MEMORADUM

TO: Energy Supply TWG members

FROM: Bill Dougherty

CC: Randy Strait, J. David Thornton, Ed Garvey, Tom Peterson

DATE: 21 May 2007

RE: Electricity supply GHG inventory and forecast spreadsheets

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Dear Colleagues,

As discussed during the Energy Supply TWG call held on 17 May 2007 from 9:30 to 11:00 AM, attached please find three spreadsheets as follows:

- *MN electric sector GHG Inventory - version 1.2.xls:* this is the spreadsheet that develops the GHG inventory for electric supply and provides an independent check against the MN PCA inventory and forecast;
- *MN electric supply GHG forecast - version 1.2.xls:* this is the spreadsheet that develops the GHG forecast for electric supply.
- *MN electric supply GHG Inventory & forecast - version 1.0.xls:* this is the spreadsheet that integrates the GHG inventory and forecast for electric supply.

The rest of this memo describes the data sources, key assumptions, and the methodology used to develop an inventory of greenhouse gas (GHG) emissions over the 1990-2005 period associated with meeting electricity demand in Minnesota, as well as data sources, key assumptions, and methodology used to develop a forecast of GHG emissions over the 2006-2020 period associated with meeting electricity demand in the state. Specifically, this memo provides details regarding the following:

- *Data sources:* This section provides an overview of the data sources that were used to develope the inventory and forecast, including publicly accessible websites where this information can be obtained and verified.
- *Greenhouse Gas Inventory methodology:* This section provides an overview of the methodological approach used to develop of the MN GHG inventory for the electric supply sector.
- *Greenhouse Gas Forecast Methodology – Reference Case:* This section provides an overview of methodological approach used to develop the MN GHG Reference Case forecast for the electric supply sector. This forecast does not include the impact of RPS legislation.
- *Greenhouse Gas Forecast Methodology – Alternative Reference Case:* This section provides an overview of methodological approach used to develop the MN GHG Alternative Reference Case forecast for the electric supply sector. This forecast includes the impact of RPS legislation.

- *Greenhouse Gas Inventory Results:* This section provides an overview of key results of the MN GHG inventory for the electric supply sector.
- *Greenhouse Gas Forecast Results:* This section provides an overview of key results of the MN GHG forecast for the electric supply sector. The results of both Reference Cases are presented.

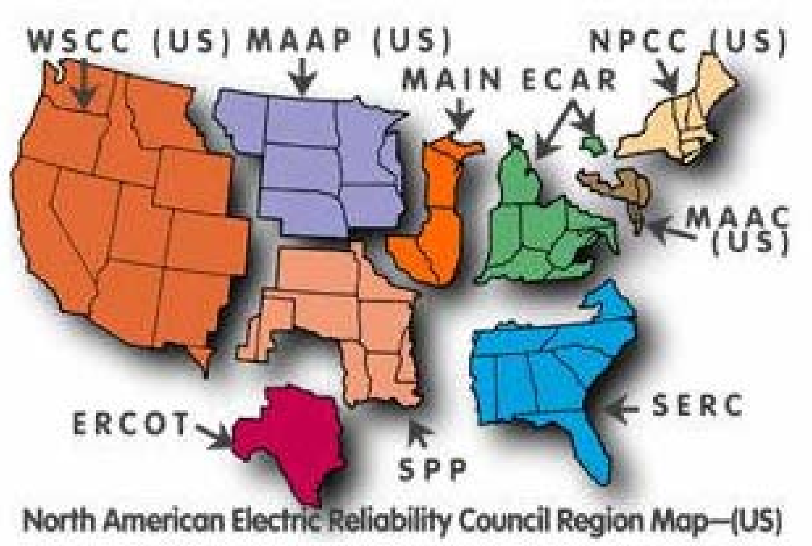
Data Sources

We considered several sources of information in the development of the inventory and forecast of carbon dioxide equivalent emissions from Minnesota power plants. These are briefly summarized below:

