Co-optimizing Planning of Generation & Transmission

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nationalgrid

Presentation Overview

Motivation: *why do we want to co-optimize generation and transmission planning?*

Approach: *how do we propose to accomplish it?*

- Transfer capability as a physical transaction
- Implementation example

Case study: *what does this look like in practice?*

- Description of study
- Key results
- Computational performance impacts

Conclusions: *what are the lessons learned and applications of this work?*

Appendix: *additional details on underlying model*

Motivation

The US electricity sector is in the midst of an accelerating transition

Decarbonization policy and supply economics are transforming the electric landscape

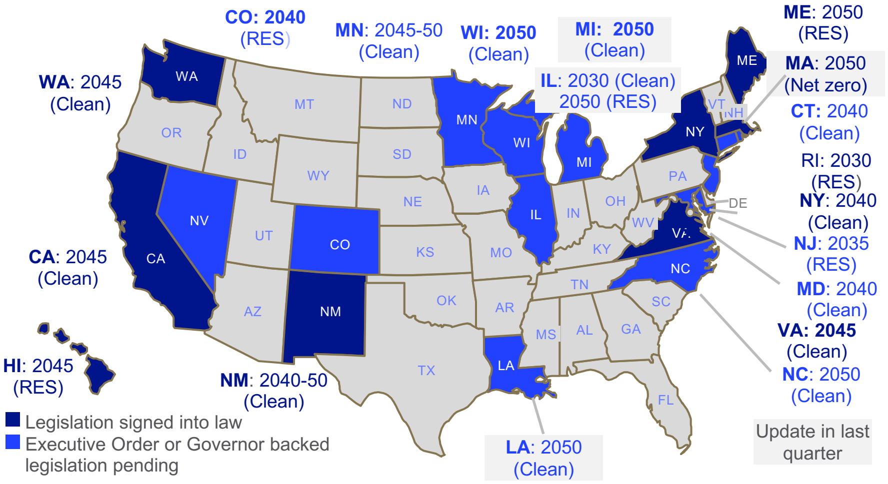
- More than 20 states currently have mandates or goals to get 100% of their energy from clean sources by 2050
- Onshore wind and solar plants have been the largest sources of new generation capacity in recent years
- Offshore wind commitments have grown to >30 GW by 2035
- Electrifying transport and buildings is pickup up steam as a principal approach to decarbonizing those sectors

Adapting to this new reality will require substantial additional generation and transmission

- Interconnect renewable generation areas and load centers
- Connect offshore wind into the grid
- Reinforce the existing grid to adapt to changing generation mix and load patterns, including electrification

Understanding the tradeoffs between transmission and generation in planning is critical for efficiently meeting this challenge

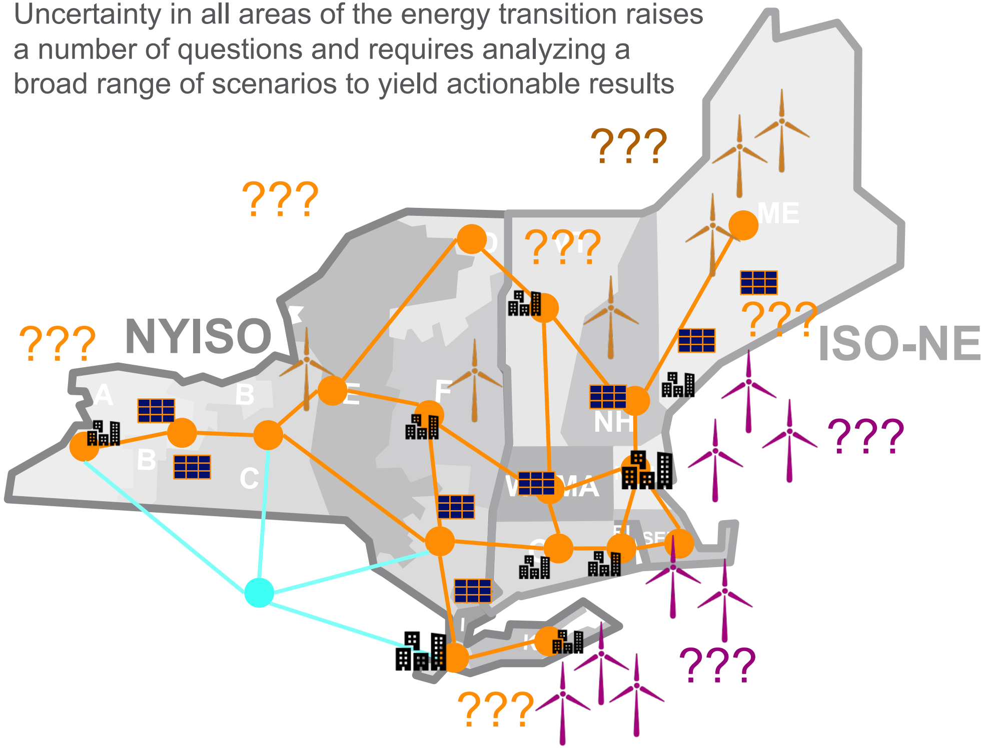
Anticipated or Enacted 100% Clean Energy Legislation



Note: Clean Energy standards generally allow for nuclear, CCS and large hydro to count towards targets, while Renewable (RES) targets generally do not. Washington DC and Puerto Rico which also have established 100% clean energy targets
Sources: NG US Market Fundamentals.

