MEMORADUM

TO: Energy Supply TWG members

FROM: Bill Dougherty

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

DATE: 8 January 2008

RE: A brief overview of major energy supply assumptions

Dear Colleagues,

Below is a brief description of my understanding of each major assumption that has been made by the ES TWG during the process thus far. These assumptions play a significant role in the level of GHG reductions and costs that result from their incorporation into the analysis.

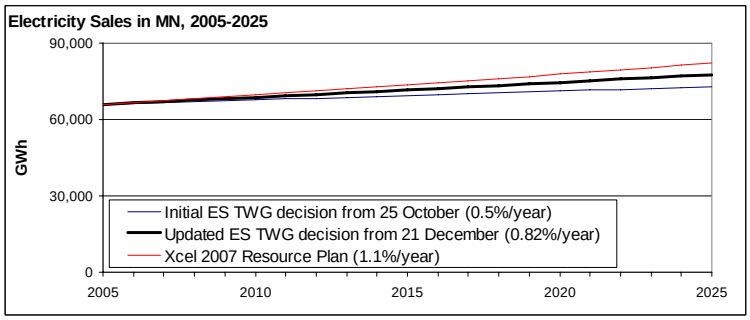
My approach is the memo below is to describe with brief text and charts - rather than with spreadsheets - the underlying basis for the last round of results. My aim is to try and make clear what were the assumptions used to develop the results, and to give you the opportunity to review and reflect.

In a follow-up memo which I aim to send later today, I am planning to do the same for each of the seven options that have been quantified.

As you may know, the consultative process is winding down. The final CCAG meeting is scheduled for 24 January 2008. This gives us just over two weeks to make any final changes/corrections to the assumptions.

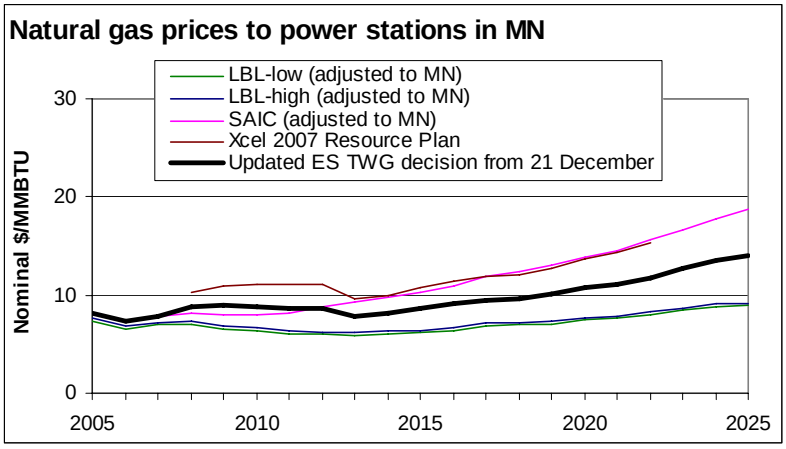
Electricity Sales in MN

The appropriate assumption concerning the electricity sales annual average growth rate has been a subject of focused discussions. This is one of the more important assumptions as it drives the need for power production. The chart below summarizes that various forecasted sales trajectories that have been proposed and discussed. **The bolded black line represents the trajectory that has been incorporated into the analysis.** For a numerical summary see the spreadsheet called "Sales growth calcualtions for the MN ES TWG - 19 December 2007.xls" sent to the ES TWG on 19 December 2007.



Fuel Prices

The appropriate assumption concerning natural gas fuel has also been a subject of discussions during meetings in November and December. The chart below summarizes that various forecasted natural gas price trajectories that have been proposed and discussed. **The bolded black line represents the trajectory that has been incorporated into the analysis.** It represents the midpoint projection between the Xcel 2007 Resource Plan and the upper LBL estimate. For a numerical summary see the spreadsheet called "NG price forecast comparisons for the MN ES TWG - 19 December 2007.xls". An inflation rate of 2.5% was assumed.



