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

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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

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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 << 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

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Overview of Methodology

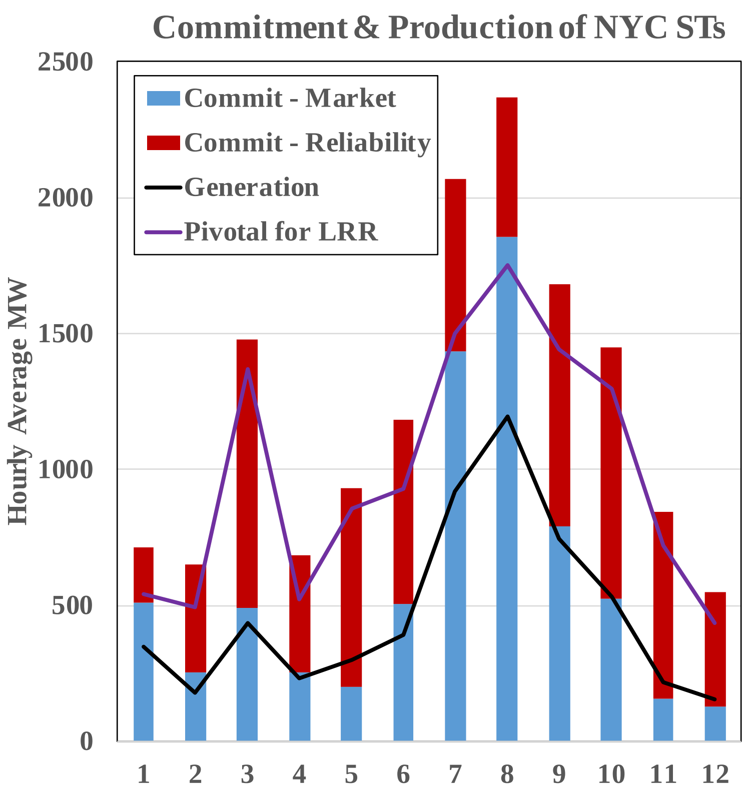
Overview of Methodology

- 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:
  Commit Requirement = Load – (ImportCapability) + (Cont #1 + Cont #2) – (70%*FastStart)

