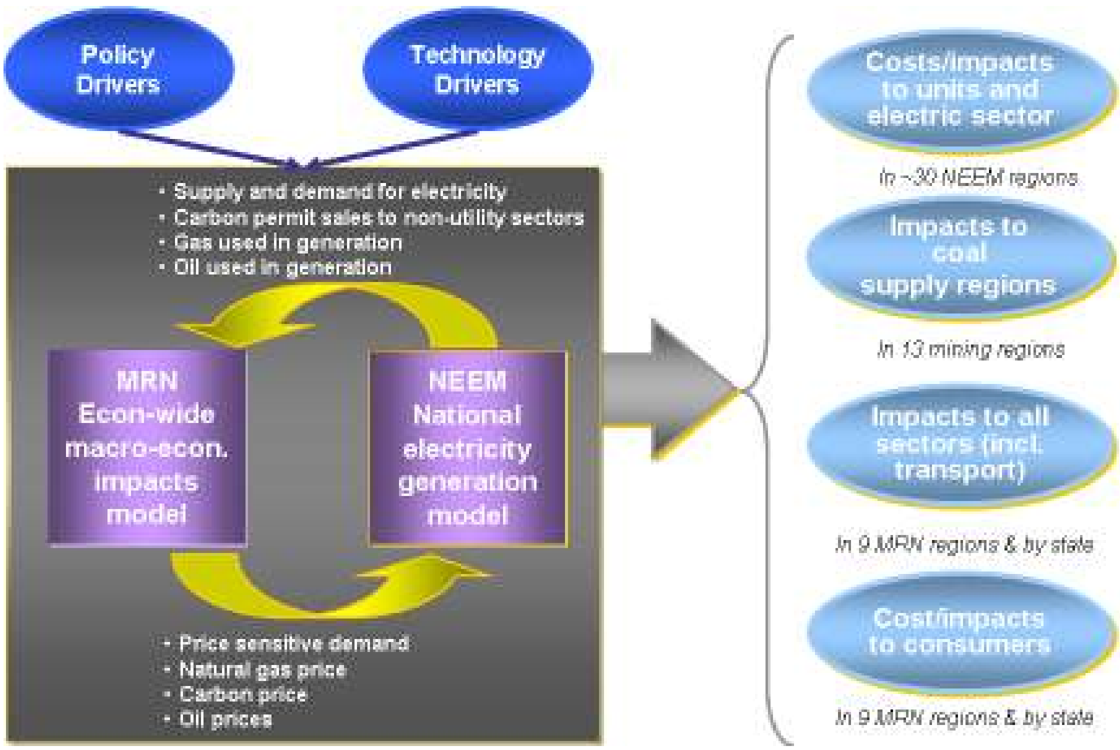
NEEM was developed by CRA to analyze the impact of environmental policy and major economic drivers on the electricity sector. The model calculates the "least-cost solution" to serve load, while complying with environmental policies and meeting resource adequacy requirements and major transmission constraints. NEEM can be used to model both regional and national environmental policies including direct taxes on emissions, emission caps, command-and-control policies, as well as renewable portfolio standards. In addition to forecasting zonal electricity and emissions prices, NEEM optimizes retirements, environmental retrofits, and construction of generating capacity.

The model employs detailed unit-level information on all of the generating units in the United States and large portions of Canada. In general, coal units of 200 MW or greater are represented individually in the model, and other unit types are aggregated within each NEEM region. NEEM models the evolution of the North American power system; taking into account demand growth, currently installed generation, future available generation technologies, pollution control technologies, and environmental regulations both present and future. The North American interconnected power system is modeled as a set of regions that are connected by a network of transmission paths. This paradigm is also referred to as a "transport model" or a "pipes-and-bubbles" model. Transfer limits are specified between the bubbles.

## 2.3. MRN-NEEM Integration Methodology

The MRN-NEEM integration methodology follows an iterative procedure to link top-down and bottom-up models. The method utilizes an iterative process where the MRN and NEEM models are solved in succession, reconciling the equilibrium prices and quantities between the two models. The solution procedure, in general, involves an iterative solution of the top-down general equilibrium model (MRN) given the net supplies from the bottom-up electric sector sub-model (NEEM), followed by the solution of the electric sector model (NEEM) based on a locally calibrated set of linear demand functions for the electric sector. The two models are solved independently using different solution techniques but are integrated through iterative solution points (see Figure 2).

**Figure 2. MRN-NEEM Iterative Process**



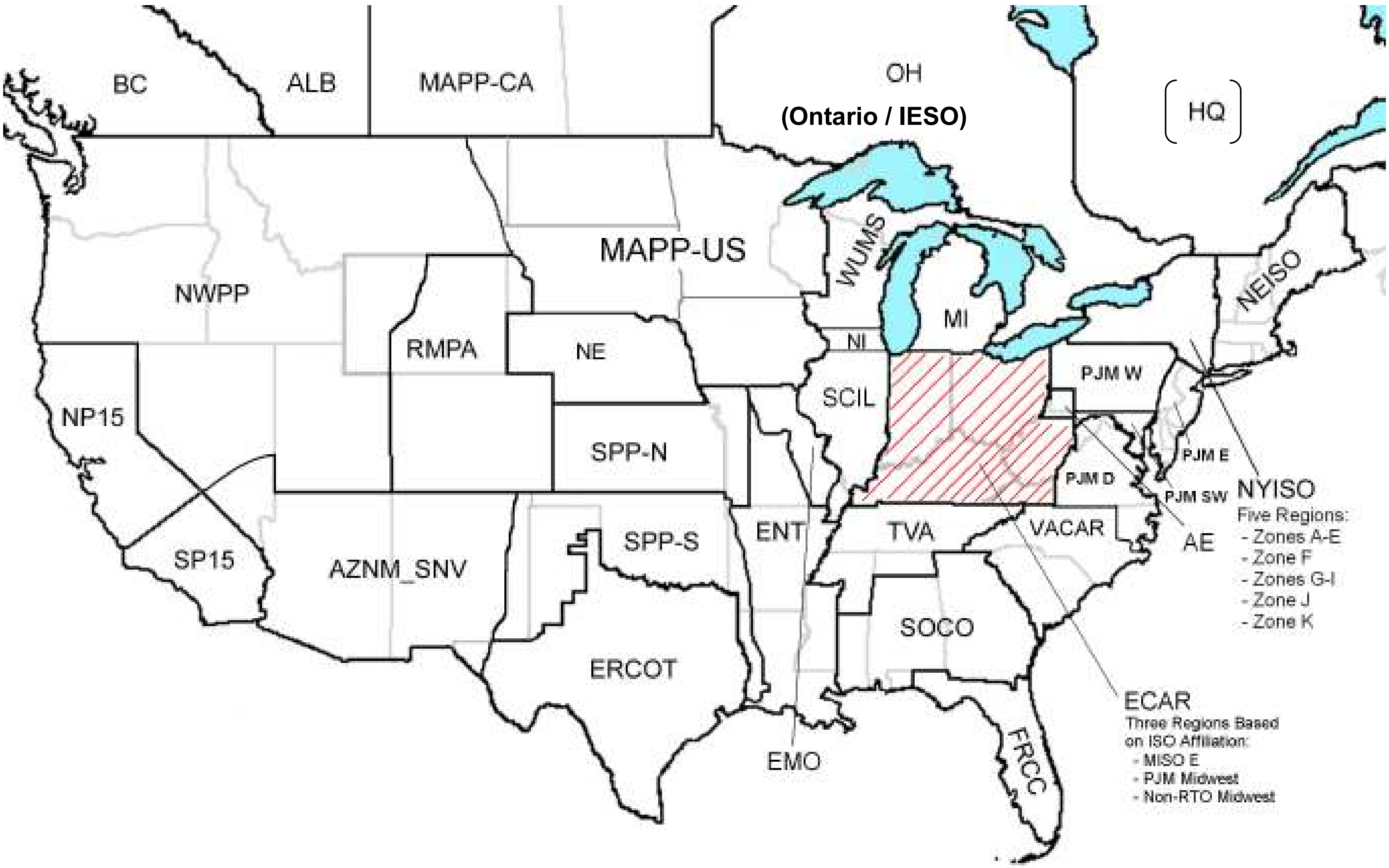

## 3. NEEM INPUTS AND DATA SOURCES

Unless otherwise noted, all financial data are reported in constant 2010 dollars.

### 3.1. NEEM REGIONS

Figure 3 contains a map of the 39 NEEM regions in the U.S. and Canada. As noted above, transmission constraints are not considered within a NEEM region, and transfer limits are used to represent transmission limitations between NEEM regions. The NEEM regions can be modified, but will require a breakdown of the load and generation and other regional input parameters for any additional regions. Presently NEEM regions do not include Maritimes provinces of Canada which are part of the Eastern Interconnection, i.e. New Brunswick and Nova Scotia. These provinces could be added to the model if appropriate information is provided to CRA.

**Figure 3. NEEM Regions**



## 3.2. Energy and Peak Demand

NEEM is a load-duration curve model. The typical NEEM model includes 20 load blocks, broken down as shown in Table 1. The total sums to 8,760 hours. Each region has a load-duration curve for the summer, the winter, and the shoulder seasons. The summer is defined as May through September; the winter includes December, January, and February; and the shoulder period includes March, April, October, and November.

The NEEM data file includes energy demand by NEEM region by load block by year. The data file also includes peak energy demands by NEEM region by year. In general, CRA bases regional energy and peak demands on forecasts provided by Regional Transmission Organizations (RTOs) where available or otherwise are taken from FERC 714 filings. For EIPC, CRA will use the RTO and FERC 714 forecasts for the next 10 years (e.g., 2020[1]). Beyond 2020, we will use the growth rates implied by AEO 2011 (early release) for the period of time between 2020 and 2035 (2035 is the end of the AEO 2011 early release forecast). After 2035, we will maintain the 2020-2035 growth rates through 2050.

For Ontario, we are using the IESO Ontario Reliability Outlook, 2009. For MAPP-CA, we are using the Mid-Continent Area Power Pool Load and Capability Report (May 1, 2009) and the SaskPower 2009 Mid-Application Update (March 26, 2009).

Since there are fewer regions in NEEM than EIA uses to create the AEO forecasts, we will proportionally adjust the growth rates for the last five years of the 714 and RTO forecasts (e.g., 2016-2020) to match the aggregate growth rates in AEO 2011 (early release) during the period after 2020. This will maintain differences in growth among NEEM regions (implied by FERC 714 filings and RTO forecasts) that comprise a single AEO region. For example, if two NEEM regions comprise one AEO region and one NEEM region has a high growth rate (in the last 5 years of the 714 forecast) while the other has a low growth rate (in the last 5 years of the 714 forecast), we will adjust each of these proportionally while meeting the AEO region's growth rate overall. Thus, in the post-2020 period, we will have AEO 2011 (early release) regional growth rates in the aggregate, with finer detail at the NEEM regional level based on the last five years of the FERC 714 and RTO forecasts. In regard to peak load after 2020, we will apply the same growth rate to peak as to energy (by NEEM region).

The annual energy demand is shaped into the load blocks. The load shapes used in NEEM are based upon 2006 actual load profiles from FERC Form 714 utility filings. Within each interconnection (western, eastern, ERCOT), the loads are sorted and shaped using the same chronology. The chronologies are different for the three separate interconnections. We propose to shape the Eastern Interconnection loads into the load duration curves based on the total Eastern Interconnection load (as opposed to basing the sort on a single region). The 2006 load shapes[2] are presented in Exhibit 1 and the top 10 hours (load block 1) are presented in Exhibit 2.

[1] There may be some deviation from 2020 by region based on the available data.

[2] CRA employs a "peak heuristic" adjustment so that if a region's peak load is growing faster than total energy demand, the load shape becomes more peaked over time. The shapes presented in Exhibit 1 are for 2011, thus the shapes are somewhat different from the actual 2006 shapes.

**Table 1: NEEM Load Blocks**

| Load Block | Season | Number of Hours |
|---|---|---|
| B1 | Summer | 10 |
| B2 | Summer | 25 |
| B3 | Summer | 75 |
| B4 | Summer | 100 |
| B5 | Summer | 200 |
| B6 | Summer | 300 |
| B7 | Summer | 400 |
| B8 | Summer | 500 |
| B9 | Summer | 800 |
| B10 | Summer | 1,262 |
| B11 | Shoulder | 25 |
| B12 | Shoulder | 200 |
| B13 | Shoulder | 600 |
| B14 | Shoulder | 900 |
| B15 | Shoulder | 1,203 |
| B16 | Winter | 25 |
| B17 | Winter | 100 |
| B18 | Winter | 400 |
| B19 | Winter | 700 |
| B20 | Winter | 935 |
| TOTAL | | 8760 |

The Energy Forecast by NEEM region is presented in Table 2, using the methodology discussed above. Control entities are mapped to NEEM regions as shown in Appendix A, Exhibit 3. Note that the NEEM regions that comprise PJM (AE, NI, PJM_D, PJM_W, PJM_SW, PJM_E, and PJM_Midwest) have energy demands that sum to the totals implied by the 2010 PJM Load Forecast Report.

**Table 2. Energy Forecast by NEEM Region**

| NEEM Region | 2011 Energy (GWh) | 2011-2020 Growth Rate | 2020-2050 Growth Rate |
|---|---|---|---|
| AE | 51,488 | 1.23% | 0.65% |
| AZ_NM_SNV_Coal | 124,203 | 1.88% | 1.31% |
| EMO | 65,661 | 1.06% | 0.94% |
| ENT | 139,469 | 1.33% | 0.53% |
| ERCOT | 316,195 | 1.69% | 0.65% |
| FRCC | 229,020 | 1.74% | 1.24% |
| MAPP_US | 159,237 | 0.79% | 0.69% |
| MI | 94,678 | 0.80% | 0.79% |
| MISO_E | 127,182 | 0.70% | 0.51% |
| NE | 29,481 | 1.81% | 1.21% |
| NEISO | 132,370 | 0.93% | 0.84% |
| NI | 107,579 | 2.35% | 1.02% |
| NonRTO_Midwest | 70,069 | 1.46% | 0.96% |
| NP15 | 110,014 | 0.94% | 0.74% |
| NWPP_Coal | 246,983 | 1.30% | 0.94% |
| NYISO_Capital | 11,422 | 0.38% | 0.48% |
| NYISO_Downstate | 20,093 | 0.82% | 0.78% |
| NYISO_LIPA | 22,290 | 1.07% | 0.88% |
| NYISO_NYC | 52,697 | 0.95% | 0.87% |
| NYISO_Upstate | 53,942 | 0.80% | 0.51% |
| PJM_D | 100,466 | 2.31% | 1.11% |
| PJM_E | 151,269 | 1.50% | 0.62% |
| PJM_Midwest | 245,376 | 1.16% | 0.44% |
| PJM_SW | 70,368 | 1.37% | 0.77% |
| PJM_W | 79,664 | 1.62% | 0.67% |
| RMPA | 72,067 | 1.21% | 1.27% |
| SCIL | 52,155 | 0.77% | 0.66% |
| SOCO | 249,461 | 1.94% | 0.81% |
| SP15 | 179,898 | 1.31% | 1.16% |
| SPP_N | 75,954 | 1.10% | 0.91% |
| SPP_S | 163,927 | 1.15% | 0.64% |
| TVA | 173,627 | 1.00% | 0.30% |
| VACAR | 236,109 | 1.62% | 0.90% |
| WUMS | 70,306 | 0.78% | 0.66% |
| ALB | 64,239 | 1.57% | 1.41% |
| BC | 63,168 | 1.15% | 0.96% |
| MAPP_CA | 48,057 | 2.00% | TBD |
| OH | 142,313 | -0.30% | TBD |

The peak demand forecast is presented in Table 3, using the methodology discussed above.

**Table 3. Peak Demand Forecast by NEEM Region**

| NEEM Region | Reserve Margin Region | 2011 Peak (MW) | 2011-2020 Growth Rate | 2020-2050 Growth Rate |
|---|---|---|---|---|
| AE | PJM | 8,872 | 1.24% | 0.65% |
| AZ_NM_SNV_Coal | AZ_NM_SNV | 27,169 | 1.91% | 1.31% |
| EMO | MISO | 14,107 | 1.05% | 0.94% |
| ENT | ENT | 25,442 | 1.20% | 0.53% |
| ERCOT | ERCOT | 64,964 | 1.69% | 0.65% |
| FRCC | FRCC | 45,382 | 1.79% | 1.24% |
| MAPP_US | MISO | 32,116 | 0.76% | 0.69% |
| MI | MI | 19,930 | 0.78% | 0.79% |
| MISO_E | MISO | 25,494 | 0.68% | 0.51% |
| NE | SPP | 5,580 | 1.52% | 1.21% |
| NEISO | NEISO | 27,393 | 1.30% | 0.84% |
| NI | PJM | 23,372 | 2.01% | 1.02% |
| NonRTO_Midwest | NonRTO_Midwest | 12,100 | 1.14% | 0.96% |
| NP15 | CA | 24,248 | 1.24% | 0.74% |
| NWPP_Coal | NWPP | 41,760 | 1.01% | 0.94% |
| NYISO_Capital | NYISO | 2,328 | 0.47% | 0.48% |
| NYISO_Downstate | NYISO | 4,366 | 0.67% | 0.78% |
| NYISO_LIPA | NYISO | 5,384 | 0.77% | 0.88% |
| NYISO_NYC | NYISO | 11,775 | 0.68% | 0.87% |
| NYISO_Upstate | NYISO | 9,207 | 0.76% | 0.51% |
| PJM_D | PJM | 20,488 | 2.41% | 1.11% |
| PJM_E | PJM | 33,727 | 1.39% | 0.62% |
| PJM_Midwest | PJM | 43,342 | 1.23% | 0.44% |
| PJM_SW | PJM | 14,800 | 1.44% | 0.77% |
| PJM_W | PJM | 13,318 | 1.43% | 0.67% |
| RMPA | RMPA | 12,556 | 1.34% | 1.27% |
| SCIL | MISO | 11,099 | 0.75% | 0.66% |
| SOCO | SOCO | 48,104 | 2.18% | 0.81% |
| SP15 | CA | 35,048 | 1.31% | 1.16% |
| SPP_N | SPP | 15,530 | 1.92% | 0.91% |
| SPP_S | SPP | 32,752 | 1.06% | 0.64% |
| TVA | TVA | 32,460 | 1.85% | 0.30% |
| VACAR | VACAR | 46,538 | 1.53% | 0.90% |
| WUMS | MISO | 14,336 | 0.82% | 0.66% |
| ALB | ALB | 9,176 | 1.63% | 1.41% |
| BC | BC | 11,441 | 1.16% | 0.96% |

| | | | | |
|---|---|---|---|---|
| MAPP_CA | TBD | 8,007 | 1.67% | TBD |
| OH (IESO) | OH | 23,625 | -0.30% | TBD |

In PJM, it is assumed that 7,800 MW of peak demand is met by demand response in 2011, rising to 9,300 MW by 2013. These numbers are based on recent ISO documentation.[3] We assume that PJM demand response maintains a constant percentage of peak load in the years following 2013. These "DSM resources" are assumed not to assist in meeting energy demand – they simply reduce the need for generation expansion.

Similarly, in ISO NE, it is assumed that 3,000 MW of peak demand is met by demand response in 2011. These numbers are based on recent ISO documentation.[4] We assume that the fraction of peak demand in ISO NE is held constant over time after 2011. In NYISO, we assume that 2,200 MW of peak demand is met by demand response in 2011. These numbers are based on recent ISO documentation.[5] We will assume that the fraction of peak demand in NYISO is held constant over time after 2011.

It is assumed that the peak load forecasts for other regions are net of DSM.

## 3.3. EXISTING GENERATOR INFORMATION

### 3.3.1. Aggregation of Units

The NEEM data file includes all existing generators in the United States and in selected regions of Canada. This includes coal-fired, natural gas-fired, steam oil/gas, nuclear, and renewable units. For purposes of model flexibility and solution speed many of the units are aggregated together based on unit type and unit size, as well as the location of the unit.

All existing coal units that are 200 MW or greater (based on summer capacity) are represented individually and not included in aggregates.

Coal units less than 200 MW and located within the same region are included in one of the three aggregates based on their capacity:

- Up to 100 MW (1_Coal)
- Between 100 MW and 150 MW (2_Coal)
- Between 150 MW and 200 MW (3_Coal)

In each region, natural gas and oil fired units are aggregated based on their heat rates:

Combined cycles:

- Up to 7,400 Btu/kWh (CC1)
- Between 7,400 and 8,200 Btu/kWh (CC2)

[3] 2013/2014 RPM Base Residual Auction Results.

[4] Maximizing Net Benefits Using Price-Responsive Demand Response.

[5] NYISO 2010 Reliability Needs Assessment.

- Between 8,200 and 9,000 Btu/kWh (CC3)
- Greater than 9,000 Btu/kWh (CC4)

Gas-fired peakers:

- Up to 14,000 Btu/kWh (PeakG_1)
- Greater than 14,000 Btu/kWh (PeakG_2)

Oil-fired peakers:

- Up to 14,000 Btu/kWh (PeakO_1)
- Greater than 14,000 Btu/kWh (PeakO_2)

Steam Oil/Gas units in each region are aggregated on the basis of their heat rates:

- Up to 14,000 Btu/kWh (STOG1)
- Greater than 14,000 Btu/kWh (STOG_2)

All other types of units (*e.g.*, nuclear, wind, *etc.*) are aggregated together within each region.

### 3.3.2. Coal Unit Characteristics

The operating data for existing coal units in NEEM includes: installed capacity, planned outage days (PODays), forced outage rates, heat rates (MMBtu/MWh), unit types, planned and existing retrofit technologies, and plant configurations. NEEM also contains unit emission rates for $NO_X$ and $CO_2$,[6] and information about the current coal being burned by each unit.

Data on the coal units comes from a number of sources. The source of the coal units operating in the United States is predominantly from EIA Form 816 and ES&D Database and matched against Energy Velocity data. Existing plant configuration also comes from a number of sources including the EIA Form 767, McIlvaine's database of controls, quarterly CEMS filings, and monitoring of the trade press. Planned outage information is from NERC Generating Availability Data System ("GADS") and is based on the plant type and unit size (for coal units). Forced outage rates also come from GADS. $NO_x$ emission rates, planned and existing retrofits, installed capacities, and heat rates are primarily based on data from Energy Velocity. The $NO_x$ emissions rates for existing units are from the EPA CEMS data. CRA assumes that coal units emit 207.9 lbs/MMBtu of $CO_2$.

Information on each coal unit's initial coal is based on coal deliveries to that plant in the most recent year for which data is available.

### 3.3.3. Other Fossil-Fired Unit Characteristics

Important characteristics for the natural gas and oil-fired units are similar to those for the coal units. The set of existing natural gas-fired and oil-fired units is regularly pulled from an Energy Velocity data set based on NERC ES&D, EIA 860, CEMS and other data sources. Installed capacities and heat rates are based on Energy Velocity. The EIPC analysis is based on an August 4, 2010 data download from Energy Velocity. Planned and forced outage rates for these units are based on GADS. For EIPC, CRA assumes that existing combined-cycles emit 0.02

[6] SO2 and Hg emissions depend on the coal choice in NEEM.

lbs/MMBtu of $NO_x$, peaking gas emits 0.1 lbs/MMBtu of $NO_x$, oil units emit 0.2 lbs/MMBtu of $NO_x$, and steam-oil-gas units emit 0.18 lbs/MMBtu of $NO_x$. We assume that sulfur emissions from these existing units are zero. Emissions of CO2 are assumed to be 116.7 lbs/MMBtu from natural gas units and 170.4 lbs/MMBtu from oil units.

### 3.3.4. Nuclear Unit Characteristics

Information on nuclear units is available from many sources including NERC ES&D, Nuclear Energy Institute, and GADS. Outage information has been set such that the capacity factor for nuclear generators is 89 percent (29 planned outage days and 3.2% forced outage rate), which is slightly below the capacity factor of the U.S. nuclear fleet over the last several years. Since nuclear generators will operate full out, the other important characteristic besides outages is capacity. Over the last several years many nuclear generators have increased their rated capacity through uprates. Many others are projected to add uprates over the next several years. These projected uprates are included in NEEM based on information from the Nuclear Regulatory Commission (NRC, November 2010 data).

### 3.3.5. Operations and Maintenance (O&M) Costs for Existing Units

Fixed and variable O&M costs ("FOM" and "VOM") for existing units begin with base assumptions. CRA assumes a base FOM cost for each technology type other than coal. For coal units, the base O&M is based on Sargent & Lundy, 2010.[7] The FOM is a function of unit age, whether the units are scrubbed or unscrubbed, and whether the unit has $NO_x$ controls or not. Additions for necessary capital expenditures, future planned retrofits, and refurbishment are applied to the base cost, as necessary. Retrofit FOM is applicable only to coal units and discussed more completely in the Retrofits section of this document.

Onn-going capital expenditures are applicable only to coal units and are assumed a constant \$17/kW-yr in 2007\$ (\$17.90/kW-yr in 2010\$). Refurbishment charges are applied at the end of the unit's operating life, which is 60 years for coal units and 30 years for gas- and oil-fired units. For coal units, CRA assumes that the refurbishment cost is 15 percent of a new coal unit's capital cost, assessed annually using the fixed charge rates provided in Table 12. NEEM makes an economic choice as to whether the unit will incur the cost increase or retire.

For gas- and oil-fired units, CRA assumes an FOM increase of \$6.79/kW-yr (2010\$) beginning at 31 years of age. Refurbishment or increasing FOM for existing renewable units is not considered in NEEM. All nuclear units are retired at the end of their 60-year licenses, but CRA assumes that nuclear units experience an FOM increase of 32.83/kW-yr (2010\$) beginning at 31 years of age.

Variable O&M is based on CRA assumptions. Existing retrofits on coal units will increase the VOM on these units by the applicable retrofit VOM for that unit and type of retrofit (see Retrofits section). VOM for non-coal units consists solely of the base VOM – there are no retrofits for these non-coal units. Table 4 shows existing unit FOM and VOM assumptions.

[7] Sargent & Lundy. "IPM Model - Revisions to Cost and Performance for APC Technologies. Wet FGD Cost Development Methodology." August 2010. [Table 1]

**Table 4: Existing Operations & Maintenance Costs (without Retrofits)**

| Unit Type | FOM ($2010/kW-yr) | VOM ($2010/MWh) |
|---|---|---|
| Coal | 48.22* | 3.56** |
| CC | 29.68 | 2.37 |
| Peak Gas | 16.62 | 8.31 |
| Peak Oil | 22.55 | 8.31 |
| STOG | 37.15 | 2.37 |
| Nuclear | 112.77 | 2.37 |
| Hydro | 14.24 | NA |
| Pumped Storage | 23.74 | NA |
| Photovoltaic | 14.66 | NA |
| Solar Thermal | 60.32 | NA |
| Wind | 34.22 | NA |
| Steam Wood | 32.05 | 2.37 |
| Landfill Gas | 120.65 | NA |
| Geothermal | 89.76 | NA |

* For a 30-40 year-old coal unit with no scrubber and no NOx controls.
This is expressed prior to the addition of the $17.90/kW-yr capital expenditure adder.
** For a coal unit with no retrofits.

### 3.3.6. Renewables Characteristics

NEEM includes information on existing renewables generation including: hydroelectric, wind, geothermal, solar, biomass, and landfill gas. The capacity in each region is also based on information from Energy Velocity and is regularly updated. The intermittency of wind generation is simulated using hourly wind profile data aggregated into the load blocks using the 2006 chronology, consistent with the load block definitions.[8] See Exhibit 4 for the onshore and offshore wind shapes in the Eastern Interconnection. These shapes are sorted on a single eastern NEEM Region's loads – when we sort on the total Eastern Interconnection load (forthcoming), the wind shapes will change somewhat. For EIPC and for simplicity, we propose to use the same shapes for existing wind units as we do for new installations. While some older wind farms have a lower output for an equal wind regime (relative to new wind farms), most of the currently installed wind capacity have been installed recently.

The contribution of renewable resources toward reserve margin is shown on Table 5. We make a static assumption (no change over time) and the assumptions are the same for existing and new renewables. The specified contributions are expressed as a percentage of nameplate capacity.

[8] Hourly wind dataset is NREL Eastern Wind Integration and Transmission study and Western Wind and Solar Integration study. Annual capacity factors are based on the 2004-2006 average capacity factors in the NREL dataset.

**Table 5: Reserve Margin Contribution of Renewable Resources**

| NEEM Region | Technology | Reserve Contribution |
|---|---|---|
| All Regions | Photovoltaic | 30% |
| All Regions | Solar Thermal | 30% |
| All Regions | Offshore Wind | 20% |
| California | Wind | 25% |
| Canada | Wind | 20% |
| ERCOT | Wind | 9% |
| New York | Wind | 10% |
| PJM | Wind | 13% |
| SPP | Wind | 6% |
| All Other Regions | Wind | 15% |

### 3.3.7. Hydroelectric and Pumped Storage

NEEM includes information on existing hydroelectric and pumped storage resources. Existing hydropower units are not treated the same as wind units in NEEM. While wind units have fixed output by load block, the hydropower units have a specified amount of energy assigned to each season. Hydroelectric generation is limited in each season based on average levels of hydroelectric generation (from CRA's GE MAPS hydro assumptions). NEEM optimizes the output of the specified hydro energy across load blocks within each season – the output cannot exceed the unit's capacity in any block.

Generally, the amount of hydro energy (by season) cannot change in future years. It is possible to use more than one hydro unit in a single region to simulate a portion of the hydro that is not optimizable and a portion that is optimizable. In this case, the non-optimizable unit (which runs flat across the load blocks) can change in size over time (exogenously).

Pumped storage is assumed to have an efficiency of 75 percent.

### 3.3.8. Installed Capacity by Region (all technologies)

Table 6 presents installed electric sector generation capacity by NEEM region as of 2010 for all technologies. Generators are mapped to NEEM regions based on the mapping in Appendix A, Exhibit 5. NEISO includes the Vermont Yankee nuclear unit. Vermont Yankee is assumed to retire at the end of 60 years of operation (2032), consistent with the retirement assumption for other U.S. nuclear units.

Table 6: Installed Capacity by NEEM Region

| NEEM Region | Installed Capacity - 2010 (GW) | Reserve Capacity - 2010 (GW) |
|---|---|---|
| AE | 10.63 | 10.61 |
| AZ_NM_SNV | 10.91 | 10.91 |
| EMO | 13.40 | 13.18 |
| ENT | 42.75 | 42.75 |
| ERCOT | 85.28 | 77.13 |
| FRCC | 56.65 | 56.61 |
| MAPP_US | 39.21 | 34.03 |
| MI | 26.47 | 26.33 |
| MISO_E | 30.91 | 30.46 |
| NE | 8.27 | 8.14 |
| NEISO | 37.53 | 37.35 |
| NI | 28.59 | 27.17 |
| NonRTO_Midwest | 14.60 | 14.55 |
| NP15 | 31.46 | 30.61 |
| NWPP_Coal | 13.97 | 13.97 |
| NYISO_Capital | 3.14 | 3.14 |
| NYISO_Downstate | 6.53 | 6.53 |
| NYISO_LIPA | 5.75 | 5.75 |
| NYISO_NYC | 9.90 | 9.90 |
| NYISO_Upstate | 16.33 | 15.18 |
| PJM_D | 22.62 | 22.39 |
| PJM_E | 31.95 | 31.93 |
| PJM_Midwest | 48.47 | 47.86 |
| PJM_SW | 12.44 | 12.44 |
| PJM_W | 32.27 | 31.64 |
| RMPA | 16.23 | 15.04 |
| SCIL | 15.17 | 14.98 |
| SOCO | 65.41 | 65.41 |
| SP15 | 33.76 | 32.19 |
| SPP_N | 19.26 | 18.11 |
| SPP_S | 42.39 | 40.23 |
| TVA | 39.17 | 39.14 |
| VACAR | 48.36 | 48.35 |
| WUMS | 18.09 | 16.99 |
| ALB | 12.27 | 11.74 |
| BC | 14.13 | 14.04 |
| MAPP_CA | 9.27 | 9.04 |
| OH | 37.14 | 36.10 |
| **Grand Total** | **1,010.68** | **981.90** |

Additional unit data for the Eastern Interconnection are provided in Appendix A, Exhibit 6.

## 3.4. NEW GENERATOR INFORMATION

NEEM allows for the addition of a range of new generation types. These additions include both forced new generation, which is the result of new generation that is already under construction, and economic new generation, which is the result of additions to lower total system costs, to comply with planning reserve requirements, and to meet RPS requirements. Forced builds in general include new generation that is already under construction and is therefore likely to be completed. Information on units under construction is obtained from Energy Velocity as well as from trade publications.

### 3.4.1. Forced New Builds

A list of forced new builds is provided Appendix A, Exhibit 7 (pending awaiting Baseline Infrastructure). For the Eastern Interconnect, these are based on the Baseline Infrastructure. A list of forced retirements is included in Appendix A, Exhibit 8. Forced retirements are all planned retirements as reported in Energy Velocity, except for those listed as "canceled." CRA also adds announced retirements reported in the trade press

### 3.4.2. New Build Costs and Performance Characteristics

NEEM currently allows the following types of new generation: natural gas combined cycle ("CC"), natural gas combustion turbine ("CT"), pulverized coal ("AC"), nuclear, integrated gasification combined cycle ("IGCC," also available with carbon capture/sequestration), and a range of renewable technologies. Renewable technologies include: wind ("WT"), solar photovoltaic ("PV"), solar thermal ("ST"), landfill gas ("LG"), biomass ("BM"), and geothermal ("GEO").

Costs and characteristics for these technologies are based on AEO 2011 (early release) along with CRA assumptions about cost adders. New addition costs are shown in Table 7.[9] A detailed build-up of the capital costs is provided in Appendix A, Exhibit 9.

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[9] Renewables capital costs are exclusive of federal investment tax credits, federal cash grants, or the first-cost equivalent of the production tax credit. AEO 2011 does not assume extension of these federal subsidies, thus they are not reflected in long-term capital costs. Such policies could be modeled in NEEM, if desirable. With respect to the wind tax credit which expires at the end of 2012, most new builds that the tax credit would incentivize will be captured by the new builds that are forced into NEEM. Thus, explicitly modeling the current wind tax credit is not critical to this analysis (however, a sensitivity analysis that assumes a lengthy or permanent extension of the tax credit might be informative).

**Table 7. New Build Costs and Characteristics**

| | Capital Costs | | Performance Data | | | |
|---|---|---|---|---|---|---|
| Technology | 2015 All-in Capital Cost (2010$/kW) | 2025 All-in Capital Cost (2010$/kW) | Total FOM (2010$/kW-yr) | Total VOM (2010$/MWh) | 2010 Heat Rate - HHV (Btu/kWh) | 2015+ Heat Rate - HHV (Btu/kWh) |
| Nuclear | 5,437 | 5,081 | 88.75 | 2.04 | 10,488 | 10,488 |
| Advanced Coal | 2,838 | 2,743 | 29.67 | 4.25 | 9,200 | 8,800 |
| CC | 1,018 | 985 | 14.39 | 3.43 | 7,050 | 6,430 |
| CT | 699 | 677 | 6.70 | 9.87 | 9,750 | 9,750 |
| IGCC | 3,208 | 3,101 | 48.90 | 6.87 | 8,700 | 8,700 |
| IGCC w/seq | 5,193 | 4,802 | 69.30 | 8.04 | 10,700 | 10,235 |
| Wind | 2,603 | 2,587 | 28.07 | 0.00 | NA | NA |
| Wind Offshore | 5,577 | 4,780 | 53.33 | 0.00 | NA | NA |
| Photovoltaic | 4,611 | 3,977 | 16.70 | 0.00 | NA | NA |
| Solar Thermal | 4,552 | 3,927 | 64.00 | 0.00 | NA | NA |
| Landfill Gas | 2,484 | 2,400 | 120.33 | 0.00 | 13,648 | 13,648 |
| Biomass | 3,644 | 3,129 | 100.50 | 5.00 | 13,500 | 13,500 |
| Geothermal | 4,176 | 3,900 | 84.27 | 9.64 | NA | NA |

New build costs in NEEM vary by region. Regional multipliers are provided in Appendix A, Exhibit 10. Regional multipliers are approximations of geographic cost differences based on EIA's AEO 2011 (early release). They can be changed as needed and as new information arises.

### 3.4.3. New Wind Units

NEEM optimizes the expansion of wind capacity. Wind units are similar to other units (e.g., coal, gas, nuclear) except they have fixed output (across the load blocks). They are not dispatched. The onshore and offshore wind shapes are presented in Exhibit 4. These shapes are currently sorted on a single eastern NEEM Region's loads – when we sort on the total Eastern Interconnection load (forthcoming), the wind shapes will change somewhat.

The capacity factors and wind resource limits are summarized in Exhibit 11. We exclude class 3 and lower wind for both onshore and offshore wind. For offshore wind, we include only the shallow depth wind resource potential. See the new build constraint section (section 3.4.5) for more information about the wind resource limits.

### 3.4.4. New Hydropower Units

NEEM does not optimize the construction of new hydropower units. Given the limitation of hydropower units within NEEM, it is not possible to represent the expansion of the Canadian hydro system using NEEM's hydro units. For those Canadian regions modeled in NEEM (MAPP-CA and Ontario in the Eastern Interconnection), we can add hydro units. One option would be to use a wind unit type to represent the hydro expansion. The "new hydro units" (actually wind units) would be fundamentally different from the existing hydro units in that the "new hydro units" would have fixed output by load block (and would not have their output optimized seasonally). The "new hydro units" could be either forced into the model or they could be chosen endogenously based on economics.

For new hydro capacity in HQ and the Maritimes, we would have to modify the inter-regional interchange. See section 3.15.2 for more detail.

### 3.4.5. Constraints on New Builds

Certain new generating technologies are unlikely to be available in all regions for resource or other reasons (e.g., regulatory). For example, there are not any new geothermal opportunities in Georgia. As a result, all generating options are not available in all regions. Also, some of the generating technologies are not currently commercially produced. For example, no new nuclear plants have been built in the United States in more than twenty years and IGCC with carbon capture/sequestration may not be available for some extended period of time. In these instances, the first year available is set well out into the future to reflect the technological barriers that must still be overcome. These inputs can vary by case.

The maximum penetration over time in the U.S. or by region can also be specified. Regional constraints on new entry by technology are specified in Appendix A, Exhibit 12. For purposes of this long-term study, a simplified set of build constraints have been developed for consideration by stakeholders. The limits in the tables are based on CRA's assessment of publicly available sources. For onshore and offshore wind, they are based on the base case from NREL's WinDS model assessment, mapped to the NEEM regions. We have included onshore and offshore wind resources of class 4 quality or higher. For offshore wind, we have only included the potential for shallow offshore wind development.

CRA is not aware of good sources of data for solar potential in the Eastern U.S. – the numbers that we have provided are CRA estimates. All limits, including those for renewables, can be changed as needed and as new information is provided. For eastern solar resources, we expect that the economics of competing resources and the policy incentives provided to solar (and not solar resource potential itself) will govern the solar capacity additions; therefore, the "total potential" estimates are not expected to be critical to the analysis.

NEEM also accepts annual build limits. These represent practical limitations on the amount of a given technology that can be installed in a given year. These limits are typically applied at the U.S. level. These limits are typically applied to coal, nuclear, and wind, for example. For purposes of this long-term study, CRA proposes that we do not incorporate annual limits.

## 3.5. RETROFITS

The NEEM data file includes environmental retrofits for existing coal-fired units to reduce emissions of $SO_2$, $NO_X$, Hg and $CO_2$. There is also a fuel switch option that requires capital investment.

Retrofit options currently include: flue gas desulfurization ("FGD") for removal of $SO_2$, selective catalytic reduction ("SCR"), and selective non-catalytic reduction ("SNCR") for removal of $NO_X$. Mercury retrofits include activated carbon injection ("ACI90") and ACI with a fabric filter ("RPJ90"). There is also a carbon capture and sequestration ("PCSEQ") retrofit to reduce $CO_2$ emissions, although this technology is not currently available and is not likely to be widely available for about ten years. Retrofits have a fixed charge rate of 14.5% applied to the capital cost of the retrofit to derive an annualized cost that applies for a period of 10 years.

CRA's sources for information on the cost of retrofitting existing units with new emission control technologies are listed in Appendix A, Exhibit 13. The capital cost information for retrofits was initially based on EPA estimates included in documentation of the IPM model.[10] Capital costs and performance data for SNCR are still based on EPA estimates. Capital and performance costs for FGDs are now built up from the new methodology in EPA's IPM Model for Wet FGD technologies.[11] The base capital costs on FGDs include equipment, installation, buildings, foundations, electrical, minor physical/chemical wastewater treatment and retrofit difficulty.

The base cost is then increased by engineering and construction management costs, labor costs, and contractor profit and fees. The final project cost will further include financing and additional project costs. The fixed O&M costs for FGD installation are a function of additional operations staff, maintenance and labor materials, and administrative labor costs. The variable O&M costs are a function of reagent use and water costs, waste disposal, supplementary power costs, and water costs. Table 8 shows an example of the FGD retrofit costs for an uncontrolled coal unit of gross size 500 MW, heat rate 9,500 Btu/kWh, and an $SO_2$ rate of 3 lbs/MMBtu.

**Table 8: Example of FGD Retrofit Costs**

| Retrofit | Unit Size (MW) | Capital Cost (2010$/kW) | Fixed O&M ($2010/kW-yr) | Variable O&M ($2010/MWh) | Heat Rate Penalty | Capacity Penalty |
|---|---|---|---|---|---|---|
| FGD | 500 | 507.97 | 8.27 | 1.84 | 2.1% | 2.1% |

Cost curves for $NO_x$ and mercury emissions controls have been developed from research by J Edward Chicanowicz. Capital costs and Fixed O&M for an SCR retrofit follows the following methodology:

$$\text{Capital Cost}_{SCR} = -44.3 * \ln(\text{Gross Unit Capacity in MW}) + 546.4$$

$$\text{Fixed O\&M}_{SCR} = 0.5\ \% * \text{Capital Cost}_{SCR}$$

Variable O&M costs are based on the sum of the costs for labor, fuel, reagent, auxiliary power, and catalyst supply. Table 9 shows an example of the SCR retrofit costs for an uncontrolled coal unit with a capacity of 500 MW.

**Table 9: Example of SCR Retrofit Costs**

| Retrofit | Unit Size (MW) | Capital Cost (2010$/kW) | Fixed O&M ($2010/kW-yr) | Variable O&M ($2010/MWh) |
|---|---|---|---|---|
| SCR | 500 | 278.42 | 1.39 | 0.54 |

[10] EPA's model documentation of retrofit costs is available at http://www.epa.gov/airmarkets/epa-ipm/bc5emission.pdf.

[11] IPM Model – Revisions to Cost and Performance for APC Technologies. Sargent & Lundy 2010. http://www.epa.gov/airmarkets/progsregs/epa-ipm/docs/v410/Appendix51A.pdf.

Capital and performance costs for mercury data are also from Chicanowicz research.[12] CRA models an option Advanced Carbon Injection ("ACI") technology for units currently equipped with a fabric filter. For units lacking a fabric filter, CRA models the cost of the mercury retrofit as the sum of a fabric filter installation and an ACI retrofit installation. The capital cost and FOM are a function of gross unit size; the VOM is a function of several assumptions regarding sorbent and disposal costs.

$$\text{Capital Cost}_{ACI} = 1237.4 * (\text{Gross Unit Capacity in MW})^{-0.846}$$

$$\text{Capital Cost}_{FF} = 3071.7 * (\text{Gross Unit Capacity in MW})^{-0.4999}$$

$$\text{Fixed O\&M}_{ACI} = 68.02 * (\text{Gross Unit Capacity in MW})^{-0.894}$$

$$\text{Fixed O\&M}_{FF} = 15.174 * (\text{Gross Unit Capacity in MW})^{-0.584}$$

Table 10 shows an example of the costs of installing an ACI and/or Fabric Filter for an uncontrolled coal unit with a capacity of 500 MW.

**Table 10: Example of Hg Retrofit Costs**

| Retrofit | Unit Size (MW)* | Capital Cost (2010$/kW) | Fixed O&M ($2010/kW-yr) | Variable O&M ($2010/MWh) |
|---|---|---|---|---|
| ACI | 500 | 7.21 | 0.29 | 0.37 |
| FF | 500 | 153.85 | 0.45 | NA |
| ACI + FF | 500 | 161.06 | 0.74 | 0.37 |

The effectiveness of different retrofits can be a function of the current plant configuration and/or the type of coal burned. The FGD retrofit is assumed to achieve a 98 percent incremental reduction in $SO_2$ emissions. It is important to note that installation of the FGD retrofit results in a 2.1 percent heat rate penalty and a 2.1 percent capacity penalty.

Reductions of $NO_X$ emission from SCR and SNCR vary depending on the initial $NO_X$ rate of the coal unit. The SCR retrofit can provide a maximum incremental reduction of 90 percent and the SNCR can provide a maximum incremental reduction of 35 percent, but there is a minimum post-control $NO_X$ rate that depends on the plant configuration and coal type. If the unit burns PRB fuel then the retrofit can reduce the $NO_X$ rate to a minimum of 0.045 lbs/MMBtu. However, if the unit has either a cyclone boiler or a wet bottom boiler, then the minimum $NO_X$ rate is 0.10 lbs/MMBtu. All other plant configurations are assumed to have a minimum $NO_X$ rate of 0.06 lbs/MMBtu. The assumed effectiveness of both ACI90 and RPJ90 is a 90 percent incremental removal. This removal is incremental to any co-benefits achieved through any other equipment. Removal efficiencies, heat rate penalties, and capacity penalties are based on CRA's internal research. They are assumptions to the model and can be changed by the user.

