Resource Adequacy for a Transitioning Electricity Grid

Executive Presentation

December 9, 2024

Energy+Environmental Economics

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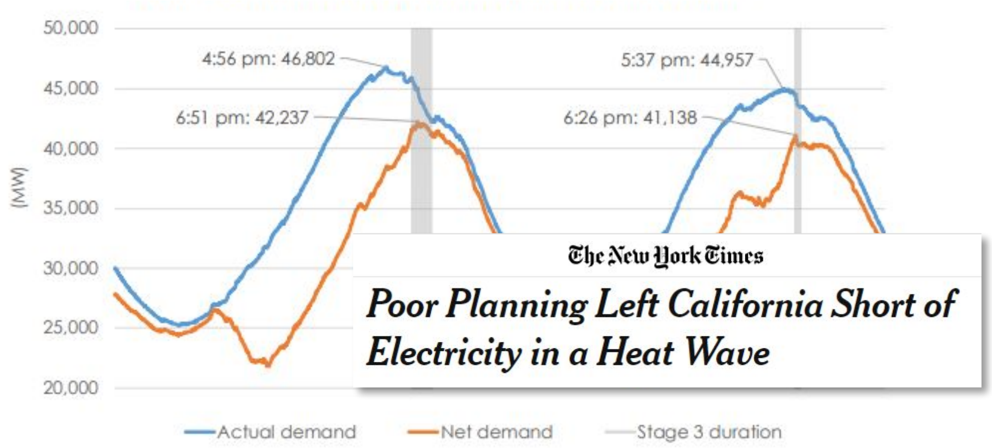
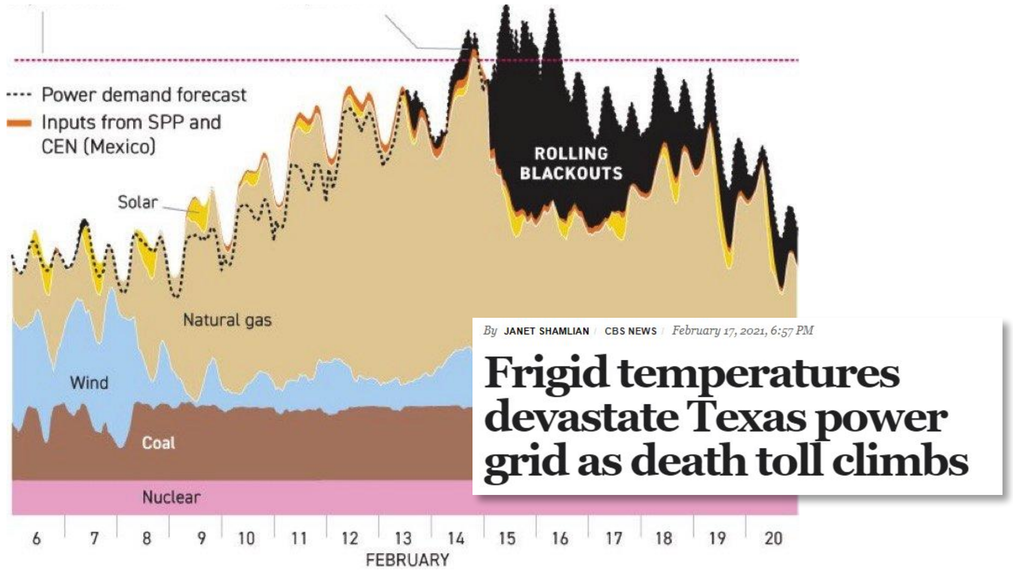
Planning for resource adequacy is increasing in complexity – and importance

- **Transition towards renewables and storage introduces new sources of complexity in resource adequacy planning**
  - The concept of planning exclusively for “peak” demand is quickly becoming obsolete
  - Frameworks for resource adequacy must be modernized to consider conditions across all hours of the year – as underscored by California’s rotating outages during August 2020 “net peak” period
- **Reliable electricity supply is essential to our day-to-day lives at home and at work – and will become increasingly important**
  - Meeting cooling and heating demands under more frequent extreme weather events is may be a matter of life or death
  - Economy-wide decarbonization goals will drive electrification of transportation and buildings, making the electric industry the keystone of future energy economy



Graph source: http://www.caiso.com/Documents/Final-Root-Cause-Analysis-Mid-August-2020-Extreme-Heat-Wave.pdf