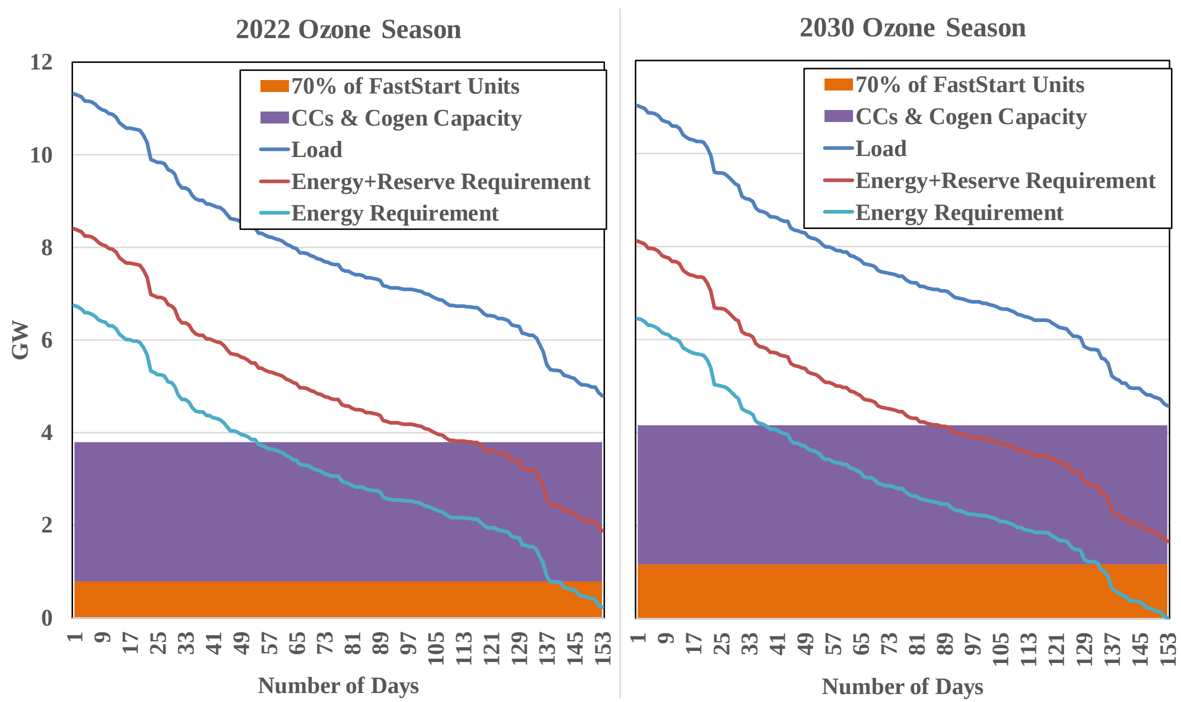


Local Reliability Requirements: Example Calculations

- Example hourly LRR calculation in 2022 (w/NOx 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 NOx restriction
    - 3.0 GW met by cogeneration and combined cycle units
    - Remaining 510 MW requires ST commitment (and also allows access to NOx bubble GTs)
- Example hourly LRR calculation in 2030 (w/o NOx 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

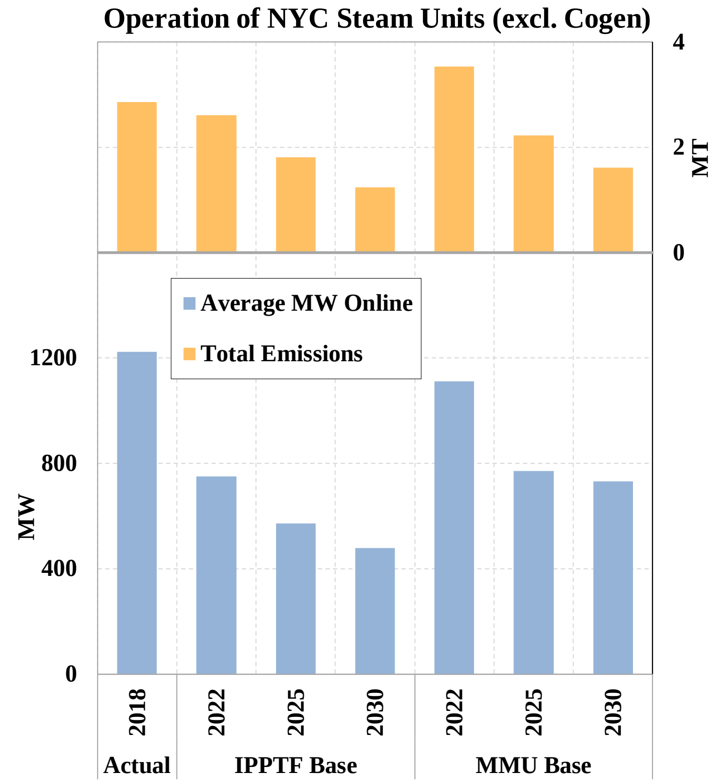
Local Reliability Requirements: Illustration of Capacity Need for One LRR

- 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



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

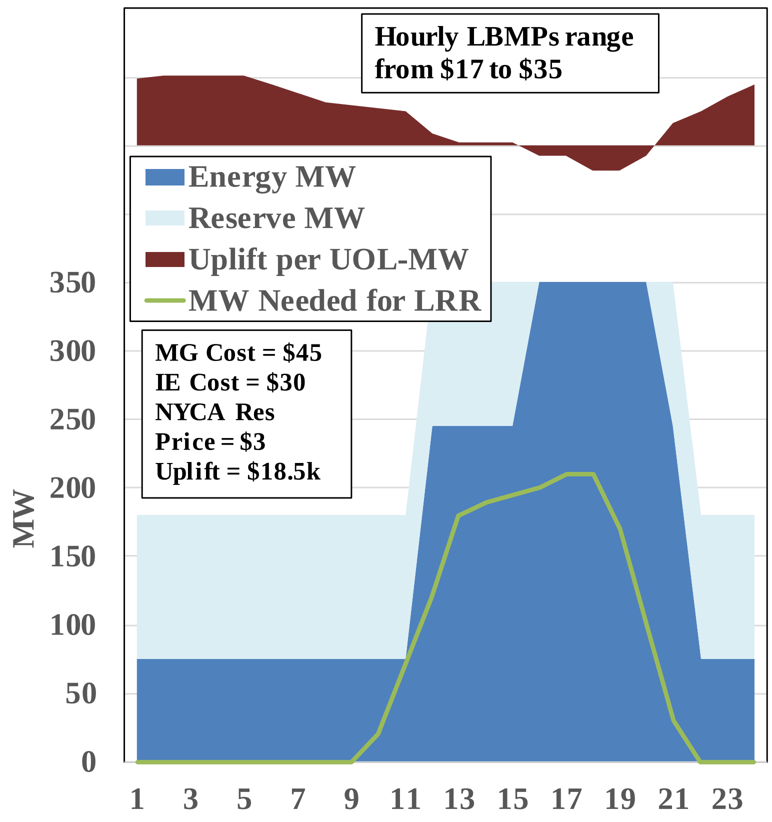
Reserve Pricing:
Method Used in MMU Study

