



MMU Evaluation of Impacts of Carbon Pricing

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Overview

- Brattle performed a thorough analysis of many key effects of the NYISO's Carbon Pricing proposal for the IPPTF
 - ✓ The study found that the proposal would lead to:
 - Modest consumer cost increases in 2022 and 2025 and
 - Consumer cost reductions in 2030
 - ✓ This presentation discusses several enhancements we made to the study
- Discussion of results:
 - ✓ Effects on generation and emission patterns
 - ✓ Consumer cost impacts
- Conclusions




Enhancements to the IPPTF Study: #1 – Modeling Local Reliability Needs

- Concern: Operation of STs in NYC+LI under-estimated
 - ✓ 2018 actual ST emissions: 5.8MT (not including cogen)
 - ✓ 2022 Base Case ST: 4.5MT despite IP retirement
 - ✓ 2030 Base Case ST: 2.3MT
 - Low emissions result from lack of LRRs in GE MAPS
 - ✓ Tends to: (a) over-estimate of impact of policy resources and (b) under-estimate of other factors (e.g., carbon pricing).
- Enhancement: Model NYC LRRs in GE MAPS (not Long Is.)
 - ✓ Estimate hourly LRRs using constraints from SCUC model
 - ✓ Use offline MIP to identify the least cost units to satisfy LRRs
 - ✓ Re-run GE MAPS using least-cost units as a “must-run list” in Base Case and Carbon Case




Enhancements to the IPPTF Study: #2 – Capacity Price Effects

- Concern: Estimated capacity price effects were not significant
 - ✓ Carbon pricing expected to raise E&AS net revenue of DC unit
 - This would lead to lower ICAP demand curve
 - E&AS procure cost increase \ll ICAP procure cost savings
 - Leads to potential for net reduction in consumer payments
- Enhancement: Refine estimated capacity procurement costs
 - ✓ Estimate DA/RT prices using techniques from DCR & BSM to estimate E&AS of Demand Curve unit
 - Reduces the ICAP demand curve
 - ✓ Simulate ICAP clearing prices and awards
 - ✓ Incorporate capacity costs into IPPTF’s model of consumer costs for Base Case and Carbon Case



Enhancements to the IPPTF Study #3 – Evaluating Incentive to Repower

- Concern: Incentives to repower were not evaluated
 - ✓ A new CT or fast-start CC can provide offline reserves:
 - Reduces ST commitment (and emissions) for LRRs
 - Helps integrate intermittent renewables better than STs
 - ✓ Net CONE lower for repowering than brownfield projects
 - Repowering can be economic even when new entry is not
- Enhancement: Evaluate incentives to repower older STs with new Frame CTs, Fast Start CCs, and/or battery storage
 - ✓ Estimate DA/RT prices using techniques from DCR & BSM
 - ✓ Estimate GFCs of older units and Net CONEs of new units
 - ✓ Run production cost simulations with repowered fossil units



Enhancements to the IPPTF Study

#4 – Considering Effects of NYC Reserve Market

- Concern: Future NYC reserve requirements not considered
 - ✓ NYC reserve market requirements would:
 - Raise E&AS net revenues of flexible units
 - Reduce ICAP demand curve
 - Increase repowering incentive
- Enhancement: Estimate the effects of NYC reserve modeling on LBMPs and reserve clearing prices
 - ✓ Assume each LRR is reflected in a reserve market requirement
 - ✓ Estimate incremental cost of satisfying each LRR based on:
Incremental uplift \$/MWh of capacity committed for each LRR
 - ✓ Use this incremental cost to adjust LBMPs and reserve clearing prices



Overview of Methodology



Overview of Methodology

- Start with Brattle’s model and “bolt-on” several enhancements:
 - ✓ Determine lowest-cost CCs and STs to satisfy LRRs and then feed into GE MAPS as a must-run list each day
 - ✓ After running GE MAPS to produce LBMP impacts:
 - Use post-process to estimate effects of reserve market on reserve clearing prices (“RCPs”) and LBMPs
 - Replace net revenue estimates from CARIS with methodology used in DCR/BSM, which consider DAM, RTM, RCPs, etc.
 - ✓ Consumer cost impacts based on new MAPS runs plus:
 - LBMP and RCP impacts from post-process
 - Capacity price impacts
- We will post a memo describing the methodology and back-up materials next week



