It's All About the Timing:
Modeling Energy Storage in Non-Chronological Capacity Expansion

Kai Van Horn

ESIG Spring Technical Workshop
March 23, 2022

Disclaimer: All results and any errors in this presentation are the responsibility of the author and do not represent the opinion of National Grid or its subsidiaries. Results shown herein are indicative and are solely intended to illustrate approaches to modeling storage in non-chronological capacity expansion.

nationalgrid

PUBLIC

Presentation Overview

Motivation: *what is driving the need for enhanced storage modeling capabilities?*

Storage in capacity expansion: *what options are available?*

- Chronological vs non-chronological capacity expansion
- Some key features of storage to capture in any model

A non-chronological approach: *how can we capture chronological features in a non-chronological model?*

Case study: *demonstrating the value of heuristics for capturing chronological features*

- Description of study
- Key results

Conclusions: *what can we take away from this?*

Disclaimer: All results and any errors in this presentation are the responsibility of the author and do not represent the opinion of National Grid or its subsidiaries. Results shown herein are indicative and are solely intended to illustrate approaches to modeling storage in non-chronological capacity expansion.

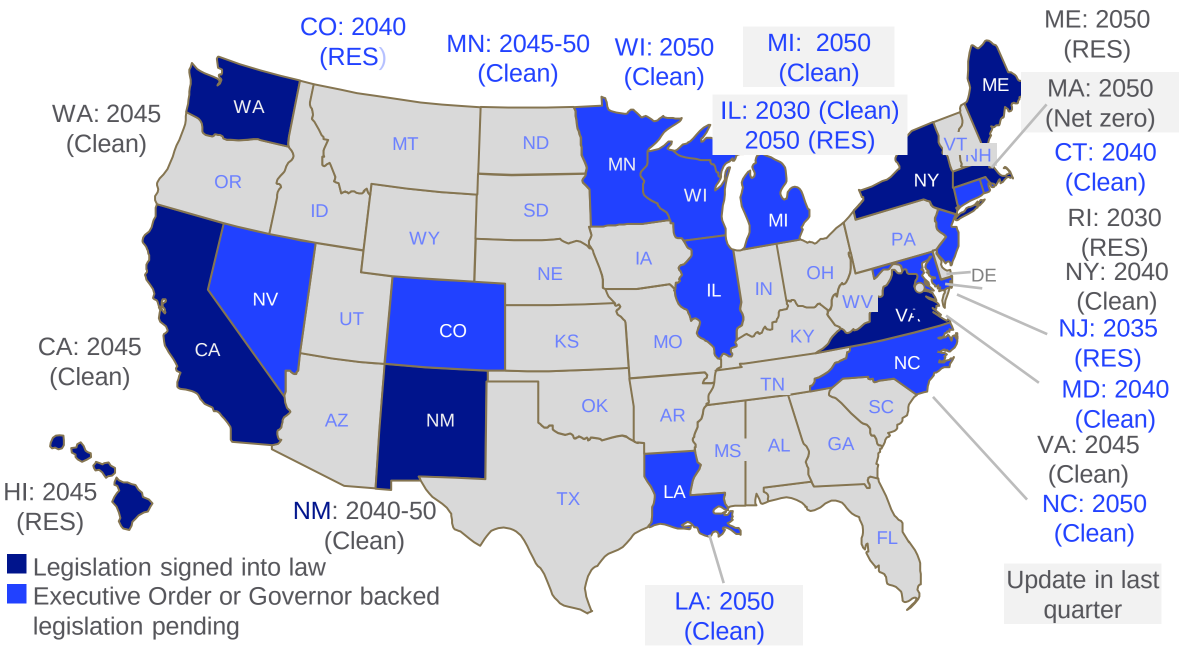
Motivation

The US electricity sector is in the midst of an accelerating transition toward decarbonization, which is creating demand for new sources of flexibility

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
- Coal-fire, and increasingly natural gas-fired, capacity continues to retire at a historic pace
- Costs for renewables & storage technologies continue to fall

Anticipated or Enacted 100% Clean Energy Legislation



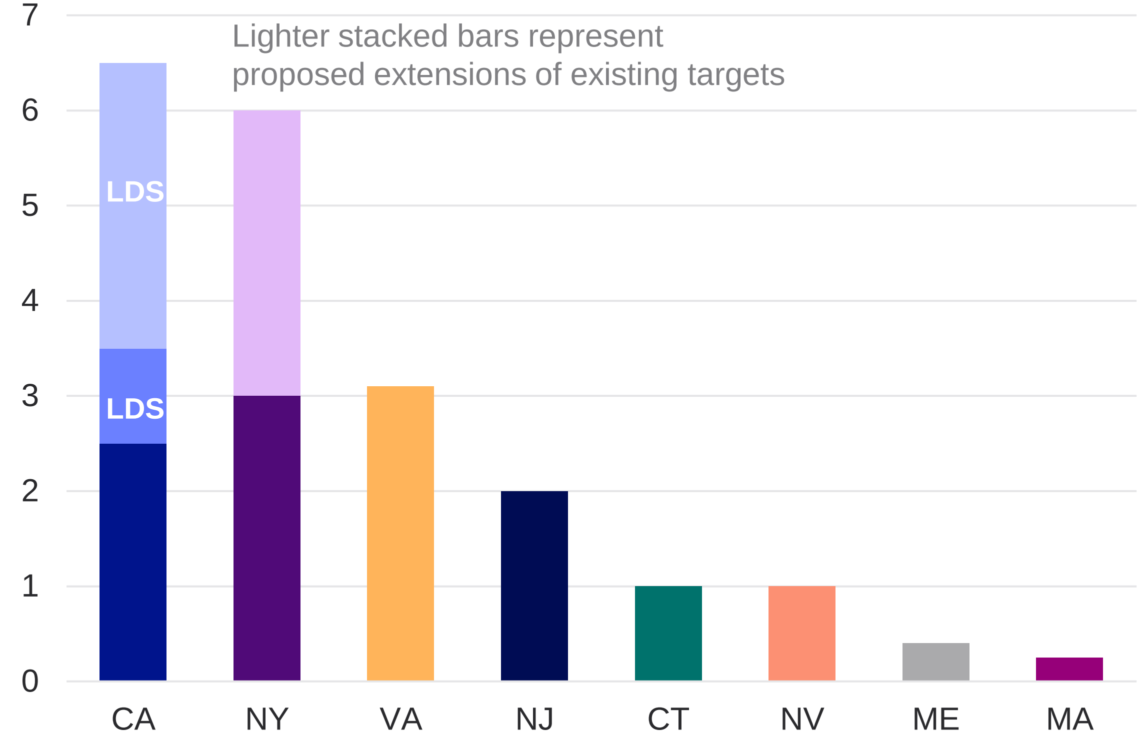
Note: Clean Energy standards generally allow for nuclear, CCS and large hydro to count towards targets, while Renewable (RES) targets generally do not. Washington DC and Puerto Rico which also have established 100% clean energy targets