Our goal with this work is to demonstrate a tractable approach to co-optimizing generation & transmission for longer-term planning

Uncertainty in all areas of the energy transition raises a number of questions and requires analyzing a broad range of scenarios to yield actionable results



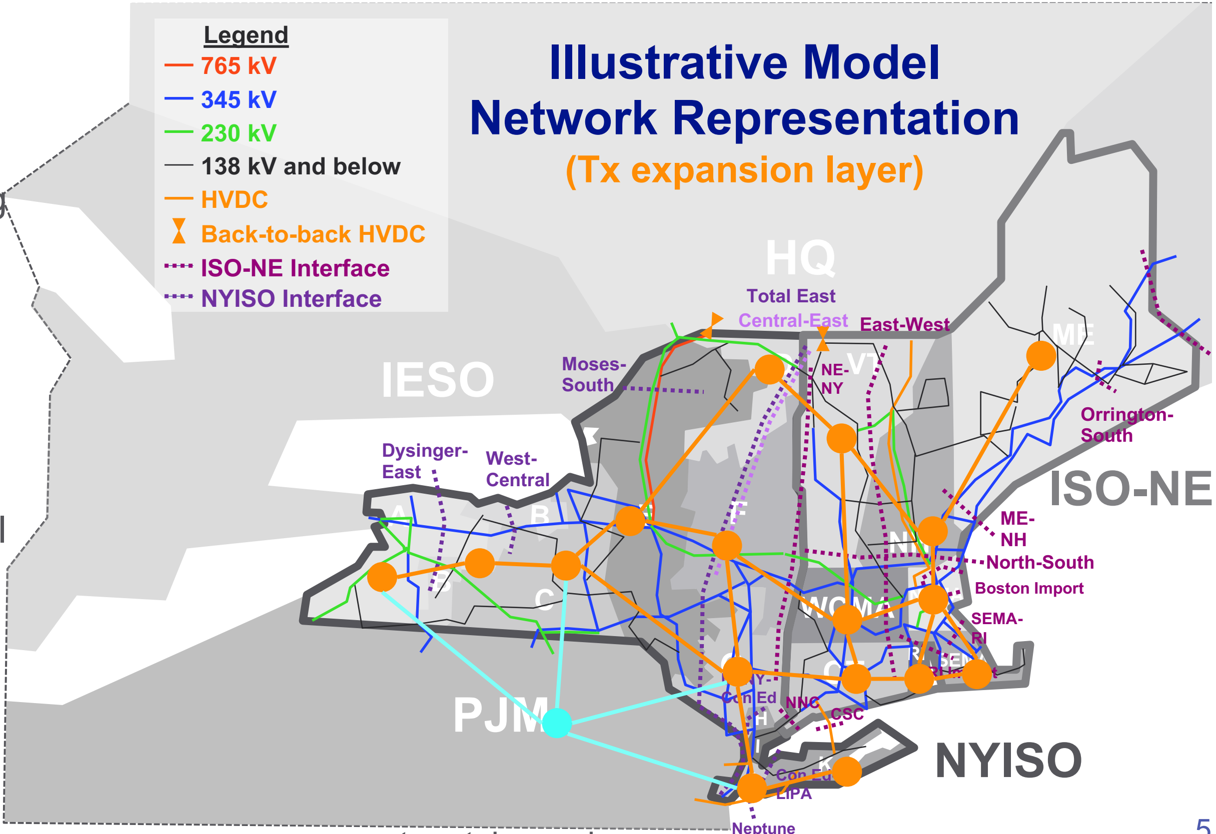
We sought an approach that would enable us to begin to answer key planning-related questions, such as:

- **Where & when** will Tx needs emerge?
- **How big** will those needs be & how much will they cost?
- **How do needs vary as outlooks / assumptions change** (e.g., level & geographic distribution of electrification)
- What is the most **complementary balance of new generation and new transmission** in each outlook?
- **Where should we focus** efforts for more in-depth analysis (e.g., power flow studies)?

