# How to simulate variability and deliverability in high-fidelity models

*Tricks of the trade:*

*Making the "Impractical" Practical*

*Russ Philbrick*

*ESIG 2026 Summer Workshop:*

*Integrating Economic and Reliability Models for Power Systems Planning Workshop*

*June 15, 2026*

# Planning processes do not value flexibility and deliverability

## Operational impacts are critically important

- Increasing **uncertainty** → value of resource flexibility
  - Impact of weather on generation, loads, outages, transmission
  - Uncertainty of technology, costs, policy
- Increasing **congestion** → value of transmission
  - "Reserve sharing" to manage variable generation and extreme weather
  - Also contributes to flexibility

## → Planning processes are MISSING risks and costs



POLARIS
SYSTEMS OPTIMIZATION

# Congestion costs are exploding

**Rising PJM congestion costs:**

**$1.8 billion in 2024 to**

**$3.2 billion in 2025 [1]**

**and $2.0 billion in Q1 2026 [2]**

**(on pace for $8 billion!!)**

***These are deliverability costs that many planning models can't see!***

[1] 2025 State of the Market Report for PJM, Monitoring Analytics, March 12, 2026

[2] 2026 Quarterly State of the Market Report for PJM: Jan - Mar, Monitoring Analytics, May 14, 2026

# Engineering Skill

**"the art of doing that well with one dollar, which any bungler can do with two after a fashion"**

The Economic Theory of the Location of Railways,
Arthur Mellen Wellington, 1877

True engineering is defined by efficiency, optimization, and cost-effectiveness, rather than just making something work.

# Where we spend two where one will do

**Traditional planning processes have been based on past needs**

- They were adequate and practical for the needs at the time

**We continue to rely on these traditional processes:  Change is difficult and costly.  However, this contributes to increasingly poor engineering:**

- Snapshot models
- Copper plate and zonal power flow
- A-priori reserve requirements
- Simplified generator models
- Fixed-load models
- Simplified models of neighbors

**Current needs have driven change, but incremental change is failing.**



POLARIS SYSTEMS OPTIMIZATION

# Slaying shibboleths

**These are WRONG:**

- **Nodal modeling takes 100x longer than zonal modeling**
- **We can't model LDES without full chronology**
- **Co-optimizing G&T is important but not practical**
- **Nodal capacity expansion is not possible**
- **Nodal resource adequacy is not possible**
- **The answer is ELCC … marginal ELCC … ELCC surfaces …**

**Better engineering solutions exist.**
**These are already deployed and used by industry.**

- *ELCC / marginal ELCC / ELCC surfaces are proxy methods to address limits we've removed —nodal modeling with smart chronological gives the answer directly.*

# Three places to apply better engineering

- **Needs have changed. Simplified view of operations is no longer valid**
- **New capabilities: modeling, optimization, computation**
- **Planning tools and processes have not adapted**

