

Overview of MRN-NEEM Results for the EIPC Future 2 Base and Soft Constraint Cases

May 26, 2011

CRA Charles River
Associates

The results presented herein use modeling assumptions developed by EIPC, EIPC stakeholders and CRA for purposes of EIPC capacity expansion modeling. As such, these results do not necessarily reflect the opinions or views of CRA or any individual EIPC stakeholder.

Overview

- Using the EIPC stakeholder-approved input assumptions, CRA has completed MRN-NEEM modeling of Future 2 “Federal Carbon Constraint – National Implementation” for:
 - *Future 2 Base Case (F2B), and*
 - *Future 2 Soft Constraint Sensitivities (F2S1 and F2S2)*
- Key input assumption changes for Future 2 from the BAU Base Case (F1S3) are:
 - *Generic Future 2 through 8 changes from BAU:*
 - New economic hydro builds allowed in the U.S. (5 GW maximum)
 - SPP reserve contribution for wind set to 15%
 - *Nuclear builds permitted in all NEEM regions except NYISO_J-K*
 - *IGCC-CCS and CCS Retrofits capacity-build limits increased by 50%*
 - *EI NEEM regions aggregated into 4 solar/wind intermittency regions, each with a 35% limit.*
 - *Heat rates for advanced coal, CCs and IGCC-CCS improved by about 5%*
 - *Carbon prices reducing U.S. CO₂ emissions by 42% by 2030 and 80% by 2050 from 2005 levels.*
 - Canada NEEM regions face the same carbon prices.

Detailed Summary Reports

- As before, a detailed summary of modeling results in excel-readable format was created for stakeholders to review for each sensitivity, including a Summary Report, Generation Report, Capacity Report and Transmission Report.
- For F2B, a MRN Report is provided showing GDP, gas prices, and carbon emissions by sector.
 - *For comparison purposes, the F1S3 MRN Report is also posted in similar format.*
- As in Future 1, a F2 Soft Constraint Report was also created showing the flows, shadow prices and overload charges for the F2B, F2S1 (75%) and F2S2 (25%) runs.

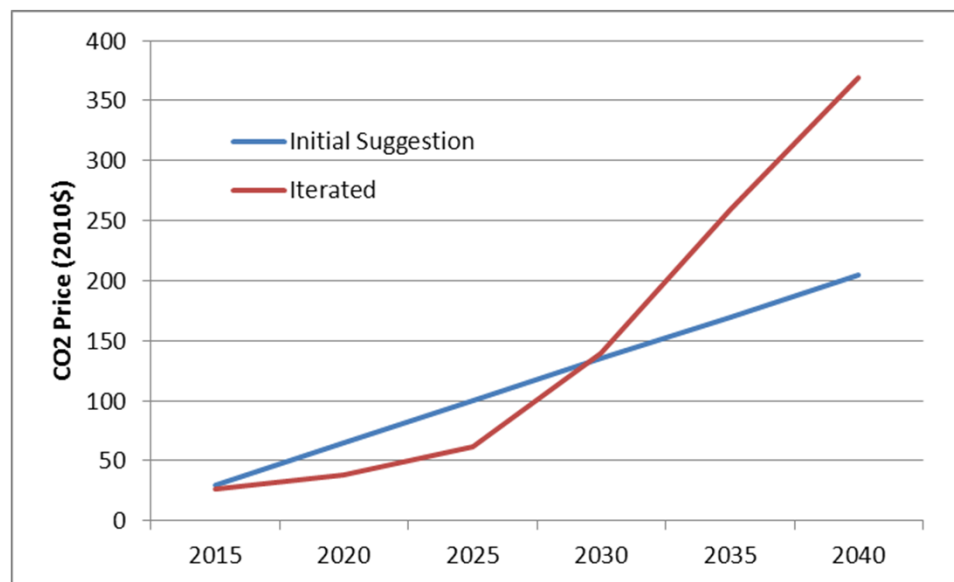
Future 2B Base Case Results

- As requested by stakeholders, MRN-NEEM was iterated in the Future 2 Base Case to meet the stakeholder-provided U.S. CO₂ emission targets in 2030 and 2050.
 - *A \$30/ton carbon price in 2015 growing at \$7 per year (2010\$) was suggested by stakeholders as a starting point for the iteration process.*
 - *A 42% reduction from 2005 emission levels in 2030 and an 80% reduction in 2050 was desired.*
 - The 2011 AEO lists 2005 U.S. CO₂ emission levels of 5,996 million metric tons from fossil fuel combustion.
 - Applying 42% and 80% reductions yields targets of 3,478 million metric tons in 2030 and 1,200 in 2050.
 - *In the BAU (F1S3), U.S. CO₂ emissions are somewhat below 5,996 million metric tons until 2030 reflecting reduced demand and some retirement of coal plants.*
 - Banking is not permitted (i.e., earlier year CO₂ reductions cannot be used to meet the 2030/2050 targets).
 - *To iterate to the carbon price by year, CRA assumed a roughly linear reduction in U.S. CO₂ emissions from 2015 to the 2030 target, and, separately, from 2030 to the 2050 target.*

