Resource Adequacy for the Energy Transition

A Critical Periods Reliability Framework and its Applications in Planning and Markets

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Energy+Environmental Economics

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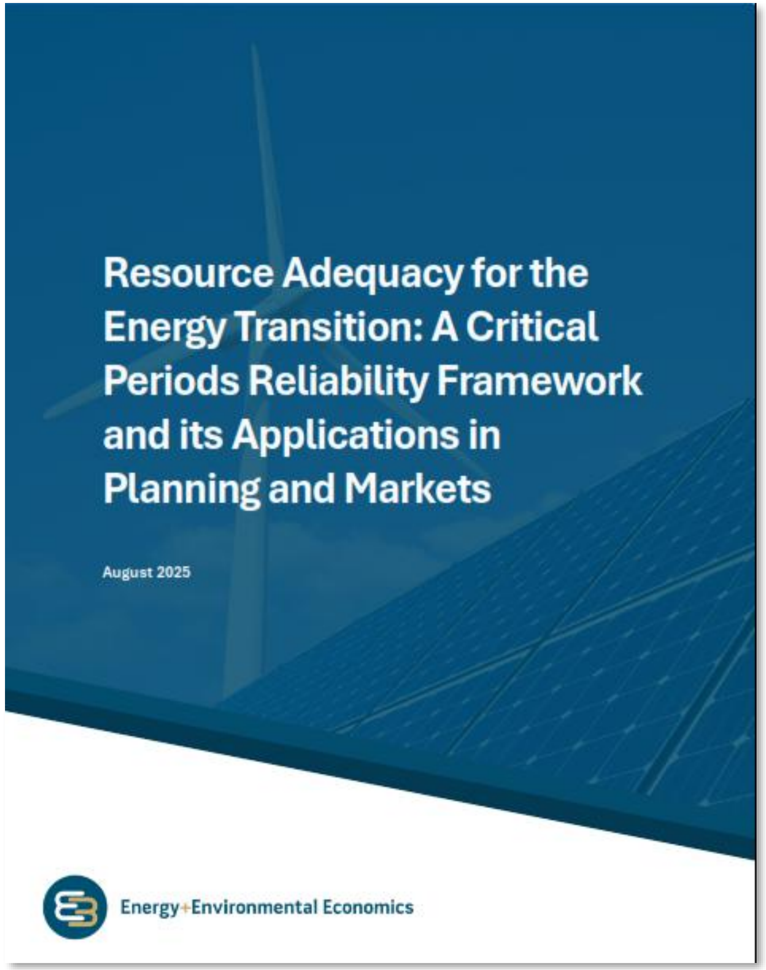
E3’s new whitepaper describes the emerging consensus around measuring power system resource adequacy



https://www.ethree.com/new-framework-resource-adequacy/

- **The paper addresses the two major problems in resource adequacy:**
  - Physical problem of ensuring reliability
  - Economic problem of ensuring efficient investment
- **Solving both problems requires robust loss-of-load probability modeling that accurately characterizes:**
  - The conditions under which power supply may be inadequate to serve load
  - The incremental impacts to reliability of changes to the resource portfolio
- **The paper provides a holistic mathematical framework with applications in both system planning and markets**

Why we need a scientific approach to resource adequacy need determination and accreditation

- Resource adequacy is an externality that must be remedied with actions outside the electricity spot market because of structural barriers that prevent the market from clearing at a societally optimal reliability level
- Determination of resource adequacy need is both critical for electric reliability and a large driver of electricity costs
- Accurate resource accreditation is a primary signal for the value of new resources and is necessary for economically efficient investment
- Effective hedging of capacity costs requires a well-formulated, fundamentals-based capacity spot market against which the forward contract can settle, enabling both the buyer and the seller to be able to reasonably anticipate potential price movements

Recent developments have made clear the need for changes in the traditional accreditation methods

1. The hours that are critical for reliability are increasingly diverging from the hours with highest peak load

2. Saturation and interactive effects among variable and energy-limited resources are becoming increasingly important as penetration grows

3. Traditional methods of accrediting conventional resources have been revealed as insufficiently accurate by widespread underperformance during major winter storm events

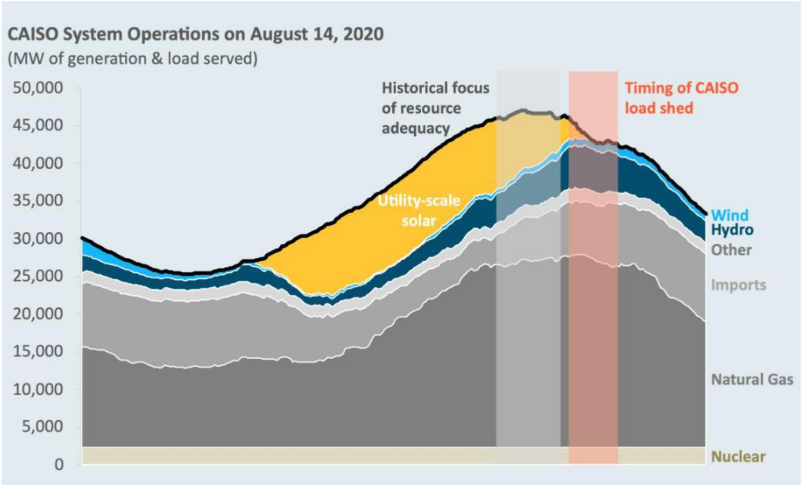


Figure 3: California's rotating blackouts on August 13-14 of 2020 occurred not during peak demand hours, but after sundown when solar generation fell to zero

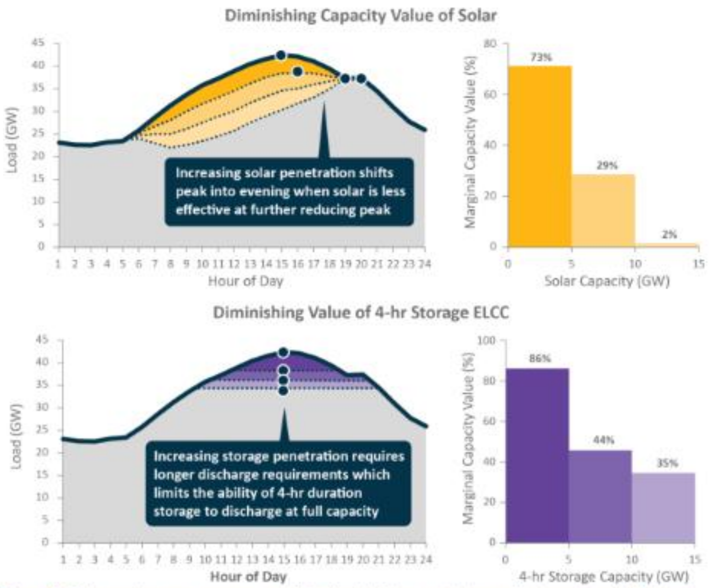


Figure 4: Solar and storage resources exhibit diminishing marginal contributions to reliability as penetration increases