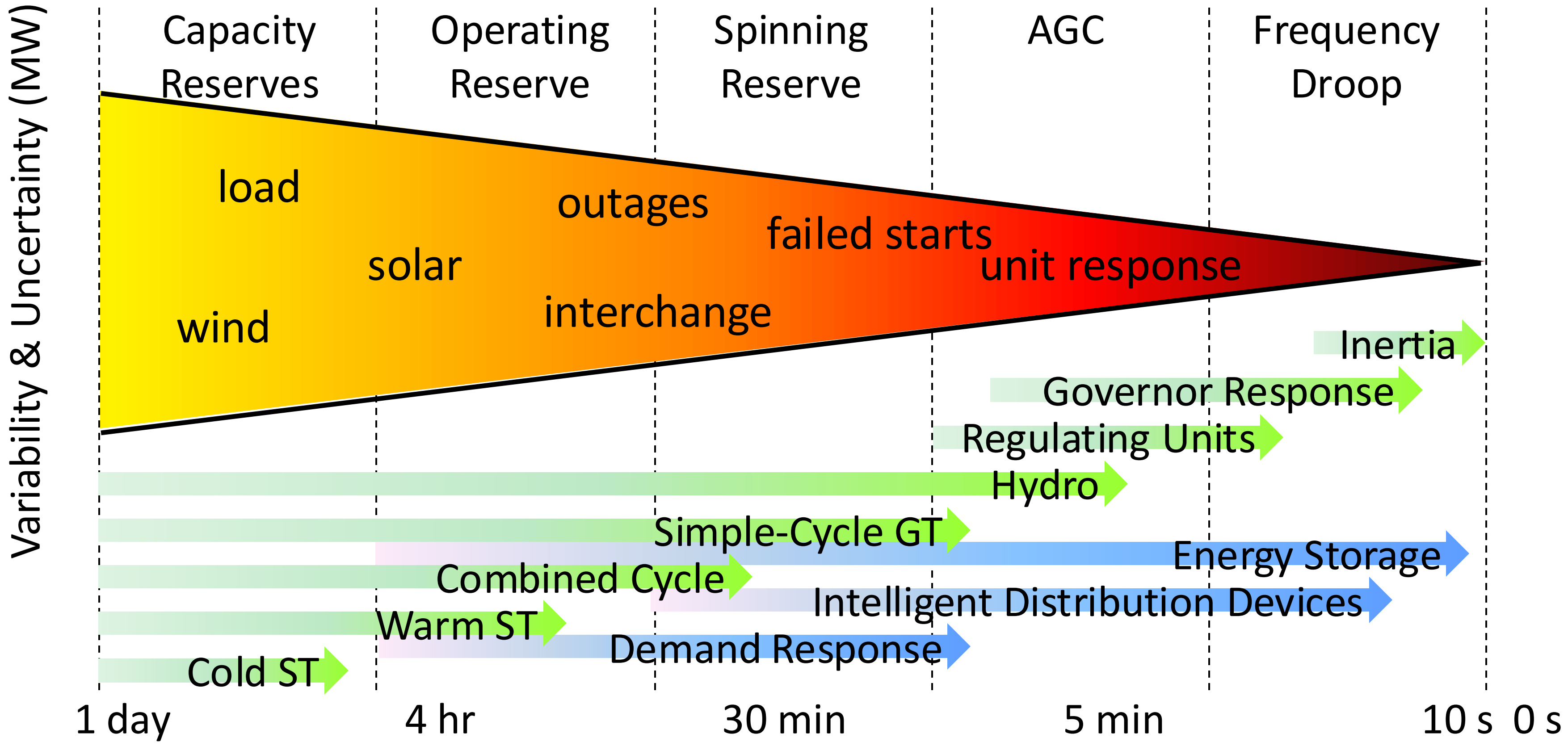
**Let’s consider how tools can better model:**

1. Flexibility
   - Overcoming simplified generator, load, reserve, and ELCC models
2. DC Power flow
   - Overcoming simplified copper plate and zonal models, and models of neighbors
3. Chronology
   - Overcoming limitations of snapshot models and full chronology