Sources: NG US Market Fundamentals.

Motivation

As policy mandates proliferate and costs fall, storage is poised to become one of the principal sources of power system flexibility

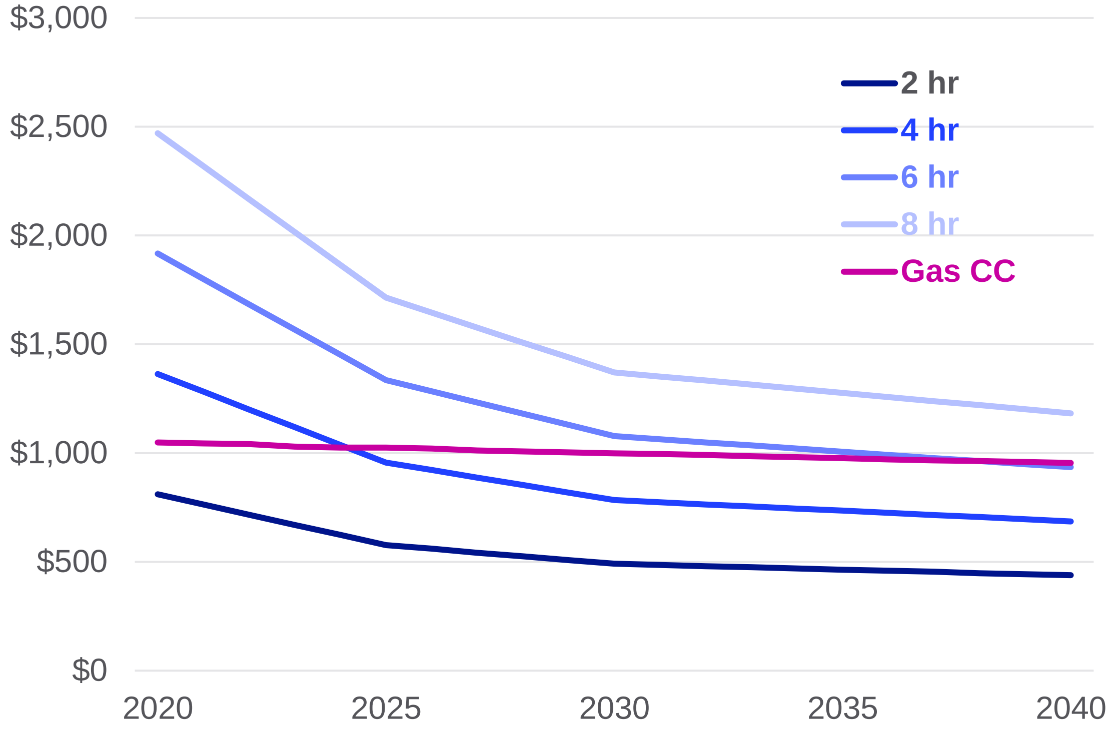
State Storage Goals/Targets
GW of cumulative additions



Target year(s)	2030 2040	2030	2035	2030	2030	2030	2030	2025

Notes: CA has achieved its near-term battery storage target (2.5 GW by 2022), but is contemplating longer-term mandates for long-duration storage (LDS). NY currently has a 3 GW target, but has proposed increasing that target to 6 GW (both by 2030). Target shown for NJ is a non-binding goal. MA target is 1000 MWh of storage, and has been converted to a MW target in chart using a 4-hour battery duration.

Li-Ion Battery and Gas CC capital costs
$/kW (real $2019), 2020-50

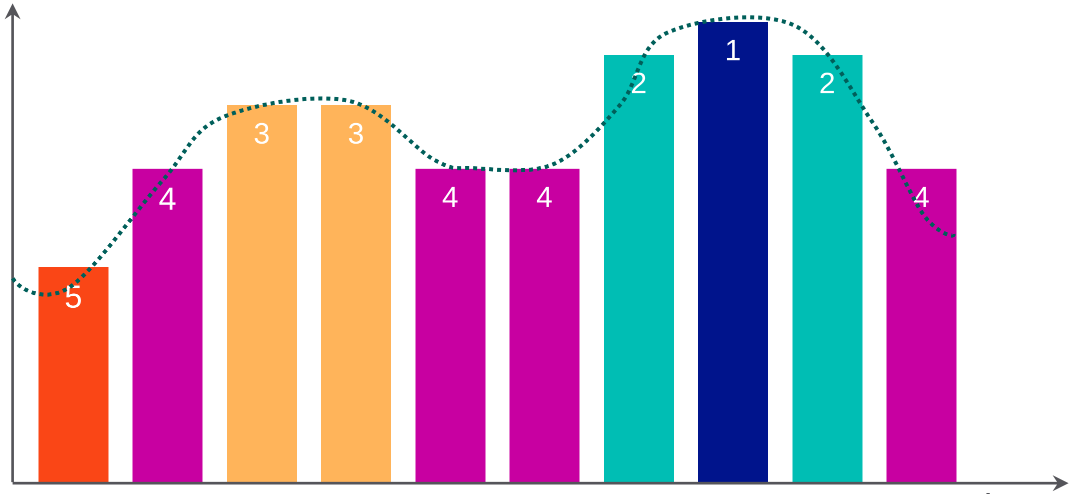


Source: NREL 2021 Annual Technology Baseline mid case.

