Summary of MRN-NEEM Modeling Results for the EIPC BAU Future and Transfer Limit Sensitivities

March 20, 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 runs of the:
  - Business-as-Usual ("BAU") Future Base Case, and
  - BAU Sensitivity 1 and 2 (transfer limits sensitivities).
- A detailed summary of modeling results in excel-readable format was created for each case for stakeholders to review.
  - *This detailed summary report will be the standard report issued for each MRN-NEEM run of a Future/Sensitivity.*
- A separate excel file compares the transfer path ("pipe") results for the three MRN-NEEM runs with respect to flows, shadow prices, and overload charges.

- In assessing each case, it is important to understand that each model run has perfect foresight about the future (i.e., future gas prices, new capacity costs, demands, etc.)
  - *The model will retire/build units to minimize costs, even if the savings are small.*
  - *With uncertainty, these decisions would not necessarily be made in the same way.*
  - *Sensitivity analyses are useful to help access the impact of uncertainty.*

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Detailed Summary Reports

- Generation Report
  - By NEEM region and for the EI in total for each model year (2015, 2020, etc.) through 2040.
    - For each generating unit type *(e.g., coal, nuclear, on-shore wind, etc.)*
      - Generation *(GWh)*, fuel consumption *(BTU)* and fuel costs *(M$)*
      - Emissions *(SO_2, NO_x, CO_2)* and emissions costs *(M$)*
      - Variable O&M and Fixed O&M costs *(M$)*
      - New capital and retrofit capital costs *(M$, levelized)*
      - Total costs (sum of above) *(M$)*
    - ACPs (alternative compliance payments) by NEEM region
    - Transmission costs *(50/50 sharing of hurdles by importing/exporting NEEM region)*
    - A comparison of energy demand and generation by NEEM region
  - Note that in all reports, EI totals do not include HQ or Maritimes imports into the EI which are separately reported.

Detailed Summary Reports

- Capacity Report
  - By NEEM region and for the EI in total for each model year.
    - New build capacity (by year and cumulative)
    - Retirements (by year and cumulative)
    - Total installed capacity by model year
    - Retrofitted capacity by type of retrofit
      - *FGD, SCR, SNCR, ACI90 (activated carbon injection), RPJ90 (ACI + Baghouse), PSCEQ (CCS Retrofit to Pulverized Coal).*
    - Resource and load balance by NEEM region
      - *Peak demand, plus reserve margin requirement*
      - *DR*
      - *Total installed capacity plus DR, adjusted for reserve contribution of renewables*
  - In practice, the model is run for the year 2010 and every 5 years thereafter, for reporting purposes retirements/additions for 2010/2015 have been cumulated in 2015.

Detailed Summary Reports

- Transmission Report:
  - For each transfer path (pipe") in each direction for each of the 20 load blocks in each model year
    - Flow
    - Shadow price ($/MWh)
    - Price in "from" region and "to" region ($/MWh)
    - Hurdle/transmission cost (wheeling + friction) on path ($/MWh)
    - *This report is not yet provided, the related information for the first three runs is provided in the separate "Soft Constraint" report.*

- MRN Report:
  - Reports the key MRN macro-economic results *(U.S. GDP, gas prices, CO_2 emissions for the non-electric sectors of the U.S. economy)* for each Future Base Case.
    - For the BAU, these parameters will match AEO 2011.
  - Because a new MRN-NEEM equilibrium is created only for each Future Base Case, the MRN report is issued only for a Future Base Case run.