Our approach leverages the capacity expansion module of the Enelytix/PSO platform

- The capacity expansion model provides a highly flexible and granular generation capacity expansion backbone*, including a DC network representation
- Existing Tx constraints captured in model, but limits on transfers are an input
- We layer on **a network of physical transactions** that provide the option for the model **to dynamically increase transfer capability between areas** in the system (at a cost)

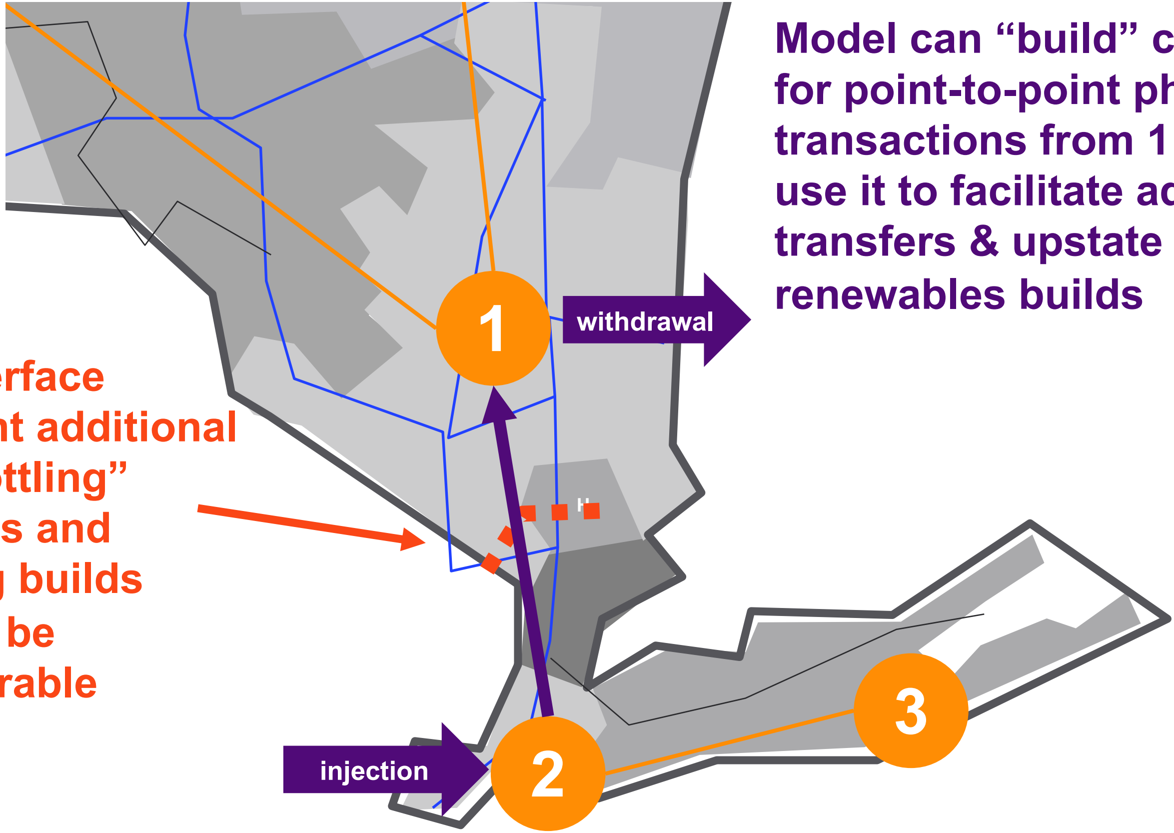
**additional details on the Enelytix/PSO platform and capacity expansion model in appendix*



This approach offers a number of advantages over more conventional approaches, such as a “pipes-and-bubbles” expansion model

- Leverages the physics-based (nodal) representation of the transmission system
- Captures impacts of new transmission on existing transmission (e.g., doesn’t allow new Tx to cause overloads on existing Tx)
- Flexible implementation supports modeling of Tx expansion at multiple levels, from zonal down to individual facilities
- Can integrate with other features of the model impacting physical flows, such as interface definitions and transmission nomograms

Example: upstate NY renewables for downstate NY load



Model can "build" capability for point-to-point physical transactions from 1 to 2 and use it to facilitate additional transfers & upstate renewables builds

Binding line & interface constraints prevent additional flow into NYC, "bottling" upstate renewables and potentially limiting builds below what would be economically desirable

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

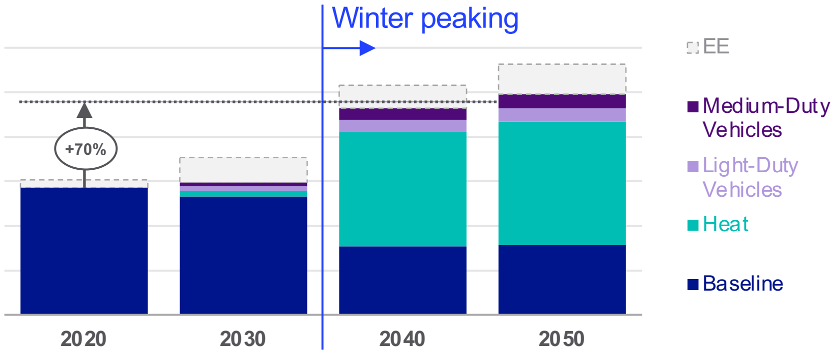
We demonstrate our approach to co-optimizing Tx and generation on a long-term decarbonization scenario