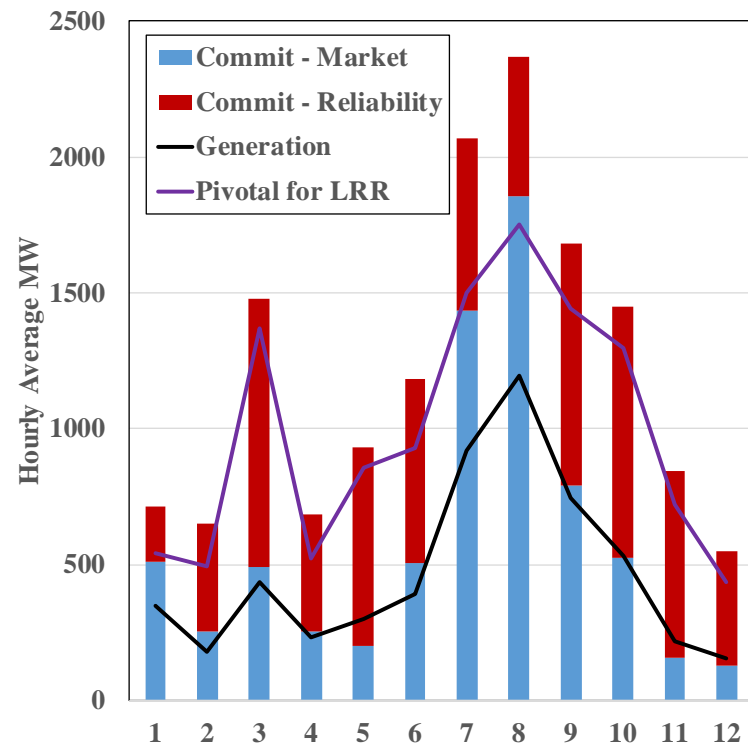
Modeling Local Reliability Requirements

Local Reliability Requirements

- LRRs are a key reason for steam turbine operation in NYC
 - ✓ The figure shows OOM and market-based operation in 2018.
 - ✓ A successful transition to future grid should consider LRRs.
- Figure shows for STs in 2018:
 - ✓ Commit for reliability = 51%
 - ✓ Share generating = 39%
 - ✓ Share pivotal for LRR = 81%
- For most LRRs:

$$\text{Commit Requirement} = \text{Load} - (\text{ImportCapability}) + (\text{Cont \#1} + \text{Cont \#2}) - (70\% * \text{FastStart})$$

Commitment & Production of NYC STs



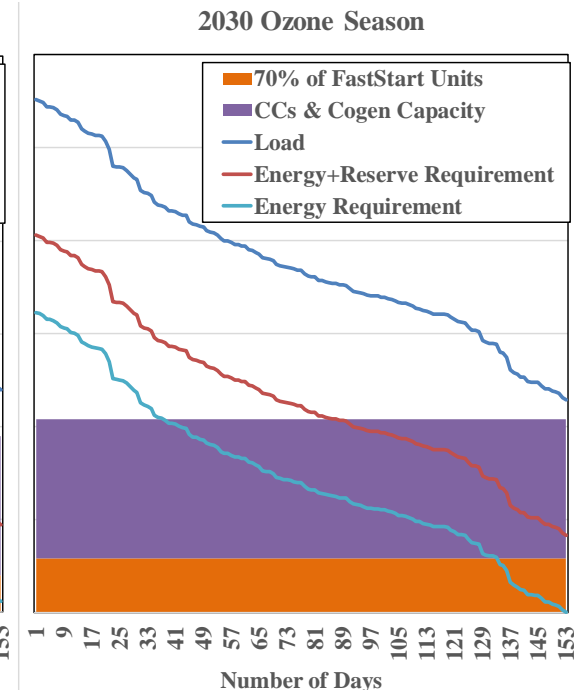
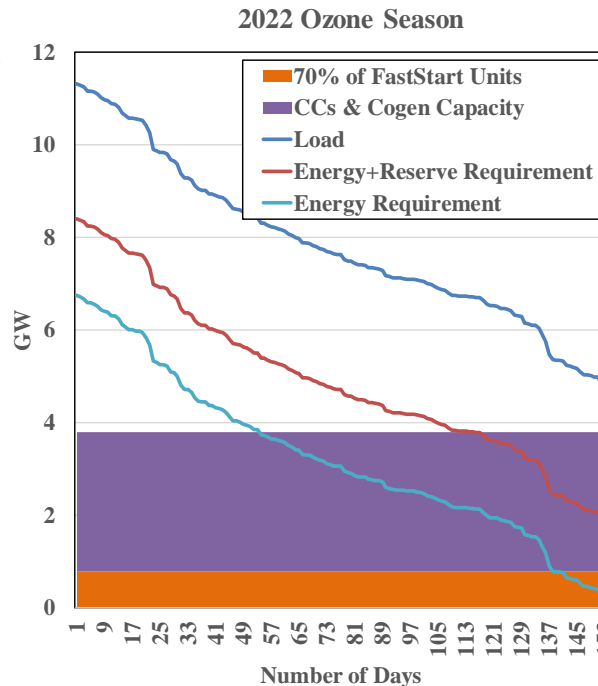