Detailed Summary Reports

- In the interest of time, the detailed output reports have been issued in draft form and have not yet been fully audited.
  - *The reports are provided in one excel file for each case with separate sheets for the Generation, Capacity and Transmission Reports.*
  - *The files are entitled "F1B", "F1S1", and "F1S2", where "F" stands for Future, "B" for Base, and "S" for Sensitivity. Subsequent case runs will continue with this numbering scheme.*
- The output reports are created directly as part of the model run. We identified the following possible improvements needed thus far and will continue this review along with stakeholders.
  - *The Capacity Report does not list nuclear uprates in new build or installed capacity, and does not include nuclear plants reaching their end of license in retirements.*
  - *The off-shore wind has not yet been separated from the on-shore wind in the Capacity Report (BAU off-shore wind builds are minimal thus far).*
  - *The HQ/Maritimes fixed interchange is not listed in installed capacity in the Capacity Report.*
  - *The energy used by pumped storage units when pumping is not reflected directly in the Generation Report.*
    - The difference between total generation and energy demand across the entire model footprint in the report is the pumping demand.

Summary of Results – BAU Base Case

- For the BAU, the Eastern Interconnect new capacity and retirements by capacity type are shown below:
  - *2030 includes additions/retirements for both the 2025 and 2030 model year results*

BAU Base Case: 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	8.4	0.0	3.3	69.7	47.6	0.0	166.4
Nuclear	99.8	2.7	4.5	0.0	0.0	0.0	1.5	105.0
CC	132.7	30.4	45.3	23.2	5.7	0.0	0.0	225.8
CT	120.3	4.9	10.2	3.3	0.9	0.0	0.0	137.8
Steam Oil/Gas	71.4	0.0	0.0	0.0	34.4	0.6	0.4	36.0
Hydro	44.6	0.0	0.0	0.0	0.0	0.0	0.0	44.6
On-shore Wind	18.7	22.2	12.7	13.0	0.0	0.0	0.0	66.6
Off-shore Wind	0.0	0.5	0.0	1.1	0.0	0.0	0.0	1.6
Other Renewables	6.7	2.3	3.3	5.9	0.8	0.0	0.0	17.4
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	69.8	75.9	49.8	111.5	48.2	0.4	818.2
DR	33.1							70.7

In practice, the model is run for the year 2010 as well, for reporting purposes retirements/additions for 2010/2015 have been cumulated in 2015.

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Summary of Results – BAU Base Case

- As shown, there are significant CC builds and even more coal retirements by 2015.
  - Low load growth results in EI capacity about 29 GW above that needed to meet reserve requirements in 2015. This 29 GW is retired by 2015.

EI Capacity in Comparison to Reserve Requirement, 2015 *(GW)*

(Capacity after adjustment for renewable and HQ interchange reserve value)

Starting Capacity 2010	766.8	
Additions	49.9	
Retirements	(111.5)	
Nuke Uprates net of Retrofit Derates	1.1	
DR "Resources"	31.8	
Net Resources for Reserves 2015	738.0	← *29 GW less than starting capacity*
Peak Demand 2015	639.7	
Peak Demand w/Required Reserves	737.6	← *But still meets reserve requirement*

  - The AEO 2011 gas price forecast makes new gas-fired capacity economically attractive in comparison to older, existing coal units with high fixed O&M and relatively high variable costs.
    - *This yields an initial wave of coal retirements by 2015 and replacement with new gas-fired resources.*

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Summary of Results – BAU Base Case

- Under stakeholder BAU assumptions, many coal units face additional costs by 2020 for cooling water, coal ash, scrubbers, SCRs and mercury controls under new EPA regulations.
  - For the EI region, 98% of coal plants above 200 MW in size would require an FGD, SCR, Cooling Tower or Mercury Controls.
    - 79% require more than one retrofit, 45% more than two, and 20% require all four.
    - *Under the stakeholder BAU assumptions, the average added cost across this fleet (for "typical" 500 MW sized units) would be:*

Average Added Costs by 2020 for EI Coal Plants > 200 MW for FGD, SCR, Cooling Towers or Mercury Control *(2010$)*

$/KW Capital	641
$/KW-yr Fixed O&M	5.2
$/MWh Variable O&M	2.6
Capacity Penalty	1.0%
Heat Rate Penalty	1.0%

← If all units are assumed to be 500 MW in size

- For units closer to 200 MW in size, the added capital costs per KW are higher. Units requiring multiple retrofits will have higher costs.
  - Coal ash costs starting in 2020 of $0.63/MWh are in addition to the costs above for all units.
- In the face of these added costs, and low gas prices, many coal plants retire instead of retrofitting.