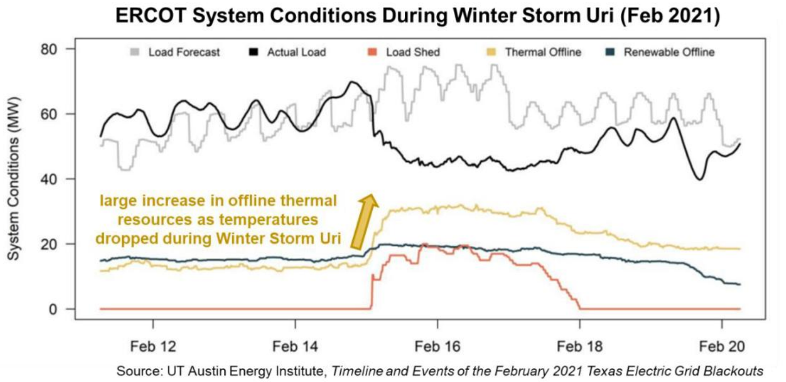


Figure 6: Significant outages of natural gas generation were a key contributor to the rotating outages on the ERCOT system during Winter Storm Uri

Key elements of the Critical Periods framework

1. **Determine Total Reliability Need (TRN)** based on quantity of equivalent perfect capacity needed to meet the specified reliability standard, and calibrate LOLP model of the power system to meet TRN

2. **Determine Marginal ELCCs** of individual resource types based on their marginal contribution toward the TRN, or equivalently their expected performance during Critical Periods

3. **Determine Total Procurement Need (TPN)** as the sum of Marginal ELCCs of individual resources in a "tuned" portfolio, or equivalently the expected load during Critical Periods

4. **Allocate TPN to Load-Serving Entities** based on their expected contribution to the need for capacity, i.e., their expected load during Critical Periods

Resource Adequacy for the Energy Transition: A Critical Periods Reliability Framework and its Applications in Planning and Markets
E3 white paper describing the theoretical basis and practical applications of this framework in wholesale markets and system planning

Loss of load probability modeling is the foundation for understanding resource adequacy needs

+ **LOLP modeling can be thought of as an organized way to analyze the potential for extreme weather and other events to cause a supply shortfall**

+ **LOLP can capture factors that matter for reliability such as:**
  - High loads due to extreme weather
  - Correlations between load and renewable conditions
  - Energy and capacity limitations
  - Dispatch behavior of energy-limited resources such as energy storage, demand response and hydro

Inputs

Load
- *Hourly load for many weather years*

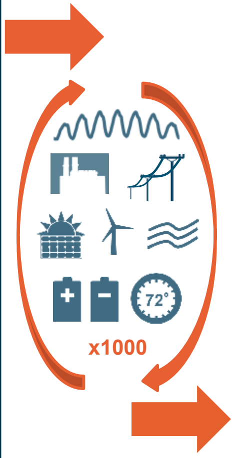
Dispatchable Generation
- *Capacity*
- *FOR*
- *Maintenance*

Renewables
- *Capacity*
- *Hourly generation profiles for many weather years*

Hydro
- *Hydro availability for many hydro years*
- *Max/min constraints*

Storage
- *Capacity*
- *Duration*
- *Roundtrip efficiency*
- *FOR*

Demand Response
- *Capacity*
- *Max # of calls*
- *Duration of each call*



Outputs

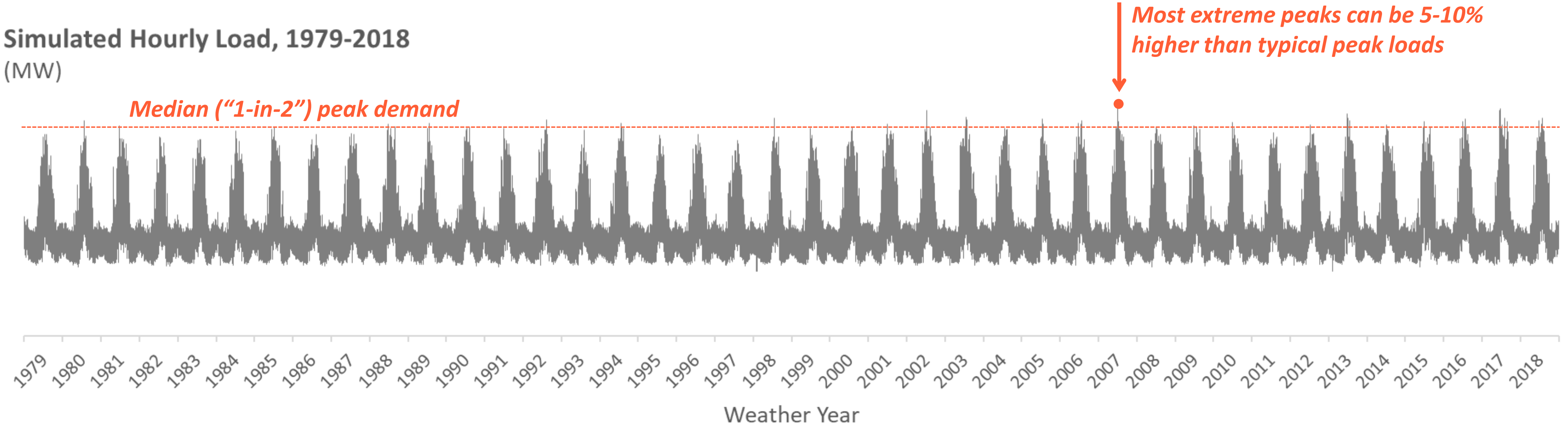
LOLE
- *Loss of load expectation*
- *days/yr of total expected lost load*