Local Reliability Requirements: Example Calculations

- Example hourly LRR calculation in 2022 (w/NO_x Bubble):
 - ✓ Zone J LRR = 4.29 GW = (Load of 7.2 GW) – (Import Cap of 4.43 GW) + (Cont #1 of 0.76 GW) + (Cont #2 of 0.76 GW)
 - 0.78 GW met by 70% *Fast Starts without NO_x restriction
 - 3.0 GW met by cogeneration and combined cycle units
 - Remaining 510 MW requires ST commitment (and also allows access to NO_x bubble GTs)
- Example hourly LRR calculation in 2030 (w/o NO_x Bubble):
 - ✓ Zone J LRR = 4.29 GW (same calculation as above)
 - 1.16 GW met by 70% *Fast Starts
 - 3.0 GW met by cogeneration and combined cycle units
 - Remaining 135 MW requires ST commitment

Local Reliability Requirements: Illustration of Capacity Need for One LRR

- Numerous distinct LRRs were binding at some point in 2018.
- Duration curves illustrate how often STs will be needed for:
 - ✓ Energy: 35% of days in 2022 and 24% of days in 2030
 - ✓ En+Reserves: 76% of days in 2022 and 57% of days in 2030
- STs run for 24 hours when needed for just the peak
- 2025 & 2030 LRRs reflect DEC Peaker Rule

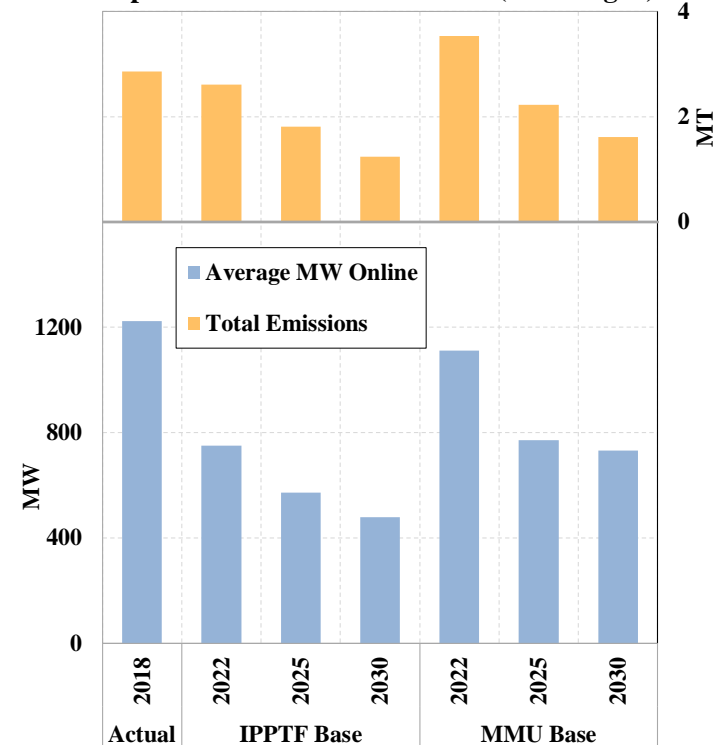




Local Reliability Requirements: Effects on Generation Patterns and Emissions

- Online STs ran at 39% of capacity in NYC in 2018
 - ✓ Average production expected to increase with IP retirement
- IPPTF estimates are low due to lack of LRR-modeling
- MMU estimates are low due to lack of Tx outage-modeling
- Emission reductions in 2030 will be limited by local needs in NYC and Long Island
 - ✓ Long Island not evaluated
- Transition to future grid would be more successful if STs were replaced with flexible units

Operation of NYC Steam Units (excl. Cogen)





Modeling NYC Reserve Pricing



Reserve Pricing

- Markets satisfy LRRs through the use of operating reserve requirements in the DAM and RTM.
- GE MAPS does not have co-optimized reserve modeling capability.
- As more intermittent renewable units are added to the grid, conventional fossil-fuel generators will often be relegated to a reserve/peaking role.
- Representation of LRRs is critical for evaluating high renewable penetration scenarios
 - ✓ Modeling of associated reserve requirements is essential for providing appropriate investment incentives