Prices for other fossil fuels (i.e., coal and oil) are based on EIA projections for the West North Central region for fuel delivered to electric power stations, as reported in AEO2007. These prices are summarized in the table below on a real basis (2005$/mmbtu). Biomass prices were assumed to be $2.5/mmbtu throughout the forecast period after discussion with the AFW TWG. Nuclear fuel prices were assumed at a flat $1/mmbtu (2005$) over the forecast period.

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
coal	1.40	1.54	1.56	1.57	1.57	1.62	1.60	1.57	1.55	1.54	1.53	1.52	1.51	1.49	1.49	1.49	1.48	1.49	1.49	1.49	1.51
Nuclear	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Biomass	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
Petroleum	7.40	8.33	7.35	7.70	7.10	6.59	6.20	5.84	5.68	5.51	5.57	5.58	5.70	5.73	5.92	5.98	6.10	6.22	6.16	6.30	6.32

Electric Capacity Expansion Plan

The electric capacity expansion plan has been developed relative to a number of scenarios, which enabled the analysis of various sensitivities. The scenarios considered are described as follows, and summarized in the tables that follow. As per a TWG decision, it was assumed that there would be no capacity retirements during the forecast period. For a numerical summary see the spreadsheet called "Estimate of MN avoided costs for RCI TWG options analysis (version 2).xls" sent to the ES TWG on 19 December 2007.

- Scenario #1: **All** planned capacity additions; **without** the RES, **with** the CIP;
- Scenario #2: **All** planned capacity additions; **with** the RES, with the CIP;
- Scenario #3: **All** planned capacity additions **except for large coal additions**; **with** the RES, with the CIP

*Scenario #1: **All** planned capacity additions; **without** the RES, **with** the CIP (MW)*

Capacity type	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	Total	Share (%)
Pulverized coal	0	7	0	0	0	0	0	0	151	25	25	28	0	0	0	0	0	0	0	0	0	236	7%
IGCC	0	0	0	0	0	0	0	0	362	60	60	121	0	0	0	0	0	0	0	0	0	603	19%
Hydroelectric	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
Natural Gas CT	0	531	290	1,108	300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,229	69%
Natural Gas CC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
Nuclear	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
Other Gas	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
Geothermal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
MSW	0	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0%
Landfill gas	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
Biomass	0	15	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25	1%
Solar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
Wind	0	80	52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	132	4%
Petroleum	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0%
Pumped Storage	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
All Sources	0	642	354	1,108	300	0	0	0	513	86	86	148	0	0	0	0	0	0	0	0	0	3,236	100%

*Scenario #2: **All** planned capacity additions; **with** the RES, with the CIP (MW)*

Capacity type	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	Total	Share (%)
Pulverized coal	0	7	0	0	0	0	0	0	151	25	25	28	0	0	0	0	0	0	0	0	0	236	2%
IGCC	0	0	0	0	0	0	0	0	362	60	60	121	0	0	0	0	0	0	0	0	0	603	6%
Hydroelectric	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
Natural Gas CT	0	531	290	1,108	300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,229	22%
Natural Gas CC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
Nuclear	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
Other Gas	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
Geothermal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
MSW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
Landfill gas	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
Biomass	0	6	4	0	0	0	0	10	10	10	10	10	10	10	10	10	10	10	10	10	10	150	1%
Solar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
Wind	0	93	60	0	0	0	0	688	962	978	995	233	237	241	246	250	385	392	398	405	412	6,975	68%
Petroleum	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0%
Pumped Storage	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
All Sources	0	642	354	1,108	300	0	0	698	1,485	1,074	1,090	391	247	251	256	260	395	402	408	415	422	10,198	100%

*Scenario #3: **All** planned capacity additions **except for large coal additions**; **with** the RES, with the CIP (MW)*

