Managing Variability with High Fidelity Capacity Expansion

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Agenda

1. **Review of capacity expansion concepts and challenges**
2. **Improvements in computational performance and fidelity**

Capacity Expansion Concepts and Challenges

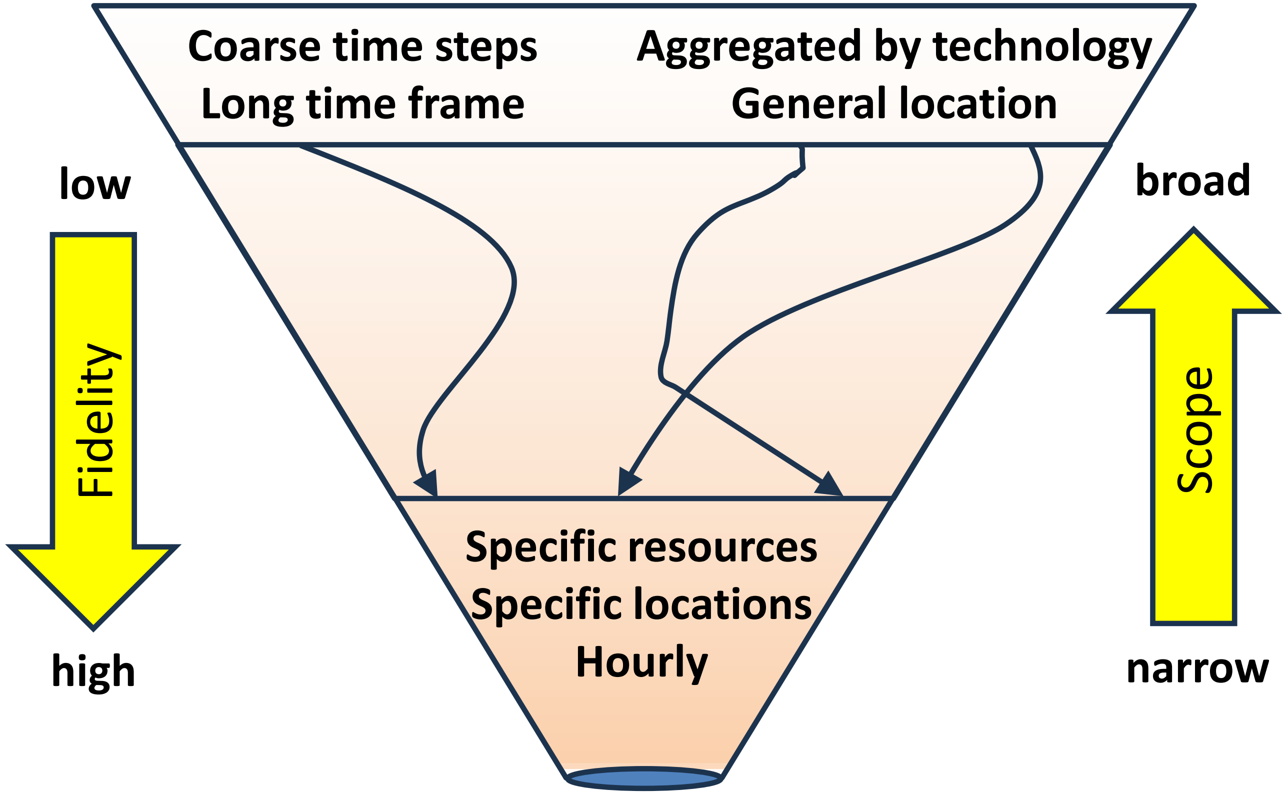
The Challenge of Capacity Expansion

Goal: Evaluate investments in new resources and retirement of old resources decades into the future.

This requires use of multiple models with varying detail:

- **Specific resource or aggregates**
- **Hourly chronology or simplified**
- **Nodal, zonal or copper plate**
- **Multi-area or single area**
- **Full market or single asset/corp.**
- **With or without other systems**

Universe of options:
generation, transmission, distribution,
customers, adjacent energy systems