[12] Cichanowicz, J Edward. "Testimony of J E Cichanowicz to the Illinois Pollution Control Board. A Review of the Status of Mercury Control Technology." July 28, 2006. [Figure B-7]

Table 11 shows the CRA-proposed costs of installing a carbon capture (CCS) retrofit. These are CRA assumptions. The assumed heat rate and capacity penalties are also shown. We assume that carbon capture retrofits become available in 2020 and only units with existing or planned FGDs and SCRs are eligible. We also model the costs of CO2 transport and storage.[13]

**Table 11. Example of Carbon Capture Retrofit Costs**

| Retrofit | Unit Size (MW) | *Capital Cost (2010$/kW) | Fixed O&M ($2010/kW-yr) | Variable O&M ($2010/MWh) | Heat Rate Penalty | Capacity Penalty |
|---|---|---|---|---|---|---|
| Carbon Capture | any | 1,287 | 1.58 | 2.80 | 30.0% | 23.1% |

* Based on the capacity prior to the retrofit derate.

*Note: Units must have existing or planned FGDs and SCRs to be eligible for this retrofit.*

In addition to forced retrofits, NEEM is capable of making economic retrofit decisions designed to minimize total costs in the model. For example, under a cap-and-trade policy, the model will select retrofits that minimize the costs associated with achieving the policy goal – taking into account both the costs of available retrofit technologies and the opportunity costs associated with replacing existing generating facilities with newer ones. Under an emission price policy, the model will only select retrofits that have a cost per ton removed lower than the specified emission price. Under a command-and-control policy, the model will either select the least-expensive retrofits to achieve compliance or it will retire the unit.

In addition to pollution control retrofits, coal units that do not currently have the capability to burn sub-bituminous coals[14] can add a fuel switch retrofit. This retrofit covers the costs of boiler modifications and coal handling equipment that would likely result from the addition of the capability of burning sub-bituminous fuels. This retrofit has a capital cost of between $90/kW and $120/kW for aggregate coal units and is $60/kW for stand-alone coal units. There is also a $0.50/MWh variable cost adder along with a 7.0 percent heat rate penalty and a 7.0 percent capacity penalty.

CRA's model also contains information about planned retrofits based on Energy Velocity. For modeling purposes, it is assumed that these retrofits will occur, but their FOM, VOM, & capital costs are the same as other new retrofits. Appendix A, Exhibit 14 provides a list of the planned retrofits currently in the model.

### 3.6. Discount Rate/Cost Of Capital

The discount rate is an important input because the model minimizes the *present value* of total system costs. Also, emissions allowance prices will tend to rise at the discount rate in the

[13] Based on IEA, "Building the Cost Curves for CO2 Storage in North America," February 2005.

[14] Coal units that have the capability to burn sub-bituminous coals are denoted with a 1 in the "CanBurnPRB" field on the ExistingUnitData worksheet.

presence of emissions banking. The cost of capital/discount rate in the model is in real (i.e., net of inflation) terms and is 5%. (All MRN/NEEM calculations and results are in real dollars).

The cost of capital/discount rate must also be used in the construction of the build-up of the real capital charge rates used for new investments. These real capital fixed charge rates (FCRs) are assessed using the tax life and assumed operating life of each type of new asset to yield a zero (i.e., compensatory) net present value to investors. The capital fixed charge rates for new construction are summarized in Table 12.

**Table 12. Real Capital Fixed Charge Rates for New Construction**

| Technology | Operating Life (yrs) | FCR |
|---|---|---|
| NG Combined-Cycle | 25 | 11.30% |
| NG Combustion Turbine | 20 | 11.80% |
| Advanced Pulverized Coal, Coal IGCC, Coal IGCC-CCS | 40 | 10.50% |
| Nuclear | 40 | 11.20% |
| Photvoltaics | 20 | 11.80% |
| Biomass | 30 | 11.60% |
| Landfill Gas | 20 | 11.80% |
| Wind | 20 | 11.80% |
| Wind Offshore | 20 | 11.80% |
| Solar Thermal | 20 | 11.80% |
| Geothermal | 20 | 11.80% |

FCR's apply to the real overnight costs. Because we use real overnight FCR's, the construction period matters to the calculation of the FCR - it is more costly on a present value basis, all else equal, to have a longer lead time, and this is not taken into account in the real overnight costs ($/kW).

Coal plants have lower FCRs than nuclear plants because nuclear plants have longer design and construction periods during which interest is accruing. Coal plants have lower FCRs than renewables because coal plants have substantially longer operating lifetimes. Because of their long lifetimes, coal plants' have lower FCRs despite the fact that renewables can typically be built more quickly than coal plants.

## 3.7. EMISSIONS

One of the primary functions of NEEM is to determine compliance strategies with different environmental policies. NEEM has the flexibility to model many different types of environmental policies and in many forms.

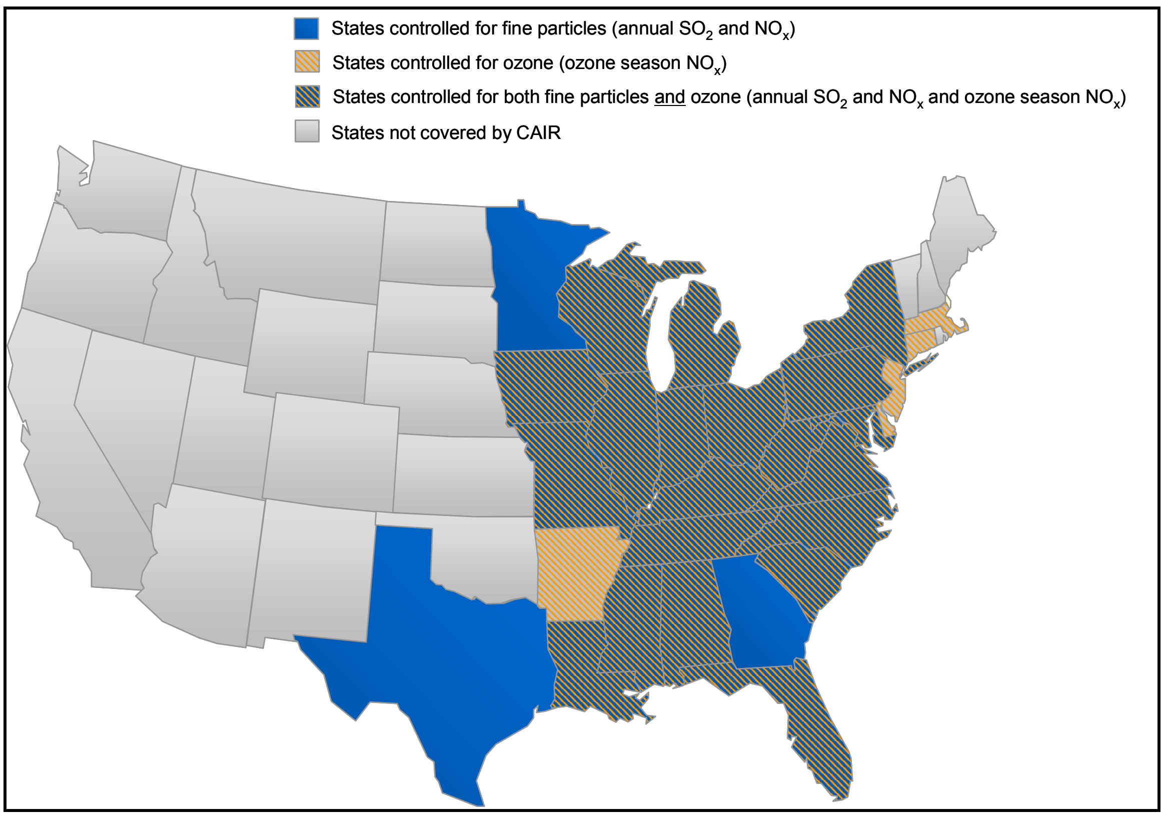
NEEM can model environmental policies affecting $SO_2$, $NO_X$, Hg, and $CO_2$. These policies can take on a number of different forms including caps, emissions prices (taxes), required emission rates, required emissions reductions (from inlet), and required technology. In addition, these policies or constraints can be applied nationally, regionally, by state, or even on particular units.

An important part of existing cap-and-trade regulations is the quantity of any banked allowances. Banked allowances are earned through early reductions below a capped level and can generally be applied in later years when a cap might be lowered. The EmissionBanking functionality includes information on beginning bank levels and allows for banking levels in any particular model year to be specified as well.

The following emissions policies are frequently included in NEEM runs: Regional Greenhouse Gas Initiative (RGGI), Title IV $SO_2$, Clean Air Interstate Rule ("CAIR") $NO_X$ Annual, and CAIR $NO_X$ Seasonal. It is likely that future rulings (such as the recently proposed Transport Rule or the forthcoming Hazardous Air Pollutant regulations) will substantially change the emission control programs for $NO_X$, $SO_2$ and Hg emissions. These programs can also be modeled. We model RGGI as a flat price of $1.86/ton of $CO_2$ (the minimum reserve price) for the entire analysis period. While the RGGI policy is not specified after 2018, we propose to retain this small carbon price within the RGGI region for the entire analysis horizon. The exception to this would be when modeling a future with a national carbon policy, in which case the RGGI policy would terminate in the year prior to the national carbon policy's implementation.

Today's CAIR caps are quite complicated in their application as depicted in Figure 4.

**Figure 4: Application of CAIR Caps**



The emissions caps for CAIR and TitleIV are specified in Table 13 below. These constraints are inputs to the model and can be changed as desired. In the CAIR region, the trade-in ratio for $SO_2$ allowances is 2.00 in 2010 and 2.86 in 2015.

**Table 13: Emission Caps for CAIR and Title IV**

| Emission Constraint | Pollutant | Year | Cap | Units |
|---|---|---|---|---|
| CAIR $NO_x$ Seasonal | $NO_x$ | 2009 | 0.57 | MM Short tons |
| CAIR $NO_x$ Seasonal | $NO_x$ | 2015 | 0.48 | MM Short tons |
| TitleIV $SO_2$ | $SO_2$ | 2010 | 8.95 | MM Short tons |
| CAIR $NO_x$ Annual | $NO_x$ | 2010 | 1.52 | MM Short tons |
| CAIR $NO_x$ Annual | $NO_x$ | 2015 | 1.27 | MM Short tons |

In addition to modeling cap-and-trade programs and emission taxes, NEEM can also model command-and-control programs. Units can be forced to either install certain retrofits or retire in a given year.

The $NO_x$ emissions from existing coal units come from EPA CEMS data. $SO_2$ and Hg emissions from coal units are a function of the pollutant content in the coal burned and the pollution control efficiency of the particular generation unit. The same is true for $CO_2$ emissions except that the $CO_2$ content of coals is relatively invariant and pollution control retrofits are not currently available (but could be in the future).

CRA assumes NOx emissions from new combined-cycles to be the same as those from existing units, 0.02 lbs/MMBtu. For new combustion turbines, CRA assumes NOx emissions to be 0.08 lbs/MMBtu. We assume that gas units do not emit any sulfur dioxide. For new coal units, NOx emissions are assumed to be 0.06 lbs/MMBtu for pulverized coal and 0.07 lbs/MMBtu for IGCC. With respect to $CO_2$ emissions, coal units emit 207.9 lbs/MMBtu and gas units emit 116.7 lbs/MMBtu.

EPA's proposed Transport Rule can also be modeled. *However, we note that the Transport Rule could be largely irrelevant if the utility MACT[15] is modeled (because the requirements for MACT may render the Transport Rule as a non-binding policy). Therefore, stakeholders may decide not to model the Transport Rule..*

The proposed Transport Rule establishes $SO_2$ and $NO_x$ caps for the states subject to the rule. The caps are specified at the state level for 31 eastern states and the District of Columbia. $NO_x$ emissions are capped both annually and during the ozone season.[16] The caps would supplant the CAIR policy starting in 2012. EPA outlines three potential approaches in the proposed Transport Rule. According to EPA's preferred approach, trading would be allowed across states in 2012 but only limited interstate trading would be allowed in 2014 and later. The $SO_2$ policy

[15] Maximum Achievable Control Technology (MACT) for Hazardous Air Pollutant (HAP) control under the Clean Air Act Amendments of 1990.

[16] While the NOx caps are relatively weak, EPA has indicated that a second proposed Transport Rule is forthcoming that could more stringently address NOx emissions.

establishes Group 1 and Group 2 caps - the Group 1 cap tightens in 2014 whereas the Group 2 cap does not tighten. CRA would use the following simplified approach to model the complex nature of the Transport Rule:[17]

1. For practical reasons (model size and run time), we would not model every state-level cap individually. Instead, we would judiciously group states in a manner that roughly aligns to NEEM regions. In some cases, we would have to sub-divide aggregate units that cross state lines. We would expect to implement between 6 and 15 caps for each policy ($SO_2$, $NO_x$ annual, and $NO_x$ seasonal). These caps would simulate the state-level caps that are specified in the proposed Transport Rule (with somewhat less spatial resolution).
2. The group-level caps for $SO_2$ and the region-wide caps for $NO_x$ would be numerically equal to the sum of the affected states' caps. These would be umbrella caps placed over smaller caps that are used to simulate the state-level caps, as discussed in #1. Therefore, the Transport Rule's caps would be met strictly at the group and region-wide levels.
3. In order to simulate limited interstate trading, we would apply the "variability limits" specified in the proposed Transport Rule. Thus, the caps that are used to simulate the state-level caps (#1 above) would be inflated by the variability limits specified in the proposed Transport Rule (e.g., 6%).
4. We would not allow banking; therefore, the variability limits would only be simulating the provisions for limited inter-state trading.

Since the utility MACT rule is forthcoming as required by an EPA consent decree,[18] the utility MACT rule might be an important part of the BAU future. As mentioned above, depending on the requirements of the forthcoming utility MACT rule, the proposed Transport Rule may become largely irrelevant due to MACT. One approach to modeling the utility MACT rule in combination with future NOx policy would be:

1. All U.S. coal units must have scrubbers by 2015.
2. All U.S. coal units must have sorbent injection and fabric filters by 2015 (HAPs control).
3. Do not model any $SO_2$ caps because the mandated scrubbers would more than adequately meet Transport Rule requirements.
4. For $NO_x$ policy, simply model CAIR $NO_x$ annual and CAIR $NO_x$ seasonal caps. Since the second Transport Rule has not been proposed, CAIR $NO_x$ might be a sufficient representation of future NOx policy. In part because the MACT policy could lead to coal plant closures, $NO_x$ prices are likely not highly significant to the evaluation of the BAU Future.

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[17] Federal Register, 75 FR 45210-45258 (August 2, 2010).

[18] *American Nurses Association vs. Lisa Jackson, US EPA*, Consent Decree, April 15, 2010.

## 3.8. Cooling Water Intake and Coal Ash Regulations

We propose to model the capital cost and energy/capacity penalties associated with forthcoming EPA cooling water intake regulations in accordance with Appendix II of NERC's recent report entitled *2010 Special Reliability Assessment: Resource Adequacy Impacts of Potential U.S. Environmental Regulations*. We propose to model the implementation date as January 1, 2017.

We propose to ignore the impact of potential coal ash regulations, as the above-referenced NERC report indicates that these regulations likely will not have a profound effect on coal unit retirements.

## 3.9. Renewable Portfolio Standards

The NEEM model includes renewable portfolio standards ("RPS") in those states that have passed such requirements. Sometimes these standards are referred to as renewable electricity standards ("RES"). A US-wide RPS can be included in the model, if desired. State RPS are included and adjusted to net out qualifying hydro resources and load that excluded from the policies. State RPS' are then aggregated into groups that correspond with NEEM regions; combined RPS requirements are then modeled as a function of the underlying NEEM regional demand and satisfied through qualified renewable resources within the region Solar carve-outs are modeled separately from general renewable requirements.

Each RPS is modeled as a minimum generation amount and can be met either through 1) generation from qualifying resources, or 2) an alternative compliance payment that is specified for each RPS. Texas and Kansas have renewable capacity requirements (as opposed to renewable generation requirements). A detailed representation of the state RPS policies included in the model are shown in Exhibit 15. We assume that in the years following the last specified date of a given RPS policy that the policy will continue at the same percentage as required in the last year of the policy.

NEEM also contains intermittent generation limits, which limit the amount of intermittent generation that can occur within a given NEEM region (or multiple NEEM regions) relative to the annual load of the region (or the same multiple set of regions). CRA typically assumes that intermittent generation cannot exceed 20% of each region's annual load. This assumption can be changed, if desired. CRA proposes the intermittent generation limits shown in Table 14, which would apply to the sum of wind and solar generation on an annual, MWh basis.

**Table 14. Intermittent Generation Limits (annual MWh basis)**

| Intermittency Region | NEEM Regions | Proposed Limit |
|---|---|---|
| SPP | SPP-S, SPP-N, NE | 20% |
| PJM | PJM_E, PJM_SW, PJM_W, PJM_D, AE, NI, PJM_Midwest | 20% |
| MAPP_CA | MAPP_CA | 20% |
| MAPP_US | MAPP_US | 20% |
| Rest of MISO | EMO, SCIL, MISO_E, WUMS, MI | 20% |
| Non-RTO Midwest | Non-RTO Midwest | 20% |
| New York | NYISO_upstate, NYISO_downstate, NYISO_capitol, NYISO_NYC, NYISO_LIPA | 20% |
| NEISO | NEISO | 20% |
| ENT | ENT | 20% |
| TVA | TVA | 20% |
| VACAR | VACAR | 20% |
| SOCO | SOCO | 20% |
| FRCC | FRCC | 20% |

## 3.10. Fuel Prices

The NEEM data file includes detailed inputs on natural gas, oil, and other (non-coal) fuel prices. Natural gas prices are provided on a seasonal basis for each year for each natural gas-fired unit in the model. There are three seasonal prices - summer, winter, and shoulder - that correspond with the three demand seasons. The natural gas prices are typically based on a combination of NYMEX Henry Hub futures and AEO 2011 (early release) forecasting; futures are typically used through 2012 and blended into AEO 2011 (early release) by 2015. The prices are then converted into regional delivered prices based on historical regressions of basis differentials. All prices are reported in $/MMBtu. Between 2035 and 2050, gas prices are increased at the same rate of increase for the 2030-2035 period.

Assumed natural gas prices at Henry Hub can be found in Appendix A, Exhibit 16. Exhibit 17 provides mapping of NEEM regions to pipeline pricing points.

Distillate oil prices are calculated in a similar manner to the natural gas prices. They are primarily based upon NYMEX Light Sweet Crude Futures and EIA's Annual Energy Outlook 2011 (early release) projections of the world oil price. Oil prices in NEEM are only included as annual prices. These prices are also reported in $/MMBtu.

NEEM also includes fuel prices for nuclear fuel and biomass. The (non-coal) fuel prices in NEEM are used differently than many of the other inputs. Because NEEM does not typically model every year, most inputs used by NEEM are based on the model years (*e.g.*, if NEEM models 2010 and 2015 then it will use inputs for 2010 and 2015). However, fuel inputs used by NEEM will be an average of the fuel inputs of the represented model years (*e.g.*, if NEEM models 2010 and 2015, the 2010 model year would represent the years 2010 through 2014).

## 3.11. Transmission

NEEM's regions have been created to address primary transmission limitations and constraints. Within a NEEM region there are no transmission limitations. Inter-regional transmission limitations will be represented based on input from EIPC planning engineers. Limits are represented in both directions (*e.g.*, from Region A to Region B and from Region B to Region A). Dummy regions are included to model joint transmission constraints into and out of a region or group of regions (dummy regions contain no load or resources). NEEM has the flexibility to allow for changes in transmission capacity over time. This is done as an input rather than through any model calculations.

## 3.12. Wheeling Charges and Hurdle Rates

Seams charges are applied by CRA in the NEEM model at the "seam" or border between regions. In the absence of seams charges, NEEM will optimize the dispatch of generation across the entire modeled footprint as if it were one balancing authority with traders and operators having perfect information about all load, resources and transmission congestion, and with no transmission wheeling charges payable for regional imports and exports.

In practice, there are impediments to trade that take place on a real-time basis, including wheeling charges and imperfect knowledge regarding flows outside of the control area. For example, trade with a neighboring region is often scheduled in blocks (e.g., eight peak hours) and the price observed by traders can change by the time that transmission service is arranged. In contrast, inside of a Day 2 RTO market, generator bids are accepted in real-time relative to the actual real-time hourly price. During prior Cost Benefit Analysis studies, CRA worked with trading analysts who estimated for CRA the price differential needed across borders before they would actively pursue trades. The cross-seam price differential needed ranged from $3 to $5 per MWh plus the applicable wheeling charge, depending on the nature of the market. An organized Day 2 market was perceived to have lower cross-seam trading friction than a traditional bi-lateral market given the improved transparency that such a market provides, the economic-based congestion management, and the existence of cross-seam agreements. In addition to these cross-seam trading friction hurdles, wheeling charges are assessed using the mid-point of each region's non-firm peak and off-peak point-to-point rate for "out" transactions. Seams charges are set to zero between NEEM regions within a contiguous market (e.g., PJM).

Transmission costs applicable between NEEM regions, including wheeling cost and trading friction, are summarized in Exhibit 18. For simplicity, Exhibit 18 does not include interfaces that involve "dummy" regions used to model joint transfer constraints – CRA will assure that the interfaces that involve dummy regions have analogously assigned transmission costs.

## 3.13. Reserve Margin

There are two NEEM worksheets related to reserve margins. The first is the ReserveMargin worksheet. Each of the 39 NEEM regions is included in a reserve margin region. Some reserve margin regions include multiple NEEM regions, while others include only a single NEEM region. Each reserve margin region then has a specified reserve requirement that must be met (or exceeded) in each model year (see Table 15). The reserve requirement is calculated based off of the peak demand in each region in each year in the MaxDemand_Pool worksheet.

The other worksheet related to reserve margins is the ReserveDerate worksheet. Resources such as wind and solar generators are not dispatchable and therefore their full capacity cannot be counted toward the reserve requirement. For each of these existing and potential units the user specified a derate such that the capacity that counts towards the reserve requirement is the unit's capacity multiplied by the specified derate (see Table 5 above).

MRN-NEEM targets the builds to meet the reserve margin requirement in the model year (e.g., 2015, 2020, etc.). The capital costs that need to be expended to meet reserve margin in a given model year (e.g., for a new combustion turbine) correspond to the same year's capital cost inputs for the technologies being built.

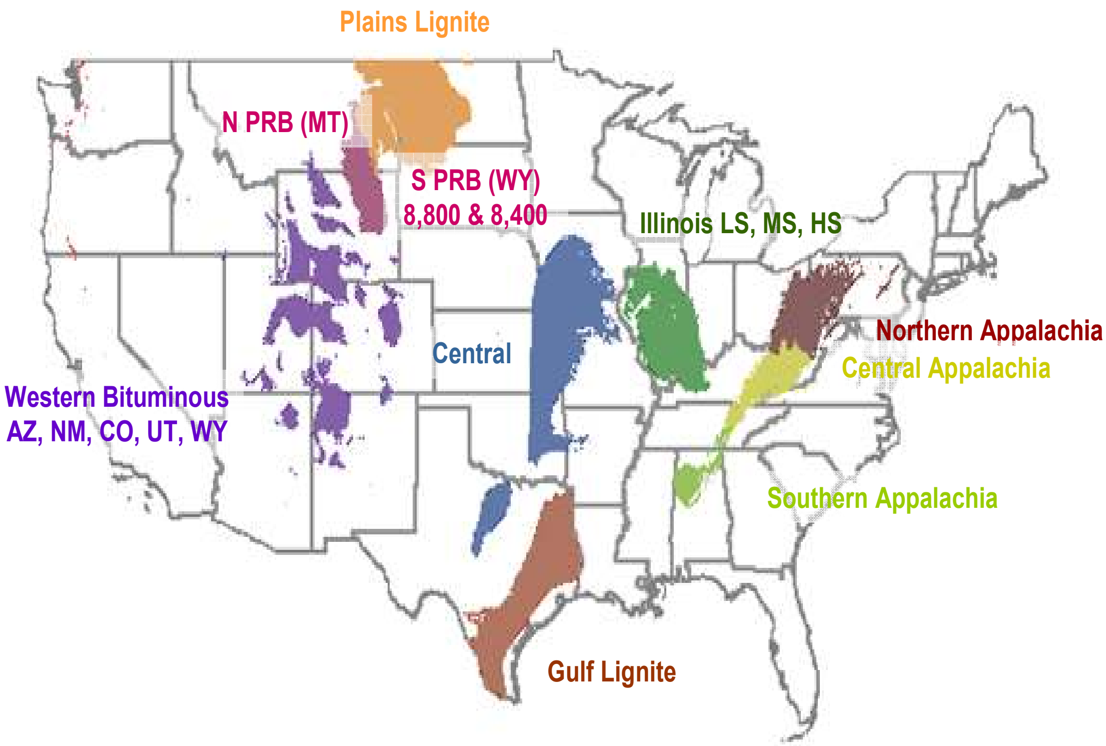
**Table 15. Reserve Margin Regions and Requirements**

| Reserve Margin | Reserve Requirement | NEEM Region(s) |
|---|---|---|
| | | |
| ALB | 18.0% | ALB |
| AZ_NM_SNV | 15.7% | AZ_NM_SNV |
| BC | 18.0% | BC |
| CA | 16.6% | NP15 |
| | | SP15 |
| ENT | 14.0% | ENT |
| ERCOT | NA | ERCOT |
| FRCC | 16.0% | FRCC |
| HQ | 15.0% | HQ |
| MI | 15.0% | MI |
| MISO | 15.4% | EMO |
| | | MAPP_US |
| | | MI |
| | | MISO_E |
| | | SCIL |
| | | WUMS |
| NEISO | 16.0% | NEISO |
| NonRTO_Midwest | 14.0% | NonRTO_Midwest |
| NWPP | 18.0% | NWPP |
| NYISO | 16.5% | NYISO_Capital |
| | | NYISO_Downstate |
| | | NYISO_LIPA |
| | | NYISO_NYC |
| | | NYISO_Upstate |
| NYISO_LIPA | -2.5% | NYISO_LIPA |
| NYISO_NYC | -18.0% | NYISO_NYC |
| OH | 14.0% | OH |
| PJM | 15.3% | AE |
| | | NI |
| | | PJM |
| | | PJM_D |
| | | PJM_E |
| | | PJM_Midwest |
| | | PJM_SW |
| | | PJM_W |
| PJM_E | -2.2% | PJM_E |
| PJM_MAAC | 14.1% | PJM_E |
| | | PJM_SW |
| | | PJM_W |
| PJM_SW | -27.4% | PJM_SW |
| RMPA | 14.0% | RMPA |
| SOCO | 14.0% | SOCO |
| SPP | 13.6% | NE |
| | | SPP_N |
| | | SPP_S |
| TVA | 14.0% | TVA |
| VACAR | 14.0% | VACAR |

## 3.14. Coal Market Data

The coal market data include coal characteristics for 21 different coals, including coal supply curves and delivery costs to each existing and potential coal plant in the NEEM data set. The 21 coals were selected to represent the coal sub markets and production regions in the United States. The major production regions are shown in Figure 5.

**Figure 5: NEEM Coal Production Regions**




### 3.14.1. Coal Supply Information

The mine-mouth coal supply curves are based on a model of projected production capabilities and production costs at mines throughout the United States. Coal transport costs are input for each coal type and coal plant (in many cases, certain coals are not deliverable to certain plants). There are also lifetime limits for each type of coal, a dynamic constraint that is reflected in the delivered coal prices. Fixed equilibrium mine-mouth coal prices can be input to the model, if desirable. Indicative minemouth coal prices in 2012 (under the proposed EPA Transport Rule) are shown in Table 16.

**Table 16. Indicative Minemouth Coal Prices in 2012 under EPA Transport Rule**

| | 2012 Minemouth Price, 2010$/MMBtu | MMBtu per Ton | 2012 Minemouth Price, 2010$ per Ton |
|---|---|---|---|
| Central Appalachian Compliance | $2.29 | 25.0 | $57.30 |
| Illinois Basin, medium-sulfur | $1.77 | 23.0 | $40.69 |
| Northern Appalachian, high-Btu, high-sulfur | $2.01 | 25.9 | $51.91 |
| Power River Basin South | $0.69 | 17.6 | $12.12 |

### 3.14.2. Coal Quality

The characteristics of the different coals are summarized in Table 17. Characteristics of each coal used by the NEEM model are: rank of coal, $SO_2$ content (lbs/MMBtu), mercury content (lbs/TBtu), $CO_2$ content (lbs/MMBtu), and calorific content in Btu per pound of coal. There are four different ranks of coal within the NEEM coal file. These are bituminous, western bituminous ("WesternBit"), subbituminous, and lignite. These different classifications are required because of the different impacts different fuels have when they are burned.

The $SO_2$ content, Hg content, and heat content are based on information from Hellerworx. The $CO_2$ content of coals does not vary significantly, as such all coals in the model have the same $CO_2$ content, 207.9 lbs/MMBtu.

**Table 17: Coal Characteristics**

| Coal Name | Rank | SO2 | Hg | Btu/lb | MMBtu/Ton |
|---|---|---|---|---|---|
| Northern Appalachia High Btu Low Sulfur | Bituminous | 2.44 | 12.30 | 12,840 | 26 |
| Northern Appalachia High Btu High Sulfur | Bituminous | 4.07 | 12.50 | 12,938 | 26 |
| Northern Appalachia Low Btu Low Sulfur | Bituminous | 1.76 | 16.00 | 12,098 | 24 |
| Northern Appalachia Low Btu High Sulfur | Bituminous | 3.77 | 20.90 | 11,516 | 23 |
| Central Appalachia Compliance | Bituminous | 1.12 | 5.90 | 12,507 | 25 |
| Central Appalachia Hi Hg Btu Non-Compliance | Bituminous | 2.00 | 8.20 | 12,325 | 25 |
| Southern Appalachia | Bituminous | 2.52 | 8.70 | 11,747 | 23 |
| Illinois Basin Hi Sulphur | Bituminous | 2.50 | 4.50 | 12,091 | 24 |
| Illinois Basin Hi Sulphur | Bituminous | 3.50 | 6.50 | 11,502 | 23 |
| Illinois Basin Hi Sulphur | Bituminous | 5.00 | 6.30 | 11,665 | 23 |

| Coal Name | Rank | SO2 | Hg | Btu/lb | MMBtu/Ton |
|---|---|---|---|---|---|
| Central Basin | Bituminous | 4.92 | 12.70 | 12,174 | 24 |
| Gulf Lignite | Lignite | 3.37 | 10.80 | 6,840 | 14 |
| Lignite | Lignite | 2.30 | 10.80 | 6,585 | 13 |
| Montana Powder River Basin | Subbituminous | 1.18 | 5.20 | 9,052 | 18 |
| Northern (WY) Powder River Basin | Subbituminous | 0.83 | 7.10 | 8,400 | 17 |
| Southern (WY) Powder River Basin | Subbituminous | 0.71 | 5.80 | 8,800 | 18 |
| Wyoming - Other | Subbituminous | 1.14 | 3.70 | 9,185 | 18 |
| Rocky Mountain Colorado | WesternBit | 0.98 | 3.70 | 11,218 | 22 |
| Rocky Mountain Utah | WesternBit | 1.28 | 4.10 | 11,790 | 24 |
| Arizona Bituminous | Bituminous | 0.93 | 4.20 | 10,915 | 22 |
| New Mexico Bituminous | Bituminous | 1.55 | 4.20 | 9,393 | 19 |
| Import | Bituminous | 1.00 | 5.50 | 12,000 | 24 |

## 3.15. Modeling of Canada in NEEM

### 3.15.1. MAPP-CA and OH (Ontario, IESO)

Demand and peak demand in MAPP-CA and Ontario are shown in Table 18. For Ontario, we are using the IESO Ontario Reliability Outlook, 2009. For MAPP-CA, we are using the Mid-Continent Area Power Pool Load and Capability Report (May 1, 2009) and the SaskPower 2009 Mid-Application Update (March 26, 2009).

**Table 18. Energy Demand and Peak Demand for MAPP-CA and Ontario**

| | 2011 Energy (GWh) | 2011-2020 Growth Rate | 2020-2050 Growth Rate |
|---|---|---|---|
| **MAPP-CA** | 48,057 | 2.00% | TBD |
| **OH (IESO)** | 142,312 | -0.29% | TBD |
| | **2011 Peak (MW)** | | |
| **MAPP-CA** | 8,007 | 1.67% | TBD |
| **OH (IESO)** | 23,625 | -0.29% | TBD |

The Ontario and MAPP_CA units are shown in Exhibit 6.

Wind resource potential, wind shape and capacity factor, and wind capital/operating costs need to be determined in conjunction with stakeholder input for the MAPP-CA.  Similarly, for Ontario, the wind resource potential and capital/operating costs are being developed in conjunction with stakeholders..

### 3.15.2. Maritimes and Quebec modeling

The Maritimes and Quebec will be modeled as a fixed interchange with the surrounding NEEM regions.  Imports and exports, based on historical data, will be represented and apportioned into representative load blocks.   The interchange data to use is being developed in conjunction with stakeholders.

# 4. MULTI-REGION NATIONAL MODEL (MRN)

## 4.1. OVERVIEW OF MRN AS A STAND-ALONE MODEL

MRN is a top-down, computable general equilibrium (CGE) model of region-specific impacts and regional interaction in the U.S. economy. The CGE tracks every dollar that is spent through the economy to reduce carbon emissions, accounting for the economic gains in those sectors that provide the goods and services that result in emissions reductions, as well as the economic costs to those who incur these added expenditures. In addition, the negative impacts associated with declining demand under higher, policy-induced prices are captured. The model can also account for any changes in the distribution of wealth that result from the combined impact of emissions control spending and the disposition of the wealth associated with newly created allowances (in a cap-and-trade case). The results of a model run like this reflect the net impact to the U.S. economy after all the impacts on the winners and losers under a proposed policy have been estimated.

The model also assumes that implementation of a policy such as a carbon emissions cap will occur in a least-cost fashion with fully-functional, competitive product and allowance markets. The only limits imposed on the efficiency of a cap-and-trade market are those that are directly specified in a policy or Bill, such as when some sectors are not covered by the proposed cap scheme (even if placed in the offsets category). Leakage of some economic activities outside of the U.S. is also estimated for sectors that face competitors in other countries that do not have their own emissions caps (or have weaker caps).

The model works with perfect foresight of future prices and policy requirements. This means that the model does not include any costs due to uncertainty and "surprises" that will probably also be associated with compliance with a new policy. It also captures only a long-run equilibrium in all of the markets, and thus does not include any of the costs of an overly rapid shift in markets due to imposition of a new policy.

The CGE model solves for production levels, trade, relative prices, income, and consumption by accounting for technological as well as behavioral responses to changes in policy. The equilibrium is fully dynamic, meaning that investment decisions determine the future capital stock, which in turn determines future income and consumption. Furthermore, decisions to consume or invest are taken with correct expectations about future policy and opportunities (i.e., perfect foresight). Investment today requires foregoing consumption of current income. Consumer decisions maximize utility inter-temporally, which implies that an optimal financial trade-off is made between consumption today and consumption in the future.

Many of the impacts of policies to reduce carbon emissions indirectly increase the cost of production and consumption, and this has effects on the demand for all commodities. For example, a limit on the quantity of allowable emissions from electric utilities will result in higher electricity prices. Higher electricity prices will then raise production costs throughout the economy, but especially in sectors that use electricity-intensive production processes. As all sectors adjust their production processes to be optimized under post-policy prices, there are changes in demand for labor, materials and commodities, capital, and different types of fuels and primary energy sources.

## 4.2. Basics of General Equilibrium Models

The top-down sub-model of the integrated MRN-NEEM model is tailored from CRA International's Multi-Region National (MRN) model. MRN is a forward-looking dynamic computable general equilibrium model of the United States. It is based on the theoretical concept of an Arrow–Debreu equilibrium in which macro-level outcomes are driven by the decisions of self-interested consumers and producers as they are in the real economy. The basic structure of CGE models, such as MRN, is built around a circular flow of goods/services and payments between households, firms, and the government, as depicted in Figure 6. Consumers are represented by a single household sector in each region that maximizes utility subject to endowments of primary factors and all production sectors are assumed to be competitive with underlying technology exhibiting constant returns to scale. Households own and supply the factors of production (capital and labor) to firms that transform these factors into goods or services. Households receive payment from the firms for supplying factors of production (capital income and labor wages). Firms in the model maximize profit subject to technology constraints to determine the level of optimal production. Firms utilize the factors supplied by households and use intermediate inputs produced by other firms. Households consume goods and services using the wage (and capital) income from firms, while the firms receive payment for goods and services that are supplied to the market. Under the circular flow concept, there is a balance of goods, services, and payments across the economy.

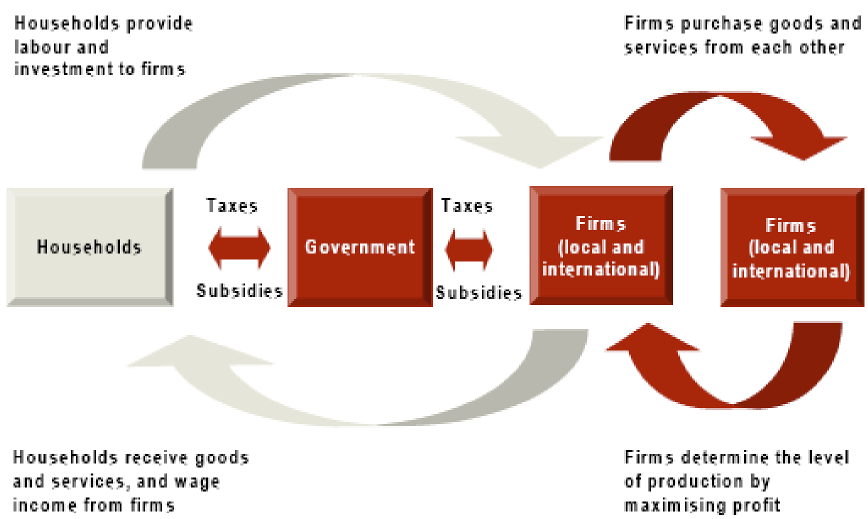



**Figure 6. Circular Flow of Goods and Services and Payment**

## 4.3. THE MRN PORTION OF MRN-NEEM IS A GENERAL EQUILIBRIUM MODEL

The theoretical basis for the version of MRN used in the integrated MRN-NEEM model is the same as that of the stand-alone MRN.[19] The only difference between the stand-alone MRN and the MRN sub-model of MRN-NEEM is the treatment of the sectors represented in the NEEM model. Since the NEEM model accounts for electricity and coal production in detail, MRN does not explicitly model these sectors. Thus, there are nine production sectors in MRN-NEEM rather than the eleven production sectors shown in Table 20. Individual states are rolled up to create the nine MRN regions (see Figure 7 for an illustrative map). The model assumes a single representative household for each region, a federal government, and the production sectors.[20] The production sectors in the model are disaggregated as listed in Table 19.[21]

**Table 19. MRN Model's Sectors in MRN-NEEM Integrated Model**

| Energy Sectors | Non-Energy Sectors |
|---|---|
| Oil and gas extraction | Agriculture |
| Oil refining/distribution | Energy-intensive sectors |
| Gas distribution | Manufacturing |
| * | Transportation services |
| * | Services |
| | Motor Vehicles |

* In the integrated MRN-NEEM model, the coal and electricity sectors are modeled using NEEM. Thus, these two sectors are shown as being part of MRN here.

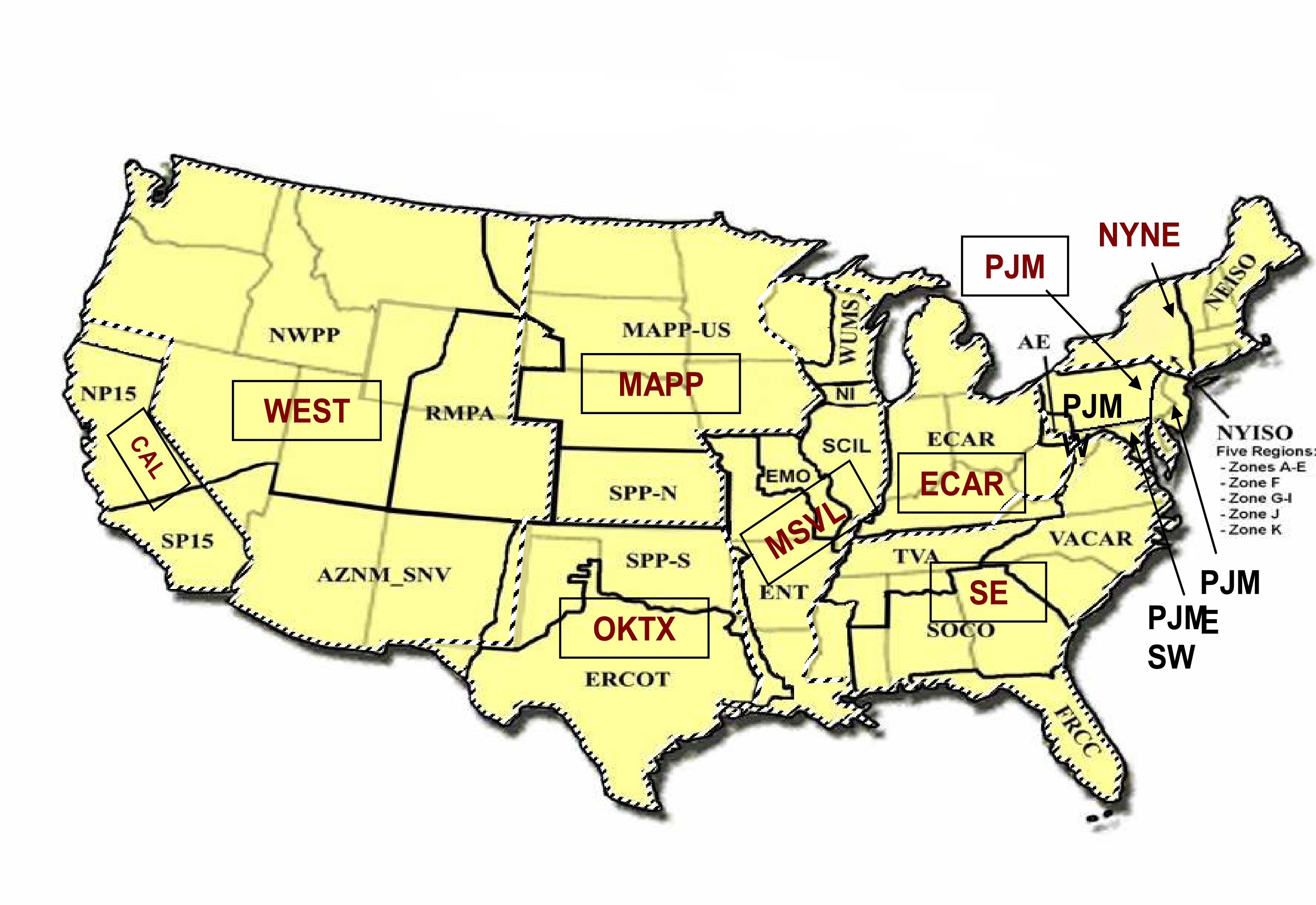
Consumers are represented as a single representative household that maximizes lifetime utility subject to its lifetime budget constraint. Utility in a given time period is measured by the consumption of goods. The budget constraint equates the present value of consumption gross of tax to the present value of income earned in the labor market and the value of the initial capital stock minus the value of post-terminal capital. In other words, consumers cannot consume more than the present value of their income and capital wealth. They typically will consume less than the present value of their income and capital wealth (in any year) in order to maximize utility over

[19] The standalone MRN model is a self-contained model that represents all sectors of the economy.

[20] The Regional and Federal government budgets are balanced over the model's analysis period. This is true for both the BAU case and the policy scenario(s). Any deficits incurred in a particular year need not be the same between the BAU case and the scenario, as long as each is balanced over entire analysis period.

[21] Note that electricity generation and coal production are modeled in the bottom-up model (NEEM) in the integrated model.

Figure 7.  Illustrative Example of How MRN Regions Map to NEEM Regions (NEEM regions shown differ from those likely used for EIPC)



many years.  Households optimally distribute wealth over the model horizon by choosing how much output in a given period to consume and how much to forgo for future investment.

Two primary factors of production are supplied by the household sector: labor, which grows exogenously and is therefore an input to the model, and capital.  In the model, depreciation of the capital stock depends on maintenance expenditures and vintage of the capital stock.  The depreciation rate in the model is not assumed to be fixed.  It is (endogenously) determined within the model and has an iso-elastic relation with maintenance expenditure and capital stock.  This captures the notion that the capital stock (equipment and machinery) is maintained and repaired during its life and its level of use will determine how much maintenance occurs.  This subtle notion is generally ignored in other models.  The dynamics in the model are partially controlled by implementing an adjustment cost in the capital stock.

As with the consumer behavior, the federal government also maximizes its model-horizon utility subject to a model-horizon budget constraint.  The government collects tax revenues at an average tax rate, purchases goods and services, and transfers income to the representative households in the model.  The government maintains a balanced budget over the model horizon meaning that there is no change in the net foreign indebtedness over the time horizon of the model.