Key scenario inputs

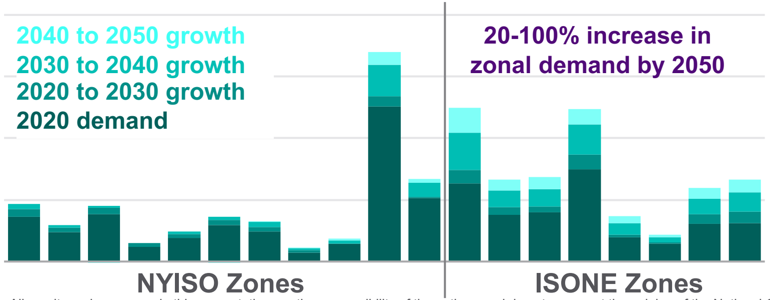
- **100% electrification** of light-duty vehicles and building heat by 2050 substantially increases electricity demand and switches system to winter peaking by 2030s
- Policy requirement for electric supply to be **100% clean in NYISO by 2040 and in ISONE by 2050**
- **OSW targets met on schedule** for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

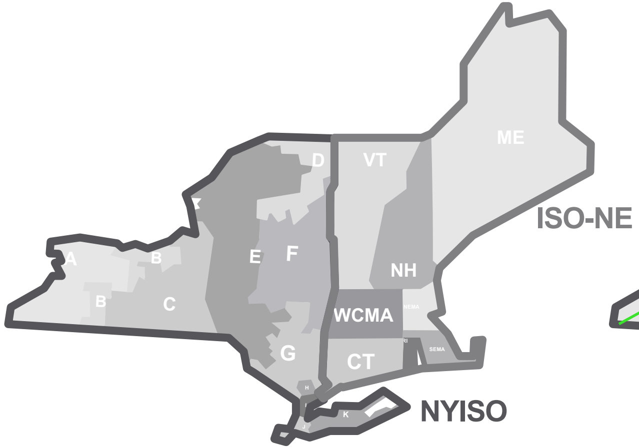


Case Study

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

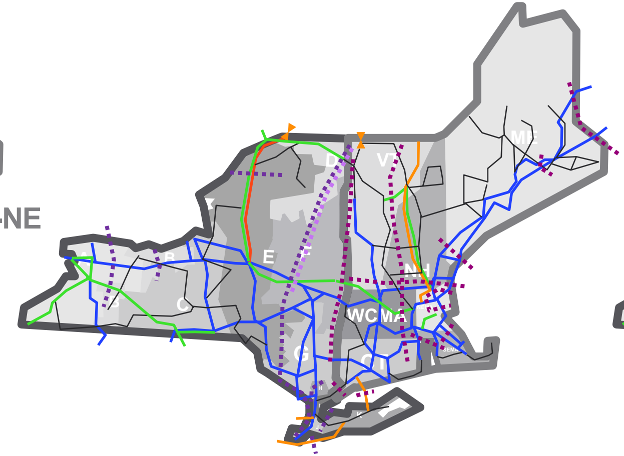
[a] Not Tx Constraints ("copper sheet")

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



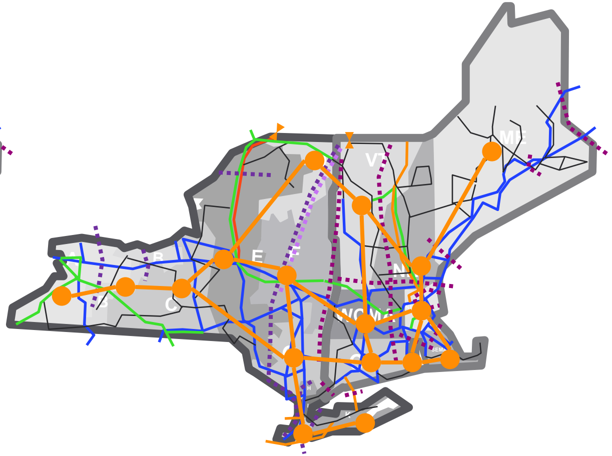
[b] Tx Constraints (but no Tx builds)