LOLH
- *Loss of load hours*
- *hrs/yr of total expected lost load*

EUE
- *Expected unserved energy*
- *MWh/yr of energy that cannot be served*

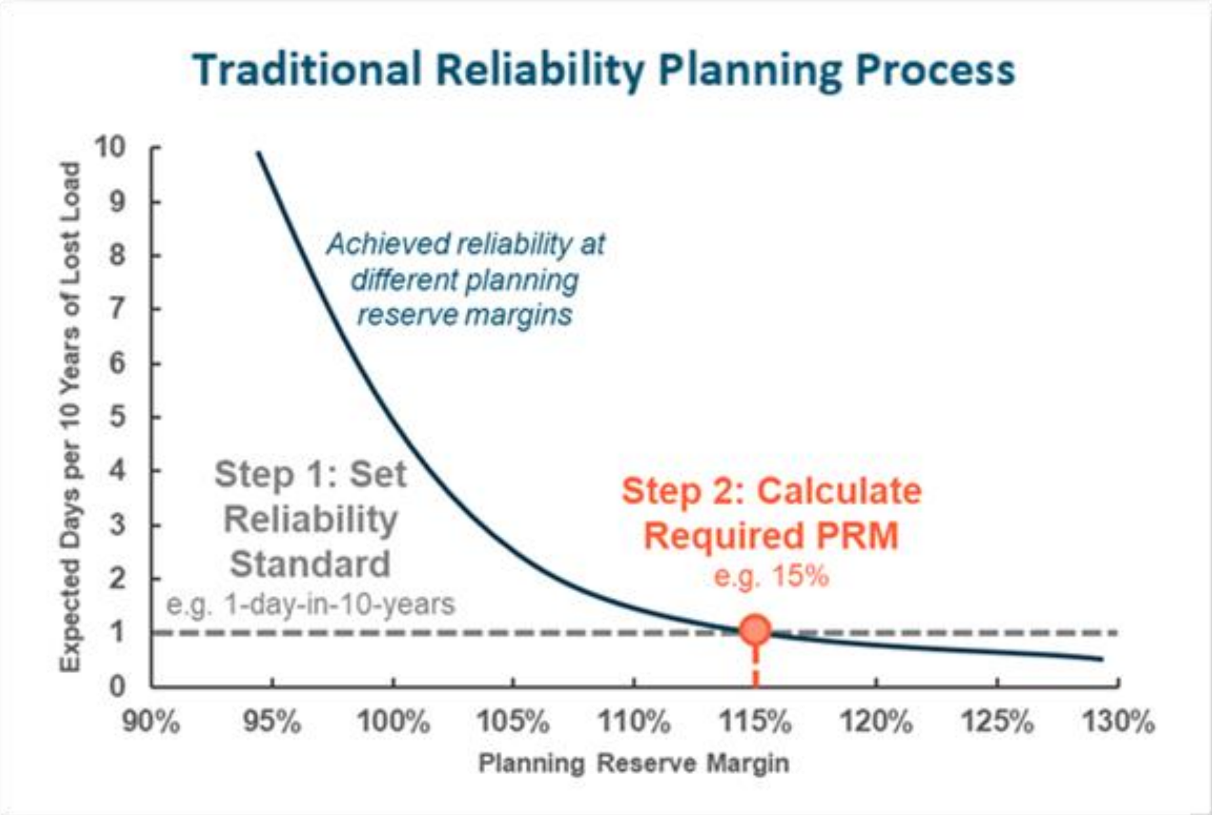
ELCC
- *Effective load carrying capability*
- *Equivalent quantity of 'perfect capacity' for a variable or energy-limited resource*

TPRM
- *Target planning reserve margin*
- *PRM required to achieve a specified reliability threshold (i.e. LOLE, ALOLP, or EUE)*



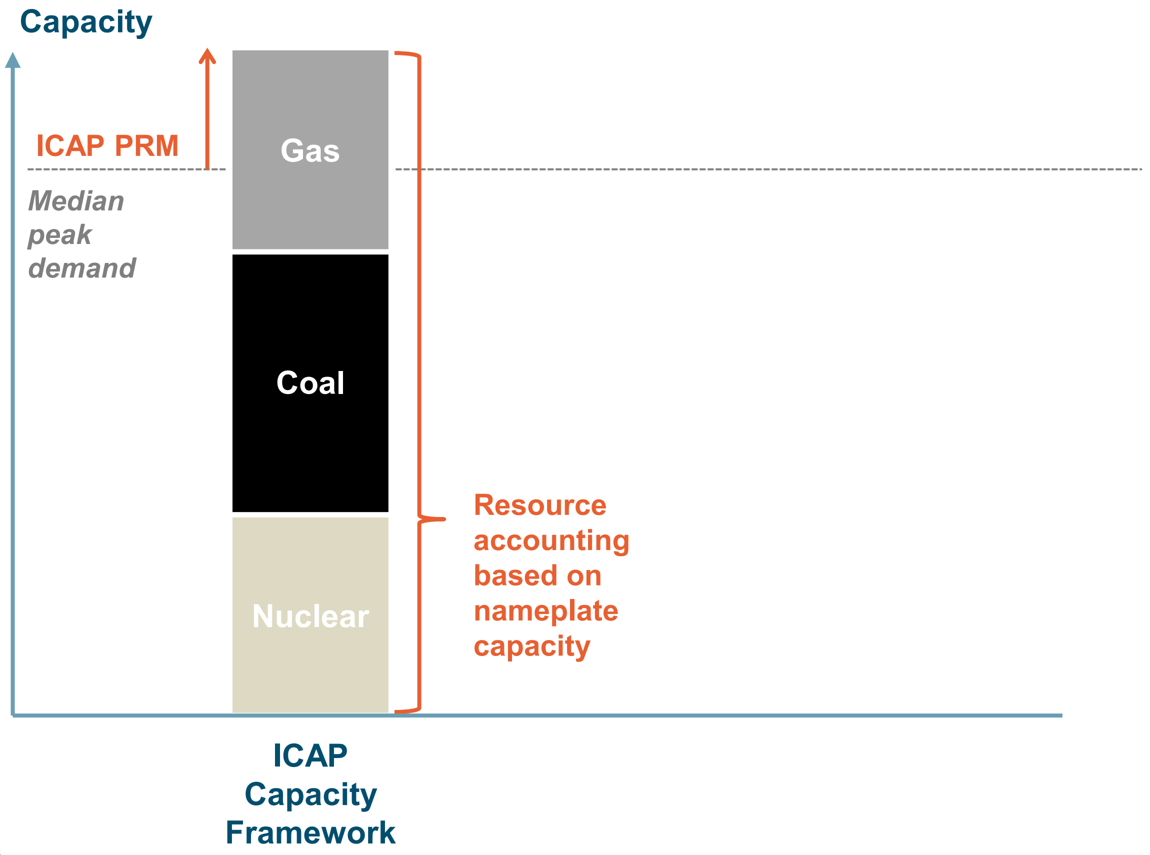
Total Reliability Need (TRN) and Planning Reserve Margin (PRM)

- **Total Reliability Need is the quantity of perfect capacity needed to meet a defined reliability standard**
  - Typically defined as "1 day in 10 years" or 0.1 LOLE but other definitions may be useful
- **PRM is measured as the quantity of capacity needed above the median year peak load to meet the LOLE standard**
  - Calculated as (TRN – Median Peak)/Median Peak
  - Serves as a simple and intuitive metric that can be utilized broadly in power system planning
  - Considers load and resource conditions during *all hours of the year*



The conventional accreditation framework rests on simplifying assumptions that are increasingly inaccurate

+ **PRM defined based on Installed Capacity method (ICAP)**
  - Covers annual peak load variation, operating reserve requirements, and thermal resource forced outages
+ **Individual resources accredited based on nameplate capacity**
  - Small differences in forced outage rates
  - No interactions among resources
  - Forced outages also incorporated through performance penalties