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Summary of Results – BAU Base Case

- In the EI, 87% of coal plants smaller than 200 MW retire by 2020, and 32% of larger plants.

Coal Retirements by EI NEEM Region (MW)

	Plants Smaller than 200 MW			Plants Larger than 200 MW		
	Existing 2010	Retired by 2015	Retired by 2020	Existing 2010	Retired by 2015	Retired by 2020
ENT	578	403	578	7,731	550	550
FRCC	136	136	136	9,327	998	3,919
IESO	306	306	306	6,110	6,110	6,110
MAPP_CA	1,746	1,010	1,010	-	-	-
MAPP_US	289	289	289	4,372	1,499	1,798
MISO_IN	2,842	395	1,978	11,905	-	764
MISO_MI	2,657	2,160	2,537	8,135	1,043	2,925
MISO_MO-IL	2,549	1,824	2,180	11,415	215	3,004
MISO_W	3,071	-	1,840	9,749	339	4,453
MISO_WUMS	1,857	1,857	1,857	5,688	-	2,547
NE	961	-	961	2,917	-	682
NEISO	768	768	768	1,803	1,483	1,803
NonRTO_Midwest	2,059	646	813	8,572	654	1,200
NYISO_A-F	1,568	1,568	1,568	684	684	684
NYISO_G-I	136	136	136	233	233	233
NYISO_J-K	-	-	-	-	-	-
PJM_E	1,132	1,132	1,132	2,721	2,153	2,721
PJM_ROM	3,829	3,829	3,829	12,552	4,217	4,738
PJM_ROR	10,420	6,500	9,889	49,448	6,812	15,767
SOCO	3,535	3,534	3,534	21,801	6,159	6,159
SPP_N	1,716	-	1,013	6,167	-	1,607
SPP_S	736	2	238	12,404	2,179	3,139
TVA	6,043	3,105	6,043	9,116	698	2,136
VACAR	5,354	2,305	4,648	14,782	1,774	3,039
Total	54,285	31,902	47,280	217,631	37,800	69,978
		59%	87%		17%	32%

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Summary of Results – BAU Base Case

- About 48 GW of new wind capacity is built in the EI by 2030.

Cumulative New Wind Capacity by NEEM Region (MW)

NEEM Region	Future 1 BAU: Base Case			
	2015	2020	2025	2030
ENT	0	0	0	0
FRCC	0	0	0	0
IESO	2,106	2,106	2,106	2,106
MAPP_CA	302	302	302	302
MAPP_US	421	778	1,129	1,224
MISO_IN	0	0	0	0
MISO_MI	2,000	2,000	2,600	2,718
MISO_MO-IL	300	300	300	300
MISO_W	2,801	4,935	7,920	8,871
MISO_WUMS	969	969	969	969
NE	202	2,628	2,628	2,628
NEISO	231	2,903	3,385	4,385
NonRTO_Midwest	0	0	0	0
NYISO_A-F	2,476	3,186	3,186	3,186
NYISO_G-I	0	60	60	60
NYISO_J-K	0	0	0	0
PJM_E	1,150	1,150	1,150	1,150
PJM_ROM	480	902	1,230	7,040
PJM_ROR	8,326	8,326	8,517	8,517
SOCO	0	0	0	0
SPP_N	0	257	370	370
SPP_S	430	580	580	580
TVA	0	0	0	0
VACAR	1	3,500	3,500	3,500
Total	22,195	34,882	39,933	47,907

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Transfer Limits Sensitivities