Detailed decisions
what — when — where

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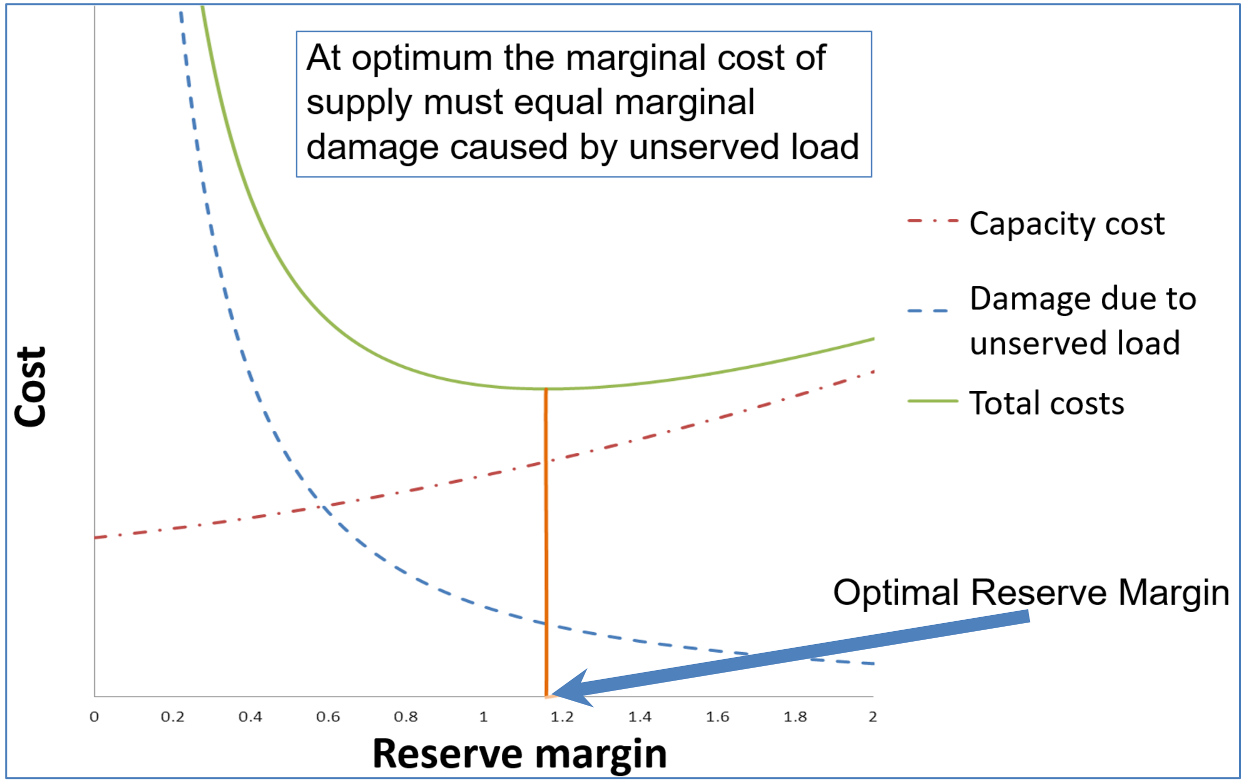
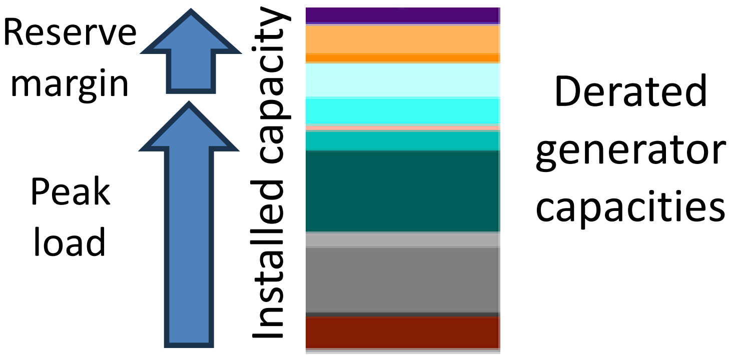
Determining the Optimal Level of Installed Capacity





Traditional Approaches Include

- Economic modeling simplified using reserve margin and capacity factors
- Reserve margin determined by simple metrics (1d in 10y) w/o economics
- Rated generation capacity stacked to meet Reserve Margin
- Limited subproblems focused on pre-defined critical events
- Little or no accounting for system flexibility and needs
- Ignored resource details, transmission, adjacent systems, …

Capacity Expansion Performance and Fidelity

Incorrect Assumptions

Assumptions about capacity expansion (CX):

- **Need capacity reserve margins and resource capacity factors (or ELCC)**
  - Arbitrary and administratively determined needs and capabilities
  - Inaccurate beyond the near-term (e.g., next year)
  - Only known after capacity expansion decisions have been made
- **Can't handle detailed system models**
  - Transmission modeled using zonal models
  - Lack of operational detail: Costs, constraints, ancillary services
- **Can't model long-duration storage without modeling full chronology**
  - Can't co-optimize LDS with other system resource

Performance: MAIN MESSAGE

Tools support detailed planning

… however, business processes are outdated and based on incorrect assumptions about what is possible.

