Carbon Charge Proposal Evaluation – Updated

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Overview

SUPERCEDES MATERIAL POSTED 10/15/2018

- Observations
- Background
- Objective
- Work Plan
- Results (updated)
- Sensitivities
- Border Charges
- Methodology
- Input Assumptions
- Appendix

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Observations

- The performance of the carbon charge proposal is sensitive to the implementation of the border adjustment mechanism; the impact of estimation error is asymmetric and tends to increase costs and emissions
- The results suggest that trading post carbon charge could result in higher in-state CO_2 emissions, even while lowering emissions over a broader market region
- Slightly less than half the wholesale cost increase to consumers is offset via allocation of carbon charge residuals
- The increased gross margins to in-state resources are likely insufficient to overcome the non-market barriers that exist to building transmission and siting, reducing the potential that a carbon charge would lead to a more optimal deployment of capital to renewable projects
- No market-based entry occurs during the study period

Background

- New York ISO (NYISO) is considering incorporating the price of carbon emissions into the wholesale energy markets
- New York State has three public policy goals that will have a direct impact on wholesale market:
  1. Ambitious greenhouse gas reduction targets
  2. Meeting at least 50% of the state's energy demand with renewable resources
  3. Proposed reduction of electricity consumption by 3% over the 2015 baseline by 2025

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Objective

- The goal of this study is to assess what impact the introduction of a carbon charge into the NYISO energy market might have on the performance of the market
- The study seeks to determine if it is likely that the carbon charge proposal will further the goals of state policy by reducing CO_2 emissions and better coordinating investment in renewable resources without imposing (at least in aggregate) additional costs on consumers

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Work plan

- Evaluate direct economic impacts of implementing a carbon charge through the NYISO markets.
- Study focuses on the delta in outcomes between two cases:
  1. A "status quo" case assuming state policies are met and the carbon charge is not implemented.
  2. A "with carbon charge" case featuring the addition of the proposed carbon charge.
- Study period includes each year between 2021 and 2025 inclusive, 2030, and 2035.
- Performance metrics selected to characterize the impact of carbon charge on the market, consumers, and economic efficiency.
- Inputs tested to assess sensitivity of metrics to assumptions.

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Metrics

For New York State and by Zone, we report the change in the following metrics between the Status Quo and Carbon Charge cases:

- CO_2 Emissions
- Production Costs
- Average LBMPs
- Zonal Capacity Prices
- Customer Credits from Emitting Resources
- Resource Gross Margin (calculated as contribution margin by proxy resource for each resource class by year)
- Net Exports
- Quantity and Location of Market-based Entry
- Renewable production

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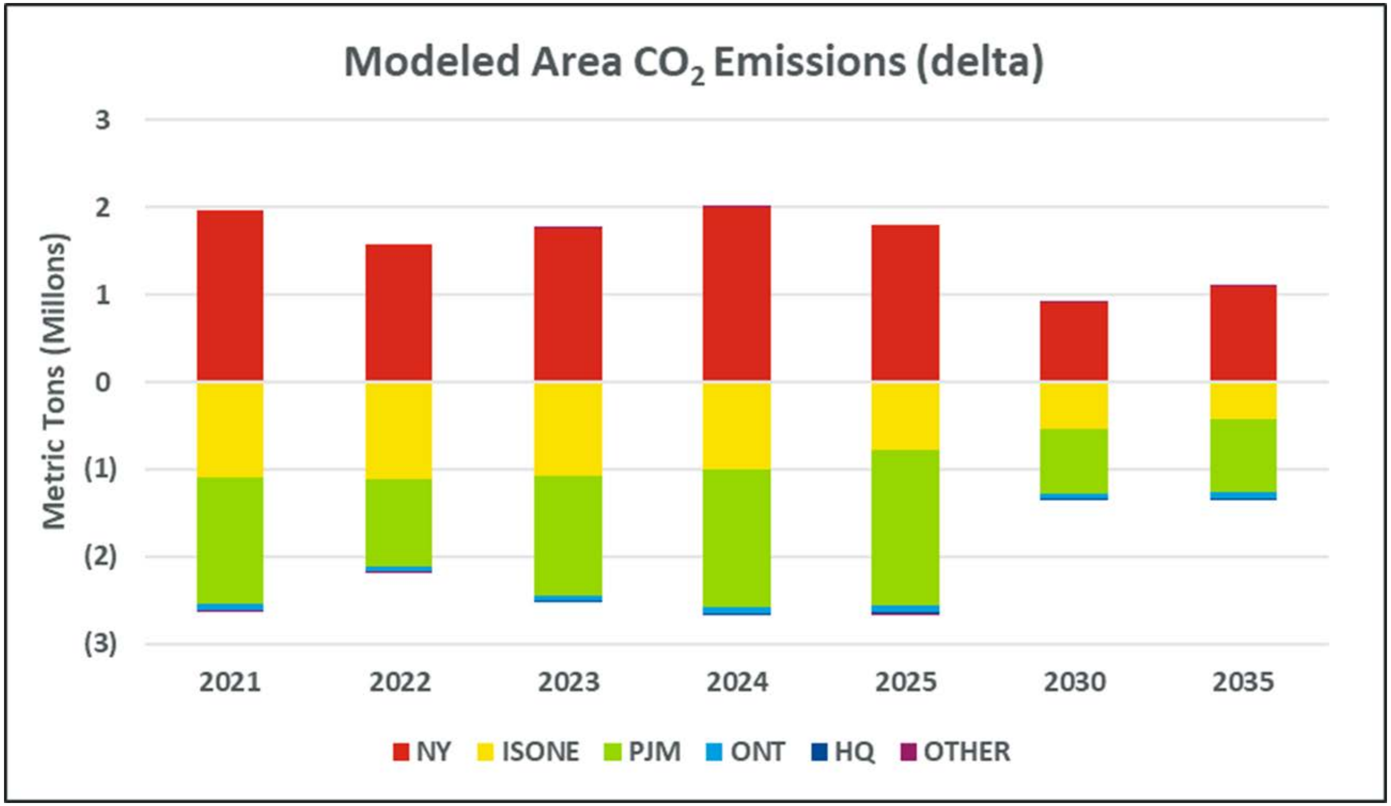
UPDATED RESULTS

SUPERCEDES MATERIAL POSTED 10/15/2018

Change in Modeled Area CO_2 emissions

Carbon Charge Case has lower total emissions across the modeled area over the study period



Results for OTHER includes New Brunswick and the Maritimes

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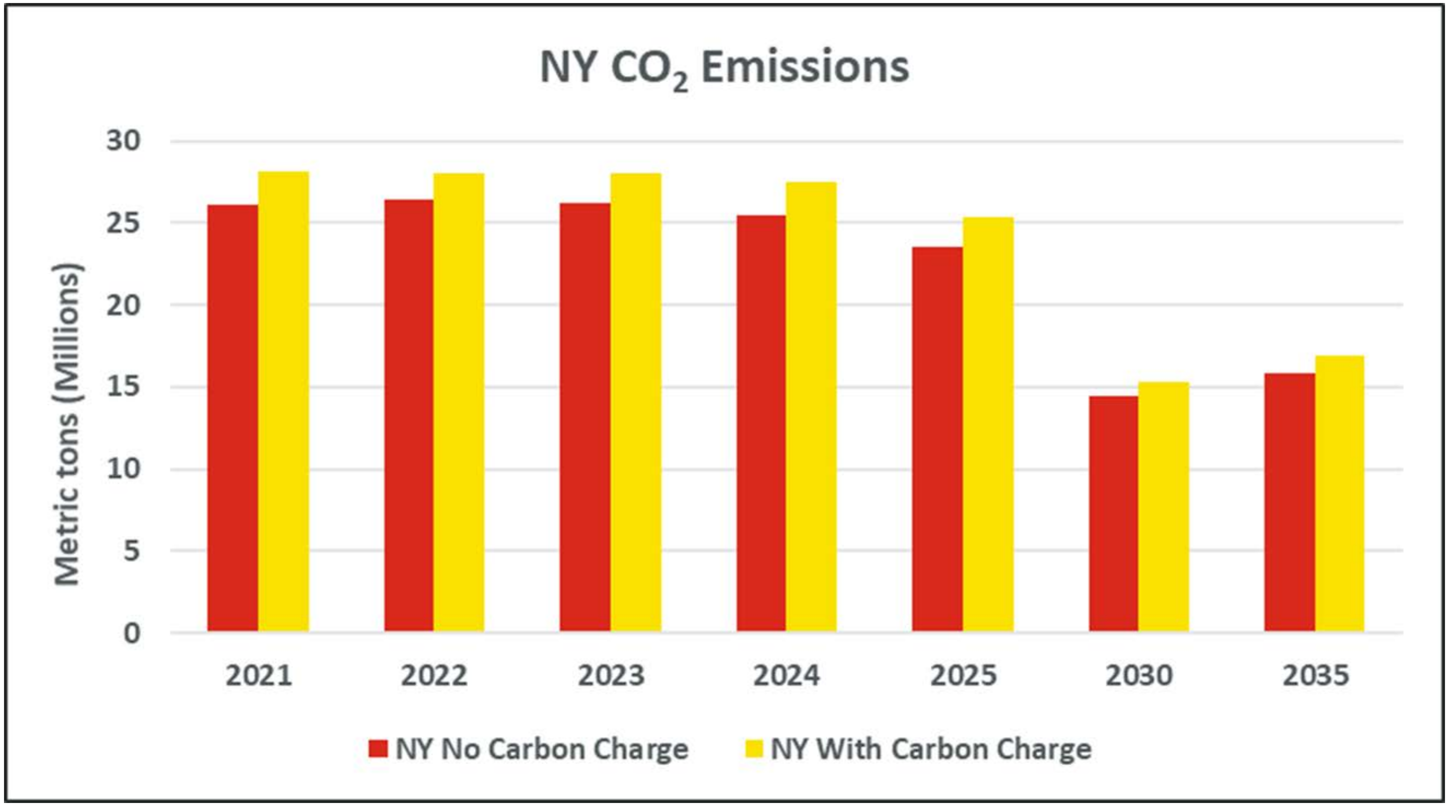
Total NY state-wide CO_2 emissions

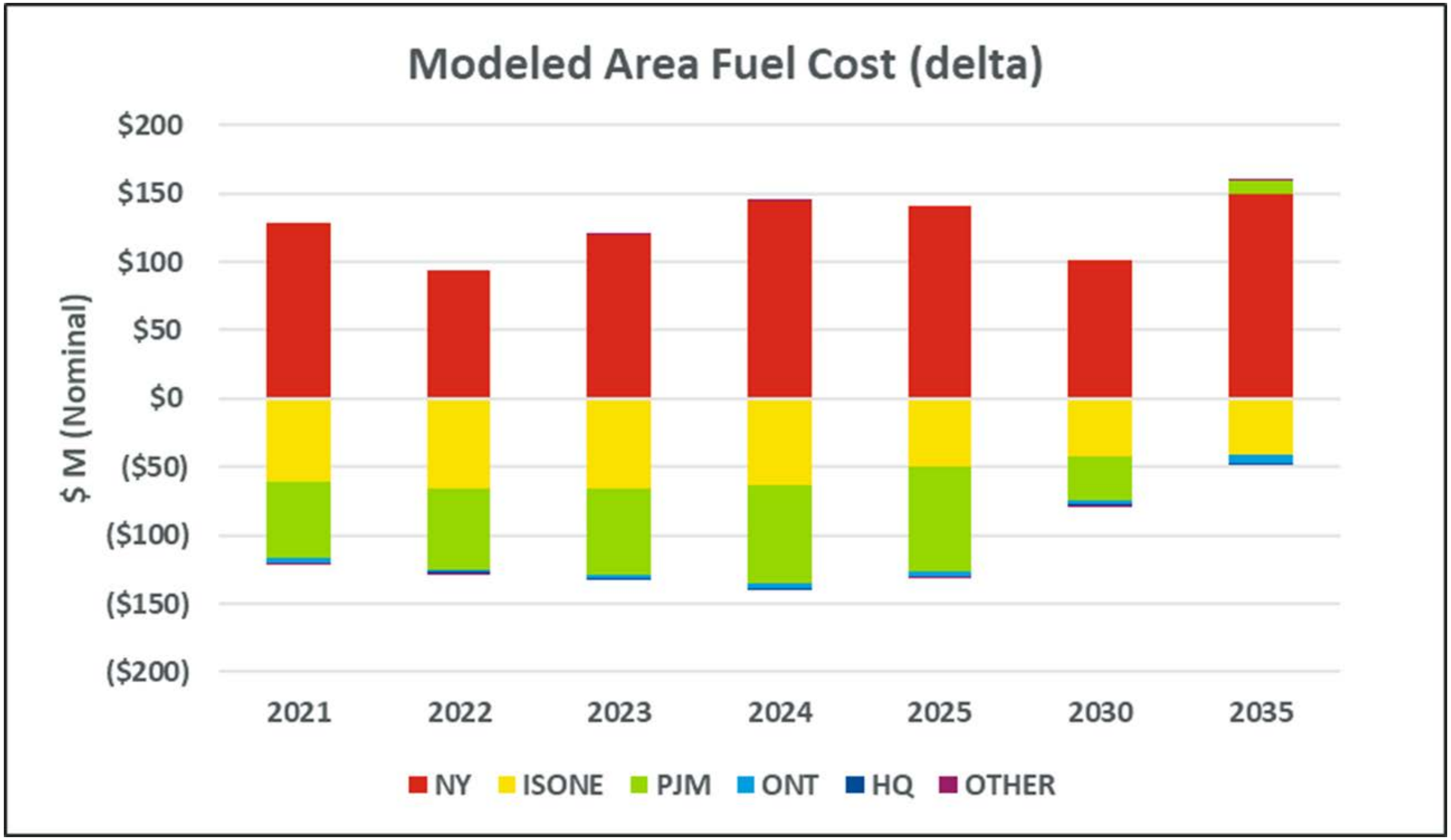
Carbon Charge Case has higher total emissions in NY state over the study period



Percent change in NY state CO_2 emissions by zone

ZONE	2021	2022	2023	2024	2025	2030	2035
A	2%	0%	2%	(1%)	(1%)	(3%)	(1%)
B	8%	6%	8%	6%	4%	5%	8%
C	5%	6%	8%	8%	7%	10%	12%
D	17%	15%	18%	17%	14%	9%	12%
E	(15%)	(18%)	(19%)	(18%)	(19%)	(1%)	4%
F	19%	17%	18%	20%	20%	19%	15%
G	8%	10%	5%	13%	11%	3%	4%
H	(12%)	(15%)	(18%)	(16%)	(16%)	(20%)	46%
I	117%	119%	118%	163%	150%	31%	0%
J	7%	6%	6%	7%	8%	3%	4%
K	5%	1%	2%	2%	2%	5%	6%