To plot a path forward for storage deployment, policy makers & planners need tools to answers the questions: how much? what types? where? & when?

Capacity expansion models are a powerful tool for exploring these questions. For storage, chronological models are the typical "go to", but **non-chronological models have many advantages despite the lack of chronology provided sufficient consideration is given to capturing the key features of storage**

Chronological (representative days/weeks)

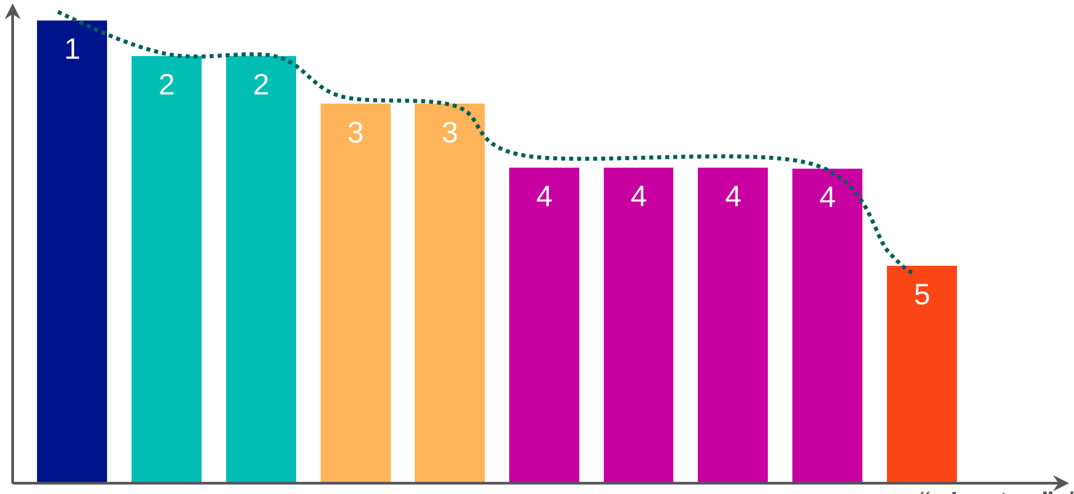


- ✓ Explicitly differentiates storage technology types
- ✓ Explicitly captures storage energy constraints

BUT

- × May overfit to limited set of chronologies
- × Intertemporal constraints can be computationally intensive

Non-Chronological (load duration curve / clustering)



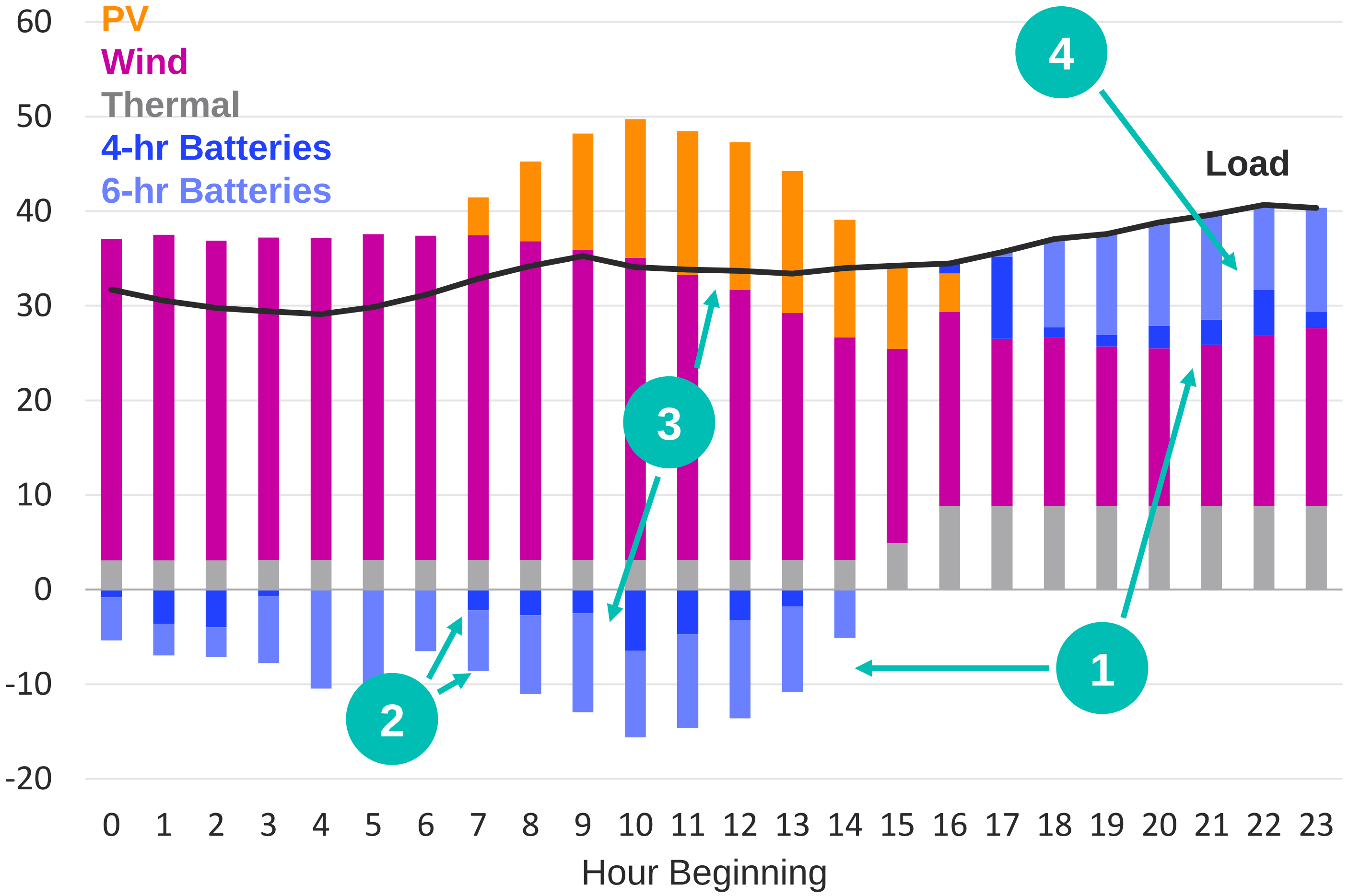
- ✓ Less computationally expensive, allowing for more model detail in other areas
- ✓ Abstraction can allow for capturing a broader range of conditions