- 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

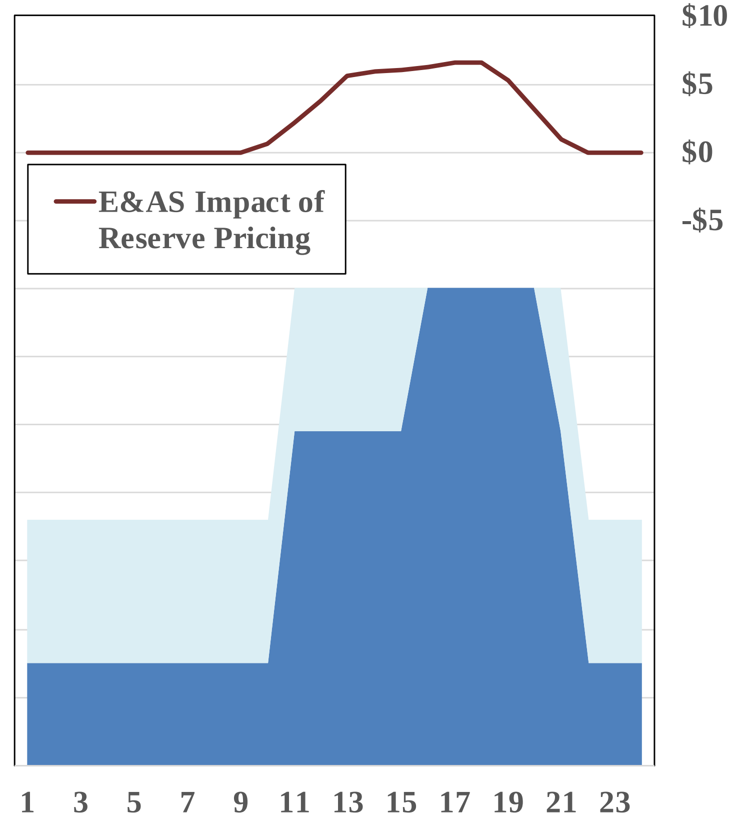
Reserve Pricing: Example

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

Uplift without NYC Reserve Prices

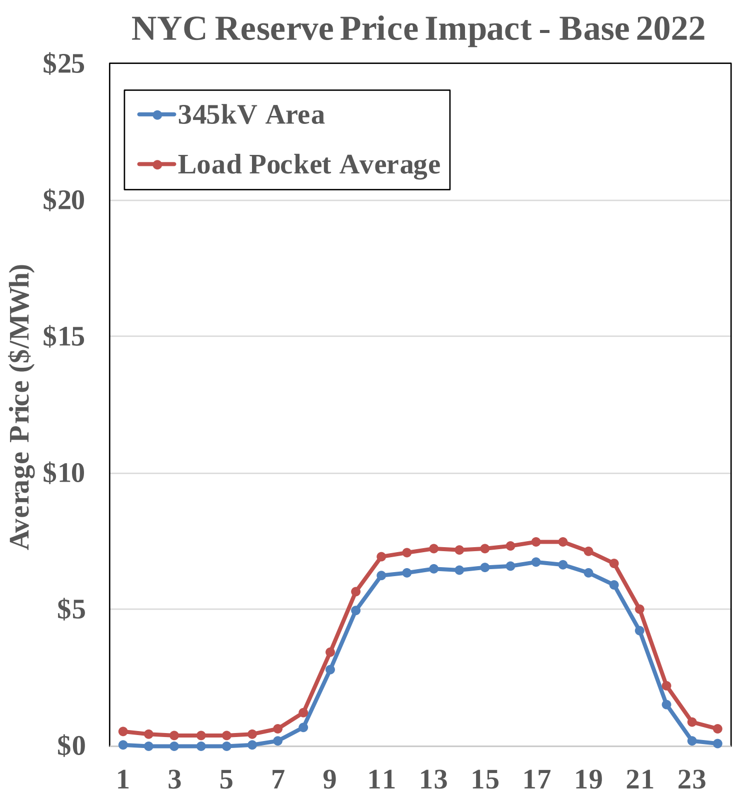