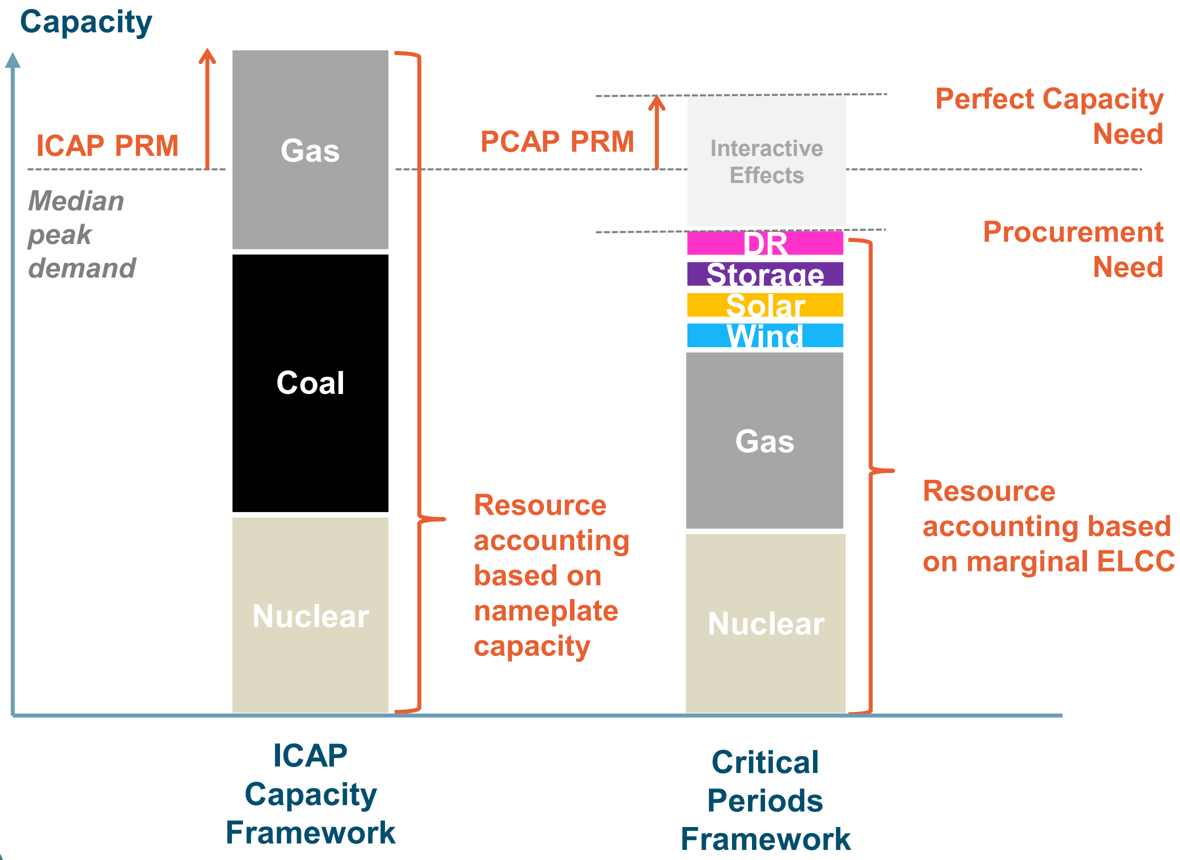


$$Installed\ Capacity = \sum_{i=1}^{n} G_i$$

The Critical Periods framework is more accurate and more adaptable for a diverse resource mix

+ **PRM defined based on need for Equivalent Perfect Capacity (PCAP)**
  - Covers annual peak load variation and operating reserves only; forced outages addressed in resource accreditation
+ **Individual resources accredited based on Marginal ELCC**
  - Large differences in availability during key hours
  - Significant interactions among resources
  - ELCC values are dynamic based on resource portfolio

$$Portfolio\ ELCC = f(G_1, G_2, \dots, G_n)$$



Measuring ELCC of a portfolio and individual resources

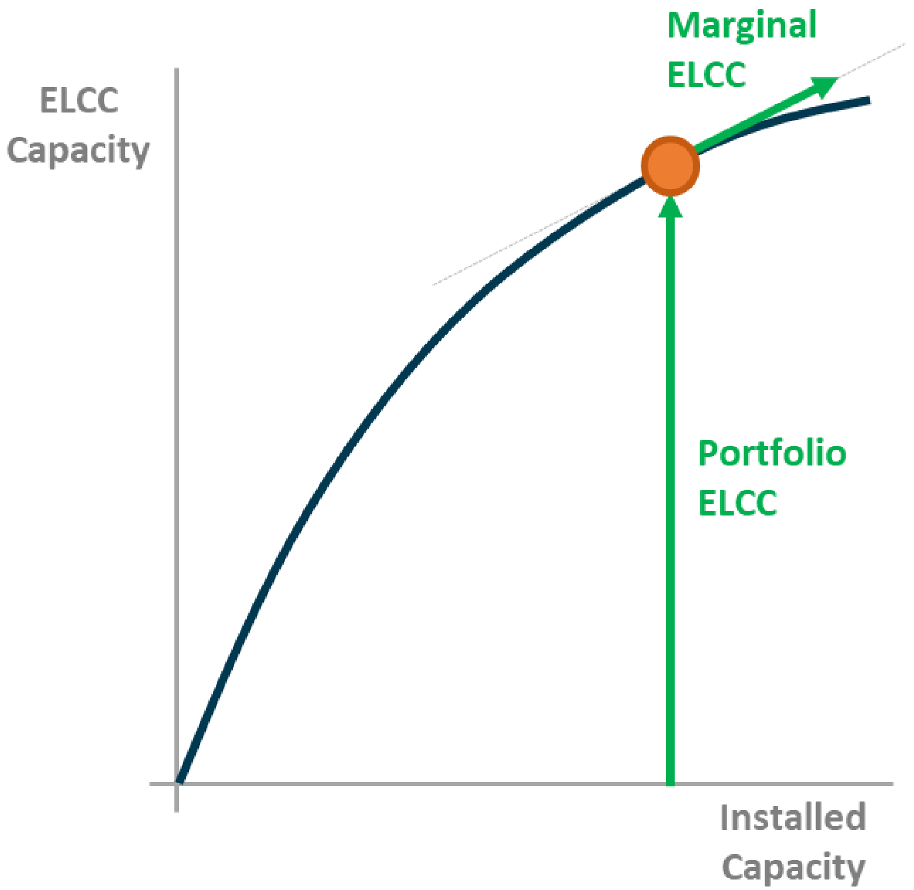
- **ELCC is a function of the portfolio of resources**
  - The function is a surface in multiple dimensions
  - The Portfolio ELCC is the height of the surface at the point representing the total portfolio

$$Portfolio\ ELCC = f(G_1, G_2, \ldots, G_n)\ (MW)$$

  - The Marginal ELCC of any individual resource is the gradient (or slope) of the surface along a single dimension – mathematically, the partial derivative of the surface with respect to that resource

$$Marginal\ ELCC_{G_1} = \frac{\partial f}{\partial G_1}(G_1, G_2, \ldots G_n)\ (\%)$$