BUT

- × Loss of chronological information means heuristics needed to effectively model storage

Boiling storage down to the key features that drive its value allows us to design modeling approaches that can answer those questions

Illustrative high-renewables 24-hour dispatch
GW of generation/load



1. **Energy constrained**: being available requires charging earlier to have "energy in the tank"
2. **Differentiating technology types**: storage duration and other attributes captured
3. **Flexibly aligns with load / renewables profiles**: storage charge/discharge meets needs to absorb & deliver energy at right times
4. **Capacity value / ELCC**: contribution to reducing loss of load risk vary by technology type and by magnitude of installed capacity

With thoughtfully designed heuristics, we can bring the chronology-dependent features of storage into non-chronological models

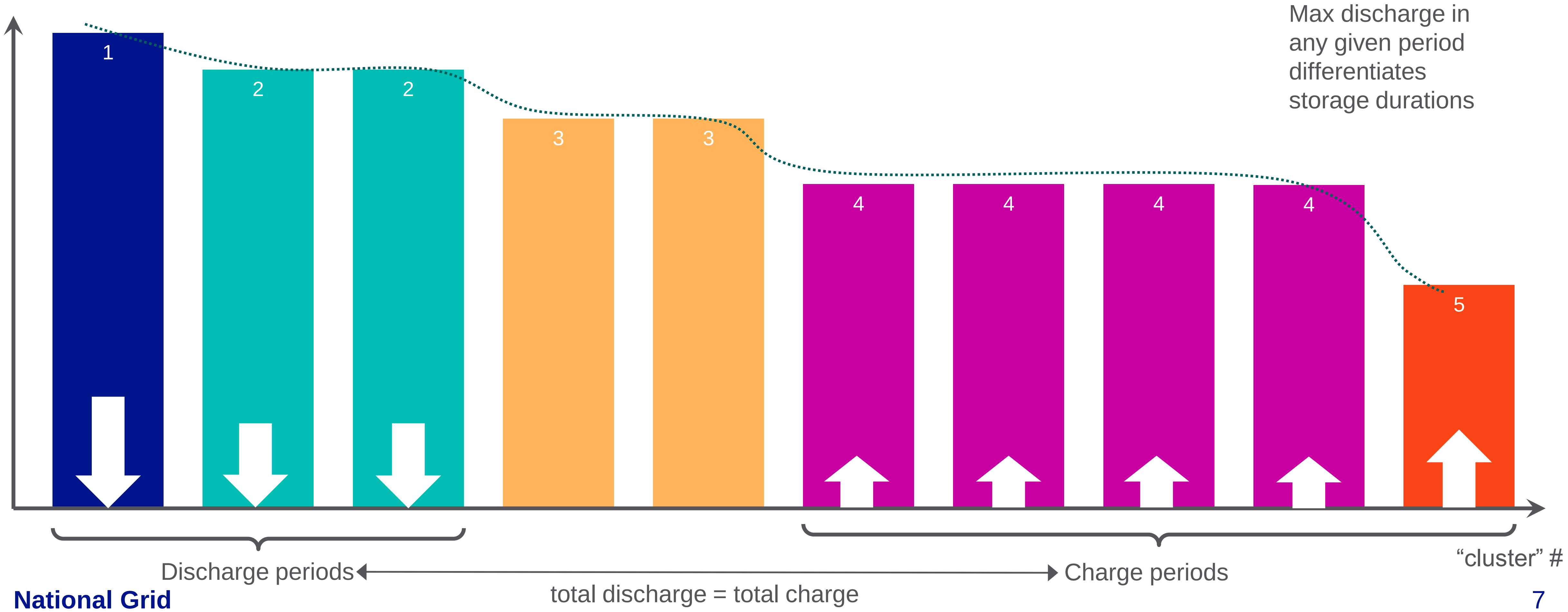
A non-chronological approach

Energy constrained

While dispatch level in each period is endogenous, we require that storage charge and discharge be in balance across all periods—a non-chronological version of the energy constraint.

Alignment of storage charge & discharge with load duration curve steps / clusters