- *GHGemitsum07.xls:* This is an inventory of GHG emissions in Minnesota for all sectors over the period 1965 through and including 2005. Electric sector data is provided in worksheets "Energy Use and CO2" and "Electric sector indicators".[1] The information in these worksheets provides a production-based estimate of GHG emissions (i.e., associated with electric generation from electric power stations located in MN) from the electric sector. A consumption-based estimate of GHG emissions (i.e., associated with electricity consumption in MN) was not prepared.
- *2005 EIA-906/920 Monthly Time Series data.* This is a database file available from the Energy Information Administration (EIA) of the US Department of Energy. The information in the database is based on information collected from utilities in Forms EIA-906/920 and EIA-860 for the forecast Base Year of 2005. Data was extracted for MN as well as neighboring states IA, ND, NE, SD, and MT. Data from these forms provide, among other things, fuel consumption and net generation in power stations located in these states for 2005 by plant type. This information can be accessed from http://www.eia.doe.gov/cneaf/electricity/page/eia906_920.html.
- *MN Certificate of Need applications.* These are submissions by major utilities in MN concerning the construction o Transmission Lines in Western Minnesota. These sources provide electricity sale and net generation forecasts up through and including 2020 for the following utilities operating in MN: Central Minnesota Municipal Power Agency, Great River Energy, Missouri River Energy Services, Otter Tail Power, Southern Minnesota Municipal Power Agency, and Xcel (note that the Certificate of Need for Excel was in reference to the Chisago County 115/161 KV transmission line). This information can be accessed directly from http://www.puc.state.mn.us/.

[1] This spreadsheet was prepared by Peter Ciborowski of the MPCA.

- *Annual Energy Outlook 2007.* This is an output of an EIA analysis using the National Energy Modeling System (NEMS), a model that forecasts electric expansion/electricity demand in the USA. In particular, regional outputs for Mid-Continent Area Power Pool (MAPP) region was used. The MAPP region is the one in which MN is located (see map at right). The MAPP results include forecasts of gross generation, net generation, combustion efficiency, total sales, and exports/imports through the year 2025. This information is available in supplemental tables that can be accessed directly from http://www.eia.doe.gov/oiaf/aeo/supplement/index.html. The sources of the above map is http://www.bydesign.com/fossilfuels/crisis/html/NERC_regions_map.html.



- *Monthly Cost and Quality of Fuels for Electric Plants.* This information is available from the Federal Energy Regulatory Commission (FERC). The database relies on information collected from utilities in the FERC-423 form. It was used to determine the share of coal type (i.e., whether bituminous, sub-bituminous, anthracite, or lignite) as well as the coal quantity consumed in MN power plants over the period 1990-2005. It can be accessed directly from http://www.eia.doe.gov/cneaf/electricity/page/ferc423.html.

- *State Electricity Profiles.* This information is available from the EIA. The database compiles capacity, net generation, and total retail electricity sales by state. It was used to determine total sales of electricity across all sectors in the Base Year 2005. It can be accessed directly from http://www.eia.doe.gov/cneaf/electricity/st_profiles/e_profiles_sum.html.

- *Energy conversion factors.* This is based on Table Y-2 of Appendix Y in the USEPA's 2003 GHG Inventory for the USA. The table is entitled "Conversion Factors to Energy Units (Heat Equivalents)". This information can be accessed directly from the following website: http://yosemite.epa.gov/oar/globalwarming.nsf/UniqueKeyLookup/LHOD5MJTCL/$File/2003-final-inventory_annex_y.pdf

- *Fuel combustion oxidation factors:* This is based on Appendix A of the USEPA's 2003 US GHG inventory for the USA. This information can be accessed directly from: http://www.epa.gov/climatechange/emissions/downloads06/06_Annex_Chapter2.pdf

- *Carbon dioxide. Methane, and nitrous oxide emission factors.* For all fuels except MSW, these emission factors are based on Appendix A of the USEPA's 2003 GHG inventory for the USA. This information can be accessed directly from: http://www.epa.gov/climatechange/emissions/downloads06/06_Annex_Chapter2.pdf. For MSW, emission factors are based on the Energy Information Administration, Office of Integrated Analysis and Forecasting, Voluntary Reporting of Greenhouse Gases Program, Table of Fuel and Energy Source: Codes and Emission Coefficients. This information can be accessed directly from http://www.eia.doe.gov/oiaf/1605/coefficients.html.