As a result, current planning efforts

1. **Provide an inaccurate guide to future conditions**
2. **Are too hard to execute**

Overcoming Limitations

CX models span decades into the future

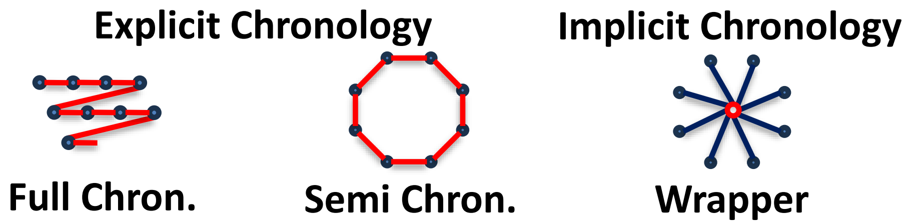
- Impractical to solve with hourly granularity
- How we model chronology is the critical decision

Need to simplify representation of chronology

- Model variability without all hours and historical weather years
- Standard approach is to use a range of scenarios (representative day/week)

Advanced representation of chronology

- Model impacts of chronology without traditional hour-to-hour constraints



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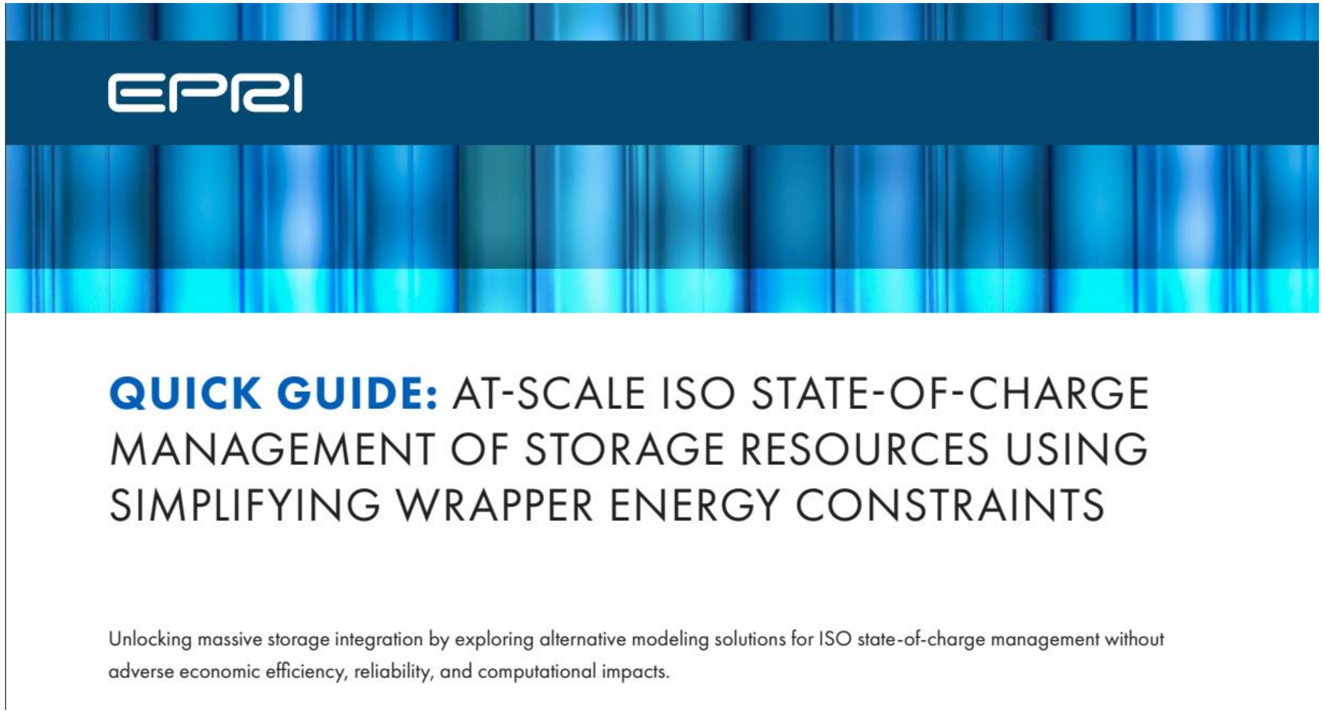
Example: New Approaches