Load & storage charge/discharge level, by period



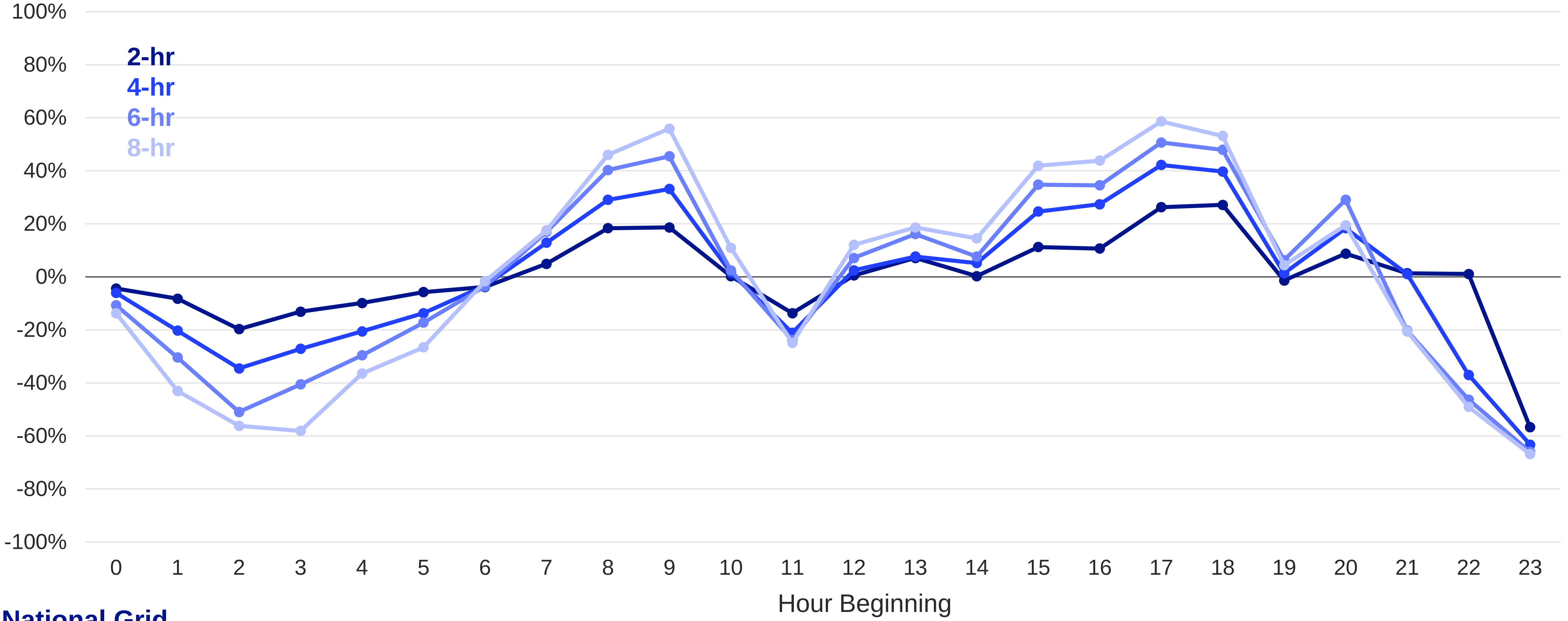
A non-chronological approach

Differentiating technology type

We can use nominal resource dispatch profiles to “shape” the availability of storage in each representative period; these profiles also differentiate battery duration by making higher duration more valuable than lower.

Normalized average daily battery storage resource profiles

Daily resource profile by battery duration, normalized to 1 MW



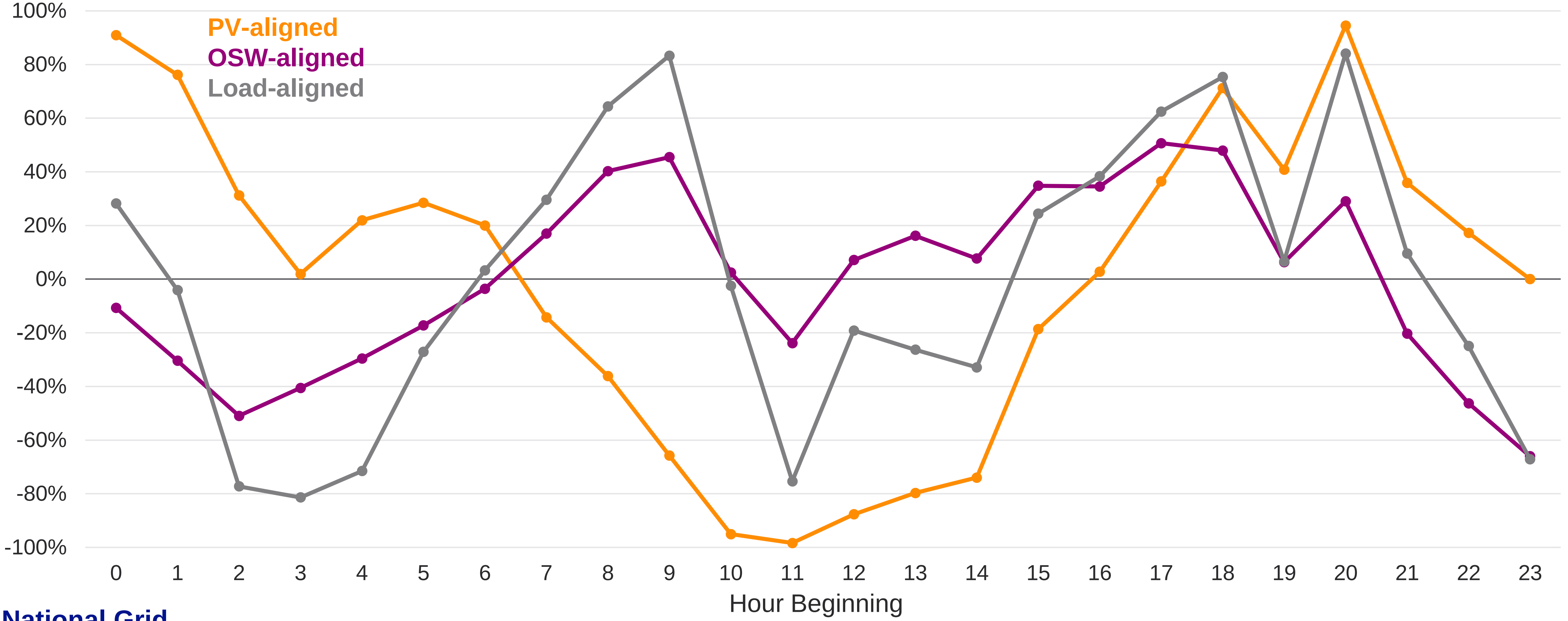
A non-chronological approach

Flexibly aligns with load/renewables profiles

Within each battery duration profile, we can allow for multiple options of dispatch profile by modeled zone to capture a diversity of potential needs. We also allow deviations from the nominal profiles for added flexibility.