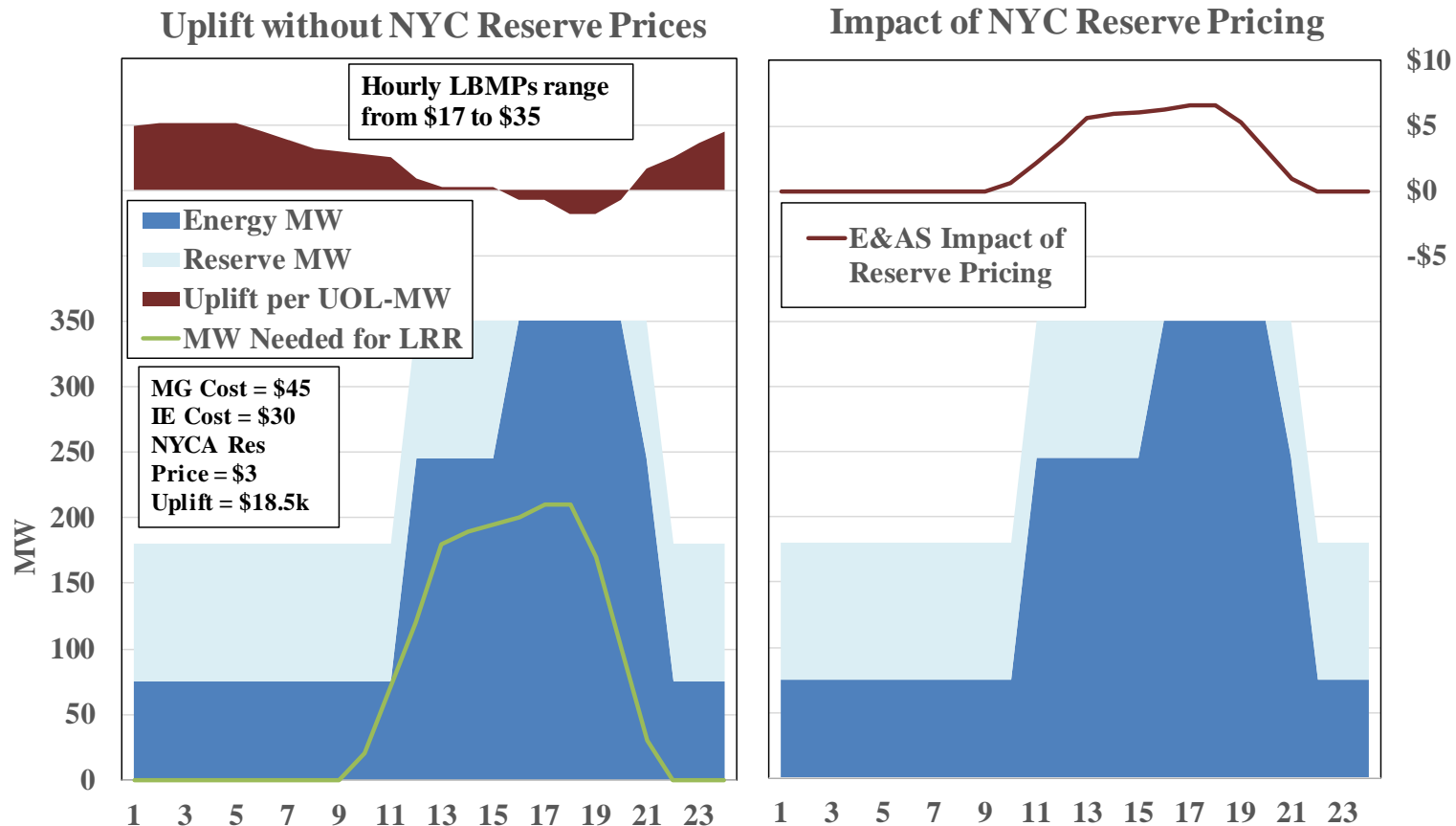


Reserve Pricing: Method Used in MMU Study

- Reserve clearing prices depend on availability bids (DAM only) and the opportunity cost of not providing energy.
 - ✓ Availability bids depend on risk & feasibility of RT generation
 - Involves private assessment → difficult to model
 - ✓ Opportunity costs depend on co-optimization of E&AS
 - MAPS does not co-optimize E&AS
 - A separate model is needed to estimate reserves prices
- LRR commitment uplift reflects marginal cost of reserves
 - ✓ Potential commitment of CCs/STs disciplines reserve offers
 - Thus, the amortized \$uplift per MWh of UOL provides a reasonable estimate of reserve prices for this study
 - We allocate to individual LRRs using LP by day