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



[c] Tx Constraints & Tx builds

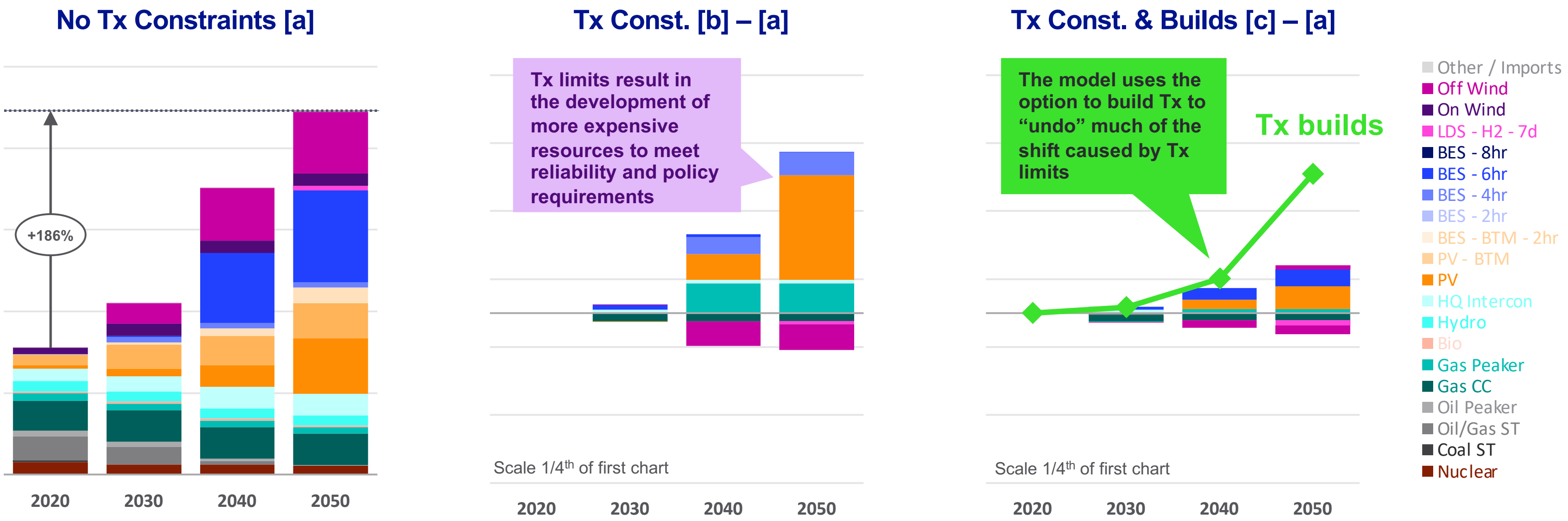
How does co-optimizing Tx builds with supply impact the mix?



Case Study

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)



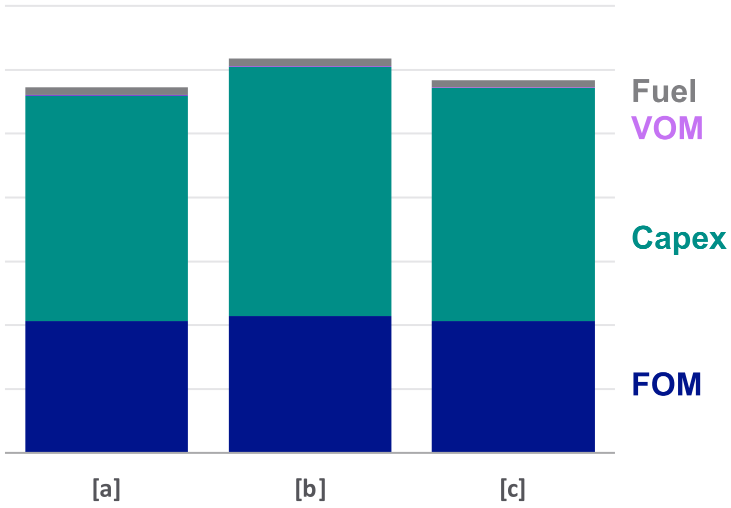
- A near tripling of installed capacity needed to meet capacity, energy, & policy requirements out to 2050
- Imposing transmission constraints displaces offshore wind with onshore resources to meet localized needs
- As we might expect, allowing builds reduces the impact of transmission constraints, resulting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

Disclaimer: All results and any errors in this presentation are the responsibility of the authors and do not represent the opinion of the National Grid, Polaris Systems Optimization, or The Newton Energy Group, or their subsidiaries and clients. Results shown herein are indicative based on one of many scenarios of the future that could be considered and are solely intended to illustrate the value of co-optimizing supply and transmission.

Case Study

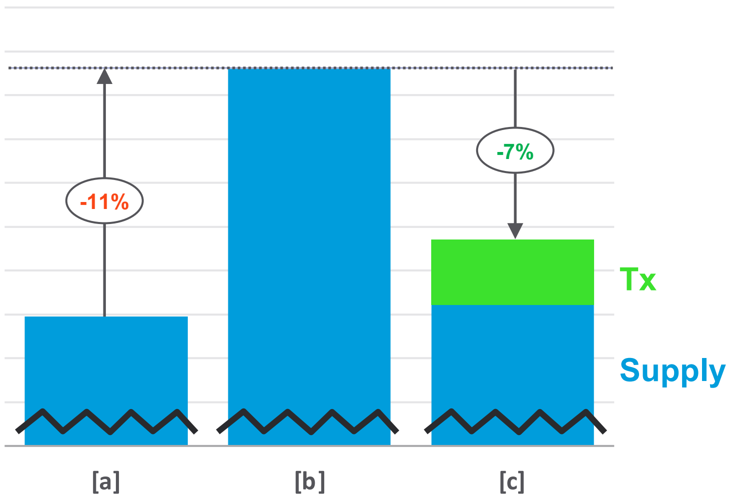
Cost results confirm the "cost-optimal" mix of builds to meet scenario policy requirements is a balance of transmission and supply