POLARIS
SYSTEMS OPTIMIZATION

## Operations challenge: Balance uncertainty/variability with flexibility



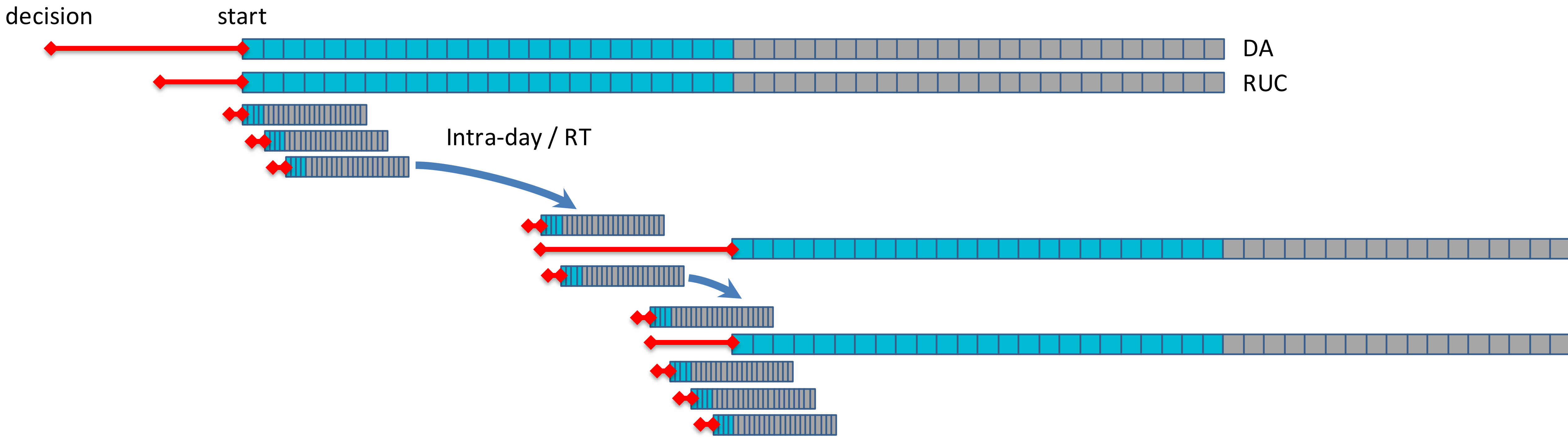

- **Simulate how the system operates**

# How to model flexibility

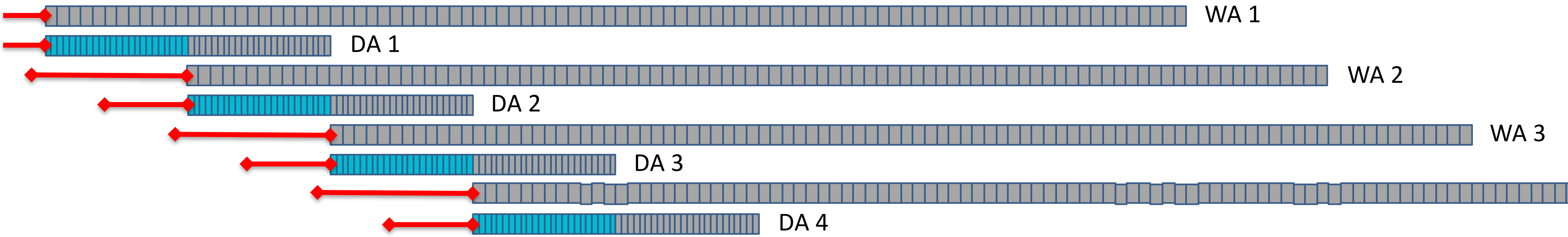
## Get away from traditional simplifications

→ **Model rolling-horizon, multi-decision cycles**

→ **Understand and apply impact of recourse and non-recourse decisions**



# Modeling flexibility in different time domains




## Decisions that need longer horizon for optimization

- Needed by inflexible generators, long-duration storage / hydro
- Incorporates long-term forecast uncertainty by establishing rule curves

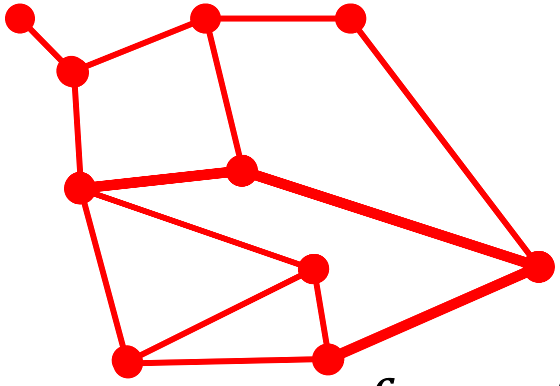
## Long-term allocation of flexible capacity to meet extreme events

- Storage, generation, bilateral trading, maintenance



POLARIS SYSTEMS OPTIMIZATION

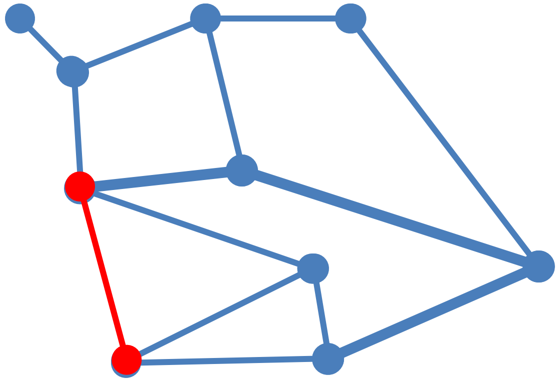
## DC Power-Flow challenge: Memory and performance



