Introduction to GridSIM
MODELING TO INFORM THE GRID IN TRANSITION

PRESENTED TO
NYISO ICAP/MIWG/PRLWG STAKEHOLDERS

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Introduction

Introduction to GridSIM and Capacity Expansion Modeling

Illustrative Analysis

Overview of Modeling Assumptions

Feedback and Next Steps
Introduction

Project purpose and scope

NYISO has retained Brattle to develop simulations of NYISO markets through 2040 to inform the Grid in Transition effort.

- New York has established aggressive clean energy and decarbonization goals, codified in the Climate Leadership and Community Protection Act (CLCPA).
- NYISO’s Grid in Transition effort seeks to understand the reliability and market implications of the State’s plans to transition to clean energy sources.
- NYISO has retained Brattle to simulate NYISO market operations and investment through 2040 to inform NYISO staff and stakeholders on market evolution.

Key Questions to Address

- How many and what types of renewable resources and storage will be needed to achieve the 70% renewable standard?
- What is the future of current New York generation (e.g. nuclear and gas)?
- How might electrification affect market operations and investments?
- What is the role of a flexible and market-engaged demand side?

We are requesting stakeholder feedback on Key Questions.
### Introduction

**High-level approach**

With stakeholders, over coming weeks **Brattle and NYISO will develop simulations of the future New York power system.**

<table>
<thead>
<tr>
<th></th>
<th><strong>Model Setup</strong></th>
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<tbody>
<tr>
<td>1.</td>
<td><strong>End of March</strong></td>
<td>Develop model inputs and vet assumptions with stakeholders</td>
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<tr>
<th></th>
<th><strong>Benchmarking</strong></th>
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<tr>
<td>2.</td>
<td><strong>April</strong></td>
<td>Calibrate and validate model by comparing to recent history (2018)</td>
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<tr>
<th></th>
<th><strong>Base Case</strong></th>
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<tr>
<td>3.</td>
<td><strong>April &amp; May</strong></td>
<td>Develop Base Case simulations of NYISO markets through 2040</td>
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<th></th>
<th><strong>Alternative Cases</strong></th>
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<td>4.</td>
<td><strong>May &amp; June</strong></td>
<td>Develop Alternative Cases through 2040, varying assumptions such as resource costs, load growth, and demand-side flexibility.</td>
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Introduction to GridSIM and Capacity Expansion Modeling
Conclusion to GridSIM

What are “capacity expansion models”?

Capacity expansion models simulate optimal generation investment and operations over a multi-year horizon.

- In traditionally regulated areas, commonly used by utilities for IRP
- In organized markets with merchant investment, simulate how investment and market conditions may evolve over time
- Especially valuable for exploring alternative futures in times of uncertainty and major change in market fundamentals, policies, and market design, as in New York
- Example models include PLEXOS, Aurora, Strategist, and Resource Planning Model (NREL)
Introduction to GridSIM
GridSIM: Brattle’s next-gen capacity expansion model

GridSIM Features

- Designed to simulate highly-decarbonized systems
- Implemented with detailed representation of NY power system and NYISO markets
- Co-optimized treatment of energy, ancillary service, and capacity markets
- Chronological commitment and dispatch to robustly model storage.

Example Insights

- How to balance a 100% carbon-free grid?
- How are nuclear revenues affected by 70% renewable energy?
- How does the cost of offshore wind influence the future NY resource mix?
Previous uses of GridSIM

- **NYISO Grid in Transition.** For NYISO, supported Grid in Transition effort to understand potential market revenue shifts for the NYISO’s recommended market enhancements.

- **Ontario Clean Energy Study.** For IESO, evaluated the costs and benefits of alternative clean energy procurement mechanisms.

- **Clean Energy Attribute Product Design & Procurement.** For NEPOOL, evaluated benefits of a dynamic clean energy market in ISO-NE.

- **Evaluation of Future Flexibility Needs.** For an investor, evaluating the future value of flexible resources within ERCOT.

- **Market Design Enhancement Study.** For an RTO, evaluated the benefits and costs of enhancements to energy and capacity markets.

- **DR and EE Assessment.** For EPRI and DOE, evaluated the potential benefits of enhanced DR and EE treatment within resource planning models.

- **Nuclear Valuation.** For a Southeast utility, evaluated the value of a nuclear plant within a resource planning context.
Introduction to GridSIM

GridSIM model framework

**Inputs**

**Supply**
- Existing resources
- Fuel prices
- Investment/fixed costs
- Variable costs

**Demand**
- Representative day hourly demand
- Capacity needs

**Transmission**
- Zonal limits
- Intertie limits

**Regulations, Policies, Market Design**
- Capacity market
- Carbon pricing
- Procurement mandates

**Outputs**

**GridSIM Optimization Engine**

**Objective Function**
Minimize NPV of Investment & Operational Costs

**Constraints**
- Market Design and Co-Optimized Operations
  - Capacity
  - Energy
  - Ancillary Services
- Regulatory & Policy Constraints
- Resource Operational Constraints
- Transmission Constraints

**Annual Investments and Retirements**

**Hourly Operations**

**System and Customer Costs**

**Supplier Revenues**

**Emissions and Clean Energy Additions**

**Market Prices**
Introduction to GridSIM

Objective function

GridSIM minimizes the present value of total system costs across a multi-year horizon, subject to constraints.