2050 Annualized Total Supply Cost by Component ($billion/yr)



- Tx builds principally impact capex, which makes up the majority of supply costs

2050 Cumulative Supply & Tx Capex ($billion)



- A mix of transmission and supply reduces total cumulative capex by around 7% relative to considering supply alone

Case Study

Modeling Tx builds as physical transactions has a modest impact on model size & solution time

Metric (avg. over all solutions)	[a]	[b]	[c]	% increase [c] over [b]
# of constraints	186,644	185,810	187,197	0.7%
# of variables	194,235	193,125	194,342	0.6%
# of non-zeros	713,425	1,048,315	1,066,169	1.7%
Solution time (s)	4.8	51.3	67.8	32%

Note: to focus on just the performance impacts of adding the Tx expansion capability we report performance results for the System Cycle only.

Takeaways

- Our physical-transaction-based approach to co-optimizing generation and transmission is feasible for realistic-size systems over long time horizons
- Using the Enelytix/PSO platform in this way provides an “additional tool in the toolbox” for planners and others seeking to understand the ramifications of the energy transition for system needs
- This coordinated approach simplifies assessing the interplay between Tx and Supply under alternative assumptions (i.e., via sensitivity or scenario analysis)
- Our case studies using the approach provide some preliminary insight on the tradeoffs between building Tx and supply to meet policy:
  - Show that increasing inter-regional transmission exchange has significant value for reducing the cost of meeting policy
  - Highlight the need for onshore transmission buildout to facilitate offshore wind delivery to loads

Speaker bios

Dr. Kai Van Horn

Manager, US Market Fundamentals
National Grid USA

Kai is an expert in leveraging electricity system modeling, analysis, and visualization to illuminate the impacts of the energy transition, and develop and communicate strategic responses. In his current role, he leads a team exploring pathways to deep decarbonization in the northeast and the challenges and opportunities they create for utilities and their customers.

Kai received a Ph.D. in Electrical and Computer Engineering (Power Systems Focus) from the University of Illinois at Urbana-Champaign.

LinkedIn Profile

Dr. Russ Philbrick

Founder & President
Polaris Systems Optimization

Dr. Charles R. Philbrick (Russ) co-founded Polaris Systems Optimization in 2010 to manage the variability and uncertainty of renewable energy with optimization-based decision support tools. He has developed many of the market clearing engines currently deployed in power markets and vertically integrated utilities, including the first commercial deployment of mixed-integer programming (MIP) security constrained unit commitment (SCUC) by the PJM Interconnection in 2004 to support its Day Ahead Market (DAM) and its Reliability Unit Commitment (RUC). A 28 year veteran of the U.S. Navy as a submarine officer, Russ also has several thousand hours experience in direct supervision of nuclear-plant operations.

LinkedIn Profile

Dr. Alex Rudkevich

President & Partner
Newton Energy Group, TCR

Dr. Rudkevich is a mathematician and economist with expertise in modeling power markets, design of power markets, and optimization of power systems and natural gas supply. He has over 30 years' experience in energy economics, regulatory policy, and quantitative analyses of market fundamentals for electric power, natural gas and crude oil production and supply. He designs, directs and manages applied projects and studies involving complex modeling of energy systems with applications to valuation of generation and transmission assets; price forecasting; market design; theoretical analysis of markets for electric energy, capacity, ancillary services, financial transmission rights and analyses of market power and mitigation measures.

