

Overview of MRN-NEEM Results for the EIPC Future 2 Sensitivities and the Future 3 Base and Soft Constraint Cases

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CRA Charles River
Associates

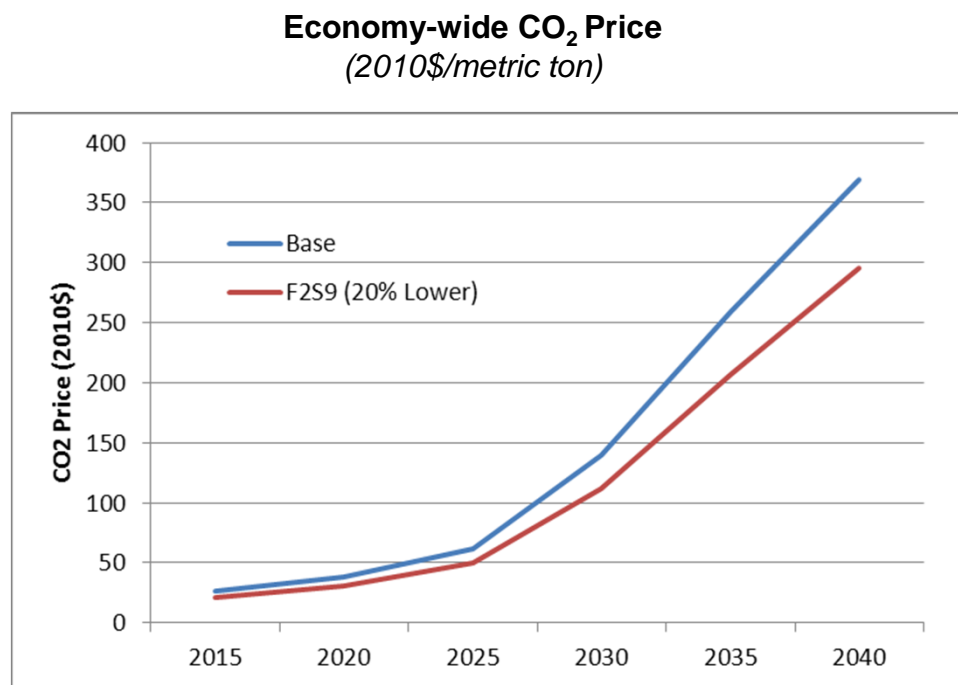
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Overview

- Using the EIPC stakeholder-approved input assumptions, CRA has completed MRN-NEEM modeling of:
 - Future 2 “Federal Carbon Constraint – National Implementation” for:
 - *F2 Sensitivities: F2S3 through F2S11 (F2S8 is reserved)*
 - The F2 “Hard Limits” selected by the SSC are applied in each of these sensitivities
 - Future 3 “Federal Carbon Constraint – State/Regional Implementation” for:
 - *Future 3 Base and 75% Soft Constraint Sensitivity (F3B and F3S1)*
- Key input assumption difference between Future 2 and Future 3:
 - *Future 2: EI NEEM regions aggregated into 4 solar/wind intermittency regions, each with a 35% limit. All transfer limits can be expanded.*
 - *Future 3: EI NEEM regions aggregated into 7 solar/wind intermittency “super-regions”, each with a 35% limit. Transfer limits cannot be expanded between super-regions.*

Overview (cont.)

- The same carbon prices derived in F2B were applied in NEEM in each of the remaining Future 2 sensitivities (20% lower in F2S9), and in Future 3 (F3B and F3S1).