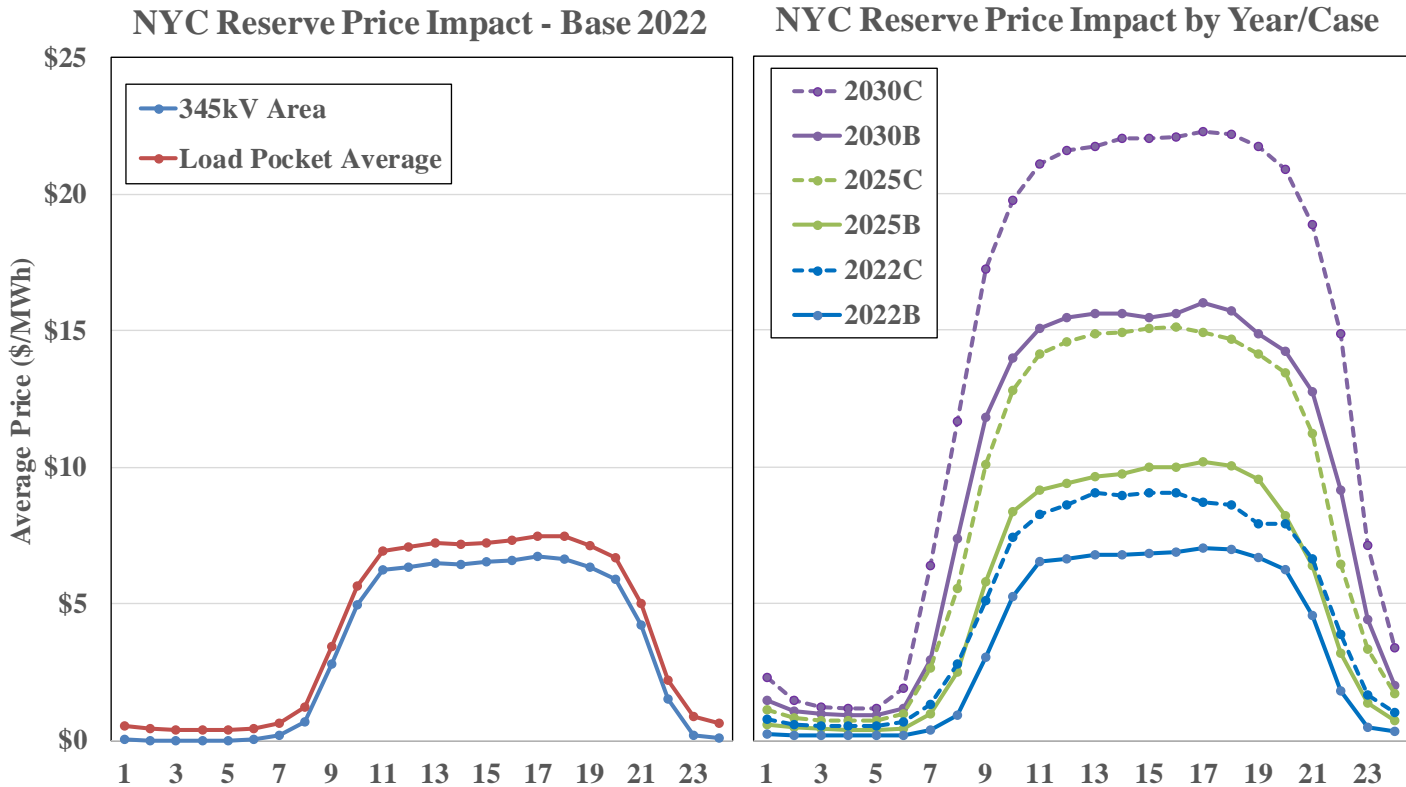
Reserve Pricing: Example

- The following example illustrates how reserve prices are developed when a ST is committed to satisfy an LRR.



Reserve Pricing: Average Prices

- Average 30-minute price impacts are summarized below.
 - ✓ Note, does not capture the effect of our 10-minute reserve pricing recommendation. (#2016-1)