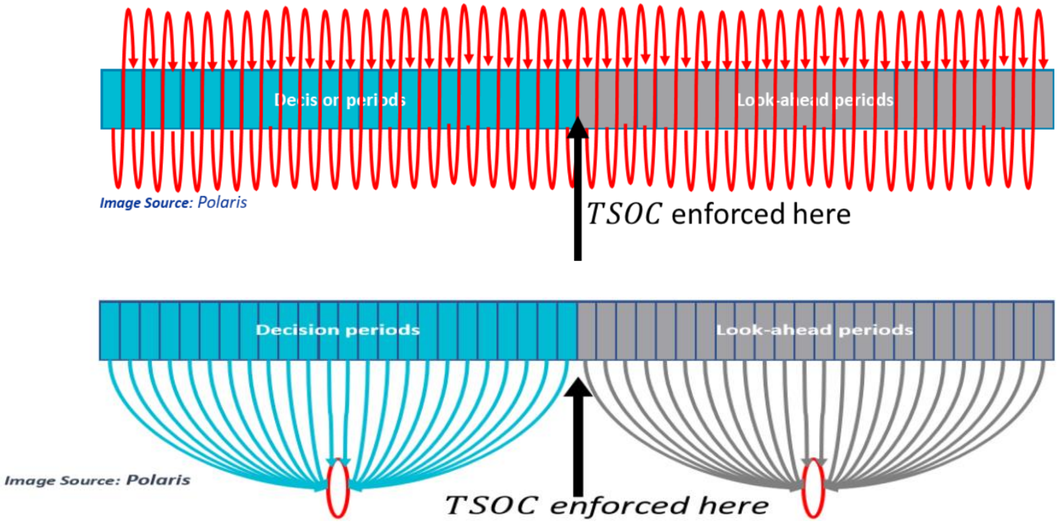


QUICK GUIDE: AT-SCALE ISO STATE-OF-CHARGE MANAGEMENT OF STORAGE RESOURCES USING SIMPLIFYING WRAPPER ENERGY CONSTRAINTS

Unlocking massive storage integration by exploring alternative modeling solutions for ISO state-of-charge management without adverse economic efficiency, reliability, and computational impacts.

- **Goal**: Enable at scale state of charge management by ISO markets
- **Outcome**: Demonstrated computational benefits of simplified state-of-charge management

Concept: Alternative formulation of chronology



W. Aslam, N. Singhal, E. Ela, and R. Philbrick, At-Scale ISO State-of-Charge Management of Storage Resources Using Simplifying Wrapper Energy Constraints. EPRI, Palo Alto, CA: 2023. 3002026964. [Online]. Available: https://www.epri.com/research/products/000000003002026964

Zonal vs Nodal Modeling

Common assumption: Capacity Expansion (CX) cannot include power flow

- Too many power flow states based on usual models of chronology

Impact of zonal models

- Need to define zones, but congestion impacts are dynamic
- Need to define zonal interchanges, but this underutilizes transmission
- Need to map zonal results to power flow
- Need to manage multiple inconsistent data sets
- Need staff to understand and manage diverse and inconsistent tools

Solution: Reduced-state representation and efficient DC power-flow models

- Avoids limitations of zonal models
- Enables new applications: Optimal Transmission Expansion

Case study: high electrification long-term decarbonization pathway scenario for the Northeast

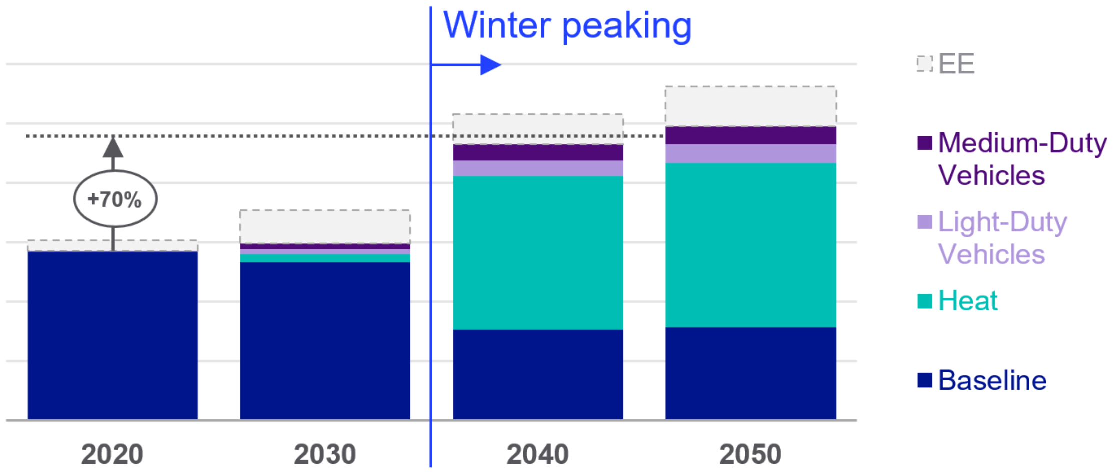
We demonstrate our approach to co-optimizing Tx and generation on a long-term decarbonization scenario

Key scenario inputs

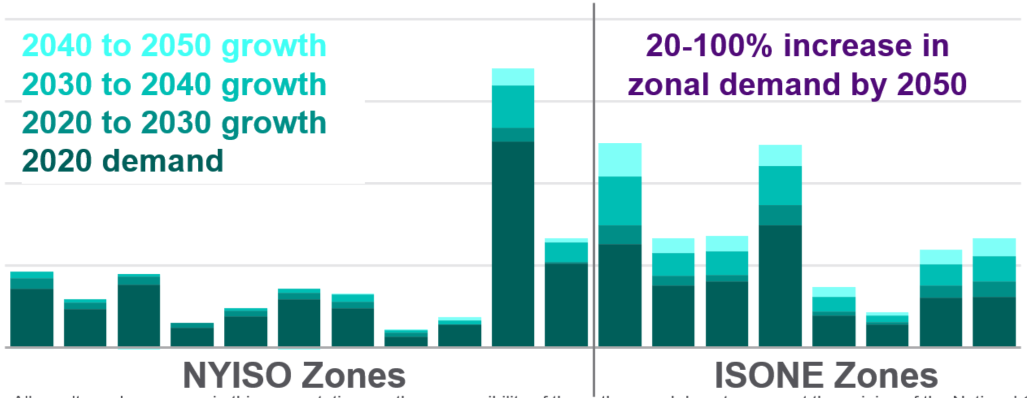
- **100% electrification** of light-duty vehicles and building heat by 2050 substantially increases electricity demand and switches system to winter peaking by 2030s
- Policy requirement for electric supply to be **100% clean in NYISO by 2040 and in ISONE by 2050**
- **OSW targets met on schedule** for Northeast states
- Technology costs for renewables and storage decline substantially out to 2050