- *Global warming potentials:* These are based on values proposed by the Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report. This information can be accessed directly from http://www.ipcc.ch/pub/reports.htm

Greenhouse Gas Inventory Methodology

The methodology used to the develop the MN inventory of GHG emissions associated with electricity production and consumption is based on methods developed by the IPCC and used by the USEPA in the development of the US GHG inventory. There are four fundamental premises of the GHG inventory developed for MN, as briefly described below:

- The GHG inventory should be estimated based on both the production and consumption of electricity. Developing the production estimate involves tallying up the GHG emissions associated with the operation of power plants physically located in MN, regardless of ownership. Developing the consumption estimate involves tallying up the GHG emissions associated with consumption of electricity in MN, regardless of where the electricity is produced. As MN is a net importer of electricity, these estimates will be different.
- The GHG inventory should be estimated based on emissions at the point of electric generation only. That is, GHG emissions associated with upstream fuel cycle process such as primary fuel extraction, transport to refinery/processing stations, refining, beneficiation, and transport to the power station are not included.
- As an approximation, it was assumed that all power generated in MN was consumed in MN. In fact, some of the power generated in MN is exported. However, given the similarity in the average carbon intensity of MN power stations and that of power stations in the surrounding MAPP region, the potential error associated with this simplifying assumption is small, on the order of 2%, plus or minus.
- Several key assumptions were used for making projections of carbon dioxide. Methane, and nitrous oxide emissions for the electric sector out to 2020. These are summarized in Table 1 below.

Table 1: Key assumptions used in the Minnesota GHG forecast

Key Assumptions	in 2005	in 2020	Average rate of growth/change (%/yr)
MN electricity demand (GWh)	66,019	85,206	1.72%
MN Gross generation (GWh)	50,790	66,991	1.86%
MN utility sales to meet MN demand (GWh)	48,321	61,178	1.59%
Import sales from MAPP region (GWh)	17,698	24,028	2.06%
Gross generation from MAPP imports (GWh)	18,602	26,311	2.34%
Power plant heat rate (btu/kWh)			
Coal	10,907	10,314	-0.37%
Nuclear	10,317	10,317	0.00%
Natural Gas	11,153	7,462	-2.64%
Oil	10,345	9,711	-0.42%
MSW	18,444	18,444	0.00%
Biomass	17,705	20,648	1.03%
LFG	11,889	7,955	-2.64%
Wind	9,884	9,884	0.00%
Hydro	9,884	9,884	0.00%
Losses (%)			
from on-site usage	1.16%	1.21%	0.29%
from T&D and on-site usage	4.86%	8.68%	3.94%

There were several steps in the methodology for the development of the electric sector GHG inventory for the period 1990-2005. These are briefly outlined below:

- Determine the coal quality used in MN power stations (i.e., share of anthracite, bituminous, lignite, sub-bituminous, and coal wastes used);
- Determine gross annual primary energy consumption by MN power stations by plant and fuel type;
- Determine gross annual generation associated with net power imports to satisfy MN electricity demand.
- Multiply gross annual primary energy consumption by MN power stations by carbon dioxide-equivalent emission factors. This provides an estimate of the MN GHG inventory on a production basis.
- Multiply annual gross generation associated with net power imports by the carbon emission intensity (in units of tonnes CO2-equivalent per MWh) of the MAPP region. This provides an estimate of the additional GHG emissions associated with meeting MN electricity demand in excess of generation from local power plants.
- Add the emissions associated with net power imports to the production-based emissions. This provides an estimate of the GHG inventory on a consumption basis.

Greenhouse Gas Forecast Methodology – Reference Case

We consider that the most useful methodology for constructing a GHG forecast is one that attempts to build information from the bottom-up. That is, the GHG forecast in developed using detailed State-specific data regarding projected sales, gross in-state generation, supply side efficiency improvements, planned capacity additions and retirements by plant type/vintage, and changes over time regarding losses associated with on-site use and transmission and distribution.

While some of this information was available in MN, some key data was not available at the time the forecast was prepared. Therefore, it was necessary to use a top-down approach. A top-down approach uses proxy information regarding future gross in-state generation, supply side efficiency improvements, and changes over time regarding losses. This approach, while less satisfactory for representing state-specific conditions, nonetheless offers an acceptable starting point for exploring projections of GHG emissions from the electric sector in MN. The methodological steps used for forecasting carbon dioxide equivalent emissions are described below.

Coal quality. An overview of the methodology applied to forecast annual gross electricity generation by MN power stations is briefly summarized below:

- For the Base Year of 2005, determine the coal quality used in MN power stations (i.e., share of anthracite, bituminous, lignite, sub-bituminous, and coal wastes used);
- For the period 2006 through and including 2020, assume that the coal quality is the same for the Base year.