Change in modeled area fuel costs



Results for OTHER includes New Brunswick and the Maritimes

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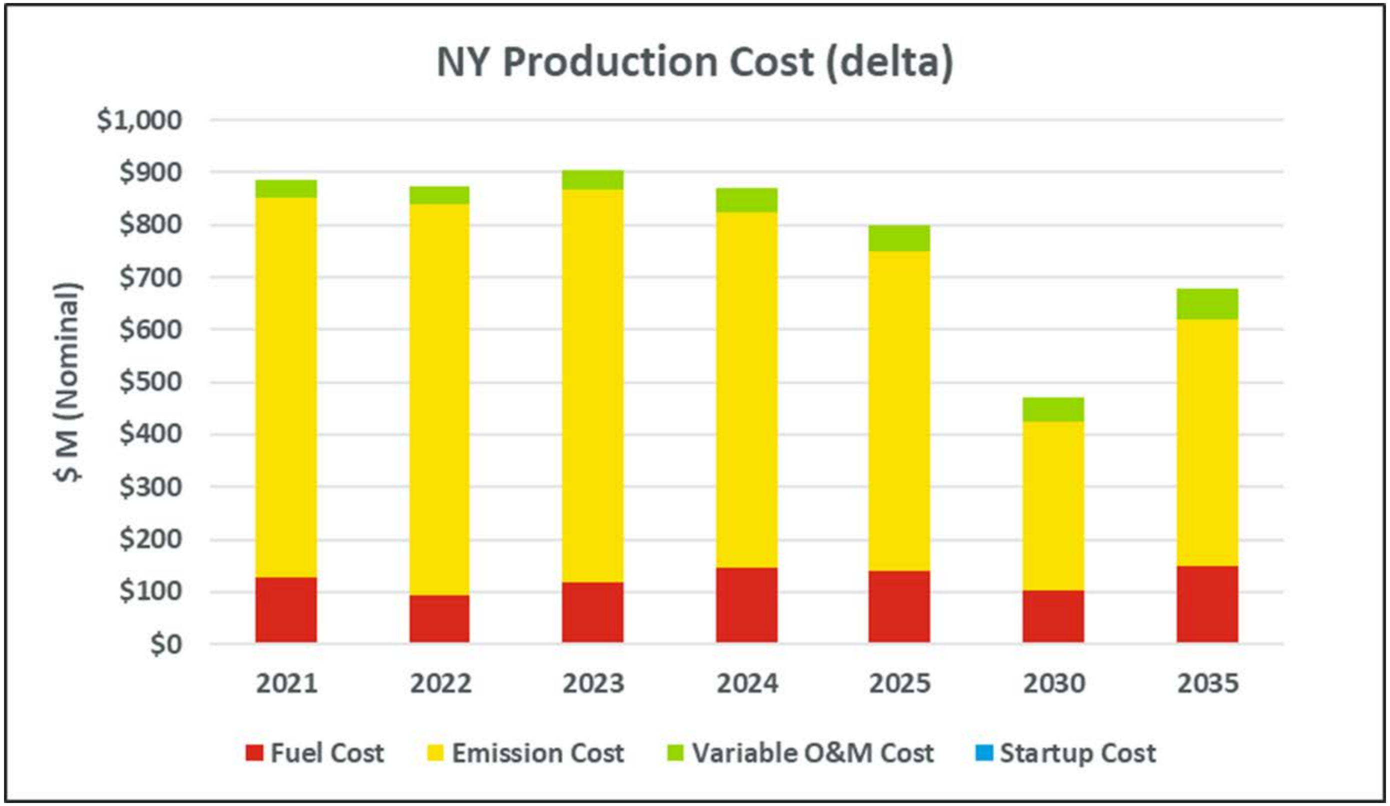
Change in New York production costs

- Emission costs are the largest portion of the production cost change
- NY generation has increased, which contributes much of this change



Gross production costs not net of carbon charge residuals

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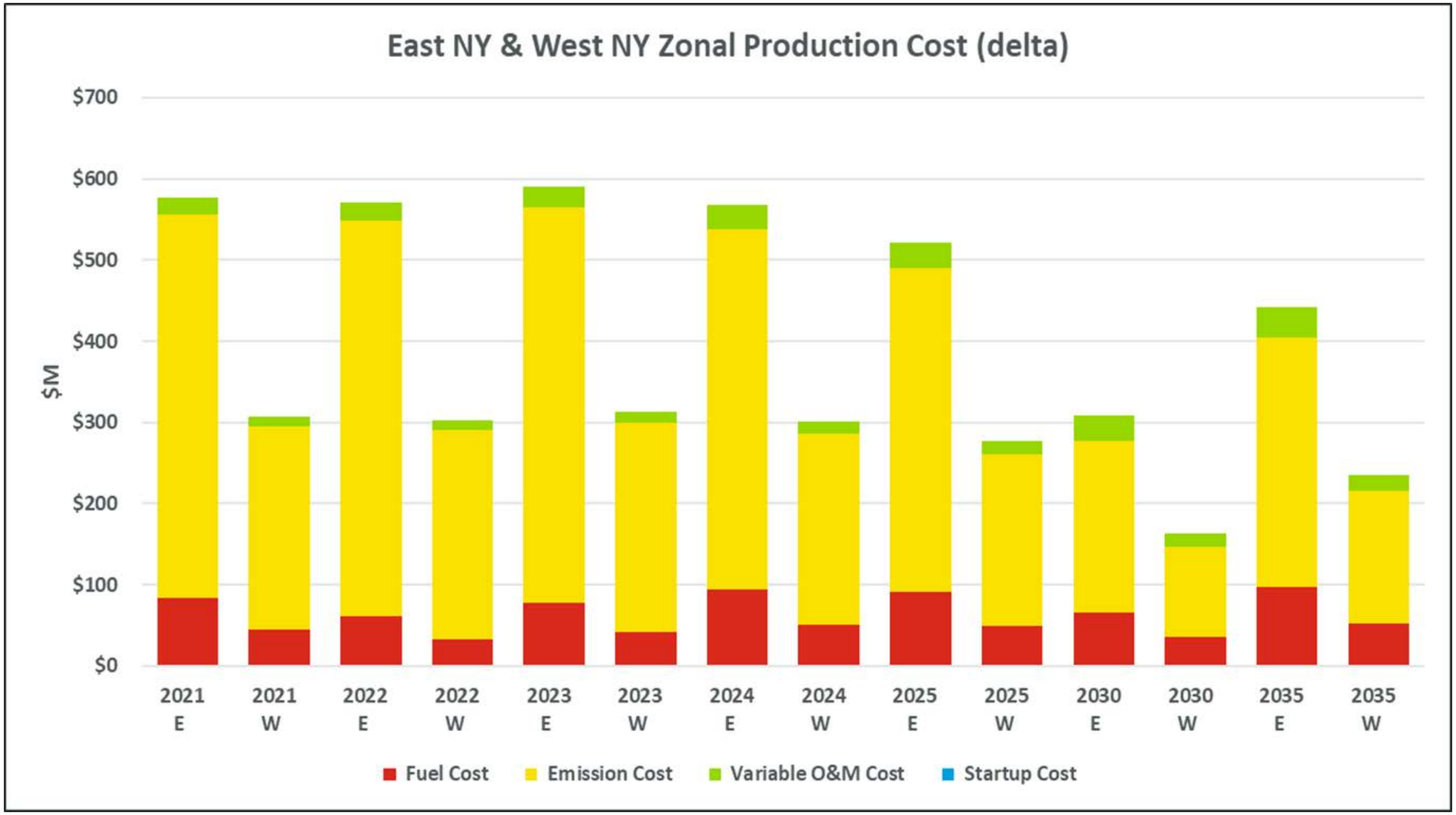
Percent change in NY zonal production costs
(West Zones A-E; East Zones F-K)



Gross production costs not net of carbon charge residuals

Percent change in NY zonal production costs

ZONE	2021	2022	2023	2024	2025	2030	2035
A	4%	4%	4%	4%	4%	3%	3%
B	3%	3%	3%	2%	2%	2%	2%
C	4%	4%	4%	4%	4%	3%	3%
D	2%	2%	2%	1%	1%	1%	1%
E	2%	2%	2%	2%	2%	1%	1%
F	3%	3%	3%	3%	3%	2%	2%
G	3%	2%	2%	2%	2%	2%	2%
H	1%	1%	1%	1%	1%	0%	1%
I	2%	2%	2%	1%	1%	1%	1%
J	14%	13%	13%	13%	12%	9%	9%
K	6%	5%	5%	5%	5%	3%	3%

Gross production costs not net of carbon charge residuals

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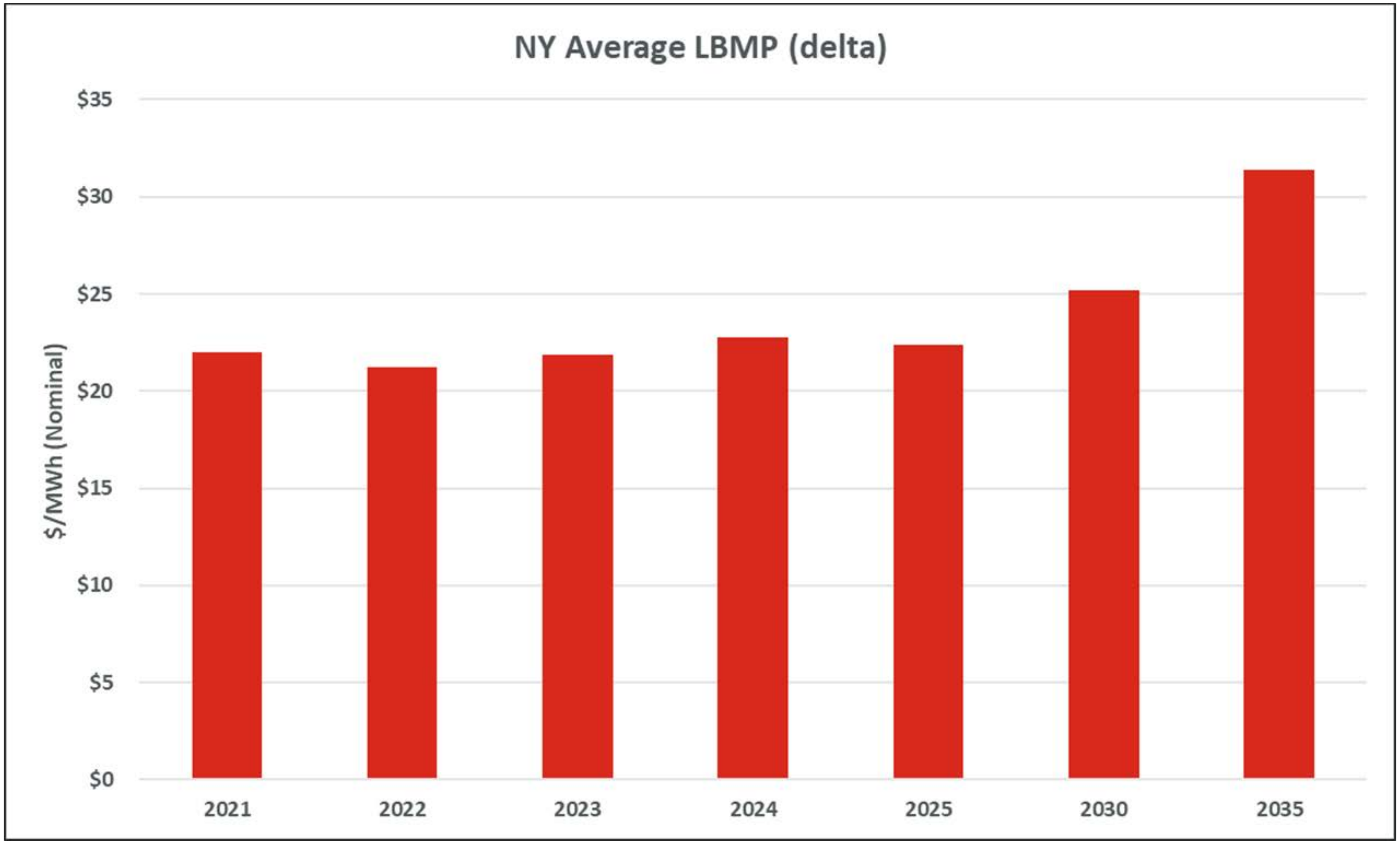
Change in NY average LBMPs

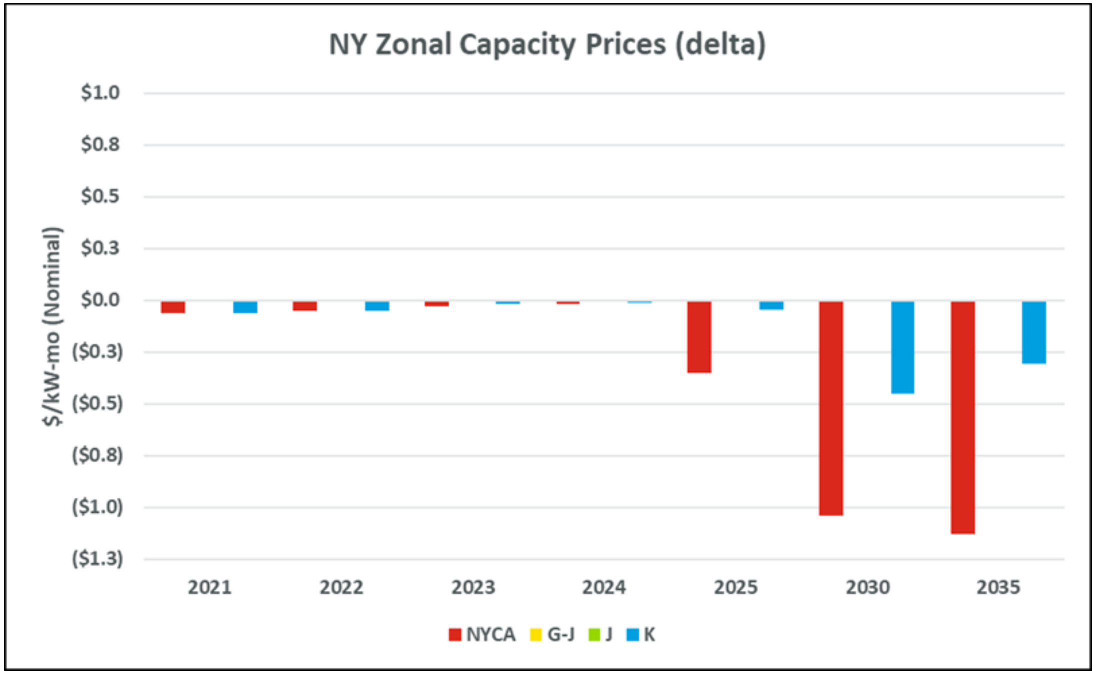


Percent change in NY zonal average LBMPs

Changes in average LBMPs in Eastern Zones (F-K) are about $7 greater than in Western Zones (A-E) over the study period

ZONE	2021	2022	2023	2024	2025	2030	2035
A	106%	99%	107%	94%	93%	87%	95%
B	70%	68%	70%	67%	66%	65%	71%
C	69%	67%	69%	66%	65%	63%	68%
D	69%	67%	70%	67%	66%	63%	68%
E	69%	67%	69%	66%	65%	63%	68%
F	70%	71%	70%	72%	73%	65%	61%
G	67%	68%	67%	70%	69%	60%	54%
H	67%	68%	67%	70%	69%	60%	54%
I	67%	68%	67%	70%	69%	60%	54%
J	67%	68%	67%	70%	69%	60%	54%
K	64%	65%	64%	68%	66%	59%	54%