LinkedIn Profile

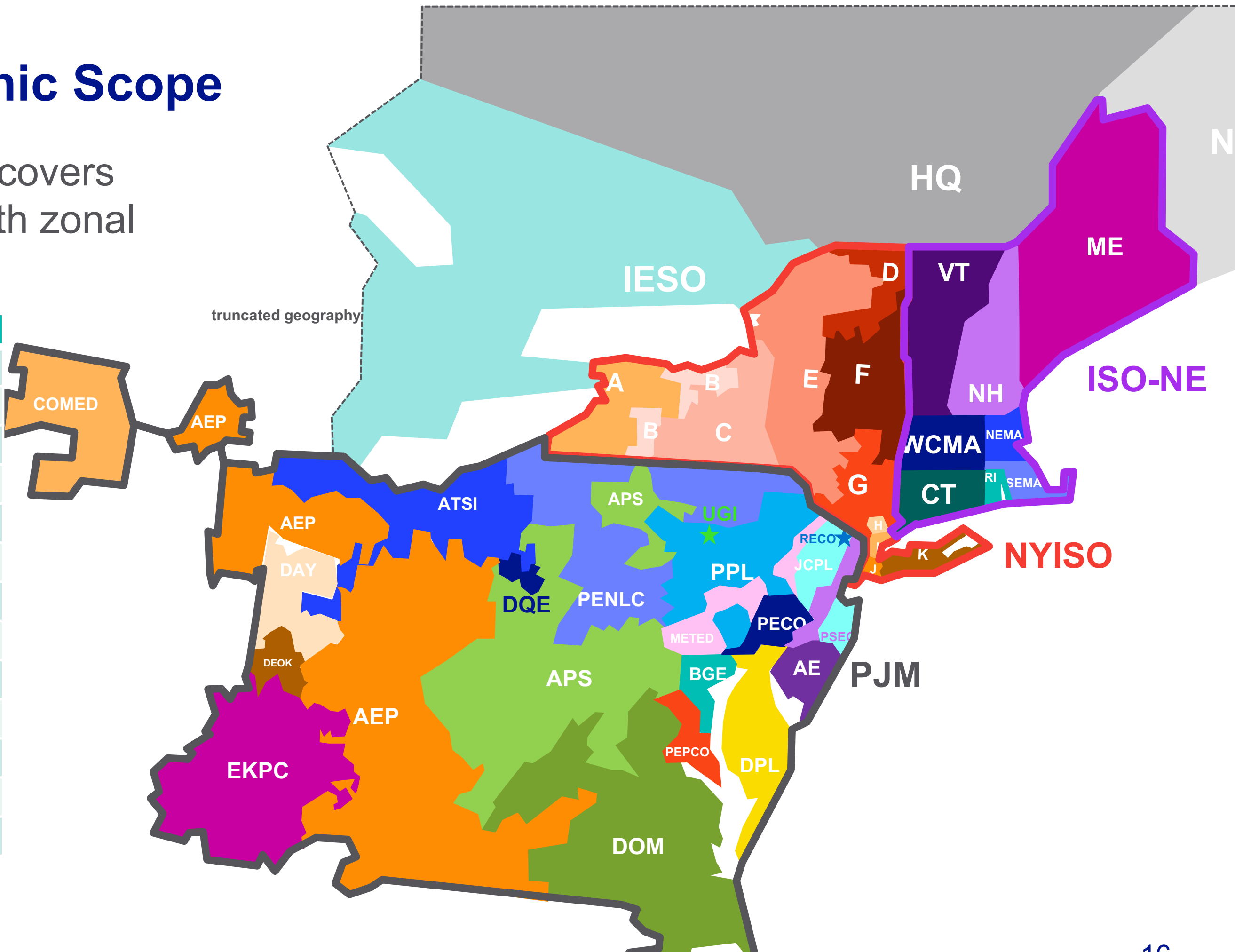
Appendix

Case Study Geographic Scope

Case study modeling scope covers ISONE, NYISO, and PJM with zonal geographic granularity

2020 Stats	ISONE	NYISO	PJM
Peak (GW)	25.3	31.7	152
Energy (TWh)	127	159	788
Miles of Tx	9,000	11,000	84,000
Installed Cap (MW)	39,000	42,000	197,000
PV	14%	7%	2%
Wind	4%	5%	6%
Hydro	10%	14%	4%
BES	0%	0%	0%
Nuclear	9%	10%	17%
Gas	54%	59%	44%
Oil	5%	4%	2%
Coal	2%	0%	25%
Other	3%	1%	1%

Note: PV capacity includes BTM PV



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Capacity expansion configured as a five-cycle, rolling horizon model

Multi-cycle implementation of capacity expansion allows for more computationally efficient modeling of wider geography without sacrificing fidelity

Model “Cycle” configuration

System Cycle
high-level short-term expansion & dispatch for full geography

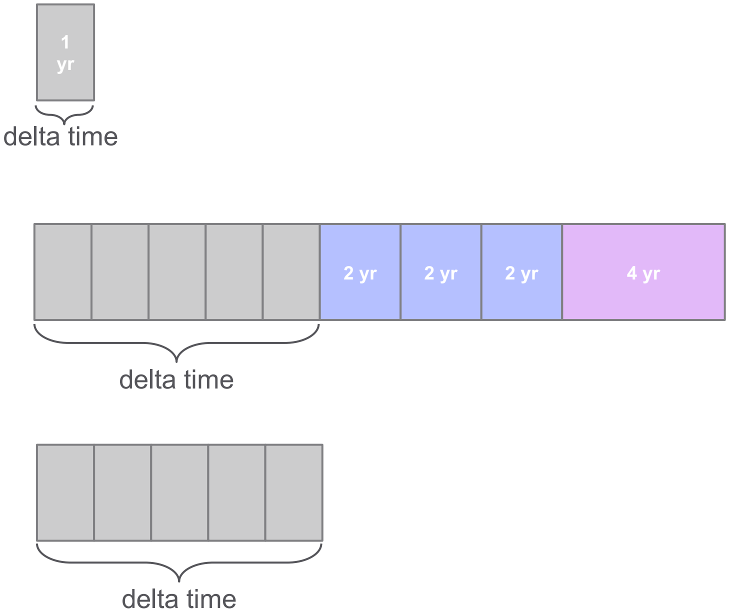
PJM Cycle
Detailed cap. expansion for PJM, holding interchange at system cycle

ISONE Cycle
Detailed cap. expansion for ISONE, holding interchange at system cycle

NYISO Cycle
Detailed cap. expansion for NYISO, holding interchange at system cycle

Dispatch Cycle
final dispatch for full geography, all adds/retires fixed from prior cycles

