New York ISO
Independent System Operator

Day Ahead Network Constrained Unit Commitment Performance

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Agenda

- New York's Day Ahead (SCUC) Structure
- Evolution of NYISO's Network Constrained Unit Commitment (NCUC)
- Current Challenges
- Summary
- Q&A

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Background and Day Ahead SCUC Structure

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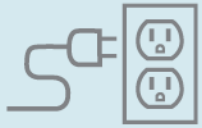
NYISO by the numbers

19.8M
New Yorkers served

NYISO Footprint

435
Market Participants

11,173
circuit miles of transmission managed and monitored



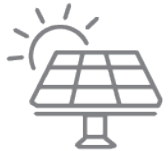
161,114
total electric energy usage, in GWh, for 2018

Supply & Demand

33,956
record peak demand, in MW, July 2013

700+
power generating units

26%
of electric energy from renewables in 2018



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Simplified Day Ahead SCUC Structure

- **Bid Pass**
  - Solves to the bid load including all price-capped load and virtual transactions.
  - Purely network security economic pass
- **AMP Pass I & II (Trigger and Impact)**
  - For Constrained Area (NYC) reference curves are used to evaluate BID pass results for conduct and impact
- **Forecast Pass**
  - Starts with BID/AMP pass results, excludes virtual transactions
  - Only start-up and min-gen costs are included, incremental energy is very inexpensive
  - Solves to NYISO load forecast, ensures capacity to meet load
  - Non GTs turned on will be on in final Re-Dispatch
- **Re-Dispatch Pass**
  - Restores bid/mitigated curves where appropriate
  - Sets final schedules and prices

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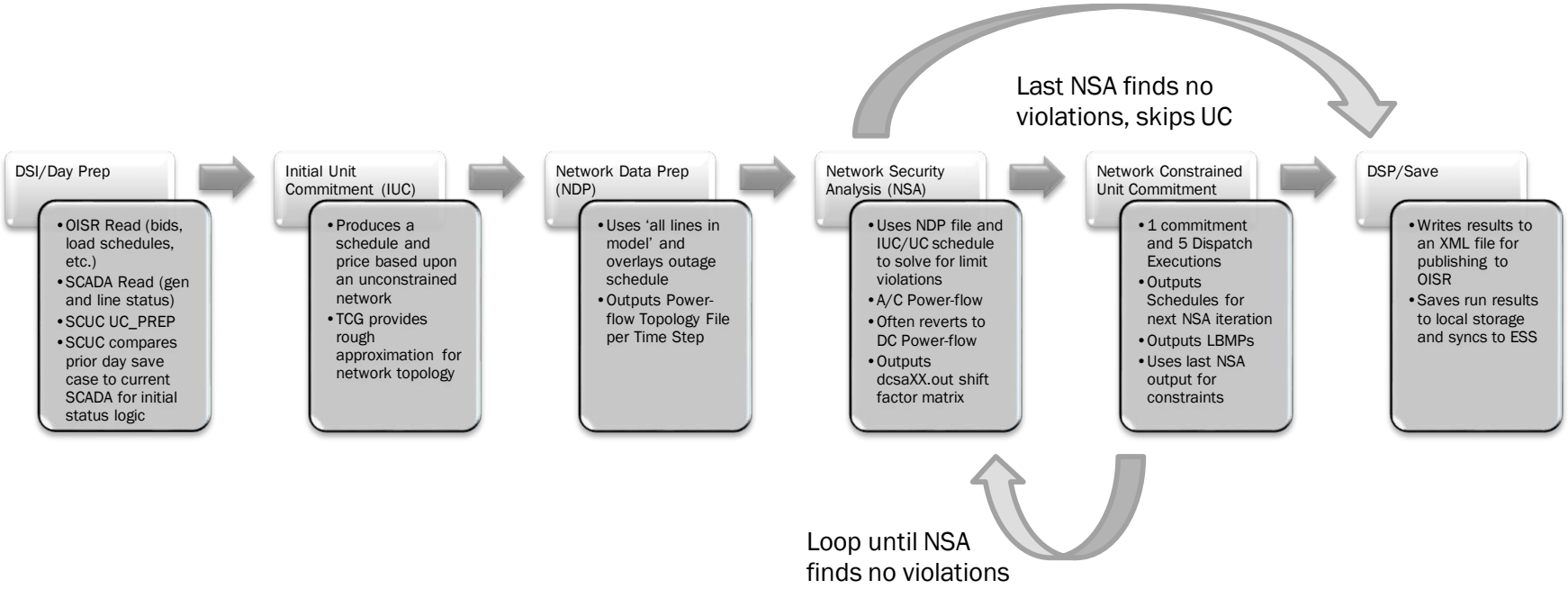
Bid Pass Breakdown



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Iterative Unit Commitment program

- **Iterative Process**
  - Network Security Analysis (Power Flow)
  - Network Constrained Unit Commitment (NCUC)
- **NCUC Itself is Multi-Pass**
  - Unit Commitment runs first and determines on/off status
  - First and Second Ideal Linear Programs (LP) determine LBMPs
  - First, Second, and Third Physical LP/Mixed Integer Linear Programs (MILP) determine physical basepoints.