Change in zonal capacity prices



- The change in zonal capacity prices for all four localities remain about $0 until 2030
- The NYCA price falls by about $1/kW-month in 2030 and 2035

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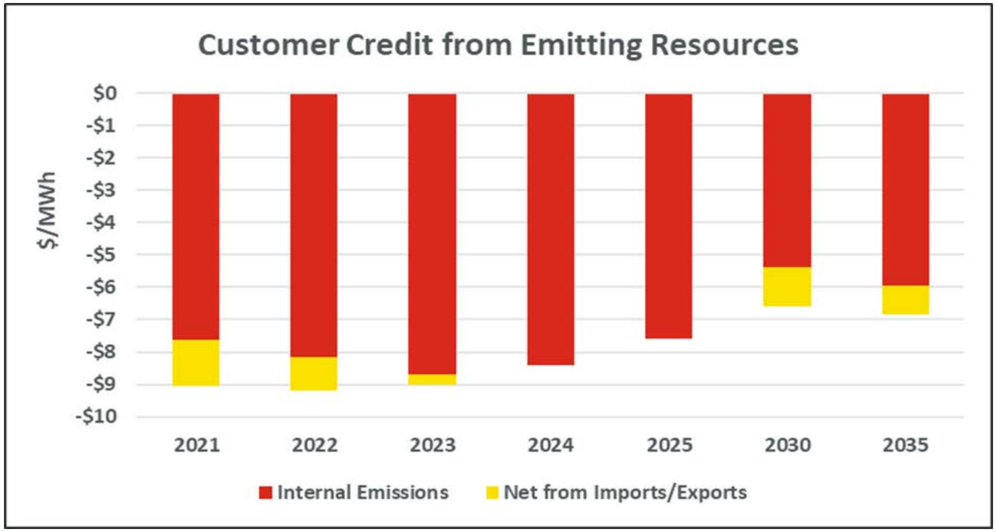
Customer Credits from Emitting Resources



	Units	2021	2022	2023	2024	2025	2030	2035
NYCA internal carbon charges	$M	$1,181	$1,234	$1,289	$1,291	$1,242	$781	$896
Carbon charges on net import ties	$M	$218	$156	$49	-$62	-$156	$177	$134
Load	TWh	155	151	149	146	143	145	151
Internal Emissions	$/MWh	-$8	-$8	-$9	-$8	-$8	-$5	-$6
Net from Imports/Exports	$/MWh	-$1	-$1	$0	$0	$1	-$1	-$1

Percent change in new resource gross margin ($/kW-year)*

TECH	ZONE	2021	2022	2023	2024	2025	2030	2035
CC	C	$14	$11	$8	$11	$10	$11	$10
CC	J	$42	$48	$44	$48	$30	$17	$23
CT	J	$13	$10	$9	$7	$6	$15	$19
SOLAR	C	$0	$28	$30	$31	$29	$22	$22
WIND	D	$59	$51	$53	$55	$52	$57	$60
OSW	J	$0	$0	$0	$0	$97	$124	$175
BATTERY	J	$0	$0	$0	$0	$3	$11	$14

*Gross Profit Margin = Revenues minus Fuel Cost

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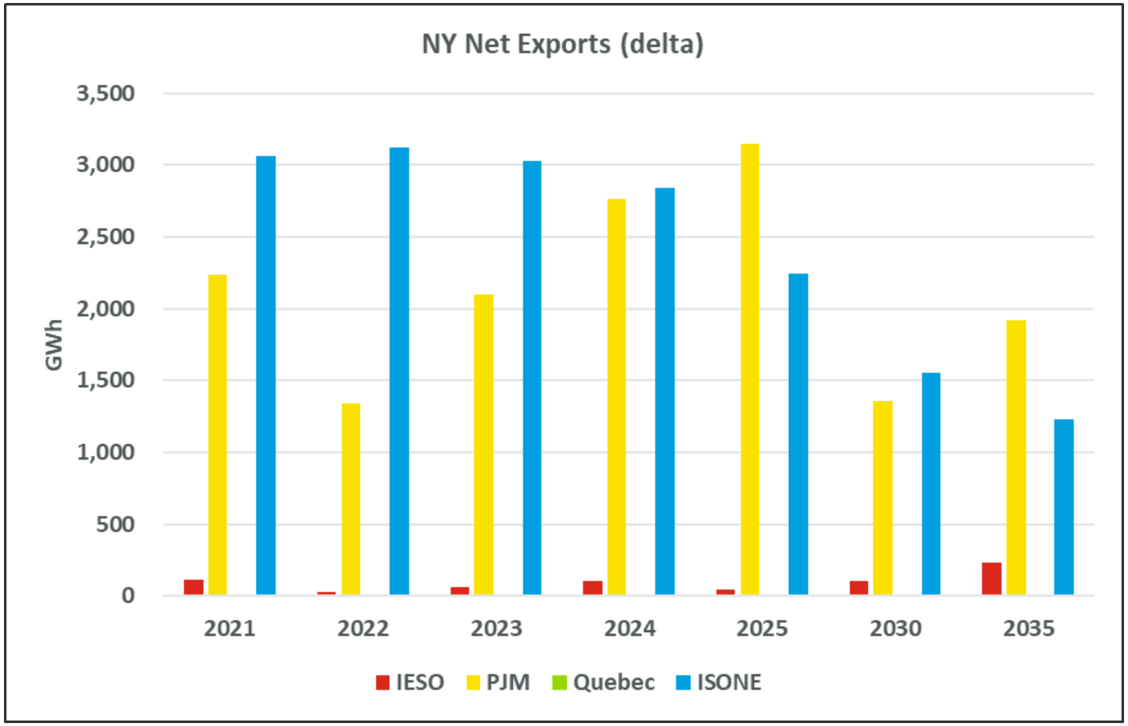
Change in net exports



- Status Quo case benchmarked to recent history
- With Carbon Charge, NY exports more to ISO-NE and imports less from IESO and PJM

Change in quantity and location of market-based entry

- Due to low capacity prices and large amount of renewables added to the system, market prices remain too low to support market-based entry during the study period.

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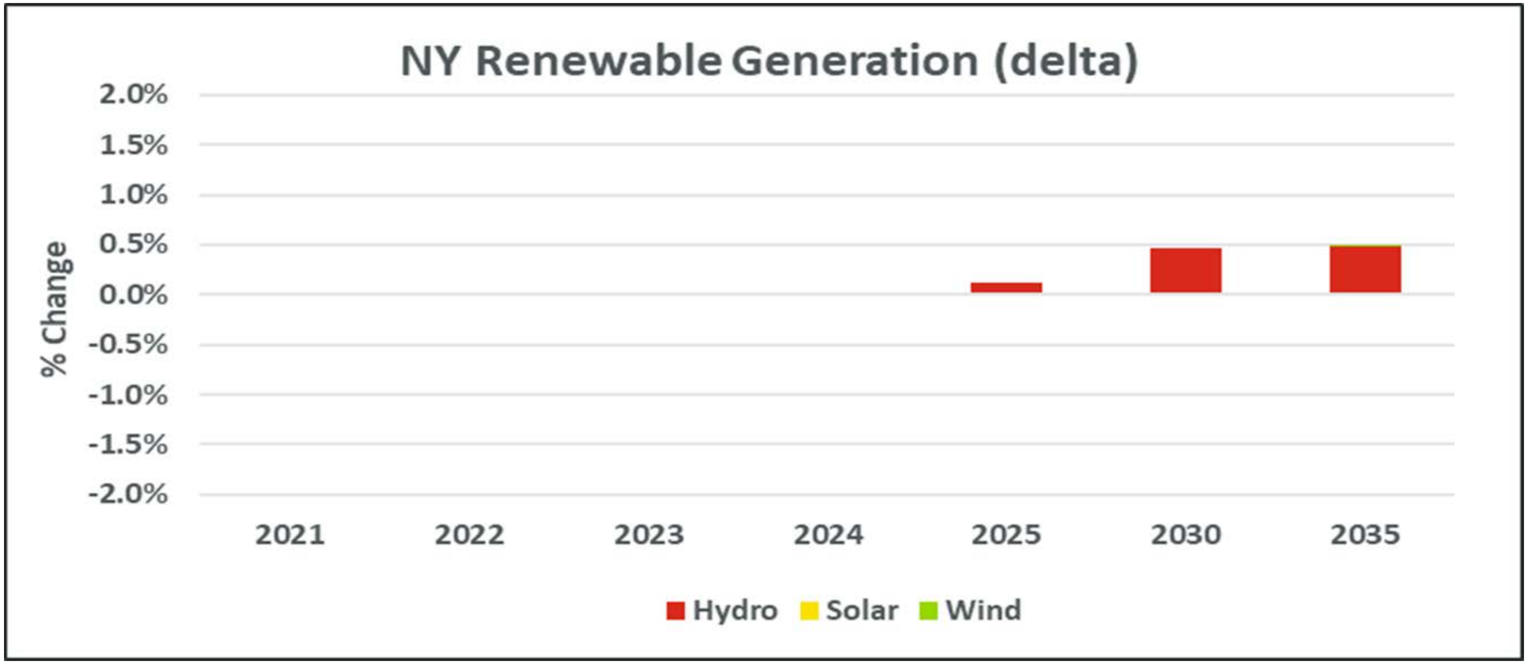
Change in NY production from renewable resources

- No change in solar generation
- Small change in hydro generation
- Negligible change in wind generation



Percent change in NY renewable generation

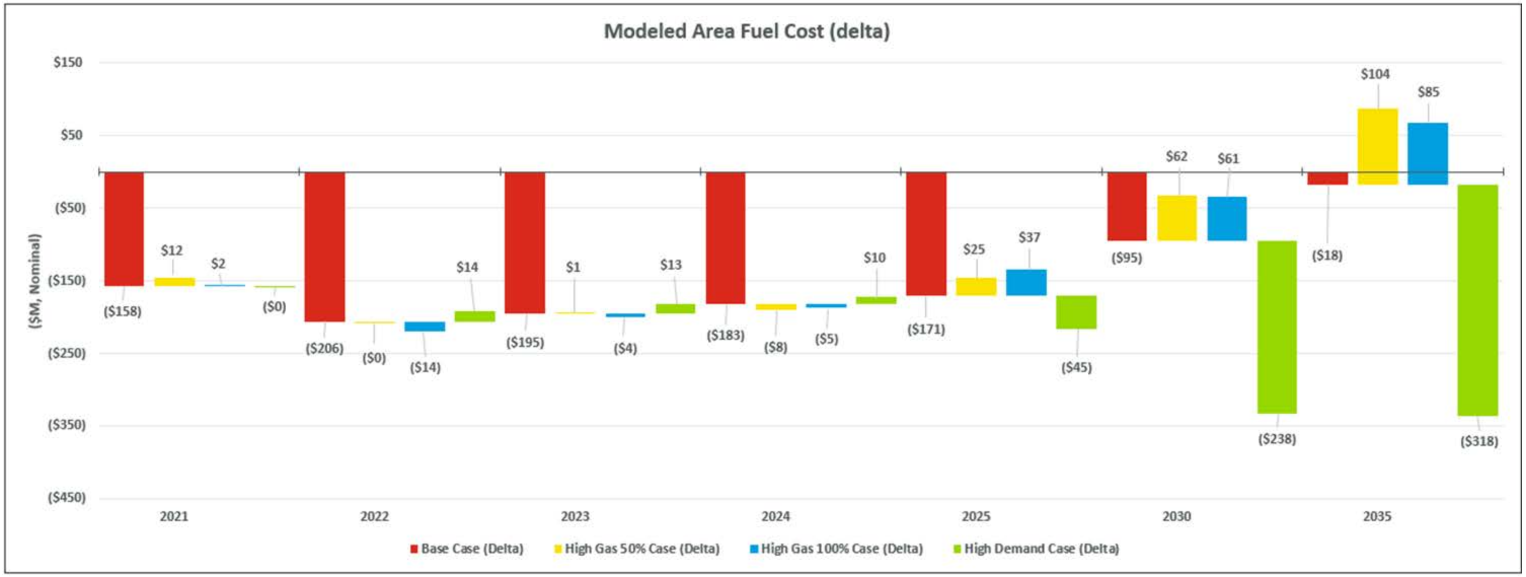
Resource	2021	2022	2023	2024	2025	2030	2035
Hydro	0.00%	-0.02%	0.02%	0.01%	0.12%	0.47%	0.48%
Solar	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Wind	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Total	0.00%	-0.02%	0.02%	0.01%	0.12%	0.47%	0.48%

Sensitivities

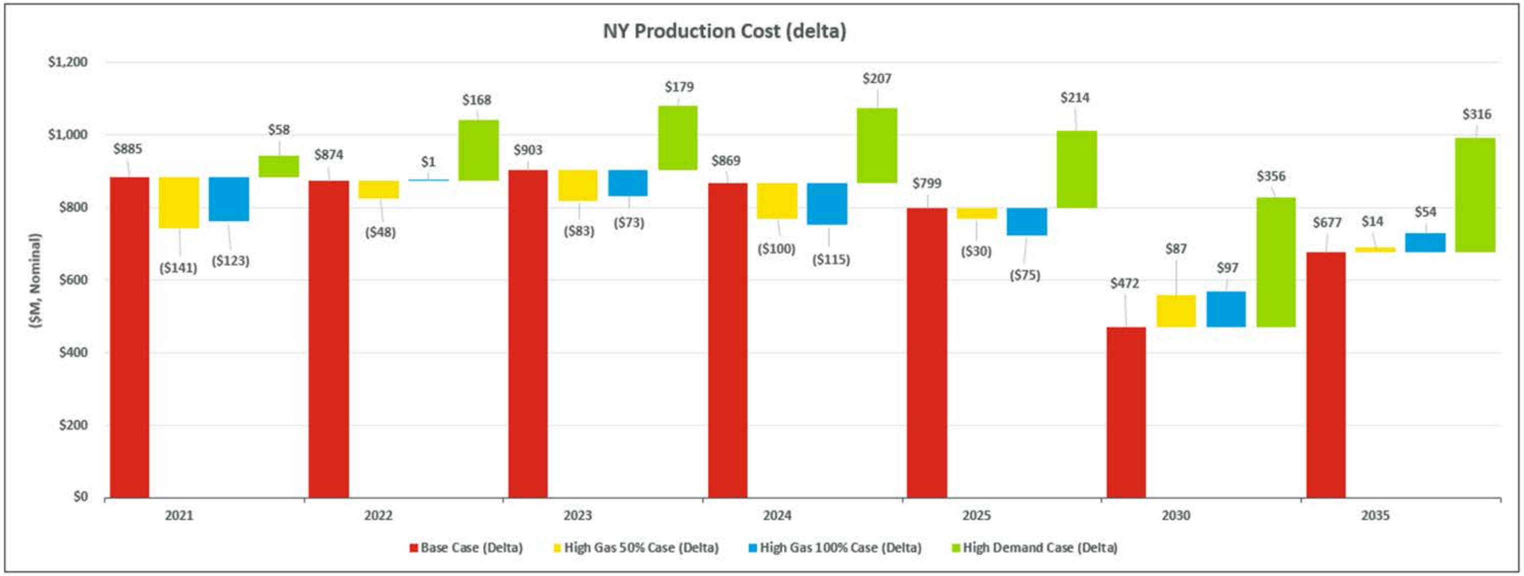
We assess the sensitivity of the carbon charge proposal to changes in three variables