Total Sales. An overview of the methodology applied to forecast annual sales of electricity to MN consumers is briefly summarized below:

- For the Base Year of 2005, establish total retail sales in MN (i.e., 66,019 GWh);

- For the period 2006 through and including 2020, obtain in-state electricity sale projections from MN-based utilities (note: this was obtained from Certificates of Need but corresponded only to about 74% of total sales in MN for the Base Year 2005)
- For the period 2006 through and including 2020, compute the annual growth rate associated with electricity sales by MN-based utilities to MN consumers and apply this growth rate to the 2005 retail sale level to forecast annual sales.

Gross Generation. An overview of the methodology applied to forecast annual gross electricity generation by MN power stations is briefly summarized below:

- For the Base Year of 2005, estimate losses associated with on-site usage of electricity by plant type for MN power plants. On-site usage losses were assumed to be equal to the MAPP regional average of 0.8% of gross generation;
- For the Base Year of 2005, combine actual net electric generation data (i.e., from the inventory) and assumed average on-site losses (i.e., from the MAPP region) to estimate gross generation by plant type;
- For the period 2006 through and including 2020, estimate total gross generation of MN power stations by multiplying the 2005 value of MN total gross generation by plant type by the annual growth rate of gross generation in the MAPP region;
- For the period 2006 through and including 2020, multiply plant type-specific gross generation by the annual growth rate of total gross generation in the MAPP region. Then benchmark the plant type-specific totals pro-rata to match the control total of gross generation;

Combustion efficiency. An overview of the methodology applied to forecast annual heat rates at MN power stations is briefly summarized below:

- For the Base Year of 2005, estimate gross heat rate of MN power stations by dividing the plant type-specific 2005 gross generation estimate by the plant type-specific 2005 gross primary energy consumption estimate.
- For the period 2006 through and including 2020, estimate the annual average gross plant type-specific heat rate for the MAPP region.
- For the period 2006 through and including 2020, estimate annual average gross plant type-specific heat rate of MN power stations by multiplying the 2005 value of the annual average gross plant type-specific heat rate of MN power plants by the annual rate of improvement of gross heat rate in the MAPP region;

Energy use. An overview of the methodology applied to forecast annual primary energy use at MN power stations is briefly summarized below:

- For the Base Year of 2005, establish the actual primary energy consumption for MN power plants as reported by the databases used to develop the inventory.
- For the period 2006 through and including 2020, multiply annual gross generation by annual heat rate for each plant type in MN.

Electricity imports. An overview of the methodology applied to forecast annual net electricity imports to meet MN demand is briefly summarized below:

- For the Base Year of 2005, establish actual total sales of electricity in MN
- For the period 2006 through and including 2020, estimate annual electricity sales in MN by multiplying the previous year's sales by the annual growth rate of the MAPP region.
- For the Base Year of 2005 through and including 2020, estimate the sales associated with imports as the difference between total sales in MN and the total sales by MN power stations;
- For the Base Year of 2005 through and including 2020, estimate the gross generation associated with imports by dividing sales from imports by one minus the percent losses from on-site usage and transmission and distribution in the MAPP region.

Carbon dioxide-equivalent emissions from MN power stations. An overview of the methodology applied to forecast annual carbon dioxide-equivalent emissions is briefly summarized below:

- For the Base Year of 2005 through and including 2020, estimate total carbon dioxide emissions from MN power stations by multiplying total primary energy use by the carbon dioxide emission factor and the global warming potential
- For the Base Year of 2005 through and including 2020, estimate total methane emissions from MN power stations by multiplying total primary energy use by the methane emission factor and the global warming potential
- For the Base Year of 2005 through and including 2020, estimate total nitrous oxide emissions from MN power stations by multiplying total primary energy use by the nitrous oxide emission factor and the global warming potential
- For the Base Year of 2005 through and including 2020, estimate total carbon dioxide-equivalent emissions from MN power stations by adding the carbon dioxide-equivalents of carbon dioxide, methane, and nitrous oxide.