Firms in the model use capital, labor, energy, and material inputs to produce goods.  Production of one good may require more of one input than the production of another good.  For example, production of energy-intensive goods (e.g., aluminum) requires more energy inputs relative to the production of service goods.  Moreover, embedded production is such that inputs are easily substituted in some cases but not in others.

The MRN model captures the substitutability of inputs for various sectors and technologies by employing a nested constant elasticity of substitution (CES) structure.  In the MRN CES process, inputs are mixed at different tiers of the production tree to form composite goods – not unlike a cooking recipe.  At the bottom of the production structure, coal and gas inputs are combined to form a coal-gas composite input which substitutes against electricity input.  An energy composite of coal-gas-electricity is then combined with a capital-labor composite (value-added composite) input to form an aggregate energy-value-added composite.  This composite is then combined with the rest-of-the-other-goods composite to produce a final commodity.  The substitutability between inputs depends upon the assumed value of the elasticity of substitution and the initial share of the inputs.  The higher the value of the elasticity of substitution, the easier it is to switch between inputs.

MRN is a national model and hence does not explicitly model other regions of the world.  However, international trade is important in the real economy, so MRN roughly interacts with the rest of the world through simulated trade.  International trade takes place in all goods except for crude oil.  Crude oil in the model is treated as a homogenous good and is perfectly substitutable across all regions.  All other goods are differentiated by their origin.  That is, domestic and imported like-products are treated as imperfect substitutes.  This is the classical Armington assumption (Armington, 1969) referred to in trade economics.  Imported goods and domestically produced goods are mixed to form an Armington aggregate good that is supplied to the domestic market for consumption and use in production.  The value of the elasticity of substitution between the imported and domestic product influences the extent to which imported products can be substituted for domestic ones.

MIT's EPPA model[22] also adopts the Armington convention that is widely used in modeling international trade.

> "..domestically produced good is treated as a different commodity from an imported good produced by the same industry. Thus, for example, imported energy-intensive goods are not perfect substitutes for domestically produced energy intensive goods."

The EPPA model Armington trade elasticities assumptions between domestic versus imported goods and between different origin imported goods are shown below.

***Armington Trade Elasticities***

| | | | |
|---|---|---|---|
| $\sigma_{DM}$ | Domestic-Imports | 2.0 – 3.0 | Varies by good |
| | | 0.3 | Electricity |
| $\sigma_{MM}$ | Among Imports from different regions | 5.0 | Non-Energy goods |
| | | 4.0 | Gas, Coal |
| | | 6.0 | ROIL |
| | | 0.5 | Electricity |

The ADAGE model,[23] an MRN-like model used by EPA to analyze US energy policies, also adopts similar Armington trade structure.

"..goods and services are assumed to be composite, differentiated "Armington" goods (Armington, 1969) made up of locally manufactured commodities and imported goods. Within this basic framework in ADAGE, some differences across modules exist to accommodate the fact that goods produced in different regions within the United States are more similar than goods produced in different nations. In the *US Regional* module, output of local industries is combined with goods from other regions in the United States using the trade elasticity *smm*. The high values for this elasticity indicates agents make relatively little distinction between output from firms located within their region and output from firms in other regions of the United States (i.e., they are close substitutes). This module then aggregates domestic goods with imports from foreign sources using lower trade elasticities (*sdm*) to capture the fact that foreign imports are more differentiated from domestic output."

The Armington trade elasticities represented in the ADAGE model are shown below (excerpted from Ross, 2008, Figure 2.2).

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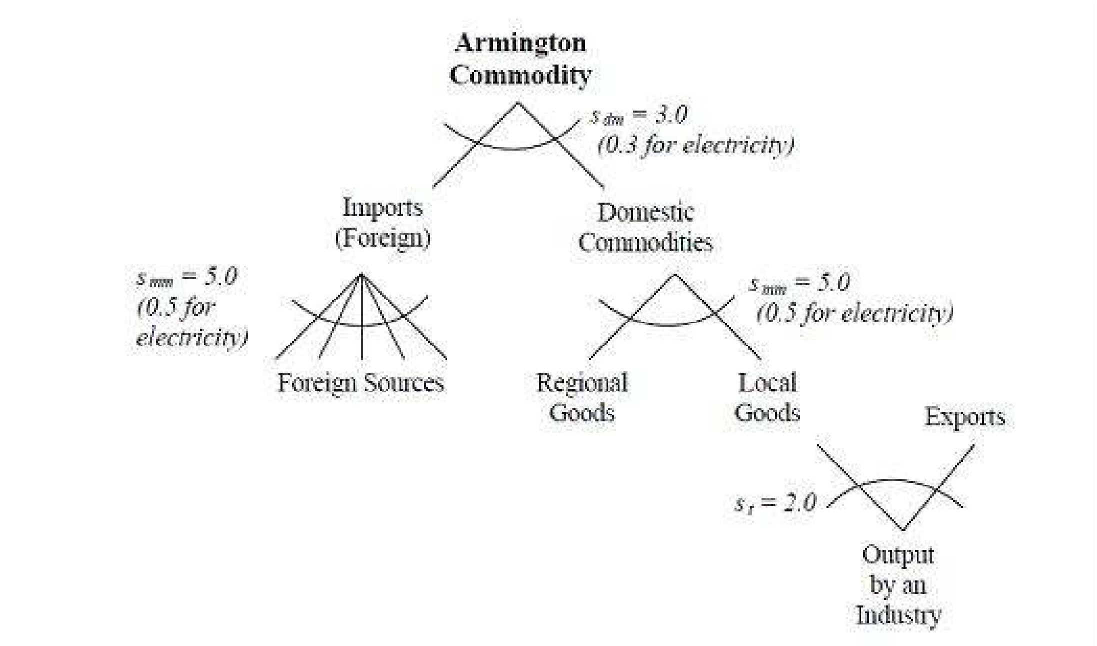
22 Paltsev, S., J.M. Reilly, H.D. Jacoby, R.S. Eckaus, J. McFarland, M. Sarofim, M. Asadoorian and M. Babiker, 2005: The MIT Emissions Prediction and Policy Analysis (EPPA) Mode Version 4, MIT Joint Program on the Science and Policy of Global Change, *Report* Cambridge, Massachusetts.
See page 7, http://globalchange.mit.edu/files/document/MITJPSPGC_Rpt125.pdf

23 Ross, M. 2008. "Documentation of the Applied Dynamic Analysis of the Global Economy (ADAGE) Model." RTI International working paper.
See page 13, http://www.rti.org/pubs/ema-model-doc_ross_apr08.pdf




The MRN model is formulated as a mixed complementary problem (MCP) using the Mathematical Programming Subsystem for General Equilibrium (MPSGE) software (Rutherford 1995) and solved using the PATH solver within the Generalized Algebraic Modeling System (GAMS) (Brooke, Kendrick, Meeraus, and Raman, 2003). The model is calibrated to the MRN dataset and is solved in five-year intervals to 2050, with 2010 as the first year with calculated model results.

## 4.4. Modeling Carbon Abatement Policy Instruments in MRN

Fossil fuels are consumed by all sectors in the economy - production, households, and government. To incorporate carbon emissions in the model, a constructed emissions permit is tracked for three fossil fuel inputs: coal, natural gas, and refined petroleum. The MRN model tracks emissions from fossil fuel use by all sectors and agents at all times in the model. Careful tracking of carbon use by fossil fuel and by sector in the model is necessary because the level of carbon emissions is used as a carbon policy instrument for abatement policies. Carbon abatement policies are represented as either a fixed cap on the amount of emissions that are permitted or a tax on emissions. The cap or tax on emissions can be applied to a particular sector or to the economy as a whole.

Along the BAU case, demand for allowances equals emissions. Since the allowances are not scarce the permit price is zero in the BAU case (by definition). Under a carbon abatement policy, however, the number of available allowances is constrained and hence creates a market for allowances. Firms that are able to hold their emissions below the allowable limits are in the position to sell their excess allowances at the market price, while those firms that (as a result of higher marginal cost of abatement) exceed their allowable emissions will have to either buy allowances from the market or switch to less carbon-intensive generation technologies, whichever is cheaper. A key outcome of trading is that carbon emissions are abated at the least cost to the economy as a whole.

A simple example illustrates this point. Assume that there are two firms (Firm-A and Firm-B) in an economy where each firm emits 100 tons of emissions. Firm-A is assumed to be equipped with an efficient technology and is able to cut emissions at (a constant) $5 per ton while Firm-B's (constant) marginal cost of reducing a ton of emissions is $10. The government asks each to reduce 10 tons of emissions so that the government achieves its target of reducing 20 tons of emissions for the economy. If these two firms decide to their cut emissions individually, then the cost to Firm-A and Firm-B would be $50 and $100 respectively, and the total cost to the economy would be $150. However, since Firm-A has a much lower marginal cost of reduction than Firm-B it would be better for Firm-A to take the burden of cutting all of the emissions and Firm-B to buy the allowances from Firm-A at any price between $5 and $10 per ton. For example, Firm-B would be better off paying Firm-A $7.50 per ton than abating at $10 per ton in this simple example, and Firm-A would profit as well. Under such a case, if Firm-A reduces its emissions by an additional 10 tons, then the cost to Firm-A is an additional $50. Firm-A then sells 10 tons of emission allowances to Firm-B at $7.50 per ton generating $75 of revenue to Firm-A. Firm-A would have been compensated for its cost of additional abatement through its permit sale to Firm-B, making a profit of $2.50 per ton or $25 in total for its additional 10 tons of abatement. Firm-B would save the difference between the $100 it would have paid in abatement costs and the $75 it paid to Firm-A instead ($25 savings). The $75 payment from Firm-B to Firm-A is a transfer, not a net cost to the economy (as previously mentioned, Firm-A incurs $50 in additional cost to abate the emissions for which Firm-B needs to purchase allowances). The net cost to the economy after trading is just $100 ($5 per ton times 20 tons of abatement by Firm-A) rather than $150 per ton ($5 per ton times 10 tons for Firm-A's abatement plus $10 per ton times 10 tons for Firm-B's abatement). Thus, the reduction of 20 tons of emissions is achieved at the least net cost to the economy, with a saving of $50 compared to the total cost that would have been incurred without trading.

## 4.5. Important Drivers of the MRN Model

General equilibrium model results, in general, are driven by the representation of taxes, elasticity assumptions, value shares of inputs, BAU energy prices, and growth rate assumptions. Correct tax representation and parametric values of elasticities are key assumptions that drive the general equilibrium results. Input value shares are based on established social accounting matrices and in general the results are robust to changes in these input value shares; therefore, input value shares are a less important driver. The MRN model incorporates detailed tax representation for the value-added components (labor and capital). The model uses marginal and average tax rates on labor and capital at the State and Federal level, which are important for public finance policy analysis in MRN. The application of tax regimes in MRN closely resembles actual tax implementation at the State and Federal levels. Carbon policy impacts depend on real-world aspects of regional economic systems and global trade that are incorporated in the benchmark data and projections used to define the BAU case, and also on key parameters that describe how supply, demand, and trade flows respond to the effects of policy changes. The key parameters that determine these impacts are end-use demand elasticities for energy and other goods, elasticities of substitution between different forms of energy, energy supply elasticities, and Armington trade elasticities.

The parametric values of the elasticity of substitution (constant elasticity of substitution and constant elasticity of transformation) are exogenously set in the MRN model (i.e., they are model inputs). These values are drawn from secondary sources, past econometric studies, or from other similar model construct such as the EPPA model from MIT. The elasticity values determine the cost of tradeoffs between inputs under a policy and hence will determine the cost of the policy. Carbon abatement policy will have a direct impact on increasing the price of carbon-intensive inputs to production and also on the prices of consumption goods and services. If the production technology is such that it allows for easy substitution away from carbon-intensive inputs then there will be less of an impact as a result of carbon abatement policy. However, for energy-intensive industries, energy composes a large share of the input to production, and hence there will be less of an opportunity to substitute away from carbon-intensive inputs (fuels). The producer will either decrease inputs of carbon-based fuel or move to lower-carbon based fuels. This will result in an increase in the cost of production (compared to BAU) but is optimized with respect to post-policy prices. The price of energy-intensive goods will rise resulting in an adverse impact on the welfare of the consumer. Hence, the cost of production or consumption of carbon-intensive goods will rise and will ultimately have an adverse impact on the economy.

If the domestically produced energy-intensive good undergoes a price change relative to the imported energy–intensive good, the terms of trade between trading partners changes. Terms of trade compare the price of a region’s exports to the price of its imports. An improvement in the terms of trade means that the prices of exports rise relative to the prices of imports, so that a region with improving terms of trade obtains a greater quantity of imports for each dollar’s worth of exports. The Armington elasticity between a domestic and imported good determines how much of an imported good can be substituted at the expense of a domestically produced good. More substitution means that domestic production decreases while the exporting region’s production increases, resulting in an increase in the exporting region’s carbon emissions. Production is shifted from one region to another and so are carbon emissions. The Armington elasticity implicitly determines the level of carbon leakage to other regions in the presence of a policy that constrains carbon emissions.

## 4.6. REPRESENTATION OF ENERGY EFFICIENCY IMPROVEMENTS

Autonomous energy efficiency improvement (AEEI) is built into the model’s BAU case, that is, the number of MWh required to produce each unit of GDP declines over time in a manner that is a plausible extension of historical trends. AEEI includes both structural changes in the economy (i.e., the shift to a more service-oriented economy) and technology changes (i.e., increased penetration of energy-efficient technologies).

Demand-side energy efficiency is captured in the parameters of the model’s production functions, including the energy sectors, the non-energy sectors, and the household sector. When electricity prices get higher (as under a carbon cap), more capital and labor (and possibly materials) are substituted for energy in the production of each unit of output. That is, production becomes less energy-intensive relative to the BAU case. An analogous shift occurs within households so that a unit of energy service (e.g., a particular number of lumens of light received, or the annual service of a refrigerator) require less energy because of the purchase and operation of more capital-intensive (but more energy-efficient) appliances. Households may also simply reduce their demand for energy services in response higher prices. Thus, household demand-response involves both increased adoption of energy-efficient technologies and behavioral changes that result in lower overall (direct) consumption of energy services. Because MRN is a general equilibrium model, final demand for products that contain embodied energy decrease (as the prices of products containing embodied energy rise under carbon cap) – this indirectly lowers energy demand in the model.

**The model's demand response implies an elasticity of about -0.2 in the short-run, but approximately -0.6 in the long-run (e.g., after 5-10 years of continuously higher energy prices). The long-run elasticity indicates more demand response than utility planners often assume, but that is precisely because this is a long-run measure – in the long-run the capital stock of the economy becomes more energy-efficient in response to higher energy prices.**

The MRN-NEEM model is not an engineering model; therefore, the model's results do not indicate specific, nameable energy-efficient technologies that were adopted more quickly under carbon policy versus the BAU case. An engineering-based model of the demand-side would identify these particular technologies because they would be completely specified as inputs. As a consequence, an engineering model would progressively step through available energy-efficient technologies (in order of increasing cost-effectiveness) as energy prices rise, potentially exhausting all such known technologies under more stringent carbon caps. Of course, a modeler using an engineering model can avoid the problem of exhausting known energy-efficient technologies by defining unknown technologies in the model that embody advanced energy-efficiency. In contrast, the MRN-NEEM model captures advanced energy-efficiency by its very nature because the possibilities for substituting capital (and labor and materials) for energy are never exhausted as energy prices rise in response to carbon policy. Again, the ease with which these substitutions occur is captured in the parameters of the model's production functions.

Since consumption of energy services and energy-containing products decline in response to carbon caps, economic welfare is reduced. The drop in welfare is somewhat offset by a shift to consumption of other goods, but the price-induced shift results in lower net welfare (as the optimal consumption bundle is altered). Similarly, welfare also is reduced because both energy and energy-containing products become more expensive under a carbon policy. In terms of net welfare, it does not matter if these increased costs are borne solely by households or if they are shared among households, appliance manufacturers, and utilities. The MRN-NEEM model does not capture the distribution of welfare impacts across these sectors.

## 4.7. MRN Data Inputs

Three components determine the baseline for the MRN-NEEM model: the dataset, the forecasts, and model assumptions. The dataset defines the economy in the benchmark year. The forecasts describe how the broad measures in the economy evolve over time such as GDP, carbon emissions, and electricity demand. But how the economy grows at the sectoral level and how electricity demand is met also depends on various model assumptions.

### 4.7.1. MRN Dataset

Data that characterize the interrelationships of commodity uses within the economy therefore are of primary importance in quantifying the impacts from alternative carbon regulations.

The starting point for constructing the baseline is the social accounting matrix, which provides a snapshot of the economy in the benchmark year 2002. The core component of the MRN dataset is based on the Social Accounting Matrix (SAM) developed by the Minnesota IMPLAN Group, Inc. (MIG) that represents the economic flows of 509 sectors of 50 states of the U.S. and the District of Columbia for the year 2002. The SAM provides data on employment, industry output, value added, institutional demand, national input-output structural matrices (use and make tables), and inter-institutional transfers. This dataset provides a snapshot of the economy for each of the U.S. states.

Conceptually, the SAM represents a “snapshot” of the economy at the current point along a dynamic growth path. MRN simulates the dynamic growth path into the future in the absence of major changes to policies that are “on the books” today. This initial growth path is known as the “business-as-usual” case, or BAU. In other words, the initial snapshot is for a single year but the BAU case is a forecast over many years. Calibration of the BAU case from the initial snapshot provided by the SAM is completed by incorporating growth forecasts for industries, population, and carbon emissions. Detailed sectoral mapping starting from the 509 IMPLAN sectors to the aggregate eleven sectors that will be used in the current study is presented in Appendix B.

Since carbon emissions are highly correlated with energy use, all the important energy sectors contained in the detailed SAM are represented as individual sectors in MRN.[24] CRA aggregates all of the remaining (non-energy) sectors in the SAM into five groups that capture the diversity in energy-intensity across all economic activities. MRN typically uses the eleven production sectors in Table 20.[25] MRN also accounts for household energy uses, as well as all the productive sectors of the economy, so that MRN can correctly account for individuals’ responses to higher fuel costs caused by carbon abatement policies.

**Table 20. Typical MRN Model's Sectors**

| Energy Sectors | Non-Energy Sectors |
|---|---|
| Gas Distribution | Agriculture |
| Oil and gas extraction | Energy-intensive sectors |
| Oil refining/distribution | Manufacturing |
| Coal extraction | Transportation services |
| Electricity generation | Services |
| | Motor Vehicles |

24 Non-CO2 greenhouse gas emissions from coal extraction and oil and gas extraction are not modeled explicitly. An (exogenous or user-defined) offset supply curve based on emissions reductions in these and other natural resource-based sectors (e.g., agriculture) is used to represent the cost of supplying offsets.

25 Coal extraction and oil and gas extraction are assumed to consume zero fossil fuels.

Note: Coal extraction and electricity generation are part of MRN if MRN is run as a stand-alone model.

MRN tracks carbon dioxide emissions (stated as metric tonnes of carbon-equivalent) from fossil fuel combustion and assumes that the costs of reducing other greenhouse gases are comparable to the cost of reducing carbon dioxide emissions. To incorporate carbon emissions in the model, an emissions permit is tracked for each of the three fossil fuel inputs (refined oil, natural gas, and coal). When there is a carbon cap, a limited, fixed number of emissions allowances is assumed available in each modeled year. If that limit is less than the BAU emissions level, a scarcity of allowances (i.e., when demand for allowances exceeds their supply) will exist. This scarcity increases the price on carbon (starting from zero) up to the point where demand for the allowances is reduced to the limit of their supply. Limiting the number of allowances available imposes an emissions constraint, and the permit price reflects the marginal cost of abatement. Instead of running a carbon policy simulation as a cap-and-trade policy (specifying the quantity of emissions), we can also specify the permit price (and not the quantity of emissions). For practical reasons, we suggest the latter approach in the EIPC context.

### 4.7.2. MRN Model Assumptions and Forecasts[26]

Key MRN Input assumptions are shown in Exhibit 19. General equilibrium model results are influenced by initial tax representation, elasticity assumptions, value shares of inputs, and baseline energy prices, and growth rate assumptions. Weyant (2000) categorizes model assumptions into five key areas that help explain model impacts and results.[27] MRN model assumptions also fall under these categories and underpin model results. The MRN model assumptions are built on published data sources. Where data are available, we describe the methodology and sources while for unavailable data we clearly document our assumptions. In the following sections, we describe the MRN model's baseline forecasts and key assumptions such as backstop technologies, tax regime, elasticity values, and implied autonomous technical progress.

#### *Default Elasticities and Tax Rates*

For each region in MRN, there is a representative consumer or agent who makes decisions consistent with utility maximization. Utility in a given time period is the Constant Elasticity of Substitution (CES) composite of consumption and leisure. The elasticity of substitution between the aggregate consumption good and leisure is determined by the leisure supply elasticity. In the MRN model, we assume a compensated labor supply elasticity of 0.25 resulting in effective elasticity of substitution between consumption and leisure of about 0.8. Over the computed finite

[26] Weyant (2000) identifies three areas of input assumptions for climate change policy analysis: (i) population and economic activity; (ii) energy resource availability and prices; and (iii) technology availability and costs.

[27] The five determinants of climate change cost estimates are "(i) projections for base case GHG emissions and climate damages; (ii) the climate policy regime considered (especially the degree of flexibility allowed in meeting the emissions constraints); (iii) the representation of substitution possibilities by producers and consumers, including how the turnover of capital equipment is handled; (iv) how the rate and processes of technological change are incorporated in the analysis ; and (v) the characterization of the benefits of GHG emissions reductions in the study, including especially how and what benefits are included." Weyant (2000).

horizon, the representative agent optimally allocates spending between consumption and leisure in each time period. The consumer's inter-temporal utility is generated combining intra-temporal utilities with an inter-temporal elasticity of 0.5. In more technical terms, household utility is defined by a constant elasticity of supply (CES) infinite sum of discounted transitory utility.

The MRN model incorporates detailed tax rates for the value added components (labor and capital). Regional marginal and average tax rates on labor and capital at the state and federal level are shown below in Table 21 and Table 22. Firms and consumers in the MRN model make investment and labor supply decisions based on the marginal tax rates, while the Government's tax revenues are computed based on the average rates. The tax regime in the model closely resembles actual tax implementation at the State and Federal level.

The tax paid by the consumer and producers are either accrued to the State government or the Federal government. In addition to capital and labor tax rates, MRN also employs federal and state level lump sum taxes which are adjusted to ensure that the governments maintain a balanced budget. The presence of an initial distortionary tax in the MRN means that its resulting solution reflects a "second best" world in which tax interaction effects are captured. "Double dividend" effects also can be calculated, if specified as part of the policy implementation. That is, we can simulate the effects of policy scenarios where revenue of permit auction revenues would be recycled to the economy by decreasing the marginal capital or labor tax rates. Similarly, we can simulate the effects of increasing marginal tax rates to offset erosion of the tax base. However, for our default values, we specify compensating lump-sum transfers that do not cause any alteration in marginal tax rates.

**Table 21. Average and Marginal State Taxes on Capital and Labor Income[28]**

| State | Average | | Marginal | |
|---|---|---|---|---|
| | Capital | Labor | Capital | Labor |
| AL | 3.3% | 3.3% | 3.8% | 3.8% |
| AR | 3.8% | 4.8% | 4.3% | 5.3% |
| AZ | 3.6% | 3.1% | 4.1% | 3.6% |
| CA | 4.6% | 5.9% | 8.1% | 7.0% |
| CO | 3.8% | 4.1% | 4.3% | 4.6% |
| CT | 3.8% | 4.5% | 4.3% | 5.0% |
| DC | 7.9% | 8.4% | 8.4% | 8.9% |
| DE | 4.8% | 4.0% | 5.3% | 4.5% |
| GA | 4.7% | 5.2% | 5.2% | 5.7% |
| HI | 4.6% | 7.3% | 7.1% | 7.3% |
| IA | 4.5% | 5.9% | 6.5% | 6.1% |
| ID | 4.4% | 5.7% | 7.1% | 7.3% |
| IL | 2.2% | 2.5% | 2.7% | 3.0% |
| IN | 2.6% | 2.9% | 3.1% | 3.4% |
| KS | 4.6% | 5.8% | 5.7% | 6.0% |
| KY | 4.8% | 4.4% | 5.3% | 4.9% |
| LA | 3.6% | 2.9% | 4.1% | 3.4% |
| MA | 4.3% | 4.7% | 4.8% | 5.2% |
| MD | 3.8% | 3.9% | 4.3% | 4.4% |
| ME | 5.3% | 7.7% | 7.7% | 7.7% |
| MI | 3.3% | 3.6% | 3.8% | 4.1% |
| MN | 4.4% | 6.7% | 7.1% | 6.9% |
| MO | 4.7% | 4.4% | 5.2% | 4.9% |
| MS | 3.9% | 4.0% | 4.4% | 4.5% |
| MT | 4.7% | 4.6% | 7.7% | 5.6% |
| NC | 4.2% | 5.8% | 7.3% | 7.2% |
| ND | 2.6% | 2.9% | 3.1% | 3.4% |
| NE | 6.2% | 5.7% | 6.7% | 6.2% |
| NJ | 4.8% | 3.4% | 5.3% | 3.9% |
| NM | 4.6% | 5.4% | 6.5% | 6.4% |
| NY | 5.6% | 6.2% | 6.1% | 6.7% |
| OH | 5.9% | 5.0% | 6.4% | 5.5% |
| OK | 4.5% | 5.0% | 5.8% | 6.2% |
| OR | 3.9% | 5.4% | 7.8% | 8.6% |
| PA | 2.1% | 2.3% | 2.6% | 2.8% |
| RI | 6.6% | 5.3% | 7.1% | 5.8% |
| SC | 3.9% | 5.6% | 3.5% | 6.6% |
| UT | 5.4% | 5.5% | 5.9% | 6.0% |
| VA | 4.7% | 5.0% | 5.2% | 5.5% |
| VT | 3.5% | 5.6% | 4.0% | 6.1% |
| WI | 4.5% | 6.2% | 5.0% | 6.7% |
| WV | 4.9% | 5.4% | 5.9% | 5.8% |

[28] States that do not impose state level taxes are not shown in the table.

**Table 22: Average and Marginal Federal Taxes on Capital and Labor Income**

| | Labor | Capital |
|---|---|---|
| Average | 18.9% | 19.1% |
| Marginal | 23.7% | 19.7% |

Substitutability of inputs in the MRN model is captured by employing a nested CES structure. The value of the elasticity of substitution determines the ease of substitution between inputs. Similarly, the value of elasticity of transformation determines switching on the output side. In the CES process, inputs are mixed at different tiers of the production tree to form composite goods. At the bottom of the production structure, coal and gas inputs are combined to form a coal-gas composite input which substitutes against electricity input according to the elasticity of substitution between the coal-gas composite and electricity (es_ele). An energy composite of coal-gas-electricity is then combined with a capital-labor composite (value-added composite) input using an elasticity of substitution (es_e) to form an aggregate energy-value-added composite. This composite is then combined with the rest-of- -goods composite (es_s) to produce a final commodity. The substitutability between inputs depends upon the assumed value of elasticity of substitution and the initial share of the inputs. The higher the value of elasticity of substitution, the easier it is to switch between inputs to make the same output. Producers also have the choice to supply to the domestic or the export markets. The elasticity of transformation between the supplied goods determines the level of supply given the relative prices. Similarly, the value of the elasticity of substitution between the imported and domestic product (es_dm) will influence the extent to which imported products can be substituted for domestically produced product. Table 23 below provides values for these elasticities.

Natural resource goods (natural gas and crude oil) are produced using fixed resources and rest-of-goods inputs. The top level elasticity of substitution between the fixed resource and other inputs are calibrated such that elasticity of supply is matched to the exogenously assumed values.[29] The parameter values for supply elasticities are assumed to be time varying (see Table 24 below). The natural gas and crude oil supply elasticity is assumed to be 0.6 and 0.3 in the short run, respectively, while in the long run both resources as elastically supplied (elasticity value of 1). The elasticity of substitution is computed to match the resource supply elasticity following Rutherford [1998], which depends upon the value share of the resource and the supply elasticity.

The elasticity values assumed for the production sectors, final demand, and Armington supply are shown in Table 23 and the resource supply elasticities are reported in Table 24.

[29] The elasticity values were based on values used in past MRN models which were based on secondary sources.

**Table 23. Default values of Elasticities in the MRN model**

| | | Non-energy Sectors | | | | | Energy Sectors | | | Final Demand | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | AGR | EIS | MAN | SRV | TRN | CRU | GAS | OIL | C | G | I |
| es_s | Top level elasticity | | | | | | | | | 0.5 | 0.0 | 0.0 |
| es_e | Energy versus value-added | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | NA | NA | NA |
| es_oil | Oil versus non-energy | | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 |
| es_va | Capital versus Labor | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | NA | NA | NA |
| es_ele | Electricity versus Coal-gas | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.5 | 0.8 | 0.8 |
| es_cg | Coal versus Gas | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| es_n | Non-energy | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 0.0 | 0.0 |
| etae | Elasticity of export supply | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | | | |
| es_dm | Domestic versus imports | 3.0 | 3.0 | 3.0 | 1.0 | 1.0 | 3.0 | 3.0 | 3.0 | | | |

NA: not applicable

**Table 24. Default Resource Supply Elasticities in the MRN model**

| | | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|---|---|---|
| Crude Oil | CRU | 0.30 | 0.51 | 0.65 | 0.76 | 0.83 | 0.88 | 0.91 | 0.94 | 0.96 |
| Natural gas | GAS | 0.60 | 0.72 | 0.80 | 0.86 | 0.90 | 0.93 | 0.95 | 0.97 | 0.98 |

### *Emissions, Energy prices, and Growth forecasts*

Key MRN Input assumptions are shown in Exhibit 19. The emissions forecast in the MRN model is based on the data from Energy Information Agency's AEO 2011 (early release) which provides estimates through 2035. Beyond 2035, we assume the carbon emission to grow by the growth rate observed in the last 10 years of AEO 2011 (early release) (2025-2035). Based on AEO, the national level forecast is proportionally scaled to the State level emissions according to the State level energy use. The MRN model's carbon emissions are adjusted to match the AEO 2011 (early release) level emissions by fossil fuel for the non-electric sectors. The electric sector carbon emission is endogenous to the NEEM model.

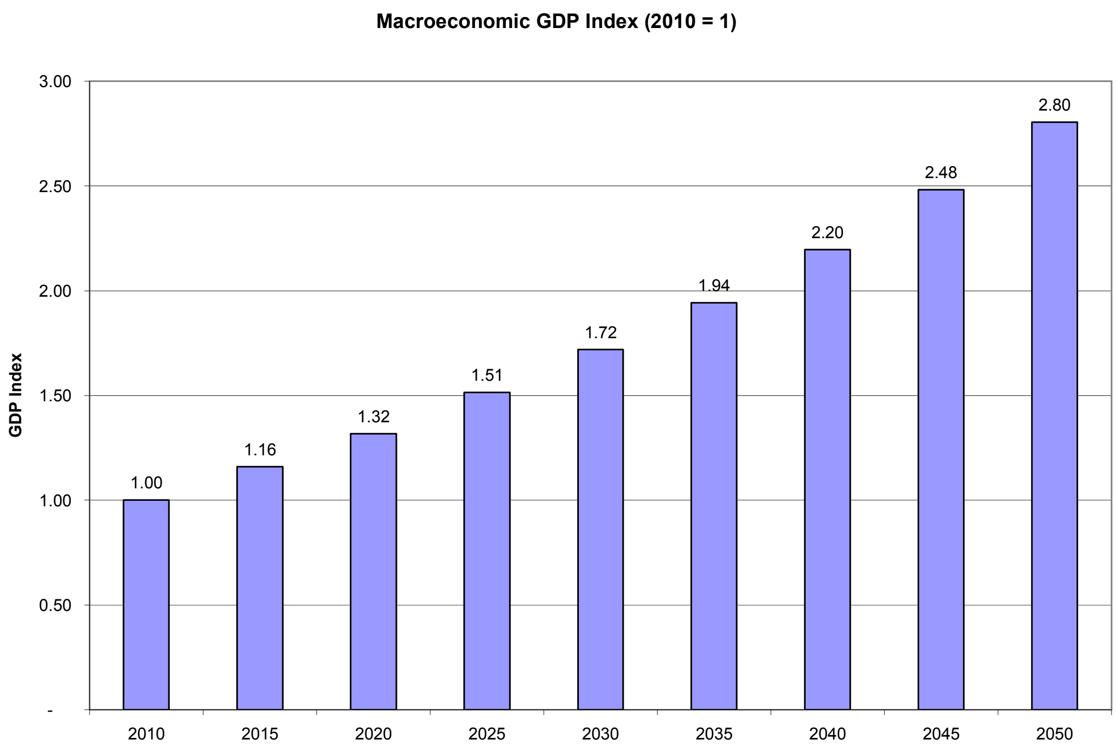
Energy price forecast assumptions are based on AEO 2011 (early release) energy prices. The cost impact of carbon policies also depends on the energy price forecast assumption. In particular, gas prices determine the amount of movement away from carbon-intensive coal to less carbon-intensive fuel, gas. We use the energy price forecast for natural gas, coal, and crude oil based on AEO 2011 (early release).[30]

The MRN model assumes a uniform GDP growth rate consistent with AEO 2011 (early release). The model assumes all regions grow at the national growth rate.[31] See Figure 8 for the assumed growth index.

[30] We assumed that beyond the AEO 2011 forecasted period (beyond 2035) the crude price remains at 2035 prices. This assumption, as all others, are subject to change based on stakeholder input.

[31] In the study, an exception will be made for the electricity sector growth. See section 3.2 above.

**Figure 8. Growth Index – United States**




*Source: AEO 2011 (early release) Reference Case*

### *Technological Progress in the Baseline*

MRN models technical changes as an exogenous scaling parameter often referred to as the autonomous energy efficiency improvement (AEEI).[32] The objective of this factor is to implement a decreasing energy use per dollar of output over time. This decrease is evident in the carbon intensity for the U.S which is consistent with the forecasted rate of improvement in emissions intensity. The baseline already includes many of the efficiency improvements that have been introduced in the policies that are part of the AEO 2011 (early release).

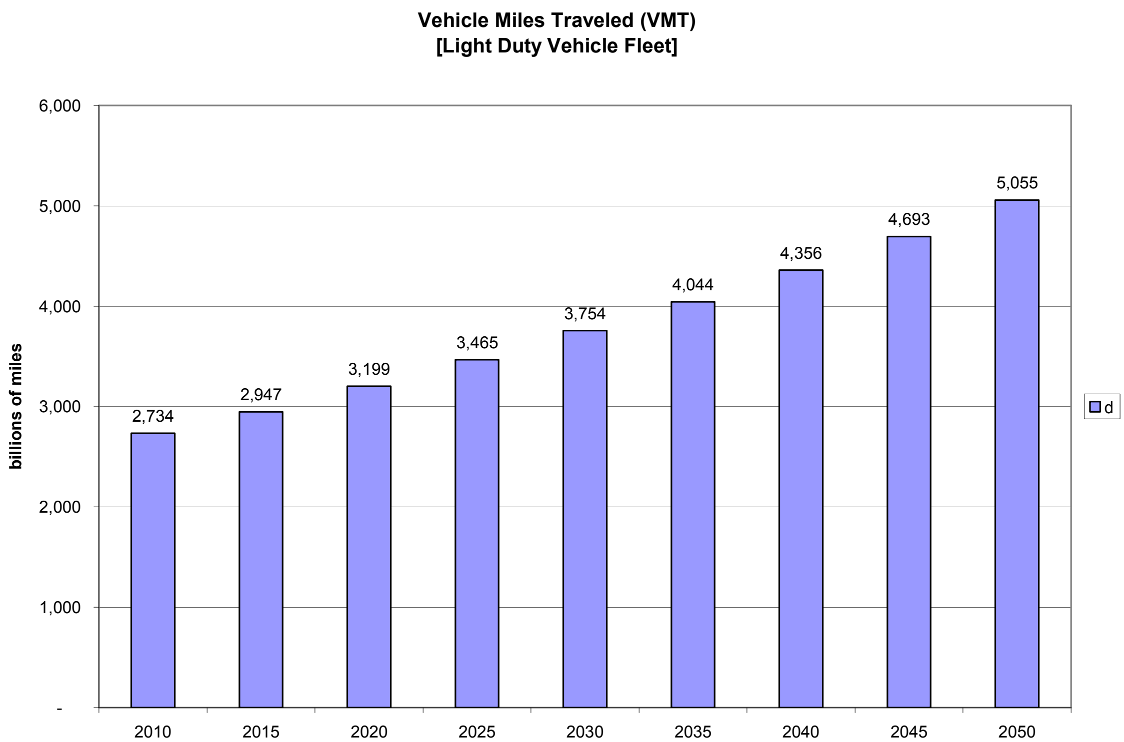
### *Vehicle Miles Traveled (VMT)*

Along the baseline, on road VMT and the new car fuel economy is calibrated to match the AEO 2011 (early release). VMT for light-duty vehicles is provided in Figure 9. We model the miles per gallon (mpg) requirement of the Corporate Average Fuel Economy (CAFE) standards according to the data provided in AEO 2011 (early release).

32 The scaling parameter is not arbitrarily chosen but is calibrated to match the model to published energy data sources. From a modeling perspective, the AEEI in the MRN model is calibrated endogenously. The scaling factor (AEEI) is computed by targeting the input implied energy inputs (AEO price time quantity).

In carbon policy futures, VMT will be lower. The response is calculated within the MRN-NEEM framework (model output). The model is also capable of modeling low carbon fuel standards as a future.

**Figure 9. VMT for Light-Duty Vehicles**




*Source: AEO 2011 (early release) Reference Case*

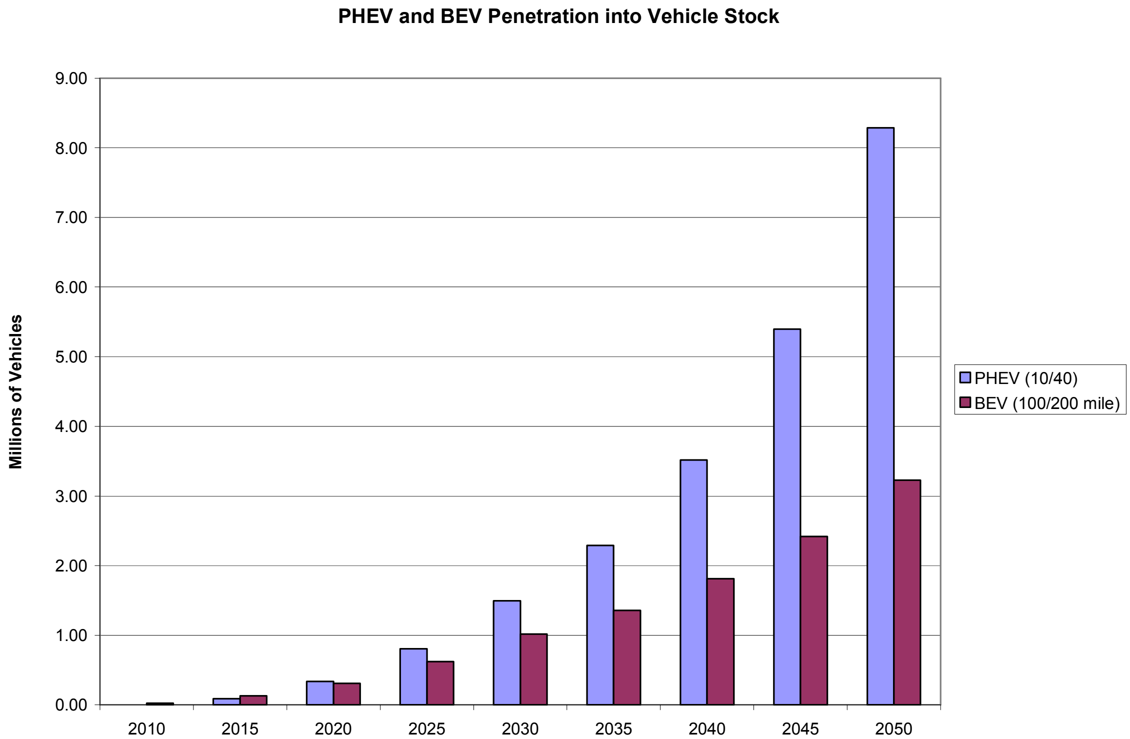
### *New Vehicle Technologies*

The BAU penetration of plug-in electric vehicles (PHEVs) and battery electric vehicles (BEVs) is based on the AEO 2011 (early release) reference case. The data are shown in Figure 10.

The plug-to-wheels electricity usage for PHEVs and BEVs, the fraction of time that the PHEV operates as an electric vehicle, and the fuel efficiency of the PHEV's gasoline engine are CRA assumptions. The cost premiums of PHEVs and BEVs relative to conventional vehicles are also CRA assumptions.

In carbon policy futures, the penetration of PHEVs and BEVs will increase within the MRN-NEEM framework (model output).

**Figure 10. PHEV and BEV Penetration**




*Source: AEO 2011 (early release) Reference Case*

### *Transportation Fuel Emissions Factors*

The CO2e emissions factors for gasoline, ethanol, and biodiesel come from the California Air Resources Board (CARB) and the U.S. Environmental Protection Agency (EPA).

The CO2e emissions factors for gasoline, ethanol, and advanced biodiesel are 96 g CO2e/MJ, 73 g CO2e/MJ, and 19 g CO2e/MJ, respectively, for gasoline, corn ethanol, and advanced biodiesel.

## 4.8. MODELING OF CANADA IN MRN

Aside from the electric sector as represented in NEEM, MRN does not model the Canadian economy. The two important feedbacks between MRN and NEEM are natural gas prices and electricity demand.

For natural gas, CRA assumes that the natural gas market is homogenous between the U.S. and Canada, and thus any natural gas price changes observed in MRN in the U.S. are used as proxy for natural gas price changes in Canada. The delivered natural gas prices in Canada are scaled accordingly in NEEM.

For electricity demand, the MRN impact on electricity demand depends upon the implied own-price demand elasticity. As a base approximation, assuming similar consumer preferences in the US and Canada, the response in the Canadian demand could be modeled as mirroring the US demand response. Hence, under this assumption, the Canadian demand would reduce by the same percentage as that in the U.S.

However, assuming CRA can obtain (from secondary econometric studies) the implied own-price demand elasticity for electricity for Canada, we will approximate the demand response using the change in electricity price observed in the U.S. Using this approach, the electricity demand in Canada would be adjusted exogenously accordingly:

$$\text{Demand Elasticity}^{\text{Canada}} = \frac{(\text{Percent Change in Demand})^{Canada}}{(\text{Percent Change in Electricity Price})^{\text{US}}}$$

Finally, we note that stakeholders have provided Ontario elasticity estimates. We could use these estimates as a proxy for all of Canada, unless better information is provided.