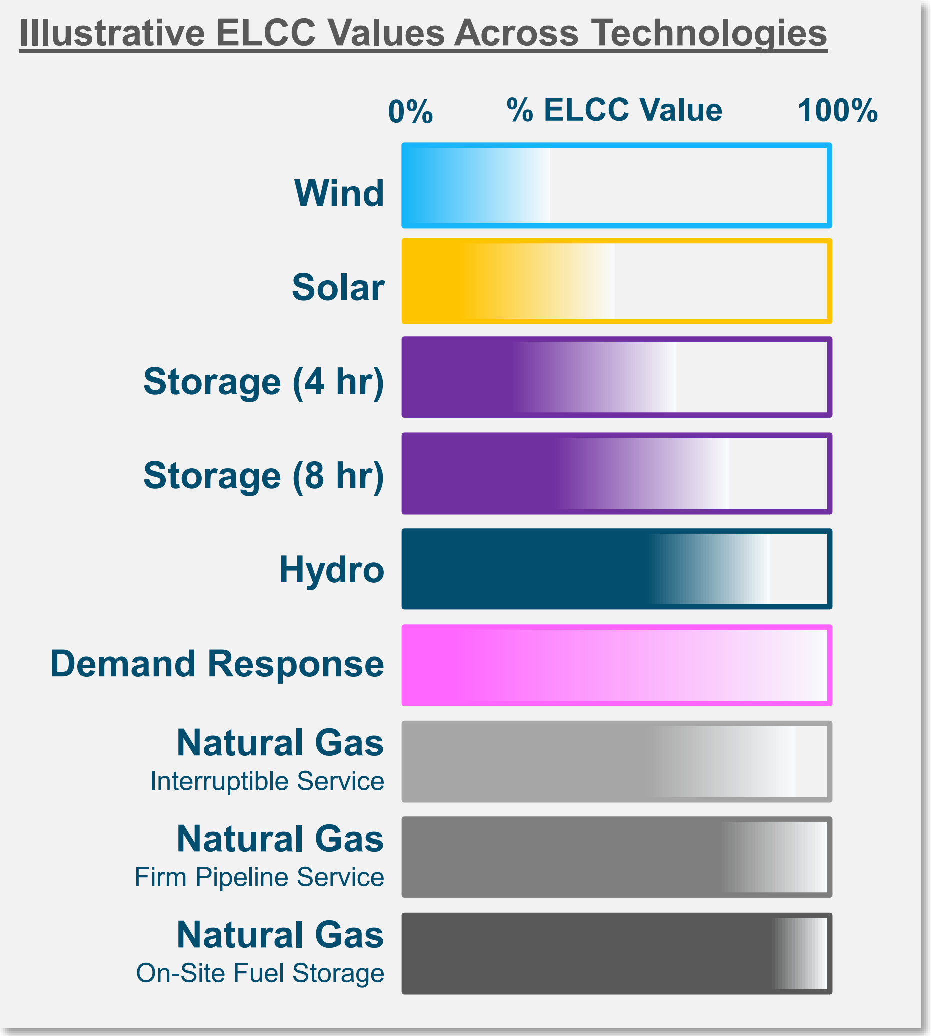
- **The functional form of the surface is unknowable**
  - Marginal ELCC calculations give us measurements of the contours of the surface at specific points
  - It is impractical to map out the entire surface



No resource is "perfect" – Marginal ELCC is applied to all resources in the Critical Periods framework

- **Marginal ELCC creates level playing field by measuring all resources against perfect capacity**
- **Accounts for all factors that can limit availability:**
  - Energy availability
  - Hourly variability in output
  - Duration and/or use limitations
  - Temperature-related de-rates and outage rates
  - Correlated outage risk
- **Interactive effects in the portfolio cannot be uniquely attributed to individual resources**

$$Portfolio\ ELCC = \sum_{i=1}^{n} MELCC_i + Interactive\ Effects$$

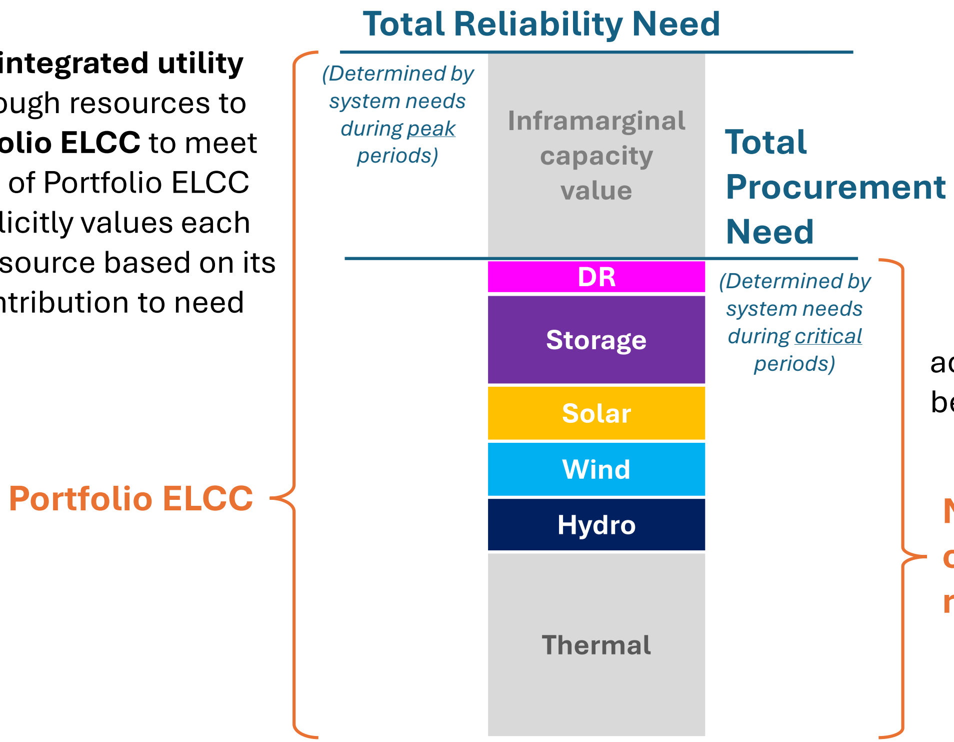


Marginal ELCC accreditation is important for both system planning and markets

- **For system planning and investment, accurate marginal accreditation is critical to identify optimal resource additions**
  - Accreditation of existing resources is unimportant

- **For markets, marginal accreditation must also be used for existing resources**
  - Existing resources are perfect substitutes for new resources
  - All grid services are compensated at their marginal value

A **vertically integrated utility** procures enough resources to provide **Portfolio ELCC** to meet **TRN**; the use of Portfolio ELCC function implicitly values each incremental resource based on its marginal contribution to need