Components of Total System Cost:

- **Operating costs:** Objective to dispatch its system in a least-cost manner across E&AS markets to minimize production costs, including fuel, variable operations and maintenance, startup, and emission costs

- **Investment costs:** A new resource built only when its total revenues exceed its total costs, such that investment and fixed costs are minimized
Introduction to GridSIM

Constraints considered

GridSIM simulates system operations subject to technical, market design, and policy constraints.

Market Design & Operations
- Must retain sufficient supply to meet resource adequacy requirements, per ICAP market
- Each hour, generation must equal load

Regulatory and Policy Constraints
- Emission caps and carbon pricing
- Technology mandates, e.g. Renewable Portfolio Standards or storage mandates

Resource Operational Constraints
- Supply resources subject to technical constraints that vary by resource type, e.g. ramp rates, unit commitment, min/max gen, hydropower flow limits, lifetime
- Availability of import supply & exports can be treated in a variety of ways

Transmission Constraints
- Internal and external flows limited by pre-specified transmission limits (pipe and bubble model)
Illustrative Analysis
Illustrative Analysis

Changes in capacity

Installed Capacity (GW)

Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Year 7

Wind
BTM Solar
Solar
Storage
Hydro
Capacity Imports
Gas
Coal

See Disclaimer on Slide 2.
Illustrative Analysis

Changes in generation

Annual Generation (TWh)

Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Year 7

Load + Exports

Wind Curtailment
Solar Curtailment

Wind
BTM Solar
Solar
Hydro
Net Imports
Gas
Coal
Illustrative Analysis
Hourly dispatch in 2030

2030 Hourly Generation (MW)

- Winter peak
- Curtailments
- Summer peak
- High gas generation on high load days
- Lowest load day
- Storage charging

Modeled Day: Jan 3, Feb 15, Apr 14, May 30, Aug 1, Aug 22, Sep 5, Oct 14, Oct 23, Nov 28

Wind Curtailment
- Storage
- Gas
- BTM Solar
- Solar
- Wind
- Net Imports
- Coal
Illustrative Analysis
Sources of supplier revenues

Unit Revenues ($/kW-yr)
Overview of Modeling Assumptions
## Modeling Assumptions

### Key assumptions

<table>
<thead>
<tr>
<th>Key Input Assumption</th>
<th>Details</th>
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<tbody>
<tr>
<td><strong>1 System Model</strong></td>
<td>- Internal and external transmission constraints (pipe/bubble model)</td>
</tr>
</tbody>
</table>
| **2 Supply Resources** | - All existing supply resources and planned builds/retirements  
- New supply resource costs and technical constraints  
- Available supply from neighbors (can be modeled in several ways) |
| **3 Demand**         | - Hourly load shapes  
- Future load forecast, including electrification and climate impacts  
- Flexibility of demand side |
| **4 Temporal Representation** | - 10 representative days modeled at hourly granularity, selected and weighted to reflect average annual system conditions  
- 2020 – 2040 time horizon |
| **5 Market Design**  | - NYISO ICAP market design  
- Ancillary service requirements & shortage pricing |
| **6 Financial Assumptions** | - Cost of capital |
Modeling Assumptions
Modeled clean energy policies

Description of Key Policies

| CLCPA | • Renewable generation: 70% of NY annual electricity supplied from renewables (solar, wind, hydro) by 2030  
• 100% carbon-free electricity by 2040  
• Solar: 6,000 MW distributed solar by 2025  
• Offshore wind: 9,000 MW by 2035  
• Storage: 3,000 MW by 2030  
• Economy-wide emissions: 85% reduction by 2050 and 40% reduction by 2030 from 1990 levels |
|---|---|
| RGGI | • Northeast regional cap-and-trade program  
• Avg. 2019 price: $5.4/ton; expected to reach $12.6 by 2030 |
| ZEC Program | • Zero emission credit payments to New York nuclear plants  
• Program expires March 2029 |
| DEC NOx rule | • DEC rule to reduce NOx emissions from peakers  
• Peakers built pre-1986 may retire instead of retrofitting to meet emissions requirements |

Policy Timeline

- **2009**: RGGI: First control period
- **2016**: ZEC: Program in effect
- **2025**: Solar: 6,000 MW mandate  
  NOx Rule: In full effect
- **2029**: ZEC: Program expires
- **2030**: CLCPA: 70% renewable electricity  
  Storage: 3,000 MW mandate
- **2035**: OSW: 9,000 MW mandate
- **2040**: CLCPA: 100% carbon-free electricity
- **2050**: CLCPA: 85% NY economy-wide decarbonization

Sources and Notes:
- RGGI Auction Allowance Price and Volumes Results
- New York DEC Adopted Subpart 227-3
- New York Senate Bill S6599

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In conjunction with NYISO, Brattle developed a 5-zone "pipe-and-bubble" representation of the New York grid.
Modeling Assumptions
Existing supply resources

We model all existing generators in New York, consistent with the 2018 Gold Book and other sources of data.