Simulation projects expansion of Northeast supply and Tx over the 2021-2050 time horizon at a zonal level, subject to policy, capacity, power balance, and operating constraints

Scenario Northeast electric peak by component & year (GW)



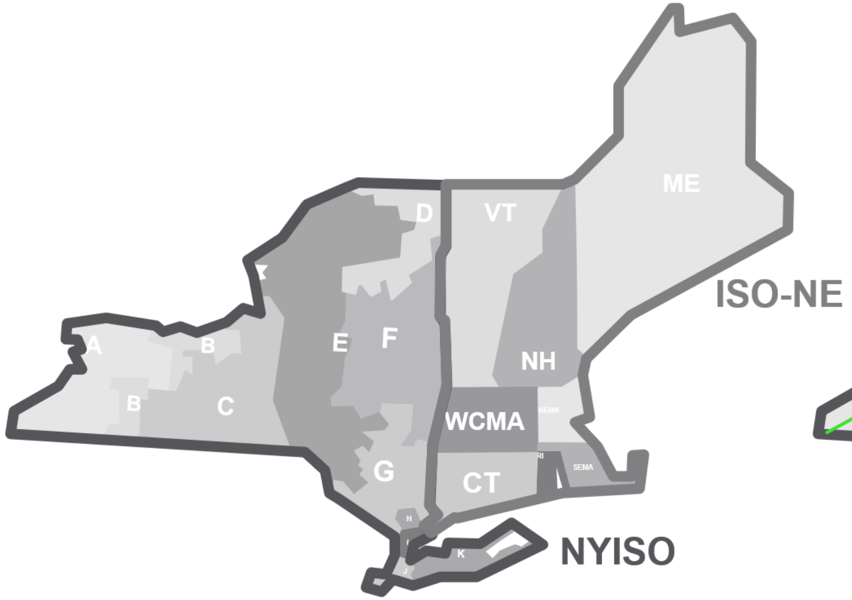
Scenario Northeast zonal energy demand growth by decade (TWh)



We analyze outcomes in the scenario under three representations of the transmission system

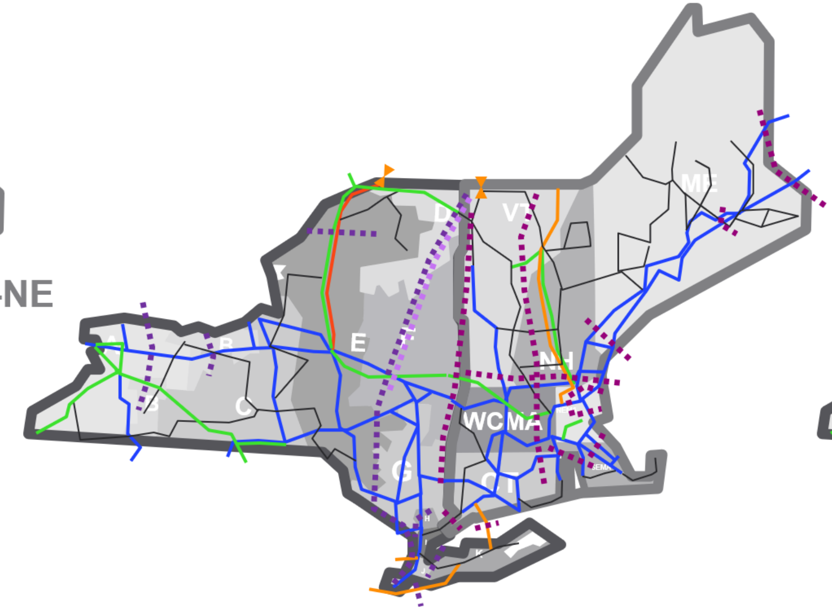
[a] Not Tx Constraints ("copper sheet")

What is the "ideal" supply mix under the scenario assumptions?