Future 2 Base Case Results (cont.)

- The CRA iteration process to match the 2030 and 2050 targets yielded a carbon price that was somewhat lower than the initial stakeholder suggestion from 2015 to 2025, about equal in 2030, and then much higher after 2030.
 - *Achieving the 80% reduction in 2050, absent earlier year banking, requires a significant increase in carbon prices.*

Economy-wide CO₂ Price
(2010\$/metric ton)



	CO₂ Price \$2010 per metric ton
2015	27
2020	38
2025	62
2030	140
2035	259
2040	369
2045	553
2050	942

Future 2 Base Case Results (cont.)

- The CO₂ emissions for the BAU (F1S3) and Future 2 Base (F2B) cases are shown below.
 - The economy-wide CO₂ emissions in F2B are close to the 2030 and 2050 targets.*
 - The reductions in the electric sector are much more significant than for the economy as a whole, reflecting less costly alternatives for reducing CO₂ emissions in the electric sector.*
 - By 2040, electric sector generation is essentially comprised of only non-fossil sources.

U.S. CO₂ Emissions in BAU and Future 2 Base Case (*millions of metric tons*)

U.S. Economy-wide

	2015	2020	2025	2030	2035	2040	2045	2050
BAU (F1S3)	5,657	5,631	5,764	5,923	6,234	6,543	6,915	7,339
Future 2 Base (F2B)	4,948	4,423	3,963	3,475	2,885	2,328	1,758	1,190
% reduction from BAU	13%	21%	31%	41%	54%	64%	75%	84%

Targets:
2030: 3478
2050: 1200

U.S. Electric Sector (NEEM)

	2015	2020	2025	2030	2035	2040	2045	2050
BAU (F1S3)	2,080	2,041	2,159	2,239	2,424	2,631	2,895	3,203
Future 2 Base (F2B)	1,570	1,086	718	487	277	117	62	41
% reduction from BAU	25%	47%	67%	78%	89%	96%	98%	99%

Future 2 Base Case Results (cont.)

- The CO₂ prices and the feedbacks between MRN and NEEM result in changes in GDP, gas prices and electricity demand between the BAU (F1S3) and Future 2 Base Case (F2B).
 - U.S. GDP is about 1.6% lower in F2B in 2030 and 2.9% lower in 2040 than in the BAU.*
 - Higher electricity prices and lower GDP reduce electricity demand in the EI as shown below.*

EI Electricity Demand (TWh)

	2015	2020	2025	2030	2035	2040
BAU (F1S3)	3,317	3,446	3,572	3,702	3,838	3,979
Future 2 Base (F2B)	3,165	3,214	3,229	3,248	3,215	3,273
% Reduction from BAU	5%	7%	10%	12%	16%	18%

- Gas prices increase as CCs are built in the early years in F2B. But as CO₂ prices increase, CCs become uneconomic reducing gas demand and yielding a significant decrease in gas prices.*
 - Including the CO₂ price in the gas price helps illustrate the impact.*

Gas Prices (2010 \$/mmBtu Henry Hub)

	2015	2020	2025	2030	2035	2040
BAU (F1S3)	4.84	5.22	6.07	6.56	7.25	8.02
Future 2 Base (F2B)	6.26	6.75	7.27	4.91	4.54	4.99
F2B w/CO₂ included	7.68	8.77	10.57	12.31	18.24	24.55

* At 0.05293 metric tons of CO₂ per mmBTU of gas burned

Summary of Results – BAU Sensitivity 3 (from April 20)

- For BAU Sensitivity 3 (F1S3), the EI capacity expansion results are shown below (as previously issued on April 20).