- BAU Future Base Case: "Hard" MW limits on each path as specified by EIPC

- Sensitivity #1: 75% Soft Constraints
  - Transfer limits can be exceeded subject to an overload charge ($/MWh)
  - Overload charge calculated as 75% of the average shadow price on the path in the model year
    - Shadow price reflects the price difference between NEEM regions in each load block
      - Net of the hurdle rate (wheeling + friction) on the path.
      - If the shadow price is zero and there is flow, the price difference on the path equals the hurdle rate
    - Overload charge is the average of the non-zero shadow prices in each of the 20 load blocks.
      - Average is weighted by the duration of the load blocks then multiplied by 75%.
    - Applied only on intra-EI paths *(not paths to/from the WECC or inside of WECC).*
    - Will be zero on unconstrained pipes *(i.e., $0 shadow prices in all load blocks in the year)*
    - Hurdle rates *(wheeling+friction)* continue to apply on all flows *(per Assumptions Exhibit 18)*

- Sensitivity #2: Same as above except using 25% instead of 75%.

Soft Constraint Report

- Soft Constraint Report
  - A separate excel-readable file compares the transfer path ("pipe") data for the BAU Base Case, and the 75% and 25% Soft Constraint sensitivities.
  - For each model year (every 5 years) and for each of the 20 load blocks in the model year by transfer path in each direction:
    - *Flow (MW)*
    - *Shadow price*
    - *Overload charge assessed (for Sensitivities 1 and 2).*
  - This report can be used by stakeholders to help them decide what transfer limits to apply on each transfer path in the remaining BAU sensitivities.
    - *Note that to speed model solution, an overload charge of $0.0001 is applied when the overload charge on a transfer path is zero.*
    - *The data is separately provided for intra-EI paths and EI to/from WECC/ERCOT paths.*

Summary of Results – Sensitivity 1 &2: Transfer Limit Cases

- Overload flow can be significant on certain paths in these cases.
  - For the 18,000+ data points for intra-EI transfer path in each direction (x 20 load blocks per year x 9 model years), the maximum and average flow data is shown below.

Intra-EI Transfer Path Flows and Shadow Prices by Case
Average and Maximum in the 20 load blocks for all Model Years for All Intra-EI Paths
Flow in MW, Prices in $/MWh

	Base Flow (MW)			Overload flow (MW)		Base Shadow Price			Overload Charge	
	BAU	OL75	OL25	OL75	OL25	BAU	OL75	OL25	OL75	OL25
Max	8,000	8,000	8,000	22,819	40,893	33.4	10.3	3.6	13.5	4.5
Avg when >0	1,472	1,844	1,897	666	1,760	5.6	2.2	0.8	2.6	0.9
Non-zero	32%	28%	26%	14%	16%	12%	11%	12%	38%	38%

  - There are many blocks in which there is no flow
    - *50% of the directional paths will have no flows because flow is only in one direction.*
    - *Other paths will be zero when economics do not dictate that the value of transporting the power exceed the hurdle rates on the path*
  - For the non-zero path-blocks, the average overflow was 666 MW on average and as high as 22,819 MW in the 75% Sensitivity, and 1,760 on average and as high as 40,893 MW.
    - *However, many of these overflows are within an RTO where hurdle rates are zero.*

Summary of Results – Sensitivity 1: 75% Transfer Limit Case

- For the 75% overload transfer limit case, the Eastern Interconnect new capacity and retirements by capacity type are shown below.
  - *Capacity builds and retirements do not change significantly from the Base Case*