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Future 2 Results

- Total EI capacity in 2030 is shown below by type for Future 2 in comparison to the BAU.
 - Hard Limits (F2S11) yield overall expansion similar to F2S1 (75%). F2S3 through F2S10 have these same hard limits and should be compared to F2S11.*
 - In comparison to F2S11, Low Gas (F2S7) and Low CO₂ prices (F2S9) yield more CCs and less wind by 2030. 50% Friction (F2S3) does not change the overall builds much.*

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

	Installed Capacity in 2030												
		F1S3	F2B	F2S1	F2S2	F2S3	F2S4	F2S5	F2S6	F2S7	F2S9	F2S10	F2S11
	Total	BAU	Fed	75%	25%	50%	High	Low	ExHi	Low	Low	ExLo	Hard
2010	Base	CO2	Soft	Soft	Frict	Load	Load	Gas	Gas	CO2	Rnw\$	Limit	
Coal	272	199	29	30	30	30	69	16	83	22	34	33	31
Nuclear	100	105	133	130	129	132	136	127	135	105	114	134	131
CC	133	202	246	230	224	226	306	166	170	265	240	213	226
CT	120	132	106	115	116	112	128	100	113	120	119	113	112
Steam Oil/Gas	75	36	22	27	28	29	35	9	21	27	28	29	29
Hydro	45	45	50	51	52	51	52	47	51	49	51	52	51
On-Shore Wind	19	68	282	313	315	320	385	232	348	243	279	357	317
Off-Shore Wind	0	2	2	2	2	2	2	2	2	2	2	3	2
Other Renewable	4	14	13	13	14	13	14	12	21	13	13	12	13
New HQ/Maritimes	0	0	0	0	3	3	3	3	3	3	3	3	3
Other	17	17	17	17	17	17	17	17	17	17	17	17	17
Total w/o DR	783	819	901	927	930	934	1,147	731	965	866	898	967	932
DR	33	71	71	71	71	71	85	58	71	71	71	71	71
Total w/DR	816	890	971	998	1,000	1,005	1,232	789	1,035	937	969	1,037	1,003

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Future 2 Results (cont.)

- EI capacity in 2030 is shown below by NEEM region for Future 2 in comparison to the BAU.
 - *The 2030 capacity in F2S11 (Hard Limits) is fairly close to F2S1 (75%).*

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

	Cum New Builds in 2030											
	F1S3	F2B	F2S1	F2S2	F2S3	F2S4	F2S5	F2S6	F2S7	F2S9	F2S10	F2S11
	BAU	Fed	75%	25%	50%	High	Low	ExHi	Low	Low	ExLo	Hard
	Base	CO2	Soft	Soft	Frict	Load	Load	Gas	Gas	CO2	Rnw\$	Limit
ENT	4	9	7	5	6	12	2	4	7	7	4	6
FRCC	16	30	32	31	30	32	26	25	18	20	30	31
IESO	5	5	5	5	5	5	5	5	5	5	5	5
MAPP_CA	2	4	5	5	4	6	1	4	4	4	4	4
MAPP_US	2	6	7	8	8	6	7	6	7	7	5	7
MISO_IN	5	57	60	3	61	69	31	54	20	46	56	59
MISO_MI	3	8	4	2	5	10	3	3	5	5	4	5
MISO_MO-IL	2	30	16	8	13	27	8	14	11	13	13	13
MISO_W	9	34	62	111	56	71	54	57	58	57	58	57
MISO_WUMS	10	18	16	27	20	17	7	18	10	9	20	19
NE	1	13	17	27	20	22	14	21	18	19	21	19
NEISO	9	9	9	9	9	9	8	14	9	9	16	9
NonRTO_Mid	1	6	6	7	6	7	5	3	7	6	6	6
NYISO_A-F	4	10	14	10	9	14	4	14	4	4	14	10
NYISO_G-I	1	1	0	0	0	2	0	0	0	0	0	0
NYISO_J-K	3	1	1	1	1	3	1	2	1	1	2	1
PJM_E	7	7	7	7	7	10	7	7	7	7	7	7
PJM_ROM	12	6	6	7	6	11	6	6	6	6	7	6
PJM_ROR	20	71	44	33	47	79	19	34	51	43	52	50
SOCO	10	23	17	14	19	26	13	15	16	15	19	20
SPP_N	3	31	60	68	65	67	54	71	58	60	74	63
SPP_S	8	45	43	46	45	61	36	53	46	46	54	45
TVA	8	11	11	11	11	16	6	7	12	11	11	11
VACAR	20	28	29	28	28	39	22	28	27	28	29	29
	165	465	480	474	484	622	340	467	407	429	512	481

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Future 2 Results (cont.)