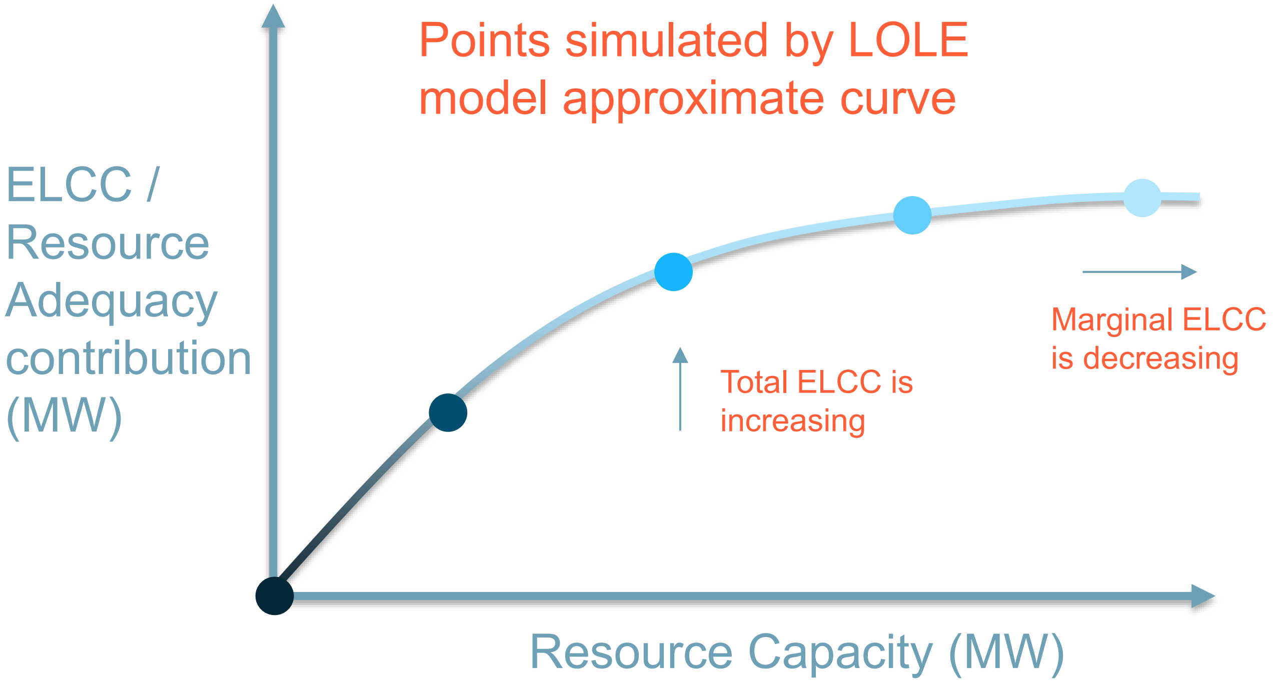


A **market operator** or **RA program administrator** accredits all resources at **marginal value** and clears sufficient accredited capacity to meet **TPN**; difference between TRN and TPN reflects inframarginal interactive effects among resources

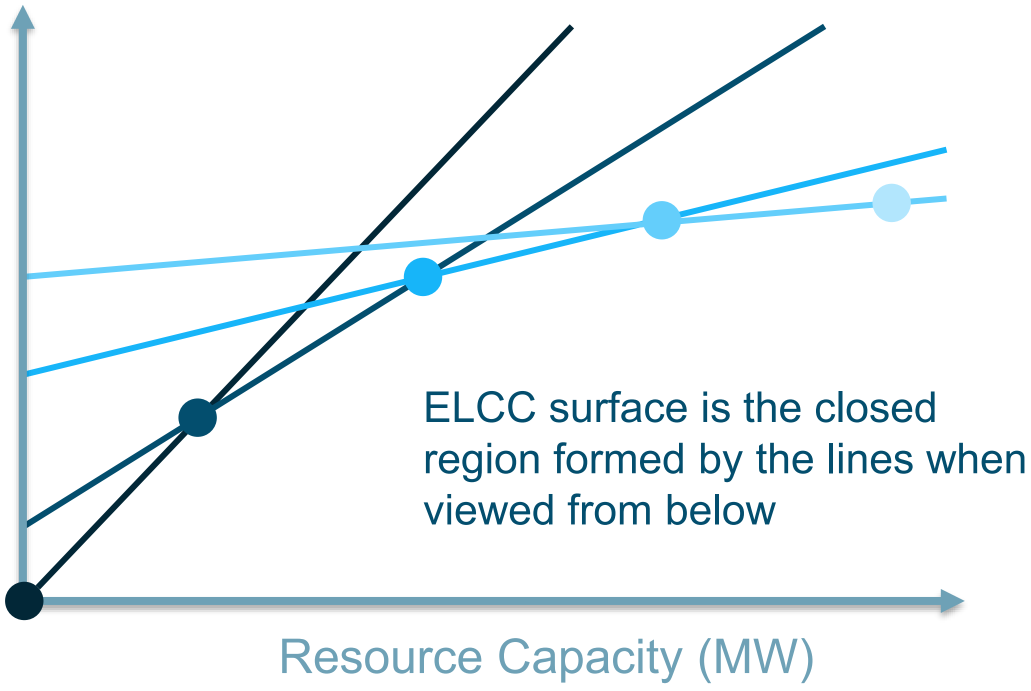
Marginal ELCC of individual resources

System Planning: piecewise-linear Portfolio ELCC function captures changing marginal values

Calculate Portfolio and Marginal ELCC at different levels of penetration through repeated LOLP model runs



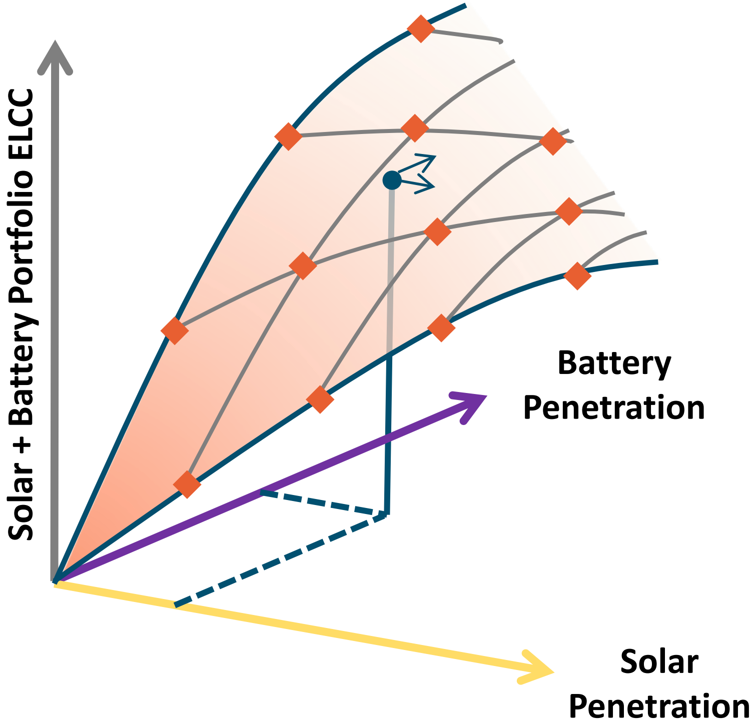
Linear equations to approximate ELCC curve and used to constrain optimal capacity expansion modeling