75% Transfer Limit: 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	8.4	0.0	3.6	69.5	48.8	0.0	165.6
Nuclear	99.8	2.7	4.5	0.0	0.0	0.0	1.5	105.0
CC	132.7	30.2	46.0	20.8	4.1	0.0	0.0	225.5
CT	120.3	4.9	10.6	5.4	2.0	0.0	0.0	139.1
Steam Oil/Gas	71.4	0.0	0.0	0.0	34.3	0.6	0.4	36.1
Hydro	44.6	0.0	0.0	0.0	0.0	0.0	0.0	44.6
On-shore Wind	18.7	22.2	11.9	13.0	0.0	0.0	0.0	65.7
Off-shore Wind	0.0	0.5	0.0	1.1	0.0	0.0	0.0	1.6
Other Renewables	6.7	2.3	3.3	5.9	0.9	0.0	0.0	17.3
New HQ/Maritimes	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.5
Other	17.1	0.0	0.0	0.0	0.0	0.0	0.0	17.1
Total	783.3	70.2	76.2	49.7	110.8	49.4	0.4	818.2
DR	33.1							70.7

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Summary of Results – Sensitivity 1: 25% Transfer Limit Case

- For the 25% overload transfer limit case, the Eastern Interconnect new capacity and retirements by capacity type are shown below:.
  - Somewhat less coal retirements and new CC builds than that prior cases.

75% Transfer Limit: 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	8.4	0.0	7.6	69.3	46.6	0.0	172.0
Nuclear	99.8	2.7	4.5	0.0	0.0	0.0	1.5	105.0
CC	132.7	29.6	43.9	16.9	4.1	0.0	0.0	219.1
CT	120.3	5.4	10.4	4.2	2.0	0.0	0.0	138.4
Steam Oil/Gas	71.4	0.0	0.0	0.0	34.4	0.6	0.3	36.0
Hydro	44.6	0.0	0.0	0.0	0.0	0.0	0.0	44.6
On-shore Wind	18.7	22.2	11.9	13.3	0.0	0.0	0.0	66.1
Off-shore Wind	0.0	0.5	0.0	1.1	0.0	0.0	0.0	1.6
Other Renewables	6.7	2.3	3.3	5.9	1.0	0.0	0.0	17.2
New HQ/Maritimes	0.0	0.5	0.0	1.2	0.0	0.0	0.0	1.7
Other	17.1	0.0	0.0	0.0	0.0	0.0	0.0	17.1
Total	783.3	70.2	74.1	49.0	110.8	47.3	0.3	818.7
DR	33.1							70.7

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Summary of Results – Sensitivity 1 &2: Transfer Limit Cases

- Coal retirements do not change significantly between the three cases.

Coal Retirements by EI NEEM Region (MW)

		BAU Base		75% Sensitivity		25% Sensitivity	
	Existing 2010	Retired by 2015	Retired by 2020	Retired by 2015	Retired by 2020	Retired by 2015	Retired by 2020
ENT	8,309	953	1,128	953	1,128	953	1,128
FRCC	9,463	1,134	4,055	1,134	4,055	1,134	4,055
IESO	6,416	6,416	6,416	6,416	6,416	6,416	6,416
MAPP_CA	1,746	1,010	1,010	1,010	1,010	635	635
MAPP_US	4,661	1,788	2,087	1,616	2,087	1,616	2,087
MISO_IN	14,747	395	2,742	395	2,742	395	2,742
MISO_MI	10,792	3,203	5,462	3,541	6,097	3,541	6,882
MISO_MO-IL	13,964	2,039	5,184	2,039	5,184	2,039	5,184
MISO_W	12,820	339	6,293	-	6,808	-	6,808
MISO_WUMS	7,545	1,857	4,404	1,857	4,404	1,857	4,404
NE	3,878	-	1,643	-	1,643	-	958
NEISO	2,571	2,251	2,571	2,251	2,571	2,251	2,571
NonRTO_Midwest	10,630	1,300	2,013	1,300	2,013	1,300	1,846
NYISO_A-F	2,252	2,252	2,252	2,252	2,252	2,252	2,252
NYISO_G-I	368	368	368	368	368	368	368
NYISO_J-K	-	-	-	-	-	-	-
PJM_E	3,853	3,285	3,853	3,285	3,853	3,285	3,853
PJM_ROM	16,381	8,045	8,566	8,046	8,567	7,697	7,764
PJM_ROR	59,868	13,312	25,656	13,312	25,656	13,661	24,862
SOCO	25,335	9,693	9,693	9,694	9,694	9,694	9,694
SPP_N	7,883	-	2,620	-	2,620	-	2,620
SPP_S	13,140	2,181	3,377	2,181	3,377	2,280	3,377
TVA	15,159	3,803	8,179	3,803	8,081	3,803	7,722
VACAR	20,136	4,079	7,687	4,079	7,687	4,099	7,687
Total	271,916	69,702	117,258	69,530	118,311	69,275	115,913
		26%	43%	26%	44%	25%	43%