- Natural gas prices
  - Increase Henry Hub prices 50%
  - Increase Henry Hub prices 100%
- High demand
- Border charges
  - Charges based on status quo marginal emissions rates
  - Adjusted border charges to smooth as calculated period-over-period volatility

Change in modeled area fuel costs



Change in NY state production costs



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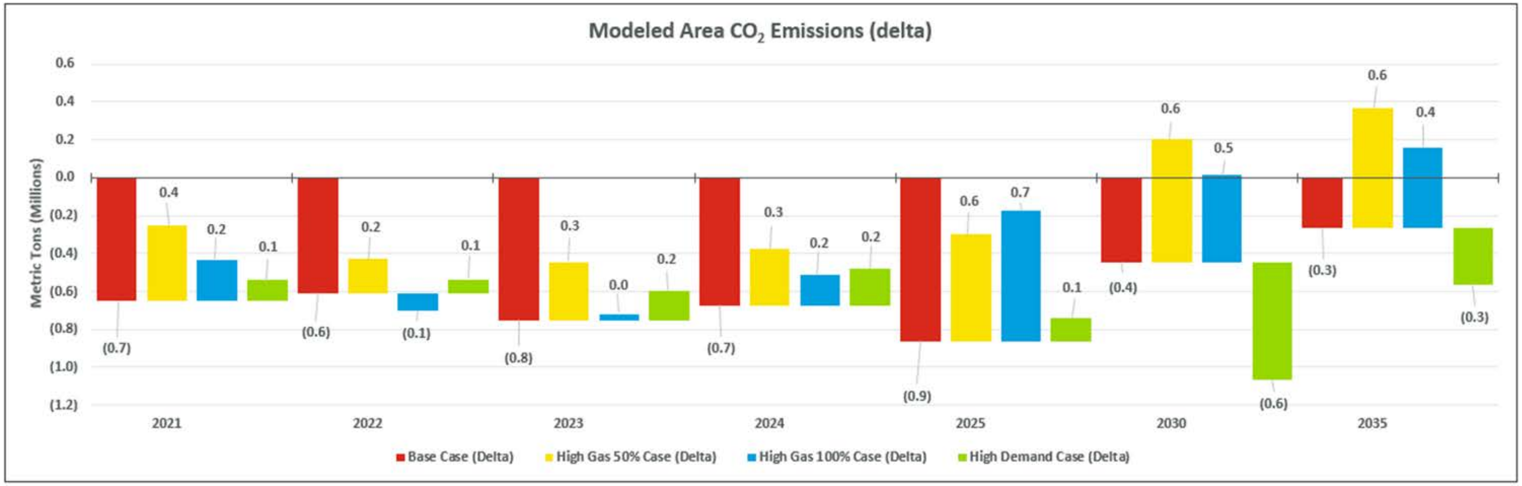
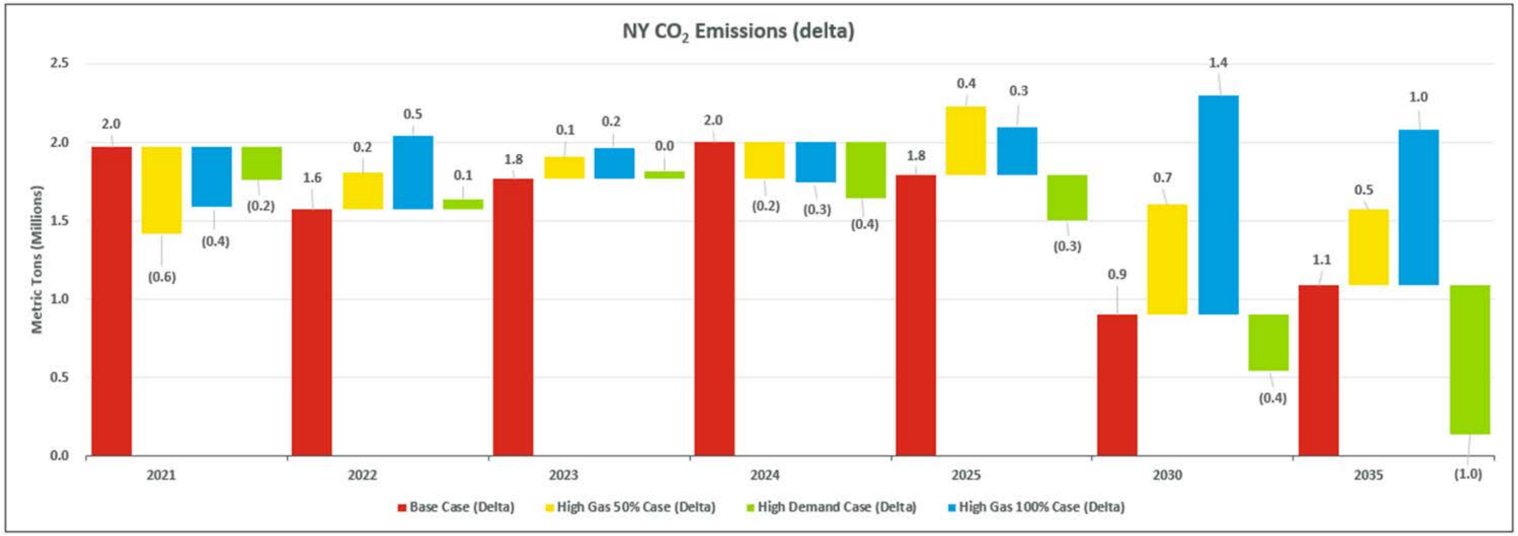
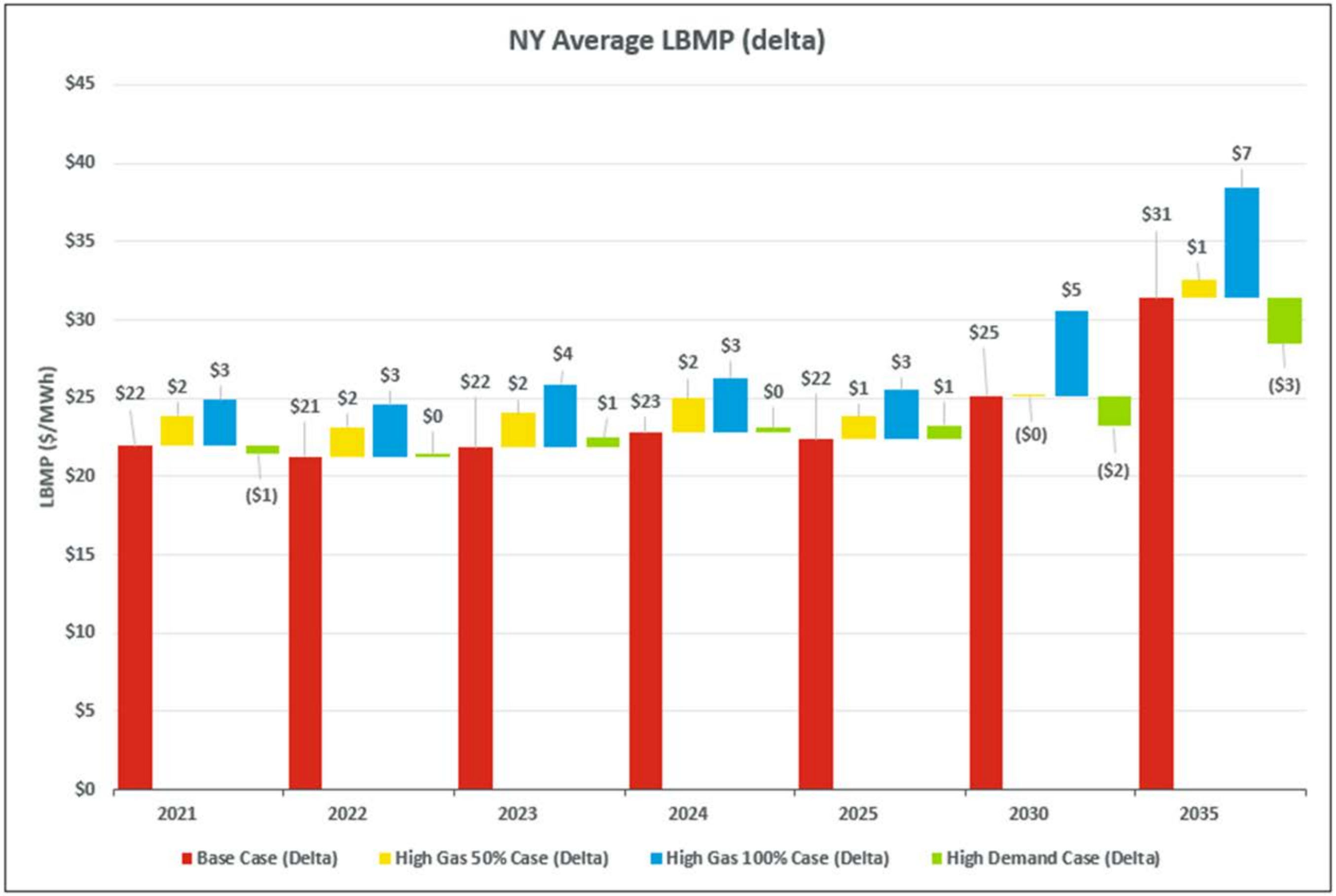
Change in Modeled Area CO_2 emissions



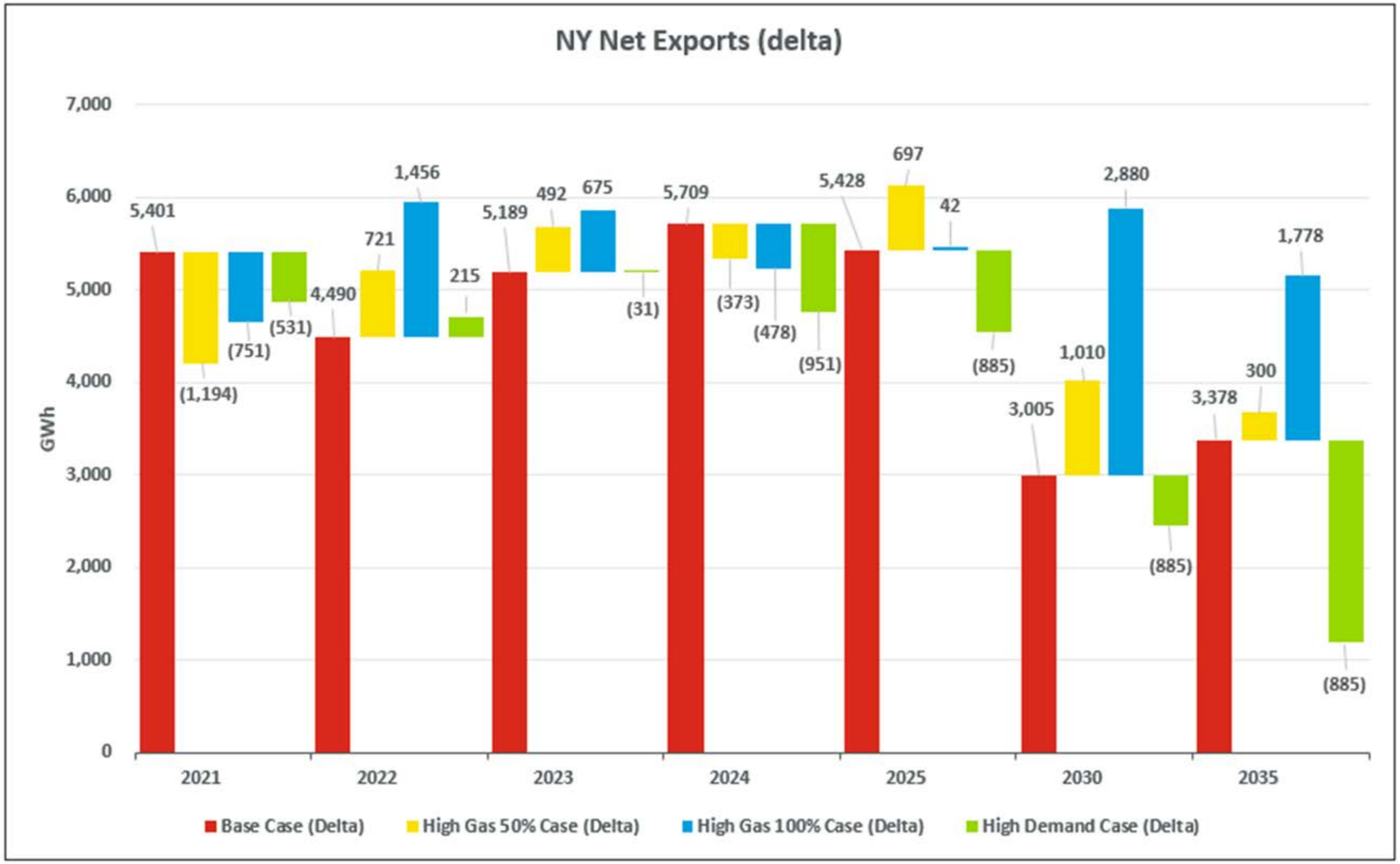
Change in NY state CO_2 emissions



Change in NY state average LBMPs



Change in NY state net exports



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Comparison of Sensitivities to Base Case

Comparison of Modeling Runs	2021	2022	2023	2024	2025	2030	2035
Residuals ($/MWh)							
Status Quo vs Carbon Charge Case	($9)	($9)	($9)	($8)	($8)	($7)	($7)
High Gas Status Quo vs High Gas Carbon Case (50% HH)	($9)	($9)	($9)	($8)	($7)	($6)	($6)
High Gas Status Quo vs High Gas Carbon Case (100% HH)	($9)	($9)	($9)	($9)	($8)	($6)	($6)
High Demand Status Quo vs High Demand Carbon Case	($10)	($10)	($11)	($11)	($10)	($9)	($10)
Change in NY Production Cost ($M, nominal)							
Status Quo vs Carbon Charge Case	$885	$874	$903	$869	$799	$472	$677
High Gas Status Quo vs High Gas Carbon Case (50% HH)	$744	$825	$820	$769	$769	$559	$690
High Gas Status Quo vs High Gas Carbon Case (100% HH)	$762	$875	$831	$754	$724	$569	$731
High Demand Status Quo vs High Demand Carbon Case	$943	$1,042	$1,082	$1,076	$1,013	$828	$993
Change in Modeled Area Fuel Cost ($M, nominal)							
Status Quo vs Carbon Charge Case	($158)	($206)	($195)	($183)	($171)	($95)	($18)
High Gas Status Quo vs High Gas Carbon Case (50% HH)	($146)	($206)	($194)	($191)	($146)	($33)	$87
High Gas Status Quo vs High Gas Carbon Case (100% HH)	($156)	($220)	($199)	($187)	($134)	($34)	$68
High Demand Status Quo vs High Demand Carbon Case	($158)	($192)	($182)	($172)	($216)	($333)	($335)
Change in New York CO_2 Emissions (M metric tons)							
Status Quo vs Carbon Charge Case	2	2	2	2	2	1	1
High Gas Status Quo vs High Gas Carbon Case (50% HH)	1	2	2	2	2	2	2
High Gas Status Quo vs High Gas Carbon Case (100% HH)	2	2	2	2	2	2	2
High Demand Status Quo vs High Demand Carbon Case	2	2	2	2	2	1	0
Change in Modeled Area CO_2 Emissions (M metric tons)							
Status Quo vs Carbon Charge Case	(1)	(1)	(1)	(1)	(1)	(0)	(0)
High Gas Status Quo vs High Gas Carbon Case (50% HH)	(0)	(0)	(0)	(0)	(0)	0	0
High Gas Status Quo vs High Gas Carbon Case (100% HH)	(0)	(1)	(1)	(1)	(0)	0	0
High Demand Status Quo vs High Demand Carbon Case	(1)	(1)	(1)	(0)	(1)	(1)	(1)
Change in Statewide Average LBMP ($/MWh)							
Status Quo vs Carbon Charge Case	$22	$21	$22	$23	$22	$25	$31
High Gas Status Quo vs High Gas Carbon Case (50% HH)	$24	$23	$25	$25	$24	$25	$33
High Gas Status Quo vs High Gas Carbon Case (100% HH)	$25	$25	$26	$26	$26	$31	$38
High Demand Status Quo vs High Demand Carbon Case	$21	$21	$22	$23	$23	$23	$28
Change in Net Exports (GWh)							
Status Quo vs Carbon Charge Case	5,401	4,490	5,189	5,709	5,428	3,005	3,378
High Gas Status Quo vs High Gas Carbon Case (50% HH)	4,208	5,211	5,681	5,337	6,125	4,015	3,678
High Gas Status Quo vs High Gas Carbon Case (100% HH)	4,650	5,945	5,864	5,232	5,470	5,885	5,157
High Demand Status Quo vs High Demand Carbon Case	4,870	4,705	5,158	4,758	4,542	2,458	1,191