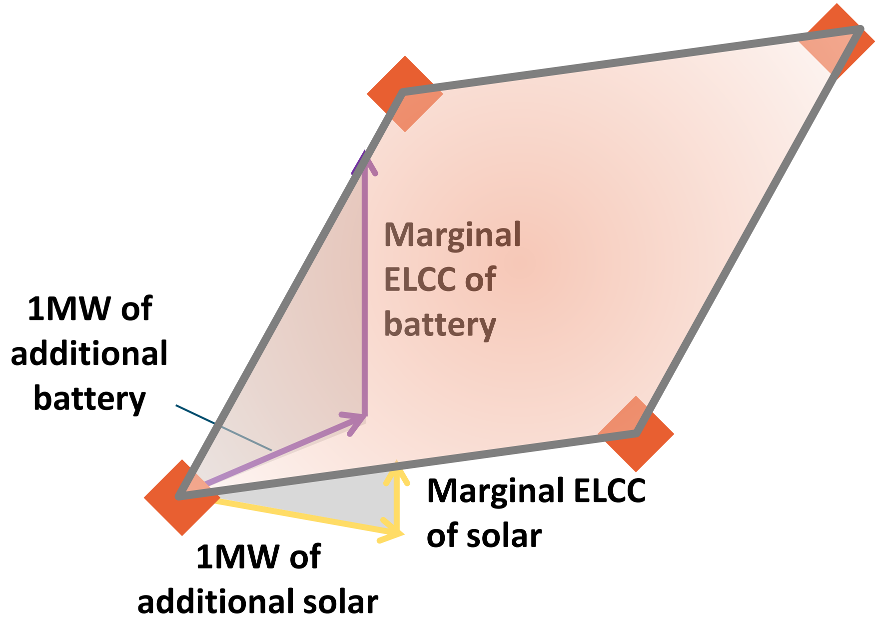
Piecewise-planar function in multiple dimensions can capture both saturation and diversity effects

The height of the orange dots gives the total solar + storage portfolio ELCC

The slope between each point gives the marginal capacity value of solar and storage at a given capacity

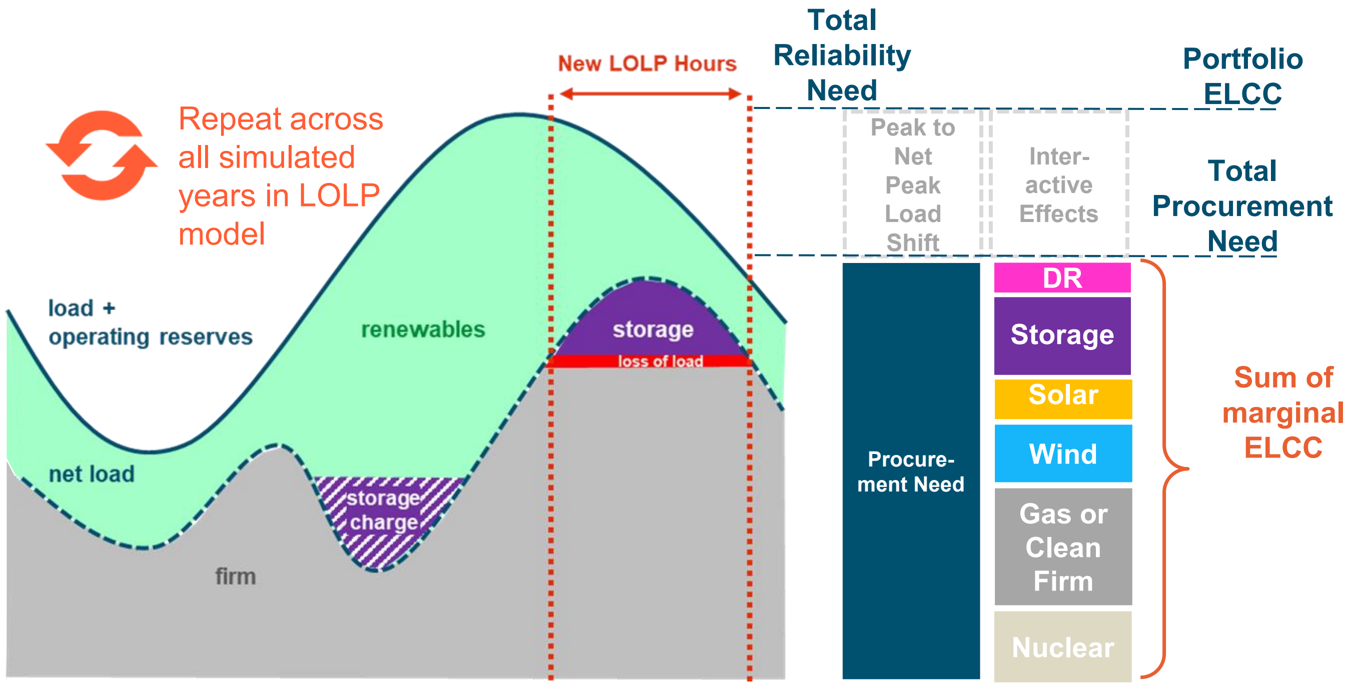


For any plane on the surface:



Application of the critical periods framework in markets requires calculating the Total Procurement Need (TPN)

+ **The TPN is the quantity of resources cleared in the auction**
  - TPN = sum of the marginal ELCCs of all the resources in a reliable portfolio
+ **The Total *Procurement* Need is less than the Total *Reliability* Need (TRN) due to portfolio effects**
  - TRN – TPN is equal to the portfolio effects among all resources in the portfolio
  - TRN – TPN is also equal to gross peak load minus the load served during critical periods in a reliable portfolio
  - TPN can even be lower than peak load
+ **Marginal ELCC is determined by performance during critical periods**



$$For\ a\ reliable\ portfolio{:}\ \ TPN\ =\sum_{i=1}^{n} MELCC_i$$

$$Portfolio\ ELCC = TRN = TPN + Interactive\ Effects$$

Most markets are moving toward the Critical Periods framework, albeit with different computational methods