Carbon dioxide-equivalent emissions from imported electricity. An overview of the methodology applied to forecast annual carbon dioxide-equivalent emissions is briefly summarized below:

- For the Base Year of 2005 through and including 2020, estimate the average annual GHG emission intensity (i.e., tonnes of carbon dioxide, methane, and nitrous oxide per MWh of gross generation) for the MAPP region from the data sources described earlier.
- For the Base Year of 2005 through and including 2020, estimate total carbon dioxide emissions associated with imported electricity by multiplying the gross generation associated with these imports by the carbon dioxide emission intensity and the global warming potential;
- For the Base Year of 2005 through and including 2020, estimate total methane emissions associated with imported electricity by multiplying the gross generation associated with these imports by the methane emission intensity and the global warming potential;
- For the Base Year of 2005 through and including 2020, estimate total nitrous oxide emissions associated with imported electricity by multiplying the gross generation associated with these imports by the nitrous oxide emission intensity and the global warming potential;
- For the Base Year of 2005 through and including 2020, estimate total carbon dioxide-equivalent emissions associated with imported electricity by adding the carbon dioxide-equivalents of carbon dioxide, methane, and nitrous oxide.

Greenhouse Gas Forecast Methodology – Alternative Reference Case

We also considered an alternative Reference Case that integrates renewable energy objectives from a Renewable Portfolio Standard as represented in amended Minnesota Statutes 2006, Section 216b.1691. This statute calls for each electric utility in MN to either generate or procure sufficient electricity generation to provide retail/wholesale customers in Minnesota with the following percentages of total retail electric sales:

- 7% of retail sales in MN met be renewable energy sources by the year 2010;
- 12% of retail sales in MN met be renewable energy sources by the year 2012
- 17% of retail sales in MN met be renewable energy sources by the year 2016
- 20% of retail sales in MN met be renewable energy sources by the year 2020

The methodology for forecasting gross generation and carbon dioxide equivalent emissions from imports is described below. The methodology for forecasting combustion efficiency, primary energy use, electricity imports, and carbon dioxide equivalent emissions from MN power stations is the same as described above.

Gross Generation. An overview of the methodology applied to forecast annual gross electricity generation in the Alternative Reference Case by MN power stations is briefly summarized below:

- For the Base Year of 2005 through 2006 (i.e., the period before the RPS takes effect), assume the same gross generation as determined in the Reference Case forecast;
- For the period 2007 through and including 2020, decrease the gross generation of fossil stations in MN by the prorata share of 20% of Reference Case sales;
- For the period 2007 through and including 2020, increase the gross generation of renewable stations (i.e., biomass, solar, hydro, and wind) in MN by the prorata share of 20% of Reference Case sales;

Carbon dioxide-equivalent emissions from imported electricity. An overview of the methodology applied to forecast annual carbon dioxide-equivalent emissions in the Alternative Reference Case is briefly summarized below:

- For the Base Year of 2005 through and including 2006 (i.e., the period before the RPS takes effect), assume the carbon dioxide-equivalent intensity of imported electricity is as determined in the Reference Case forecast;
- For the period 2007 through and including 2020, decrease the carbon dioxide-equivalent emission intensity of imported electricity by 20% of the Reference Case emission intensity.

Greenhouse Gas Inventory Results

The charts and table below summarize the characteristics of the electric generation system in MN, together with a breakdown in generation and carbon-equivalent emissions for MN power stations in the Base year of 2005.

Figure 1: Breakdown of MN generation, capacity and CO2 emissions for the 2005 Base Year