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Comparison of Border Charge Sensitivities to Base Case (2030)

- Annual Average MCC
- Monthly Average MCC
- 50% decrease in MCC
- 50% increase in MCC

Comparison of Border Charge Modeling Runs	2030
Residuals ($/MWh)	
Status Quo vs Carbon Charge Case	($7)
Status Quo vs Carbon Charge Case (Annual Average MCC)	($6)
Status Quo vs Carbon Charge Case (Monthly Average MCC)	($6)
Status Quo vs Carbon Charge Case (50% decrease in MCC)	($6)
Status Quo vs Carbon Charge Case (50% increase in MCC)	($6)
Change in NY Production Cost ($M, nominal)	
Status Quo vs Carbon Charge Case	$677
Status Quo vs Carbon Charge Case (Annual Average MCC)	$388
Status Quo vs Carbon Charge Case (Monthly Average MCC)	$417
Status Quo vs Carbon Charge Case (50% decrease in MCC)	$301
Status Quo vs Carbon Charge Case (50% increase in MCC)	$474
Change in Modeled Area Fuel Cost ($M, nominal)	
Status Quo vs Carbon Charge Case	($18)
Status Quo vs Carbon Charge Case (Annual Average MCC)	($117)
Status Quo vs Carbon Charge Case (Monthly Average MCC)	($109)
Status Quo vs Carbon Charge Case (50% decrease in MCC)	($65)
Status Quo vs Carbon Charge Case (50% increase in MCC)	($33)
Change in New York CO_2 Emissions (M metric tons)	
Status Quo vs Carbon Charge Case	1
Status Quo vs Carbon Charge Case (Annual Average MCC)	1
Status Quo vs Carbon Charge Case (Monthly Average MCC)	1
Status Quo vs Carbon Charge Case (50% decrease in MCC)	(2)
Status Quo vs Carbon Charge Case (50% increase in MCC)	3
Change in Modeled Area CO_2 Emissions (M metric tons)	
Status Quo vs Carbon Charge Case	(0)
Status Quo vs Carbon Charge Case (Annual Average MCC)	(0)
Status Quo vs Carbon Charge Case (Monthly Average MCC)	(0)
Status Quo vs Carbon Charge Case (50% decrease in MCC)	1
Status Quo vs Carbon Charge Case (50% increase in MCC)	(1)
Change in Statewide Average LBMP ($/MWh)	
Status Quo vs Carbon Charge Case	$31
Status Quo vs Carbon Charge Case (Annual Average MCC)	$25
Status Quo vs Carbon Charge Case (Monthly Average MCC)	$25
Status Quo vs Carbon Charge Case (50% decrease in MCC)	$16
Status Quo vs Carbon Charge Case (50% increase in MCC)	$36
Change in Net Exports (GWh)	
Status Quo vs Carbon Charge Case	3,378
Status Quo vs Carbon Charge Case (Annual Average MCC)	3,481
Status Quo vs Carbon Charge Case (Monthly Average MCC)	3,462
Status Quo vs Carbon Charge Case (50% decrease in MCC)	(5,705)
Status Quo vs Carbon Charge Case (50% increase in MCC)	8,640

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Summary of Sensitivity Results

Comparison of Modeling Runs	2021	2022	2023	2024	2025	2030	2035
NY Average MCCs (2012 $/MWh) - East (Zones F-K)							
Carbon Charge Case (Approach A)	$20.66	$20.09	$19.93	$21.08	$20.42	$20.10	$22.01
Carbon Charge Case (Approach B)	$20.23	$20.94	$21.28	$21.46	$21.72	$22.00	$23.16
High Gas Carbon Case (50% HH)	$22.41	$22.46	$23.01	$23.50	$22.94	$19.87	$22.36
High Gas Carbon Case (100% HH)	$22.92	$23.59	$24.22	$24.38	$24.19	$25.11	$27.45
High Demand Carbon Case	$19.96	$19.88	$20.30	$20.66	$20.86	$18.30	$19.55
NY Average MCCs (2012 $/MWh) - West (Zones A-E)							
Carbon Charge Case (Approach A)	$16.78	$15.45	$16.09	$15.62	$14.69	$14.07	$15.85
Carbon Charge Case (Approach B)	$20.34	$18.42	$19.48	$19.21	$18.11	$20.26	$21.70
High Gas Carbon Case (50% HH)	$17.64	$16.07	$17.12	$16.54	$15.10	$14.71	$16.95
High Gas Carbon Case (100% HH)	$19.31	$17.88	$18.56	$18.07	$16.88	$19.48	$22.16
High Demand Carbon Case	$16.38	$15.59	$16.44	$15.90	$15.31	$12.86	$13.78
NY Average Marginal Emission Rates (2012 tons/MWh) - East (Zones F-K)							
Carbon Charge Case (Approach A)	0.60	0.57	0.56	0.58	0.55	0.52	0.55
Carbon Charge Case (Approach B)	0.59	0.60	0.59	0.59	0.59	0.57	0.58
High Gas Carbon Case (50% HH)	0.65	0.64	0.64	0.65	0.62	0.51	0.56
High Gas Carbon Case (100% HH)	0.66	0.67	0.68	0.67	0.65	0.65	0.68
High Demand Carbon Case	0.58	0.57	0.57	0.57	0.56	0.47	0.49
NY Average Marginal Emission Rates (2012 tons/MWh) - West (Zones A-E)							
Carbon Charge Case (Approach A)	0.49	0.44	0.45	0.43	0.40	0.36	0.40
Carbon Charge Case (Approach B)	0.59	0.52	0.54	0.53	0.49	0.52	0.54
High Gas Carbon Case (50% HH)	0.51	0.46	0.48	0.45	0.41	0.38	0.42
High Gas Carbon Case (100% HH)	0.56	0.51	0.52	0.50	0.46	0.50	0.55
High Demand Carbon Case	0.47	0.44	0.46	0.44	0.41	0.33	0.34

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BORDER CHARGES

Carbon charge case border prices

NY Average MCCs (2012 $/MWh)

	2021	2022	2023	2024	2025	2030	2035
MCC Approach A							
East	$20.66	$20.09	$19.93	$21.08	$20.42	$20.10	$22.01
West	$16.78	$15.45	$16.09	$15.62	$14.69	$14.07	$15.85
MCC Approach B (Alternative)							
East	$20.23	$20.94	$21.28	$21.46	$21.72	$22.00	$23.16
West	$20.34	$18.42	$19.48	$19.21	$18.11	$20.26	$21.70

- East – average MCC assigned to Eastern NY zones with links to ISONE and Eastern PJM
- West – average MCC assigned to Western NY zones with links to IESO and Western PJM
- MCC mechanism is sensitive; small changes in dispatch can shift marginal unit emission rate and lead to large changes in net exports

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Carbon charge case marginal emissions rates

NY Average Marginal Emission Rates (tons/MWh)

	2021	2022	2023	2024	2025	2030	2035
MCC Approach A							
East	0.60	0.57	0.56	0.58	0.55	0.52	0.55
West	0.49	0.44	0.45	0.43	0.40	0.36	0.40
MCC Approach B (Alternative)							
East	0.59	0.60	0.59	0.59	0.59	0.57	0.58
West	0.59	0.52	0.54	0.53	0.49	0.52	0.54

- East – average marginal emission rates assigned to Eastern NY zones that have links to ISONE and Eastern PJM
- West – average marginal emission rates assigned to Western NY zones that have links to IESO and Western PJM
- Marginal emission rates are based on the marginal unit setting the MCC for each hour

Impact of modeling approach on results

- Both MCC forecast methods result in increased net exports
- Daymark's application of the MCC mechanism does not assume friction-free trades at the borders
- Our method attempt to reflects that hourly MCCs at the border may be greater or lesser than the "true" hourly values in any given hour
- Mismatches between the actual carbon costs of other NY generators and the forecast carbon charges will cause volatility along the NY border

STUDY METHODOLOGY

Models

DaymarkEA CapMarket Model	Simulates NYISO capacity auctions to forecast capacity prices and economic entry and exit
DaymarkEA GasBasis Model	Simulates natural gas basis prices at market trading locations based on supply and demand and delivery constraints
EPIS AURORA Zonal Model	Zonal level (bubble and pipe representation) production cost model run hourly to simulate economic dispatch of power plants within a competitive framework
EPIS AURORA Nodal Model	Nodal level production cost model that includes the full system topology down to individual level nodes and transmission lines run hourly to simulate security constrained economic dispatch of power plants within a competitive framework

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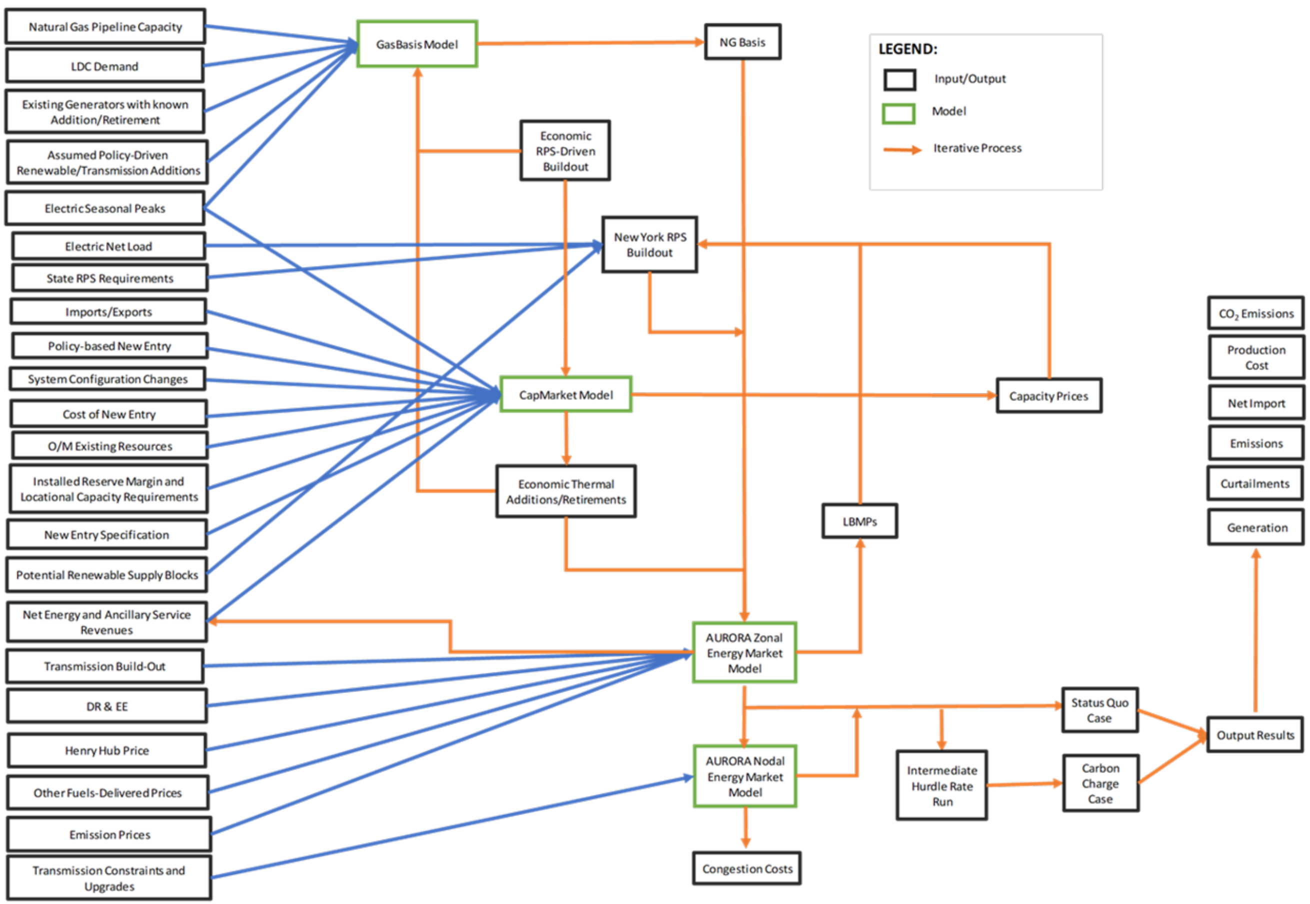
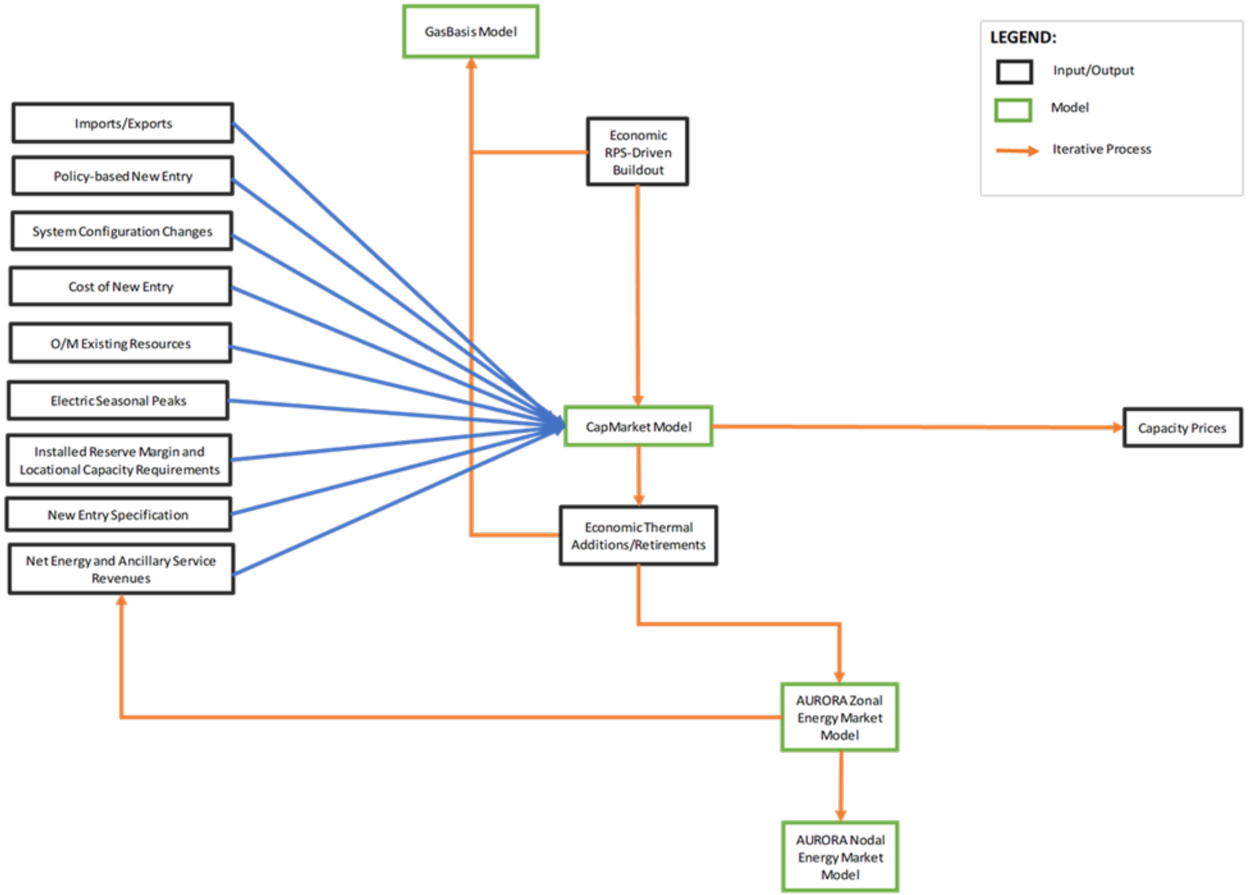
Carbon charge analysis schematic