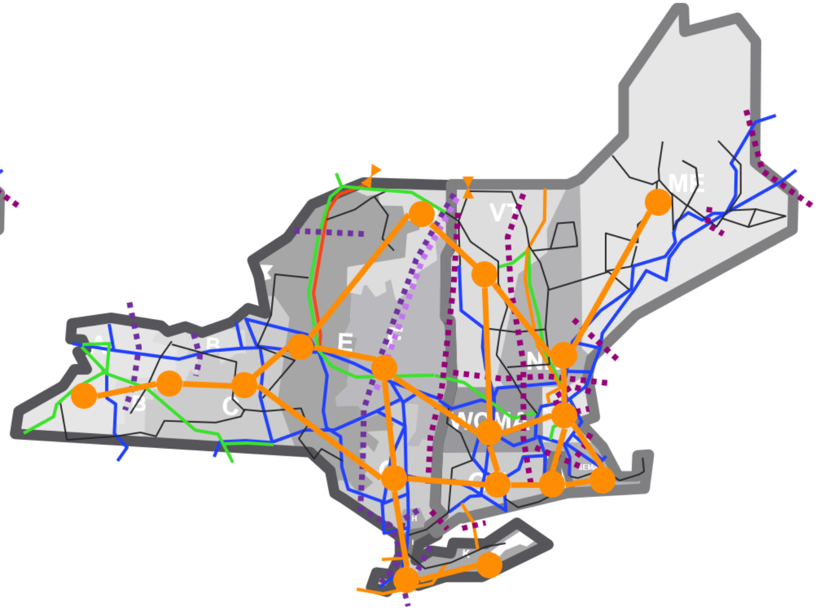
[b] Tx Constraints (but no Tx builds)

How is the "ideal" supply mix impacted by transmission bottlenecks?

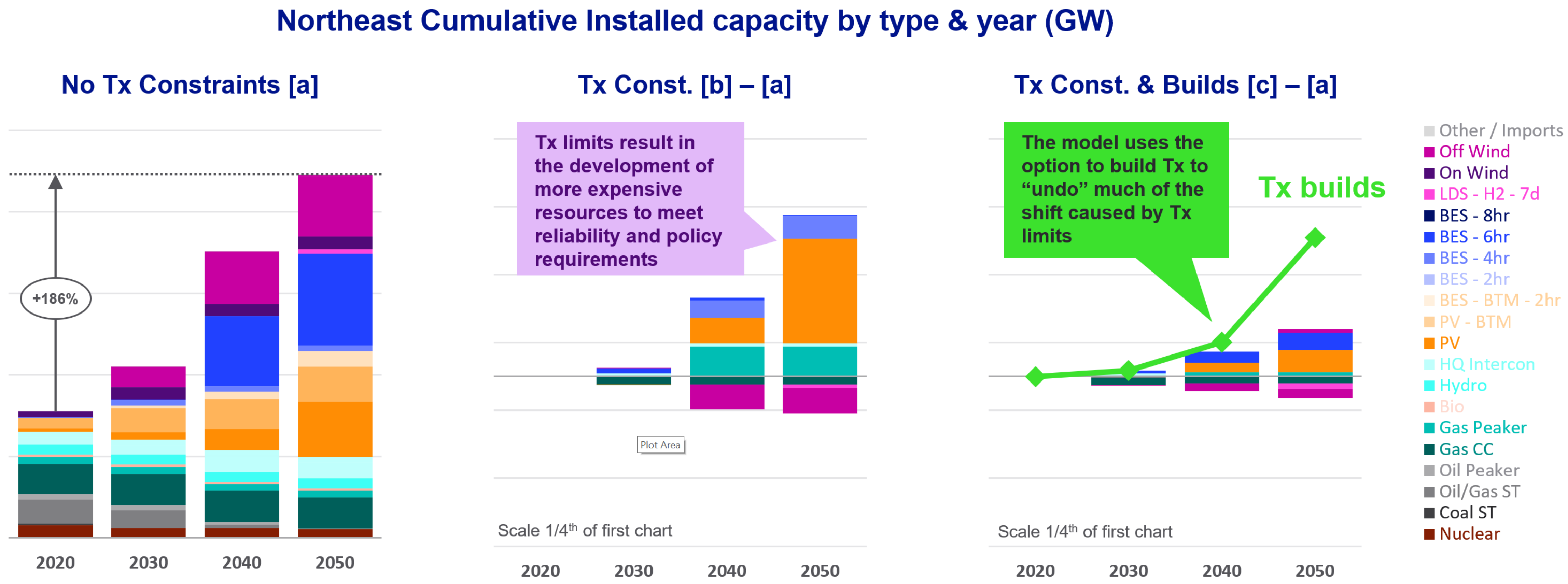


[c] Tx Constraints & Tx builds

How does co-optimizing Tx builds with supply impact the mix?