**Appendix A, Exhibit 1 - 2006 Load Shapes**
**Based on eastern interconnection sorting.**

## By Load Blocks - Eastern Interconnection Regions

*Average Load during block relative to average of highest block*

| | Season | Summer | | | | | | | | | | Shoulder | | | | | Winter | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hours | 10 | 25 | 75 | 100 | 200 | 300 | 400 | 500 | 800 | 1262 | 25 | 200 | 600 | 900 | 1203 | 25 | 100 | 400 | 700 | 935 |
| NEEM Region | Year | B1 | B2 | B3 | B4 | B5 | B6 | B7 | B8 | B9 | B10 | B11 | B12 | B13 | B14 | B15 | B16 | B17 | B18 | B19 | B20 |
| AE | 2006 | 1.000 | 0.976 | 0.914 | 0.865 | 0.836 | 0.795 | 0.738 | 0.693 | 0.649 | 0.553 | 0.722 | 0.741 | 0.704 | 0.660 | 0.568 | 0.938 | 0.871 | 0.802 | 0.739 | 0.648 |
| EMO | 2006 | 1.000 | 0.963 | 0.889 | 0.833 | 0.798 | 0.730 | 0.677 | 0.607 | 0.529 | 0.441 | 0.699 | 0.584 | 0.542 | 0.511 | 0.439 | 0.754 | 0.655 | 0.604 | 0.557 | 0.495 |
| ENT | 2006 | 1.000 | 0.989 | 0.946 | 0.953 | 0.920 | 0.876 | 0.843 | 0.797 | 0.726 | 0.628 | 0.835 | 0.688 | 0.643 | 0.609 | 0.545 | 0.743 | 0.690 | 0.653 | 0.621 | 0.567 |
| FRCC | 2006 | 1.000 | 0.945 | 0.916 | 0.903 | 0.877 | 0.832 | 0.794 | 0.745 | 0.675 | 0.516 | 0.801 | 0.676 | 0.631 | 0.584 | 0.446 | 0.705 | 0.632 | 0.583 | 0.552 | 0.450 |
| MAPP_CA | 2006 | 1.000 | 1.016 | 0.998 | 0.954 | 0.916 | 0.863 | 0.825 | 0.762 | 0.701 | 0.598 | 0.787 | 0.767 | 0.748 | 0.699 | 0.599 | 0.937 | 0.874 | 0.844 | 0.781 | 0.611 |
| MAPP_US | 2006 | 1.000 | 1.022 | 0.999 | 0.942 | 0.893 | 0.825 | 0.772 | 0.694 | 0.628 | 0.532 | 0.724 | 0.706 | 0.688 | 0.643 | 0.551 | 0.877 | 0.815 | 0.784 | 0.723 | 0.554 |
| MI | 2006 | 1.000 | 0.923 | 0.830 | 0.772 | 0.730 | 0.691 | 0.648 | 0.608 | 0.565 | 0.486 | 0.606 | 0.603 | 0.586 | 0.540 | 0.451 | 0.715 | 0.656 | 0.622 | 0.574 | 0.474 |
| MISO_E | 2006 | 1.000 | 0.974 | 0.908 | 0.855 | 0.821 | 0.764 | 0.690 | 0.625 | 0.563 | 0.481 | 0.667 | 0.626 | 0.599 | 0.560 | 0.482 | 0.765 | 0.700 | 0.650 | 0.604 | 0.522 |
| NE | 2006 | 1.000 | 1.009 | 0.997 | 0.972 | 0.938 | 0.893 | 0.851 | 0.782 | 0.706 | 0.600 | 0.760 | 0.693 | 0.669 | 0.625 | 0.534 | 0.784 | 0.731 | 0.710 | 0.674 | 0.581 |
| NEISO | 2006 | 1.000 | 0.958 | 0.877 | 0.801 | 0.765 | 0.721 | 0.671 | 0.633 | 0.583 | 0.466 | 0.649 | 0.644 | 0.618 | 0.572 | 0.449 | 0.723 | 0.697 | 0.672 | 0.625 | 0.503 |
| NI | 2006 | 1.000 | 0.924 | 0.835 | 0.772 | 0.730 | 0.680 | 0.638 | 0.595 | 0.543 | 0.453 | 0.604 | 0.576 | 0.552 | 0.507 | 0.421 | 0.656 | 0.612 | 0.591 | 0.554 | 0.465 |
| NYISO_Capital | 2006 | 1.000 | 0.952 | 0.893 | 0.819 | 0.781 | 0.734 | 0.679 | 0.644 | 0.595 | 0.479 | 0.662 | 0.652 | 0.618 | 0.578 | 0.463 | 0.742 | 0.708 | 0.679 | 0.630 | 0.515 |
| NYISO_Downstate | 2006 | 1.000 | 0.958 | 0.857 | 0.785 | 0.753 | 0.702 | 0.653 | 0.613 | 0.561 | 0.448 | 0.607 | 0.590 | 0.560 | 0.520 | 0.413 | 0.663 | 0.632 | 0.610 | 0.567 | 0.464 |
| NYISO_LIPA | 2006 | 1.000 | 0.970 | 0.869 | 0.785 | 0.745 | 0.691 | 0.630 | 0.584 | 0.523 | 0.411 | 0.562 | 0.531 | 0.498 | 0.461 | 0.360 | 0.590 | 0.554 | 0.537 | 0.495 | 0.396 |
| NYISO_NYC | 2006 | 1.000 | 0.968 | 0.884 | 0.808 | 0.778 | 0.718 | 0.652 | 0.609 | 0.554 | 0.442 | 0.615 | 0.563 | 0.553 | 0.504 | 0.398 | 0.577 | 0.560 | 0.553 | 0.531 | 0.422 |
| NYISO_Upstate | 2006 | 1.000 | 0.967 | 0.914 | 0.856 | 0.823 | 0.789 | 0.750 | 0.723 | 0.686 | 0.587 | 0.745 | 0.767 | 0.741 | 0.693 | 0.583 | 0.843 | 0.822 | 0.797 | 0.753 | 0.637 |
| NonRTO_Midwest | 2006 | 1.000 | 0.983 | 0.936 | 0.898 | 0.869 | 0.824 | 0.771 | 0.721 | 0.657 | 0.567 | 0.767 | 0.733 | 0.684 | 0.643 | 0.567 | 0.938 | 0.847 | 0.777 | 0.712 | 0.637 |
| OH | 2006 | 1.000 | 0.957 | 0.895 | 0.855 | 0.826 | 0.801 | 0.770 | 0.736 | 0.699 | 0.604 | 0.765 | 0.789 | 0.761 | 0.715 | 0.604 | 0.873 | 0.854 | 0.829 | 0.782 | 0.658 |
| PJM_D | 2006 | 1.000 | 0.975 | 0.914 | 0.861 | 0.840 | 0.791 | 0.716 | 0.644 | 0.581 | 0.474 | 0.647 | 0.616 | 0.571 | 0.536 | 0.455 | 0.796 | 0.728 | 0.654 | 0.596 | 0.526 |
| PJM_E | 2006 | 1.000 | 0.970 | 0.874 | 0.805 | 0.773 | 0.714 | 0.647 | 0.597 | 0.542 | 0.442 | 0.585 | 0.557 | 0.530 | 0.491 | 0.402 | 0.640 | 0.606 | 0.579 | 0.537 | 0.450 |
| PJM_Midwest | 2006 | 1.000 | 0.965 | 0.903 | 0.854 | 0.820 | 0.780 | 0.727 | 0.687 | 0.642 | 0.553 | 0.713 | 0.716 | 0.687 | 0.639 | 0.552 | 0.846 | 0.797 | 0.750 | 0.698 | 0.607 |
| PJM_SW | 2006 | 1.000 | 0.974 | 0.905 | 0.841 | 0.815 | 0.767 | 0.690 | 0.621 | 0.563 | 0.463 | 0.622 | 0.588 | 0.555 | 0.520 | 0.434 | 0.749 | 0.688 | 0.629 | 0.579 | 0.499 |
| PJM_W | 2006 | 1.000 | 0.982 | 0.922 | 0.873 | 0.848 | 0.810 | 0.759 | 0.725 | 0.685 | 0.573 | 0.757 | 0.775 | 0.742 | 0.686 | 0.568 | 0.933 | 0.877 | 0.825 | 0.764 | 0.644 |
| SCIL | 2006 | 1.000 | 0.952 | 0.870 | 0.817 | 0.791 | 0.733 | 0.683 | 0.627 | 0.553 | 0.468 | 0.712 | 0.587 | 0.554 | 0.515 | 0.442 | 0.735 | 0.639 | 0.594 | 0.548 | 0.480 |
| SOCO | 2006 | 1.000 | 0.977 | 0.963 | 0.941 | 0.908 | 0.861 | 0.803 | 0.735 | 0.651 | 0.528 | 0.752 | 0.648 | 0.597 | 0.557 | 0.472 | 0.804 | 0.711 | 0.632 | 0.581 | 0.511 |
| SPP_N | 2006 | 1.000 | 0.963 | 0.917 | 0.882 | 0.834 | 0.758 | 0.699 | 0.624 | 0.542 | 0.443 | 0.717 | 0.673 | 0.619 | 0.571 | 0.475 | 0.762 | 0.744 | 0.728 | 0.695 | 0.602 |
| SPP_S | 2006 | 1.000 | 0.985 | 0.951 | 0.941 | 0.890 | 0.830 | 0.787 | 0.727 | 0.650 | 0.548 | 0.768 | 0.612 | 0.575 | 0.546 | 0.475 | 0.699 | 0.635 | 0.603 | 0.571 | 0.514 |
| TVA | 2006 | 1.000 | 0.978 | 0.937 | 0.923 | 0.879 | 0.818 | 0.756 | 0.697 | 0.619 | 0.521 | 0.737 | 0.662 | 0.615 | 0.580 | 0.509 | 0.895 | 0.772 | 0.678 | 0.622 | 0.558 |
| VACAR | 2006 | 1.000 | 0.974 | 0.940 | 0.897 | 0.862 | 0.813 | 0.740 | 0.679 | 0.612 | 0.497 | 0.674 | 0.643 | 0.590 | 0.553 | 0.474 | 0.846 | 0.746 | 0.650 | 0.592 | 0.527 |
| WUMS | 2006 | 1.000 | 0.977 | 0.904 | 0.838 | 0.788 | 0.743 | 0.697 | 0.650 | 0.600 | 0.498 | 0.671 | 0.665 | 0.644 | 0.595 | 0.487 | 0.787 | 0.722 | 0.684 | 0.634 | 0.522 |

**Appendix A, Exhibit 2 - Top 10 hours (load block 1)**

## Hours in Top Load Block, B1

Descending Order in 2006 Load Shape

**Based on total Eastern Interconnection Load**

| Hour No. | Date | Hour (1-24) |
|---|---|---|
| 1 | 8/2/2006 | 17 |
| 2 | 8/1/2006 | 17 |
| 3 | 8/2/2006 | 16 |
| 4 | 8/1/2006 | 16 |
| 5 | 8/2/2006 | 18 |
| 6 | 8/1/2006 | 18 |
| 7 | 8/2/2006 | 15 |
| 8 | 8/1/2006 | 15 |
| 9 | 7/17/2006 | 17 |
| 10 | 7/31/2006 | 17 |

**Appendix A, Exhibit 3 - Mapping of Control Entities to NEEM Regions (for load mapping)**

| Planning Area | NEEM Region |
|---|---|
| | |
| Allegheney Power | AE |
| Arizona Electric Power Coop Inc | AZ_NM_SNV |
| Arizona Public Service Co | AZ_NM_SNV |
| El Paso Electric Co | AZ_NM_SNV |
| Nevada Power Co | AZ_NM_SNV |
| Public Service Co of New Mexico | AZ_NM_SNV |
| Salt River Project | AZ_NM_SNV |
| Tucson Electric Power Co | AZ_NM_SNV |
| WAPA Lower Colorado Region | AZ_NM_SNV |
| Ameren Corporation Control Area | EMO |
| Associated Electric Coop Inc | EMO |
| Columbia (MO) Water & Light | EMO |
| City of Conway | ENT |
| Entergy Services Inc | ENT |
| North Little Rock AR (City of) | ENT |
| Sam Rayburn G&T Electric Coop Inc | ENT |
| Clarksdale Public Utilities Commission | ENT |
| Louisiana Generating LLC | ENT |
| ERCOT | ERCOT |
| Florida Municipal Power Agency | FRCC |
| Florida Power & Light Co | FRCC |
| Gainesville Regional Utilities | FRCC |
| JEA | FRCC |
| Lakeland Dept of Electric Water Utilities | FRCC |
| Orlando Utilities Commission | FRCC |
| Progress Energy (Florida Power Corp.) | FRCC |
| Seminole Electric Coop Inc | FRCC |
| St Cloud (City of) | FRCC |
| Tallahassee FL (City of) | FRCC |
| Tampa Electric Co | FRCC |
| Algona Municipal Utilities | MAPP_US |
| Allete (Minnesota Power) | MAPP_US |
| Alliant Energy-West | MAPP_US |
| Ames Municipal Electric System | MAPP_US |
| Atlantic Municipal Utilities | MAPP_US |
| Basin Electric Power Cooperative | MAPP_US |
| Central Minnesota Municipal Power Agency | MAPP_US |
| Great River Energy | MAPP_US |
| Harlan Municipal Utilities | MAPP_US |
| Heartland Consumers Power District | MAPP_US |
| Hutchinson Utilities Commission | MAPP_US |
| Marshall Municipal Utilities | MAPP_US |
| MidAmerican Energy Company | MAPP_US |
| Minnesota Municipal Power Agency | MAPP_US |
| Minnkota Power Coop | MAPP_US |
| Missouri River Energy Services | MAPP_US |
| Montana-Dakota Utilities Company | MAPP_US |
| Muscatine Power & Water | MAPP_US |
| New Ulm Public Utilities | MAPP_US |
| Northern States Power Company | MAPP_US |
| NorthWestern Energy (South Dakota) | MAPP_US |
| Otter Tail Power Company | MAPP_US |
| Pella (City of) | MAPP_US |
| Rochester Public Utilities | MAPP_US |
| Southern Minnesota Municipal Power Agency | MAPP_US |
| Square Butte Electric Coop | MAPP_US |
| WAPA Upper Great Plains East | MAPP_US |
| Willmar Municipal Utilities Commission | MAPP_US |
| Consumers Energy Company | MI |
| Detroit Edison Company | MI |
| Wolverine Power Supply Coop Inc | MI |
| Duke Energy Corp. | MISO_E |
| Hoosier Energy REC, Inc. | MISO_E |
| Indianapolis Power & Light Company | MISO_E |

**Appendix A, Exhibit 3 - Mapping of Control Entities to NEEM Regions (for load mapping)**

| Planning Area | NEEM Region |
|---|---|
| Northern Indiana Public Service Company | MISO_E |
| Southern Indiana Gas & Electric Company | MISO_E |
| Wabash Valley Power Association | MISO_E |
| American Municipal Power-Ohio, Inc. | MISO_E |
| Indiana Municipal Power Agency | MISO_E |
| Hastings Utilities (NE) | NE |
| Lincoln Electric System | NE |
| Municipal Energy Agency of Nebraska | NE |
| Nebraska Public Power District | NE |
| Omaha Public Power District | NE |
| NEISO | NEISO |
| Commonwealth Edison | NI |
| Big Rivers Electric Corp | NonRTO_Midwest |
| Buckeye Power Inc | NonRTO_Midwest |
| East Kentucky Power Coop Inc | NonRTO_Midwest |
| Louisville Gas & Electric Co | NonRTO_Midwest |
| Ohio Valley Electric Corp | NonRTO_Midwest |
| Modesto Irrigation District | NP15 |
| Pacific Gas & Electric Co | NP15 |
| Sacramento Municipal Utility District | NP15 |
| Turlock Irrigation District | NP15 |
| Avista Corp | NWPP |
| Bonneville Power Administration | NWPP |
| Eugene Water & Electric Board | NWPP |
| Idaho Power Co | NWPP |
| NorthWestern Energy | NWPP |
| PacifiCorp | NWPP |
| Portland General Electric Co | NWPP |
| PUD No 1 of Chelan County | NWPP |
| PUD No 1 of Douglas County | NWPP |
| PUD No 2 of Grant County | NWPP |
| Puget Sound Energy Inc | NWPP |
| Seattle City Light | NWPP |
| Sierra Pacific Power Co | NWPP |
| Tacoma Power | NWPP |
| WAPA Upper Great Plains West | NWPP |
| NYISO Zone F | NYISO_Capital |
| NYISO Zone G | NYISO_Downstate |
| NYISO Zone H | NYISO_Downstate |
| NYISO Zone I | NYISO_Downstate |
| NYISO Zone K | NYISO_LIPA |
| NYISO Zone J | NYISO_NYC |
| NYISO Zone A | NYISO_Upstate |
| NYISO Zone B | NYISO_Upstate |
| NYISO Zone C | NYISO_Upstate |
| NYISO Zone D | NYISO_Upstate |
| NYISO Zone E | NYISO_Upstate |
| Dominion | PJM_D |
| Atlantic Electric | PJM_E |
| Delmarva Power & Light | PJM_E |
| Jersey Central | PJM_E |
| PECO | PJM_E |
| Public Service | PJM_E |
| Rockland Electric | PJM_E |
| American Electric Power | PJM_Midwest |
| Dayton Power & Light | PJM_Midwest |
| Duquesne Light Company | PJM_Midwest |
| First Energy | PJM_Midwest |
| Baltimore Gas & Electric | PJM_SW |
| PEPCO | PJM_SW |
| Metropolitan Edison | PJM_W |
| PennElec | PJM_W |
| PP&L and UGI | PJM_W |
| Black Hills Corp | RMPA |
| Colorado Springs Utilities | RMPA |

**Appendix A, Exhibit 3 - Mapping of Control Entities to NEEM Regions (for load mapping)**

| Planning Area | NEEM Region |
|---|---|
| Platte River Power Authority | RMPA |
| Public Service Co of Colorado | RMPA |
| Tri State G & T Association Inc | RMPA |
| WAPA Rocky Mountain Region | RMPA |
| Ameren (Illinois Power Co. Control Area) | SCIL |
| City of Springfield | SCIL |
| Southern Illinois Power Coop | SCIL |
| Alabama Power Co | SOCO |
| Georgia Power Co | SOCO |
| Gulf Power Co | SOCO |
| Mississippi Power Co | SOCO |
| Oglethorpe Power Corp | SOCO |
| PowerSouth Energy Coop | SOCO |
| South Mississippi Electric Power Association | SOCO |
| Southern Power Co | SOCO |
| MEAG Power | SOCO |
| Burbank (City of) | SP15 |
| Imperial Irrigation District | SP15 |
| Los Angeles Dept of Water & Power | SP15 |
| Metropolitan Water District | SP15 |
| San Diego Gas & Electric Co | SP15 |
| Southern California Edison | SP15 |
| City of Independence MO | SPP_N |
| City Utilities of Springfield (MO) | SPP_N |
| Empire District Electric Co (The) | SPP_N |
| Kansas City KS (City of) | SPP_N |
| Kansas City Power & Light Co | SPP_N |
| KCP&L Greater Missouri Operations | SPP_N |
| Sunflower Electric Power Corp | SPP_N |
| Westar Energy (KPL) | SPP_N |
| American Electric Power Co Inc (AEP West) | SPP_S |
| Cleco Corp | SPP_S |
| Golden Spread Electric Coop Inc | SPP_S |
| Grand River Dam Authority | SPP_S |
| Lafayette Utilities System | SPP_S |
| Louisiana Energy & Power Authority | SPP_S |
| Northeast Texas Electric Coop Inc | SPP_S |
| Oklahoma Gas & Electric Co | SPP_S |
| Oklahoma Municipal Power Authority | SPP_S |
| Southwestern Power Administration | SPP_S |
| Southwestern Public Service Co | SPP_S |
| Tex La Electric Coop of Texas Inc | SPP_S |
| Western Farmers Electric Coop | SPP_S |
| Arkansas Electric Cooperative | SPP_S |
| Fayetteville Public Service | TVA |
| Tennessee Valley Authority | TVA |
| Central Electric Power Coop Inc | VACAR |
| Duke Energy Carolinas LLC | VACAR |
| Greenville Utilities Commission | VACAR |
| Progress Energy Carolina | VACAR |
| South Carolina Electric & Gas | VACAR |
| South Carolina Public Service Authority | VACAR |
| Alliant Energy-East | WUMS |
| Dairyland Power Coop | WUMS |
| Madison Gas & Electric Company | WUMS |
| Upper Peninsula Power Company | WUMS |
| Wisconsin Electric Power Company | WUMS |
| Wisconsin Public Service Corporation | WUMS |
| WPPI Energy | WUMS |

**Appendix A, Exhibit 4 - NEEM Wind Shapes (Existing Units and New Installations)**

**PRELIMINARY. Sorted into load blocks based on a single Eastern NEEM Region's load, will be udpated for entire EI load**

**Wind Capacity Factors by Block - Eastern Interconnection**

*(Blanks indicate no onshore/offshore wind potential in the region)*

| **ONSHORE WIND** | | Summer | | | | | | | | | | Shoulder | | | | | Winter | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hours | 10 | 25 | 75 | 100 | 200 | 300 | 400 | 500 | 800 | 1262 | 25 | 200 | 600 | 900 | 1203 | 25 | 100 | 400 | 700 | 935 |
| NEEM Region | Year | B1 | B2 | B3 | B4 | B5 | B6 | B7 | B8 | B9 | B10 | B11 | B12 | B13 | B14 | B15 | B16 | B17 | B18 | B19 | B20 |
| AE | All | 16% | 17% | 9% | 10% | 13% | 13% | 14% | 12% | 20% | 20% | 13% | 24% | 29% | 24% | 28% | 68% | 41% | 40% | 47% | 43% |
| EMO | All | 9% | 39% | 28% | 24% | 21% | 22% | 24% | 30% | 38% | 37% | 36% | 34% | 38% | 42% | 48% | 59% | 52% | 43% | 42% | 46% |
| ENT | All | 10% | 11% | 11% | 11% | 13% | 14% | 17% | 21% | 30% | 33% | 30% | 37% | 35% | 36% | 43% | 47% | 45% | 41% | 37% | 44% |
| FRCC | All | | | | | | | | | | | | | | | | | | | | |
| (a) MAPP_US | All | 19% | 17% | 24% | 22% | 30% | 29% | 31% | 29% | 37% | 39% | 28% | 36% | 42% | 39% | 42% | 38% | 47% | 44% | 49% | 51% |
| MAPP_CA | All | TBD | | | | | | | | | | | | | | | | | | | |
| MI | All | 10% | 30% | 17% | 21% | 17% | 21% | 20% | 19% | 25% | 24% | 9% | 20% | 32% | 28% | 34% | 70% | 46% | 43% | 47% | 41% |
| NE | All | 42% | 30% | 26% | 26% | 26% | 27% | 30% | 34% | 38% | 37% | 47% | 36% | 43% | 44% | 45% | 54% | 48% | 48% | 45% | 49% |
| NEISO_CT | All | 26% | 21% | 17% | 18% | 15% | 17% | 20% | 19% | 19% | 23% | 22% | 32% | 31% | 27% | 27% | 52% | 29% | 31% | 38% | 35% |
| NEISO_MA | All | 27% | 25% | 19% | 21% | 17% | 20% | 22% | 21% | 23% | 27% | 25% | 35% | 35% | 31% | 31% | 63% | 39% | 37% | 44% | 41% |
| NEISO_NH | All | 11% | 20% | 15% | 16% | 16% | 20% | 21% | 22% | 25% | 29% | 24% | 36% | 39% | 34% | 35% | 60% | 43% | 41% | 48% | 45% |
| NEISO_VT | All | 13% | 24% | 14% | 17% | 17% | 20% | 22% | 23% | 28% | 30% | 23% | 35% | 39% | 34% | 36% | 69% | 49% | 44% | 52% | 45% |
| NEISO_ME | All | 9% | 12% | 18% | 19% | 18% | 23% | 22% | 23% | 27% | 29% | 19% | 32% | 39% | 34% | 38% | 61% | 47% | 43% | 49% | 45% |
| NI | All | 11% | 29% | 17% | 19% | 16% | 20% | 23% | 26% | 32% | 31% | 25% | 30% | 35% | 37% | 45% | 73% | 51% | 43% | 45% | 44% |
| NYISO_Capital | All | 43% | 31% | 17% | 23% | 22% | 21% | 24% | 24% | 26% | 29% | 29% | 38% | 40% | 34% | 36% | 64% | 40% | 41% | 49% | 44% |
| NYISO_Downstate | All | 42% | 34% | 26% | 29% | 25% | 26% | 29% | 26% | 26% | 28% | 27% | 36% | 37% | 33% | 32% | 63% | 37% | 38% | 44% | 41% |
| NYISO_LIPA | All | | | | | | | | | | | | | | | | | | | | |
| NYISO_NYC | All | | | | | | | | | | | | | | | | | | | | |
| NYISO_Upstate | All | 26% | 32% | 16% | 20% | 18% | 19% | 22% | 21% | 26% | 27% | 16% | 29% | 37% | 31% | 35% | 73% | 47% | 45% | 52% | 45% |
| NonRTO_Midwest | All | 19% | 24% | 16% | 16% | 17% | 21% | 21% | 18% | 27% | 25% | 22% | 29% | 33% | 30% | 40% | 73% | 51% | 45% | 46% | 42% |
| OH | All | Data provided by stakeholders on an 8760 basis. CRA will map into the load blocks based on the entire EI load. | | | | | | | | | | | | | | | | | | | |
| PJM_D | All | 22% | 16% | 15% | 19% | 19% | 19% | 20% | 18% | 25% | 24% | 22% | 31% | 31% | 32% | 33% | 35% | 28% | 35% | 39% | 43% |
| PJM_E | All | 17% | 13% | 12% | 14% | 14% | 14% | 17% | 16% | 17% | 17% | 27% | 28% | 28% | 24% | 23% | 41% | 23% | 28% | 35% | 30% |
| PJM_Midwest | All | 19% | 24% | 16% | 16% | 17% | 21% | 21% | 18% | 27% | 25% | 22% | 29% | 33% | 30% | 40% | 73% | 51% | 45% | 46% | 42% |
| PJM_SW | All | 15% | 13% | 12% | 13% | 16% | 15% | 18% | 16% | 22% | 21% | 21% | 30% | 34% | 28% | 30% | 58% | 38% | 40% | 48% | 43% |
| PJM_W | All | 22% | 19% | 13% | 13% | 14% | 14% | 17% | 17% | 21% | 21% | 15% | 30% | 34% | 27% | 31% | 65% | 38% | 39% | 47% | 41% |
| SCIL | All | 12% | 22% | 18% | 16% | 18% | 20% | 21% | 23% | 30% | 29% | 25% | 33% | 35% | 35% | 45% | 69% | 51% | 43% | 45% | 45% |
| SOCO | All | | | | | | | | | | | | | | | | | | | | |
| SPP_N | All | 14% | 35% | 31% | 28% | 25% | 26% | 32% | 39% | 36% | 36% | 43% | 37% | 41% | 44% | 47% | 46% | 43% | 42% | 38% | 44% |
| SPP_S | All | 19% | 35% | 30% | 28% | 26% | 26% | 29% | 38% | 33% | 37% | 41% | 38% | 41% | 44% | 48% | 41% | 40% | 41% | 39% | 44% |
| TVA | All | 12% | 7% | 9% | 11% | 10% | 10% | 12% | 13% | 25% | 26% | 32% | 33% | 28% | 32% | 38% | 46% | 36% | 40% | 36% | 43% |
| VACAR | All | 22% | 16% | 15% | 19% | 19% | 19% | 20% | 18% | 25% | 24% | 22% | 31% | 31% | 32% | 33% | 35% | 28% | 35% | 39% | 43% |
| WUMS | All | 7% | 28% | 22% | 21% | 17% | 19% | 22% | 25% | 30% | 31% | 21% | 21% | 30% | 33% | 40% | 65% | 43% | 38% | 44% | 40% |

*(a) still in process - this is an approximate example for MAPP_US.*

| **OFFSHORE WIND** | | Summer | | | | | | | | | | Shoulder | | | | | Winter | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hours | 10 | 25 | 75 | 100 | 200 | 300 | 400 | 500 | 800 | 1262 | 25 | 200 | 600 | 900 | 1203 | 25 | 100 | 400 | 700 | 935 |
| NEEM Region | Year | B1 | B2 | B3 | B4 | B5 | B6 | B7 | B8 | B9 | B10 | B11 | B12 | B13 | B14 | B15 | B16 | B17 | B18 | B19 | B20 |
| AE | All | | | | | | | | | | | | | | | | | | | | |
| EMO | All | | | | | | | | | | | | | | | | | | | | |
| ENT | All | | | | | | | | | | | | | | | | | | | | |
| FRCC | All | | | | | | | | | | | | | | | | | | | | |
| MAPP_US | All | | | | | | | | | | | | | | | | | | | | |
| MI | All | 8% | 17% | 32% | 32% | 25% | 26% | 29% | 25% | 33% | 31% | 12% | 22% | 37% | 35% | 38% | 69% | 47% | 43% | 51% | 42% |
| MISO_E | All | 10% | 32% | 23% | 25% | 23% | 25% | 28% | 22% | 30% | 24% | 17% | 27% | 39% | 35% | 40% | 84% | 57% | 51% | 54% | 47% |
| NE | All | | | | | | | | | | | | | | | | | | | | |
| NEISO_CT | All | 52% | 52% | 36% | 35% | 30% | 32% | 33% | 27% | 28% | 27% | 36% | 39% | 41% | 35% | 32% | 69% | 38% | 42% | 49% | 45% |
| NEISO_MA | All | 55% | 45% | 40% | 47% | 42% | 44% | 44% | 39% | 41% | 41% | 47% | 43% | 47% | 47% | 42% | 65% | 48% | 51% | 58% | 52% |
| NEISO_NH | All | 17% | 20% | 26% | 35% | 30% | 34% | 34% | 33% | 36% | 33% | 26% | 38% | 39% | 34% | 34% | 52% | 35% | 38% | 47% | 43% |
| NEISO_VT | All | | | | | | | | | | | | | | | | | | | | |
| NEISO_ME | All | 11% | 19% | 31% | 38% | 36% | 39% | 39% | 37% | 41% | 38% | 24% | 35% | 40% | 38% | 38% | 57% | 41% | 42% | 50% | 45% |
| NI | All | 4% | 40% | 21% | 22% | 21% | 26% | 27% | 26% | 29% | 29% | 19% | 31% | 40% | 39% | 46% | 75% | 53% | 44% | 48% | 42% |
| NYISO_Capital | All | | | | | | | | | | | | | | | | | | | | |
| NYISO_Downstate | All | | | | | | | | | | | | | | | | | | | | |
| NYISO_LIPA | All | 45% | 44% | 38% | 47% | 39% | 41% | 44% | 33% | 35% | 33% | 49% | 43% | 46% | 42% | 37% | 67% | 44% | 45% | 52% | 46% |
| NYISO_NYC | All | | | | | | | | | | | | | | | | | | | | |
| NYISO_Upstate | All | 17% | 34% | 26% | 31% | 25% | 28% | 31% | 23% | 32% | 23% | 21% | 29% | 40% | 35% | 38% | 85% | 58% | 55% | 58% | 48% |
| NonRTO_Midwest | All | 10% | 32% | 23% | 25% | 23% | 25% | 28% | 22% | 30% | 24% | 17% | 27% | 39% | 35% | 40% | 84% | 57% | 51% | 54% | 47% |
| OH | All | TBD | | | | | | | | | | | | | | | | | | | |
| PJM_D | All | 50% | 30% | 34% | 42% | 41% | 40% | 37% | 32% | 34% | 32% | 38% | 41% | 41% | 44% | 40% | 31% | 31% | 39% | 45% | 45% |
| PJM_E | All | 47% | 37% | 36% | 43% | 38% | 44% | 43% | 33% | 36% | 34% | 45% | 44% | 46% | 45% | 39% | 54% | 43% | 45% | 52% | 47% |
| PJM_Midwest | All | 10% | 32% | 23% | 25% | 23% | 25% | 28% | 22% | 30% | 24% | 17% | 27% | 39% | 35% | 40% | 84% | 57% | 51% | 54% | 47% |
| PJM_SW | All | 35% | 28% | 38% | 41% | 41% | 43% | 42% | 34% | 34% | 33% | 41% | 43% | 43% | 44% | 38% | 39% | 35% | 42% | 49% | 46% |
| PJM_W | All | 17% | 34% | 26% | 31% | 25% | 28% | 31% | 23% | 32% | 23% | 21% | 29% | 40% | 35% | 38% | 85% | 58% | 55% | 58% | 48% |
| SCIL | All | | | | | | | | | | | | | | | | | | | | |
| SOCO | All | | | | | | | | | | | | | | | | | | | | |
| SPP_N | All | | | | | | | | | | | | | | | | | | | | |
| SPP_S | All | | | | | | | | | | | | | | | | | | | | |
| TVA | All | | | | | | | | | | | | | | | | | | | | |
| VACAR | All | 50% | 30% | 34% | 42% | 41% | 40% | 37% | 32% | 34% | 32% | 38% | 41% | 41% | 44% | 40% | 31% | 31% | 39% | 45% | 45% |
| WUMS | All | 14% | 25% | 30% | 30% | 23% | 24% | 27% | 26% | 32% | 32% | 17% | 21% | 33% | 34% | 39% | 62% | 45% | 37% | 44% | 37% |

**Appendix A, Exhibit 5 - Mapping of BA's to NEEM Regions (for generator mapping)**

| Plant Balancing Authority Area Name | NEEM Region(s) |
|---|---|
| | |
| Alberta Electric System Operator | ALB |
| Allegheny Power Service | AE |
| Alliant Energy | MAPP_US |
| Alliant Energy East | WUMS |
| Ameren | EMO, SCIL |
| American Electric Power | PJM_Midwest |
| American Electric Power West | SPP_S |
| Aquila Networks MPS | SPP_N |
| Arizona Public Service Co | AZ_NM_SNV |
| Associated Electric Coop Inc | EMO |
| Avista Corp | NWPP |
| Big Rivers Electric Corp | NonRTO_Midwest |
| Bonneville Power Administration | NWPP |
| British Columbia Hydro & Power Authority | BC |
| British Columbia Transmission Corp | BC |
| California Independent System Operator | NP15, SP15 |
| Central & Southwest Services | SPP_S |
| Central Illinois Light Co | SCIL |
| Cleco Corp | SPP_S |
| Columbia Water & Light | EMO |
| Commonwealth Edison Co | NI |
| Dairyland Power Coop | WUMS |
| Dayton Power & Light | PJM_Midwest |
| Duke Energy Carolinas LLC | VACAR |
| Duke Energy Corp | MISO_E |
| Duquesne Light | PJM_Midwest |
| East Kentucky Power Coop Inc | NonRTO_Midwest |
| El Paso Electric | AZ_NM_SNV |
| Electric Energy Inc | SCIL |
| Empire District Electric Co | SPP_N |
| Entergy | ENT |
| ERCOT ISO | ERCOT |
| FirstEnergy | PJM_Midwest |
| Florida Municipal Power Pool | FRCC |
| Florida Power & Light | FRCC |
| Gainesville Regional Utilities | FRCC |
| Grand River Dam Authority | SPP_S |
| Great River Energy | MAPP_US |
| Homestead (City of) | FRCC |
| Hoosier Energy | MISO_E |
| Idaho Power Co | NWPP |
| IESO (Ontario) | OH |
| Illinois Power Co | SCIL |
| Imperial Irrigation District | SP15 |
| Independence MO (City of) | SPP_N |
| Indianapolis Power & Light Co | MISO_E |
| JEA | FRCC |
| Kansas City KS (City of) | SPP_N |
| Kansas City Power & Light | SPP_N |
| KGE A Westar Energy Co | SPP_N |
| Lafayette Utilities System | SPP_S |
| Lake Worth Utilities | FRCC |
| Lincoln Electric System | NE |
| Los Angeles Dept of Water & Power | SP15 |
| Louisiana Energy & Power Authority | SPP_S |
| Louisiana Generating LLC | ENT |
| Louisville Gas & Electric Co | NonRTO_Midwest |
| Madison Gas & Electric Co | WUMS |
| Michigan Electric Coordinated System | MI |
| MidAmerican Energy Co | MAPP_US |
| Mid-Columbia (includes CHPD,GCPD,DOPD) | NWPP |
| Minnesota Power Co | MAPP_US |
| Muscatine Power & Water | MAPP_US |
| Nebraska Public Power District | NE |
| Nevada Power Co | AZ_NM_SNV |

**Appendix A, Exhibit 5 - Mapping of BA's to NEEM Regions (for generator mapping)**

| Plant Balancing Authority Area Name | NEEM Region(s) |
|---|---|
| New England ISO | NEISO |
| New Smyrna Beach Utilities Commission | FRCC |
| New York ISO | NYISO_Upstate, NYISO_Downstate, NYISO_Capital, NYISO_NYC, NYISO_LIPA |
| Northern Indiana Public Service Co | MISO_E |
| Northern States Power | MAPP_US |
| Northwestern Energy | NWPP |
| Oglethorpe Power Corp | SOCO |
| Ohio Valley Electric Corp | NonRTO_Midwest |
| Oklahoma Gas & Electric Co | SPP_S |
| Omaha Public Power District | NE |
| Otter Tail Power Co | MAPP_US |
| PacifiCorp | NWPP |
| PacifiCorp East | NWPP |
| PacifiCorp West | NWPP |
| PJM Interconnection | PJM_E, PJM_W, PJM_SW, PJM_Midwest |
| Portland General Electric | NWPP |
| PowerSouth Energy Coop | SOCO |
| Progress Energy Carolina East | VACAR |
| Progress Energy Carolina West | VACAR |
| Progress Energy Florida | FRCC |
| Public Service Co of Colorado | RMPA |
| Public Service Co of New Mexico | AZ_NM_SNV |
| PUD No 1 of Douglas County | NWPP |
| PUD No 2 of Grant County | NWPP |
| Puget Sound Energy Inc | NWPP |
| Sacramento Municipal Utility District | NP15 |
| Salt River Project | AZ_NM_SNV |
| Seattle City Light | NWPP |
| Seminole Electric Coop Inc | FRCC |
| Sierra Pacific Power Co | NWPP |
| South Carolina Electric & Gas Co | VACAR |
| South Carolina Public Service Authority | VACAR |
| South Mississippi Electric Power Association | SOCO |
| Southern Co Services Inc | SOCO |
| Southern Illinois Power Coop | SCIL |
| Southern Indiana Gas & Electric Co | MISO_E |
| Southern Minnesota Municipal Power | MAPP_US |
| Southwestern Power Administration | SPP_S |
| Southwestern Public Service Co | SPP_S |
| Springfield IL City Water Light & Power | SCIL |
| Sunflower Electric Power Corp | SPP_N |
| Tacoma Power | NWPP |
| Tallahassee FL (City of) | FRCC |
| Tampa Electric Co | FRCC |
| Tennessee Valley Authority | TVA |
| Tucson Electric Power Co | AZ_NM_SNV |
| TXU Electric Co | ERCOT |
| Upper Peninsula Power Co | WUMS |
| Virginia Electric & Power Co | PJM_D |
| WAPA Desert Southwest Region | AZ_NM_SNV |
| WAPA Rocky Mountain Region | RMPA |
| WAPA Upper Great Plains Region East | MAPP_US |
| WAPA Upper Great Plains Region West | NWPP |
| Westar Energy | SPP_N |
| Western Farmers Electric Coop | SPP_S |
| Westplains Energy (KS) | SPP_N |
| Wisconsin Electric Power | WUMS |
| Wisconsin Public Service Corp | WUMS |

**Appendix A, Exhibit 6 - Existing Units**

| Capacity Description | Aggregated/ Stand Alone | Gen Type | NEEM Region | Summer Capacity MW | Wtd. Avg. Forced Outage Rate | Wtd. Avg. Planned Outage Days |
|---|---|---|---|---|---|---|
| Fort Martin | Stand Alone | Coal | AE | 1,107 | 7.7% | 34.4 |
| Harrison (WV) | Stand Alone | Coal | AE | 1,954 | 6.3% | 33.8 |
| Hatfields Ferry Power Station | Stand Alone | Coal | AE | 1,590 | 7.7% | 34.4 |
| Mitchell Power Station | Stand Alone | Coal | AE | 277 | 6.0% | 28.3 |
| Pleasants | Stand Alone | Coal | AE | 1,278 | 6.3% | 33.8 |
| Labadie | Stand Alone | Coal | EMO | 2,406 | 6.6% | 33.9 |
| Meramec | Stand Alone | Coal | EMO | 603 | 6.2% | 29.2 |
| New Madrid (Memphis) | Stand Alone | Coal | EMO | 1,160 | 7.7% | 34.4 |
| Rush Island | Stand Alone | Coal | EMO | 1,181 | 7.0% | 34.1 |
| Sioux | Stand Alone | Coal | EMO | 993 | 7.7% | 34.4 |
| Thomas Hill | Stand Alone | Coal | EMO | 945 | 6.2% | 32.2 |
| Big Cajun 2 | Stand Alone | Coal | ENT | 1,743 | 7.7% | 34.4 |
| Independence (AR) | Stand Alone | Coal | ENT | 1,678 | 3.6% | 31.6 |
| Roy S Nelson | Stand Alone | Coal | ENT | 550 | 7.7% | 34.4 |
| White Bluff | Stand Alone | Coal | ENT | 1,655 | 3.6% | 31.6 |
| Big Bend (FL) | Stand Alone | Coal | FRCC | 1,550 | 6.7% | 31.1 |
| C D McIntosh Jr | Stand Alone | Coal | FRCC | 342 | 6.4% | 29.9 |
| Cedar Bay Generating Co LP | Stand Alone | Coal | FRCC | 250 | 6.0% | 28.3 |
| Crystal River | Stand Alone | Coal | FRCC | 2,388 | 6.6% | 33.3 |
| Deerhaven Generating Station | Stand Alone | Coal | FRCC | 228 | 6.0% | 28.3 |
| Indiantown Cogeneration Facility | Stand Alone | Coal | FRCC | 330 | 6.4% | 29.9 |
| Northside Generating | Stand Alone | Coal | FRCC | 550 | 6.0% | 28.3 |
| Polk Station | Stand Alone | Coal | FRCC | 235 | 6.0% | 28.3 |
| Seminole (FL) | Stand Alone | Coal | FRCC | 1,316 | 6.3% | 33.8 |
| St Johns River Power Park | Stand Alone | Coal | FRCC | 1,252 | 6.3% | 33.8 |
| Stanton Energy Center | Stand Alone | Coal | FRCC | 886 | 7.7% | 34.4 |
| Boundary Dam | Stand Alone | Coal | MAPP_CA | 273 | 6.6% | 27.3 |
| Poplar River | Stand Alone | Coal | MAPP_CA | 562 | 6.6% | 27.3 |
| Shand | Stand Alone | Coal | MAPP_CA | 276 | 6.6% | 27.3 |
| Allen S King Plant | Stand Alone | Coal | MAPP_US | 528 | 7.7% | 34.4 |
| Antelope Valley | Stand Alone | Coal | MAPP_US | 900 | 6.7% | 29.8 |
| Big Stone | Stand Alone | Coal | MAPP_US | 475 | 7.7% | 34.4 |
| Clay Boswell | Stand Alone | Coal | MAPP_US | 886 | 7.2% | 32.6 |
| Coal Creek | Stand Alone | Coal | MAPP_US | 1,114 | 5.8% | 25.2 |
| Coyote | Stand Alone | Coal | MAPP_US | 427 | 5.8% | 25.2 |
| George Neal North | Stand Alone | Coal | MAPP_US | 810 | 7.1% | 32.2 |
| George Neal South | Stand Alone | Coal | MAPP_US | 644 | 6.3% | 33.8 |
| Lansing | Stand Alone | Coal | MAPP_US | 262 | 6.0% | 28.3 |
| Laramie River | Stand Alone | Coal | MAPP_US | 565 | 23.2% | 103.9 |
| Leland Olds 1 & 2 | Stand Alone | Coal | MAPP_US | 669 | 5.8% | 25.2 |
| Louisa | Stand Alone | Coal | MAPP_US | 745 | 6.3% | 33.8 |
| M L Kapp | Stand Alone | Coal | MAPP_US | 212 | 6.0% | 28.3 |
| Milton R Young | Stand Alone | Coal | MAPP_US | 697 | 5.8% | 25.2 |
| Ottumwa (IA IPL) | Stand Alone | Coal | MAPP_US | 710 | 6.3% | 33.8 |
| Sherburne County | Stand Alone | Coal | MAPP_US | 2,243 | 5.2% | 32.9 |
| Walter Scott Jr Energy Center | Stand Alone | Coal | MAPP_US | 1,490 | 4.8% | 32.6 |
| Belle River | Stand Alone | Coal | MI | 1,270 | 6.3% | 33.8 |
| D E Karn | Stand Alone | Coal | MI | 515 | 6.0% | 28.3 |
| J H Campbell | Stand Alone | Coal | MI | 1,440 | 4.7% | 30.6 |
| Monroe (MI) | Stand Alone | Coal | MI | 3,115 | 6.3% | 33.8 |
| River Rouge | Stand Alone | Coal | MI | 523 | 6.0% | 28.3 |
| St Clair | Stand Alone | Coal | MI | 752 | 7.1% | 32.6 |
| Trenton Channel | Stand Alone | Coal | MI | 520 | 7.7% | 34.4 |
| A B Brown | Stand Alone | Coal | MISO_E | 490 | 6.0% | 28.3 |
| AES Petersburg (IN) | Stand Alone | Coal | MISO_E | 1,752 | 7.5% | 33.6 |
| Bailly | Stand Alone | Coal | MISO_E | 320 | 6.4% | 29.9 |
| Cayuga | Stand Alone | Coal | MISO_E | 995 | 7.7% | 34.4 |
| East Bend | Stand Alone | Coal | MISO_E | 600 | 6.3% | 33.8 |
| F B Culley | Stand Alone | Coal | MISO_E | 270 | 6.0% | 28.3 |
| Gibson Station | Stand Alone | Coal | MISO_E | 3,131 | 6.3% | 33.8 |
| Harding Street | Stand Alone | Coal | MISO_E | 435 | 7.7% | 34.4 |
| Merom | Stand Alone | Coal | MISO_E | 955 | 7.7% | 34.4 |
| Miami Fort | Stand Alone | Coal | MISO_E | 1,000 | 7.7% | 34.4 |
| Michigan City | Stand Alone | Coal | MISO_E | 469 | 7.7% | 34.4 |
| R M Schahfer | Stand Alone | Coal | MISO_E | 1,625 | 7.1% | 32.4 |
| W H Zimmer | Stand Alone | Coal | MISO_E | 1,300 | 7.6% | 35.3 |
| Wabash River | Stand Alone | Coal | MISO_E | 592 | 6.2% | 29.2 |
| Walter C Beckjord | Stand Alone | Coal | MISO_E | 652 | 7.1% | 32.2 |
| Gerald Gentleman | Stand Alone | Coal | NE | 1,365 | 6.3% | 33.8 |
| Nebraska City | Stand Alone | Coal | NE | 1,328 | 6.0% | 29.4 |
| North Omaha | Stand Alone | Coal | NE | 224 | 6.0% | 28.3 |
| Brayton PT | Stand Alone | Coal | NEISO | 1,100 | 6.2% | 31.3 |
| Bridgeport Station | Stand Alone | Coal | NEISO | 383 | 6.4% | 29.9 |

**LEGEND**

| Gen Type | Description |
|---|---|
| CC | Combined Cycle - Natural Gas |
| Coal | Steam Turbine - Coal |
| CT | Combustion Turbine - Natural Gas or Oil |
| GEO | Geothermal |
| HY | Hydro - Conventional |
| LFG | Landfill Gas |
| NU | Nuclear |
| PS | Hydro - Pumped Storage |
| PV | Solar - Photovoltaic |
| ST | Solar - Solar Thermal/Conc Solar Power |
| STOG | Steam Turbine - Oil/Gas |
| STWD | Steam Turbine - Wood |
| WT | Wind Turbine |