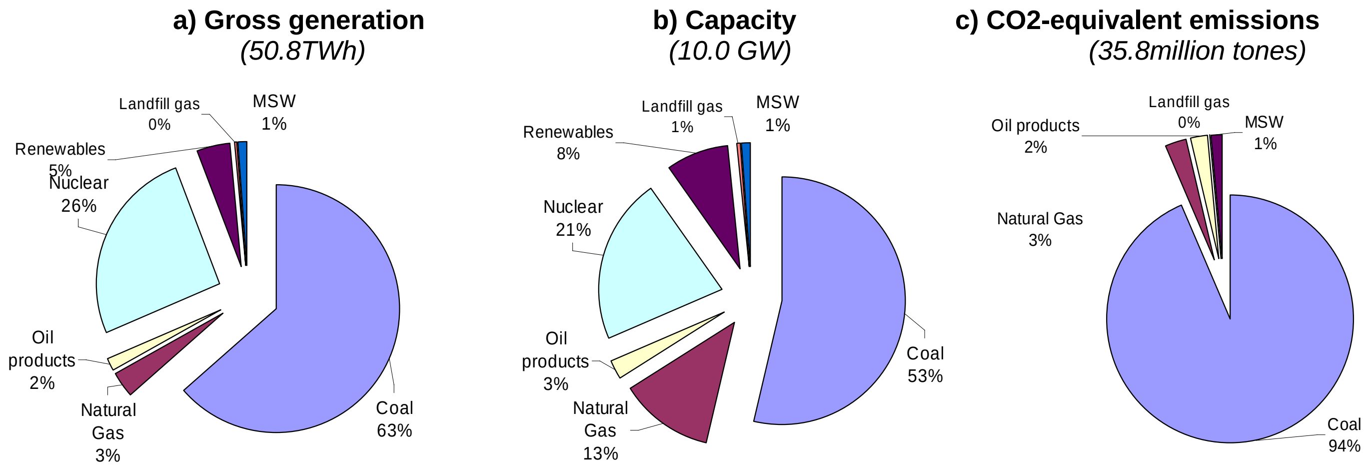


Table 2: Summary of MN electric generator characteristics for the 2005 Base Year

Type	Fuel	Gross Gen (GWh)	Cap (MW)	Fuel use (E9 btu)	Heat rate (btu/kwh)	E6 tonnes of CO2e
Steam plants	Non-lignite coal	32,298	5,367	352,272	10,907	33.49
	Lignite coal	0	0	0	0	0.00
	Natural Gas	166	28	1,974	11,921	0.11
	Residual oil	44	7	462	10,598	0.04
	Diesel oil	26	4	270	10,518	0.02
	Petroleum coke	619	103	6,137	9,912	0.61
	LFG	0	0	0	0	0.00
	Refuse derived fuel/MSW	619	103	11,413	18,444	0.48
	Biomass	18	3	323	17,705	0.00
	Nuclear	12,985	2,158	133,974	10,317	0.00
	subtotal:	*46,775*	*7,772*	*506,826*		*34.74*
Turbines	Natural Gas	847	1,059	10,732	12,668	0.58
	Diesel	63	79	899	14,227	0.07
	Landfill Gas	0	0	0	0	0.00
	Waste oils/solvents	0	NA	0	0	0.00
	subtotal:	*910*	*1,138*	*11,631*		*0.64*
Combined Cycle	Natural Gas	683	0	5,913	8,655	0.32
	Diesel	2	0	23	10,686	0.00
	Landfill Gas	44	0	534	12,124	0.03
	subtotal:	*729*	*0*	*6,470*		*0.35*
Engines	Natural Gas	30	166	632	21,017	0.03
	Diesel	11	63	125	10,929	0.01
	Landfill Gas	12	68	136	11,051	0.01
	LPG	0	0	0	0	0.00
	subtotal:	*54*	*296*	*892*		*0.05*
Renew	Wind	1,601	634	15,823	9,884	0.00
	Solar PV	0	0	0	0	0.00
	Hydroelectric	721	164	7,130	9,884	0.00
	subtotal:	*2,322*	*798*	*22,954*		*0.00*
All	***Total***	**50,790**	**10,005**	**548,772**		**35.78**

Greenhouse Gas Forecast Results

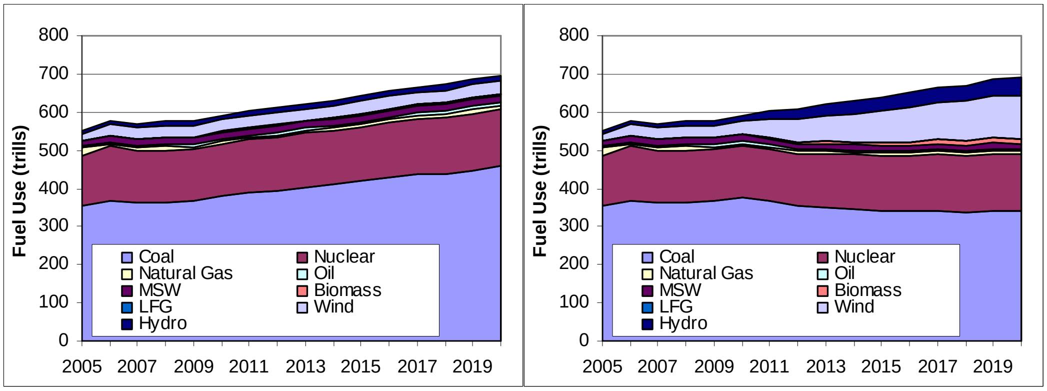
The following subsections provide an overview of the results obtained after applying the methodological approach described above.