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Evolution of NCUC 1999-2020

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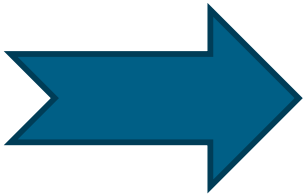
NCUC algorithmic evolution

- **Lagrangian Relaxation (LR)**
  - 1999 to 2014, LR was the optimization methodology used.
  - Lagrangian relaxation is a relaxation method which approximates a difficult problem of constrained optimization by a simpler problem. A solution to the relaxed problem is an approximate solution to the original problem and provides useful information.



- **Mixed Integer Linear Programming (MILP)**
  - Improved Performance
  - Ability to model non-convex constraints
  - Leverage continuous performance improvements in Gurobi
  - Large community of optimization experts

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Continuous Growth and Challenges

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ESR is Especially Challenging

- Must account for negative and positive schedules
- Intertemporal Ramp Constraints
- State of Charge (SOC) Optimization with efficiency factors
  - Five Economic Dispatch LPs became MILP
- Initial modelling attempts produced very long run times

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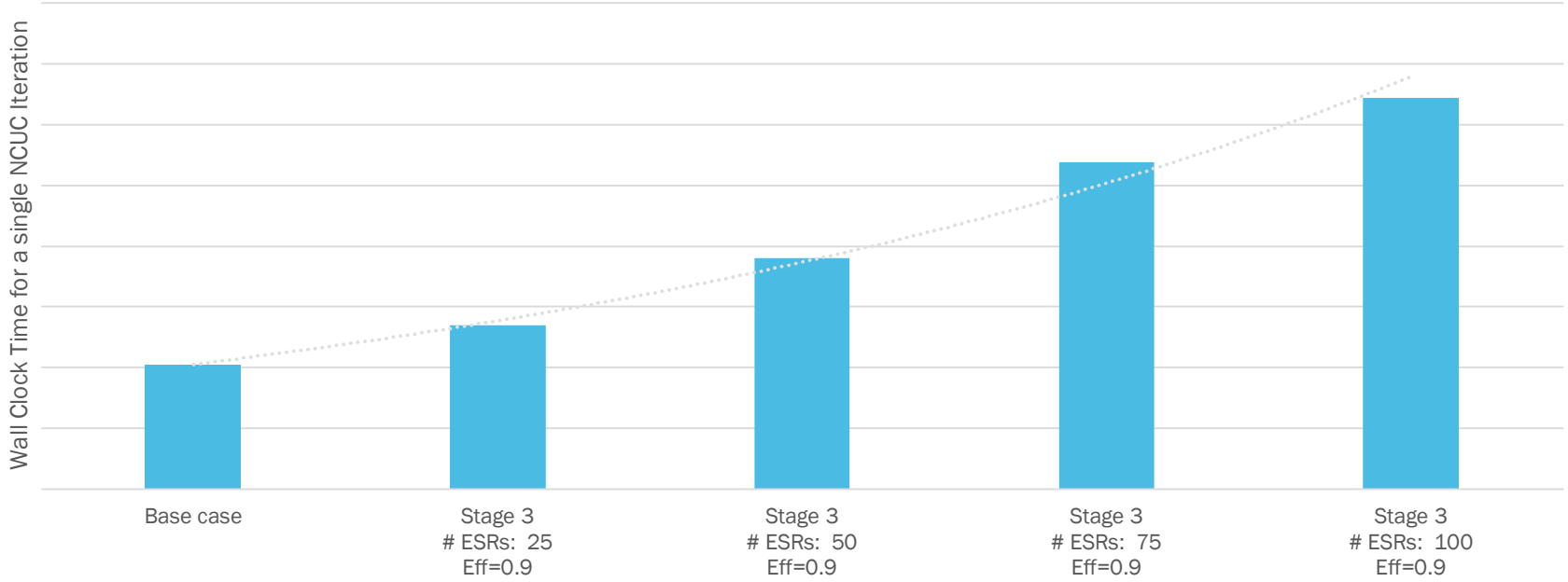
Complex models are challenging to scale