CapMarket Model schematic



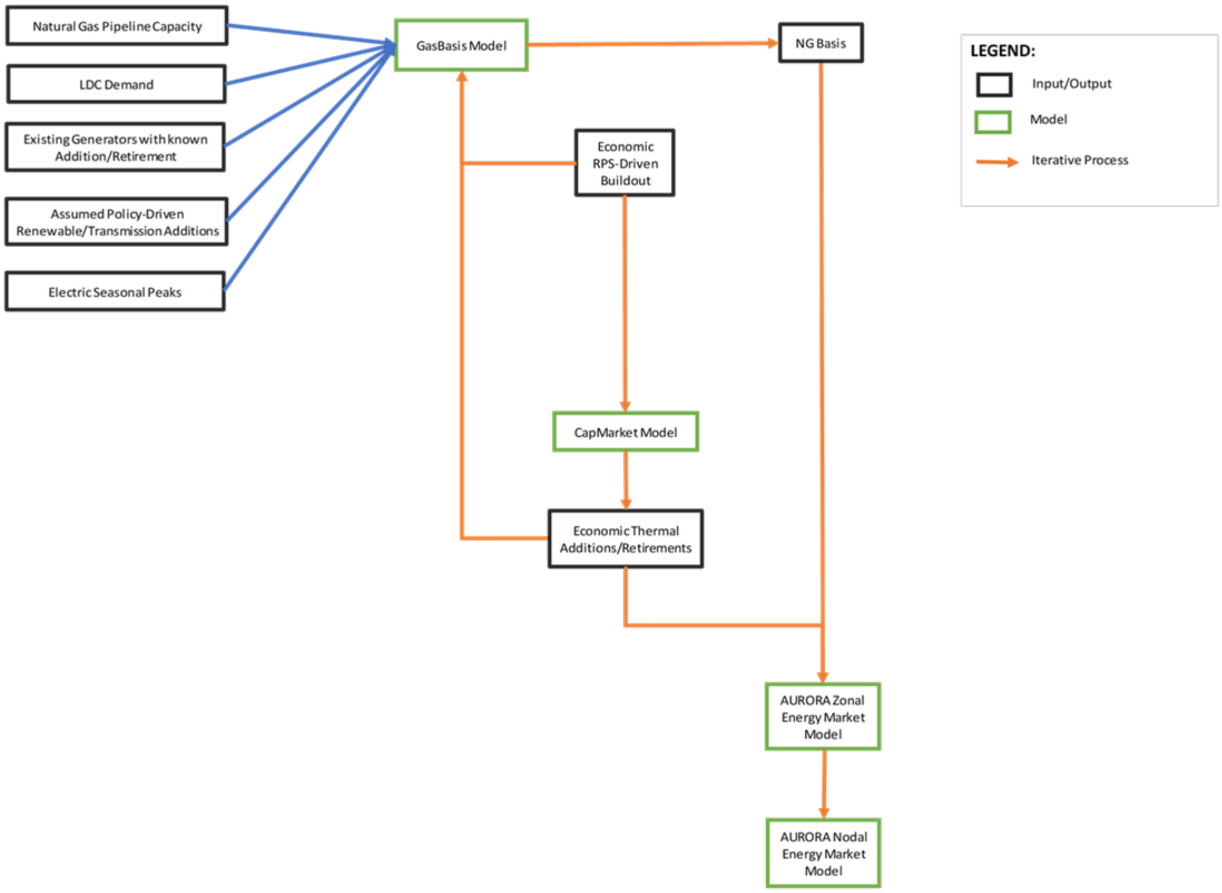
Create demand and supply curves

- Update Demand Curve characteristics (IRM, LCR, CONE and Reference Points)
  - NYCA IRM assumed to be around 18% across study period
  - Adjust for net Energy and Ancillary Service revenues
- Create supply curve
  - Estimate going forward costs for new and existing units
  - Incorporate Must Offer Renewables – Federal and State incentives
  - Estimate net imports (Note impact of expected prices in neighboring regions)

Simulate ICAP market and assess incremental changes

- The model outputs zonal capacity prices
- Add/remove resources based on historical behavior
  - Resources do not enter and exit solely based on capacity market spot prices
  - Uneconomic units tend to delay exit
  - New resources tend to enter the market at prices below administrative net CONE
- Iterative process: added and retired resources are inputs for the AURORA Models and resulting power sector gas demand in GasBasis Model

GasBasis Model schematic



Forecast natural gas basis against Henry Hub for NY market trading locations

- Forecast basis prices for pricing locations: Algonquin Citygate, NY Transco Zone 6, TETCO M3, Iroquois Zone 2, and Dominion South
- Input natural gas pipeline capacity, LDC demand, electric demand, imports and renewable additions, historical natural gas basis
- Calculate available natural gas pipeline capacity based on forecasted natural gas supply and demand for relevant trading regions

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Forecast delivered natural gas prices

- Simulate future basis prices
- Power sector gas demand is linked to AURORA-modeled gas-fired generation and is adjusted by iteration
- Add basis prices to Henry Hub prices
- Zonal gas prices for generation in NY assume the gas trading point weights from the most recent CARIS study

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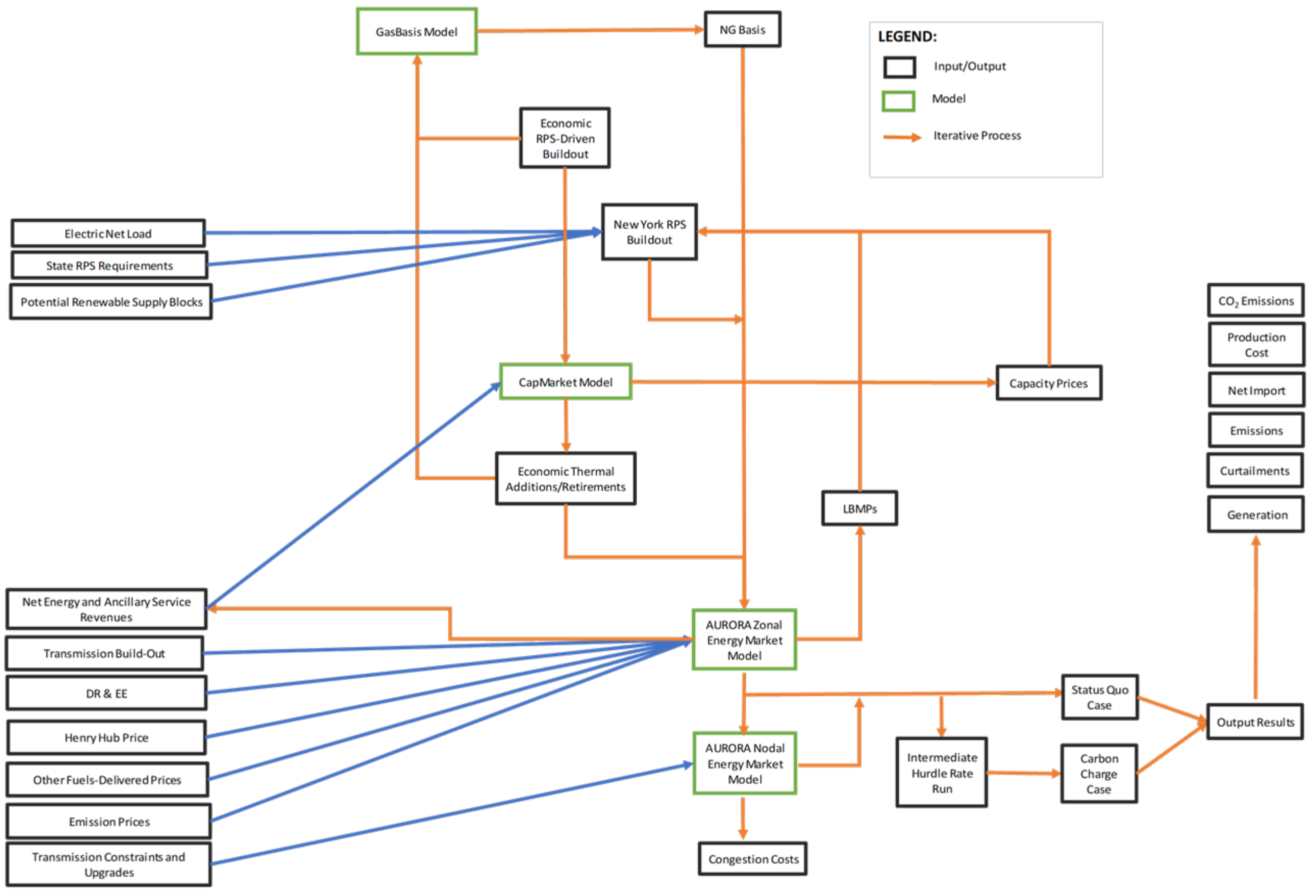
AURORA Zonal and Nodal Model schematic



Build New York energy market at the zonal level

- Inputs: demand, transmission, renewables, fuel prices, new and existing resources
- Model topology: NY and neighboring control areas consistent with 2018 IRM Study
  - NY is divided into 11 zones (A-K)
  - NY interfaces to PJM, ISONE, Ontario, and HydroQuebec
  - Nested interface constraints
- Outputs: hourly production data and clearing prices for each zone

Simulate New York energy market at the zonal level

- Iterative process:
  - Net Energy and Ancillary Service revenues are output to CapMarket Model
  - AURORA Zonal Model receives economic-based resource entry and exit from the CapMarket Model
  - Power sector gas demand is input to the GasBasis Model
  - Natural gas prices input to AURORA Zonal Model
- Run models and produce outputs for the Status Quo case

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Marginal Carbon Charge (MCC) border adjustment

- NYISO proposes to post a forecast of carbon charges to be applied to DA and RT transactions
- Dynamic modeling of this proposal is infeasible
- We estimate a schedule of border charges, rather than fixing net imports
- Approach approximates impact of charges on external transactions
- Border adjustment charges are estimated in two stages

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Stage 1

- All carbon emitting resources are charged the Gross Social Cost of Carbon (SCC) on CO_2 emissions
- Model is run to simulate commitment and dispatch with “universal” carbon charge
- NYISO Upstate (Zones A-F) and Downstate (Zones G-K) proxy marginal units are identified for each hourly interval
- The emission rate for the proxy unit times the net SCC (Gross SCC minus RGGI price) is recorded as the marginal cost of carbon (MCC) for each hourly period

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Stage 2

- Hourly schedule of MCCs ($/MWh) from Stage 1 is input border adjustments between NYISO and external zones
  - Positive adjustments for flows into NYISO zones
  - Negative adjustments for flows out of NYISO zones
- Carbon charges are removed for external resources (only RGGI as applicable remains)
- NYISO resources are charged gross SCC on CO_2 emissions
- Model run to simulate commitment and dispatch for Approach A

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Alternative MCC border adjustment

- To evaluate the sensitivity of the results to MCC modeling approach, an alternative MCC border adjustment approach (Approach B) is evaluated
- Stage 1: Emissions rates of proxy marginal units are identified for each hourly interval from the Status Quo case and then multiplied by the SCC to establish the schedule of border charges fed to the next stage
- Stage 2: The model is rerun assuming the carbon charges are in place in in NYISO with the stage 1 border charges