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Summary of Results – Sensitivity 1 &2: Transfer Limit Cases

- Wind builds do not change significantly between the cases.

Cumulative New Wind Capacity by NEEM Region (MW)

NEEM Region	Future 1 BAU: Base Case				Future 1 BAU, Sensitivity 1: 75% Transfer Limits				Future 1 BAU, Sensitivity 2: 25% Transfer Limits			
	2015	2020	2025	2030	2015	2020	2025	2030	2015	2020	2025	2030
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	2,106	2,106	2,106	2,106	2,106	2,106	2,106	2,106	2,106	2,106	2,106	2,106
MAPP_CA	302	302	302	302	302	302	302	302	302	302	302	302
MAPP_US	421	778	1,129	1,224	421	1,037	1,129	1,224	421	1,037	1,129	1,224
MISO_IN	0	0	0	0	0	0	0	0	0	0	0	0
MISO_MI	2,000	2,000	2,600	2,718	2,000	2,000	2,600	2,669	2,000	2,000	2,600	2,808
MISO_MO-IL	300	300	300	300	300	300	300	300	300	300	300	300
MISO_W	2,801	4,935	7,920	8,871	2,801	4,684	7,944	8,898	2,801	4,684	7,944	8,898
MISO_WUMS	969	969	969	969	969	969	969	969	969	969	969	969
NE	202	2,628	2,628	2,628	202	2,669	2,669	2,669	202	2,902	3,270	3,270
NEISO	231	2,903	3,385	4,385	231	2,069	2,539	3,515	231	2,109	2,517	3,501
NonRTO_Midwest	0	0	0	0	0	0	0	0	0	0	0	0
NYISO_A-F	2,476	3,186	3,186	3,186	2,476	3,186	3,186	3,186	2,476	3,186	3,186	3,186
NYISO_G-I	0	60	60	60	0	60	60	60	0	60	60	60
NYISO_J-K	0	0	0	0	0	0	0	0	0	0	0	0
PJM_E	1,150	1,150	1,150	1,150	1,150	1,150	1,150	1,150	1,150	1,150	1,150	1,150
PJM_ROM	480	902	1,230	7,040	480	903	1,230	7,040	480	903	1,230	7,040
PJM_ROR	8,326	8,326	8,517	8,517	8,326	8,326	8,517	8,517	8,326	8,326	8,517	8,517
SOCO	0	0	0	0	0	0	0	0	0	0	0	0
SPP_N	0	257	370	370	0	219	331	331	0	0	0	0
SPP_S	430	580	580	580	430	580	580	580	430	580	580	580
TVA	0	0	0	0	0	0	0	0	0	0	0	0
VACAR	1	3,500	3,500	3,500	1	3,500	3,500	3,500	1	3,500	3,500	3,500
Total	22,195	34,882	39,933	47,907	22,195	34,060	39,113	47,017	22,195	34,114	39,360	47,412

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Summary of Results – Sensitivity 1 &2: Transfer Limit Cases

- CC builds change somewhat between regions in the cases, particularly within an RTO.