The option to build transmission result in a supply mix similar to that in the "copper sheet" case

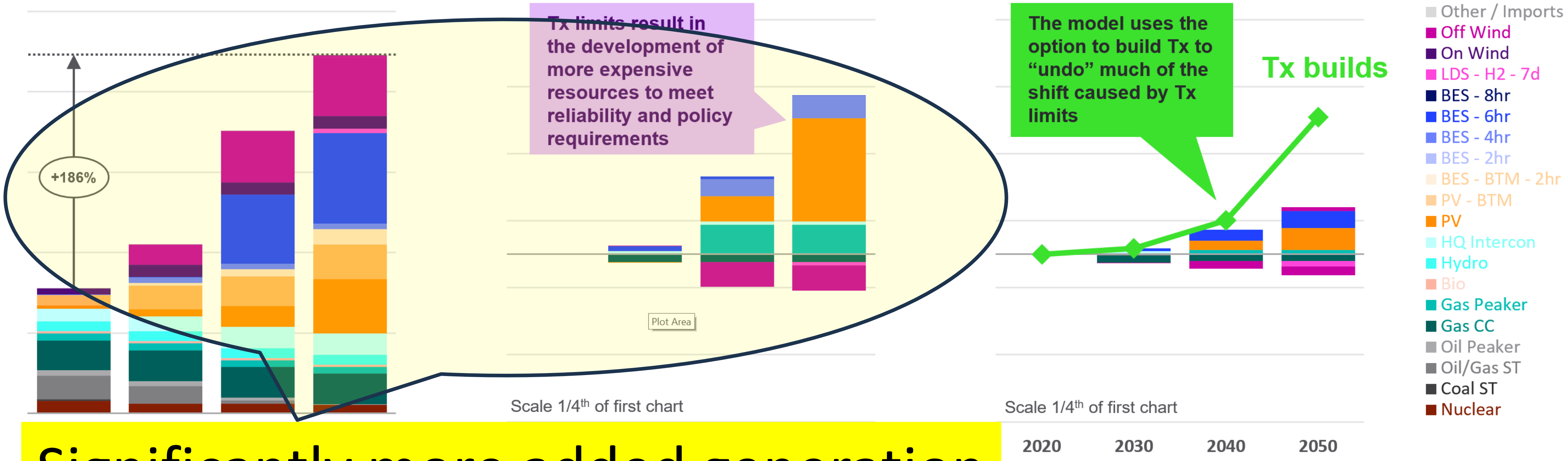


- A near tripling of installed capacity needed to meet capacity, energy, & policy requirements out to 2050
- Imposing transmission constraints displaces offshore wind with onshore resources to meet localized needs
- As we might expect, allowing builds reduces the impact of transmission constraints, resulting in a more "optimal" mix

The option to build transmission result in a supply mix similar to that in the “copper sheet” case

Northeast Cumulative Installed capacity by type & year (GW)

No Tx Constraints [a] | Tx Const. [b] – [a] | Tx Const. & Builds [c] – [a]



Significantly more added generation when transmission is considered

- A … we might expect, allowing builds
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The option to build transmission result in a supply mix similar to that in the “copper sheet” case

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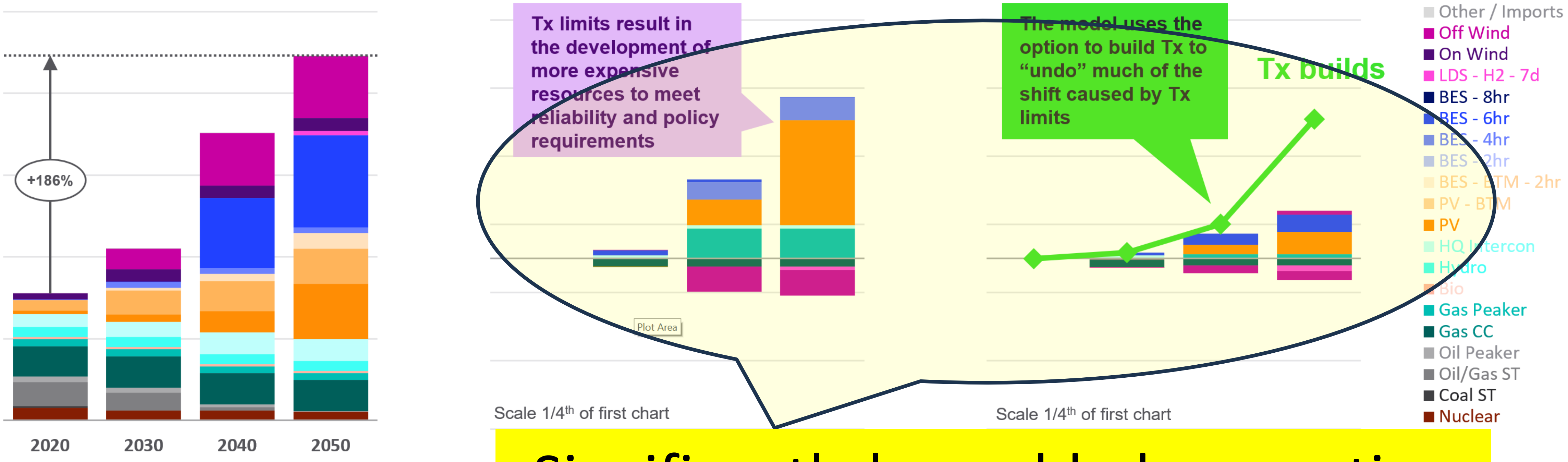