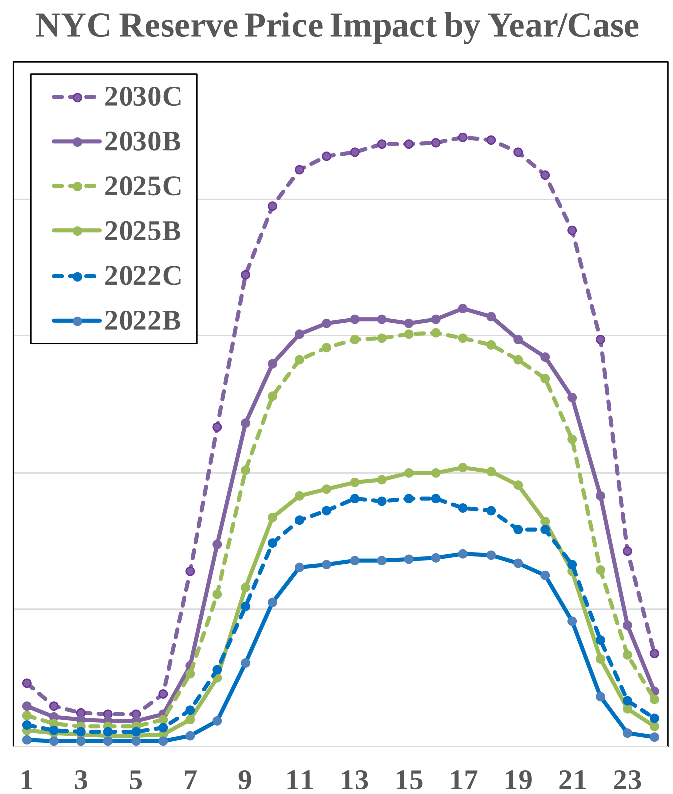
Impact of NYC Reserve Pricing



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)





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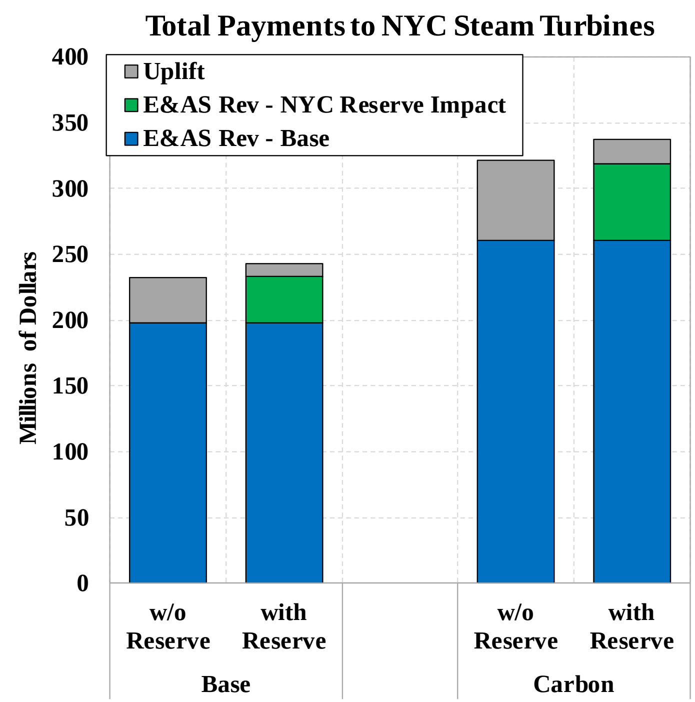
Capacity Price Effects