BAU Sensitivity 3: New Builds and Retirements by Capacity Type for the Eastern Interconnection 2015, 2020 and 2030 (GW)

	2010 In- service	----- Additions -----			----- Retirements -----			2030 In- service
		2015	2020	2030	2015	2020	2030	
Coal	271.9	8.5	0.0	0.0	66.9	14.8	0.0	198.7
Nuclear	99.8	2.7	4.5	0.0	0.0	0.6	1.5	105.0
CC	132.7	30.7	18.1	26.2	5.7	0.0	0.0	202.0
CT	120.3	4.7	4.4	4.5	2.0	0.0	0.0	131.9
Steam Oil/Gas	74.5	0.0	0.0	0.0	37.1	0.6	0.4	36.4
Hydro	44.6	0.0	0.0	0.0	0.0	0.0	0.0	44.6
On-shore Wind	18.7	22.2	12.1	14.8	0.0	0.0	0.0	67.8
Off-shore Wind	0.0	0.5	0.0	1.1	0.0	0.0	0.0	1.6
Other Renewables	3.6	2.3	3.3	4.5	0.0	0.0	0.0	13.7
New HQ/Maritimes	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other	17.1	0.0	0.0	0.0	0.0	0.0	0.0	17.1
Total	783.3	71.6	42.5	51.0	111.7	16.0	1.9	818.8
DR	33.1	-1.3	16.8	22.1				70.7

7 The results presented herein use modeling assumptions developed by EIPC, EIPC stakeholders and CRA for purposes of EIPC capacity expansion modeling. As such, these results do not necessarily reflect the opinions or views of CRA or any individual EIPC stakeholder.

Summary of Results – Future 2 Base Case

- For Future 2 Base Case, additional coal plants are retired in the early years and replaced largely with CCs. Later, wind expansion becomes dominant along with nuclear.
 - At these CO₂ prices, both new IGCC w/CCS plants and CCS retrofits are minimal as these options are uneconomic in comparison to CCs in the early years and later to wind/nuclear.*
 - 26 GW of off-shore wind is constructed in 2035, but little prior to that time. Biomass similarly begins to be constructed in significant amounts in 2035.

Future 2 Base Case: New Builds/Retirements by Type for the EI in 2015, 2020 and 2030 (GW)

	2010 In-service	----- Additions -----			----- Retirements -----			2030 In-service
		2015	2020	2030	2015	2020	2030	
Coal	271.9	8.5	0.0	0.0	148.1	67.8	35.0	29.5
Nuclear	99.8	2.7	4.5	28.4	0.0	0.6	1.5	133.4
CC	132.7	85.9	49.1	0.3	7.0	3.0	12.0	245.9
CT	120.3	4.7	0.4	0.6	3.9	0.0	15.8	106.4
Steam Oil/Gas	74.5	0.0	0.0	0.0	45.0	0.0	7.8	21.7
Hydro	44.6	0.0	1.2	4.6	0.0	0.0	0.0	50.5
On-shore Wind	18.7	22.2	80.5	160.3	0.0	0.0	0.0	281.6
Off-shore Wind	0.0	0.5	0.0	1.1	0.0	0.0	0.0	1.6
Other Renewables	3.6	2.3	3.3	3.7	0.0	0.0	0.0	12.9
New HQ/Maritimes	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other	17.1	0.0	0.0	0.0	0.0	0.0	0.0	17.1
Total	783.3	126.8	139.0	199.0	203.9	71.4	72.1	900.6
DR	33.1	-1.3	16.8	22.1	0.0	0.0	0.0	70.7

* These carbon capture and sequestration (“CCS”) options have 90% CO₂ capture.

8 The results presented herein use modeling assumptions developed by EIPC, EIPC stakeholders and CRA for purposes of EIPC capacity expansion modeling. As such, these results do not necessarily reflect the opinions or views of CRA or any individual EIPC stakeholder.

Future 2 Results

- The mix of EI generation as a percent of EI load changes considerably from the BAU to Future 2 as shown below for six key capacity types.
 - In F2B, the CC share increases rapidly while coal is reduced significantly; later, on-shore wind and nuclear become dominant. Other renewables (not shown) become significant by 2035.*

EI Generation as Percent of EI Energy Demand for Six Key Capacity Types

Future 1 Base (F1S3)

	2015	2020	2025	2030	2035	2040
CC	22%	26%	24%	25%	29%	32%
Coal	42%	37%	39%	38%	40%	42%
Nuclear	24%	24%	23%	22%	16%	11%
On-Shore Wind	4%	4%	5%	5%	6%	6%
Off-Shore Wind	0%	0%	0%	0%	0%	0%
Hydro	6%	6%	6%	5%	5%	5%
Total of above	97%	97%	96%	96%	96%	97%

Future 2 Base (F2B)

	2015	2020	2025	2030	2035	2040
CC	36%	44%	44%	31%	20%	6%
Coal	26%	9%	1%	1%	2%	2%
Nuclear	25%	26%	27%	32%	32%	37%
On-Shore Wind	4%	12%	17%	25%	28%	29%
Off-Shore Wind	0%	0%	0%	0%	3%	4%
Hydro	6%	6%	7%	7%	7%	7%
Total of above	97%	97%	97%	97%	93%	84%

Future 2 Results (cont.)