Normalized average daily battery storage resource profiles

Daily resource profile by alignment type, normalized to 1 MW



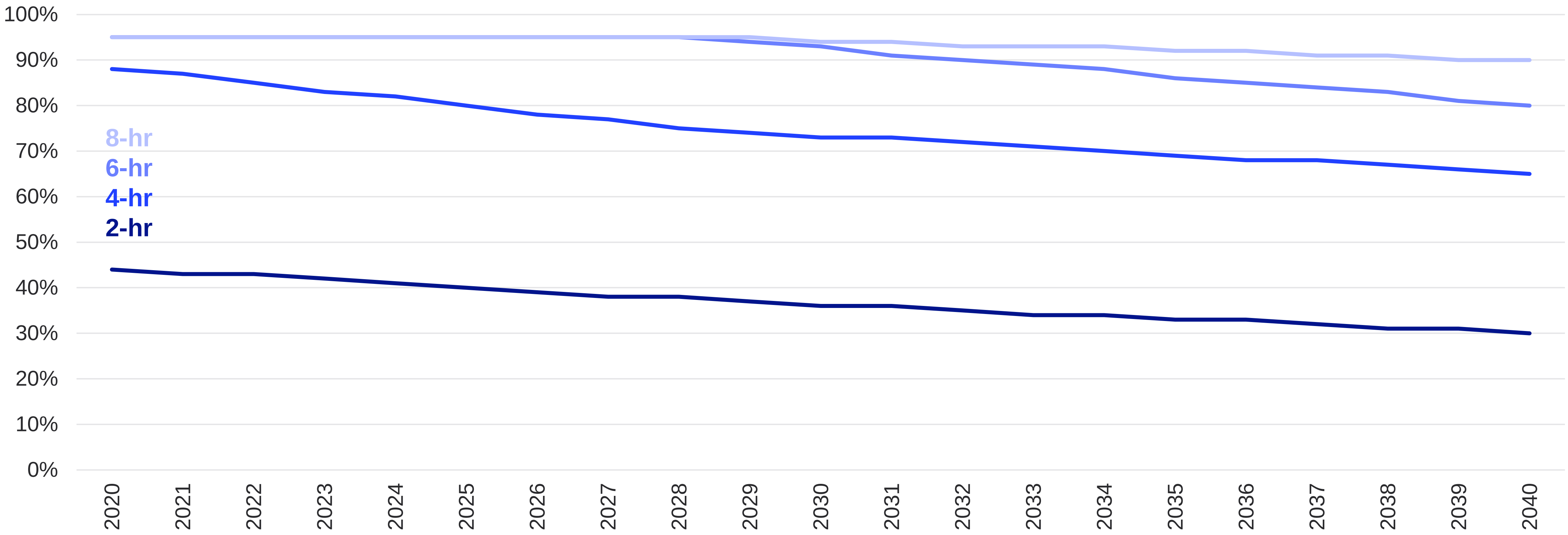
A non-chronological approach

Capacity value / ELCC

We further differentiate battery storage durations by varying the capacity value of storage by duration and over time to reflect declining ELCC with increasing capacity

Capacity value of storage by duration

%, normalized to 1 MW



Case study: illustrating value of heuristics for modeling storage in non-chronological capacity expansion

We compare three cases to demonstrate the features:

Reference: using the heuristics described in the prior slides

Capacity Only: storage as capacity resource only (no dispatches)

Extra Flexibility: no storage dispatch profiles (full flexibility for all durations across periods)

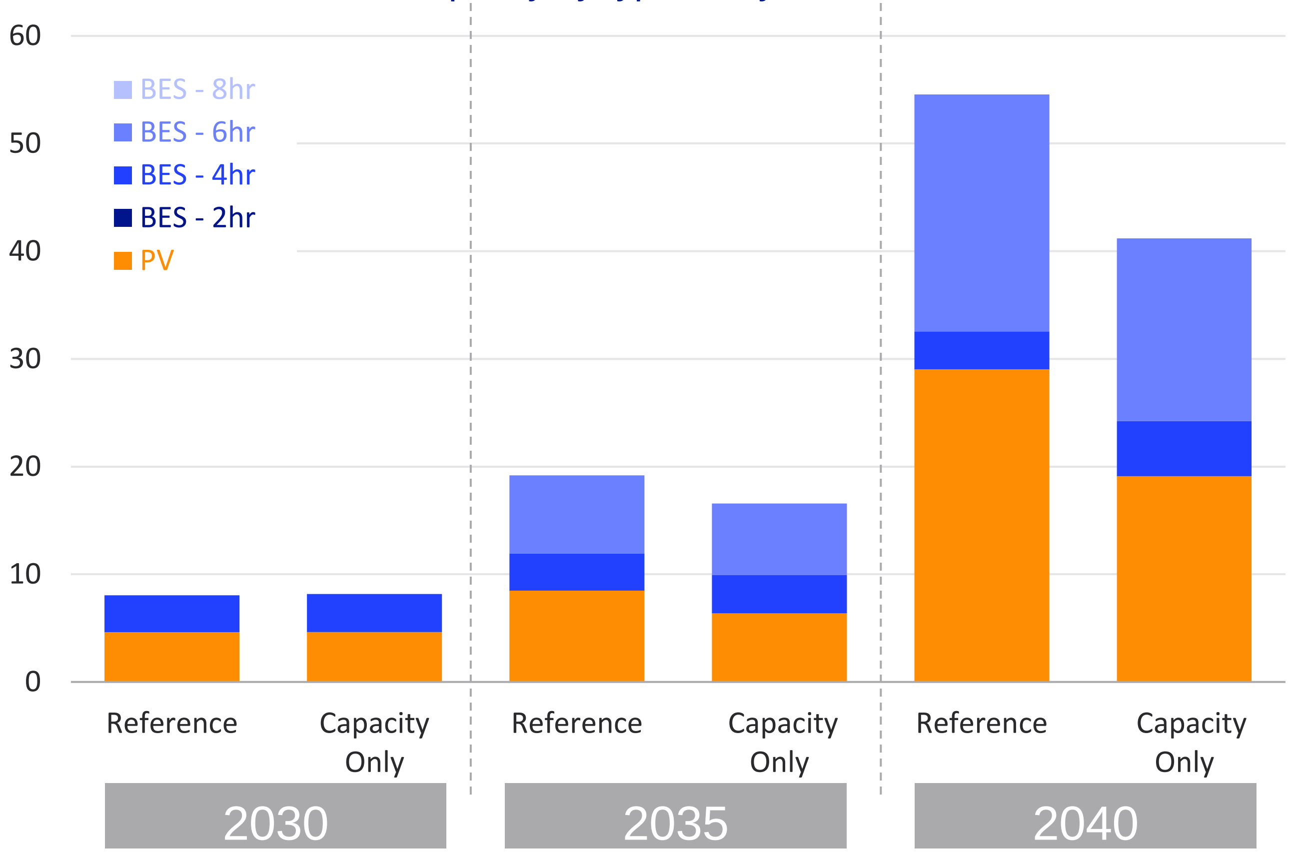
Cases use otherwise identical cost, transmission, and build limit assumptions. Additionally, all cases include some amount of transport and heat electrification, as well as clean energy policy targets.