**Appendix A, Exhibit 6 - Existing Units**

| Capacity Description | Aggregated/ Stand Alone | Gen Type | NEEM Region | Summer Capacity MW | Wtd. Avg. Forced Outage Rate | Wtd. Avg. Planned Outage Days |
|---|---|---|---|---|---|---|
| Merrimack | Stand Alone | Coal | NEISO | 320 | 6.4% | 29.9 |
| Crawford (IL) | Stand Alone | Coal | NI | 532 | 6.2% | 29.3 |
| Fisk Street | Stand Alone | Coal | NI | 326 | 6.4% | 29.9 |
| Joliet 29 | Stand Alone | Coal | NI | 1,036 | 7.7% | 34.4 |
| Joliet 9 | Stand Alone | Coal | NI | 314 | 6.4% | 29.9 |
| Kincaid Generation LLC | Stand Alone | Coal | NI | 1,158 | 7.7% | 34.4 |
| Powerton | Stand Alone | Coal | NI | 1,538 | 6.3% | 33.8 |
| State Line Energy | Stand Alone | Coal | NI | 318 | 6.4% | 29.9 |
| Waukegan | Stand Alone | Coal | NI | 689 | 6.4% | 29.9 |
| Will County | Stand Alone | Coal | NI | 761 | 7.1% | 32.4 |
| Cane Run | Stand Alone | Coal | NonRTO_Midwest | 240 | 6.0% | 28.3 |
| Clifty Creek | Stand Alone | Coal | NonRTO_Midwest | 1,203 | 6.0% | 28.3 |
| D B Wilson | Stand Alone | Coal | NonRTO_Midwest | 417 | 7.7% | 34.4 |
| E W Brown | Stand Alone | Coal | NonRTO_Midwest | 429 | 7.7% | 34.4 |
| Elmer Smith | Stand Alone | Coal | NonRTO_Midwest | 261 | 6.0% | 28.3 |
| Ghent | Stand Alone | Coal | NonRTO_Midwest | 1,918 | 7.7% | 34.4 |
| Hugh L Spurlock | Stand Alone | Coal | NonRTO_Midwest | 1,381 | 6.7% | 30.9 |
| J Sherman Cooper | Stand Alone | Coal | NonRTO_Midwest | 225 | 6.0% | 28.3 |
| Kyger Creek | Stand Alone | Coal | NonRTO_Midwest | 200 | 6.0% | 28.3 |
| Mill Creek (KY) | Stand Alone | Coal | NonRTO_Midwest | 1,472 | 6.8% | 31.4 |
| Robert D Green | Stand Alone | Coal | NonRTO_Midwest | 454 | 6.0% | 28.3 |
| Trimble Station (LGE) | Stand Alone | Coal | NonRTO_Midwest | 1,243 | 6.9% | 34.0 |
| Danskammer Generating Station | Stand Alone | Coal | NYISO_Downstate | 233 | 6.0% | 28.3 |
| AES Somerset LLC | Stand Alone | Coal | NYISO_Upstate | 684 | 6.3% | 33.8 |
| Atikokan GS | Stand Alone | Coal | OH | 211 | 6.0% | 28.3 |
| Lambton GS | Stand Alone | Coal | OH | 1,961 | 7.7% | 34.4 |
| Nanticoke | Stand Alone | Coal | OH | 3,938 | 7.7% | 34.4 |
| Birchwood Power Facility | Stand Alone | Coal | PJM_D | 238 | 6.0% | 28.3 |
| Chesapeake | Stand Alone | Coal | PJM_D | 217 | 6.0% | 28.3 |
| Chesterfield | Stand Alone | Coal | PJM_D | 982 | 6.3% | 32.5 |
| Clover | Stand Alone | Coal | PJM_D | 865 | 7.7% | 34.4 |
| MT Storm | Stand Alone | Coal | PJM_D | 1,560 | 7.7% | 34.4 |
| Carneys Point Generating Plant | Stand Alone | Coal | PJM_E | 262 | 6.0% | 28.3 |
| Eddystone Generating Station | Stand Alone | Coal | PJM_E | 588 | 6.2% | 29.2 |
| Hudson Generating Station | Stand Alone | Coal | PJM_E | 568 | 7.7% | 34.4 |
| Indian River Generating Station (DE) | Stand Alone | Coal | PJM_E | 436 | 7.7% | 34.4 |
| Logan Generating Plant | Stand Alone | Coal | PJM_E | 219 | 6.0% | 28.3 |
| Mercer Generating Station | Stand Alone | Coal | PJM_E | 648 | 6.4% | 29.9 |
| Ashtabula | Stand Alone | Coal | PJM_Midwest | 244 | 6.0% | 28.3 |
| Avon Lake | Stand Alone | Coal | PJM_Midwest | 625 | 6.3% | 33.8 |
| Bay Shore | Stand Alone | Coal | PJM_Midwest | 215 | 6.0% | 28.3 |
| Big Sandy | Stand Alone | Coal | PJM_Midwest | 1,060 | 4.2% | 30.8 |
| Bruce Mansfield | Stand Alone | Coal | PJM_Midwest | 2,510 | 3.6% | 31.6 |
| Cardinal | Stand Alone | Coal | PJM_Midwest | 1,800 | 7.2% | 34.2 |
| Cheswick Power Plant | Stand Alone | Coal | PJM_Midwest | 580 | 7.7% | 34.4 |
| Clinch River | Stand Alone | Coal | PJM_Midwest | 690 | 6.0% | 28.3 |
| Conesville | Stand Alone | Coal | PJM_Midwest | 1,530 | 6.3% | 31.9 |
| Eastlake (OH) | Stand Alone | Coal | PJM_Midwest | 837 | 7.2% | 32.7 |
| Gavin | Stand Alone | Coal | PJM_Midwest | 2,640 | 7.6% | 35.3 |
| Glen Lyn | Stand Alone | Coal | PJM_Midwest | 235 | 6.0% | 28.3 |
| J M Stuart | Stand Alone | Coal | PJM_Midwest | 2,340 | 7.7% | 34.4 |
| John E Amos | Stand Alone | Coal | PJM_Midwest | 2,900 | 5.4% | 33.3 |
| Kammer | Stand Alone | Coal | PJM_Midwest | 600 | 6.0% | 28.3 |
| Kanawha River | Stand Alone | Coal | PJM_Midwest | 400 | 6.0% | 28.3 |
| Killen Station | Stand Alone | Coal | PJM_Midwest | 600 | 6.3% | 33.8 |
| Lake Shore | Stand Alone | Coal | PJM_Midwest | 245 | 6.0% | 28.3 |
| Mitchell (WV) | Stand Alone | Coal | PJM_Midwest | 1,560 | 6.3% | 33.8 |
| Mountaineer | Stand Alone | Coal | PJM_Midwest | 1,310 | 7.6% | 35.3 |
| Muskingum River | Stand Alone | Coal | PJM_Midwest | 995 | 7.0% | 31.9 |
| Phil Sporn | Stand Alone | Coal | PJM_Midwest | 440 | 7.7% | 34.4 |
| Rockport | Stand Alone | Coal | PJM_Midwest | 2,600 | 7.6% | 35.3 |
| Tanners Creek | Stand Alone | Coal | PJM_Midwest | 700 | 7.2% | 32.7 |
| W H Sammis | Stand Alone | Coal | PJM_Midwest | 1,500 | 6.3% | 33.0 |
| Brandon Shores | Stand Alone | Coal | PJM_SW | 1,286 | 6.3% | 33.8 |
| Chalk Point | Stand Alone | Coal | PJM_SW | 683 | 6.4% | 29.9 |
| Herbert A Wagner | Stand Alone | Coal | PJM_SW | 324 | 6.4% | 29.9 |
| Morgantown Generating Station | Stand Alone | Coal | PJM_SW | 1,244 | 6.3% | 33.8 |
| Conemaugh | Stand Alone | Coal | PJM_W | 1,700 | 3.6% | 31.6 |
| Homer City Station | Stand Alone | Coal | PJM_W | 1,884 | 6.3% | 33.8 |
| Keystone (PA) | Stand Alone | Coal | PJM_W | 1,700 | 3.6% | 31.6 |
| Montour | Stand Alone | Coal | PJM_W | 1,525 | 6.3% | 33.8 |
| Portland (PA) | Stand Alone | Coal | PJM_W | 243 | 6.0% | 28.3 |
| PPL Brunner Island | Stand Alone | Coal | PJM_W | 1,442 | 6.3% | 31.9 |

**LEGEND**

| Gen Type | Description |
|---|---|

Appendix A, Exhibit 6 - Existing Units

| Capacity Description | Aggregated/ Stand Alone | Gen Type | NEEM Region | Summer Capacity MW | Wtd. Avg. Forced Outage Rate | Wtd. Avg. Planned Outage Days |
|---|---|---|---|---|---|---|
| Seward | Stand Alone | Coal | PJM_W | 521 | 7.7% | 34.4 |
| Baldwin Energy Complex | Stand Alone | Coal | SCIL | 1,764 | 7.7% | 34.4 |
| Coffeen | Stand Alone | Coal | SCIL | 900 | 7.2% | 32.7 |
| Dallman | Stand Alone | Coal | SCIL | 200 | 6.0% | 28.3 |
| Duck Creek | Stand Alone | Coal | SCIL | 358 | 6.4% | 29.9 |
| E D Edwards | Stand Alone | Coal | SCIL | 598 | 6.2% | 29.2 |
| Havana | Stand Alone | Coal | SCIL | 438 | 7.7% | 34.4 |
| Hennepin Power Station | Stand Alone | Coal | SCIL | 215 | 6.0% | 28.3 |
| Meredosia | Stand Alone | Coal | SCIL | 203 | 6.0% | 28.3 |
| Newton (IL) | Stand Alone | Coal | SCIL | 1,201 | 7.0% | 34.1 |
| Wood River (IL) | Stand Alone | Coal | SCIL | 355 | 6.4% | 29.9 |
| Bowen | Stand Alone | Coal | SOCO | 3,221 | 4.8% | 32.6 |
| Charles R Lowman | Stand Alone | Coal | SOCO | 470 | 6.0% | 28.3 |
| Crist | Stand Alone | Coal | SOCO | 774 | 7.2% | 32.7 |
| E C Gaston | Stand Alone | Coal | SOCO | 1,862 | 4.9% | 29.8 |
| Gorgas 2 & 3 | Stand Alone | Coal | SOCO | 677 | 6.3% | 33.8 |
| Greene County (AL) | Stand Alone | Coal | SOCO | 497 | 6.0% | 28.3 |
| Hammond | Stand Alone | Coal | SOCO | 503 | 7.7% | 34.4 |
| Harllee Branch | Stand Alone | Coal | SOCO | 1,607 | 7.1% | 32.5 |
| Jack McDonough | Stand Alone | Coal | SOCO | 503 | 6.0% | 28.3 |
| Jack Watson | Stand Alone | Coal | SOCO | 706 | 7.1% | 32.4 |
| James H Miller Jr | Stand Alone | Coal | SOCO | 2,752 | 6.3% | 33.8 |
| James M Barry Electric Generating Plant | Stand Alone | Coal | SOCO | 1,345 | 6.3% | 31.7 |
| Scherer | Stand Alone | Coal | SOCO | 3,405 | 3.6% | 31.6 |
| Victor J Daniel Jr | Stand Alone | Coal | SOCO | 1,020 | 7.7% | 34.4 |
| Wansley (GPC) | Stand Alone | Coal | SOCO | 1,752 | 3.6% | 31.6 |
| Yates | Stand Alone | Coal | SOCO | 707 | 6.4% | 29.9 |
| Hawthorne (MO) | Stand Alone | Coal | SPP_N | 563 | 7.7% | 34.4 |
| Holcomb East | Stand Alone | Coal | SPP_N | 362 | 6.4% | 29.9 |
| Iatan | Stand Alone | Coal | SPP_N | 651 | 6.3% | 33.8 |
| Jeffrey Energy Center | Stand Alone | Coal | SPP_N | 2,170 | 6.3% | 33.8 |
| La Cygne | Stand Alone | Coal | SPP_N | 1,418 | 6.3% | 33.8 |
| Lawrence Energy Center (KS) | Stand Alone | Coal | SPP_N | 373 | 6.4% | 29.9 |
| Nearman Creek | Stand Alone | Coal | SPP_N | 229 | 6.0% | 28.3 |
| Sibley (MO) | Stand Alone | Coal | SPP_N | 401 | 7.7% | 34.4 |
| Brame Energy Center | Stand Alone | Coal | SPP_S | 1,112 | 7.7% | 34.4 |
| Dolet Hills | Stand Alone | Coal | SPP_S | 672 | 5.8% | 25.2 |
| Flint Creek (AR) | Stand Alone | Coal | SPP_S | 528 | 7.7% | 34.4 |
| Grda 1 & 2 | Stand Alone | Coal | SPP_S | 1,010 | 7.7% | 34.4 |
| Harrington | Stand Alone | Coal | SPP_S | 1,041 | 6.4% | 29.9 |
| Hugo (OK) | Stand Alone | Coal | SPP_S | 440 | 7.7% | 34.4 |
| Muskogee | Stand Alone | Coal | SPP_S | 1,530 | 7.7% | 34.4 |
| Northeastern | Stand Alone | Coal | SPP_S | 920 | 7.7% | 34.4 |
| Oklaunion | Stand Alone | Coal | SPP_S | 533 | 6.0% | 28.3 |
| Pirkey | Stand Alone | Coal | SPP_S | 675 | 5.8% | 25.2 |
| Sikeston | Stand Alone | Coal | SPP_S | 233 | 6.0% | 28.3 |
| Sooner | Stand Alone | Coal | SPP_S | 1,046 | 7.7% | 34.4 |
| Tolk | Stand Alone | Coal | SPP_S | 1,080 | 7.7% | 34.4 |
| Welsh Station | Stand Alone | Coal | SPP_S | 1,584 | 7.7% | 34.4 |
| Allen Steam Plant (TN) | Stand Alone | Coal | TVA | 741 | 6.0% | 28.3 |
| Bull Run (TN) | Stand Alone | Coal | TVA | 870 | 3.6% | 31.6 |
| Colbert | Stand Alone | Coal | TVA | 472 | 7.7% | 34.4 |
| Cumberland (TN) | Stand Alone | Coal | TVA | 2,478 | 7.6% | 35.3 |
| Gallatin (TN) | Stand Alone | Coal | TVA | 976 | 6.0% | 28.3 |
| Paradise (KY) | Stand Alone | Coal | TVA | 2,201 | 5.1% | 32.8 |
| Red Hills Generating Facility | Stand Alone | Coal | TVA | 440 | 5.8% | 25.2 |
| Widows Creek | Stand Alone | Coal | TVA | 938 | 7.7% | 34.4 |
| Belews Creek | Stand Alone | Coal | VACAR | 2,270 | 7.6% | 35.3 |
| Cliffside | Stand Alone | Coal | VACAR | 562 | 7.7% | 34.4 |
| Cope | Stand Alone | Coal | VACAR | 420 | 7.7% | 34.4 |
| Cross | Stand Alone | Coal | VACAR | 2,320 | 7.3% | 34.2 |
| G G Allen | Stand Alone | Coal | VACAR | 815 | 6.0% | 28.3 |
| L V Sutton | Stand Alone | Coal | VACAR | 403 | 7.7% | 34.4 |
| Lee | Stand Alone | Coal | VACAR | 246 | 6.0% | 28.3 |
| Marshall (NC DUKE) | Stand Alone | Coal | VACAR | 2,110 | 6.3% | 32.4 |
| Mayo | Stand Alone | Coal | VACAR | 742 | 6.3% | 33.8 |
| Roxboro | Stand Alone | Coal | VACAR | 2,424 | 6.3% | 33.2 |
| Wateree | Stand Alone | Coal | VACAR | 700 | 6.4% | 29.9 |
| Williams (SC SCGC) | Stand Alone | Coal | VACAR | 615 | 6.3% | 33.8 |
| Winyah | Stand Alone | Coal | VACAR | 1,155 | 6.0% | 28.3 |
| Columbia (WI) | Stand Alone | Coal | WUMS | 1,118 | 7.7% | 34.4 |
| Edgewater (WI) | Stand Alone | Coal | WUMS | 734 | 7.1% | 32.5 |
| Genoa No3 | Stand Alone | Coal | WUMS | 351 | 6.4% | 29.9 |

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| Gen Type | Description |
|---|---|

**Appendix A, Exhibit 6 - Existing Units**

| Capacity Description | Aggregated/ Stand Alone | Gen Type | NEEM Region | Summer Capacity MW | Wtd. Avg. Forced Outage Rate | Wtd. Avg. Planned Outage Days |
|---|---|---|---|---|---|---|
| John P Madgett | Stand Alone | Coal | WUMS | 393 | 6.4% | 29.9 |
| Oak Creek Power Plant | Stand Alone | Coal | WUMS | 615 | 6.3% | 33.8 |
| Pleasant Prairie | Stand Alone | Coal | WUMS | 1,216 | 6.3% | 33.8 |
| South Oak Creek | Stand Alone | Coal | WUMS | 1,135 | 6.1% | 28.7 |
| Weston | Stand Alone | Coal | WUMS | 870 | 7.2% | 32.7 |
| AE Aggregated CC | Aggregated | CC | AE | 1,110 | 8.3% | 24.7 |
| AE Aggregated Coal | Aggregated | Coal | AE | 1,642 | 7.2% | 26.4 |
| AE Aggregated CT | Aggregated | CT | AE | 1,200 | 8.3% | 15.9 |
| AE Aggregated HY | Aggregated | HY | AE | 239 | 7.7% | 0.0 |
| AE Aggregated LFG | Aggregated | LFG | AE | 14 | 8.3% | 18.3 |
| AE Aggregated STOG | Aggregated | STOG | AE | 164 | 8.3% | 32.1 |
| AE Aggregated STWD | Aggregated | STWD | AE | 38 | 8.3% | 36.5 |
| AE Aggregated WT | Aggregated | WT | AE | 15 | 8.3% | 0.0 |
| EMO Aggregated CC | Aggregated | CC | EMO | 1,029 | 7.3% | 24.7 |
| EMO Aggregated Coal | Aggregated | Coal | EMO | 519 | 6.9% | 26.9 |
| EMO Aggregated CT | Aggregated | CT | EMO | 2,214 | 8.4% | 13.7 |
| EMO Aggregated HY | Aggregated | HY | EMO | 378 | 6.3% | 0.0 |
| EMO Aggregated LFG | Aggregated | LFG | EMO | 5 | 8.3% | 18.3 |
| EMO Aggregated NU | Aggregated | NU | EMO | 1,190 | 8.3% | 28.6 |
| EMO Aggregated PS | Aggregated | PS | EMO | 471 | 0.5% | 0.0 |
| EMO Aggregated PV | Aggregated | PV | EMO | 0 | 60.0% | 36.5 |
| EMO Aggregated STOG | Aggregated | STOG | EMO | 51 | 7.8% | 32.1 |
| EMO Aggregated WT | Aggregated | WT | EMO | 257 | 8.3% | 0.0 |
| ENT Aggregated CC | Aggregated | CC | ENT | 12,917 | 7.0% | 24.7 |
| ENT Aggregated Coal | Aggregated | Coal | ENT | 337 | 7.1% | 26.6 |
| ENT Aggregated CT | Aggregated | CT | ENT | 2,267 | 8.4% | 15.6 |
| ENT Aggregated HY | Aggregated | HY | ENT | 714 | 6.3% | 0.0 |
| ENT Aggregated LFG | Aggregated | LFG | ENT | 8 | 6.3% | 18.3 |
| ENT Aggregated NU | Aggregated | NU | ENT | 5,252 | 6.2% | 28.6 |
| ENT Aggregated PS | Aggregated | PS | ENT | 28 | 8.3% | 0.0 |
| ENT Aggregated PV | Aggregated | PV | ENT | 0 | 8.3% | 36.5 |
| ENT Aggregated STOG | Aggregated | STOG | ENT | 14,865 | 7.4% | 32.1 |
| ENT Aggregated STWD | Aggregated | STWD | ENT | 206 | 8.8% | 36.5 |
| ENT Aggregated WT | Aggregated | WT | ENT | 0 | 8.3% | 0.0 |
| FRCC Aggregated CC | Aggregated | CC | FRCC | 21,784 | 7.2% | 24.7 |
| FRCC Aggregated Coal | Aggregated | Coal | FRCC | 136 | 6.6% | 27.3 |
| FRCC Aggregated CT | Aggregated | CT | FRCC | 10,878 | 8.4% | 14.0 |
| FRCC Aggregated HY | Aggregated | HY | FRCC | 55 | 8.3% | 0.0 |
| FRCC Aggregated LFG | Aggregated | LFG | FRCC | 486 | 6.5% | 18.3 |
| FRCC Aggregated NU | Aggregated | NU | FRCC | 3,902 | 4.3% | 28.6 |
| FRCC Aggregated PV | Aggregated | PV | FRCC | 51 | 8.9% | 36.5 |
| FRCC Aggregated STOG | Aggregated | STOG | FRCC | 9,833 | 7.7% | 32.1 |
| FRCC Aggregated STWD | Aggregated | STWD | FRCC | 195 | 9.6% | 36.5 |
| MAPP_CA Aggregated CC | Aggregated | CC | MAPP_CA | 730 | 7.4% | 24.7 |
| MAPP_CA Aggregated Coal | Aggregated | Coal | MAPP_CA | 635 | 7.0% | 26.7 |
| MAPP_CA Aggregated CT | Aggregated | CT | MAPP_CA | 563 | 8.3% | 15.8 |
| MAPP_CA Aggregated HY | Aggregated | HY | MAPP_CA | 5,834 | 7.9% | 0.0 |
| MAPP_CA Aggregated STOG | Aggregated | STOG | MAPP_CA | 126 | 6.7% | 32.1 |
| MAPP_CA Aggregated WT | Aggregated | WT | MAPP_CA | 275 | 4.8% | 0.0 |
| MAPP_US Aggregated CC | Aggregated | CC | MAPP_US | 3,313 | 8.0% | 24.7 |
| MAPP_US Aggregated Coal | Aggregated | Coal | MAPP_US | 3,112 | 7.3% | 26.2 |
| MAPP_US Aggregated CT | Aggregated | CT | MAPP_US | 7,459 | 8.5% | 13.1 |
| MAPP_US Aggregated GEO | Aggregated | GEO | MAPP_US | 44 | 8.0% | 0.0 |
| MAPP_US Aggregated HY | Aggregated | HY | MAPP_US | 2,657 | 7.2% | 0.0 |
| MAPP_US Aggregated LFG | Aggregated | LFG | MAPP_US | 188 | 7.3% | 18.3 |
| MAPP_US Aggregated NU | Aggregated | NU | MAPP_US | 2,267 | 5.9% | 28.6 |
| MAPP_US Aggregated PV | Aggregated | PV | MAPP_US | 0 | 31.8% | 36.5 |
| MAPP_US Aggregated STOG | Aggregated | STOG | MAPP_US | 208 | 7.7% | 32.1 |
| MAPP_US Aggregated STWD | Aggregated | STWD | MAPP_US | 313 | 8.9% | 36.5 |
| MAPP_US Aggregated WT | Aggregated | WT | MAPP_US | 6,090 | 4.8% | 0.0 |
| MI Aggregated CC | Aggregated | CC | MI | 4,338 | 8.0% | 24.7 |
| MI Aggregated Coal | Aggregated | Coal | MI | 2,657 | 6.9% | 26.8 |
| MI Aggregated CT | Aggregated | CT | MI | 4,094 | 8.5% | 14.7 |
| MI Aggregated HY | Aggregated | HY | MI | 141 | 7.7% | 0.0 |
| MI Aggregated LFG | Aggregated | LFG | MI | 163 | 7.5% | 18.3 |
| MI Aggregated NU | Aggregated | NU | MI | 1,889 | 6.2% | 28.6 |
| MI Aggregated PS | Aggregated | PS | MI | 1,872 | 8.3% | 0.0 |
| MI Aggregated PV | Aggregated | PV | MI | 0 | 60.0% | 36.5 |
| MI Aggregated STOG | Aggregated | STOG | MI | 2,852 | 8.2% | 32.1 |
| MI Aggregated STWD | Aggregated | STWD | MI | 163 | 8.7% | 36.5 |
| MI Aggregated WT | Aggregated | WT | MI | 161 | 6.4% | 0.0 |
| MISO_E Aggregated CC | Aggregated | CC | MISO_E | 1,448 | 6.1% | 24.7 |
| MISO_E Aggregated Coal | Aggregated | Coal | MISO_E | 2,812 | 7.1% | 26.6 |

**LEGEND**

| Gen Type | Description |
|---|---|

**Appendix A, Exhibit 6 - Existing Units**

| Capacity Description | Aggregated/ Stand Alone | Gen Type | NEEM Region | Summer Capacity MW | Wtd. Avg. Forced Outage Rate | Wtd. Avg. Planned Outage Days |
|---|---|---|---|---|---|---|
| MISO_E Aggregated CT | Aggregated | CT | MISO_E | 4,853 | 8.4% | 14.8 |
| MISO_E Aggregated HY | Aggregated | HY | MISO_E | 147 | 8.1% | 0.0 |
| MISO_E Aggregated LFG | Aggregated | LFG | MISO_E | 40 | 6.6% | 18.3 |
| MISO_E Aggregated STOG | Aggregated | STOG | MISO_E | 314 | 8.3% | 32.1 |
| MISO_E Aggregated WT | Aggregated | WT | MISO_E | 535 | 8.3% | 0.0 |
| NE Aggregated CC | Aggregated | CC | NE | 358 | 7.6% | 24.7 |
| NE Aggregated Coal | Aggregated | Coal | NE | 961 | 7.0% | 26.8 |
| NE Aggregated CT | Aggregated | CT | NE | 1,631 | 8.4% | 14.1 |
| NE Aggregated HY | Aggregated | HY | NE | 167 | 7.8% | 0.0 |
| NE Aggregated LFG | Aggregated | LFG | NE | 6 | 8.3% | 18.3 |
| NE Aggregated NU | Aggregated | NU | NE | 1,252 | 8.3% | 28.6 |
| NE Aggregated STOG | Aggregated | STOG | NE | 270 | 8.1% | 32.1 |
| NE Aggregated WT | Aggregated | WT | NE | 142 | 4.7% | 0.0 |
| NEISO Aggregated CC | Aggregated | CC | NEISO | 11,463 | 7.4% | 24.7 |
| NEISO Aggregated Coal | Aggregated | Coal | NEISO | 767 | 7.0% | 26.7 |
| NEISO Aggregated CT | Aggregated | CT | NEISO | 2,384 | 8.8% | 11.5 |
| NEISO Aggregated HY | Aggregated | HY | NEISO | 1,933 | 6.9% | 0.0 |
| NEISO Aggregated LFG | Aggregated | LFG | NEISO | 532 | 6.6% | 18.3 |
| NEISO Aggregated NU | Aggregated | NU | NEISO | 4,645 | 5.5% | 28.6 |
| NEISO Aggregated PS | Aggregated | PS | NEISO | 1,674 | 2.8% | 0.0 |
| NEISO Aggregated PV | Aggregated | PV | NEISO | 2 | 52.2% | 36.5 |
| NEISO Aggregated STOG | Aggregated | STOG | NEISO | 6,236 | 7.5% | 32.1 |
| NEISO Aggregated STWD | Aggregated | STWD | NEISO | 609 | 8.8% | 36.5 |
| NEISO Aggregated WT | Aggregated | WT | NEISO | 202 | 4.3% | 0.0 |
| NI Aggregated CC | Aggregated | CC | NI | 1,833 | 8.3% | 24.7 |
| NI Aggregated Coal | Aggregated | Coal | NI | 496 | 6.6% | 27.3 |
| NI Aggregated CT | Aggregated | CT | NI | 7,378 | 8.3% | 15.4 |
| NI Aggregated HY | Aggregated | HY | NI | 27 | 6.9% | 0.0 |
| NI Aggregated LFG | Aggregated | LFG | NI | 116 | 7.2% | 18.3 |
| NI Aggregated NU | Aggregated | NU | NI | 10,412 | 7.4% | 28.6 |
| NI Aggregated PV | Aggregated | PV | NI | 10 | 8.3% | 36.5 |
| NI Aggregated STWD | Aggregated | STWD | NI | 20 | 10.0% | 36.5 |
| NI Aggregated WT | Aggregated | WT | NI | 1,625 | 2.7% | 0.0 |
| NonRTO_Midwest Aggregated Coal | Aggregated | Coal | NonRTO_Midwest | 2,873 | 6.8% | 27.0 |
| NonRTO_Midwest Aggregated CT | Aggregated | CT | NonRTO_Midwest | 3,430 | 8.3% | 15.7 |
| NonRTO_Midwest Aggregated HY | Aggregated | HY | NonRTO_Midwest | 143 | 7.0% | 0.0 |
| NonRTO_Midwest Aggregated LFG | Aggregated | LFG | NonRTO_Midwest | 14 | 6.9% | 18.3 |
| NonRTO_Midwest Aggregated STWD | Aggregated | STWD | NonRTO_Midwest | 0 | 8.3% | 36.5 |
| NonRTO_Midwest Aggregated WT | Aggregated | WT | NonRTO_Midwest | 66 | 8.3% | 0.0 |
| NYISO_Capital Aggregated CC | Aggregated | CC | NYISO_Capital | 1,382 | 7.6% | 24.7 |
| NYISO_Capital Aggregated CT | Aggregated | CT | NYISO_Capital | 2 | 8.3% | 7.0 |
| NYISO_Capital Aggregated HY | Aggregated | HY | NYISO_Capital | 378 | 6.4% | 0.0 |
| NYISO_Capital Aggregated LFG | Aggregated | LFG | NYISO_Capital | 20 | 6.4% | 18.3 |
| NYISO_Capital Aggregated PS | Aggregated | PS | NYISO_Capital | 1,172 | 8.3% | 0.0 |
| NYISO_Capital Aggregated STOG | Aggregated | STOG | NYISO_Capital | 23 | 8.3% | 32.1 |
| NYISO_Capital Aggregated WT | Aggregated | WT | NYISO_Capital | 0 | 6.6% | 0.0 |
| NYISO_Downstate Aggregated CC | Aggregated | CC | NYISO_Downstate | 1,157 | 8.3% | 24.7 |
| NYISO_Downstate Aggregated Coal | Aggregated | Coal | NYISO_Downstate | 136 | 6.6% | 27.3 |
| NYISO_Downstate Aggregated CT | Aggregated | CT | NYISO_Downstate | 152 | 8.8% | 10.8 |
| NYISO_Downstate Aggregated HY | Aggregated | HY | NYISO_Downstate | 32 | 6.2% | 0.0 |
| NYISO_Downstate Aggregated LFG | Aggregated | LFG | NYISO_Downstate | 64 | 5.6% | 18.3 |
| NYISO_Downstate Aggregated NU | Aggregated | NU | NYISO_Downstate | 2,045 | 8.3% | 28.6 |
| NYISO_Downstate Aggregated STOG | Aggregated | STOG | NYISO_Downstate | 2,431 | 7.5% | 32.1 |
| NYISO_Downstate Aggregated WT | Aggregated | WT | NYISO_Downstate | 0 | 8.3% | 0.0 |
| NYISO_LIPA Aggregated CC | Aggregated | CC | NYISO_LIPA | 731 | 7.5% | 24.7 |
| NYISO_LIPA Aggregated CT | Aggregated | CT | NYISO_LIPA | 2,102 | 8.8% | 10.4 |
| NYISO_LIPA Aggregated HY | Aggregated | HY | NYISO_LIPA | 0 | 4.9% | 0.0 |
| NYISO_LIPA Aggregated LFG | Aggregated | LFG | NYISO_LIPA | 124 | 8.3% | 18.3 |
| NYISO_LIPA Aggregated STOG | Aggregated | STOG | NYISO_LIPA | 2,574 | 7.1% | 32.1 |
| NYISO_NYC Aggregated CC | Aggregated | CC | NYISO_NYC | 2,210 | 8.1% | 24.7 |
| NYISO_NYC Aggregated CT | Aggregated | CT | NYISO_NYC | 2,846 | 8.3% | 13.2 |
| NYISO_NYC Aggregated STOG | Aggregated | STOG | NYISO_NYC | 4,225 | 7.7% | 32.1 |
| NYISO_Upstate Aggregated CC | Aggregated | CC | NYISO_Upstate | 2,212 | 7.7% | 24.7 |
| NYISO_Upstate Aggregated Coal | Aggregated | Coal | NYISO_Upstate | 1,568 | 6.9% | 26.8 |
| NYISO_Upstate Aggregated CT | Aggregated | CT | NYISO_Upstate | 259 | 8.5% | 14.6 |
| NYISO_Upstate Aggregated HY | Aggregated | HY | NYISO_Upstate | 4,017 | 8.1% | 0.0 |
| NYISO_Upstate Aggregated LFG | Aggregated | LFG | NYISO_Upstate | 147 | 6.9% | 18.3 |
| NYISO_Upstate Aggregated NU | Aggregated | NU | NYISO_Upstate | 3,197 | 4.6% | 28.6 |
| NYISO_Upstate Aggregated PS | Aggregated | PS | NYISO_Upstate | 240 | 8.3% | 0.0 |
| NYISO_Upstate Aggregated PV | Aggregated | PV | NYISO_Upstate | 0 | 60.0% | 36.5 |
| NYISO_Upstate Aggregated STOG | Aggregated | STOG | NYISO_Upstate | 1,678 | 6.7% | 32.1 |
| NYISO_Upstate Aggregated STWD | Aggregated | STWD | NYISO_Upstate | 86 | 9.3% | 36.5 |
| NYISO_Upstate Aggregated WT | Aggregated | WT | NYISO_Upstate | 1,283 | 7.1% | 0.0 |

**LEGEND**

| Gen Type | Description |
|---|---|

**Appendix A, Exhibit 6 - Existing Units**

| Capacity Description | Aggregated/ Stand Alone | Gen Type | NEEM Region | Summer Capacity MW | Wtd. Avg. Forced Outage Rate | Wtd. Avg. Planned Outage Days |
|---|---|---|---|---|---|---|
| OH Aggregated CC | Aggregated | CC | OH | 5,943 | 7.3% | 24.7 |
| OH Aggregated Coal | Aggregated | Coal | OH | 306 | 6.6% | 27.3 |
| OH Aggregated CT | Aggregated | CT | OH | 760 | 8.3% | 13.8 |
| OH Aggregated HY | Aggregated | HY | OH | 8,004 | 6.3% | 0.0 |
| OH Aggregated LFG | Aggregated | LFG | OH | 103 | 7.8% | 18.3 |
| OH Aggregated NU | Aggregated | NU | OH | 11,478 | 6.9% | 28.6 |
| OH Aggregated PS | Aggregated | PS | OH | 123 | 0.0% | 0.0 |
| OH Aggregated PV | Aggregated | PV | OH | 30 | 43.4% | 36.5 |
| OH Aggregated STOG | Aggregated | STOG | OH | 2,126 | 8.3% | 32.1 |
| OH Aggregated STWD | Aggregated | STWD | OH | 139 | 8.4% | 36.5 |
| OH Aggregated WT | Aggregated | WT | OH | 1,280 | 5.1% | 0.0 |
| PJM_D Aggregated CC | Aggregated | CC | PJM_D | 3,524 | 7.3% | 24.7 |
| PJM_D Aggregated Coal | Aggregated | Coal | PJM_D | 2,037 | 7.1% | 26.5 |
| PJM_D Aggregated CT | Aggregated | CT | PJM_D | 3,978 | 8.4% | 14.8 |
| PJM_D Aggregated HY | Aggregated | HY | PJM_D | 646 | 7.7% | 0.0 |
| PJM_D Aggregated LFG | Aggregated | LFG | PJM_D | 273 | 7.7% | 18.2 |
| PJM_D Aggregated NU | Aggregated | NU | PJM_D | 3,650 | 3.2% | 28.6 |
| PJM_D Aggregated PS | Aggregated | PS | PJM_D | 2,843 | 8.3% | 0.0 |
| PJM_D Aggregated PV | Aggregated | PV | PJM_D | 0 | 42.8% | 36.5 |
| PJM_D Aggregated STOG | Aggregated | STOG | PJM_D | 1,923 | 6.7% | 32.1 |
| PJM_D Aggregated STWD | Aggregated | STWD | PJM_D | 124 | 9.4% | 36.5 |
| PJM_D Aggregated WT | Aggregated | WT | PJM_D | 264 | 8.3% | 0.0 |
| PJM_E Aggregated CC | Aggregated | CC | PJM_E | 8,366 | 7.6% | 24.7 |
| PJM_E Aggregated Coal | Aggregated | Coal | PJM_E | 1,132 | 7.0% | 26.7 |
| PJM_E Aggregated CT | Aggregated | CT | PJM_E | 6,899 | 8.6% | 12.3 |
| PJM_E Aggregated HY | Aggregated | HY | PJM_E | 4 | 6.1% | 0.0 |
| PJM_E Aggregated LFG | Aggregated | LFG | PJM_E | 462 | 7.0% | 18.3 |
| PJM_E Aggregated NU | Aggregated | NU | PJM_E | 8,472 | 5.2% | 28.6 |
| PJM_E Aggregated PS | Aggregated | PS | PJM_E | 400 | 0.0% | 0.0 |
| PJM_E Aggregated PV | Aggregated | PV | PJM_E | 22 | 36.1% | 36.5 |
| PJM_E Aggregated STOG | Aggregated | STOG | PJM_E | 3,252 | 7.8% | 32.1 |
| PJM_E Aggregated WT | Aggregated | WT | PJM_E | 10 | 8.3% | 0.0 |
| PJM_Midwest Aggregated CC | Aggregated | CC | PJM_Midwest | 4,023 | 7.5% | 24.7 |
| PJM_Midwest Aggregated Coal | Aggregated | Coal | PJM_Midwest | 5,461 | 6.9% | 26.8 |
| PJM_Midwest Aggregated CT | Aggregated | CT | PJM_Midwest | 7,014 | 8.4% | 15.2 |
| PJM_Midwest Aggregated HY | Aggregated | HY | PJM_Midwest | 619 | 6.0% | 0.0 |
| PJM_Midwest Aggregated LFG | Aggregated | LFG | PJM_Midwest | 76 | 7.4% | 18.3 |
| PJM_Midwest Aggregated NU | Aggregated | NU | PJM_Midwest | 5,938 | 7.2% | 28.6 |
| PJM_Midwest Aggregated PS | Aggregated | PS | PJM_Midwest | 238 | 0.0% | 0.0 |
| PJM_Midwest Aggregated PV | Aggregated | PV | PJM_Midwest | 14 | 60.0% | 36.5 |
| PJM_Midwest Aggregated STWD | Aggregated | STWD | PJM_Midwest | 11 | 9.3% | 36.5 |
| PJM_Midwest Aggregated WT | Aggregated | WT | PJM_Midwest | 693 | 8.3% | 0.0 |
| PJM_SW Aggregated CC | Aggregated | CC | PJM_SW | 226 | 6.1% | 24.7 |
| PJM_SW Aggregated Coal | Aggregated | Coal | PJM_SW | 1,548 | 6.8% | 27.1 |
| PJM_SW Aggregated CT | Aggregated | CT | PJM_SW | 2,176 | 8.9% | 10.9 |
| PJM_SW Aggregated HY | Aggregated | HY | PJM_SW | 548 | 8.3% | 0.0 |
| PJM_SW Aggregated LFG | Aggregated | LFG | PJM_SW | 122 | 6.6% | 18.3 |
| PJM_SW Aggregated NU | Aggregated | NU | PJM_SW | 1,845 | 8.3% | 28.6 |
| PJM_SW Aggregated PV | Aggregated | PV | PJM_SW | 1 | 14.8% | 36.5 |
| PJM_SW Aggregated STOG | Aggregated | STOG | PJM_SW | 2,439 | 8.2% | 32.1 |
| PJM_W Aggregated CC | Aggregated | CC | PJM_W | 3,760 | 8.0% | 24.7 |
| PJM_W Aggregated Coal | Aggregated | Coal | PJM_W | 2,281 | 7.2% | 26.3 |
| PJM_W Aggregated CT | Aggregated | CT | PJM_W | 1,379 | 8.9% | 11.9 |
| PJM_W Aggregated HY | Aggregated | HY | PJM_W | 687 | 5.6% | 0.0 |
| PJM_W Aggregated LFG | Aggregated | LFG | PJM_W | 215 | 7.7% | 18.3 |
| PJM_W Aggregated NU | Aggregated | NU | PJM_W | 3,191 | 3.2% | 28.6 |
| PJM_W Aggregated PS | Aggregated | PS | PJM_W | 1,513 | 0.0% | 0.0 |
| PJM_W Aggregated PV | Aggregated | PV | PJM_W | 3 | 60.0% | 36.5 |
| PJM_W Aggregated STOG | Aggregated | STOG | PJM_W | 1,670 | 8.3% | 32.1 |
| PJM_W Aggregated STWD | Aggregated | STWD | PJM_W | 70 | 9.7% | 36.5 |
| PJM_W Aggregated WT | Aggregated | WT | PJM_W | 731 | 6.6% | 0.0 |
| SCIL Aggregated CC | Aggregated | CC | SCIL | 997 | 8.3% | 24.7 |
| SCIL Aggregated Coal | Aggregated | Coal | SCIL | 2,271 | 7.0% | 26.6 |
| SCIL Aggregated CT | Aggregated | CT | SCIL | 3,839 | 8.4% | 15.1 |
| SCIL Aggregated HY | Aggregated | HY | SCIL | 4 | 8.3% | 0.0 |
| SCIL Aggregated LFG | Aggregated | LFG | SCIL | 13 | 7.4% | 18.3 |
| SCIL Aggregated NU | Aggregated | NU | SCIL | 1,043 | 8.3% | 28.6 |
| SCIL Aggregated PV | Aggregated | PV | SCIL | 0 | 47.5% | 36.5 |
| SCIL Aggregated STOG | Aggregated | STOG | SCIL | 542 | 7.9% | 32.1 |
| SCIL Aggregated WT | Aggregated | WT | SCIL | 228 | 2.0% | 0.0 |
| SOCO Aggregated CC | Aggregated | CC | SOCO | 14,812 | 7.5% | 24.7 |
| SOCO Aggregated Coal | Aggregated | Coal | SOCO | 3,535 | 6.8% | 26.9 |
| SOCO Aggregated CT | Aggregated | CT | SOCO | 12,062 | 8.4% | 15.0 |