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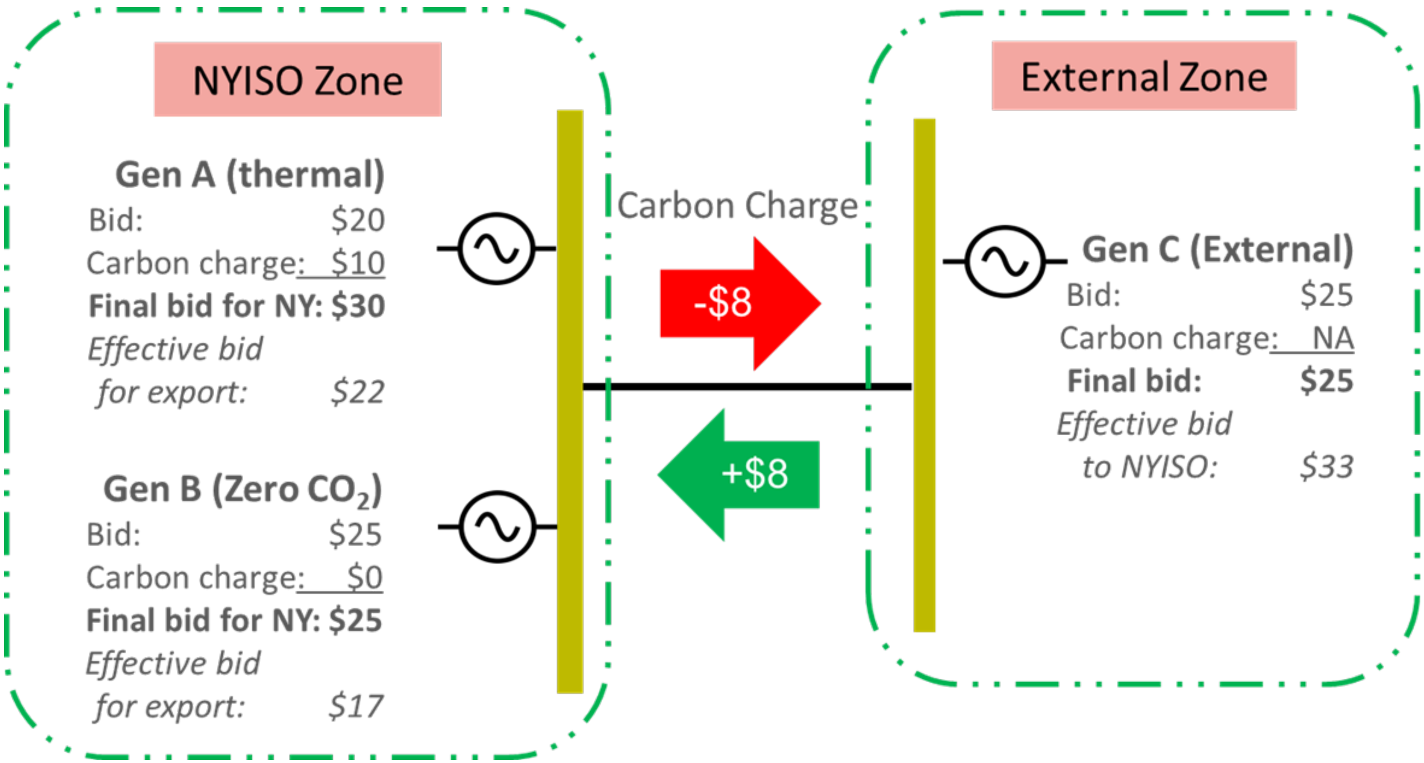
Example of carbon charge modeling

- For interval, Marginal Cost of Carbon (MCC) in Stage 1 was $8/MWh. This becomes the Border Adjustment on interfaces connecting the NYISO zone to the external zone in that interval
- Imports into NY *add* Border Adjustment to offers
- Exports from NY *subtract* Border Adjustment from offers



Nodal modeling

Simulate New York energy market at the bus level and assess incremental changes

- Evaluate changes in congestion, technical curtailments, and LBMPs due to changes in power flow with a carbon charge
- All inputs and iterative modeling used with the AURORA Zonal Model plus complete transmission topology
- Requires mapping injection and withdrawal points to pricing nodes
- Run a security constrained economic commitment and dispatch
- We examine 2030 at the nodal level

INPUT ASSUMPTIONS

Common assumptions

- Demand Net of BTM/EE (Peak and Base) (2018 Gold Book/NYISO EE Assumptions by 2025)
- Internal/External Transmission (2018 Gold Book)
- Existing Capacity and Specific New Units (2018 Gold Book)
- Renewable Buildout (CARIS Shift Case adjusted to include new off-shore wind and EE targets)
- Fixed O&M for existing resources (SNL Financial)
- Capital and operating costs of new technologies (2018 AEO)
- Installed Reserve Margin and Locational Capacity Requirements (NYISO ICAP Manual-Demand Curve Reset)
- Planned Retirements (2018 Gold Book)
- Oil Prices (NYISO Assumptions)
- Henry Hub prices (Futures prices escalated at 2018 AEO growth rate)
- Historical spot natural gas indexes (SNL Financial)
- Pipeline capacity, historical LDC and power sector natural gas demand (SNL Financial)
- Solar Shapes (NREL PV Watts)
- Onshore Wind Shapes (NREL SAM)
- Offshore Wind Shape (NREL SAM)
- Emission Prices – RGGI and SCC (NYISO)

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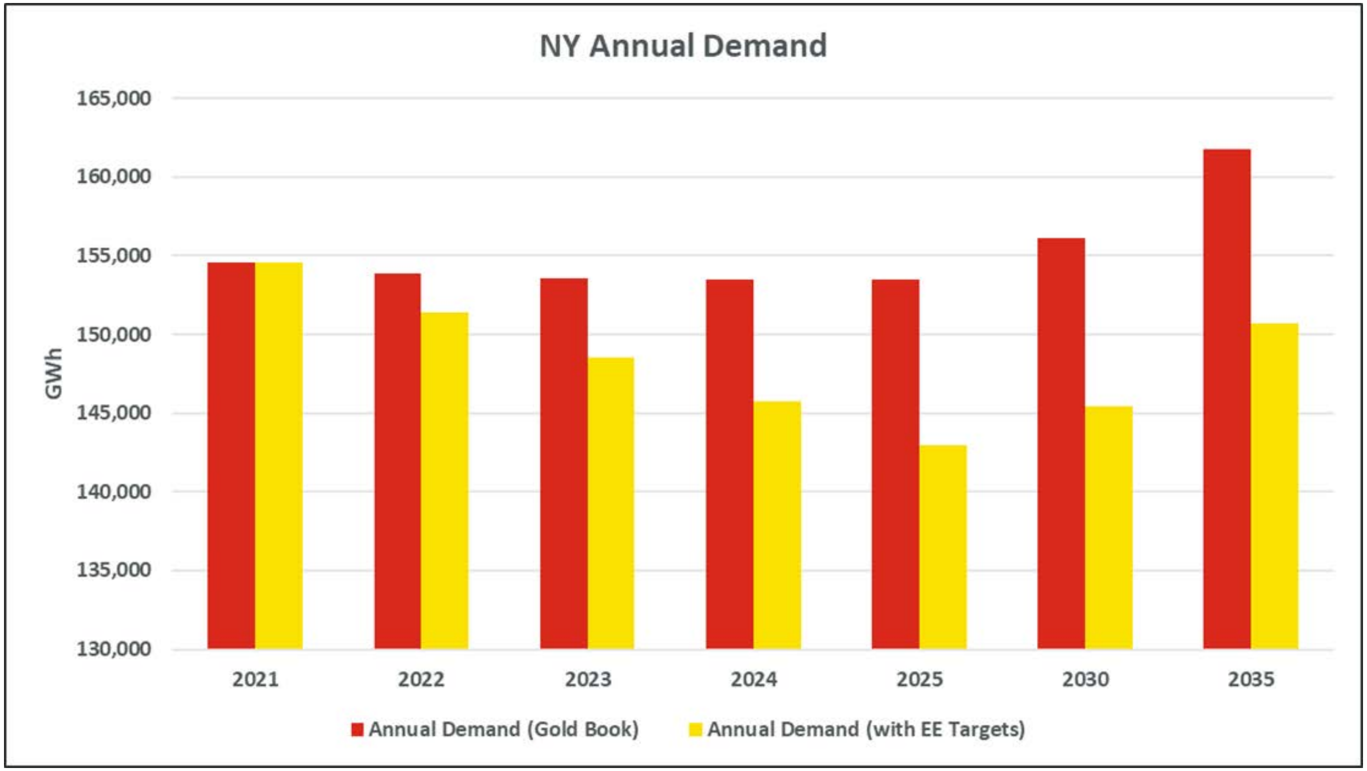
Nodal Model assumptions

- Power Flow Inputs and Topology (FERC 715 Base Case)
- Interface Definitions and Limits (Reliability Needs Assessment Report and NYCA IRM Report)
- Future Transmission Upgrades (Gold Book and System Planning Studies)
- Future Generation and Network Upgrades (Gold Book, Interconnection Queue, and System Planning Studies)
- Transmission buildout only includes firm upgrades (same as NYISO)
- All interface transmission upgrades and renewable additions to meet 50 by 30 goals will be part of this model for both case runs

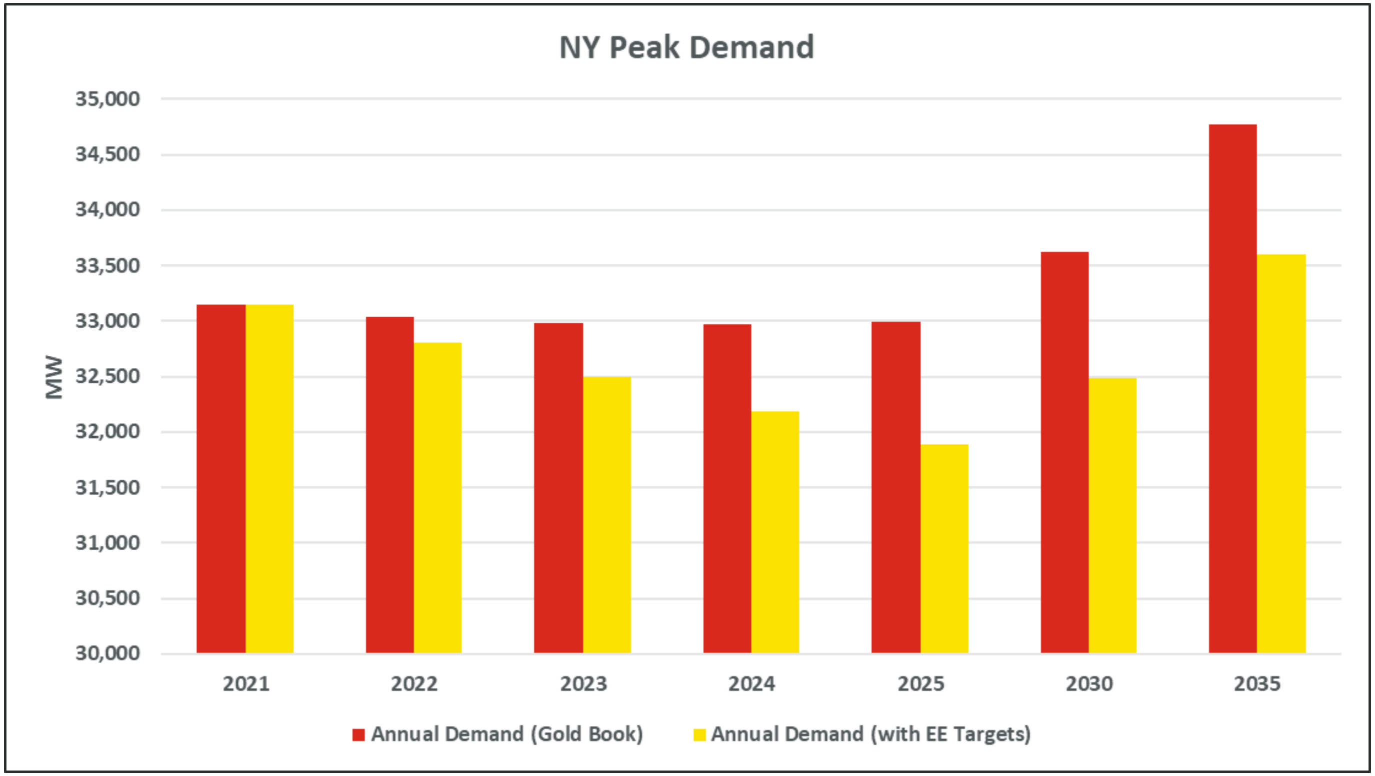
Annual energy load

- Annual energy load from 2018 Gold Book net of EE and BTM
- Quantity of energy efficiency is increased from the baseline load forecast in 2018 Gold Book to reach NY State reduction target of 3% by 2025 (matches NYISO forecast)



Annual peak demand

- Annual peak demand from 2018 Gold Book net of EE and BTM
- Energy efficiency is increased from the baseline forecast in 2018 Gold Book to reach NY State reduction target of 3% by 2025 (Matches NYISO Forecast)



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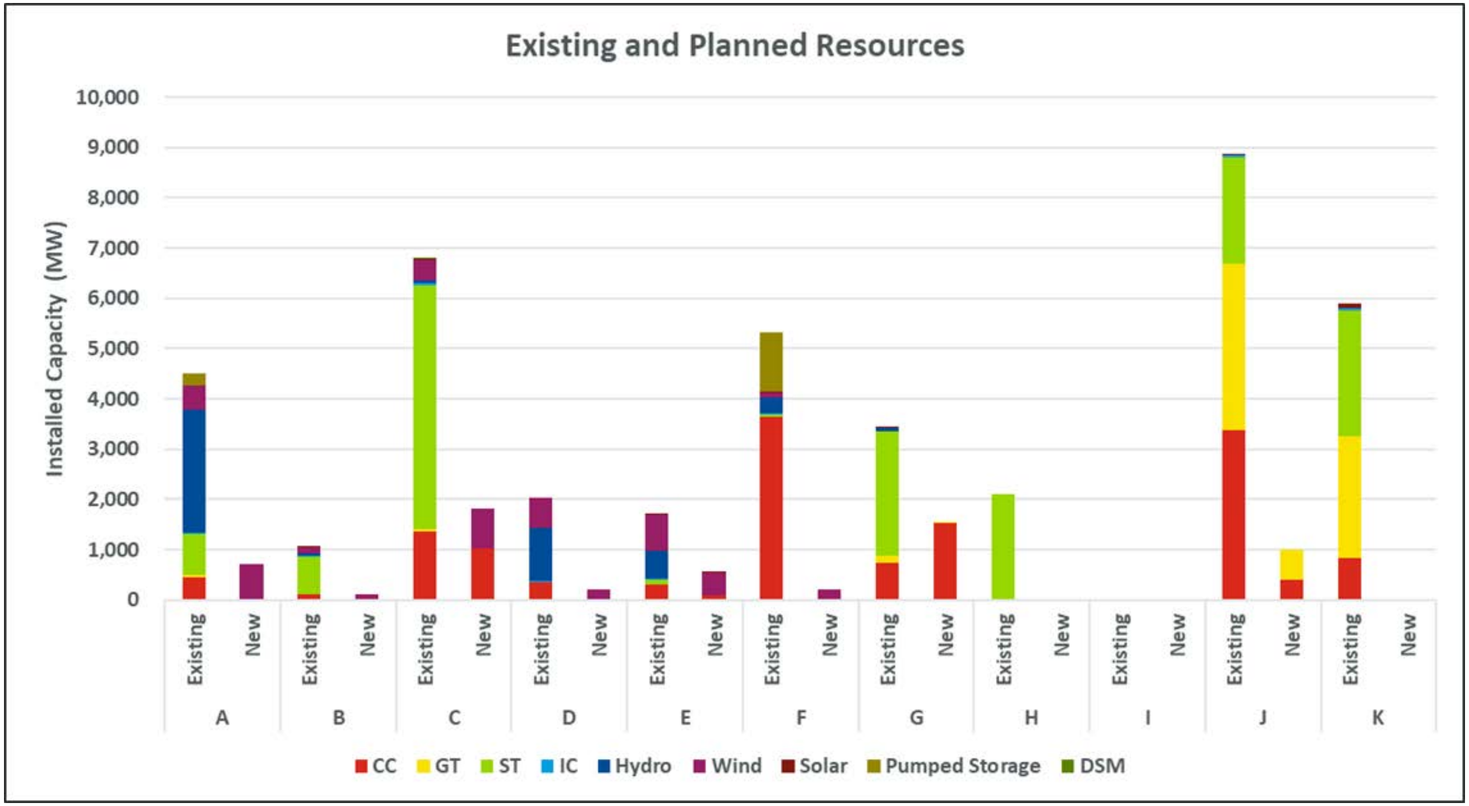
Existing and planned resources

- Per 2018 NYISO Gold Book for capacity MW, type, and location existing and planned resources in NYCA



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Planned retirements

NAME	NAMEPLATE CAPACITY (MW)	ZONE	FUEL	RETIREMENT YEAR
Ravenswood (GT7)	22	J	Natural Gas	2017
Hawkeye Energy Greenport LLC	54	K	Kerosene	2018
Hofstra University (GEN1)	1.1	K	Natural Gas	2019
Hofstra University (GEN2)	1.1	K	Natural Gas	2019
Indian Point 2	1,299	H	Nuclear	2020
Indian Point 3	1,012	H	Nuclear	2021

We assume all coal units retire before start of study period

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Renewable and storage additions

- Three types of renewable resources are added in the model to achieve the 50 by 30 policy:
  - Land-based wind energy resources
  - Offshore wind energy resources
  - Utility-scale solar energy resources
- After 2030, we add renewable resources sufficient to meet approximately 50% of the incremental annual energy load.
- Offshore wind is added in Zone J and Zone K
- Battery energy storage systems each with 4 hours of energy storage capability are added to Zones C, F, and J in 2020 and 2025.