### B-Theta

$$f_{i \to j} = (\theta_i - \theta_j + \pi_{i \to j})/x_{ij}$$

$$p_i = \sum_j f_{i \to j}$$



### PTDF

$$\mathbf{f} = \widehat{\boldsymbol{\Psi}}\ \widehat{\mathbf{p}}$$

- **With a PTDF formulation, good engineering focuses on security analysis**
- **Brute force won't beat the contingency combinatorics — you need smart security analysis**

# How to model DC Power Flow

**Deliverability = DC power flow done right.**

- → **Ignore what you learned in school and see how today's markets work**
- → **If we don't care about it, don't model it**

**At any moment in time, there are only a limited number of binding transmission constraints.**

- → **If you can identify them in advance, nodal models are faster to solve and avoid planning complexities from**
  - → Defining zones
  - → Identifying interchanges between zones (which are mostly wrong)
  - → Translating results back to nodal models
- → **Smart "security analysis" beats memory and performance problems**



POLARIS SYSTEMS OPTIMIZATION

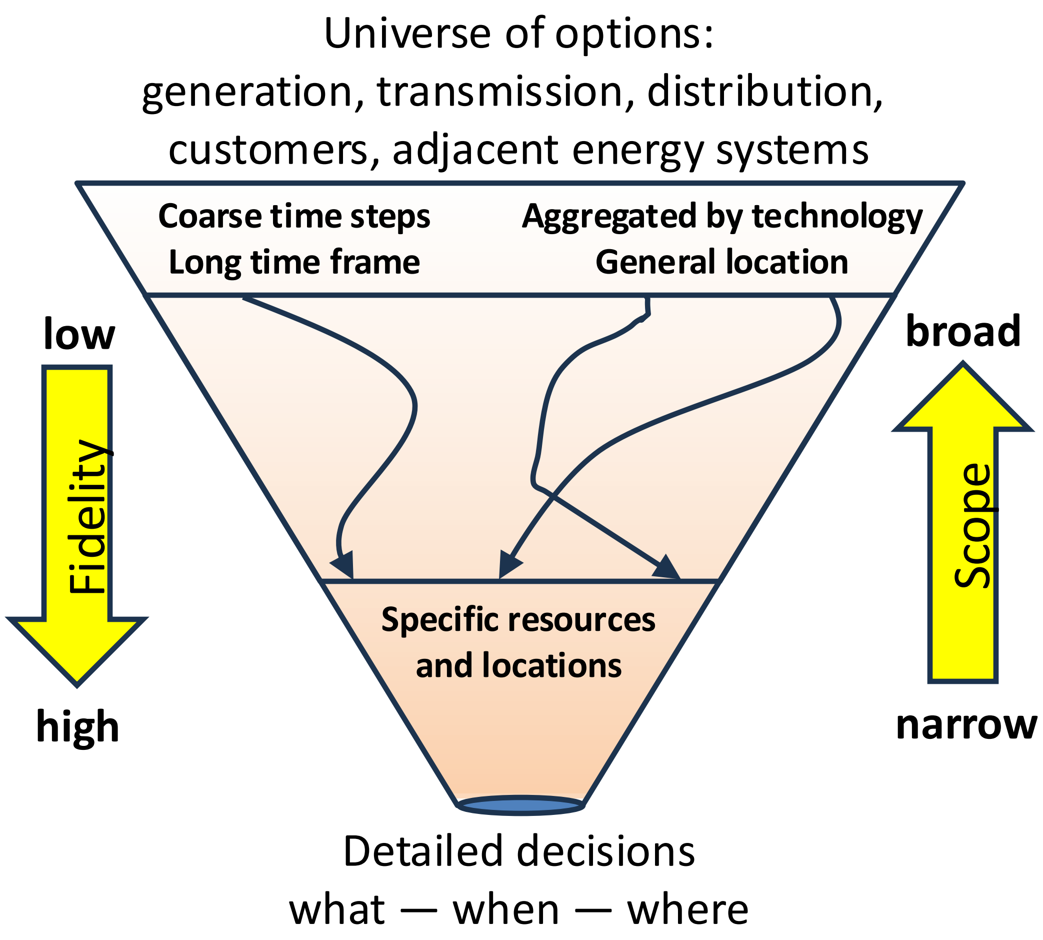
## Chronology challenge: Simulating variability