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Simplified ESR Model

- Interconnection queue only contains lithium ion storage which physically supports continuous dispatch from negative to positive, no dead-band around 0MW.
- Simplified model as ternary model added computational complexity
- Extended current modelling for unit commitment and first and second economic dispatch executions to use average ramp rates rather than introduce non convexity of up to six units for ramp segments

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Not Just ESR – New Technologies Introduce Complexities

- Intertemporal Constraints
- Volume of Units
- Many Smaller Units
- Modelling of Units
  - Ternary modeling of units (Charing, Off, Injecting)
  - Four Combinations - Combined Cycle, similarly, is nonconvex
- Intermittency challenges of forecasts

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Continued investment solves problems

Hardware and software

- **Continually improving**
  - AMD EPYC and Gurobi 9 have produced large gains
  - Multithreading of MIP and LP (Branch and Bound, Barrier vs Dual-Simplex)
  - Focus on the entire solution process rather that just unit commitment

Vendor partnerships

- **Smarter modeling, improved constraints**
  - Working with ABB, NYISO internal resources and others on innovative modeling with focus on methods suitable for parallelization
  - So far in 2020, efforts have resulted in four times more ESR units being able to be supported than originally anticipated

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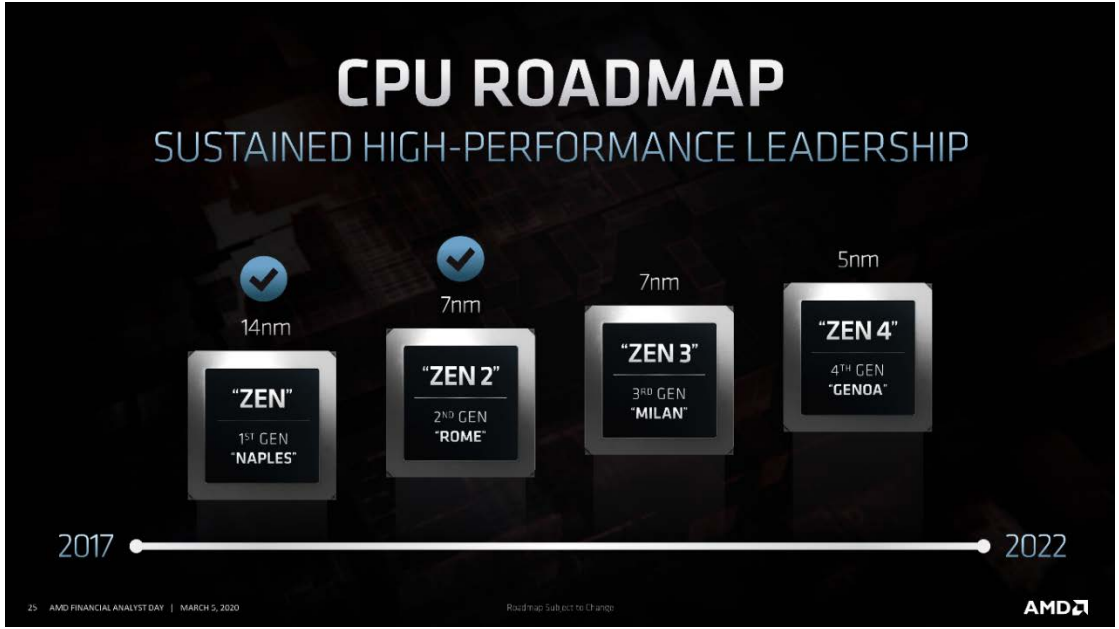
Hardware and Software

- Since 2017 core counts have exploded from 18 to 64.
- NYISO deployed 32 Core Naples and Gurobi 8.1 in February 2020
- Already evaluating 32 Core ‘Rome’ and Gurobi 9
- Targeting 2021 deployment of ‘Milan’ and Gurobi 9.x, expecting 100% performance uplift



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Successes

- The NYISO continues to broaden participant base and access to the energy markets
- Performance requirements and timeliness have improved
- Producing higher quality of solutions with more precise modeling and more accurate algorithms

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Questions?

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Our mission, in collaboration with our stakeholders, is to serve the public interest and provide benefit to consumers by:

- Maintaining and enhancing regional reliability
- Operating open, fair and competitive wholesale electricity markets
- Planning the power system for the future
- Providing factual information to policymakers, stakeholders and investors in the power system

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