YEAR	BATTERY STORAGE ADDED IN ZONE C (MW)	BATTERY STORAGE ADDED IN ZONE F (MW)	BATTERY STORAGE ADDED IN ZONE J (MW)
2025	125	125	250
2030	250	250	500

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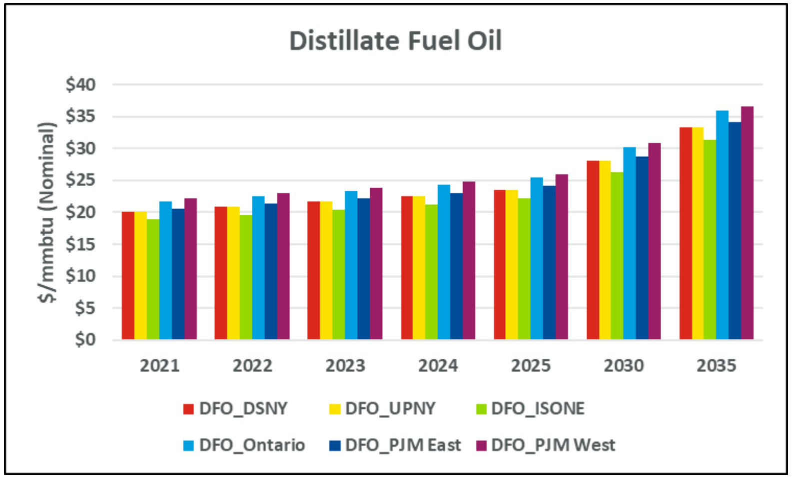
Renewable and storage additions (cont'd)

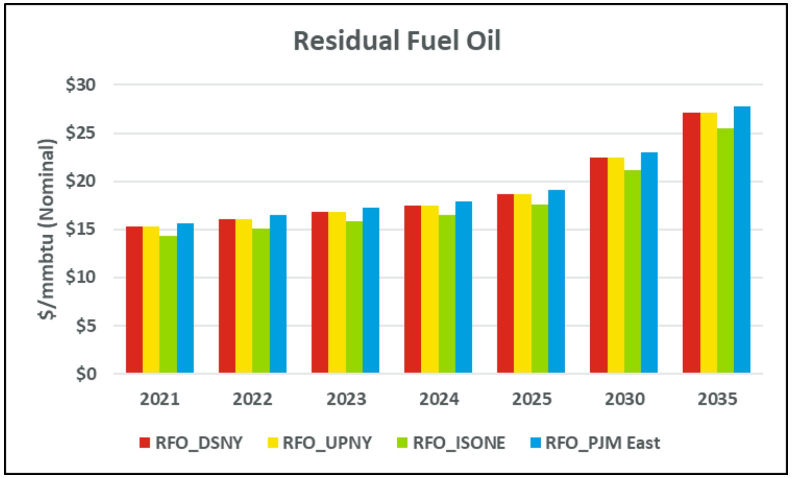
TECHNOLOGY	NAMEPLATE CAPACITY[2] (MW)	ANNUAL CAPACITY FACTOR (%)	COMMENTS
Utility-Scale Solar	11,189	20%	
Land-Based Wind	1,976	35%	Only added in Zones A, C, E, F, G
Offshore Wind	2,400	45%	Only added in Zone J and Zone K
Battery Energy Storage[1]	1500	NA	

YEAR	OFFSHORE WIND ADDED IN ZONE J[2] (MW)	OFFSHORE WIND ADDED IN ZONE K[2] (MW)
2025	500	300
2030	1,100	500

[1] Battery Energy Storage base assumptions being revised to reflect storage roadmap
[2] 2020 – 2035 Renewable Buildout Total Nameplate (MW)

Oil prices





- We use NYISO's assumption through 2030
- After 2030, prices increase at rate equal to 2020 – 2030 CAGR:
  - Distillate Fuel Oil prices increase at 3.5% per year
  - Residual Fuel Oil prices increase at 3.8% per year

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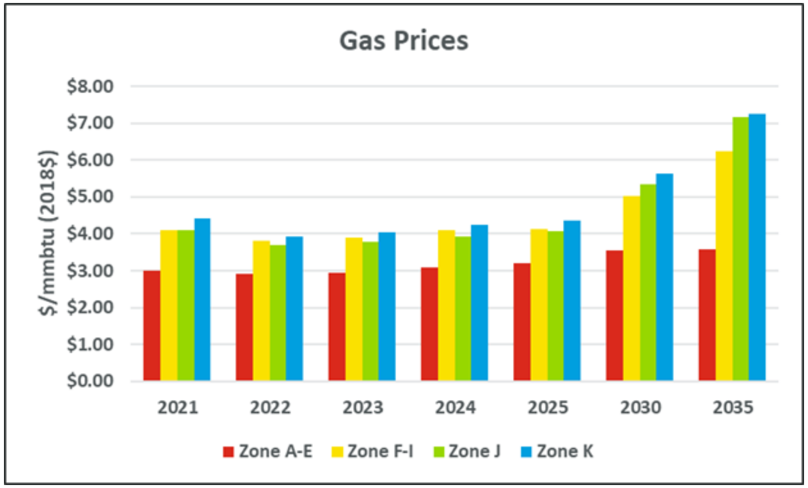
Gas prices



- Modeled gas basis for Transco Zone 6 NY, TETCO M3, Iroquois Zone 2, Dominion South, and Algonquin Citygate
- Added calculated basis to Henry Hub
- Zonal gas prices use weights assumed in CARIS study

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Planned gas pipeline buildout

PROJECT	PIPELINE	MMcf/d
CPV Valley Lateral Project	Millennium Pipeline	127
New Market Project	Dominion Transmission	82
Atlantic Bridge Project	Algonquin Gas Transmission	133
Eastern System Upgrade Project	Millennium Pipeline	223
Lambertville-East Project	Texas Eastern Transmission	180

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Gross and net social cost of carbon in nominal $/US-ton

YEAR	GROSS SCC	RGGI	NET SCC
2020	$47	$6	$42
2021	$48	$6	$42
2022	$50	$7	$44
2023	$53	$7	$46
2024	$55	$8	$47
2025	$57	$8	$49
2026	$60	$9	$51
2027	$63	$10	$53
2028	$65	$10	$55
2029	$67	$11	$55
2030	$69	$12	$57
2031	$72	$13	$59
2032	$75	$14	$61
2033	$78	$15	$63
2034	$81	$16	$65
2035	$84	$18	$66

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APPENDIX

Change in modeled area fuel costs

(nominal $millions)

AREA	2021	2022	2023	2024	2025	2030	2035
NY	$128	$94	$119	$145	$140	$101	$149
ISONE	($62)	($66)	($66)	($63)	($50)	($42)	($41)
PJM	($56)	($59)	($63)	($72)	($77)	($32)	$11
ONT	($3)	($2)	($3)	($4)	($4)	($4)	($6)
HQ	($0)	($0)	($0)	($0)	($0)	($1)	($1)
OTHER	($0)	($0)	$0	$0	($0)	($0)	$0
Total	$7	($34)	($13)	$6	$10	$23	$113

Results for OTHER includes New Brunswick and the Maritimes

Change in New York state production costs
(nominal $millions)

	2021	2022	2023	2024	2025	2030	2035
Fuel Cost	$128	$94	$119	$145	$140	$101	$149
Emission Cost	$722	$745	$746	$679	$610	$322	$471
Variable O&M Cost	$34	$35	$38	$44	$48	$48	$57
Startup Cost	$0	$0	$0	$0	$0	$0	$0
Total Production Cost	$885	$874	$903	$869	$799	$472	$677

Gross production costs not net of carbon charge residuals

Change in NY state production costs
(nominal $millions)

ZONE	2021	2022	2023	2024	2025	2030	2035
A	$86	$85	$87	$84	$77	$46	$65
B	$55	$55	$56	$54	$50	$29	$42
C	$89	$88	$91	$87	$80	$47	$68
D	$34	$34	$35	$34	$31	$18	$26
E	$43	$42	$44	$42	$39	$23	$33
F	$66	$66	$68	$65	$60	$35	$51
G	$54	$53	$55	$53	$49	$29	$41
H	$16	$16	$17	$16	$15	$9	$13
I	$33	$33	$34	$33	$30	$18	$25
J	$293	$289	$299	$288	$264	$156	$224
K	$115	$114	$117	$113	$104	$61	$88
NY Total	$885	$874	$903	$869	$799	$472	$677

Gross production costs not net of carbon charge residuals

Change in NY zonal production costs by component

East NY Zonal Production Costs (zones F-K)

	2021	2022	2023	2024	2025	2030	2035
Fuel Cost	$84	$44	$61	$33	$78	$41	$95
Emission Cost	$472	$251	$487	$259	$487	$259	$444
Variable O&M Cost	$22	$12	$23	$12	$25	$13	$29
Startup Cost	$0	$0	$0	$0	$0	$0	$0
Total Production Cost	$578	$307	$570	$303	$590	$313	$567

West NY Zonal Production Costs (zones A-E)

	2021	2022	2023	2024	2025	2030	2035
Fuel Cost	$44	$61	$33	$78	$41	$95	$50
Emission Cost	$251	$487	$259	$487	$259	$444	$236
Variable O&M Cost	$12	$23	$12	$25	$13	$29	$15
Startup Cost	$0	$0	$0	$0	$0	$0	$0
Total Production Cost	$307	$570	$303	$590	$313	$567	$302

Gross production costs not net of carbon charge residuals

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Percent change in NY zonal renewable generation

ZONE	2021	2022	2023	2024	2025	2030	2035
A	0.0%	0.0%	0.0%	0.0%	0.2%	0.6%	0.6%
B	0.0%	0.0%	0.0%	0.0%	0.0%	0.6%	0.8%
C	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%	0.3%
D	0.0%	0.0%	0.0%	0.0%	0.1%	0.4%	0.3%
E	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.4%
F	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
G	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
H	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
I	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
J	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
K	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Change in Modeled Area CO_2 emissions

(Million Metric Tons)

AREA	2021	2022	2023	2024	2025	2030	2035
NY	2	2	2	2	2	1	1
ISONE	(1)	(1)	(1)	(1)	(1)	(1)	(0)
PJM	(1)	(1)	(1)	(2)	(2)	(1)	(1)
ONT	(0)	(0)	(0)	(0)	(0)	(0)	(0)
HQ	(0)	(0)	(0)	(0)	(0)	(0)	(0)
OTHER	(0)	(0)	0	0	(0)	0	0
Total	(1)	(1)	(1)	(1)	(1)	(0)	(0)

Results for OTHER includes New Brunswick and the Maritimes

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Total NY CO_2 emissions
(Million Metric Tons)

	2021	2022	2023	2024	2025	2030	2035
Status Quo	26	26	26	25	24	14	16
Carbon Charge	28	28	28	27	25	15	17
Difference	2	2	2	2	2	1	1

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Change in NY zonal CO_2 emissions

(Thousand Metric Tons)

ZONE	2021	2022	2023	2024	2025	2030	2035
A	22	3	16	(6)	(11)	(20)	(9)
B	13	9	10	7	5	7	9
C	272	294	365	332	270	218	251
D	101	79	91	84	69	2	2
E	(147)	(164)	(165)	(162)	(161)	(4)	16
F	713	578	629	655	621	449	401
G	183	148	105	332	298	18	62
H	(24)	(31)	(36)	(33)	(32)	(18)	0
I	0	0	0	0	0	0	0
J	722	634	694	745	701	154	261
K	117	24	60	49	34	95	96

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NY state average LBMPs

(nominal $/MWh)

	2021	2022	2023	2024	2025	2030	2035
Status Quo	$31	$31	$31	$32	$32	$40	$52
Carbon Charge	$53	$52	$53	$55	$55	$65	$83
Difference	$22	$21	$22	$23	$22	$25	$31

Change in NY Zonal Average LBMPs

(nominal $/MWh)

ZONE	2021	2022	2023	2024	2025	2030	2035
A	$20	$19	$20	$20	$19	$21	$26
B	$19	$18	$19	$19	$18	$21	$26
C	$20	$18	$19	$19	$18	$20	$26
D	$19	$18	$19	$19	$18	$20	$26
E	$20	$18	$19	$19	$18	$21	$26
F	$23	$24	$24	$25	$25	$27	$32
G	$24	$24	$24	$26	$25	$29	$36
H	$24	$24	$24	$26	$26	$29	$36
I	$24	$24	$24	$26	$26	$30	$37
J	$24	$24	$24	$27	$26	$30	$37
K	$24	$24	$24	$26	$26	$30	$37

Change in Zonal capacity prices

(nominal $/kW-month)

Zone	2021	2022	2023	2024	2025	2030	2035
NYCA	($0.1)	($0.0)	($0.0)	($0.0)	($0.3)	($1.1)	($1.1)
G-J	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
J	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
K	($0.1)	($0.0)	($0.0)	($0.0)	($0.0)	($0.5)	($0.3)

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Change in NY net exports (GWh)

AREA	2021	2022	2023	2024	2025	2030	2035
IESO	111	30	63	106	42	103	228
PJM	2,232	1,337	2,102	2,760	3,143	1,353	1,919
Quebec	0	0	0	0	0	0	0
ISONE	3,058	3,122	3,024	2,843	2,243	1,549	1,231
Total	5,401	4,490	5,189	5,709	5,428	3,005	3,378

List of changes to August 20 presentation

- First year of study period 2021 instead of 2020 (all slides updated to reflect change)
- Eastern Interconnection replaced with NY and neighbors (defined as Modeled Area)
- Existing resources and planned resource additions combined into one slide in one figure
- Updated battery storage level to 1500 MW and added a table breaking out the additions
- SCC table updated to reflect CARIS-based RGGI forecast (escalated at an 8% growth rate)
- All figured labeled to be in nominal or real dollars
- All zonal figures changed to tables
- Added a section on border charges
- Added a few slides to describe an alternative MCC approach
- Added Day Ahead commitment constraints to the AURORA Model
- Added a slide on customer credit from emitting resources
- Added sensitivities and an appendix with additional zonal tables

QUESTIONS

Thank you

Let’s continue the conversation

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