- EI CC capacity in 2030 is shown below by NEEM region for Future 2.
 - *The 2030 capacity in F2S11 (Hard Limits) is reasonably close to F2S1 (75%).*

2030 EI New CC Builds by Region: BAU vs. Future 2 (GW)

	Cum New CCs in 2030											
	F1S3	F2B	F2S1	F2S2	F2S3	F2S4	F2S5	F2S6	F2S7	F2S9	F2S10	F2S11
	BAU	Fed	75%	25%	50%	High	Low	ExHi	Low	Low	ExLo	Hard
	Base	CO2	Soft	Soft	Frict	Load	Load	Gas	Gas	CO2	Rnw\$	Limit
ENT	3	8	6	4	5	11	0	3	6	5	2	5
FRCC	13	12	13	13	12	18	9	9	15	13	13	12
IESO	1	1	1	1	1	1	1	1	1	1	1	1
MAPP_CA	2	0	0	0	0	1	0	0	0	0	0	0
MAPP_US	0	0	0	0	0	0	0	0	0	0	0	0
MISO_IN	4	14	16	1	15	16	12	7	19	15	12	15
MISO_MI	0	5	2	0	3	7	0	1	2	2	1	2
MISO_MO-IL	0	1	0	0	0	5	0	0	3	1	0	1
MISO_W	0	1	0	0	0	1	0	0	1	0	0	0
MISO_WUMS	4	6	7	25	7	9	5	4	8	7	5	7
NE	0	0	0	0	0	0	0	0	0	0	0	0
NEISO	2	2	2	2	2	2	2	2	2	2	2	2
NonRTO_Mid	1	5	5	4	5	6	3	1	7	5	4	5
NYISO_A-F	1	1	1	1	1	1	1	1	1	1	1	1
NYISO_G-I	1	0	0	0	0	1	0	0	0	0	0	0
NYISO_J-K	1	1	1	1	1	3	1	1	1	1	1	1
PJM_E	5	5	5	5	5	7	5	5	5	5	5	5
PJM_ROM	2	2	2	2	2	3	2	2	2	2	2	2
PJM_ROR	8	28	24	20	22	30	7	5	31	23	20	22
SOCO	8	12	12	12	12	18	6	7	13	13	13	12
SPP_N	2	1	0	0	0	0	0	0	0	0	0	0
SPP_S	2	4	0	0	0	5	0	0	1	1	0	0
TVA	4	9	9	8	9	12	4	5	10	9	8	9
VACAR	11	15	15	15	15	21	12	7	19	15	15	15
	75	135	121	114	118	179	71	61	147	121	104	118

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Future 2 Results (cont.)

- EI on-shore wind capacity in 2030 is shown below by NEEM region for Future 2.
 - *The 2030 capacity in F2S11 (Hard Limits) is reasonably close to F2S1 (75%).*