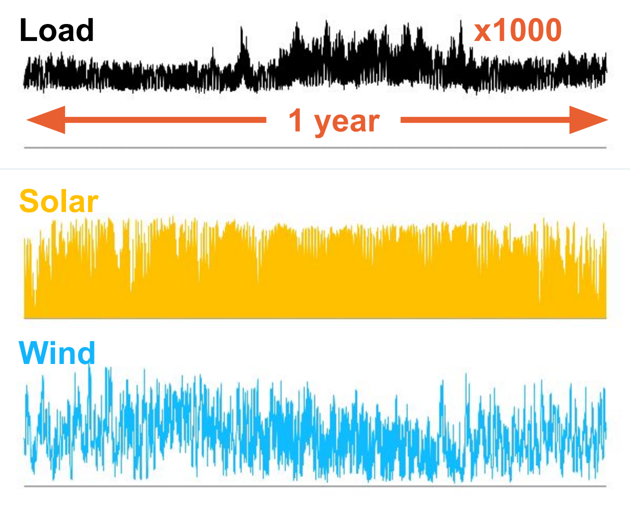


Graph source: https://twitter.com/bcshaffer/status/1364635609214586882

Overview of best practices in resource adequacy analysis

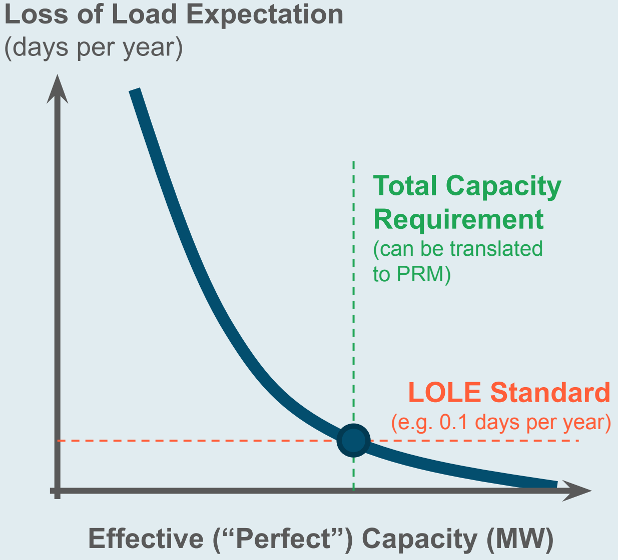
Step 1: Develop a representation of the loads and resources of an electric system in a loss of load probability model

LOLP modeling allows a utility to evaluate resource adequacy across all hours of the year under a broad range of weather conditions, producing statistical measures of the risk of loss of load



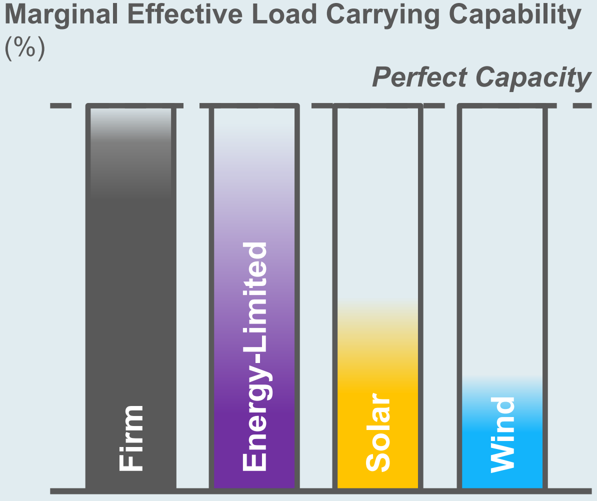
Step 2: Identify the amount of perfect capacity needed to achieve the desired level of reliability

Factors that impact the amount of perfect capacity needed include load & weather variability, operating reserve needs



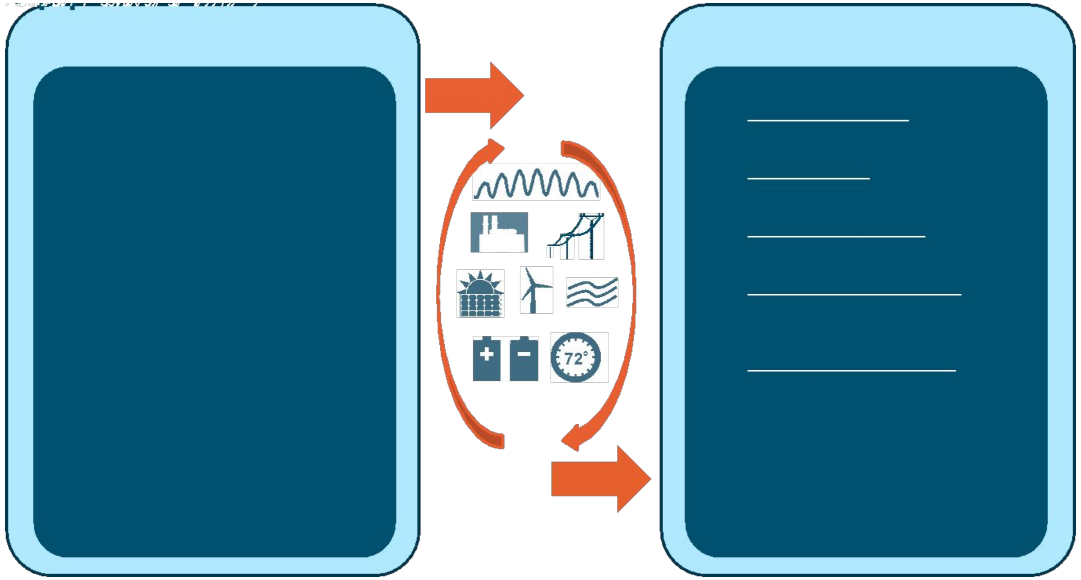
Step 3: Calculate capacity contributions of different resources using effective load carrying capability