Capacity type	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	Total	Share (%)
Pulverized coal	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0%
IGCC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
Hydroelectric	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
Natural Gas CT	0	531	290	1,108	300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,229	24%
Natural Gas CC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
Nuclear	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
Other Gas	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
Geothermal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
MSW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
Landfill gas	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
Biomass	0	6	4	0	0	0	0	10	10	10	10	10	10	10	10	10	10	10	10	10	10	150	2%
Solar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
Wind	0	93	60	0	0	0	0	688	962	978	995	233	237	241	246	250	385	392	398	405	412	6,975	74%
Petroleum	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0%
Pumped Storage	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
All Sources	0	642	354	1,108	300	0	0	698	972	988	1,005	243	247	251	256	260	395	402	408	415	422	9,366	100%

Cost and Performance of New Electric Generating Capacity

Assumptions regarding the cost and performance of new electric generating capacity (not including carbon capture and storage technology) have been discussed in several meetings starting from the meeting held on 25 October. For the Base Year of 2005, the following has been assumed (for reference, these assumptions are in the spreadsheet called "Estimate of MN avoided costs for RCI TWG options analysis (version 2).xls" sent to the ES TWG on 19 December 2007):

	Cost component							
	Overnight Capital	Trans	Fixed O&M	Variable O&M	Cap factor	Heat rate		
	2005 $/kW	2005 $/kW	2005 $/kW-yr	2005 mills/kWh	%	btu/kWh	Source	EPC Percentage
Pulverized coal	2,350	80	24.55	4.75	85%	9,200	NETL	2%
IGCC	2,705	80	34.40	6.33	80%	9,000	NETL	2%
Hydroelectric	2,296	80	13.13	3.30	47%	10,107	EIA	2%
Natural Gas CT	643	80	3.36	11.40	50%	10,807	EIA	2%
Natural Gas CC	826	80	9.57	1.29	65%	6,990	NETL	2%
Nuclear	2,973	80	63.88	0.47	84%	10,400	EIA	2%
Geothermal	2,819	80	154.92	0.00	50%	36,025	EIA	2%
MSW	2,441	80	107.50	0.01	75%	13,648	EIA	2%
Landfill gas	2,441	80	107.50	0.01	75%	13,648	EIA	2%
Biomass	2,806	80	50.18	2.96	75%	8,911	EIA	2%
Solar	6,609	80	10.99	0.00	35%	10,280	EIA	2%
Wind	1,845	80	28.51	0.00	35%	10,280	EIA	2%
Petroleum	630	80	11.40	3.36	10%	10,807	EIA	2%

Assumptions regarding the cost and performance of carbon capture and storage technology were made assuming low, central and high estimates (the central estimate is the default in the analysis thus far). For the Base Year of 2005, the following has been assumed:

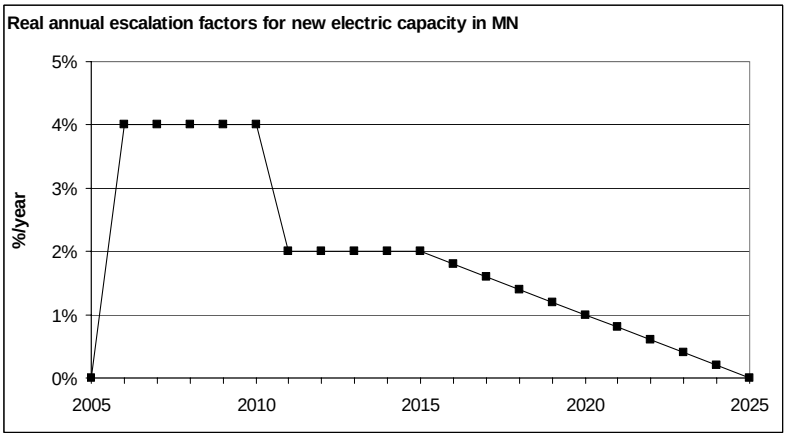
		Range		
Component	Units	Low	High	Central
Capture from IGCC	2005$/tCO2 captured	15.0	75.0	45.0
Transportation	2005$/tCO2 transported	1.0	8.0	4.5
Geologic storage	2005$/tCO2 injeceted	0.5	8.0	4.3
Monitoring/verification	2005$/tCO2 injected	0.1	0.3	0.2
Incremental capital cost	2005 $/kW	245	705	499
Incremental fixed O&M	2005 $/kW-yr	0.00	0.00	0.00
Incremental variable O&M	2005 mills/kWh	0.00	0.00	0.00
Heat rate penalty	btu/kWh	32%	3%	17%
CO2 emission reduction	%	81%	91%	86%
Capacity factor	%	75%	75%	75%