### What we care about:

- Reliability AND Efficiency
- Impact of capacity mix
- Impact of operating policies

### Applies to all planning domains:

- CEM, RA, PCM
- Voltage, RMS, EMT



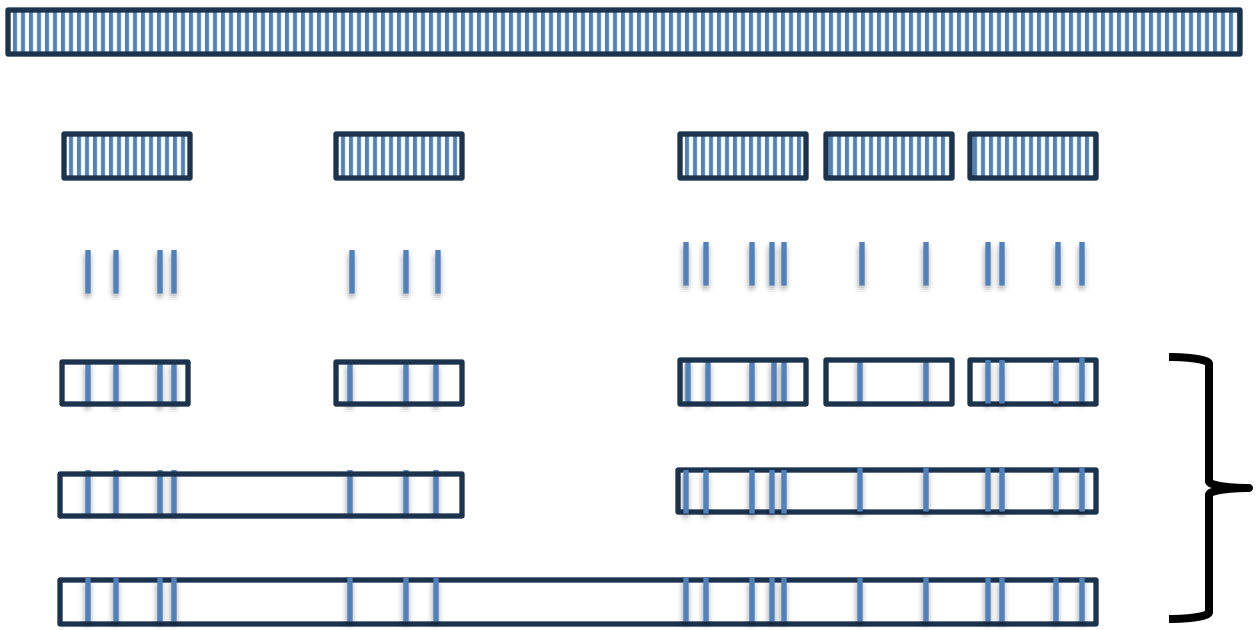

- **Adapt chronology to the goal of the model**
- **Recognize choices beyond “full” vs “snapshot” chronologies**

# How to model Chronology

**Adapt chronology to EFFICIENTLY capture impacts of variability**

**→ Reduce number of states while preserving variability and causality**

**→ Simplify time-coupled constraints**



Granular data (e.g., 8760) — Full chronology

Representative days — Semi-chronology

State reduction — Implicit chron.

Day cliques

Month cliques

Year cliques

Define using wrapper constraints

# Change Is Hard

**Stop accepting simplified models of flexibility, power flow, and chronology.**

**Demand tools that make high-fidelity practical.**