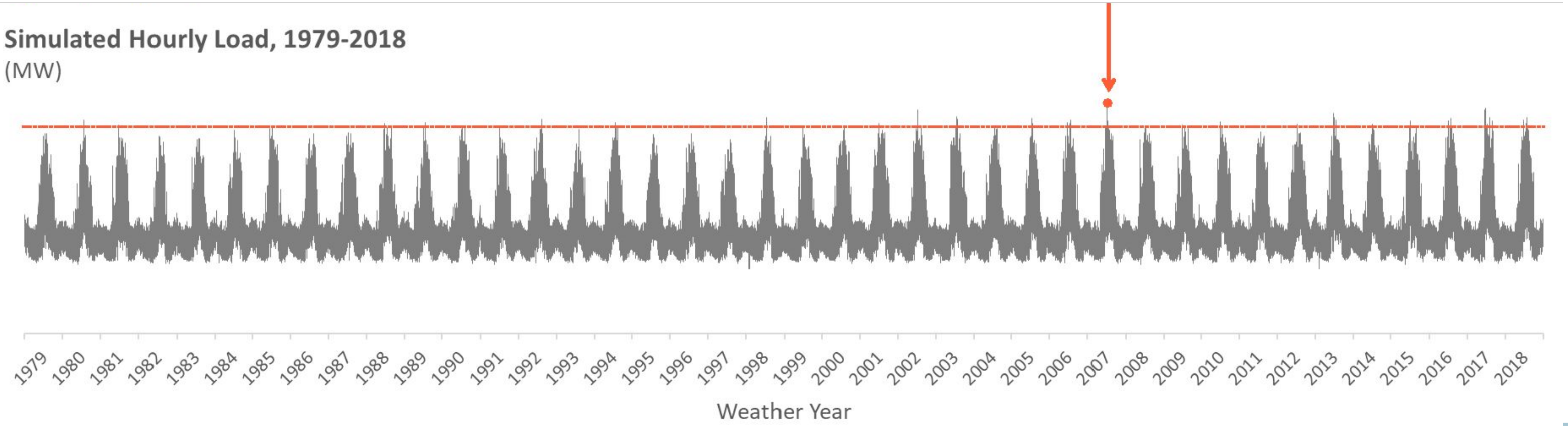
ELCC measures a resource's contribution to the system's needs relative to perfect capacity, accounting for its limitations and constraints