The cost and performance of new IGCC units including carbon capture and storage technology were increased to account for the incremental costs associated with carbon capture and storage technology. For the Base Year of 2005, the following has been assumed:

	Cost assumptions					
	Capital	Trans	Fixed O&M	Var O&M	Capacity factor	Heat rate
Capacity type	2005 $/kW	2005 $/kW	2005 $/kW-yr	2005 mills/kWh	%	btu per kWh
IGCC/CCS (low)	2,950	80	34.40	6.33	75%	12,144
IGCC/CCS (mid)	3,204	80	34.40	6.33	75%	10,764
IGCC/CCS (high)	3,410	80	34.40	6.33	75%	9,476

Escalation in Capital Costs of New Electric Generating Capacity

The TWG attempted to account for recent trends in the escalation in capital costs of new capacity by incorporating real escalation in capital costs, as shown below. There was no escalation assumed for transmission, fixed O&M, and variable O&M (for reference, these assumptions are in the spreadsheet called "Estimate of MN avoided costs for RCI TWG options analysis (version 2).xls" sent to the ES TWG on 19 December 2007).



The effect of this real escalation on capital costs (2005$/kW) of each capacity type considered is summarized in the table below.

online year>>>	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Pulverized coal	2,350	2,443	2,541	2,643	2,749	2,859	2,916	2,974	3,033	3,094	3,156	3,213	3,264	3,310	3,350	3,383	3,410	3,431	3,444	3,451	3,451
IGCC	2,705	2,813	2,925	3,042	3,164	3,290	3,356	3,423	3,492	3,562	3,633	3,698	3,758	3,810	3,856	3,894	3,926	3,949	3,965	3,973	3,973
Hydroelectric	2,296	2,387	2,483	2,582	2,686	2,793	2,849	2,906	2,964	3,023	3,084	3,139	3,189	3,234	3,273	3,306	3,332	3,352	3,365	3,372	3,372
Natural Gas CT	643	668	695	723	752	782	797	813	830	846	863	879	893	905	916	925	933	938	942	944	944
Natural Gas CC	826	859	894	930	967	1,005	1,026	1,046	1,067	1,088	1,110	1,130	1,148	1,164	1,178	1,190	1,200	1,207	1,212	1,214	1,214
Nuclear	2,973	3,092	3,216	3,345	3,478	3,617	3,690	3,764	3,839	3,916	3,994	4,066	4,131	4,189	4,239	4,281	4,316	4,342	4,359	4,368	4,368
Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Gas	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Geothermal	2,819	2,932	3,049	3,171	3,298	3,430	3,499	3,569	3,640	3,713	3,787	3,855	3,917	3,972	4,019	4,060	4,092	4,117	4,133	4,141	4,141
MSW	2,441	2,539	2,640	2,746	2,856	2,970	3,029	3,090	3,152	3,215	3,279	3,338	3,391	3,439	3,480	3,515	3,543	3,564	3,578	3,586	3,586
Landfill gas	2,441	2,539	2,640	2,746	2,856	2,970	3,029	3,090	3,152	3,215	3,279	3,338	3,391	3,439	3,480	3,515	3,543	3,564	3,578	3,586	3,586
Biomass	2,806	2,918	3,035	3,156	3,283	3,414	3,482	3,552	3,623	3,695	3,769	3,837	3,898	3,953	4,000	4,040	4,073	4,097	4,114	4,122	4,122
Solar	6,609	6,874	7,148	7,434	7,732	8,041	8,202	8,366	8,533	8,704	8,878	9,038	9,182	9,311	9,423	9,517	9,593	9,651	9,689	9,709	9,709
Wind	1,845	1,919	1,996	2,075	2,158	2,245	2,290	2,335	2,382	2,430	2,478	2,523	2,563	2,599	2,630	2,657	2,678	2,694	2,705	2,710	2,710
Petroleum	630	655	681	709	737	766	782	797	813	830	846	862	875	888	898	907	914	920	924	925	925
IGCC/CCS (low)	2,950	3,068	3,190	3,318	3,451	3,589	3,660	3,734	3,808	3,884	3,962	4,033	4,098	4,155	4,205	4,247	4,281	4,307	4,324	4,333	4,333
IGCC/CCS (mid)	3,204	3,332	3,465	3,604	3,748	3,898	3,976	4,055	4,136	4,219	4,303	4,381	4,451	4,513	4,567	4,613	4,650	4,678	4,696	4,706	4,706
IGCC/CCS (high)	3,410	3,546	3,688	3,835	3,989	4,148	4,231	4,316	4,402	4,490	4,580	4,662	4,737	4,803	4,861	4,910	4,949	4,979	4,998	5,008	5,008