**LEGEND**

| Gen Type | Description |
|---|---|

**Appendix A, Exhibit 6 - Existing Units**

| Capacity Description | Aggregated/ Stand Alone | Gen Type | NEEM Region | Summer Capacity MW | Wtd. Avg. Forced Outage Rate | Wtd. Avg. Planned Outage Days |
|---|---|---|---|---|---|---|
| SOCO Aggregated HY | Aggregated | HY | SOCO | 4,194 | 7.2% | 0.0 |
| SOCO Aggregated LFG | Aggregated | LFG | SOCO | 37 | 6.0% | 18.3 |
| SOCO Aggregated NU | Aggregated | NU | SOCO | 5,771 | 6.3% | 28.6 |
| SOCO Aggregated PS | Aggregated | PS | SOCO | 1,675 | 1.4% | 0.0 |
| SOCO Aggregated PV | Aggregated | PV | SOCO | 0 | 60.0% | 36.5 |
| SOCO Aggregated STOG | Aggregated | STOG | SOCO | 854 | 8.1% | 32.1 |
| SOCO Aggregated STWD | Aggregated | STWD | SOCO | 668 | 8.9% | 36.5 |
| SOCO Aggregated WT | Aggregated | WT | SOCO | 0 | 4.4% | 0.0 |
| SPP_N Aggregated CC | Aggregated | CC | SPP_N | 1,386 | 7.5% | 24.7 |
| SPP_N Aggregated Coal | Aggregated | Coal | SPP_N | 1,716 | 7.1% | 26.6 |
| SPP_N Aggregated CT | Aggregated | CT | SPP_N | 5,596 | 8.6% | 14.0 |
| SPP_N Aggregated HY | Aggregated | HY | SPP_N | 21 | 5.4% | 0.0 |
| SPP_N Aggregated LFG | Aggregated | LFG | SPP_N | 7 | 5.0% | 18.3 |
| SPP_N Aggregated NU | Aggregated | NU | SPP_N | 1,160 | 3.2% | 28.6 |
| SPP_N Aggregated PV | Aggregated | PV | SPP_N | 0 | 8.3% | 36.5 |
| SPP_N Aggregated STOG | Aggregated | STOG | SPP_N | 1,748 | 7.9% | 32.1 |
| SPP_N Aggregated WT | Aggregated | WT | SPP_N | 1,227 | 5.9% | 0.0 |
| SPP_S Aggregated CC | Aggregated | CC | SPP_S | 10,917 | 7.6% | 24.7 |
| SPP_S Aggregated Coal | Aggregated | Coal | SPP_S | 736 | 7.0% | 26.7 |
| SPP_S Aggregated CT | Aggregated | CT | SPP_S | 3,564 | 8.3% | 15.6 |
| SPP_S Aggregated HY | Aggregated | HY | SPP_S | 2,108 | 7.0% | 0.0 |
| SPP_S Aggregated LFG | Aggregated | LFG | SPP_S | 19 | 5.0% | 18.3 |
| SPP_S Aggregated PS | Aggregated | PS | SPP_S | 446 | 3.5% | 0.0 |
| SPP_S Aggregated STOG | Aggregated | STOG | SPP_S | 10,570 | 7.3% | 32.1 |
| SPP_S Aggregated STWD | Aggregated | STWD | SPP_S | 84 | 8.3% | 36.5 |
| SPP_S Aggregated WT | Aggregated | WT | SPP_S | 2,297 | 4.5% | 0.0 |
| TVA Aggregated CC | Aggregated | CC | TVA | 4,463 | 8.3% | 24.7 |
| TVA Aggregated Coal | Aggregated | Coal | TVA | 6,043 | 6.6% | 27.3 |
| TVA Aggregated CT | Aggregated | CT | TVA | 5,949 | 8.3% | 15.8 |
| TVA Aggregated HY | Aggregated | HY | TVA | 5,111 | 6.7% | 0.0 |
| TVA Aggregated LFG | Aggregated | LFG | TVA | 13 | 8.3% | 18.3 |
| TVA Aggregated NU | Aggregated | NU | TVA | 6,697 | 5.7% | 28.6 |
| TVA Aggregated PS | Aggregated | PS | TVA | 1,743 | 0.4% | 0.0 |
| TVA Aggregated PV | Aggregated | PV | TVA | 0 | 8.3% | 36.5 |
| TVA Aggregated STWD | Aggregated | STWD | TVA | 5 | 8.3% | 36.5 |
| TVA Aggregated WT | Aggregated | WT | TVA | 29 | 8.3% | 0.0 |
| VACAR Aggregated CC | Aggregated | CC | VACAR | 3,524 | 7.4% | 24.7 |
| VACAR Aggregated Coal | Aggregated | Coal | VACAR | 5,354 | 7.0% | 26.6 |
| VACAR Aggregated CT | Aggregated | CT | VACAR | 9,576 | 8.4% | 14.7 |
| VACAR Aggregated HY | Aggregated | HY | VACAR | 2,122 | 6.6% | 0.0 |
| VACAR Aggregated LFG | Aggregated | LFG | VACAR | 63 | 7.3% | 18.3 |
| VACAR Aggregated NU | Aggregated | NU | VACAR | 11,430 | 6.7% | 28.6 |
| VACAR Aggregated PS | Aggregated | PS | VACAR | 2,616 | 8.3% | 0.0 |
| VACAR Aggregated PV | Aggregated | PV | VACAR | 16 | 46.9% | 36.5 |
| VACAR Aggregated STOG | Aggregated | STOG | VACAR | 92 | 8.3% | 32.1 |
| VACAR Aggregated STWD | Aggregated | STWD | VACAR | 281 | 8.5% | 36.5 |
| VACAR Aggregated WT | Aggregated | WT | VACAR | 0 | 4.2% | 0.0 |
| WUMS Aggregated CC | Aggregated | CC | WUMS | 2,724 | 6.6% | 24.7 |
| WUMS Aggregated Coal | Aggregated | Coal | WUMS | 2,104 | 7.4% | 26.0 |
| WUMS Aggregated CT | Aggregated | CT | WUMS | 3,995 | 8.4% | 14.4 |
| WUMS Aggregated HY | Aggregated | HY | WUMS | 362 | 6.9% | 0.0 |
| WUMS Aggregated LFG | Aggregated | LFG | WUMS | 89 | 6.5% | 18.3 |
| WUMS Aggregated NU | Aggregated | NU | WUMS | 1,582 | 5.0% | 28.6 |
| WUMS Aggregated PV | Aggregated | PV | WUMS | 0 | 60.0% | 36.5 |
| WUMS Aggregated STOG | Aggregated | STOG | WUMS | 359 | 7.6% | 32.1 |
| WUMS Aggregated STWD | Aggregated | STWD | WUMS | 105 | 9.7% | 36.5 |
| WUMS Aggregated WT | Aggregated | WT | WUMS | 1,296 | 4.9% | 0.0 |

**LEGEND**

| Gen Type | Description |
|---|---|

**Appendix A, Exhibit 7 - Forced New Builds**

Appendix A, Exhibit 8 - Forced Retirements

| NEEM Region | Retire Year | Plant Name | Unit | MW | Tech-nology | Plant State |
|---|---|---|---|---|---|---|
| AE | 2011 | Richard H Gorsuch | 1 | 50 | Coal | OH |
| AE | 2011 | Richard H Gorsuch | 2 | 50 | Coal | OH |
| AE | 2011 | Richard H Gorsuch | 3 | 50 | Coal | OH |
| AE | 2011 | Richard H Gorsuch | 4 | 50 | Coal | OH |
| ENT | 2011 | Big Cajun 1 | 1 | 113.6 | STOG | LA |
| ENT | 2011 | Big Cajun 1 | 2 | 113.6 | STOG | LA |
| FRCC | 2011 | Cape Canaveral | 1 | 402 | STOG | FL |
| FRCC | 2011 | Cape Canaveral | 2 | 402 | STOG | FL |
| FRCC | 2020 | Crystal River | 1 | 440.5 | Coal | FL |
| FRCC | 2020 | Crystal River | 2 | 523.8 | Coal | FL |
| MAPP_US | 2014 | Univ of Iowa Main | GEN1 | 3 | Coal | IA |
| MAPP_US | 2014 | Univ of Iowa Main | GEN2 | 3 | Coal | IA |
| MAPP_US | 2014 | Univ of Iowa Main | GEN6 | 15 | Coal | IA |
| MI | 2012 | James de Young | 3 | 11.5 | Coal | MI |
| MI | 2018 | B C Cobb | 4 | 156.3 | Coal | MI |
| MI | 2018 | B C Cobb | 5 | 156.3 | Coal | MI |
| MI | 2018 | J C Weadock | 7 | 156.3 | Coal | MI |
| MI | 2018 | J C Weadock | 8 | 156.3 | Coal | MI |
| MI | 2018 | J R Whiting | 1 | 106.3 | Coal | MI |
| MI | 2018 | J R Whiting | 2 | 106.3 | Coal | MI |
| MI | 2018 | J R Whiting | 3 | 132.8 | Coal | MI |
| MISO_E | 2012 | Edwardsport | 7 | 40.2 | Coal | IN |
| MISO_E | 2012 | Edwardsport | 8 | 69 | Coal | IN |
| NEISO | 2012 | Somerset Station | SOM6 | 100 | Coal | MA |
| NI | 2011 | Will County | 1 | 187.5 | Coal | IL |
| NI | 2011 | Will County | 2 | 183.7 | Coal | IL |
| NYISO_NYC | 2011 | Astoria Gas Turbines | 10 | 31.8 | CT | NY |
| NYISO_NYC | 2011 | Astoria Gas Turbines | 11 | 31.8 | CT | NY |
| NYISO_NYC | 2011 | Astoria Gas Turbines | 12 | 31.8 | CT | NY |
| NYISO_NYC | 2011 | Astoria Gas Turbines | 13 | 31.8 | CT | NY |
| NYISO_NYC | 2015 | Astoria Gas Turbines | 2 1 | 46.5 | CT | NY |
| NYISO_NYC | 2015 | Astoria Gas Turbines | 2 2 | 46.5 | CT | NY |
| NYISO_NYC | 2015 | Astoria Gas Turbines | 2 3 | 46.5 | CT | NY |
| NYISO_NYC | 2015 | Astoria Gas Turbines | 2 4 | 46.5 | CT | NY |
| NYISO_NYC | 2015 | Astoria Gas Turbines | 3 1 | 46.5 | CT | NY |
| NYISO_NYC | 2015 | Astoria Gas Turbines | 3 2 | 46.5 | CT | NY |
| NYISO_NYC | 2015 | Astoria Gas Turbines | 3 3 | 46.5 | CT | NY |
| NYISO_NYC | 2015 | Astoria Gas Turbines | 3 4 | 46.5 | CT | NY |
| NYISO_NYC | 2015 | Astoria Gas Turbines | 4 1 | 46.5 | CT | NY |
| NYISO_NYC | 2015 | Astoria Gas Turbines | 4 2 | 46.5 | CT | NY |
| NYISO_NYC | 2015 | Astoria Gas Turbines | 4 3 | 46.5 | CT | NY |
| NYISO_NYC | 2015 | Astoria Gas Turbines | 4 4 | 46.5 | CT | NY |
| NYISO_NYC | 2015 | Astoria Gas Turbines | 5 | 19.2 | CT | NY |
| NYISO_NYC | 2015 | Astoria Gas Turbines | 7 | 19.2 | CT | NY |
| NYISO_NYC | 2015 | Astoria Gas Turbines | 8 | 19.2 | CT | NY |
| OH | 2011 | Lambton GS | 1 | 520 | Coal | ON |
| OH | 2011 | Lambton GS | 2 | 520 | Coal | ON |
| OH | 2011 | Nanticoke | 3 | 510 | Coal | ON |
| OH | 2011 | Nanticoke | 4 | 505 | Coal | ON |
| OH | 2012 | Webeque First Nation | GEN1 | 0.65 | CT | ON |
| OH | 2014 | Atikokan GS | 1 | 211 | Coal | ON |
| OH | 2014 | Lambton GS | 3 | 489 | Coal | ON |
| OH | 2014 | Lambton GS | 4 | 502 | Coal | ON |
| OH | 2014 | Nanticoke | 1 | 490 | Coal | ON |
| OH | 2014 | Nanticoke | 2 | 490 | Coal | ON |
| OH | 2014 | Nanticoke | 5 | 490 | Coal | ON |
| OH | 2014 | Nanticoke | 6 | 490 | Coal | ON |
| OH | 2014 | Nanticoke | 7 | 508 | Coal | ON |
| OH | 2014 | Nanticoke | 8 | 490 | Coal | ON |
| PJM_D | 2011 | North Branch (WV) | 1 | 80 | Coal | WV |
| PJM_E | 2010 | Indian River Generating Station (DE) | 2 | 89 | Coal | DE |
| PJM_E | 2011 | Cromby Generating Station | 1 | 187.5 | Coal | PA |
| PJM_E | 2011 | Cromby Generating Station | 2 | 230 | STOG | PA |
| PJM_E | 2011 | Eddystone Generating Station | 1 | 353.6 | Coal | PA |
| PJM_E | 2011 | Howard M Down | 9 | 16.5 | STOG | NJ |
| PJM_E | 2011 | Indian River Generating Station (DE) | 1 | 81.6 | Coal | DE |
| PJM_E | 2013 | Eddystone Generating Station | 2 | 353.6 | Coal | PA |
| PJM_E | 2013 | Kearny Generating Station | 9 | 18.5 | CT | NJ |
| PJM_E | 2014 | Indian River Generating Station (DE) | 3 | 176.8 | Coal | DE |
| PJM_Midwest | 2013 | Conesville | 3 | 161.5 | Coal | OH |
| PJM_Midwest | 2014 | Phil Sporn | 5 | 495.5 | Coal | WV |
| PJM_Midwest | 2016 | Muskingum River | 3 | 237.5 | Coal | OH |
| PJM_Midwest | 2016 | Muskingum River | 4 | 237.5 | Coal | OH |
| PJM_Midwest | 2016 | Muskingum River | 1 | 219.6 | Coal | OH |
| PJM_Midwest | 2016 | Muskingum River | 2 | 219.6 | Coal | OH |

Appendix A, Exhibit 8 - Forced Retirements

| NEEM Region | Retire Year | Plant Name | Unit | MW | Tech-nology | Plant State |
|---|---|---|---|---|---|---|
| PJM_SW | 2012 | Benning | 15 | 290 | STOG | DC |
| PJM_SW | 2012 | Benning | 16 | 290 | STOG | DC |
| PJM_SW | 2012 | Buzzard Point | E1 | 18 | CT | DC |
| PJM_SW | 2012 | Buzzard Point | E2 | 18 | CT | DC |
| PJM_SW | 2012 | Buzzard Point | E4 | 18 | CT | DC |
| PJM_SW | 2012 | Buzzard Point | E5 | 18 | CT | DC |
| PJM_SW | 2012 | Buzzard Point | E6 | 18 | CT | DC |
| PJM_SW | 2012 | Buzzard Point | E7 | 18 | CT | DC |
| PJM_SW | 2012 | Buzzard Point | E8 | 18 | CT | DC |
| PJM_SW | 2012 | Buzzard Point | W10 | 18 | CT | DC |
| PJM_SW | 2012 | Buzzard Point | W11 | 18 | CT | DC |
| PJM_SW | 2012 | Buzzard Point | W12 | 18 | CT | DC |
| PJM_SW | 2012 | Buzzard Point | W13 | 18 | CT | DC |
| PJM_SW | 2012 | Buzzard Point | W14 | 18 | CT | DC |
| PJM_SW | 2012 | Buzzard Point | W15 | 18 | CT | DC |
| PJM_SW | 2012 | Buzzard Point | W16 | 18 | CT | DC |
| PJM_SW | 2012 | Buzzard Point | W9 | 18 | CT | DC |
| PJM_W | 2010 | Hunlock Power Station | 3 | 43 | Coal | PA |
| SOCO | 2011 | Mitchell (GA) | 3 | 163.2 | Coal | GA |
| SOCO | 2012 | Scholz | 1 | 46 | Coal | FL |
| SOCO | 2012 | Scholz | 2 | 46 | Coal | FL |
| SOCO | 2013 | Jack McDonough | 1 | 251 | Coal | GA |
| SOCO | 2013 | Jack McDonough | 2 | 252 | Coal | GA |
| SP15 | 2011 | Escondido | GEN1 | 44 | CT | CA |
| SP15 | 2011 | Mesa Wind Developers (ZPI) | WT1 300 | 19.5 | WT | CA |
| SP15 | 2011 | Mesa Wind Developers (ZPI) | WT301 460 | 10.4 | WT | CA |
| SP15 | 2011 | Ridgetop Energy LLC II | WT1 | 46.8 | WT | CA |
| SP15 | 2011 | South Bay | 2 | 136 | STOG | CA |
| SP15 | 2011 | South Bay | ST1 | 136 | STOG | CA |
| SP15 | 2012 | 251 Project | WGNS | 18.4 | WT | CA |
| SP15 | 2012 | MT Poso Cogeneration | TG01 | 57 | Coal | CA |
| SP15 | 2012 | Ridgetop Energy LLC | WT1 | 31.1 | WT | CA |
| SP15 | 2013 | Haynes | 5 | 343 | STOG | CA |
| SP15 | 2013 | Haynes | 6 | 343 | STOG | CA |
| SP15 | 2013 | South Bay | 5 | 15 | CT | CA |
| VACAR | 2011 | Cliffside | 1 | 40 | Coal | NC |
| VACAR | 2011 | Cliffside | 2 | 40 | Coal | NC |
| VACAR | 2011 | Cliffside | 3 | 65 | Coal | NC |
| VACAR | 2011 | Cliffside | 4 | 65 | Coal | NC |
| VACAR | 2012 | Buck Steam Station (NC) | 3 | 80 | Coal | NC |
| VACAR | 2012 | Buck Steam Station (NC) | 4 | 40 | Coal | NC |
| VACAR | 2013 | Dan River (NC) | 1 | 70 | Coal | NC |
| VACAR | 2013 | Dan River (NC) | 2 | 70 | Coal | NC |
| VACAR | 2013 | Dan River (NC) | 3 | 142 | Coal | NC |
| VACAR | 2013 | Lee | 3 | 252.4 | Coal | NC |
| VACAR | 2013 | Lee | 1 | 75 | Coal | NC |
| VACAR | 2013 | Lee | 2 | 75 | Coal | NC |
| VACAR | 2014 | L V Sutton | 3 | 446.6 | Coal | NC |
| VACAR | 2014 | L V Sutton | 1 | 112.5 | Coal | NC |
| VACAR | 2014 | L V Sutton | 2 | 112.5 | Coal | NC |
| VACAR | 2015 | Riverbend (NC) | 4 | 94 | Coal | NC |
| VACAR | 2015 | Riverbend (NC) | 5 | 94 | Coal | NC |
| VACAR | 2015 | Riverbend (NC) | 6 | 133 | Coal | NC |
| VACAR | 2015 | Riverbend (NC) | 7 | 133 | Coal | NC |
| VACAR | 2015 | W S Lee | 1 | 100 | Coal | SC |
| VACAR | 2015 | W S Lee | 2 | 100 | Coal | SC |
| VACAR | 2015 | W S Lee | 3 | 170 | Coal | SC |
| VACAR | 2018 | Cape Fear | 5 | 140.6 | Coal | NC |
| VACAR | 2018 | Cape Fear | 6 | 187.9 | Coal | NC |
| VACAR | 2018 | W H Weatherspoon | 1 | 46 | Coal | NC |
| VACAR | 2018 | W H Weatherspoon | 2 | 46 | Coal | NC |
| VACAR | 2018 | W H Weatherspoon | 3 | 73.5 | Coal | NC |
| WUMS | 2012 | Blount Street | 5 | 23 | Coal | WI |
| WUMS | 2012 | Blount Street | 3 | 34.5 | STOG | WI |
| WUMS | 2012 | Blount Street | 4 | 20 | STOG | WI |
| WUMS | 2014 | Rothschild (WI) | TG2 | 5 | STOG | WI |

## Appendix A, Exhibit 9 - Capital Cost Detail

| Technology | AEO: Base Overnight Costs in 2011 (2010$/kW) | Learning by 2025 | Base Overnight Capital Costs in 2025 ($2010/kW) | Gas Pipeline Cost | Electrical transmission | Rail Spur | Nuclear Decommissioning Cost | All-in Capital Cost in 2011 w/o IDC ($2010/kW) | All-in Capital Cost in 2025 w/o IDC ($2010/kW) | Sources |
|---|---|---|---|---|---|---|---|---|---|---|
| Nuclear | 5,339 | 10% | 4,805 | - | 21.92 | - | 253.97 | 5,615 | 5,081 | [1] |
| Advanced Coal | 2,844 | 5% | 2,702 | - | 21.92 | 18.99 | - | 2,885 | 2,743 | [2] |
| CC F-Frame | 978 | 5% | 929 | 9.98 | 21.92 | - | - | 1,010 | 961 | [3] |
| CC H-Frame | 1,003 | 5% | 953 | 9.98 | 21.92 | - | - | 1,035 | 985 | [4] |
| CT F-Frame | 665 | 5% | 632 | 24.41 | 20.66 | - | - | 710 | 677 | [5] |
| IGCC | 3,221 | 5% | 3,060 | - | 21.92 | 18.99 | - | 3,262 | 3,101 | [6] |
| IGCC w/seq | 5,348 | 11.0% | 4,762 | - | 21.92 | 18.99 | - | 5,389 | 4,802 | [7] |
| Wind | 2,438 | 1% | 2,414 | - | 172.98 | - | - | 2,611 | 2,587 | [8] |
| Wind Offshore | 5,975 | 20% | 4,780 | - | - | - | - | 5,975 | 4,780 | [9] |
| Photovoltaic | 4,755 | 20% | 3,804 | - | 172.98 | - | - | 4,928 | 3,977 | [10] |
| Solar Thermal | 4,692 | 20% | 3,754 | - | 172.98 | - | - | 4,865 | 3,927 | [11] |
| Landfill Gas | 2,503 | 5% | 2,378 | - | 21.92 | - | - | 2,525 | 2,400 | [12] |
| Biomass | 3,860 | 20% | 3,088 | - | 21.92 | 18.99 | - | 3,901 | 3,129 | [13] |
| Geothermal | 4,141 | 10% | 3,727 | - | 172.98 | - | - | 4,314 | 3,900 | [14] |

[1] Overnight Capital Costs: AEO 2011 ER, Table 1. Learning Assumptions: AEO 2010 Assumptions, Table 8.3. Contingency and Optimism factors included in AEO 2011 ER overnight costs; 22% Owner's costs also included, Table 12-1. Electric transmission source: PJM's "CONE Combined Cycle Revenue Requirements Update", Aug 26, 2008, Table 2, page 3. Nuclear Decommissioning Cost: CRA analysis.

[2] Overnight Capital Costs: AEO 2011 ER, Table 1. Learning Assumptions: AEO 2010 Assumptions, Table 8.3. Contingency and Optimism factors included in AEO 2011 ER overnight costs; 18% Owner's costs also included, Table 3-2. Electric transmission source: PJM's "CONE Combined Cycle Revenue Requirements Update", Aug 26, 2008, Table 2, page 3. Rail spur: CRA a

[3] Overnight Capital Costs: AEO 2011 ER, Table 1. Learning Assumptions: AEO 2010 Assumptions, Table 8.3. Contingency and Optimism factors included in AEO 2011 ER overnight costs; 20% Owner's costs also included, Table 5-1. Owner's Cost: CRA analysis. Gas pipeline source: PJM's "CONE Combined Cycle Revenue Requirements Update", Aug 26, 2008, Table 2, pag Electric transmission source: PJM's "CONE Combined Cycle Revenue Requirements Update", Aug 26, 2008, Table 2, page 3.

[4] Overnight Capital Costs: AEO 2011 ER, Table 1. Learning Assumptions: AEO 2010 Assumptions, Table 8.3. Contingency and Optimism factors included in AEO 2011 ER overnight costs; 20% Owner's costs also included, Table 6-1. Gas pipeline source: PJM's "CONE Combined Cycle Revenue Requirements Update", Aug 26, 2008, Table 2, page 3. Electric transmission sourc CONE Combined Cycle Revenue Requirements Update, Aug 26, 2008, Table 2, page 3.

[5] Overnight Capital Costs: AEO 2011 ER, Table 1. Learning Assumptions: AEO 2010 Assumptions, Table 8.3. Contingency and Optimism factors included in AEO 2011 ER overnight costs; 20% Owner's costs also included, Table 9-1. Gas pipeline source: PJM's "CONE Revenue Requirements 2008 Update", Table 5, page 14. PJM's "CONE Revenue Requirements 2008 Update"

[6] Overnight Capital Costs: AEO 2011 ER, Table 1. Learning Assumptions: AEO 2010 Assumptions, Table 8.3. Contingency and Optimism factors included in AEO 2011 ER overnight costs; 18% Owner's costs also included, Table 10-2. Electric transmission source: PJM's "CONE Combined Cycle Revenue Requirements Update", Aug 26, 2008, Table 2, page 3. Rail spur: CRA

[7] Overnight Capital Costs: AEO 2011 ER, Table 1. Learning Assumptions: AEO 2010 Assumptions, Table 8.3. Learning for IGCC with CCS equals the weighted average of the 5% learning fo and the 20% learning for CCS from AEO 2010. Contingency and Optimism factors included in AEO 2011 ER overnight costs; 20% Owner's costs also included, Table 11-1. Electric transmi PJM's "CONE Combined Cycle Revenue Requirements Update", Aug 26, 2008, Table 2, page 3. Rail spur source: CRA assumption.

[8] Overnight Capital Costs: AEO 2011 ER, Table 1. Learning Assumptions: AEO 2010 Assumptions, Table 8.3. Contingency and Optimism factors included in AEO 2011 ER overnight costs; 6% Owner's costs also included, Table 21-1. Electric transmission source: NREL's Wind Deployment System (WinDS) Model - average interconnection cost for the least expensive 300 GW i

[9] Overnight Capital Costs: AEO 2011 ER, Table 1. Learning Assumptions: AEO 2010 Assumptions, Table 8.3. Contingency and Optimism factors included in AEO 2011 ER overnight costs; 25% Owner's costs also included, Table 22-1. Electric transmission source: assumed to be located near load center.

[10] Overnight Capital Costs: AEO 2011 ER, Table 1. Learning Assumptions: AEO 2010 Assumptions, Table 8.3. Contingency and Optimism factors included in AEO 2011 ER overnight costs; 12% Owner's costs also included, Table 24-2. Electric transmission source: Assumed to be the same as wind.

[11] Overnight Capital Costs: AEO 2011 ER, Table 1. Learning Assumptions: AEO 2010 Assumptions, Table 8.3. Contingency and Optimism factors included in AEO 2011 ER overnight costs; 15% Owner's costs also included, Table 23-1. Electric transmission source: Assumed to be the same as wind.

[12] AEO 2010 Assumptions, Tables 8.2 & 8.3. Learning Assumptions: AEO 2010 Assumptions, Table 8.3. Electrical transmission cost assumed to be the same as nuclear, coal, CC's, etc.

[13] Overnight Capital Costs: AEO 2011 ER, Table 1. Learning Assumptions: AEO 2010 Assumptions, Table 8.3. Contingency and Optimism factors included in AEO 2011 ER overnight costs; 20% Owner's costs also included, Table 14-1. Electric transmission source: PJM's "CONE Combined Cycle Revenue Requirements Update", Aug 26, 2008, Table 2, page 3. Rail spur: CRA

[14] Overnight Capital Costs: AEO 2011 ER, Table 1. Learning Assumptions: AEO 2010 Assumptions, Table 8.3. Contingency and Optimism factors included in AEO 2011 ER overnight costs; 18% Owner's costs also included, Table 17-1. Electric transmission source: Assumed to be the same as wind.

| Technology | All-in Capital Cost in 2011 w/o IDC ($2010/kW) 2010 | 2015 | 2020 | 2025 | 2030 |
|---|---|---|---|---|---|
| Nuclear | 5,615 | 5,437 | 5,259 | 5,081 | 5,081 |
| Advanced Coal | 2,885 | 2,838 | 2,790 | 2,743 | 2,743 |
| CC | 1,010 | 1,018 | 1,001 | 985 | 985 |
| CT | 710 | 699 | 688 | 677 | 677 |
| IGCC | 3,262 | 3,208 | 3,155 | 3,101 | 3,101 |
| IGCC w/seq | 5,389 | 5,193 | 4,998 | 4,802 | 4,802 |
| Wind | 2,611 | 2,603 | 2,595 | 2,587 | 2,587 |
| Wind Offshore | 5,975 | 5,577 | 5,178 | 4,780 | 4,780 |
| Photovoltaic | 4,928 | 4,611 | 4,294 | 3,977 | 3,977 |
| Solar Thermal | 4,865 | 4,552 | 4,239 | 3,927 | 3,927 |
| Landfill Gas | 2,525 | 2,484 | 2,442 | 2,400 | 2,400 |
| Biomass | 3,901 | 3,644 | 3,386 | 3,129 | 3,129 |
| Geothermal | 4,314 | 4,176 | 4,038 | 3,900 | 3,900 |

Note: 2010 costs are assumed to equal 2011 costs. 2015 and 2020 costs are interpolated on a straightline basis between 2010 and 2025. 2030 costs are assumed to equal 2025 costs
CCs are assumed to use F-Frame technology until 2015 when the switch is made to H-Frame technology.

**Appendix A, Exhibit 10 - Regional Multipliers**
**(based on AEO 2011 early release)**

| Representative AEO Region | NEEM Region | Nuclear | Adv Coal | CC F-Frame | CC H-Frame | CT F-Frame | IGCC | IGCC w/Seq | Wind | Wind Offshr | Photo-voltaic | Solar Thermal | Landfill Gas | Bio-mass | Geo-thermal |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wilkes-Barre, Pennsylvania | AE | 0.985 | 0.962 | 0.983 | 0.984 | 1.617 | 0.970 | 0.959 | 0.982 | 1.000 | 0.950 | 0.927 | 0.966 | 0.941 | 1.000 |
| Phoenix, Arizona | AZ_NM_SNV_Coal | 0.976 | 0.943 | 1.026 | 1.026 | 1.044 | 0.954 | 0.945 | 0.976 | 1.000 | 0.938 | 0.911 | 0.955 | 1.000 | 0.970 |
| St. Louis, Missouri | EMO | 1.028 | 1.077 | 1.056 | 1.054 | 1.010 | 1.069 | 1.055 | 1.036 | 1.000 | 1.044 | 0.943 | 1.030 | 1.047 | 1.000 |
| Little Rock, Arkansas | ENT | 0.975 | 0.941 | 0.925 | 0.933 | 0.966 | 0.952 | 0.943 | 0.975 | 1.000 | 0.935 | 0.907 | 0.953 | 0.919 | 1.000 |
| Houston, Texas | ERCOT | 0.961 | 0.897 | 0.912 | 0.915 | 1.012 | 0.915 | 0.917 | 0.952 | 0.918 | 0.899 | 0.858 | 0.927 | 0.884 | 1.000 |
| Tampa, Florida | FRCC | 0.979 | 0.946 | 0.940 | 0.942 | 0.954 | 0.956 | 0.955 | 0.978 | 1.000 | 0.890 | 0.936 | 0.921 | 0.943 | 1.000 |
| St. Pual, Minnesota | MAPP_US | 1.019 | 1.041 | 1.045 | 1.044 | 0.994 | 1.036 | 1.034 | 0.925 | 1.048 | 1.060 | 1.072 | 1.023 | 1.043 | 1.000 |
| | MAPP_CA | TBD | TBD | TBD | TBD | TBD | TBD | TBD | TBD | TBD | TBD | TBD | TBD | TBD | TBD |
| Detroit, Michigan | MI | 1.016 | 1.040 | 1.053 | 1.052 | 0.970 | 1.035 | 1.035 | 0.973 | 1.028 | 1.034 | 1.048 | 1.027 | 1.039 | 1.000 |
| Indianapolis, Indiana | MISO_E | 1.020 | 1.035 | 1.009 | 1.009 | 1.017 | 1.033 | 1.012 | 0.997 | 0.990 | 0.988 | 0.981 | 0.991 | 1.015 | 1.000 |
| Omaha, Nebraska | NE | 0.985 | 0.961 | 0.985 | 0.986 | 1.343 | 0.969 | 0.962 | 1.035 | 1.000 | 0.983 | 0.965 | 0.970 | 0.949 | 1.000 |
| Boston, Massachusetts | NEISO | 1.183 | 1.387 | 1.400 | 1.389 | 1.126 | 1.338 | 1.262 | 1.111 | 1.132 | 1.164 | 1.222 | 1.118 | 1.335 | 1.000 |
| Chicago, Illinois | NI | 1.090 | 1.213 | 1.167 | 1.161 | 1.161 | 1.182 | 1.179 | 1.142 | 1.160 | 1.199 | 1.268 | 1.125 | 1.227 | 1.000 |
| Louisville, Kentucky | NonRTO_Midwest | 0.976 | 0.939 | 0.946 | 0.948 | 0.954 | 0.951 | 0.942 | 0.971 | 1.000 | 0.934 | 0.906 | 0.952 | 0.924 | 1.000 |
| Sacramento, California | NP15 | 1.065 | 1.157 | 1.205 | 1.199 | 1.013 | 1.137 | 1.111 | 1.105 | 1.000 | 1.105 | 1.133 | 1.057 | 1.119 | 1.054 |
| Salt Lake City, Utah | NWPP_Coal | 0.985 | 0.967 | 0.960 | 0.962 | 1.047 | 0.976 | 0.954 | 1.037 | 1.000 | 0.962 | 0.931 | 0.951 | 1.000 | 0.971 |
| Syracuse, New York | NYISO_Capital | 1.066 | 1.120 | 1.163 | 1.159 | 1.056 | 1.108 | 1.055 | 1.008 | 0.988 | 0.986 | 0.976 | 0.996 | 1.075 | 1.000 |
| Syracuse, New York | NYISO_Downstate | 1.066 | 1.120 | 1.163 | 1.159 | 1.056 | 1.108 | 1.055 | 1.008 | 0.988 | 0.986 | 0.976 | 0.996 | 1.075 | 1.000 |
| New York City, New York | NYISO_LIPA | 1.134 | 1.348 | 1.684 | 1.664 | 0.966 | 1.295 | 1.314 | 1.246 | 1.294 | 1.366 | 1.501 | 1.263 | 1.383 | 1.000 |
| New York City, New York | NYISO_NYC | 1.134 | 1.348 | 1.684 | 1.664 | 0.966 | 1.295 | 1.314 | 1.246 | 1.294 | 1.366 | 1.501 | 1.263 | 1.383 | 1.000 |
| Syracuse, New York | NYISO_Upstate | 1.066 | 1.120 | 1.163 | 1.159 | 1.056 | 1.108 | 1.055 | 1.008 | 0.988 | 0.986 | 0.976 | 0.996 | 1.075 | 1.000 |
| | OH (IESO) | TBD | TBD | TBD | TBD | TBD | TBD | TBD | TBD | TBD | TBD | TBD | TBD | TBD | TBD |
| Alexandria, Virginia | PJM_D | 1.062 | 1.109 | 1.160 | 1.156 | 1.017 | 1.099 | 1.045 | 1.019 | 0.973 | 0.964 | 0.952 | 0.984 | 1.062 | 1.000 |
| Philadelphia, Pennsylvania | PJM_E | 1.049 | 1.129 | 1.261 | 1.253 | 1.037 | 1.110 | 1.113 | 1.061 | 1.000 | 1.116 | 1.161 | 1.085 | 1.131 | 1.000 |
| Cincinnati, Ohio | PJM_Midwest | 1.008 | 1.005 | 0.983 | 0.984 | 0.998 | 1.008 | 0.985 | 0.981 | 1.000 | 0.954 | 0.934 | 0.969 | 0.980 | 1.000 |
| Baltimore, Maryland | PJM_SW | 1.034 | 1.053 | 1.204 | 1.199 | 1.056 | 1.050 | 1.011 | 1.017 | 0.979 | 0.974 | 0.956 | 0.983 | 1.016 | 1.000 |
| Wilkes-Barre, Pennsylvania | PJM_W | 0.985 | 0.962 | 0.983 | 0.984 | 1.617 | 0.970 | 0.959 | 0.982 | 1.000 | 0.950 | 0.927 | 0.966 | 0.941 | 1.000 |
| Denver, Colorado | RMPA | 0.974 | 0.934 | 1.021 | 1.021 | 1.206 | 0.946 | 0.937 | 1.022 | 1.000 | 0.956 | 0.927 | 0.953 | 0.918 | 0.973 |
| Davenport, Iowa | SCIL | 0.994 | 0.982 | 1.005 | 1.005 | 1.166 | 0.986 | 0.985 | 1.045 | 1.000 | 1.011 | 1.004 | 0.990 | 0.981 | 1.000 |
| Atlanta, Georgia | SOCO | 0.965 | 0.911 | 0.934 | 0.937 | 0.985 | 0.927 | 0.919 | 0.961 | 0.930 | 0.913 | 0.877 | 0.937 | 0.895 | 1.000 |
| Los Angeles, California | SP15 | 1.095 | 1.224 | 1.290 | 1.282 | 1.056 | 1.198 | 1.137 | 1.124 | 1.077 | 1.096 | 1.114 | 1.052 | 1.134 | 0.935 |
| Wichita, Kansas | SPP_N | 0.972 | 0.927 | 0.950 | 0.957 | 0.970 | 0.940 | 0.931 | 1.019 | 1.000 | 0.949 | 0.917 | 0.946 | 0.909 | 1.000 |
| Wichita, Kansas | SPP_S | 0.972 | 0.927 | 0.950 | 0.957 | 0.970 | 0.940 | 0.931 | 1.019 | 1.000 | 0.949 | 0.917 | 0.946 | 0.909 | 1.000 |
| Knoxville, Tennessee | TVA | 0.963 | 0.903 | 0.915 | 0.918 | 0.985 | 0.921 | 0.909 | 0.954 | 1.000 | 0.898 | 0.856 | 0.927 | 0.883 | 1.000 |
| Charlotte, North Carolina | VACAR | 0.959 | 0.896 | 0.895 | 0.909 | 1.012 | 0.915 | 0.899 | 0.951 | 0.907 | 0.884 | 0.836 | 0.917 | 0.866 | 1.000 |
| Green Bay, Wisconsin | WUMS | 1.010 | 1.006 | 0.987 | 0.987 | 0.948 | 1.008 | 0.995 | 0.990 | 0.973 | 0.966 | 0.951 | 0.977 | 0.990 | 1.000 |

Source: EIA Updated Capital Cost Estimates for Electricity Generation Plants, Nov 2010
http://www.eia.gov/oiaf/beck_plantcosts/pdf/updatedplantcosts.pdf

**Appendix A, Exhibit 11 - NEEM Capacity Factors (New and Existing) and Resource Potentials**

| NEEM Region | Onshore Potential (Class 4+), MW | Avg Capacity Factor | | Onshore Potential (shallow offshore only, Class 4+), MW | Avg Capacity Factor |
|---|---|---|---|---|---|
| AE | 1,095 | 26.7% | | 1,180 | NA |
| AZ_NM_SNV | 63,277 | 30.6% | | - | NA |
| EMO | 200 | 38.9% | | - | NA |
| ENT | 396 | 33.6% | | - | NA |
| ERCOT | 14,967 | 33.3% | | - | NA |
| FRCC | - | 0.0% | | - | NA |
| MAPP_US | 1,303,570 | (a) 40% | | - | NA |
| MAPP_CA | TBD | TBD | | NA | NA |
| MI | 200 | 30.5% | | 4,360 | 35.7% |
| MISO_E | 200 | 32.1% | | 765 | 35.8% |
| NE | 157,050 | 40.5% | | - | NA |
| NEISO_CT | 2 | 26.4% | | 176 | 35.0% |
| NEISO_MA | 668 | 30.7% | | 7,944 | 45.6% |
| NEISO_ME | 3,404 | 34.1% | | 174 | 39.9% |
| NEISO_NH | 1,014 | 33.2% | | 20 | 36.5% |
| NEISO_RI | 36 | 22.4% | | 223 | 42.7% |
| NEISO_VT | 2,102 | 34.2% | | - | NA |
| NI | 637 | 35.7% | | 960 | 36.3% |
| NonRTO_Midwest | 200 | 32.1% | | - | 35.8% |
| NP15 | 1,908 | 29.7% | | 135 | 40.0% |
| NWPP | 302,688 | 26.4% | | 193 | 40.0% |
| NYISO_Capital | 171 | 33.9% | | - | NA |
| NYISO_Downstate | 63 | 33.1% | | 245 | NA |
| NYISO_LIPA | 915 | 0.0% | | 2,368 | 40.7% |
| NYISO_NYC | - | 0.0% | | - | NA |
| NYISO_Upstate | 280 | 33.0% | | 486 | 36.6% |
| OH (Ontario) | 12,500 | 28.8% | | TBD | TBD |
| PJM_D | 384 | 29.5% | | 4,058 | 38.9% |
| PJM_E | 2 | 22.6% | | 9,588 | 41.4% |
| PJM_Midwest | 217 | 32.1% | | 14,032 | 35.8% |
| PJM_SW | 144 | 28.7% | | 15,589 | 40.0% |
| PJM_W | 200 | 28.4% | | 1,329 | 36.6% |
| RMPA | 338,965 | 34.3% | | - | NA |
| SCIL | 1,861 | 34.9% | | - | NA |
| SOCO | 398 | 0.0% | | - | NA |
| SP15 | 15,646 | 29.7% | | - | NA |
| SPP_N | 238,677 | 39.2% | | - | NA |
| SPP_S | 354,053 | 39.2% | | - | NA |
| TVA | 442 | 29.1% | | - | NA |
| VACAR | 602 | 29.5% | | 39,250 | 38.9% |
| WUMS | 350 | 32.9% | | 2,054 | 33.8% |

*(a) exact figure in process*

**Appendix A, Exhibit 12 - New Resource Limits**

**Cumulative New Build GW Limit Potential by NEEM Region** *Note: Forced New Builds are included in this constraint*

| | Pulverized Coal | Nuclear | On-Shore Wind | Off-Shore Wind | Biomass | Photo-voltaic | Landfill Gas | Geoth-ermal | Solar Thermal | IGCC-CCS |
|---|---|---|---|---|---|---|---|---|---|---|
| **AE** | ∞ | ∞ | 1.1 | 1.2 | 0.2 | 0.0 | 0.1 | 0.0 | 0.0 | ∞ |
| **AZ_NM_SNV** | ∞ | ∞ | 63.3 | 0.0 | 6.5 | 10.0 | 0.05 | 1.5 | 10.0 | ∞ |
| **EMO** | ∞ | ∞ | 0.2 | 0.0 | 2.4 | 5.0 | 0.2 | 0.0 | 0.0 | ∞ |
| **ENT** | ∞ | ∞ | 0.4 | 0.0 | 10.1 | 5.0 | 0.1 | 0.0 | 0.0 | ∞ |
| **ERCOT** | ∞ | ∞ | 15.0 | 0.0 | 4.1 | 10.0 | 0.4 | 0.0 | 0.0 | ∞ |
| **FRCC** | ∞ | ∞ | 0.0 | 0.0 | 2.0 | 10.0 | 0.2 | 0.0 | 0.0 | ∞ |
| **MAPP_US** | ∞ | ∞ | 1303.6 | 0.0 | 10.8 | 2.0 | 0.1 | 0.0 | 0.0 | ∞ |
| **MI** | ∞ | ∞ | 0.2 | 4.4 | 6.1 | 1.3 | 0.1 | 0.0 | 0.0 | ∞ |
| **MISO_E** | ∞ | ∞ | 0.2 | 0.8 | 6.1 | 1.3 | 0.1 | 0.0 | 0.0 | ∞ |
| **NE** | ∞ | ∞ | 157.1 | 0.0 | 10.8 | 2.0 | 0.1 | 0.0 | 0.0 | ∞ |
| **NEISO** | 0.0 | ∞ | 7.2 | 8.5 | 1.7 | 12.0 | 0.7 | 0.0 | 0.0 | 4.0 |
| **NI** | ∞ | ∞ | 0.6 | 1.0 | 0.7 | 5.0 | 0.1 | 0.0 | 0.0 | ∞ |
| **NonRTO_Midwest** | ∞ | ∞ | 0.2 | 0.0 | 6.1 | 1.3 | 0.1 | 0.0 | 0.0 | ∞ |
| **NP15** | 0.0 | 0.0 | 1.9 | 0.1 | 0.8 | 10.0 | 0.6 | 0.6 | 0.1 | ∞ |
| **NWPP** | ∞ | ∞ | 302.7 | 0.2 | 9.1 | 5.0 | 0.3 | 0.5 | 0.0 | ∞ |
| **NYISO_Capital** | 0.0 | ∞ | 0.2 | 0.0 | 0.2 | 2.0 | 0.2 | 0.0 | 0.0 | ∞ |
| **NYISO_Downstate** | 0.0 | 0.0 | 0.1 | 0.2 | 0.8 | 2.0 | 0.2 | 0.0 | 0.0 | ∞ |
| **NYISO_LIPA** | 0.0 | 0.0 | 0.9 | 2.4 | 0.0 | 2.0 | 0.2 | 0.0 | 0.0 | 0.0 |
| **NYISO_NYC** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.0 | 0.2 | 0.0 | 0.0 | 0.0 |
| **NYISO_Upstate** | 0.0 | ∞ | 0.3 | 0.5 | 0.8 | 2.0 | 0.2 | 0.0 | 0.0 | ∞ |
| **PJM_D** | ∞ | ∞ | 0.4 | 4.1 | 3.5 | 0.7 | 0.0 | 0.0 | 0.0 | ∞ |
| **PJM_E** | 0.0 | ∞ | 0.0 | 9.6 | 0.3 | 2.0 | 0.1 | 0.0 | 0.0 | ∞ |
| **PJM_Midwest** | ∞ | ∞ | 0.2 | 14.0 | 6.1 | 1.3 | 0.1 | 0.0 | 0.0 | ∞ |
| **PJM_SW** | ∞ | ∞ | 0.1 | 15.6 | 0.8 | 2.0 | 0.1 | 0.0 | 0.0 | ∞ |
| **PJM_W** | ∞ | ∞ | 0.2 | 1.3 | 1.6 | 2.0 | 0.1 | 0.0 | 0.0 | ∞ |
| **RMPA** | ∞ | ∞ | 339.0 | 0.0 | 3.7 | 5.0 | 0.1 | 2.6 | 9.4 | ∞ |
| **SCIL** | ∞ | ∞ | 1.9 | 0.0 | 6.5 | 2.0 | 0.3 | 0.0 | 0.0 | ∞ |
| **SOCO** | ∞ | ∞ | 0.4 | 0.0 | 6.6 | 2.0 | 0.1 | 0.0 | 0.0 | ∞ |
| **SP15** | 0.0 | 0.0 | 15.6 | 0.0 | 0.7 | 10.0 | 0.6 | 1.5 | 10.0 | ∞ |
| **SPP_N** | ∞ | ∞ | 238.7 | 0.0 | 6.4 | 2.0 | 0.1 | 0.0 | 0.0 | ∞ |
| **SPP_S** | ∞ | ∞ | 354.1 | 0.0 | 4.5 | 2.0 | 0.1 | 0.0 | 0.0 | ∞ |
| **TVA** | ∞ | ∞ | 0.4 | 0.0 | 7.4 | 2.0 | 0.1 | 0.0 | 0.0 | ∞ |
| **VACAR** | ∞ | ∞ | 0.6 | 39.3 | 7.0 | 1.3 | 0.1 | 0.0 | 0.0 | ∞ |
| **WUMS** | ∞ | ∞ | 0.4 | 2.1 | 3.2 | 2.0 | 0.2 | 0.0 | 0.0 | ∞ |
| **ALB** | 0.0 | ∞ | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **BC** | 0.0 | ∞ | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **OH** | 0.0 | ∞ | 12.5 | 0.0 | TBD | 0.1 | 0.0 | 0.0 | 0.0 | TBD |
| **MAPP_CA** | 0.0 | ∞ | TBD | 0.0 | TBD | 0.0 | TBD | 0.0 | 0.0 | TBD |
| **Total** | ∞ | ∞ | 2,819.9 | 105.1 | 137.7 | 126.1 | 6.5 | 6.7 | 29.5 | 4.0 |

New Pulverized Coal assumed not to be built in California, New York, New England, PJM East, and Canada
New Nuclear assumed not to be built in California or near New York City
CCS is a proposed CRA assumption.    PV and solar thermal are proposed CRA assumptions.
On- and Off-shore wind resource potential based on Win DS base case
Biomass based on CRA judgment, informed by USDA/DOE 2005 "Billion Ton Study".
Landfill gas based on CRA judgment, informed by EPA NEEDS report (2006).
Geothermal based on Lovekin & Pletka, GRC Transactions, vol. 33, 2009 (note: could be used for capital costs in lieu of AEO 2011)

**Cumulative GW of New Build Allowed in Total U.S. and Canada through This Year**
*Note: If %, represents % of total in table above; Forced Builds are included in constraint; if no figure listed the table above applies*

| | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|---|---|
| Pulverized Coal | 0 | F | F+10 | | | | | | |
| Nuclear | 0 | F1 | *F2 | *F2+15 | *F2+50 | *F2+100 | *F2+150 | *F2+200 | *F2+250 |
| On-Shore Wind | 0 | F | F+175 | | | | | | |
| Off-Shore Wind | 0 | F | F+20 | | | | | | |
| Biomass | 0 | F | 25% | 50% | 75% | 100% | | | |
| Photovoltaic | 0 | F | 10 | | | | | | |
| Landfill Gas | 0 | F | 33% | 67% | 100% | | | | |
| Geo Thermal | 0 | F | 33% | | | | | | |
| Solar Thermal | 0 | F | 33% | | | | | | |
| IGCC-CCS | 0 | F | F+2 | F+12 | F+32 | | | | |
| IGCC | 0 | F | F+60 | | | | | | |
| CCS Retrofits | 0 | F | F+5 | F+25 | F+65 | | | | |

F: Forced builds only    * F2 = F1 + (2016-2020 nuclear builds)
Represents practical constraints on building over time, such as permitting/siting, construction lead times. CRA assumptions.
2020 limits in place for all technologies, most other types unlimited (other than in table above) by 2025
Transfer limits, reserve margins, hurdle rates, and intermittent resource limits will limit construction inside any particular NEEM regior
Nuclear likely to be highly economic in certain scenarios, thus on-going limitations in place to represent licensing issues.
IGCC-CCS not available until 2020 (for economic builds); CCS Retrofits available in the same year.