- A near tripling of installed capacity needed to meet capacity, energy, & policy requirements out to 2050
- Imp
dis
res

Significantly less added generation with ability to build transmission

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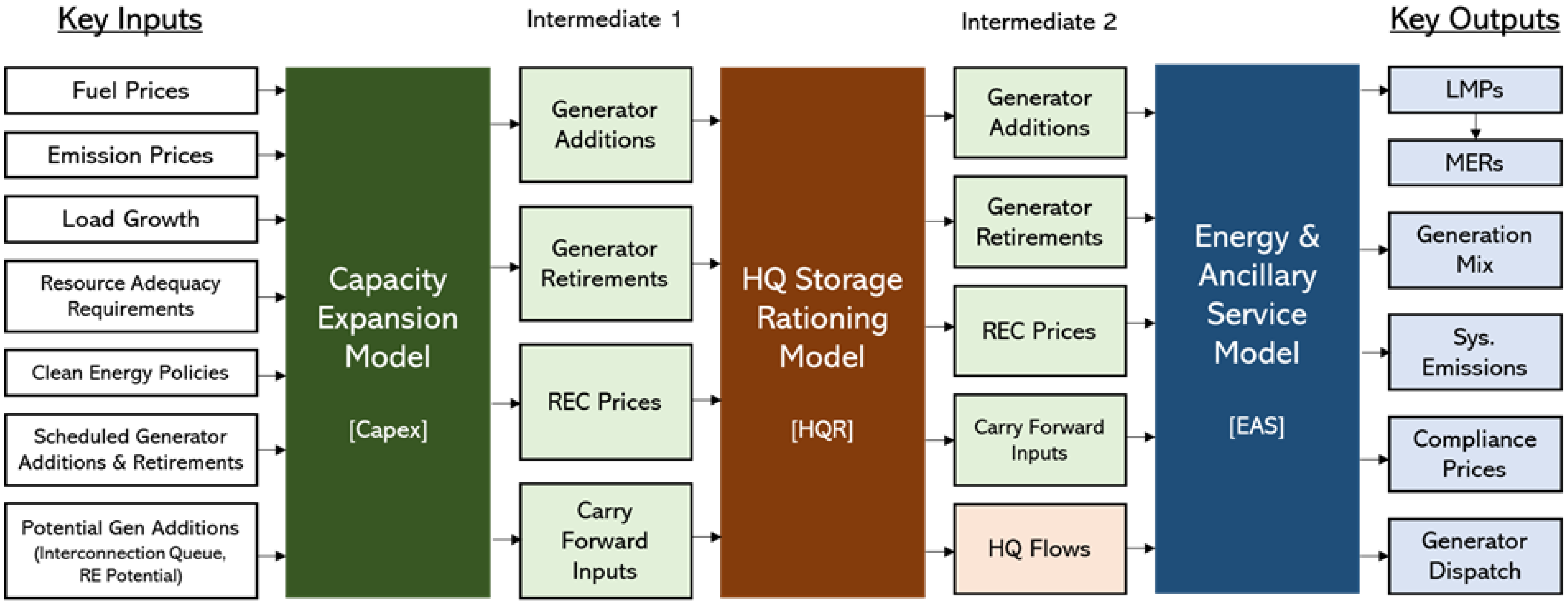
Example: Hydro Quebec LDES service to New England



Additional benefits of detailed CX models:

- Accurate impacts from a changing mix of flexible, variable and base-load generation
- Dynamically define capacity contributions without ELCC or other metrics
- Define reliable resource mix without the “safety net” of capacity reserve margins

Current Gaps

Though we can apply CX to high-fidelity models, work still remains:

- Data on the cost of scarcity
  - Quit treating load as a monolithic and unresponsive participant
- Getting operations into planning
  - Planners that understand operations
  - Planning that incorporates operational data, details and practices
- Coordination between economic tools and reliability tools
  - Quantify and optimize ancillary services (e.g., inertia, fault current)
- Simulation of other energy systems
  - Gas network constraints and impacts on power systems
  - Flexibility from integrated energy systems (heat, transportation, load)
  - Potential for new fuels (H2, NH3, CH4) to support long-duration storage

Summary

Models are excessively simplified

- Presentation focused on simplifications using zonal models, but impacts also from simplifications applied to models of
  - Ancillary-services requirements
  - Resource flexibility and ability to provide ancillary services
  - Resource costs and efficient resource mix to achieve reliable operations
  - Long-duration storage (including fuels, emissions and policy requirements)
  - Adjacent energy systems (gas networks, heat, fuel conversion)

Modeling is too hard

- Simple approaches create challenges
  - Impacts on data, people, process

Perspective