Look-ahead periods & delta time



Platform for Power Market Modeling

ENELYTIX®
powered by PSO

ENELYTIX® is the advanced power market modeling platform for forecasting, asset valuation, system planning, operational analysis, policymaking, and market design

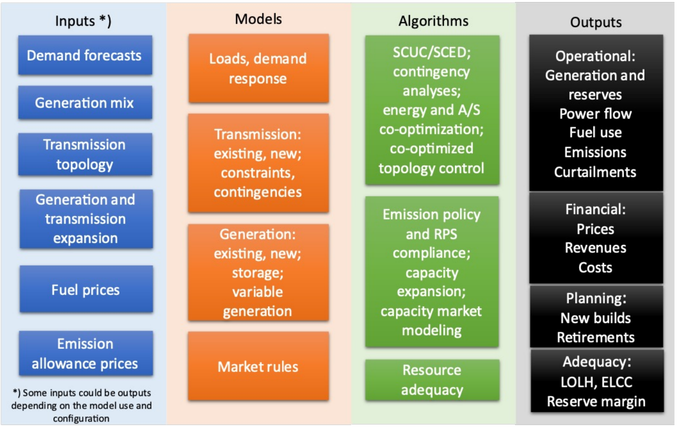
- Expansion planning, optimal commitment and dispatch, and resource adequacy model of power markets
- Purpose-built to model power market dynamics on a path to decarbonized future while modeling energy, ancillary, capacity, REC, and carbon markets. More accurate and sophisticated than any other commercially available platform
- Flexibility to configure models and data set-ups across a wide range of alternative market structures, policies, and business use cases and desired spatial/temporal granularity ranging from minutes to decades
- Cutting edge cloud-based architecture can scale up/down to match business needs. The automated workflow, parallelization and scalability enable high peak usage at record performance/run time)

For more details, see:
http://www.enelytix.com/

ENELYTIX Core Capabilities

- Market modeling engine *Power Systems Optimizer* (PSO) by Polaris uses IBM's CPLEX MIP solver
- In each application configuration, PSO minimizes relevant system costs over certain time horizon, market footprints and specific scopes of decision variables
- Nodal, zonal or hybrid power network representation per user's specifications
- Accurate representation of existing and future generation, transmission, storage and demand-side technologies
- Optimization is conducted subject to multiple constraint layers: physical, operational, reliability, environmental, contractual and financial
- Consolidated datasets seamlessly support and integrate all applications
- Automated temporal and geographical decomposition of optimization problem for parallelized solution within ENELYTIX cloud environment

PSO Schematics



Constraint Layers

Financial / investments

Clean Energy & Other Policies

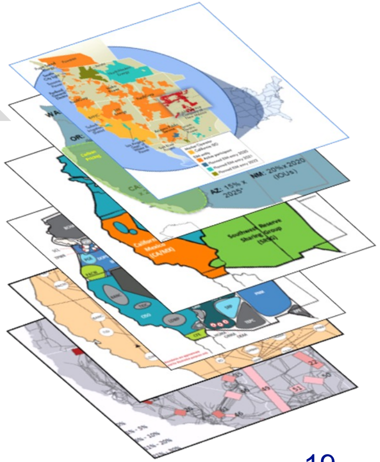
Resource Adequacy

Ancillary Services

Contractual

Physical Flows, Energy Balance,

Operational



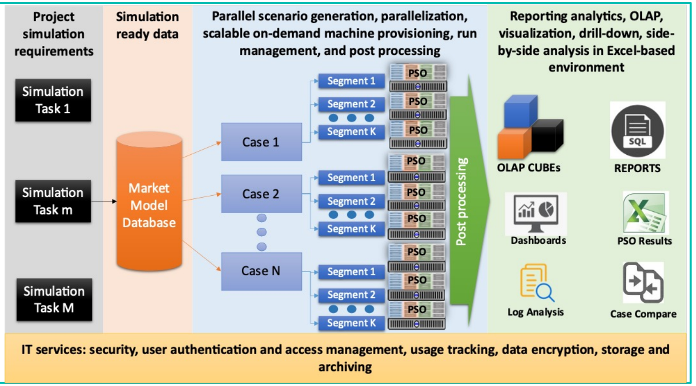
Advanced IT Architecture Supports Business Needs

ENELYTIX architecture supports global users and capability to meet peak demand in record turn around time through massive parallelization over a cloud platform

ENELYTIX provides automated workflow control, API access, self service Business Intelligence for results analysis, custom reports, quality control processes, run logs.

ENELYTIX architecture is primarily designed for

- multi-market,
- multi-scenario,
- multi-year,
- multi-decision-cycle
- case generation and parallel execution with a single click



- ENELYTIX supports full automation through API access
- The entire solution is deployable within customer's AWS environment
- ENELYTIX is easy to integrate with upstream and downstream processes due to modular structure, standard data format, and PSO open library capability
- Self-healing features to support solution reliability
- System is configurable to balance performance and infrastructure cost