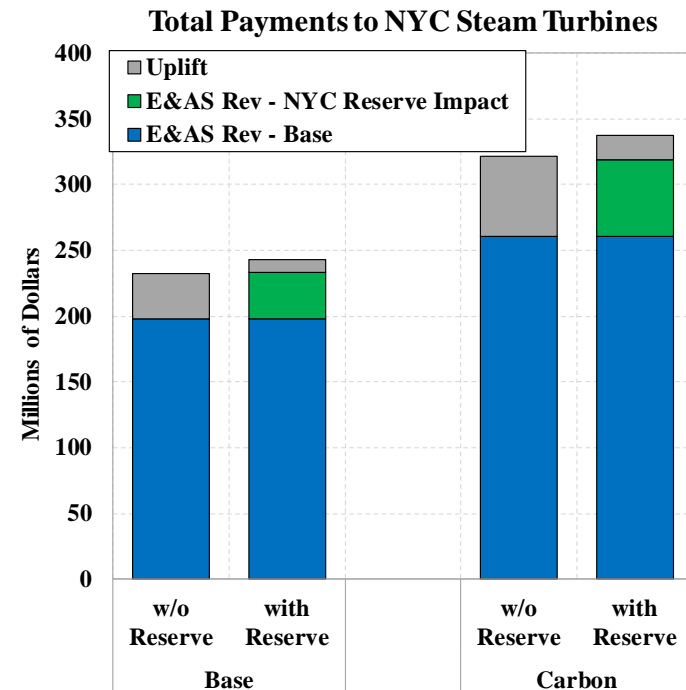




Capacity Price Effects

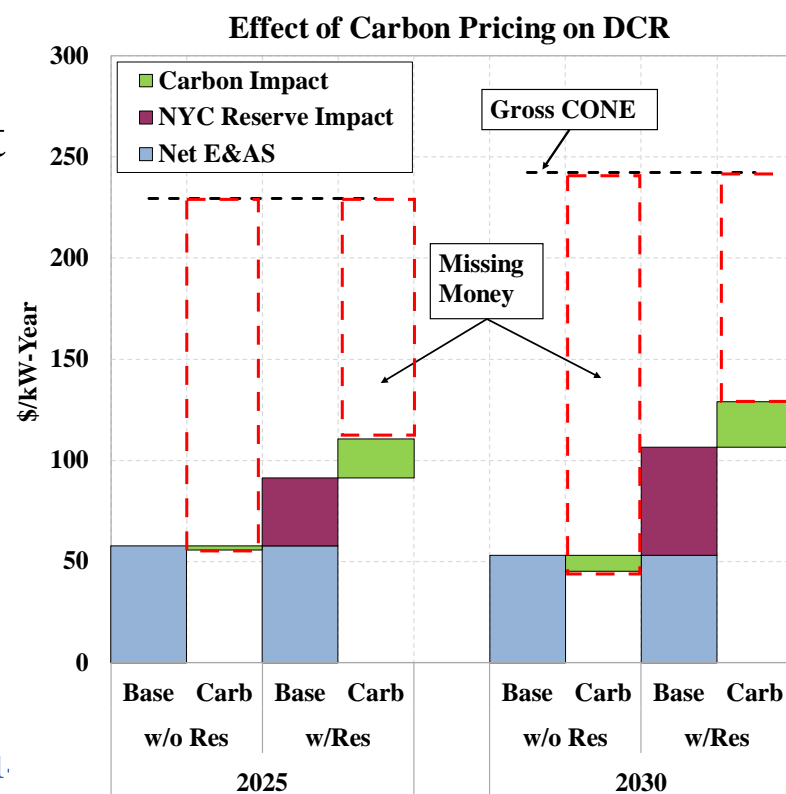
Capacity Price Effects

- Carbon pricing should lead to higher generator offers
 - ✓ This should lead to higher prices
 - ✓ However, NYC LRRs are met through OOM commitment
 - ✓ Thus, additional cost recouped through uplift rather than prices
- NYC Steam units' 2025 uplift:
 - ✓ Base w/o reserve: \$34M
 - ✓ Carbon w/o reserve: \$61M
 - ✓ Base w/reserve: \$10M
 - ✓ Carbon w/reserve: \$19M
- Reserve pricing ensures that increased price of carbon is not recovered through uplift



Capacity Price Effects

- ICAP demand curve provides the “missing money” needed to satisfy IRM & LCRs
- NYC reserve modeling would reduce missing money of the demand curve unit
- Carbon pricing affects DC unit Net CONE in 2025:
 - ✓ Without NYC reserves: from \$172 to \$174/kW-year
 - ✓ With NYC reserves: from \$138 to \$119/kW-year
- Carbon pricing (with reserves) reduces capacity prices