Capacity Price Effects

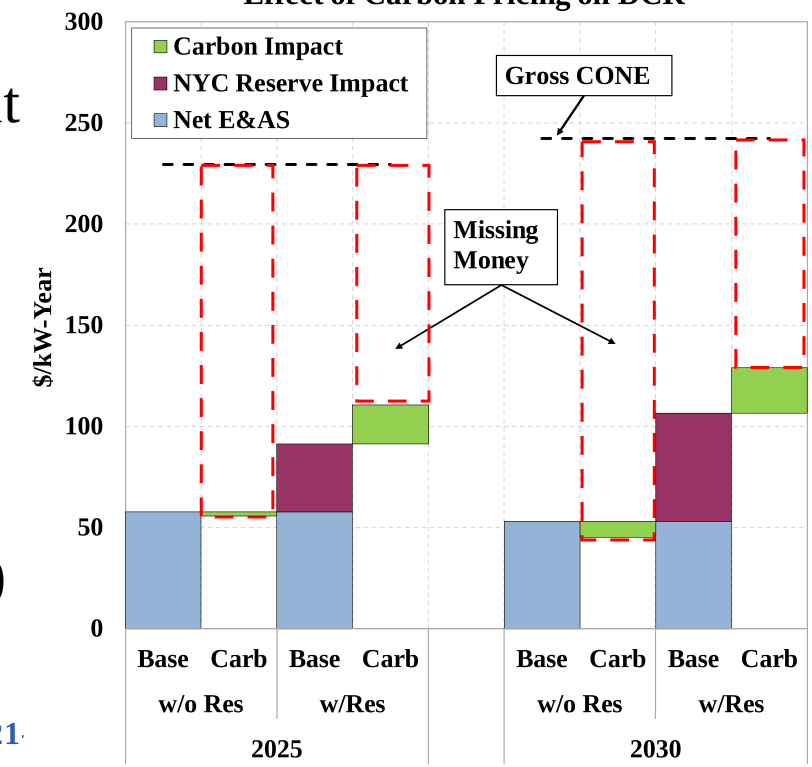
- Carbon pricing should lead to higher generator offers
  - ✓ This should lead to higher prices
  - ✓ However, NYC LRRs are met through OOM commitment
  - ✓ Thus, additional cost recouped through uplift rather than prices
- NYC Steam units' 2025 uplift:
  - ✓ Base w/o reserve: $34M
  - ✓ Carbon w/o reserve: $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

Effect of Carbon Pricing on DCR



Repowering Incentives

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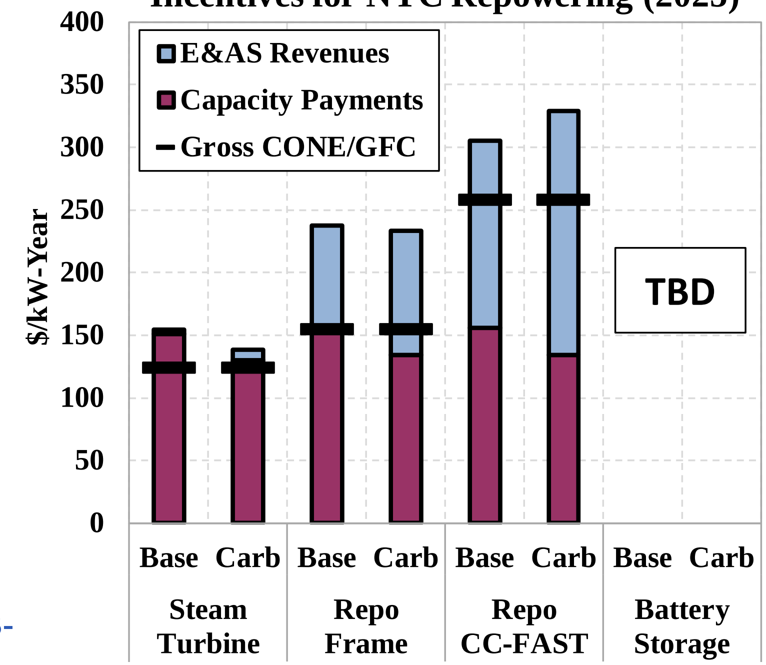
Incentives to Repower

- 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 for NYC Repowering (2025)



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

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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
NYC reserve impact on E&AS prices		$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
million tons of abatement	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**

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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
NYC reserve impact on E&AS prices		$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
million tons of abatement	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**

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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
NYC reserve impact on E&AS prices		$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
million tons of abatement	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.

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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.

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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