Disclaimer: All results and any errors in this presentation are the responsibility of the author and do not represent the opinion of National Grid or its subsidiaries. Results shown herein are indicative and are solely intended to illustrate approaches to modeling storage in non-chronological capacity expansion.

Case study

Comparing reference & capacity only cases reveals value of heuristics for capturing ability of storage to flexibly align load & renewables profiles

Added PV and Battery Capacity
GW of cumulative added capacity by type and year



Observations

1. 6-hour storage still dominant build variety due to balance of capacity value & cost
2. Focus on a single value stream (capacity) for storage reduces overall storage build
3. In the absence of the capability for storage to move energy in time, build of PV suffers, illustrating how the heuristics can capture “alignment value” of storage

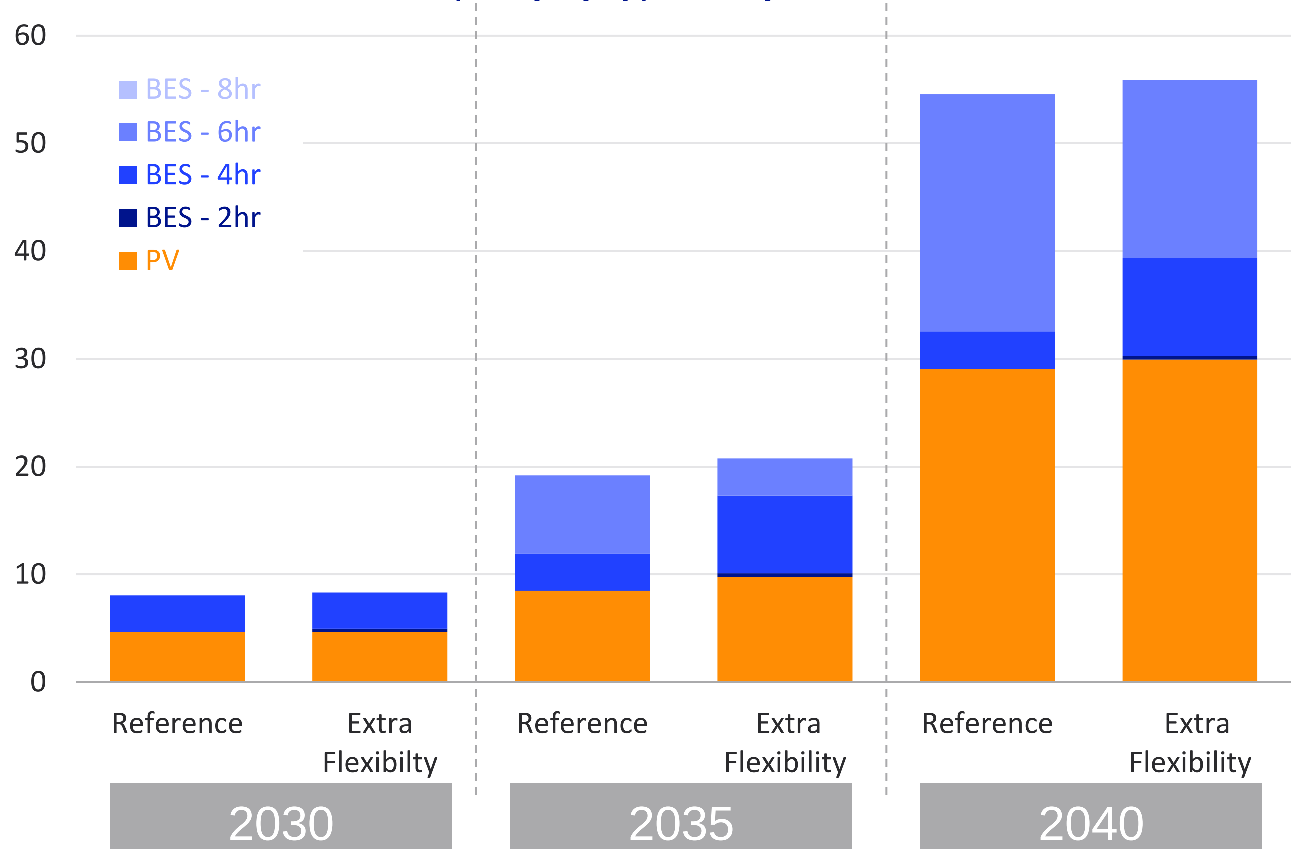
Disclaimer: All results and any errors in this presentation are the responsibility of the author and do not represent the opinion of National Grid or its subsidiaries. Results shown herein are indicative and are solely intended to illustrate approaches to modeling storage in non-chronological capacity expansion.