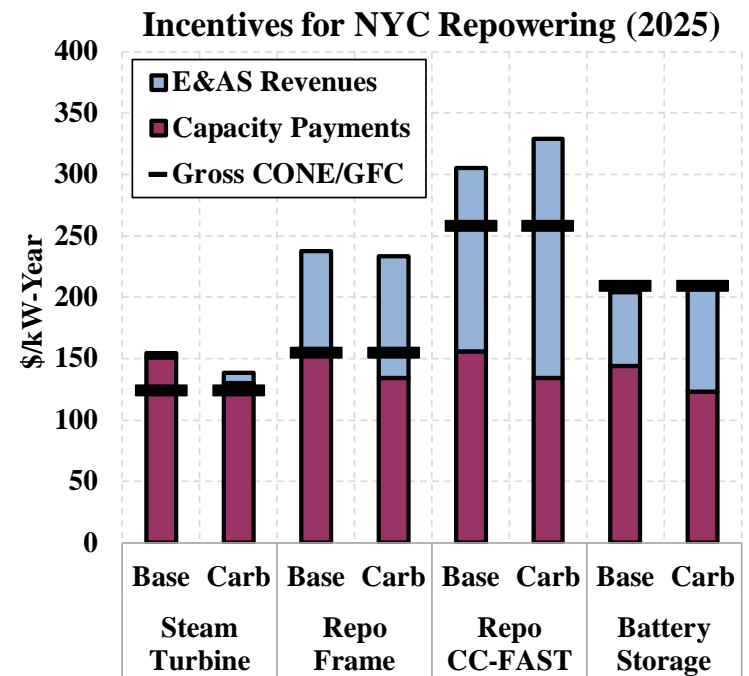


Repowering Incentives



Incentives to Repower

- New entry and repowering costs reduced by new tax law
- Repowering and new entry incentives are similar except:
 - ✓ Interconnection costs lower for repowering
 - ✓ Economics of existing unit relevant for repowering
- Carbon pricing (w/ NYC Res):
 - ✓ Reduces profitability of ST
 - ✓ Shifts incentives from CTs toward:
 - Fuel-efficient CC-Fast technology
 - Battery storage





Incentives to Repower

- We ran the following GE MAPS cases in which two 360-MW steam turbines were repowered with fast start units:
 - ✓ In 2022, emissions fell 90/150k tons in the base/carbon case
 - ✓ In 2025, emissions fell 220/260k tons in the base/carbon case
 - ✓ In 2030, emissions fell 360/300k tons in the base/carbon case
- Increased renewable penetration shifts fossil-fuel units to operate in more of a reserve role.
 - ✓ Fast start units provide reserves without producing emissions while older CCs and STs only provide reserves while running.
- As renewable penetration increases, the effects of repowering on emissions will also increase.



Consumer Cost Impacts

Consumer Cost Impacts in 2022

	IPPTF	MMU Base	MMU Repo
STATIC ANALYSIS (\$/MWh)			
I. Increase in Wholesale Energy & Reserve Prices	\$16.97	\$16.45	\$15.87
<i>NYC reserve impact on E&AS prices</i>		\$0.55	\$0.50
II. Customer Credit from Emitting Resources	-\$10.35	-\$10.17	-\$10.00
III. Lower ZEC Prices	\$0.00	\$0.00	\$0.00
IV. Lower REC Prices	-\$1.84	-\$1.74	-\$1.67
V. Increased TCC Value	-\$0.98	-\$0.95	-\$0.92
VI. Increased TCC Value due to NYC reserve impact on E&AS prices		-\$0.22	-\$0.20
VII. Lower Capacity Price		-\$0.54	-\$1.01
Subtotal	\$3.80	\$2.83	\$2.08
DYNAMIC ANALYSIS (\$/MWh)			
VIII. Market Adjustments to Static Analysis	-\$0.94	-\$0.69	-\$0.48
VIII. A. Nuclear Retention	\$0.00	\$0.00	\$0.00
VIII. B. Renewable Shift Downstate	\$0.00	\$0.00	\$0.00
VIII. C. New Resource Entry	\$0.00	\$0.00	\$0.00
VIII. D. Load Elasticity	-\$0.94	-\$0.69	-\$0.48
IX. Carbon Price-Induced Abatement (Avoided RECs)	-\$0.04	-\$0.05	-\$0.06
<i>million tons of abatement</i>	0.6	0.6	0.6
Subtotal	-\$0.98	-\$0.74	-\$0.55
Net Change in Customer Costs (\$/MWh)	\$2.82	\$2.08	\$1.53