- Total EI capacity in 2030 is shown below by type for Future 2 in comparison to the BAU.
 - Compared to F2B, more wind is added in F2S1 (75%) and F2S2 (25%) largely in place of CCs.*
 - Also more CTs are added/less steam oil-gas retired to meet reserves when importing more wind energy.
 - Average EI transfer path flow by load block from 2015-2040 increases from 502 MW in F2B to 802 MW in F1S2 to 1170 MW in F2S2 (simple average, including zero flow blocks).
 - High overload adders (based on IESO paths) inhibit construction of HQ/Maritimes units in F2S1 and F2S2.
 - F2S1 and F2S2 EI builds are not dramatically different as wind is reaching intermittency limits.*
 - In 2030, EI wind generation is 25% of EI energy demand in F2B, 30% in F2S1 and 32% in F2S2.

Installed 2030 EI Capacity by Type: BAU vs. Future 2 (GW)

	Total 2010	Installed Capacity in 2030				Increase from BAU		
		F1S3	F2B	F2S1	F2S2	F2B	F2S1	F2S2
		BAU Base	Fed CO2	75% Soft	25% Soft	Fed CO2	75% Soft	25% Soft
Coal	272	199	29	30	30	(169)	(169)	(169)
Nuclear	100	105	133	130	129	28	25	24
CC	133	202	246	230	224	44	28	22
CT	120	132	106	115	116	(25)	(17)	(15)
Steam Oil/Gas	75	36	22	27	28	(15)	(9)	(8)
Hydro	45	45	50	51	52	6	7	7
On-Shore Wind	19	68	282	313	315	214	245	248
Off-Shore Wind	0	2	2	2	2	0	(0)	(0)
Other Renewable	4	14	13	13	14	(1)	(1)	0
New HQ/Maritimes	0	0	0	0	3	0	0	3
Other	17	17	17	17	17	0	0	0
Total w/o DR	783	819	901	927	930	82	108	111
DR	33	71	71	71	71	0	0	0
Total w/DR	816	890	971	998	1,000	82	108	111
EI Demand 2030 (TWh)		3702	3248	3248	3248			
Change from F1S3			-12%	-12%	-12%			

The results presented herein use modeling assumptions developed by EIPC, EIPC stakeholders and CRA for purposes of EIPC capacity expansion modeling. As such, these results do not necessarily reflect the opinions or views of CRA or any individual EIPC stakeholder.

Future 2 Results (cont.)

- EI capacity in 2030 is shown below by NEEM region for Future 2 in comparison to the BAU.
 - From F2B to F2S1 to F2S2, wind increasingly moves to MISO_W, SPP_N and NE (Nebraska).