- 2018 Gold Book primary source of generator data
- Most generators aggregated by zone and type (e.g., gas CC & CT, nuclear, OSW)
- Subset of generators modeled independently due to unique characteristics
- Generator characteristics (e.g., heat rate, VOM) developed with NYISO input
- UCAP value of renewables modeled dynamically
Modeling Assumptions
New supply resources

Future generator investment costs based on review of multiple sources, including NREL, EIA, and NYISO DCR study.

Select Resource Costs (2018$)
To be Refined

Additional technologies to be considered
• Carbon capture
• Power-to-gas
• Small modular nuclear
• Seasonal storage

Resource Cost (2018$/kW)

- Wind – Offshore
- Bio
- Wind – Onshore
- Solar – Wholesale
- Solar – Behind the Meter
- Gas CT
- Gas CC
- Storage ($/kW-hour)
Modeling Assumptions

Load Shapes

We select and weight representative days to reflect NYISO’s 2018 hourly load duration curves.

- Day selection and weighting considers seasonality, gas price, and renewable generation
- Will evaluate how representative load shapes may evolve with electrification

### Representative Days

<table>
<thead>
<tr>
<th>Day</th>
<th>Weight</th>
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<tbody>
<tr>
<td>1/3/2018</td>
<td>14</td>
</tr>
<tr>
<td>2/15/2018</td>
<td>76</td>
</tr>
<tr>
<td>4/14/2018</td>
<td>28</td>
</tr>
<tr>
<td>5/30/2018</td>
<td>39</td>
</tr>
<tr>
<td>8/1/2018</td>
<td>27</td>
</tr>
<tr>
<td>8/22/2018</td>
<td>23</td>
</tr>
<tr>
<td>9/5/2018</td>
<td>12</td>
</tr>
<tr>
<td>10/14/2018</td>
<td>6</td>
</tr>
<tr>
<td>10/23/2018</td>
<td>76</td>
</tr>
<tr>
<td>11/28/2018</td>
<td>64</td>
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2018 NYISO Load Historical vs. Simulated

- **Winter Peak**
- **Summer Peak**
- **Low Load Day**

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Modeling Assumptions
Load Forecasts

We will utilize load forecasts consistent with current NYISO outlooks.

- Initial modeling utilized load forecasts from 2018 Gold Book
- Will update forecasts to be consistent with most recent NYISO outlook and leverage Climate Change Phase 1 forecast
- Will consider impacts of electrification and climate change
We model New York interties consistent with historical flows, but reflect some ability of neighboring systems to help balance NY renewable generation.

- **Hydro Quebec** modeled as fully flexible
  - Reflects HQ’s hydro storage potential
  - In all hours, allow flows up to line limit (1500 MW import, 1000 MW export)

- **All other interties** modeled as less flexible
  - Reflects similar balancing challenges in neighboring systems
  - Lock **hourly exports** at 2018 levels
  - **Hourly imports** allowed to flex between zero and 2018 levels (e.g. model can reduce imports if uneconomic)
Feedback and Next Steps
Feedback & Next Steps
Study timeline and workplan

- **March 6 (today)**: MIWG: Introduction to GridSIM, stakeholder feedback
  - Brattle & NYISO: Develop initial assumptions

- **March 30**: MIWG: Discuss modeling & assumptions, stakeholder feedback
  - Brattle & NYISO: Finalize assumptions, develop base case

- **Mid-May**: MIWG: Initial results, finalize alternative cases
  - Brattle & NYISO: Develop alternative cases

- **Early June**: MIWG: Alternative case results
Brattle and NYISO will develop two alternative cases that vary key assumptions.

Potential cases:

- **High load growth** due to electrification
- Increased **demand-side flexibility** and market participation
- **Rapid technology improvement** for wind, solar, other clean resources
- **Increased transmission** capacity
- Continued **nuclear support** after expiration of ZEC program in 2029

**What alternative cases would stakeholders find most valuable?**
Feedback & Next Steps
Request for stakeholder input

What questions would be most helpful for this study to answer?

What feedback do you have on inputs and assumptions?

Detailed inputs and assumptions to be presented March 30.
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