**Appendix A, Exhibit 13 - Retrofit Costs Source Information**

| Retrofit Type | Emissions Type | Capital Cost | Fixed O&M | Variable O&M |
|---|---|---|---|---|
| FGD | SO2 | Sargent & Lundy. "IPM Model - Revisions to Cost and Performance for APC Technologies. Wet FGD Cost Development Methodology." August 2010. [Table 1] | Sargent & Lundy. "IPM Model - Revisions to Cost and Performance for APC Technologies. Wet FGD Cost Development Methodology." August 2010. [Table 1] | Sargent & Lundy. "IPM Model - Revisions to Cost and Performance for APC Technologies. Wet FGD Cost Development Methodology." August 2010. [Table 1] |
| SCR | NOx | Cichanowicz, J Edward. "Current Capital Cost and Cost-Effectiveness of Power Plant Emissions Control Technologies." January 2010. [Figure 6-1] | Cichanowicz, J Edward. "Current Capital Cost and Cost-Effectiveness of Power Plant Emissions Control Technologies." January 2010. [Table 6-1] | Cichanowicz, J Edward. "Current Capital Cost and Cost-Effectiveness of Power Plant Emissions Control Technologies." January 2010. [Table 6-1] |
| SNCR | NOx | EPA IPM 2006 Documentation | EPA IPM 2006 Documentation | EPA IPM 2006 Documentation |
| ACI | Hg | Cichanowicz, J Edward. "Testimony of J E Cichanowicz to the Illinois Pollution Control Board. A Review of the Status of Mercury Control Technology." July 28, 2006. [Figures B-6 and B-8] | Cichanowicz, J Edward. "Testimony of J E Cichanowicz to the Illinois Pollution Control Board. A Review of the Status of Mercury Control Technology." July 28, 2006. [Figure B-7] | Cichanowicz, J Edward. "Testimony of J E Cichanowicz to the Illinois Pollution Control Board. A Review of the Status of Mercury Control Technology." July 28, 2006. [Pages 65-66]; CRA discussion with Cichanowicz. |
| RPJ | Hg | Cichanowicz, J Edward. "Testimony of J E Cichanowicz to the Illinois Pollution Control Board. A Review of the Status of Mercury Control Technology." July 28, 2006. [Figures B-6 and B-8] | Cichanowicz, J Edward. "Testimony of J E Cichanowicz to the Illinois Pollution Control Board. A Review of the Status of Mercury Control Technology." July 28, 2006. [Figure B-7] | Cichanowicz, J Edward. "Testimony of J E Cichanowicz to the Illinois Pollution Control Board. A Review of the Status of Mercury Control Technology." July 28, 2006. [Pages 65-66]; CRA discussion with Cichanowicz. |

Appendix A, Exhibit 14 - Forced Retrofits

| NEEM Region | Installation Year Modeled | Plant Name | Unit | Control Type (NOx, SO2, PM, HG, CO, VOC, Multi, CO2) | Control Equipment | Install Date | Retrofit Modeled |
|---|---|---|---|---|---|---|---|
| EMO | 2011 | Sioux | 1 | SO2 | Wet Lime FGD | 9/30/2010 | FGD |
| EMO | 2011 | Sioux | 2 | SO2 | Wet Lime FGD | 9/30/2010 | FGD |
| MAPP_US | 2011 | Lansing | 4 | NOx | Selective Catalytic Reduction | 9/30/2010 | SCR |
| MAPP_US | 2011 | Leland Olds 1 & 2 | 1 | SO2 | Wet Limestone | 3/31/2011 | FGD |
| MAPP_US | 2011 | Leland Olds 1 & 2 | 2 | SO2 | Wet Limestone | 10/31/2010 | FGD |
| MAPP_US | 2011 | Sutherland (IA) | 3 | NOx | Selective Non-catalytic Reduction | 10/31/2010 | SNCR |
| MI | 2012 | J H Campbell | 2 | NOx | Selective Catalytic Reduction | 9/30/2011 | SCR |
| NEISO | 2012 | Merrimack | 1 | SO2 | Wet Limestone | 12/31/2011 | FGD |
| NEISO | 2012 | Merrimack | 2 | SO2 | Wet Limestone | 12/31/2011 | FGD |
| NonRTO_Midwest | 2011 | Clifty Creek | 1 | SO2 | Wet Limestone | 6/30/2011 | FGD |
| NonRTO_Midwest | 2011 | Clifty Creek | 2 | SO2 | Wet Limestone | 6/30/2011 | FGD |
| NonRTO_Midwest | 2011 | Clifty Creek | 3 | SO2 | Wet Limestone | 6/30/2011 | FGD |
| NonRTO_Midwest | 2011 | Clifty Creek | 4 | SO2 | Wet Limestone | 6/30/2011 | FGD |
| NonRTO_Midwest | 2011 | Clifty Creek | 5 | SO2 | Wet Limestone | 6/30/2011 | FGD |
| NonRTO_Midwest | 2011 | Clifty Creek | 6 | SO2 | Wet Limestone | 6/30/2011 | FGD |
| NonRTO_Midwest | 2011 | Kyger Creek | 1 | SO2 | Flue Gas Desulfurization | 3/31/2011 | FGD |
| NonRTO_Midwest | 2011 | Kyger Creek | 2 | SO2 | Flue Gas Desulfurization | 3/31/2011 | FGD |
| NonRTO_Midwest | 2011 | Kyger Creek | 3 | SO2 | Flue Gas Desulfurization | 3/31/2011 | FGD |
| NonRTO_Midwest | 2011 | Kyger Creek | 4 | SO2 | Flue Gas Desulfurization | 6/30/2011 | FGD |
| NonRTO_Midwest | 2011 | Kyger Creek | 5 | SO2 | Flue Gas Desulfurization | 6/30/2011 | FGD |
| PJM_D | 2011 | Chesterfield | 3 | SO2 | Flue Gas Desulfurization | 6/30/2011 | FGD |
| PJM_D | 2011 | Chesterfield | 4 | SO2 | Flue Gas Desulfurization | 6/30/2011 | FGD |
| PJM_D | 2011 | Chesterfield | 5 | SO2 | Flue Gas Desulfurization | 6/30/2011 | FGD |
| PJM_E | 2011 | Hudson Generating Station | 2 | NOx | Selective Catalytic Reduction | 12/31/2010 | SCR |
| PJM_E | 2011 | Hudson Generating Station | 2 | SO2 | Dry Lime FGD | 12/31/2010 | FGD |
| PJM_Midwest | 2011 | Cardinal | 3 | SO2 | Wet Limestone | 3/31/2011 | FGD |
| PJM_Midwest | 2011 | W H Sammis | 1 | NOx | Selective Non-catalytic Reduction | 12/31/2010 | SNCR |
| PJM_Midwest | 2011 | W H Sammis | 3 | NOx | Selective Non-catalytic Reduction | 12/31/2010 | SNCR |
| PJM_Midwest | 2011 | W H Sammis | 4 | NOx | Selective Non-catalytic Reduction | 12/31/2010 | SNCR |
| SCIL | 2011 | Baldwin Energy Complex | 3 | SO2 | Dry Lime FGD | 12/31/2010 | FGD |
| SCIL | 2013 | Havana | 6 | SO2 | Dry Lime FGD | 12/1/2012 | FGD |
| SOCO | 2012 | R D Morrow | 1 | SO2 | Wet Limestone | 8/30/2011 | FGD |
| SOCO | 2012 | R D Morrow | 2 | SO2 | Wet Limestone | 8/30/2011 | FGD |
| SOCO | 2014 | Scherer | 1 | NOx | Selective Catalytic Reduction | 12/31/2013 | SCR |
| SOCO | 2014 | Scherer | 1 | SO2 | Flue Gas Desulfurization | 12/31/2013 | FGD |
| SOCO | 2014 | Scherer | 2 | NOx | Selective Catalytic Reduction | 12/31/2013 | SCR |
| SOCO | 2014 | Scherer | 2 | SO2 | Flue Gas Desulfurization | 12/31/2013 | FGD |
| SOCO | 2014 | Scherer | 3 | NOx | Selective Catalytic Reduction | 12/31/2013 | SCR |
| SOCO | 2014 | Scherer | 3 | SO2 | Flue Gas Desulfurization | 12/31/2013 | FGD |
| SOCO | 2014 | Scherer | 4 | NOx | Selective Catalytic Reduction | 12/31/2013 | SCR |
| SOCO | 2014 | Scherer | 4 | SO2 | Flue Gas Desulfurization | 12/31/2013 | FGD |
| VACAR | 2011 | Cliffside | 5 | SO2 | Wet Limestone | 10/31/2010 | FGD |
| WUMS | 2012 | South Oak Creek | 7 | NOx | Selective Catalytic Reduction | 6/1/2012 | SCR |
| WUMS | 2012 | South Oak Creek | 7 | SO2 | Wet Limestone | 6/1/2012 | FGD |
| WUMS | 2012 | South Oak Creek | 8 | NOx | Selective Catalytic Reduction | 6/1/2012 | SCR |
| WUMS | 2012 | South Oak Creek | 8 | SO2 | Wet Limestone | 6/1/2012 | FGD |
| WUMS | 2013 | Edgewater (WI) | 5 | NOx | Selective Catalytic Reduction | 10/31/2012 | SCR |
| WUMS | 2013 | South Oak Creek | 5 | NOx | Selective Catalytic Reduction | 12/1/2012 | SCR |
| WUMS | 2013 | South Oak Creek | 5 | SO2 | Wet Limestone | 12/1/2012 | FGD |
| WUMS | 2013 | South Oak Creek | 6 | NOx | Selective Catalytic Reduction | 12/1/2012 | SCR |
| WUMS | 2013 | South Oak Creek | 6 | SO2 | Wet Limestone | 12/1/2012 | FGD |

**Appendix A, Exhibit 15 - State RPS Mapping to NEEM Region**

**** See separate workbook that shows the buildup and percent requirements over time for the State RPS policies.***

| State RPS | NEEM RPS | Component Pools | Alternative Compliance Payment in 2020 ($2010/MWh) |
|---|---|---|---|
| PA | PJM | PJM_W, PJM_E, PJM_SW | $53.12 |
| NJ | PJM | PJM_W, PJM_E, PJM_SW | $53.12 |
| DE | PJM | PJM_W, PJM_E, PJM_SW | $53.12 |
| MD | PJM | PJM_W, PJM_E, PJM_SW | $53.12 |
| DC | PJM | PJM_W, PJM_E, PJM_SW | $53.12 |
| PA Solar | PJM Solar | PJM_W, PJM_E, PJM_SW | $318.71 |
| NJ Solar | PJM Solar | PJM_W, PJM_E, PJM_SW | $318.71 |
| DE Solar | PJM Solar | PJM_W, PJM_E, PJM_SW | $318.71 |
| MD Solar | PJM Solar | PJM_W, PJM_E, PJM_SW | $318.71 |
| DC Solar | PJM Solar | PJM_W, PJM_E, PJM_SW | $318.71 |
| AZ | AZNMSNV | AZ_NM_SNV | $39.31 |
| NM | AZNMSNV | AZ_NM_SNV | $39.31 |
| NV | AZNMSNV | AZ_NM_SNV | $39.31 |
| AZ Solar | AZNMSNV Solar | AZ_NM_SNV | $235.89 |
| NM Solar | AZNMSNV Solar | AZ_NM_SNV | $235.89 |
| NV Solar | AZNMSNV Solar | AZ_NM_SNV | $235.89 |
| WA | NWPP | NWPP | $48.52 |
| OR | NWPP | NWPP | $48.52 |
| MT | NWPP | NWPP | $48.52 |
| WI | MRETS | MAPP_US | $41.79 |
| MN | MRETS | MAPP_US | $41.79 |
| IL | MRETS | MAPP_US | $41.79 |
| MI | MI | MI | $45.43 |
| OH | Ohio | PJM_Midwest, MISO_E, NonRTO_Midwest | $45.43 |
| OH Solar | Ohio Solar | PJM_Midwest, MISO_E, NonRTO_Midwest | $151.41 |
| KS | KS | SPP_N | NA |
| MO | MO | EMO, ENT | $20.22 |
| MO Solar | MO Solar | EMO, ENT | $121.37 |
| CO | CO | RMPA | $59.35 |
| CO Solar | CO Solar | RMPA | $356.10 |
| CA | CA | NP15, SP15 | $51.84 |
| TX | TX | ERCOT | NA |
| NY | NY | NYISO x 5 | $31.10 |
| MA | NEISO | NEISO | $61.53 |
| CT | NEISO | NEISO | $61.53 |
| ME | NEISO | NEISO | $61.53 |
| RI | NEISO | NEISO | $61.53 |
| NH | NEISO | NEISO | $61.53 |
| MA Solar | MA Solar | NEISO | $612.39 |
| NH Solar | NH Solar | NEISO | $163.31 |
| NC | NC | VACAR | $22.17 |
| NC Solar | NC Solar | VACAR | $133.04 |

**Appendix A, Exhibit 16 - Natural Gas Prices, Base Case**
**AEO 2011 Reference Case (early release)**

| Year | Henry Hub Spot Price (2010$/MMBtu) |
|---|---|
| 2011 | $ 4.52 |
| 2012 | $ 4.61 |
| 2013 | $ 4.74 |
| 2014 | $ 4.81 |
| 2015 | $ 4.85 |
| 2016 | $ 4.88 |
| 2017 | $ 4.92 |
| 2018 | $ 5.00 |
| 2019 | $ 5.08 |
| 2020 | $ 5.22 |
| 2021 | $ 5.38 |
| 2022 | $ 5.53 |
| 2023 | $ 5.72 |
| 2024 | $ 5.90 |
| 2025 | $ 6.07 |
| 2026 | $ 6.21 |
| 2027 | $ 6.33 |
| 2028 | $ 6.42 |
| 2029 | $ 6.48 |
| 2030 | $ 6.56 |
| 2031 | $ 6.68 |
| 2032 | $ 6.82 |
| 2033 | $ 6.94 |
| 2034 | $ 7.07 |
| 2035 | $ 7.25 |

**Between 2035 and 2050, CRA proposes to increase gas prices at the same rate of increase for the 2030-2035 period.**

**Appendix A, Exhibit 17 - Natural Gas Basis Point Mapping**

| NEEM Region | Basis Point(s) |
|---|---|
| AE | CNGL (25%), COLAP (25%), DOMS (50%) |
| AZ_NM_SNV | EPNB (50%), EPP (50%) |
| BC | WCST2 (100%) |
| MI, PJM_Midwest, MISO_E, NON-RTO Midwest | CHI (20%), CNGL (15%), COLAP (15%), DOMS (30%), MICMC (20%) |
| EMO | CHI (50%), VENT (50%) |
| ENT | HENRY (67%), VENT (33%) |
| ERCOT | SHIP (100%) |
| FRCC | FGTCG (100%) |
| HQ | DRACT (50%), TENN6 (50%) |
| MAPP_CA | VIKEM (100%) |
| MAPP_US | VIKEM (75%), VENT (25%) |
| NEISO | ALGCG (50%), DRACT (25%), TENN6 (25%) |
| NI | CHI (50%), VENT (50%) |
| NP15 | MALIN (50%), PGECG (50%) |
| NWPP | NWWYO (19%), CIG (13%), NWSTA (25%), SUMAS (19%), MALIN (6%), KINGS (6%), QUEST (6%), KERN (6%) |
| NYISO_Capital (F) | NIAG (50%), DOMS (50%) |
| NYISO_Downstate (G-I) | IROWA (50%), TRNON (50%) |
| NYISO_LIPA (K) | TRNY (104.5%) |
| NYISO_NYC (J) | TRNY (104.5%) |
| NYISO_Upstate (A-E) | DAWN (25%), DOMS (50%), NIAG (25%) |
| OH | NIAG (50%), DAWN (50%) |
| PJM | TETM3 (50%), TRNON (50%) |
| RMPA | CIG (75%), NWWYO (25%) |
| SCIL | CHI (100%) |
| SOCO | TRS85 (50%), FGTMB (50%) |
| SP15 | SOCAL (100%) |
| SPP_N | NGPLM (100%) |
| SPP_S | NGPLM (100%) |
| TVA | TETM1 (100%) |
| VACAR | TETM3 (50%), FGTMB (50%) |
| WUMS | CHI (100%) |

**Appendix A, Exhibit 18 - Wheeling Charges, Trading Friction, and Total Hurdle**

| From | To | Wheeling Cost 2010$/MWh | Trading Friction (2010$/MWh) | Total Hurdle 2010$/MWh |
|---|---|---|---|---|
| EMO | ENT | 5 | 3 | 8 |
| EMO | MAPP_US | 0 | 0 | 0 |
| EMO | SCIL | 0 | 0 | 0 |
| EMO | SPP_N | 5 | 3 | 8 |
| EMO | TVA | 5 | 3 | 8 |
| ENT | EMO | 3 | 5 | 8 |
| ENT | SOCO | 3 | 5 | 8 |
| ENT | SPP_S | 3 | 5 | 8 |
| ENT | TVA | 3 | 5 | 8 |
| ERCOT | SPP_S | 3 | 5 | 8 |
| FRCC | SOCO | 3 | 5 | 8 |
| MAPP_CA | MAPP_US | 0 | 3 | 3 |
| MAPP_CA | OH | 5 | 3 | 8 |
| MAPP_US | EMO | 0 | 0 | 0 |
| MAPP_US | MAPP_CA | 0 | 3 | 3 |
| MAPP_US | NE | 5 | 3 | 8 |
| MAPP_US | NWPP_Coal | 5 | 3 | 8 |
| MAPP_US | OH | 5 | 3 | 8 |
| MAPP_US | RMPA | 5 | 3 | 8 |
| MAPP_US | WUMS | 0 | 0 | 0 |
| MI | OH | 5 | 3 | 8 |
| MI | PJM_Midwest | 0 | 2 | 2 |
| MISO_E | NonRTO_Midwest | 5 | 3 | 8 |
| MISO_E | PJM_Midwest | 0 | 2 | 2 |
| MISO_E | SCIL | 0 | 0 | 0 |
| NE | MAPP_US | 2 | 3 | 5 |
| NE | RMPA | 2 | 3 | 5 |
| NE | SPP_N | 0 | 0 | 0 |
| NEISO | NYISO_LIPA | 0 | 3 | 3 |
| NI | MAPP_US | 0 | 2 | 2 |
| NI | SCIL | 0 | 2 | 2 |
| NI | WUMS | 0 | 2 | 2 |
| NI_dummy | NI | 0 | 0 | 0 |
| NonRTO_Midwest | MISO_E | 3 | 5 | 8 |
| NonRTO_Midwest | PJM_Midwest | 3 | 5 | 8 |
| NonRTO_Midwest | TVA | 3 | 5 | 8 |
| NWPP_Coal | MAPP_US | 3 | 5 | 8 |
| NYISO_LIPA | NEISO | 0 | 3 | 3 |
| NYISO_LIPA | NYISO_NYC | 0 | 0 | 0 |
| NYISO_NYC | NYISO_LIPA | 0 | 0 | 0 |
| NYISO_Upstate | OH | 4 | 3 | 7 |
| OH | MAPP_CA | 1 | 5 | 6 |
| OH | MAPP_US | 1 | 5 | 6 |
| OH | MI | 1 | 5 | 6 |
| OH | NYISO_Upstate | 1 | 5 | 6 |
| PJM_D | VACAR | 0 | 0 | 0 |

**Appendix A, Exhibit 18 - Wheeling Charges, Trading Friction, and Total Hurdle**

| From | To | Wheeling Cost 2010$/MWh | Trading Friction (2010$/MWh) | Total Hurdle 2010$/MWh |
|---|---|---|---|---|
| PJM_E | NYISO_Downstate | 3 | 3 | 6 |
| PJM_E | NYISO_LIPA | 3 | 3 | 6 |
| PJM_E | NYISO_NYC | 3 | 3 | 6 |
| PJM_Midwest | AE | 0 | 0 | 0 |
| PJM_Midwest | MI | 0 | 2 | 2 |
| PJM_Midwest | MISO_E | 0 | 2 | 2 |
| PJM_Midwest | NonRTO_Midwest | 3 | 3 | 6 |
| PJM_Midwest | PJM_D | 0 | 0 | 0 |
| PJM_Midwest | VACAR | 3 | 3 | 6 |
| PJM_W | AE | 0 | 0 | 0 |
| RMPA | MAPP_US | 3 | 5 | 8 |
| RMPA | NE | 3 | 5 | 8 |
| RMPA | SPP_N | 3 | 5 | 8 |
| SCIL | EMO | 0 | 0 | 0 |
| SCIL | MISO_E | 0 | 0 | 0 |
| SCIL | TVA | 5 | 3 | 8 |
| SOCO | ENT | 5 | 5 | 10 |
| SOCO | FRCC | 5 | 5 | 10 |
| SOCO | TVA | 5 | 5 | 10 |
| SOCO | VACAR | 5 | 5 | 10 |
| SPP_N | EMO | 2 | 3 | 5 |
| SPP_N | NE | 0 | 0 | 0 |
| SPP_N | RMPA | 2 | 3 | 5 |
| SPP_N | SPP_S | 0 | 0 | 0 |
| SPP_S | AZ_NM_SNV_Coal | 2 | 3 | 5 |
| SPP_S | ENT | 2 | 3 | 5 |
| SPP_S | ERCOT | 2 | 3 | 5 |
| SPP_S | SPP_N | 0 | 0 | 0 |
| TVA | EMO | 3 | 5 | 8 |
| TVA | ENT | 3 | 5 | 8 |
| TVA | NonRTO_Midwest | 3 | 5 | 8 |
| TVA | PJM_Midwest | 3 | 5 | 8 |
| TVA | SCIL | 3 | 5 | 8 |
| TVA | SOCO | 3 | 5 | 8 |
| TVA | VACAR | 3 | 5 | 8 |
| VACAR | NonRTO_Midwest | 2 | 5 | 7 |
| VACAR | PJM_D | 2 | 5 | 7 |
| VACAR | SOCO | 2 | 5 | 7 |
| VACAR | TVA | 2 | 5 | 7 |
| WUMS | MAPP_US | 0 | 0 | 0 |

## Appendix A, Exhibit 19: Key MRN Parameters

| | | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Energy Prices** | Gas price (2009 dollars per million Btu)* | 4.10 | 4.26 | 4.59 | 5.32 | 5.76 | 6.37 | 7.04 | 7.78 | 8.61 | (a) |
| | World crude oil price (2009 dollars per barrel) | 74.86 | 86.94 | 98.71 | 107.53 | 112.35 | 114.05 | 115.78 | 117.54 | 119.32 | (a) |
| **Resources/Endowments** | Gas supply resource index (2010 = 1)* | 1.00 | 1.04 | 1.08 | 1.11 | 1.16 | 1.22 | 1.29 | 1.37 | 1.44 | (a) |
| **Macro economic** | GDP Index (2010 = 1) | 1.00 | 1.16 | 1.32 | 1.51 | 1.72 | 1.94 | 2.20 | 2.48 | 2.80 | (a) (c) |
| **Alternate transporation fuels defaults** | Cost of Ethanol (relative to gasoline) | 1.09 | 1.34 | 1.41 | 1.44 | 1.44 | 1.44 | 1.44 | 1.44 | 1.44 | |
| | Cost of advanced biodiesel (relative to gasoline) | 0.15 | 0.33 | 0.58 | 1.19 | 1.38 | 1.38 | 1.38 | 1.38 | 1.38 | |
| **New vehicle technologies defaults** | Plug to Wheels Electricity Usage for PHEV40 KWH per Mile | 0.36 | 0.35 | 0.33 | 0.31 | 0.29 | 0.28 | 0.27 | 0.26 | 0.24 | |
| | Plug to Wheels Electricity Usage for BEV100 KWH per Mile | 0.36 | 0.35 | 0.33 | 0.31 | 0.29 | 0.28 | 0.27 | 0.26 | 0.24 | |
| | % of time on electric engine for PHEV40 | 0.50 | 0.55 | 0.60 | 0.62 | 0.64 | 0.66 | 0.67 | 0.69 | 0.70 | |
| | Vehicle cost premium for PHEV40 (relative to conventional) | 2.00 | 1.80 | 1.71 | 1.65 | 1.59 | 1.54 | 1.50 | 1.46 | 1.42 | (b) |
| | Vehicle cost premium for BEV100 (relative to conventional) | 4.19 | 3.46 | 3.16 | 2.92 | 2.73 | 2.55 | 2.40 | 2.25 | 2.12 | (b) |
| | miles per gallon of Internal Combustion Engine in PHEV4( | 30.00 | 34.55 | 39.10 | 41.00 | 42.90 | 44.35 | 45.80 | 47.00 | 48.20 | |
| **New vehicle stock (millions)** | Plug-in 10/40 Gasoline Hybrid | 0.00 | 0.09 | 0.34 | 0.80 | 1.49 | 2.29 | 3.52 | 5.40 | 8.29 | (a) |
| | 100/200 Mile Electric Vehicle | 0.02 | 0.13 | 0.31 | 0.62 | 1.02 | 1.36 | 1.81 | 2.42 | 3.23 | (a) |
| **Total VMT for Light-Duty Vehicles (billions of miles)** | | 2,734 | 2,947 | 3,199 | 3,465 | 3,754 | 4,044 | 4,356 | 4,693 | 5,055 | (a) |
| **Alternative Fuel VMT (billions of miles)** | Plug-in 10/40 Gasoline Hybrid | 0.00 | 1.95 | 5.94 | 14.38 | 28.64 | 46.20 | 74.54 | 120.25 | 193.99 | (a) |
| | 100/200 Mile Electric Vehicle | 0.29 | 1.49 | 3.74 | 7.78 | 13.28 | 18.92 | 26.94 | 38.37 | 54.64 | (a) |
| **Emissions factors for transport fuel defaults** | Gasoline (CO2e/MJ) | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | |
| | Ethanol (CO2e/MJ) | 73 | 73 | 73 | 73 | 73 | 73 | 73 | 73 | 73 | |
| | Advanced biodiesel (CO2e/MJ) | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | |
| **Carbon tax** | Carbon tax (in $ per metric ton of CO2) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |

* Gas price and gas resource are interdependent. Tightening or loosening the gas resource will be used to obtain high and low gas price sensitivities
(a) Data based on ER AEO2011 through 2035. Growth after 2035 based on growth from 2030 to 2035
(b) CRA may modify these two parameters as needed to approximately match the PHEV/BEV AEO 2011 new vehicle stock projection. These two parameters then will be modified to create higher EV penetration sensitivities.
(c) The GDP parameters can be modified to create high or low economic growth sensitivities

**Default values of Elasticities in the MRN Model**

| | | Non-energy Sectors | | | | | Energy Sectors | | | Final Demand | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | AGR | EIS | MAN | SRV | TRN | CRU | GAS | OIL | C | G | I |
| es_s | Top level elasticity | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 | 0.0 | 0.0 |
| es_e | Energy versus value-added | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | NA | NA | NA |
| es_oil | Oil versus non-energy | 0.0 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 |
| es_va | Capital vesus Labor | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | NA | NA | NA |
| es_ele | Electricity versus Coal-gas | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.5 | 0.8 | 0.8 |
| es_cg | Coal versus Gas | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| es_n | Non-energy | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 0.0 | 0.0 |
| etae | Elasticity of export supply | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | | | |
| es_dm | Domestic versus imports | 3.0 | 3.0 | 3.0 | 1.0 | 1.0 | 3.0 | 3.0 | 3.0 | | | |

NA: not applicable

**Deafault Resource Supply Elasticities in the MRN Model**

| | | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|---|---|---|
| Crude Oil | CRU | 0.3 | 0.51 | 0.65 | 0.76 | 0.83 | 0.88 | 0.91 | 0.94 | 0.96 |
| Natural gas | GAS | 0.6 | 0.72 | 0.8 | 0.86 | 0.9 | 0.93 | 0.95 | 0.97 | 0.98 |

**Appendix B**

## Sectoral mapping of IMPLAN Sectors based on NAICS 2002

**EIPC Sector - 11 Sectors**
**MRN Sectors - 29 Sectors**
**IMPLAN Sectors - 509 Sectors**

| S.No. | EIPC Sector | Description | MRN Sector | | Description |
|---|---|---|---|---|---|
| 1 | COL | Coal | 1 | COL | Coal |
| 2 | CRU | Natural Gas and Crude | 2 | CRU | Natural Gas and Crude |
| 3 | ELE | Electric Generation | 3 | ELE | Electric Generation |
| 4 | GAS | Natural Gas Distribution | 4 | GAS | Natural Gas Distribution |
| 5 | OIL | Refined Petroleum | 5 | OIL | Refined Petroleum |
| 6 | TRN | Transportation Services | 6 | TRN | Transportation Services Commercial |
| 7 | AGR | Agriculture | 7 | FOO | Food and Kindred Products plus tobacco and beverages |
| | AGR | | 8 | AGR | Agriculture |
| 8 | SRV | Services | 9 | SRV | Services |
| | SRV | | 10 | DWE | Owner-occupied dwellings |
| 9 | MAN | Manufactured and processed goods | 11 | RUB | Plastics and Rubber |
| | MAN | | 12 | ELQ | Electrical Equipment and Appliances |
| | MAN | | 13 | TRQ | Transportation Equipment |
| | MAN | | 14 | MAC | Machinery |
| | MAN | | 15 | MSC | Miscellaneous Manufacturing |
| | MAN | | 16 | PRN | Printing and Related Support |
| | MAN | | 17 | TEX | Textiles and Apparel and Leather |
| | MAN | | 18 | COM | Computer and Electronic Products |
| | MAN | | 19 | WOO | Wood Products and Furniture |
| 10 | M_V | Motor Vehicle | 20 | M_V | Motor Vehicles |
| 11 | EIS | Energy Intensive sectors | 21 | MIN | Metal and Nonmetal Mining |
| | EIS | | 22 | ALU | Aluminum |
| | EIS | | 23 | CHM | Chemicals |
| | EIS | | 24 | FAB | Fabricated Metal Products |
| | EIS | | 25 | CNS | Construction |
| | EIS | | 26 | I_S | Iron and Steel |
| | EIS | | 27 | OPM | Other Primary Metals |
| | EIS | | 28 | PAP | Paper and Pulp Mills |
| | EIS | | 29 | SCG | Nonmetallic Mineral Products - silica cement glass |

**Appendix B**

## Detailed IMPLN to MRN sector mapping

| EIPC Sector | MRN Sector | IMPLAN Sector | Sector (NAICS code) | IMPLAN Description |
|---|---|---|---|---|
| AGR | AGR | 1 | Oilseed farming (1111A0:11111,11112) | Oilseed farming |
| AGR | AGR | 2 | Grain farming (1111B0:11113,11114,11115,11116,11119) | Grain farming |
| AGR | AGR | 3 | Vegetable and melon farming (111200:1112) | Vegetable and melon farming |
| AGR | AGR | 4 | Tree nut farming (111335:111335) | Tree nut farming |
| AGR | AGR | 5 | Fruit farming (1113A0:11131,11132,11133 exc. 111335) | Fruit farming |
| AGR | AGR | 6 | Greenhouse and nursery production (111400:1114) | Greenhouse and nursery production |
| AGR | AGR | 7 | Tobacco farming (111910:11191) | Tobacco farming |
| AGR | AGR | 8 | Cotton farming (111920:11192) | Cotton farming |
| AGR | AGR | 9 | Sugarcane and sugar beet farming (1119A0:11193,111991) | Sugarcane and sugar beet farming |
| AGR | AGR | 10 | All other crop farming (1119B0:11194,111992,111998) | All other crop farming |
| AGR | AGR | 11 | Cattle ranching and farming (112100:11211,11212,11213) | Cattle ranching and farming |
| AGR | AGR | 12 | Poultry and egg production (112300:1123) | Poultry and egg production |
| AGR | AGR | 13 | Animal production, except cattle and poultry and eggs (112A00:1122,1124,1125,1129) | Animal production, except cattle and poultry and eggs |
| AGR | AGR | 14 | Logging (113300:1133) | Logging |
| AGR | AGR | 15 | Forest nurseries, forest products, and timber tracts (113A00:1131,1132) | Forest nurseries, forest products, and timber tracts |
| AGR | AGR | 16 | Fishing (114100:1141) | Fishing |
| AGR | AGR | 17 | Hunting and trapping (114200:1142) | Hunting and trapping |
| AGR | FOO | 46 | Dog and cat food manufacturing (311111:311111) | Dog and cat food manufacturing |
| AGR | FOO | 47 | Other animal food manufacturing (311119:311119) | Other animal food manufacturing |
| AGR | FOO | 48 | Flour milling (311211:311211) | Flour milling |
| AGR | FOO | 49 | Rice milling (311212:311212) | Rice milling |
| AGR | FOO | 50 | Malt manufacturing (311213:311213) | Malt manufacturing |
| AGR | FOO | 51 | Wet corn milling (311221:311221) | Wet corn milling |
| AGR | FOO | 52 | Soybean processing (311222:311222) | Soybean processing |
| AGR | FOO | 53 | Other oilseed processing (311223:311223) | Other oilseed processing |
| AGR | FOO | 54 | Fats and oils refining and blending (311225:311225) | Fats and oils refining and blending |
| AGR | FOO | 55 | Breakfast cereal manufacturing (311230:31123) | Breakfast cereal manufacturing |
| AGR | FOO | 56 | Sugar manufacturing (311310:31131) | Sugar manufacturing |
| AGR | FOO | 57 | Confectionery manufacturing from cacao beans (311320:31132) | Confectionery manufacturing from cacao beans |
| AGR | FOO | 58 | Confectionery manufacturing from purchased chocolate (311330:31133) | Confectionery manufacturing from purchased chocolate |
| AGR | FOO | 59 | Nonchocolate confectionery manufacturing (311340:31134) | Nonchocolate confectionery manufacturing |
| AGR | FOO | 60 | Frozen food manufacturing (311410:31141) | Frozen food manufacturing |
| AGR | FOO | 61 | Fruit and vegetable canning and drying (311420:31142) | Fruit and vegetable canning and drying |
| AGR | FOO | 62 | Fluid milk manufacturing (311511:311511) | Fluid milk manufacturing |
| AGR | FOO | 63 | Creamery butter manufacturing (311512:311512) | Creamery butter manufacturing |
| AGR | FOO | 64 | Cheese manufacturing (311513:311513) | Cheese manufacturing |
| AGR | FOO | 65 | Dry, condensed, and evaporated dairy products (311514:311514) | Dry, condensed, and evaporated dairy products |
| AGR | FOO | 66 | Ice cream and frozen dessert manufacturing (311520:31152) | Ice cream and frozen dessert manufacturing |
| AGR | FOO | 67 | Animal, except poultry, slaughtering (311611:311611) | Animal, except poultry, slaughtering |
| AGR | FOO | 68 | Meat processed from carcasses (311612:311612) | Meat processed from carcasses |
| AGR | FOO | 69 | Rendering and meat byproduct processing (311613:311613) | Rendering and meat byproduct processing |
| AGR | FOO | 70 | Poultry processing (311615:311615) | Poultry processing |
| AGR | FOO | 71 | Seafood product preparation and packaging (311700:3117) | Seafood product preparation and packaging |
| AGR | FOO | 72 | Frozen cakes and other pastries manufacturing (311813:311813) | Frozen cakes and other pastries manufacturing |
| AGR | FOO | 73 | Bread and bakery product, except frozen, manufacturing (31181A:311811,311812) | Bread and bakery product, except frozen, manufacturing |
| AGR | FOO | 74 | Cookie and cracker manufacturing (311821:311821) | Cookie and cracker manufacturing |
| AGR | FOO | 75 | Mixes and dough made from purchased flour (311822:311822) | Mixes and dough made from purchased flour |
| AGR | FOO | 76 | Dry pasta manufacturing (311823:311823) | Dry pasta manufacturing |
| AGR | FOO | 77 | Tortilla manufacturing (311830:31183) | Tortilla manufacturing |
| AGR | FOO | 78 | Roasted nuts and peanut butter manufacturing (311911:311911) | Roasted nuts and peanut butter manufacturing |
| AGR | FOO | 79 | Other snack food manufacturing (311919:311919) | Other snack food manufacturing |
| AGR | FOO | 80 | Coffee and tea manufacturing (311920:31192) | Coffee and tea manufacturing |
| AGR | FOO | 81 | Flavoring syrup and concentrate manufacturing (311930:31193) | Flavoring syrup and concentrate manufacturing |
| AGR | FOO | 82 | Mayonnaise, dressing, and sauce manufacturing (311941:311941) | Mayonnaise, dressing, and sauce manufacturing |
| AGR | FOO | 83 | Spice and extract manufacturing (311942:311942) | Spice and extract manufacturing |
| AGR | FOO | 84 | All other food manufacturing (311990:31199) | All other food manufacturing |
| AGR | FOO | 85 | Soft drink and ice manufacturing (312110:31211) | Soft drink and ice manufacturing |
| AGR | FOO | 86 | Breweries (312120:31212) | Breweries |
| AGR | FOO | 87 | Wineries (312130:31213) | Wineries |
| AGR | FOO | 88 | Distilleries (312140:31214) | Distilleries |
| AGR | FOO | 89 | Tobacco stemming and redrying (312210:31221) | Tobacco stemming and redrying |
| AGR | FOO | 90 | Cigarette manufacturing (312221:312221) | Cigarette manufacturing |
| AGR | FOO | 91 | Other tobacco product manufacturing (312229:312229) | Other tobacco product manufacturing |
| COL | COL | 20 | Coal mining (212100:2121) | Coal mining |
| CRU | CRU | 19 | Oil and gas extraction (211000:211) | Oil and gas extraction |
| EIS | MIN | 21 | Iron ore mining (212210:21221) | Iron ore mining |
| EIS | MIN | 22 | Copper, nickel, lead, and zinc mining (212230:21223) | Copper, nickel, lead, and zinc mining |
| EIS | MIN | 23 | Gold, silver, and other metal ore mining (2122A0:21222,21229) | Gold, silver, and other metal ore mining |
| EIS | MIN | 24 | Stone mining and quarrying (212310:21231) | Stone mining and quarrying |
| EIS | MIN | 25 | Sand, gravel, clay, and refractory mining (212320:21232) | Sand, gravel, clay, and refractory mining |
| EIS | MIN | 26 | Other nonmetallic mineral mining (212390:21239) | Other nonmetallic mineral mining |
| EIS | MIN | 27 | Drilling oil and gas wells (213111:213111) | Drilling oil and gas wells |
| EIS | MIN | 28 | Support activities for oil and gas operations (213112:213112) | Support activities for oil and gas operations |
| EIS | MIN | 29 | Support activities for other mining (21311A:213113,213114,213115) | Support activities for other mining |
| EIS | CNS | 33 | New residential 1-unit structures, nonfarm (230110:23*) | New residential 1-unit structures, nonfarm |
| EIS | CNS | 34 | New multifamily housing structures, nonfarm (230120:23*) | New multifamily housing structures, nonfarm |
| EIS | CNS | 35 | New residential additions and alterations, nonfarm (230130:23*) | New residential additions and alterations, nonfarm |
| EIS | CNS | 36 | New farm housing units and additions and alterations (230140:23*) | New farm housing units and additions and alterations |
| EIS | CNS | 37 | Manufacturing and industrial buildings (230210:23*) | Manufacturing and industrial buildings |