2030 EI Capacity by Region: BAU vs. Future 2 (GW)

	Cum New Builds 2030				Cum New CCs 2030				Cum New On-Sh Wind 2030				Cum Coal Retire 2030			
	F1S3	F2B	F2S1	F2S2	F1S3	F2B	F2S1	F2S2	F1S3	F2B	F2S1	F2S2	F1S3	F2B	F2S1	F2S2
	BAU	Fed	75%	25%	BAU	Fed	75%	25%	BAU	Fed	75%	25%	BAU	Fed	75%	25%
	Base	CO2	Soft	Soft	Base	CO2	Soft	Soft	Base	CO2	Soft	Soft	Base	CO2	Soft	Soft
ENT	4	9	7	5	3	8	6	4	0	0	0	0	1	8	8	8
FRCC	16	30	32	31	13	12	13	13	0	0	0	0	1	8	8	9
IESO	5	5	5	5	1	1	1	1	2	2	2	2	6	6	6	6
MAPP_CA	2	4	5	5	2	0	0	0	0	0	0	0	1	2	2	2
MAPP_US	2	6	7	8	0	0	0	0	1	5	6	8	1	3	3	3
MISO_IN	5	57	60	3	4	14	16	1	0	42	42	0	1	11	11	11
MISO_MI	3	8	4	2	0	5	2	0	3	3	3	2	4	11	11	11
MISO_MO-IL	2	30	16	8	0	1	0	0	0	27	14	6	2	13	13	13
MISO_W	9	34	62	111	0	1	0	0	9	33	62	111	3	13	13	13
MISO_WUMS	10	18	16	27	4	6	7	25	1	11	8	1	3	6	6	6
NE	1	13	17	27	0	0	0	0	0	13	17	27	0	3	3	3
NEISO	9	9	9	9	2	2	2	2	5	5	5	5	3	3	3	3
NonRTO_Mid	1	6	6	7	1	5	5	4	0	0	0	0	1	9	8	9
NYISO_A-F	4	10	14	10	1	1	1	1	4	10	13	9	2	2	2	2
NYISO_G-I	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
NYISO_J-K	3	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0
PJM_E	7	7	7	7	5	5	5	5	1	1	1	1	4	3	3	3
PJM_ROM	12	6	6	7	2	2	2	2	7	1	1	1	8	16	16	16
PJM_ROR	20	71	44	33	8	28	24	20	9	40	16	9	20	54	53	52
SOCO	10	23	17	14	8	12	12	12	0	0	0	0	9	24	23	23
SPP_N	3	31	60	68	2	1	0	0	0	28	59	67	0	7	8	8
SPP_S	8	45	43	46	2	4	0	0	3	38	41	44	2	13	13	13
TVA	8	11	11	11	4	9	9	8	0	0	0	0	5	15	15	15
VACAR	20	28	29	28	11	15	15	15	4	4	4	4	6	19	19	19
	165	465	480	474	75	135	121	114	49	263	294	297	82	251	251	251

The results presented herein use modeling assumptions developed by EIPC, EIPC stakeholders and CRA for purposes of EIPC capacity expansion modeling. As such, these results do not necessarily reflect the opinions or views of CRA or any individual EIPC stakeholder.

Future 2 Results (cont.)

- The CO₂ emissions for the Future 2 Base and soft constraint cases are shown below.
 - As with all sensitivities, only the NEEM electric sector was modified in the soft constraint cases, thus non-electric sector emissions are unchanged between F2B, F2S1 and F2S2.
 - After 2015 (new economic wind is not available until 2020), CO₂ emissions decrease somewhat in the F2S1 and F2S2 cases
 - With the same CO₂ prices, more economic power can be built (particularly wind) given the increased ability to transfer power in the soft constraint cases.

U.S. CO₂ Emissions in BAU and Future 2 (Millions of metric tons)

U.S. Economy-wide

	2015	2020	2025	2030	2035	2040	2045	2050
BAU (F1S3)	5,657	5,631	5,764	5,923	6,234	6,543	6,915	7,339
Future 2 Base (F2B)	4,948	4,423	3,963	3,475	2,885	2,328	1,758	1,190
F2S1 (75%)	4,968	4,413	3,906	3,425	2,841	2,322	1,762	1,189
F2S2 (25%)	4,999	4,405	3,811	3,393	2,820	2,319	1,759	1,187

U.S. Electric Sector (NEEM)

	2015	2020	2025	2030	2035	2040	2045	2050
BAU (F1S3)	2,080	2,041	2,159	2,239	2,424	2,631	2,895	3,203
Future 2 Base (F2B)	1,570	1,086	718	487	277	117	62	41
F2S1 (75%)	1,590	1,076	661	436	234	112	66	40
F2S2 (25%)	1,621	1,069	566	405	212	108	63	39

The results presented herein use modeling assumptions developed by EIPC, EIPC stakeholders and CRA for purposes of EIPC capacity expansion modeling. As such, these results do not necessarily reflect the opinions or views of CRA or any individual EIPC stakeholder.

Next Steps

1. Hardened transfer limits are selected for remaining Future 2 sensitivities
2. The CO₂ price trajectory to apply for remaining Future 2 sensitivities is selected (may be the same as Future 2 Base Case).
3. Future 2 high/low demand sensitivities will be conducted by applying the same absolute differences between the base and high/low demand in the BAU runs, only applied to the Future 2 base demand.
4. Use the same procedure in #3 for the gas price sensitivities.
5. The CO₂ price sensitivities (like all sensitivities, these will be NEEM-electric sector only) will be +/- 20% of the CO₂ prices selected in step 2 above.