2030 EI New On-Shore Wind Builds by Region: BAU vs. Future 2 (GW)

	Cum New On-Sh Wind in 2030											
	F1S3	F2B	F2S1	F2S2	F2S3	F2S4	F2S5	F2S6	F2S7	F2S9	F2S10	F2S11
	BAU	Fed	75%	25%	50%	High	Low	ExHi	Low	Low	ExLo	Hard
	Base	CO2	Soft	Soft	Frict	Load	Load	Gas	Gas	CO2	Rnw\$	Limit
ENT	0	0	0	0	0	0	0	0	0	0	0	0
FRCC	0	0	0	0	0	0	0	0	0	0	0	0
IESO	2	2	2	2	2	2	2	2	2	2	2	2
MAPP_CA	0	0	0	0	0	0	0	0	0	0	0	0
MAPP_US	1	5	6	8	7	4	7	5	6	6	4	6
MISO_IN	0	42	42	0	45	52	17	46	0	29	42	43
MISO_MI	3	3	3	2	3	3	3	3	2	3	3	3
MISO_MO-IL	0	27	14	6	10	19	6	12	6	10	10	10
MISO_W	9	33	62	111	56	70	54	56	57	57	58	57
MISO_WUMS	1	11	8	1	12	5	1	12	1	1	13	11
NE	0	13	17	27	20	22	14	21	18	18	21	18
NEISO	5	5	5	5	5	6	4	10	5	5	12	5
NonRTO_Mid	0	0	0	0	0	0	0	0	0	0	0	0
NYISO_A-F	4	10	13	9	8	13	3	13	3	3	13	9
NYISO_G-I	0	0	0	0	0	0	0	0	0	0	0	0
NYISO_J-K	0	0	0	0	0	0	0	0	0	0	0	0
PJM_E	1	1	1	1	1	1	1	1	1	1	1	1
PJM_ROM	7	1	1	1	1	1	1	1	1	1	1	1
PJM_ROR	9	40	16	9	19	45	9	20	16	17	26	23
SOCO	0	0	0	0	0	0	0	0	0	0	0	0
SPP_N	0	28	59	67	64	65	53	70	58	59	74	62
SPP_S	3	38	41	44	43	52	34	51	43	43	53	43
TVA	0	0	0	0	0	0	0	0	0	0	0	0
VACAR	4	4	4	4	4	4	4	4	4	4	4	4
	49	263	294	297	302	366	214	329	224	260	338	299

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Future 3 Results

- Total EI capacity in 2030 is shown below by type for Future 3 in comparison to F2B and the BAU.
 - *Compared to Future 2, less wind and more CCs are added in Future 3 by 2030.*
 - With 7 intermittency regions in Future 3, the 35% intermittency limit is more binding on the best wind locations (e.g., the Midwest ISO intermittency region is separate from PJM in Future 3).
 - *F3B and F3S1 builds are not significantly different as transfer limits between the 7 super-regions cannot be increased to allow for greater importation of power.*

Installed 2030 EI Capacity by Type: Future 3 vs. BAU and Future 2 (GW)

	Installed Capacity in 2030					
	Total 2010	F1S3	F2B	F2S1	F3B	F3S1
		BAU Base	Fed CO2	75% Soft	Reg CO2	75% Soft
Coal	272	199	29	30	40	35
Nuclear	100	105	133	130	134	134
CC	133	202	246	230	256	256
CT	120	132	106	115	104	105
Steam Oil/Gas	75	36	22	27	18	18
Hydro	45	45	50	51	52	52
On-Shore Wind	19	68	282	313	199	195
Off-Shore Wind	0	2	2	2	2	2
Other Renewable	4	14	13	13	13	13
New HQ/Maritimes	0	0	0	0	0	3
Other	17	17	17	17	17	17
Total w/o DR	783	819	901	927	833	829
DR	33	71	71	71	71	71
Total w/DR	816	890	971	998	904	900

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Future 3 Results (cont.)

- EI on-shore wind capacity in 2030 is shown below by NEEM region for Future 3.
 - *In F3B relative to F2B, PJM_ROR has more wind (it is a separate super-region); MISO wind is reduced and more to the west (to MISO_W and MAPP_US), and SPP wind is reduced.*
 - *Builds are similar between F3B and F3S1 (75%).*