Primary Energy Consumption

Total primary energy consumption associated with electricity generation in MN is summarized the figures below for both Reference Cases. In the Reference Case without the RPS, primary energy consumption in MN is dominated by coal and nuclear resources. In the Reference Case with the RPS, primary energy consumption in MN, while still dependent on coal and nuclear resources, has a sharply increased share of wind and hydro resources. The figures below summarize primary energy use with and without the RPS.

Figure 2: Primary energy use at MN power stations

a) not including the RPS **b) including the RPS**

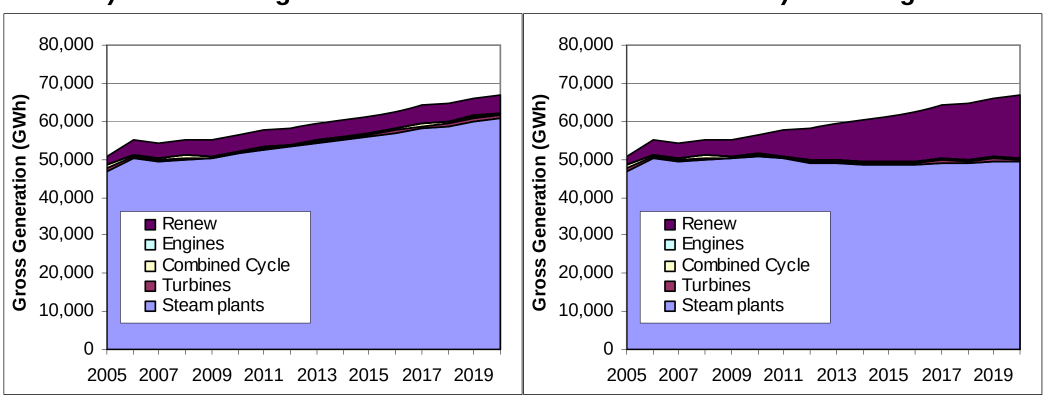


Gross Generation

Total gross generation by MN power plants is summarized in the figures below for both Reference Cases. In the Reference Case without the RPS, gross generation in MN is dominated by steam units, which are primarily based on coal and nuclear fuel. In the Reference Case with the RPS, renewable energy accounts for a substantially increased share of wind and hydro resources. The figures below summarize gross power generation with and without the RPS.

Figure 3: Gross generation at MN power stations

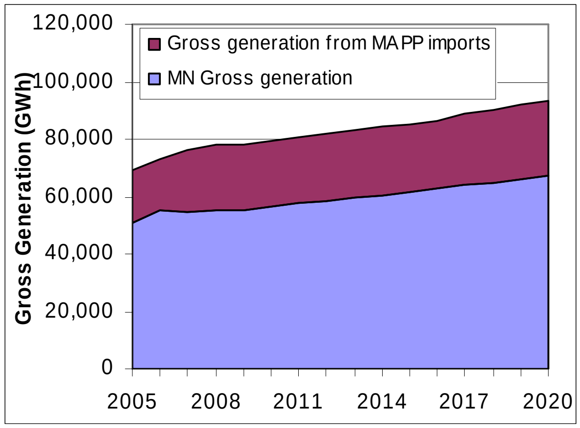
a) not including the RPS **b) including the RPS**



Imported Electricity

To meet annual demand for electricity in MN, total gross generation by MN power plants needs to be augmented by electricity imports. As indicated earlier, it was assumed that this power is imported from the MAPP region. The figure below summarizes the gross generation within and beyond Minnesota border needed to satisfy electricity demand in Minnesota.

Figure 4: Composition of gross generation to meet demand for electricity in MN



Carbon Dioxide-equivalent Emissions

Total carbon dioxide-equivalent emissions associated with generation by MN power plants as well as generation by power located outside MN but which meet electricity demand within MN are summarized in the figures below for both Reference Cases. In the Reference Case without the RPS, carbon dioxide-equivalent emissions reach 65.9 million tonnes in 2020. In the Reference Case with the RPS, renewable energy accounts for a substantially decrease in emissions, resulting in a total of 50.2 million tonnes in 2020. This represents is roughly equal to Base Year 2005 levels. The figures below summarize carbon dioxide-equivalent emissions with and without the RPS.

Figure 5: Total carbon dioxide-equivalent emissions associated with electric demand in MN

a) not including the RPS **b) including the RPS**