Cumulative New CCs by EI NEEM Region (MW)

NEEM Region	Future 1 BAU: Base Case				Future 1 BAU, Sensitivity 1: 75% Transfer Limits				Future 1 BAU, Sensitivity 2: 25% Transfer Limits			
	2015	2020	2025	2030	2015	2020	2025	2030	2015	2020	2025	2030
ENT	184	1,366	1,366	2,273	66	1,248	1,248	2,155	362	1,544	1,544	2,391
FRCC	1,517	8,984	11,199	15,078	1,517	8,984	11,199	15,078	1,517	8,984	11,199	15,078
IESO	1,263	1,263	1,263	1,263	1,263	1,263	1,263	1,263	1,263	1,263	1,263	1,263
MAPP_CA	913	1,424	1,599	2,007	913	1,424	1,599	1,764	0	396	396	396
MAPP_US	0	0	0	0	0	0	0	0	0	0	0	0
MISO_IN	0	7,239	8,006	8,947	0	7,149	7,262	8,745	0	0	0	0
MISO_MI	0	0	0	802	0	0	0	0	0	0	0	0
MISO_MO-IL	0	0	0	0	0	0	0	0	0	0	0	0
MISO_W	0	0	0	0	0	0	0	0	0	0	0	0
MISO_WUMS	0	4,368	4,402	5,093	0	5,234	5,881	5,881	0	13,390	14,150	14,150
NE	0	0	0	0	0	0	0	0	0	0	0	0
NEISO	2,050	2,050	2,050	2,050	2,050	2,050	2,050	2,050	2,050	2,050	2,050	2,050
NonRTO_Midwest	0	1,460	1,537	1,744	0	1,398	1,476	1,690	0	1,177	1,254	1,469
NYISO_A-F	639	639	639	639	639	639	639	639	639	639	639	639
NYISO_G-I	0	0	739	1,150	0	0	0	0	0	0	0	0
NYISO_J-K	1,175	1,175	1,175	1,175	1,175	1,175	1,175	1,175	1,175	1,175	1,175	1,175
PJM_E	4,634	4,634	4,634	4,634	4,634	4,634	4,634	4,634	4,634	4,634	4,634	4,634
PJM_ROM	1,679	1,679	1,679	1,679	1,679	1,679	1,679	1,679	1,679	1,679	1,679	1,679
PJM_ROR	3,077	9,871	9,871	15,319	3,077	9,871	9,871	15,319	3,077	8,287	8,287	12,188
SOCO	5,027	5,426	5,699	7,143	5,027	5,426	5,699	8,149	5,027	5,426	5,591	8,149
SPP_N	0	3,708	3,708	3,708	0	2,347	2,347	2,347	0	705	705	705
SPP_S	0	3,548	3,548	4,573	0	4,906	4,906	4,906	0	5,756	5,756	5,756
TVA	1,418	6,924	6,924	6,924	1,418	6,873	6,873	6,873	1,418	6,584	6,584	6,584
VACAR	6,777	9,889	10,408	12,632	6,777	9,889	10,408	12,630	6,797	9,889	10,408	12,152
Total	30,352	75,647	80,446	98,831	30,235	76,189	80,208	96,977	29,637	73,578	77,314	90,457

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Impact of Soft Constraints on Advanced Coal Additions

Opening up of transmission pipes creates incentives for adding more advanced coal capacity in the EI in total

The impact varies by region

Relaxing transmission constraints:

- Increases coal capacity additions in the MISO_W and NE regions.
- Eliminates coal capacity additions in the SOCO region.

Technology/Region	BAU additions through 2030	Increase under OL75%	Increase under 25%
Adv. Coal	**11,086**	**281**	**4,259**
ENT	720	-	-
FRCC	-	-	-
MAPP_US	-	-	252
MISO_IN	-	-	-
MISO_MO-IL	1,790	-	-
MISO_W	0	261	4,036
MISO_WUMS	513	-	-
NE	1,525	1,025	976
NonRTO_Midwest	-	-	-
PJM_E	27	-	-
PJM_ROM	33	-	-
PJM_ROR	2,164	-	-
SOCO	1,005	(1,005)	(1,005)
SPP_N	465	-	-
SPP_S	988	-	-
TVA	1,031	0	0
VACAR	825	-	-

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Impact of Soft Constraints on Combined Cycle Additions

Opening up of transmission pipes reduces the level of CCGT capacity additions in the EI in total.