Case study

Comparing reference with the extra flexibility case demonstrates value of heuristics for differentiating battery durations

Added PV and Battery Capacity

GW of cumulative added capacity by type and year



Observations

1. 4-hr storage builds replace some 6-hr when duration limits on flexibility not imposed
2. Overall storage build similar in both cases, showing that level of storage flexibility principally impacts the type of storage that gets built, rather than the overall amount
3. PV build only slightly higher than in our reference case, demonstrating that even with shape limitations of reference case the model reaches a nearly "optimal" amount of PV

With the right heuristics, non-chronological capacity expansion offers a viable approach to study the role of storage in the energy transition

- **Can provide meaningful answers to questions: how much? what types? where? & when?**
  - Captures value of aligning resource profiles and load (despite lack of chronology)
  - Differentiate durations via shapes & capacity value
- **Especially valuable for very long time horizons, and/or where additional detail is required in other aspects of model (e.g., detailed transmission constraint representation)**
- **Some caveats:**
  - Capacity expansion modeling is not a substitute for detailed operational simulations when question of interest involve “tail events” such as weeks-long wind droughts
  - Seasonal shifting, an important feature of long-duration storage need, would require additional heuristics to capture
  - Though not discussed here, cluster selection (i.e., net load curve steps, time-series reduction) is critically important for getting sensible results from non-chronological models

Speaker bio

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 is exploring pathways to deep decarbonization 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

Disclaimer: All results and any errors in this presentation are the responsibility of the author and do not represent the opinion of National Grid or its subsidiaries. Results shown herein are indicative and are solely intended to illustrate approaches to modeling storage in non-chronological capacity expansion.

Appendix

All simulations for this work performed using ENELYTIX

ENELYTIX®
powered by PSO

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

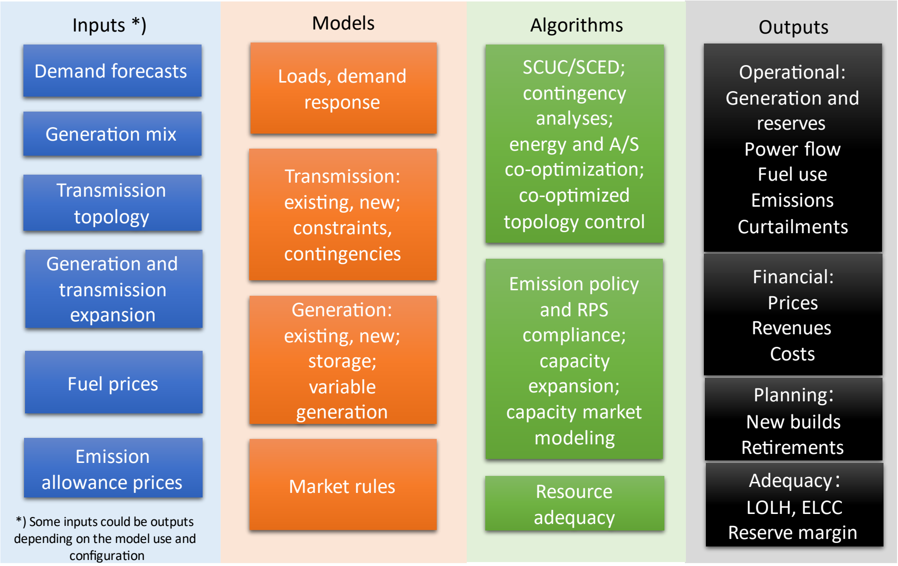
ENELYTIX® is the advanced power market modeling platform for forecasting, asset valuation, system planning, operational analysis, policymaking, and market design

- 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)

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

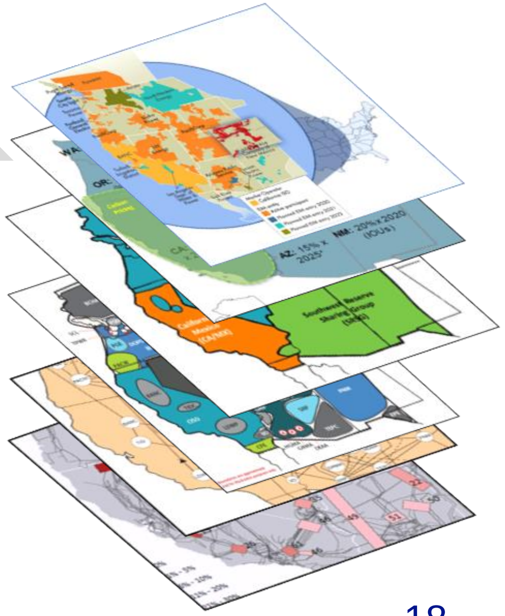
Clean Energy & Other Policies

Resource Adequacy

Ancillary Services

Contractual

Physical Flows, Energy Balance, Operational



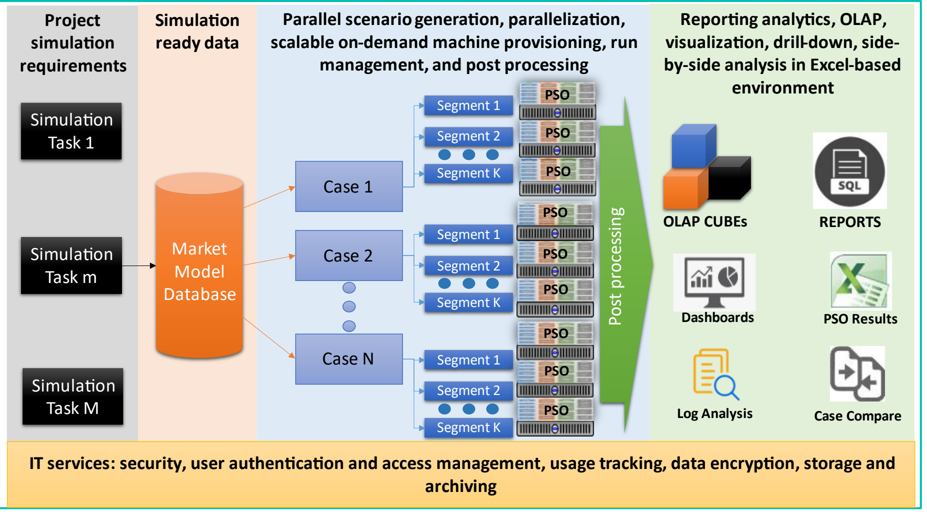
Advanced IT Architecture Supports Business Needs

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