Levelized Costs of New Electric Generating Capacity

Using the above information, levelized costs were calculated for each capacity type. The levelized cost of a capacity type represents the present value of the total cost of building and operating the plant over its economic life, converted to equal annual payments. Costs were levelized in real dollars (2005$/MWh) to remove the impact of inflation and are summarized below for a plant coming online in 2005.

Capacity type	Capacity	Transmission	Fixed O&M	Variable O&M	Fuel	Total
Pulverized coal	69	2	6	9	23	109
IGCC	84	2	9	11	23	129
Hydroelectric	121	4	6	6	0	137
Natural Gas CT	32	4	1	20	159	217
Natural Gas CC	32	3	3	2	103	143
Nuclear	88	2	16	1	19	125
Geothermal	140	4	64	0	0	208
MSW	81	3	29	0	0	113
Landfill gas	81	3	29	0	0	113
Biomass	93	3	14	5	40	155
Solar	470	6	6	0	0	482
Wind	131	6	17	0	0	154
Petroleum	157	20	23	6	144	350
IGCC/CCS (low)	98	3	9	11	18	140
IGCC/CCS (mid)	106	3	9	11	16	146
IGCC/CCS (high)	113	3	9	11	14	151

These capital costs were adjusted upward, as per the escalation schedule shown above, to capture the higher capital costs associated with plants coming online between 2006 and 2025. A real discount rate of 5% was assumed.

Avoided Costs for the Electric Capacity Expansion Plans

Estimates of avoided costs were developed for the three capacity expansion scenarios described earlier. These avoided costs represent the weighted average of the levelized costs across all capacity types coming on line. To account for the intermittency of wind power a capacity credit of 50% was assumed though this is a placeholder estimate until a better number can be obtained.[1] For costing purposes, this assumption has the effect of doubling the cost of wind. To account for the assumed capital cost escalation, capital costs were adjusted upward in each expansion scenario relative to the projected online year. Avoided costs (2005$/MWh) are summarized in the table below.

Cost Component	Scenario #1	Scenario #2	Scenario #3
Capacity	50	108	111
Transmission	4	5	5
Fixed O&M	4	13	13
Variable O&M	17	5	5
Fuel	112	32	33
Total	**187**	**163**	**166**

[1] The estimate is based on a recent study in Europe reported entitled, *Wind Power Has A Capacity Credit A Catalogue Of 50+ Supporting Studies*, which is available at http://ejournal.windeng.net/3/01/GGiebel-CapCredLit_WindEngEJournal_2005_right_links.pdf