The impact varies by region

Relaxing transmission constraints:

- Reduces CCGT capacity additions in NYISO, TVA, VACAR and MAPP_CA, in SPP (but reshuffles capacity between SPP_N and SPP_S)
- Significantly reshuffles CCGT capacity additions in the Midwest ISO.
- Increases CCGT capacity additions in SOCO

Technology/Region	BAU additions through 2030	Increase under OL75%	Increase under 25%
New CC	**98,831**	**(1,855)**	**(8,375)**
ENT	2,273	(118)	118
FRCC	15,078	(0)	(0)
MISO_IN	8,947	(202)	(8,947)
MISO_MI	802	(802)	(802)
MISO_WUMS	5,093	788	9,056
NE	0	(0)	(0)
NEISO	2,050	-	-
NonRTO Midwest	1,744	(54)	(275)
NYISO_A-F	639	-	-
NYISO_G-I	1,150	(1,150)	(1,150)
NYISO_J-K	1,175	-	-
PJM_E	4,634	-	-
PJM_ROM	1,679	-	-
PJM_ROR	15,319	0	(3,131)
SOCO	7,143	1,005	1,006
SPP_N	3,708	(1,361)	(3,003)
SPP_S	4,573	333	1,183
TVA	6,924	(51)	(340)
VACAR	12,632	(1)	(480)
IESO	1,263	-	-
MAPP_CA	2,007	(242)	(1,610)

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Impact of Soft Constraints on CT Additions

Opening up of transmission pipes increases the level of new CT capacity additions in the EAI in total.

The impact varies by region

Relaxing transmission constraints:

- Reduces CT additions in MAPP_US and TVA
- Increases CT additions in MISO_WUMS under 75% scenario, but reduces it under 25% scenario
- Increases CT additions in NYISO, Non-RTO Midwest, VACAR and MAPP Canada

Technology/Region	BAU additions through 2030	Increase under OL75%	Increase under 25%
New CT	18,335	2,485	1,731
FRCC	2,480	-	-
MAPP_US	560	0	(252)
MISO_WUMS	9,653	1,085	(1,466)
NEISO	334	-	-
NonRTO Midwest	207	54	111
NYISO_J-K	761	1,150	193
PJM_E	26	-	1,547
PJM_ROM	16	-	-
PJM_ROR	29	-	-
SPP_S	713	-	-
TVA	1,968	(47)	(118)
VACAR	1,220	1	480
IESO	368	-	-
MAPP_CA	-	242	1,236

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Summary of Results – Sensitivity 1 &2: Transfer Limit Cases

- Despite the increase in overload flows, the overall builds/retirements by type are similar for the EI between the cases.
- We attribute this to the favorable economics for gas-fired capacity in the BAU Base assumptions.
  - *Gas-fired capacity can be constructed in any NEEM region.*
  - *The key determinants of exactly where the gas-fired capacity will be built are:*
    - Regional multiplier differences for the capital cost of gas-fired plants,
    - Reserve margin regions,
    - Hurdle rates on transfer paths,
    - Transfer limits/overload charges on transfer paths, and
    - Gas basis differentials.
      - For example, the capital cost for a new CC is 6.5% less in MISO_WUMS than in MISO_MI.
      - With no hurdles on transfer paths within an RTO, this leads to plants being built in the lower cost region.
      - With transfer path overloads allowed, even more will be constructed in the lower cost region.
  - *In the BAU, state RPS requirements will drive the installation of some renewable resources.*