| | | | | |
|---|---|---|---|---|
| EIS | CNS | 38 | Commercial and institutional buildings (230220:23*) | Commercial and institutional buildings |
| EIS | CNS | 39 | Highway, street, bridge, and tunnel construction (230230:23*) | Highway, street, bridge, and tunnel construction |
| EIS | CNS | 40 | Water, sewer, and pipeline construction (230240:23*) | Water, sewer, and pipeline construction |
| EIS | CNS | 41 | Other new construction (230250:23*) | Other new construction |
| EIS | CNS | 42 | Maintenance and repair of farm and nonfarm residential structure (230310:23*) | Maintenance and repair of farm and nonfarm residential structures |
| EIS | CNS | 43 | Maintenance and repair of nonresidential buildings (230320:23*) | Maintenance and repair of nonresidential buildings |
| EIS | CNS | 44 | Maintenance and repair of highways, streets, bridges, and tunnel (230330:23*) | Maintenance and repair of highways, streets, bridges, and tunnels |
| EIS | CNS | 45 | Other maintenance and repair construction (230340:23*) | Other maintenance and repair construction |
| EIS | PAP | 124 | Pulp mills (322110:32211) | Pulp mills |
| EIS | PAP | 125 | Paper and paperboard mills (3221A0:32212,32213) | Paper and paperboard mills |
| EIS | PAP | 126 | Paperboard container manufacturing (322210:32221) | Paperboard container manufacturing |
| EIS | PAP | 127 | Flexible packaging foil manufacturing (322225:322225) | Flexible packaging foil manufacturing |
| EIS | PAP | 128 | Surface-coated paperboard manufactuing (322226:322226) | Surface-coated paperboard manufactuing |
| EIS | PAP | 129 | Coated and laminated paper and packaging materials (32222A:322221,322222) | Coated and laminated paper and packaging materials |
| EIS | PAP | 130 | Coated and uncoated paper bag manufacturing (32222B:322223,322224) | Coated and uncoated paper bag manufacturing |
| EIS | PAP | 131 | Die-cut paper office supplies manufacturing (322231:322231) | Die-cut paper office supplies manufacturing |
| EIS | PAP | 132 | Envelope manufacturing (322232:322232) | Envelope manufacturing |
| EIS | PAP | 133 | Stationery and related product manufacturing (322233:322233) | Stationery and related product manufacturing |
| EIS | PAP | 134 | Sanitary paper product manufacturing (322291:322291) | Sanitary paper product manufacturing |
| EIS | PAP | 135 | All other converted paper product manufacturing (322299:322299) | All other converted paper product manufacturing |
| EIS | SCG | 143 | Asphalt paving mixture and block manufacturing (324121:324121) | Asphalt paving mixture and block manufacturing |
| EIS | SCG | 144 | Asphalt shingle and coating materials manufacturing (324122:324122) | Asphalt shingle and coating materials manufacturing |
| EIS | SCG | 145 | Petroleum lubricating oil and grease manufacturing (324191:324191) | Petroleum lubricating oil and grease manufacturing |
| EIS | CHM | 147 | Petrochemical manufacturing (325110:32511) | Petrochemical manufacturing |
| EIS | CHM | 148 | Industrial gas manufacturing (325120:32512) | Industrial gas manufacturing |
| EIS | CHM | 149 | Synthetic dye and pigment manufacturing (325130:32513) | Synthetic dye and pigment manufacturing |
| EIS | CHM | 150 | Other basic inorganic chemical manufacturing (325180:32518) | Other basic inorganic chemical manufacturing |
| EIS | CHM | 151 | Other basic organic chemical manufacturing (325190:32519) | Other basic organic chemical manufacturing |
| EIS | CHM | 152 | Plastics material and resin manufacturing (325211:325211) | Plastics material and resin manufacturing |
| EIS | CHM | 153 | Synthetic rubber manufacturing (325212:325212) | Synthetic rubber manufacturing |
| EIS | CHM | 154 | Cellulosic organic fiber manufacturing (325221:325221) | Cellulosic organic fiber manufacturing |
| EIS | CHM | 155 | Noncellulosic organic fiber manufacturing (325222:325222) | Noncellulosic organic fiber manufacturing |
| EIS | CHM | 156 | Nitrogenous fertilizer manufacturing (325311:325311) | Nitrogenous fertilizer manufacturing |
| EIS | CHM | 157 | Phosphatic fertilizer manufacturing (325312:325312) | Phosphatic fertilizer manufacturing |
| EIS | CHM | 158 | Fertilizer, mixing only, manufacturing (325314:325314) | Fertilizer, mixing only, manufacturing |
| EIS | CHM | 159 | Pesticide and other agricultural chemical manufacturing (325320:32532) | Pesticide and other agricultural chemical manufacturing |
| EIS | CHM | 160 | Pharmaceutical and medicine manufacturing (325400:32541) | Pharmaceutical and medicine manufacturing |
| EIS | CHM | 161 | Paint and coating manufacturing (325510:32551) | Paint and coating manufacturing |
| EIS | CHM | 162 | Adhesive manufacturing (325520:32552) | Adhesive manufacturing |
| EIS | CHM | 163 | Soap and other detergent manufacturing (325611:325611) | Soap and other detergent manufacturing |
| EIS | CHM | 164 | Polish and other sanitation good manufacturing (325612:325612) | Polish and other sanitation good manufacturing |
| EIS | CHM | 165 | Surface active agent manufacturing (325613:325613) | Surface active agent manufacturing |
| EIS | CHM | 166 | Toilet preparation manufacturing (325620:32562) | Toilet preparation manufacturing |
| EIS | CHM | 167 | Printing ink manufacturing (325910:32591) | Printing ink manufacturing |
| EIS | CHM | 168 | Explosives manufacturing (325920:32592) | Explosives manufacturing |
| EIS | CHM | 169 | Custom compounding of purchased resins (325991:325991) | Custom compounding of purchased resins |
| EIS | CHM | 170 | Photographic film and chemical manufacturing (325992:325992) | Photographic film and chemical manufacturing |
| EIS | CHM | 171 | Other miscellaneous chemical product manufacturing (325998:325998) | Other miscellaneous chemical product manufacturing |
| EIS | SCG | 182 | Vitreous china plumbing fixture manufacturing (327111:327111) | Vitreous china plumbing fixture manufacturing |
| EIS | SCG | 183 | Vitreous china and earthenware articles manufacturing (327112:327112) | Vitreous china and earthenware articles manufacturing |
| EIS | SCG | 184 | Porcelain electrical supply manufacturing (327113:327113) | Porcelain electrical supply manufacturing |
| EIS | SCG | 185 | Brick and structural clay tile manufacturing (327121:327121) | Brick and structural clay tile manufacturing |
| EIS | SCG | 186 | Ceramic wall and floor tile manufacturing (327122:327122) | Ceramic wall and floor tile manufacturing |
| EIS | SCG | 187 | Nonclay refractory manufacturing (327125:327125) | Nonclay refractory manufacturing |
| EIS | SCG | 188 | Clay refractory and other structural clay products (32712A:327123,327124) | Clay refractory and other structural clay products |
| EIS | SCG | 189 | Glass container manufacturing (327213:327213) | Glass container manufacturing |
| EIS | SCG | 190 | Glass and glass products, except glass containers (32721A:327211,327212,327215) | Glass and glass products, except glass containers |
| EIS | SCG | 191 | Cement manufacturing (327310:32731) | Cement manufacturing |
| EIS | SCG | 192 | Ready-mix concrete manufacturing (327320:32732) | Ready-mix concrete manufacturing |
| EIS | SCG | 193 | Concrete block and brick manufacturing (327331:327331) | Concrete block and brick manufacturing |
| EIS | SCG | 194 | Concrete pipe manufacturing (327332:327332) | Concrete pipe manufacturing |
| EIS | SCG | 195 | Other concrete product manufacturing (327390:32739) | Other concrete product manufacturing |
| EIS | SCG | 196 | Lime manufacturing (327410:32741) | Lime manufacturing |
| EIS | SCG | 197 | Gypsum product manufacturing (327420:32742) | Gypsum product manufacturing |
| EIS | SCG | 198 | Abrasive product manufacturing (327910:32791) | Abrasive product manufacturing |
| EIS | SCG | 199 | Cut stone and stone product manufacturing (327991:327991) | Cut stone and stone product manufacturing |
| EIS | SCG | 200 | Ground or treated minerals and earths manufacturing (327992:327992) | Ground or treated minerals and earths manufacturing |
| EIS | SCG | 201 | Mineral wool manufacturing (327993:327993) | Mineral wool manufacturing |
| EIS | SCG | 202 | Miscellaneous nonmetallic mineral products (327999:327999) | Miscellaneous nonmetallic mineral products |
| EIS | I_S | 203 | Iron and steel mills (331111:331111) | Iron and steel mills |
| EIS | I_S | 204 | Ferroalloy and related product manufacturing (331112:331112) | Ferroalloy and related product manufacturing |
| EIS | I_S | 205 | Iron, steel pipe and tube from purchased steel (331210:33121) | Iron, steel pipe and tube from purchased steel |
| EIS | I_S | 206 | Rolled steel shape manufacturing (331221:331221) | Rolled steel shape manufacturing |
| EIS | I_S | 207 | Steel wire drawing (331222:331222) | Steel wire drawing |
| EIS | ALU | 208 | Alumina refining (331311:331311) | Alumina refining |
| EIS | ALU | 209 | Primary aluminum production (331312:331312) | Primary aluminum production |
| EIS | ALU | 210 | Secondary smelting and alloying of aluminum (331314:331314) | Secondary smelting and alloying of aluminum |
| EIS | ALU | 211 | Aluminum sheet, plate, and foil manufacturing (331315:331315) | Aluminum sheet, plate, and foil manufacturing |
| EIS | ALU | 212 | Aluminum extruded product manufacturing (331316:331316) | Aluminum extruded product manufacturing |
| EIS | ALU | 213 | Other aluminum rolling and drawing (331319:331319) | Other aluminum rolling and drawing |
| EIS | OPM | 214 | Primary smelting and refining of copper (331411:331411) | Primary smelting and refining of copper |
| EIS | OPM | 215 | Primary nonferrous metal, except copper and aluminum (331419:331419) | Primary nonferrous metal, except copper and aluminum |
| EIS | OPM | 216 | Copper rolling, drawing, and extruding (331421:331421) | Copper rolling, drawing, and extruding |
| EIS | OPM | 217 | Copper wire, except mechanical, drawing (331422:331422) | Copper wire, except mechanical, drawing |

| | | | | |
|---|---|---|---|---|
| EIS | OPM | 218 | Secondary processing of copper (331423:331423) | Secondary processing of copper |
| EIS | OPM | 219 | Nonferrous metal, except copper and aluminum, shaping (331491:331491) | Nonferrous metal, except copper and aluminum, shaping |
| EIS | OPM | 220 | Secondary processing of other nonferrous (331492:331492) | Secondary processing of other nonferrous |
| EIS | I_S | 221 | Ferrous metal foundries (331510:33151) | Ferrous metal foundries |
| EIS | OPM | 222 | Aluminum foundries (33152A:331521,331524) | Aluminum foundries |
| EIS | OPM | 223 | Nonferrous foundries, except aluminum (33152B:331522,331525,331528) | Nonferrous foundries, except aluminum |
| EIS | FAB | 224 | Iron and steel forging (332111:332111) | Iron and steel forging |
| EIS | FAB | 225 | Nonferrous forging (332112:332112) | Nonferrous forging |
| EIS | FAB | 226 | Custom roll forming (332114:332114) | Custom roll forming |
| EIS | FAB | 227 | All other forging and stamping (33211A:332115,332116,332117) | All other forging and stamping |
| EIS | FAB | 228 | Cutlery and flatware, except precious, manufacturing (332211:332211) | Cutlery and flatware, except precious, manufacturing |
| EIS | FAB | 229 | Hand and edge tool manufacturing (332212:332212) | Hand and edge tool manufacturing |
| EIS | FAB | 230 | Saw blade and handsaw manufacturing (332213:332213) | Saw blade and handsaw manufacturing |
| EIS | FAB | 231 | Kitchen utensil, pot, and pan manufacturing (332214:332214) | Kitchen utensil, pot, and pan manufacturing |
| EIS | FAB | 232 | Prefabricated metal buildings and components (332311:332311) | Prefabricated metal buildings and components |
| EIS | FAB | 233 | Fabricated structural metal manufacturing (332312:332312) | Fabricated structural metal manufacturing |
| EIS | FAB | 234 | Plate work manufacturing (332313:332313) | Plate work manufacturing |
| EIS | FAB | 235 | Metal window and door manufacturing (332321:332321) | Metal window and door manufacturing |
| EIS | FAB | 236 | Sheet metal work manufacturing (332322:332322) | Sheet metal work manufacturing |
| EIS | FAB | 237 | Ornamental and architectural metal work manufacturing (332323:332323) | Ornamental and architectural metal work manufacturing |
| EIS | FAB | 238 | Power boiler and heat exchanger manufacturing (332410:33241) | Power boiler and heat exchanger manufacturing |
| EIS | FAB | 239 | Metal tank, heavy gauge, manufacturing (332420:33242) | Metal tank, heavy gauge, manufacturing |
| EIS | FAB | 240 | Metal can, box, and other container manufacturing (332430:33243) | Metal can, box, and other container manufacturing |
| EIS | FAB | 241 | Hardware manufacturing (332500:3325) | Hardware manufacturing |
| EIS | FAB | 242 | Spring and wire product manufacturing (332600:3326) | Spring and wire product manufacturing |
| EIS | FAB | 243 | Machine shops (332710:33271) | Machine shops |
| EIS | FAB | 244 | Turned product and screw, nut, and bolt manufacturing (332720:33272) | Turned product and screw, nut, and bolt manufacturing |
| EIS | FAB | 245 | Metal heat treating (332811:332811) | Metal heat treating |
| EIS | FAB | 246 | Metal coating and nonprecious engraving (332812:332812) | Metal coating and nonprecious engraving |
| EIS | I_S | 247 | Electroplating, anodizing, and coloring metal (332813:332813) | Electroplating, anodizing, and coloring metal |
| EIS | FAB | 248 | Metal valve manufacturing (332910:33291) | Metal valve manufacturing |
| EIS | FAB | 249 | Ball and roller bearing manufacturing (332991:332991) | Ball and roller bearing manufacturing |
| EIS | FAB | 250 | Small arms manufacturing (332994:332994) | Small arms manufacturing |
| EIS | FAB | 251 | Other ordnance and accessories manufacturing (332995:332995) | Other ordnance and accessories manufacturing |
| EIS | FAB | 252 | Fabricated pipe and pipe fitting manufacturing (332996:332996) | Fabricated pipe and pipe fitting manufacturing |
| EIS | FAB | 253 | Industrial pattern manufacturing (332997:332997) | Industrial pattern manufacturing |
| EIS | FAB | 254 | Enameled iron and metal sanitary ware manufacturing (332998:332998) | Enameled iron and metal sanitary ware manufacturing |
| EIS | FAB | 255 | Miscellaneous fabricated metal product manufacturing (332999:332999) | Miscellaneous fabricated metal product manufacturing |
| EIS | FAB | 256 | Ammunition manufacturing (33299A:332992,332993) | Ammunition manufacturing |
| ELE | ELE | 30 | Power generation and supply (221100:2211) | Power generation and supply |
| ELE | ELE | 495 | Federal electric utilities (S00101) | Federal electric utilities |
| ELE | ELE | 498 | State and local government electric utilities (S00202) | State and local government electric utilities |
| GAS | GAS | 31 | Natural gas distribution (221200:2212) | Natural gas distribution |
| M_V | M_V | 344 | Automobile and light truck manufacturing (336110:33611) | Automobile and light truck manufacturing |
| M_V | M_V | 345 | Heavy duty truck manufacturing (336120:33612) | Heavy duty truck manufacturing |
| M_V | M_V | 346 | Motor vehicle body manufacturing (336211:336211) | Motor vehicle body manufacturing |
| M_V | M_V | 347 | Truck trailer manufacturing (336212:336212) | Truck trailer manufacturing |
| M_V | M_V | 348 | Motor home manufacturing (336213:336213) | Motor home manufacturing |
| M_V | M_V | 349 | Travel trailer and camper manufacturing (336214:336214) | Travel trailer and camper manufacturing |
| M_V | M_V | 350 | Motor vehicle parts manufacturing (336300:3363) | Motor vehicle parts manufacturing |
| M_V | M_V | 401 | Motor vehicle and parts dealers (4A0000:441) | Motor vehicle and parts dealers |
| MAN | TEX | 92 | Fiber, yarn, and thread mills (313100:3131) | Fiber, yarn, and thread mills |
| MAN | TEX | 93 | Broadwoven fabric mills (313210:31321) | Broadwoven fabric mills |
| MAN | TEX | 94 | Narrow fabric mills and schiffli embroidery (313220:31322) | Narrow fabric mills and schiffli embroidery |
| MAN | TEX | 95 | Nonwoven fabric mills (313230:31323) | Nonwoven fabric mills |
| MAN | TEX | 96 | Knit fabric mills (313240:31324) | Knit fabric mills |
| MAN | TEX | 97 | Textile and fabric finishing mills (313310:31331) | Textile and fabric finishing mills |
| MAN | TEX | 98 | Fabric coating mills (313320:31332) | Fabric coating mills |
| MAN | TEX | 99 | Carpet and rug mills (314110:31411) | Carpet and rug mills |
| MAN | TEX | 100 | Curtain and linen mills (314120:31412) | Curtain and linen mills |
| MAN | TEX | 101 | Textile bag and canvas mills (314910:31491) | Textile bag and canvas mills |
| MAN | TEX | 102 | Tire cord and tire fabric mills (314992:314992) | Tire cord and tire fabric mills |
| MAN | TEX | 103 | Other miscellaneous textile product mills (31499A:314991,314999) | Other miscellaneous textile product mills |
| MAN | TEX | 104 | Sheer hosiery mills (315111:315111) | Sheer hosiery mills |
| MAN | TEX | 105 | Other hosiery and sock mills (315119:315119) | Other hosiery and sock mills |
| MAN | TEX | 106 | Other apparel knitting mills (315190:31519) | Other apparel knitting mills |
| MAN | TEX | 107 | Cut and sew apparel manufacturing (315200:3152) | Cut and sew apparel manufacturing |
| MAN | TEX | 108 | Accessories and other apparel manufacturing (315900:3159) | Accessories and other apparel manufacturing |
| MAN | TEX | 109 | Leather and hide tanning and finishing (316100:3161) | Leather and hide tanning and finishing |
| MAN | TEX | 110 | Footwear manufacturing (316200:3162) | Footwear manufacturing |
| MAN | TEX | 111 | Other leather product manufacturing (316900:3169) | Other leather product manufacturing |
| MAN | WOO | 112 | Sawmills (321113:321113) | Sawmills |
| MAN | WOO | 113 | Wood preservation (321114:321114) | Wood preservation |
| MAN | WOO | 114 | Reconstituted wood product manufacturing (321219:321219) | Reconstituted wood product manufacturing |
| MAN | WOO | 115 | Veneer and plywood manufacturing (32121A:321211,321212) | Veneer and plywood manufacturing |
| MAN | WOO | 116 | Engineered wood member and truss manufacturing (32121B:321213,321214) | Engineered wood member and truss manufacturing |
| MAN | WOO | 117 | Wood windows and door manufacturing (321911:321911) | Wood windows and door manufacturing |
| MAN | WOO | 118 | Cut stock, resawing lumber, and planing (321912:321912) | Cut stock, resawing lumber, and planing |
| MAN | WOO | 119 | Other millwork, including flooring (321918:321918) | Other millwork, including flooring |
| MAN | WOO | 120 | Wood container and pallet manufacturing (321920:32192) | Wood container and pallet manufacturing |
| MAN | WOO | 121 | Manufactured home, mobile home, manufacturing (321991:321991) | Manufactured home, mobile home, manufacturing |
| MAN | WOO | 122 | Prefabricated wood building manufacturing (321992:321992) | Prefabricated wood building manufacturing |
| MAN | WOO | 123 | Miscellaneous wood product manufacturing (321999:321999) | Miscellaneous wood product manufacturing |
| MAN | PRN | 136 | Manifold business forms printing (323116:323116) | Manifold business forms printing |

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| MAN | PRN | 137 | Books printing (323117:323117) | Books printing |
| MAN | PRN | 138 | Blankbook and looseleaf binder manufacturing (323118:323118) | Blankbook and looseleaf binder manufacturing |
| MAN | PRN | 139 | Commercial printing (32311A:323111,323112,323113,323114,323115,323119) | Commercial printing |
| MAN | PRN | 140 | Tradebinding and related work (323121:323121) | Tradebinding and related work |
| MAN | PRN | 141 | Prepress services (323122:323122) | Prepress services |
| MAN | RUB | 172 | Plastics packaging materials, film and sheet (326110:32611) | Plastics packaging materials, film and sheet |
| MAN | RUB | 173 | Plastics pipe, fittings, and profile shapes (326120:32612) | Plastics pipe, fittings, and profile shapes |
| MAN | RUB | 174 | Laminated plastics plate, sheet, and shapes (326130:32613) | Laminated plastics plate, sheet, and shapes |
| MAN | RUB | 175 | Plastics bottle manufacturing (326160:32616) | Plastics bottle manufacturing |
| MAN | RUB | 176 | Resilient floor covering manufacturing (326192:326192) | Resilient floor covering manufacturing |
| MAN | RUB | 177 | Plastics plumbing fixtures and all other plastics products (32619A:326191,326199) | Plastics plumbing fixtures and all other plastics products |
| MAN | RUB | 178 | Foam product manufacturing (3261A0:32614,32615) | Foam product manufacturing |
| MAN | RUB | 179 | Tire manufacturing (326210:32621) | Tire manufacturing |
| MAN | RUB | 180 | Rubber and plastics hose and belting manufacturing (326220:32622) | Rubber and plastics hose and belting manufacturing |
| MAN | RUB | 181 | Other rubber product manufacturing (326290:32629) | Other rubber product manufacturing |
| MAN | MAC | 257 | Farm machinery and equipment manufacturing (333111:333111) | Farm machinery and equipment manufacturing |
| MAN | MAC | 258 | Lawn and garden equipment manufacturing (333112:333112) | Lawn and garden equipment manufacturing |
| MAN | MAC | 259 | Construction machinery manufacturing (333120:33312) | Construction machinery manufacturing |
| MAN | MAC | 260 | Mining machinery and equipment manufacturing (333131:333131) | Mining machinery and equipment manufacturing |
| MAN | MAC | 261 | Oil and gas field machinery and equipment (333132:333132) | Oil and gas field machinery and equipment |
| MAN | MAC | 262 | Sawmill and woodworking machinery (333210:33321) | Sawmill and woodworking machinery |
| MAN | MAC | 263 | Plastics and rubber industry machinery (333220:33322) | Plastics and rubber industry machinery |
| MAN | MAC | 264 | Paper industry machinery manufacturing (333291:333291) | Paper industry machinery manufacturing |
| MAN | MAC | 265 | Textile machinery manufacturing (333292:333292) | Textile machinery manufacturing |
| MAN | MAC | 266 | Printing machinery and equipment manufacturing (333293:333293) | Printing machinery and equipment manufacturing |
| MAN | MAC | 267 | Food product machinery manufacturing (333294:333294) | Food product machinery manufacturing |
| MAN | MAC | 268 | Semiconductor machinery manufacturing (333295:333295) | Semiconductor machinery manufacturing |
| MAN | MAC | 269 | All other industrial machinery manufacturing (333298:333298) | All other industrial machinery manufacturing |
| MAN | MAC | 270 | Office machinery manufacturing (333313:333313) | Office machinery manufacturing |
| MAN | MAC | 271 | Optical instrument and lens manufacturing (333314:333314) | Optical instrument and lens manufacturing |
| MAN | MAC | 272 | Photographic and photocopying equipment manufacturing (333315:333315) | Photographic and photocopying equipment manufacturing |
| MAN | MAC | 273 | Other commercial and service industry machinery manufacturing (333319:333319) | Other commercial and service industry machinery manufacturing |
| MAN | MAC | 274 | Automatic vending, commercial laundry and drycleaning machinery (33331A:333311,33 | Automatic vending, commercial laundry and drycleaning machinery |
| MAN | MAC | 275 | Air purification equipment manufacturing (333411:333411) | Air purification equipment manufacturing |
| MAN | MAC | 276 | Industrial and commercial fan and blower manufacturing (333412:333412) | Industrial and commercial fan and blower manufacturing |
| MAN | MAC | 277 | Heating equipment, except warm air furnaces (333414:333414) | Heating equipment, except warm air furnaces |
| MAN | MAC | 278 | AC, refrigeration, and forced air heating (333415:333415) | AC, refrigeration, and forced air heating |
| MAN | MAC | 279 | Industrial mold manufacturing (333511:333511) | Industrial mold manufacturing |
| MAN | MAC | 280 | Metal cutting machine tool manufacturing (333512:333512) | Metal cutting machine tool manufacturing |
| MAN | MAC | 281 | Metal forming machine tool manufacturing (333513:333513) | Metal forming machine tool manufacturing |
| MAN | MAC | 282 | Special tool, die, jig, and fixture manufacturing (333514:333514) | Special tool, die, jig, and fixture manufacturing |
| MAN | MAC | 283 | Cutting tool and machine tool accessory manufacturing (333515:333515) | Cutting tool and machine tool accessory manufacturing |
| MAN | MAC | 284 | Rolling mill and other metalworking machinery (33351A:333516,333518) | Rolling mill and other metalworking machinery |
| MAN | MAC | 285 | Turbine and turbine generator set units manufacturing (333611:333611) | Turbine and turbine generator set units manufacturing |
| MAN | MAC | 286 | Other engine equipment manufacturing (333618:333618) | Other engine equipment manufacturing |
| MAN | MAC | 287 | Speed changers and mechanical power transmission equipment (33361A:333612,3336 | Speed changers and mechanical power transmission equipment |
| MAN | MAC | 288 | Pump and pumping equipment manufacturing (333911:333911) | Pump and pumping equipment manufacturing |
| MAN | MAC | 289 | Air and gas compressor manufacturing (333912:333912) | Air and gas compressor manufacturing |
| MAN | MAC | 290 | Measuring and dispensing pump manufacturing (333913:333913) | Measuring and dispensing pump manufacturing |
| MAN | MAC | 291 | Elevator and moving stairway manufacturing (333921:333921) | Elevator and moving stairway manufacturing |
| MAN | MAC | 292 | Conveyor and conveying equipment manufacturing (333922:333922) | Conveyor and conveying equipment manufacturing |
| MAN | MAC | 293 | Overhead cranes, hoists, and monorail systems (333923:333923) | Overhead cranes, hoists, and monorail systems |
| MAN | MAC | 294 | Industrial truck, trailer, and stacker manufacturing (333924:333924) | Industrial truck, trailer, and stacker manufacturing |
| MAN | MAC | 295 | Power-driven handtool manufacturing (333991:333991) | Power-driven handtool manufacturing |
| MAN | MAC | 296 | Welding and soldering equipment manufacturing (333992:333992) | Welding and soldering equipment manufacturing |
| MAN | MAC | 297 | Packaging machinery manufacturing (333993:333993) | Packaging machinery manufacturing |
| MAN | MAC | 298 | Industrial process furnace and oven manufacturing (333994:333994) | Industrial process furnace and oven manufacturing |
| MAN | MAC | 299 | Fluid power cylinder and actuator manufacturing (333995:333995) | Fluid power cylinder and actuator manufacturing |
| MAN | MAC | 300 | Fluid power pump and motor manufacturing (333996:333996) | Fluid power pump and motor manufacturing |
| MAN | MAC | 301 | Scales, balances, and miscellaneous general purpose machinery (33399A:333997,3339 | Scales, balances, and miscellaneous general purpose machinery |
| MAN | COM | 302 | Electronic computer manufacturing (334111:334111) | Electronic computer manufacturing |
| MAN | COM | 303 | Computer storage device manufacturing (334112:334112) | Computer storage device manufacturing |
| MAN | COM | 304 | Computer terminal manufacturing (334113:334113) | Computer terminal manufacturing |
| MAN | COM | 305 | Other computer peripheral equipment manufacturing (334119:334119) | Other computer peripheral equipment manufacturing |
| MAN | COM | 306 | Telephone apparatus manufacturing (334210:33421) | Telephone apparatus manufacturing |
| MAN | COM | 307 | Broadcast and wireless communications equipment (334220:33422) | Broadcast and wireless communications equipment |
| MAN | COM | 308 | Other communications equipment manufacturing (334290:33429) | Other communications equipment manufacturing |
| MAN | COM | 309 | Audio and video equipment manufacturing (334300:3343) | Audio and video equipment manufacturing |
| MAN | COM | 310 | Electron tube manufacturing (334411:334411) | Electron tube manufacturing |
| MAN | COM | 311 | Semiconductors and related device manufacturing (334413:334413) | Semiconductors and related device manufacturing |
| MAN | COM | 312 | All other electronic component manufacturing (33441A:334412,334414,334415,334416, | All other electronic component manufacturing |
| MAN | COM | 313 | Electromedical apparatus manufacturing (334510:334510) | Electromedical apparatus manufacturing |
| MAN | COM | 314 | Search, detection, and navigation instruments (334511:334511) | Search, detection, and navigation instruments |
| MAN | COM | 315 | Automatic environmental control manufacturing (334512:334512) | Automatic environmental control manufacturing |
| MAN | COM | 316 | Industrial process variable instruments (334513:334513) | Industrial process variable instruments |
| MAN | COM | 317 | Totalizing fluid meters and counting devices (334514:334514) | Totalizing fluid meters and counting devices |
| MAN | COM | 318 | Electricity and signal testing instruments (334515:334515) | Electricity and signal testing instruments |
| MAN | COM | 319 | Analytical laboratory instrument manufacturing (334516:334516) | Analytical laboratory instrument manufacturing |
| MAN | COM | 320 | Irradiation apparatus manufacturing (334517:334517) | Irradiation apparatus manufacturing |
| MAN | COM | 321 | Watch, clock, and other measuring and controlling device manufac (33451A:334518,33 | Watch, clock, and other measuring and controlling device manufacturing |
| MAN | COM | 322 | Software reproducing (334611:334611) | Software reproducing |
| MAN | COM | 323 | Audio and video media reproduction (334612:334612) | Audio and video media reproduction |
| MAN | COM | 324 | Magnetic and optical recording media manufacturing (334613:334613) | Magnetic and optical recording media manufacturing |
| MAN | ELQ | 325 | Electric lamp bulb and part manufacturing (335110:33511) | Electric lamp bulb and part manufacturing |

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| MAN | ELQ | 326 | Lighting fixture manufacturing (335120:33512) | Lighting fixture manufacturing |
| MAN | ELQ | 327 | Electric housewares and household fan manufacturing (335211:335211) | Electric housewares and household fan manufacturing |
| MAN | ELQ | 328 | Household vacuum cleaner manufacturing (335212:335212) | Household vacuum cleaner manufacturing |
| MAN | ELQ | 329 | Household cooking appliance manufacturing (335221:335221) | Household cooking appliance manufacturing |
| MAN | ELQ | 330 | Household refrigerator and home freezer manufacturing (335222:335222) | Household refrigerator and home freezer manufacturing |
| MAN | ELQ | 331 | Household laundry equipment manufacturing (335224:335224) | Household laundry equipment manufacturing |
| MAN | ELQ | 332 | Other major household appliance manufacturing (335228:335228) | Other major household appliance manufacturing |
| MAN | ELQ | 333 | Electric power and specialty transformer manufacturing (335311:335311) | Electric power and specialty transformer manufacturing |
| MAN | ELQ | 334 | Motor and generator manufacturing (335312:335312) | Motor and generator manufacturing |
| MAN | ELQ | 335 | Switchgear and switchboard apparatus manufacturing (335313:335313) | Switchgear and switchboard apparatus manufacturing |
| MAN | ELQ | 336 | Relay and industrial control manufacturing (335314:335314) | Relay and industrial control manufacturing |
| MAN | ELQ | 337 | Storage battery manufacturing (335911:335911) | Storage battery manufacturing |
| MAN | ELQ | 338 | Primary battery manufacturing (335912:335912) | Primary battery manufacturing |
| MAN | ELQ | 339 | Fiber optic cable manufacturing (335921:335921) | Fiber optic cable manufacturing |
| MAN | ELQ | 340 | Other communication and energy wire manufacturing (335929:335929) | Other communication and energy wire manufacturing |
| MAN | ELQ | 341 | Wiring device manufacturing (335930:33593) | Wiring device manufacturing |
| MAN | ELQ | 342 | Carbon and graphite product manufacturing (335991:335991) | Carbon and graphite product manufacturing |
| MAN | ELQ | 343 | Miscellaneous electrical equipment manufacturing (335999:335999) | Miscellaneous electrical equipment manufacturing |
| MAN | TRQ | 351 | Aircraft manufacturing (336411:336411) | Aircraft manufacturing |
| MAN | TRQ | 352 | Aircraft engine and engine parts manufacturing (336412:336412) | Aircraft engine and engine parts manufacturing |
| MAN | TRQ | 353 | Other aircraft parts and equipment (336413:336413) | Other aircraft parts and equipment |
| MAN | TRQ | 354 | Guided missile and space vehicle manufacturing (336414:336414) | Guided missile and space vehicle manufacturing |
| MAN | TRQ | 355 | Propulsion units and parts for space vehicles and guided missile (33641A:336415,33641 | Propulsion units and parts for space vehicles and guided missiles |
| MAN | TRQ | 356 | Railroad rolling stock manufacturing (336500:3365) | Railroad rolling stock manufacturing |
| MAN | TRQ | 357 | Ship building and repairing (336611:336611) | Ship building and repairing |
| MAN | TRQ | 358 | Boat building (336612:336612) | Boat building |
| MAN | TRQ | 359 | Motorcycle, bicycle, and parts manufacturing (336991:336991) | Motorcycle, bicycle, and parts manufacturing |
| MAN | TRQ | 360 | Military armored vehicles and tank parts manufacturing (336992:336992) | Military armored vehicles and tank parts manufacturing |
| MAN | TRQ | 361 | All other transportation equipment manufacturing (336999:336999) | All other transportation equipment manufacturing |
| MAN | WOO | 362 | Wood kitchen cabinet and countertop manufacturing (337110:33711) | Wood kitchen cabinet and countertop manufacturing |
| MAN | WOO | 363 | Upholstered household furniture manufacturing (337121:337121) | Upholstered household furniture manufacturing |
| MAN | WOO | 364 | Nonupholstered wood household furniture manufacturing (337122:337122) | Nonupholstered wood household furniture manufacturing |
| MAN | WOO | 365 | Metal household furniture manufacturing (337124:337124) | Metal household furniture manufacturing |
| MAN | WOO | 366 | Institutional furniture manufacturing (337127:337127) | Institutional furniture manufacturing |
| MAN | WOO | 367 | Other household and institutional furniture (33712A:337125,337129) | Other household and institutional furniture |
| MAN | WOO | 368 | Wood office furniture manufacturing (337211:337211) | Wood office furniture manufacturing |
| MAN | WOO | 369 | Custom architectural woodwork and millwork (337212:337212) | Custom architectural woodwork and millwork |
| MAN | WOO | 370 | Office furniture, except wood, manufacturing (337214:337214) | Office furniture, except wood, manufacturing |
| MAN | WOO | 371 | Showcases, partitions, shelving, and lockers (337215:337215) | Showcases, partitions, shelving, and lockers |
| MAN | WOO | 372 | Mattress manufacturing (337910:33791) | Mattress manufacturing |
| MAN | WOO | 373 | Blind and shade manufacturing (337920:33792) | Blind and shade manufacturing |
| MAN | MSC | 374 | Laboratory apparatus and furniture manufacturing (339111:339111) | Laboratory apparatus and furniture manufacturing |
| MAN | MSC | 375 | Surgical and medical instrument manufacturing (339112:339112) | Surgical and medical instrument manufacturing |
| MAN | MSC | 376 | Surgical appliance and supplies manufacturing (339113:339113) | Surgical appliance and supplies manufacturing |
| MAN | MSC | 377 | Dental equipment and supplies manufacturing (339114:339114) | Dental equipment and supplies manufacturing |
| MAN | MSC | 378 | Ophthalmic goods manufacturing (339115:339115) | Ophthalmic goods manufacturing |
| MAN | MSC | 379 | Dental laboratories (339116:339116) | Dental laboratories |
| MAN | MSC | 380 | Jewelry and silverware manufacturing (339910:33991) | Jewelry and silverware manufacturing |
| MAN | MSC | 381 | Sporting and athletic goods manufacturing (339920:33992) | Sporting and athletic goods manufacturing |
| MAN | MSC | 382 | Doll, toy, and game manufacturing (339930:33993) | Doll, toy, and game manufacturing |
| MAN | MSC | 383 | Office supplies, except paper, manufacturing (339940:33994) | Office supplies, except paper, manufacturing |
| MAN | MSC | 384 | Sign manufacturing (339950:33995) | Sign manufacturing |
| MAN | MSC | 385 | Gasket, packing, and sealing device manufacturing (339991:339991) | Gasket, packing, and sealing device manufacturing |
| MAN | MSC | 386 | Musical instrument manufacturing (339992:339992) | Musical instrument manufacturing |
| MAN | MSC | 387 | Broom, brush, and mop manufacturing (339994:339994) | Broom, brush, and mop manufacturing |
| MAN | MSC | 388 | Burial casket manufacturing (339995:339995) | Burial casket manufacturing |
| MAN | MSC | 389 | Buttons, pins, and all other miscellaneous manufacturing (33999A:339993,339999) | Buttons, pins, and all other miscellaneous manufacturing |
| OIL | OIL | 142 | Petroleum refineries (324110:32411) | Petroleum refineries |
| OIL | OIL | 146 | All other petroleum and coal products manufacturing (324199:324199) | All other petroleum and coal products manufacturing |
| SRV | SRV | 18 | Agriculture and forestry support activities (115000:115) | Agriculture and forestry support activities |
| SRV | SRV | 32 | Water, sewage and other systems (221300:2213) | Water, sewage and other systems |
| SRV | SRV | 390 | Wholesale trade (420000:42) | Wholesale trade |
| SRV | SRV | 398 | Postal service (491000:491110) | Postal service |
| SRV | SRV | 399 | Couriers and messengers (492000:492) | Couriers and messengers |
| SRV | SRV | 400 | Warehousing and storage (493000:493) | Warehousing and storage |
| SRV | SRV | 402 | Furniture and home furnishings stores (4A0000:442) | Furniture and home furnishings stores |
| SRV | SRV | 403 | Electronics and appliance stores (4A0000:443) | Electronics and appliance stores |
| SRV | SRV | 404 | Building material and garden supply stores (4A0000:444) | Building material and garden supply stores |
| SRV | SRV | 405 | Food and beverage stores (4A0000:445) | Food and beverage stores |
| SRV | SRV | 406 | Health and personal care stores (4A0000:446) | Health and personal care stores |
| SRV | SRV | 407 | Gasoline stations (4A0000:447) | Gasoline stations |
| SRV | SRV | 408 | Clothing and clothing accessories stores (4A0000:448) | Clothing and clothing accessories stores |
| SRV | SRV | 409 | Sporting goods, hobby, book and music stores (4A0000:451) | Sporting goods, hobby, book and music stores |
| SRV | SRV | 410 | General merchandise stores (4A0000:452) | General merchandise stores |
| SRV | SRV | 411 | Miscellaneous store retailers (4A0000:453) | Miscellaneous store retailers |
| SRV | SRV | 412 | Nonstore retailers (4A0000:454) | Nonstore retailers |
| SRV | SRV | 413 | Newpaper publishers (511110:51111) | Newpaper publishers |
| SRV | SRV | 414 | Periodical publishers (511120:51112) | Periodical publishers |
| SRV | SRV | 415 | Book publishers (511130:51113) | Book publishers |
| SRV | SRV | 416 | Database, directory, and other publishers (5111A0:51114,51119) | Database, directory, and other publishers |
| SRV | SRV | 417 | Software publishers (511200:5112) | Software publishers |
| SRV | SRV | 418 | Motion picture and video industries (512100:5121) | Motion picture and video industries |
| SRV | SRV | 419 | Sound recording industries (512200:5122) | Sound recording industries |
| SRV | SRV | 420 | Radio and television broadcasting (513100:5131) | Radio and television broadcasting |

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| SRV | SRV | 421 | Cable networks and program distribution (513200:5132) | Cable networks and program distribution |
| SRV | SRV | 422 | Telecommunications (513300:5133) | Telecommunications |
| SRV | SRV | 423 | Information services (514100:5141) | Information services |
| SRV | SRV | 424 | Data processing services (514200:5142) | Data processing services |
| SRV | SRV | 425 | Nondepository credit intermediation and related activities (522A00:5222,5223) | Nondepository credit intermediation and related activities |
| SRV | SRV | 426 | Securities, commodity contracts, investments (523000:523) | Securities, commodity contracts, investments |
| SRV | SRV | 427 | Insurance carriers (524100:5241) | Insurance carriers |
| SRV | SRV | 428 | Insurance agencies, brokerages, and related (524200:5242) | Insurance agencies, brokerages, and related |
| SRV | SRV | 429 | Funds, trusts, and other financial vehicles (525000:525) | Funds, trusts, and other financial vehicles |
| SRV | SRV | 430 | Monetary authorities and depository credit intermediation (52A000:521,5221) | Monetary authorities and depository credit intermediation |
| SRV | SRV | 431 | Real estate (531000:531) | Real estate |
| SRV | SRV | 432 | Automotive equipment rental and leasing (532100:5321) | Automotive equipment rental and leasing |
| SRV | SRV | 433 | Video tape and disc rental (532230:53223) | Video tape and disc rental |
| SRV | SRV | 434 | Machinery and equipment rental and leasing (532400:5324) | Machinery and equipment rental and leasing |
| SRV | SRV | 435 | General and consumer goods rental except video tapes and discs (532A00:53221,5322 | General and consumer goods rental except video tapes and discs |
| SRV | SRV | 436 | Lessors of nonfinancial intangible assets (533000:533) | Lessors of nonfinancial intangible assets |
| SRV | SRV | 437 | Legal services (541100:5411) | Legal services |
| SRV | SRV | 438 | Accounting and bookkeeping services (541200:5412) | Accounting and bookkeeping services |
| SRV | SRV | 439 | Architectural and engineering services (541300:5413) | Architectural and engineering services |
| SRV | SRV | 440 | Specialized design services (541400:5414) | Specialized design services |
| SRV | SRV | 441 | Custom computer programming services (541511:541511) | Custom computer programming services |
| SRV | SRV | 442 | Computer systems design services (541512:541512) | Computer systems design services |
| SRV | SRV | 443 | Other computer related services, including facilities management (54151A:541513,5415 | Other computer related services, including facilities management |
| SRV | SRV | 444 | Management consulting services (541610:54161) | Management consulting services |
| SRV | SRV | 445 | Environmental and other technical consulting services (5416A0:54162,54169) | Environmental and other technical consulting services |
| SRV | SRV | 446 | Scientific research and development services (541700:5417) | Scientific research and development services |
| SRV | SRV | 447 | Advertising and related services (541800:5418) | Advertising and related services |
| SRV | SRV | 448 | Photographic services (541920:54192) | Photographic services |
| SRV | SRV | 449 | Veterinary services (541940:54194) | Veterinary services |
| SRV | SRV | 450 | All other miscellaneous professional and technical services (5419A0:54191,54193,5419 | All other miscellaneous professional and technical services |
| SRV | SRV | 451 | Management of companies and enterprises (550000:55) | Management of companies and enterprises |
| SRV | SRV | 452 | Office administrative services (561100:5611) | Office administrative services |
| SRV | SRV | 453 | Facilities support services (561200:5612) | Facilities support services |
| SRV | SRV | 454 | Employment services (561300:5613) | Employment services |
| SRV | SRV | 455 | Business support services (561400:5614) | Business support services |
| SRV | SRV | 456 | Travel arrangement and reservation services (561500:5615) | Travel arrangement and reservation services |
| SRV | SRV | 457 | Investigation and security services (561600:5616) | Investigation and security services |
| SRV | SRV | 458 | Services to buildings and dwellings (561700:5617) | Services to buildings and dwellings |
| SRV | SRV | 459 | Other support services (561900:5619) | Other support services |
| SRV | SRV | 460 | Waste management and remediation services (562000:562) | Waste management and remediation services |
| SRV | SRV | 461 | Elementary and secondary schools (611100:6111) | Elementary and secondary schools |
| SRV | SRV | 462 | Colleges, universities, and junior colleges (611A00:6112,6113) | Colleges, universities, and junior colleges |
| SRV | SRV | 463 | Other educational services (611B00:6114,6115,6116,6117) | Other educational services |
| SRV | SRV | 464 | Home health care services (621600:6216) | Home health care services |
| SRV | SRV | 465 | Offices of physicians, dentists, and other health practioners (621A00:6211,6212,6213) | Offices of physicians, dentists, and other health practioners |
| SRV | SRV | 466 | Other ambulatory health care services (621B00:6214,6215,6219) | Other ambulatory health care services |
| SRV | SRV | 467 | Hospitals (622000:622) | Hospitals |
| SRV | SRV | 468 | Nursing and residential care facilities (623000:623) | Nursing and residential care facilities |
| SRV | SRV | 469 | Child day care services (624400:6244) | Child day care services |
| SRV | SRV | 470 | Social assistance, except child day care services (624A00:6241,6242,6243) | Social assistance, except child day care services |
| SRV | SRV | 471 | Performing arts companies (711100:7111) | Performing arts companies |
| SRV | SRV | 472 | Spectator sports (711200:7112) | Spectator sports |
| SRV | SRV | 473 | Independent artists, writers, and performers (711500:7115) | Independent artists, writers, and performers |
| SRV | SRV | 474 | Promoters of performing arts and sports and agents for public fi (711A00:7113,7114) | Promoters of performing arts and sports and agents for public figures |
| SRV | SRV | 475 | Museums, historical sites, zoos, and parks (712000:712) | Museums, historical sites, zoos, and parks |
| SRV | SRV | 476 | Fitness and recreational sports centers (713940:71394) | Fitness and recreational sports centers |
| SRV | SRV | 477 | Bowling centers (713950:71395) | Bowling centers |
| SRV | SRV | 478 | Other amusement, gambling, and recreation industries (713A00:7131,7132,71391,7139 | Other amusement, gambling, and recreation industries |
| SRV | SRV | 479 | Hotels and motels, including casino hotels (7211A0:72111,72112) | Hotels and motels, including casino hotels |
| SRV | SRV | 480 | Other accommodations (721A00:72119,7212,7213) | Other accommodations |
| SRV | SRV | 481 | Food services and drinking places (722000:722) | Food services and drinking places |
| SRV | SRV | 482 | Car washes (811192:811192) | Car washes |
| SRV | SRV | 483 | Automotive repair and maintenance, except car washes (8111A0:81111,81112,811191, | Automotive repair and maintenance, except car washes |
| SRV | SRV | 484 | Electronic equipment repair and maintenance (811200:8112) | Electronic equipment repair and maintenance |
| SRV | SRV | 485 | Commercial machinery repair and maintenance (811300:8113) | Commercial machinery repair and maintenance |
| SRV | SRV | 486 | Household goods repair and maintenance (811400:8114) | Household goods repair and maintenance |
| SRV | SRV | 487 | Personal care services (812100:8121) | Personal care services |
| SRV | SRV | 488 | Death care services (812200:8122) | Death care services |
| SRV | SRV | 489 | Drycleaning and laundry services (812300:8123) | Drycleaning and laundry services |
| SRV | SRV | 490 | Other personal services (812900:8129) | Other personal services |
| SRV | SRV | 491 | Religious organizations (813100:8131) | Religious organizations |
| SRV | SRV | 492 | Grantmaking and giving and social advocacy organizations (813A00:8132,8133) | Grantmaking and giving and social advocacy organizations |
| SRV | SRV | 493 | Civic, social, professional and similar organizations (813B00:8134,8139) | Civic, social, professional and similar organizations |
| SRV | SRV | 494 | Private households (814000:814) | Private households |
| SRV | SRV | 496 | Other Federal Government enterprises (S00102) | Other Federal Government enterprises |
| SRV | SRV | 499 | Other State and local government enterprises (S00203) | Other State and local government enterprises |
| SRV | SRV | 500 | Noncomparable imports (S00300) | Noncomparable imports |
| SRV | SRV | 501 | Scrap (S00401) | Scrap |
| SRV | SRV | 502 | Used and secondhand goods (S00402) | Used and secondhand goods |
| SRV | SRV | 503 | State & Local Education (S00500) | State & Local Education |
| SRV | SRV | 504 | State & Local Non-Education (S00500) | State & Local Non-Education |
| SRV | SRV | 505 | Federal Military (S00500) | Federal Military |
| SRV | SRV | 506 | Federal Non-Military (S00500) | Federal Non-Military |
| SRV | SRV | 507 | Rest of the world adjustment to final uses (S00600) | Rest of the world adjustment to final uses |

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| SRV | SRV | 508 | Inventory valuation adjustment (S00700) | Inventory valuation adjustment |
| SRV | DWE | 509 | Owner-occupied dwellings (S00800) | Owner-occupied dwellings |
| TRN | TRN | 391 | Air transportation (481000:481) | Air transportation |
| TRN | TRN | 392 | Rail transportation (482000:482) | Rail transportation |
| TRN | TRN | 393 | Water transportation (483000:483) | Water transportation |
| TRN | TRN | 394 | Truck transportation (484000:484) | Truck transportation |
| TRN | TRN | 395 | Transit and ground passenger transportation (485000:485) | Transit and ground passenger transportation |
| TRN | TRN | 396 | Pipeline transportation (486000:486) | Pipeline transportation |
| TRN | TRN | 397 | Scenic and sightseeing transportation and support activities for (48A000:487,488) | Scenic and sightseeing transportation and support activities for transportation |
| TRN | TRN | 497 | State and local government passenger transit (S00201) | State and local government passenger transit |