2030 EI Capacity by Region: Future 3 vs. BAU and Future 2 (GW)

	Cum New Builds in 2030					Cum New CCs in 2030					Cum New On-Sh Wind 2030				
	F1S3	F2B	F2S1	F3B	F3S1	F1S3	F2B	F2S1	F3B	F3S1	F1S3	F2B	F2S1	F3B	F3S1
	BAU Base	Fed CO2	75% Soft	Reg CO2	75% Soft	BAU Base	Fed CO2	75% Soft	Reg CO2	75% Soft	BAU Base	Fed CO2	75% Soft	Reg CO2	75% Soft
ENT	4	9	7	9	9	3	8	6	8	8	0	0	0	0	0
FRCC	16	30	32	29	29	13	12	13	12	13	0	0	0	0	0
IESO	5	5	5	5	5	1	1	1	1	1	2	2	2	2	2
MAPP_CA	2	4	5	5	5	2	0	0	0	0	0	0	0	0	0
MAPP_US	2	6	7	12	12	0	0	0	0	0	1	5	6	12	11
MISO_IN	5	57	60	21	24	4	14	16	20	23	0	42	42	0	0
MISO_MI	3	8	4	6	3	0	5	2	3	1	3	3	3	2	2
MISO_MO-IL	2	30	16	11	8	0	1	0	3	0	0	27	14	6	6
MISO_W	9	34	62	40	41	0	1	0	0	0	9	33	62	40	40
MISO_WUMS	10	18	16	9	11	4	6	7	7	8	1	11	8	1	1
NE	1	13	17	3	3	0	0	0	2	2	0	13	17	0	0
NEISO	9	9	9	9	9	2	2	2	2	2	5	5	5	5	5
NonRTO_Mid	1	6	6	7	7	1	5	5	6	6	0	0	0	0	0
NYISO_A-F	4	10	14	10	7	1	1	1	1	1	4	10	13	9	6
NYISO_G-I	1	1	0	1	0	1	0	0	0	0	0	0	0	0	0
NYISO_J-K	3	1	1	1	1	1	1	1	1	1	0	0	0	0	0
PJM_E	7	7	7	7	7	5	5	5	5	5	1	1	1	1	1
PJM_ROM	12	6	6	6	6	2	2	2	2	2	7	1	1	1	1
PJM_ROR	20	71	44	82	84	8	28	24	25	26	9	40	16	54	54
SOCO	10	23	17	23	23	8	12	12	12	12	0	0	0	0	0
SPP_N	3	31	60	17	17	2	1	0	4	2	0	28	59	12	14
SPP_S	8	45	43	38	38	2	4	0	5	7	3	38	41	29	27
TVA	8	11	11	11	11	4	9	9	9	9	0	0	0	0	0
VACAR	20	28	29	28	28	11	15	15	16	16	4	4	4	4	4
	165	465	480	392	389	75	135	121	144	145	49	263	294	180	176

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Future 3 Results (cont.)

- From F2B to F3B, a portion of wind generation is replaced with CC generation.

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

	BAU F1S3		F2B		F3B	
	2020	2030	2020	2030	2020	2030
CC	26%	25%	44%	31%	46%	37%
Coal	37%	38%	9%	1%	9%	2%
Nuclear	24%	22%	26%	32%	26%	32%
On-Shore Wind	4%	5%	12%	25%	10%	18%
Off-Shore Wind	0%	0%	0%	0%	0%	0%
Hydro	6%	5%	6%	7%	6%	7%
Total	97%	96%	97%	97%	97%	96%

- With the same CO₂ prices, the U.S. electric sector CO₂ emissions in Future 3 are somewhat higher (less wind) than in Future 2, but the difference is less than 5% or so of BAU CO₂ emissions.

U.S. Electric Sector CO₂ Emissions (*Millions of metric tons*)

	2020	2025	2030	2035
F1S2 (BAU)	2,041	2,159	2,239	2,424
F2B	1,086	718	487	277
F2S1 (75%)	1,076	661	436	234
F3B	1,105	747	556	320
F3S1	1,101	743	555	317

Next Steps

1. Hardened Future 3 transfer limits are calculated by the MWG to use in the remaining Future 3 sensitivities using the F3S1 (75%) soft constraint results.
2. The remaining Future 3 sensitivities are run in NEEM.
3. The Future 4 cases are run in NEEM.
4. Future 5 base case (F5B) and soft-constraint sensitivities (F5S1 and F5S2) are run, and a soft constraint report is created for the MWG to calculate the hardened limits to use for the remaining F5 sensitivities using the 25% soft constraint results.
5. Based on the last SSC call, we will:
 1. Continue to reserve the F2S8 and F3S7 “high carbon” sensitivities.
 2. Run both the F5S1 (75%) and F5S2 (25%) cases.