Consumer Cost Impacts in 2025

	IPPTF	MMU Base	MMU Repo
STATIC ANALYSIS (\$/MWh)			
I. Increase in Wholesale Energy Prices	\$17.94	\$17.73	\$16.40
<i>NYC reserve impact on E&AS prices</i>		\$1.24	\$0.87
II. Customer Credit from Emitting Resources	-\$10.61	-\$10.34	-\$10.15
III. Lower ZEC Prices	-\$2.43	-\$2.27	-\$2.22
IV. Lower REC Prices	-\$2.41	-\$2.28	-\$2.16
V. Increased TCC Value	-\$0.58	-\$0.58	-\$0.53
VI. Increased TCC Value due to NYC reserve impact on E&AS prices		-\$0.50	-\$0.35
VII. Lower Capacity Price		-\$1.37	-\$0.99
Subtotal	\$1.91	\$0.39	-\$0.01
DYNAMIC ANALYSIS (\$/MWh)			
VIII. Market Adjustments to Static Analysis	-\$1.07	-\$0.88	-\$0.84
VIII. A. Nuclear Retention	\$0.00	\$0.00	\$0.00
VIII. B. Renewable Shift Downstate	-\$0.88	-\$0.88	-\$0.88
VIII. C. New Resource Entry	-\$0.05	-\$0.05	-\$0.05
VIII. D. Load Elasticity	-\$0.13	\$0.06	\$0.10
IX. Carbon Price-Induced Abatement (Avoided RECs)	-\$0.04	-\$0.04	-\$0.05
<i>million tons of abatement</i>	0.3	0.3	0.3
Subtotal	-\$1.11	-\$0.92	-\$0.89
Net Change in Customer Costs (\$/MWh)	\$0.81	-\$0.53	-\$0.90

Consumer Cost Impacts in 2030

	IPPTF	MMU Base	MMU Repo
STATIC ANALYSIS (\$/MWh)			
I. Increase in Wholesale Energy Prices	\$13.27	\$12.78	\$11.35
<i>NYC reserve impact on E&AS prices</i>		\$1.67	\$1.17
II. Customer Credit from Emitting Resources	-\$9.06	-\$8.48	-\$8.17
III. Lower ZEC Prices	\$0.00	\$0.00	\$0.00
IV. Lower REC Prices	-\$2.96	-\$2.56	-\$2.44
V. Increased TCC Value	-\$2.16	-\$2.08	-\$1.85
VI. Increased TCC Value due to NYC reserve impact on E&AS prices		-\$0.69	-\$0.48
VII. Lower Capacity Price	-\$0.40	-\$1.64	-\$1.37
Subtotal	-\$1.31	-\$2.68	-\$2.95
DYNAMIC ANALYSIS (\$/MWh)			
VIII. Market Adjustments to Static Analysis	-\$0.22	\$0.04	\$0.10
VIII. A. Nuclear Retention	\$0.00	\$0.00	\$0.00
VIII. B. Renewable Shift Downstate	-\$0.35	-\$0.35	-\$0.35
VIII. C. New Resource Entry	-\$0.01	-\$0.01	-\$0.01
VIII. D. Load Elasticity	\$0.13	\$0.40	\$0.45
IX. Carbon Price-Induced Abatement (Avoided RECs)	-\$0.36	-\$0.54	-\$0.52
<i>million tons of abatement</i>	1.4	1.7	1.6
Subtotal	-\$0.59	-\$0.50	-\$0.43
Net Change in Customer Costs (\$/MWh)	-\$1.90	-\$3.17	-\$3.38



Conclusions



Conclusions

- Consideration of LRRs is critical for understanding how to reduce reliance on fossil fuels.
 - ✓ LRRs require STs & CCs to run in order to provide reserves.
 - ✓ GE MAPS does not model:
 - Most NYC LRRs – Leads to under-estimate of fossil fuel output in load pockets that cannot be displaced by renewables.
 - Co-optimization of energy and operating reserves – Makes it difficult to evaluate the effects of market design changes on the incentives to build peaking units.
 - Most Long Island LRRs and local congestion – Leads to under-estimates of fossil fuel (particularly oil)-fired generation, which affect analyses of public policy resources and carbon pricing.



Conclusions

- Offline peakers provide reserves to satisfy LRRs with much lower emissions and operating costs than existing CCs and STs.
 - ✓ This includes some clean technologies like battery storage which provide similar benefits.
 - ✓ These units have better attributes for renewable integration.
 - ✓ Repowering old units with new fossil-fueled peakers may be an important component of path to high renewable penetration.
 - ✓ Preventing repowering increases the likelihood that RMR contracts will be necessary in the future.
- Significant consumer savings result from carbon pricing when coupled with reserve pricing.



Conclusions

- Carbon pricing improves incentives to repower with:
 - ✓ More fuel efficient technology
 - ✓ Battery storage
- This study incorporates several enhancements to the modeling of NYC LRRs and reserve requirements.
 - ✓ However, a similar analysis of Long Island would likely find similar benefits.
 - ✓ We are still developing models to estimate:
 - LRRs for Long Island
 - Local congestion that requires frequent operation of Long Island generation, particularly oil-fired units