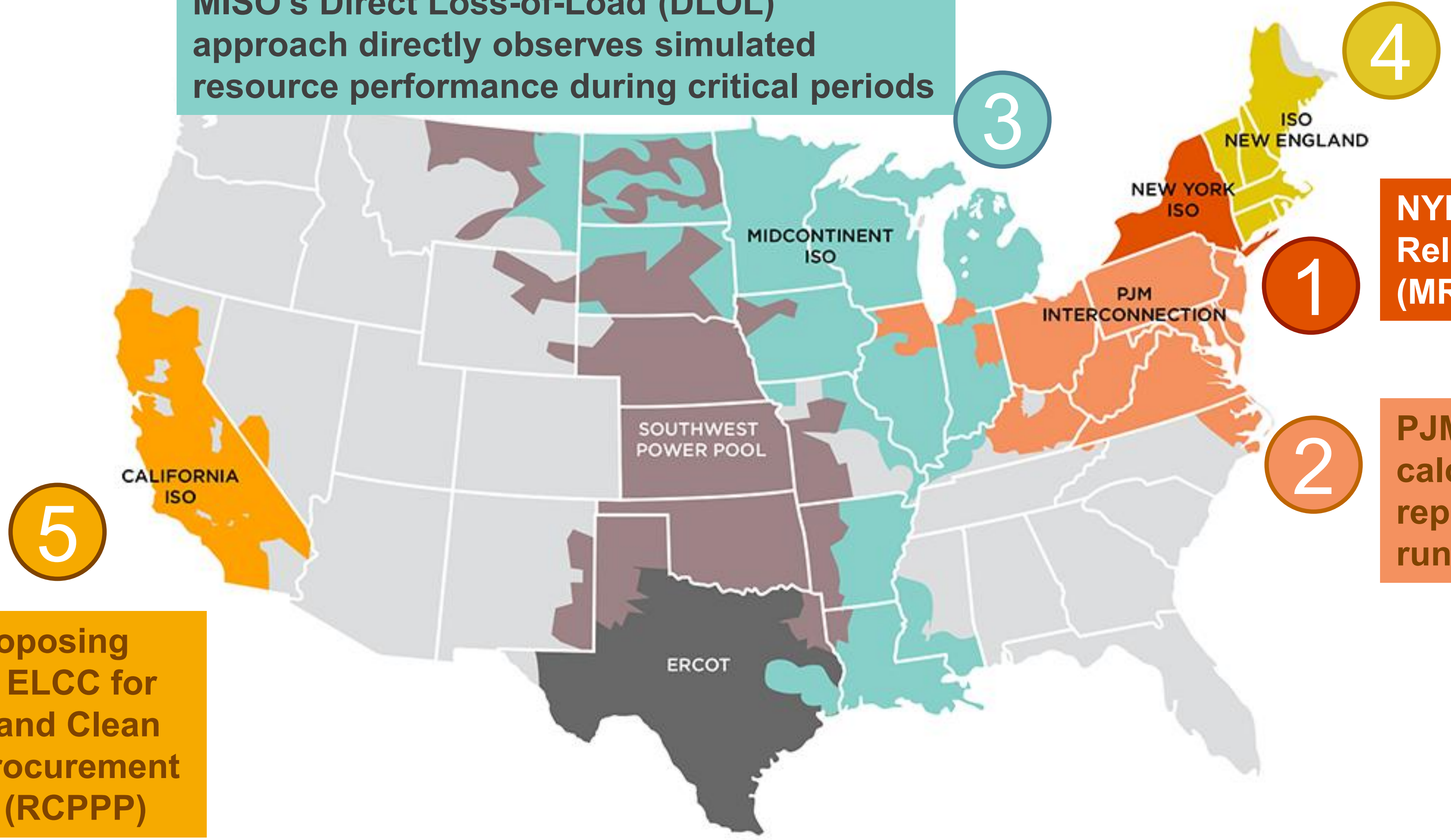
MISO's Direct Loss-of-Load (DLOL) approach directly observes simulated resource performance during critical periods

ISO-NE currently proposing an MRI approach

NYISO: Using Marginal Reliability Improvement (MRI) method

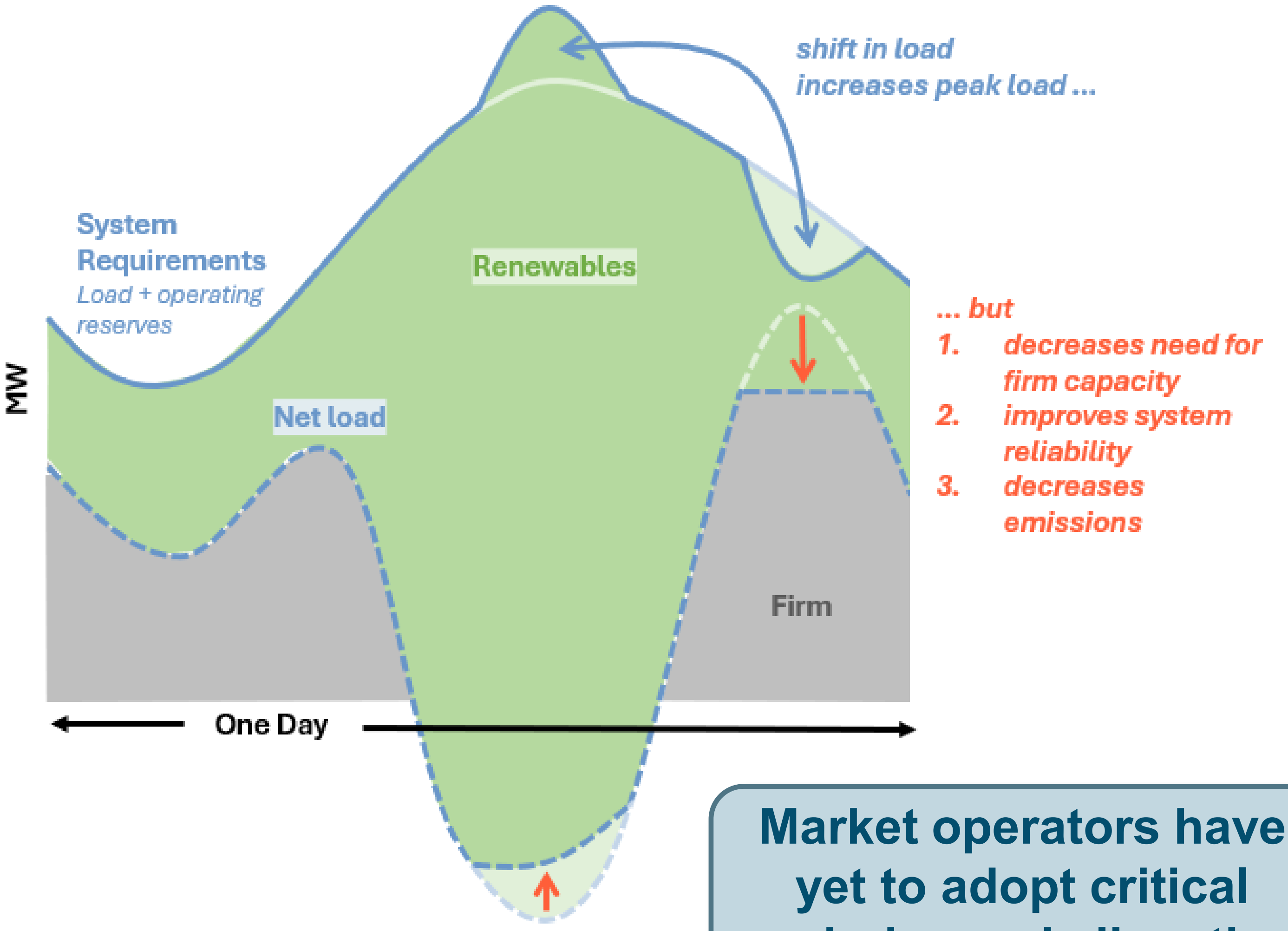
PJM: Marginal ELCC calculated through repeated LOLP model runs

CPUC proposing marginal ELCC for Reliable and Clean Power Procurement Program (RCPPP)



Allocating need based on load during critical periods is important to encourage load participation

- **Aligns need allocation method with periods of expected scarcity**
- **Encourages load reduction during critical hours**
  - Reducing consumption during high load but not critical periods is harmful to reliability by making loads less likely to respond when needed
  - Demand-side measures such as daytime EV charging are disincentivized by allocating need based on peak load
- **Aligns incentives for "event-based" and "price-based" DR**



Market operators have yet to adopt critical periods need allocation

Thank you!

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