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

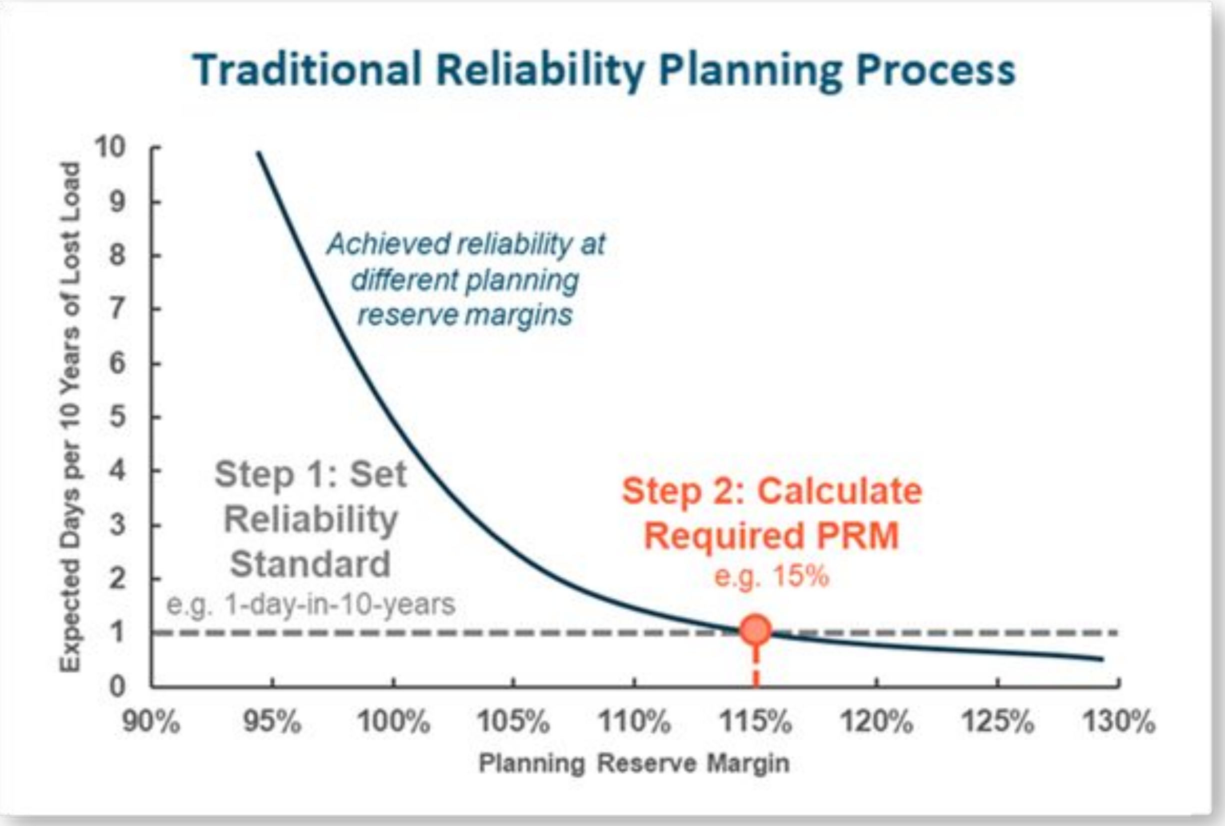




Total Resource Need (TRN) and Planning Reserve Margin (PRM)

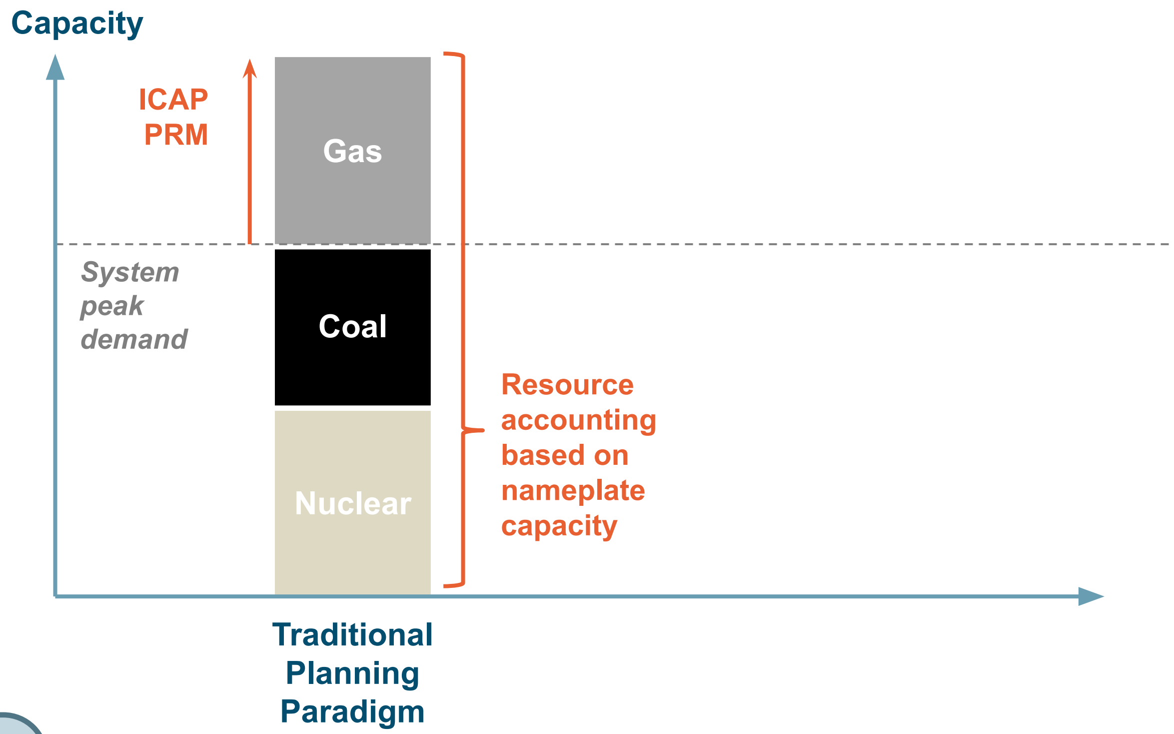
- **Total Resource Need is the quantity of effective capacity needed to meet a defined reliability standard**
  - Typically defined as "1 day in 10 years" or 0.1 LOLE but other definitions may be useful

- **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*



Resource accreditation is simple in the traditional planning paradigm

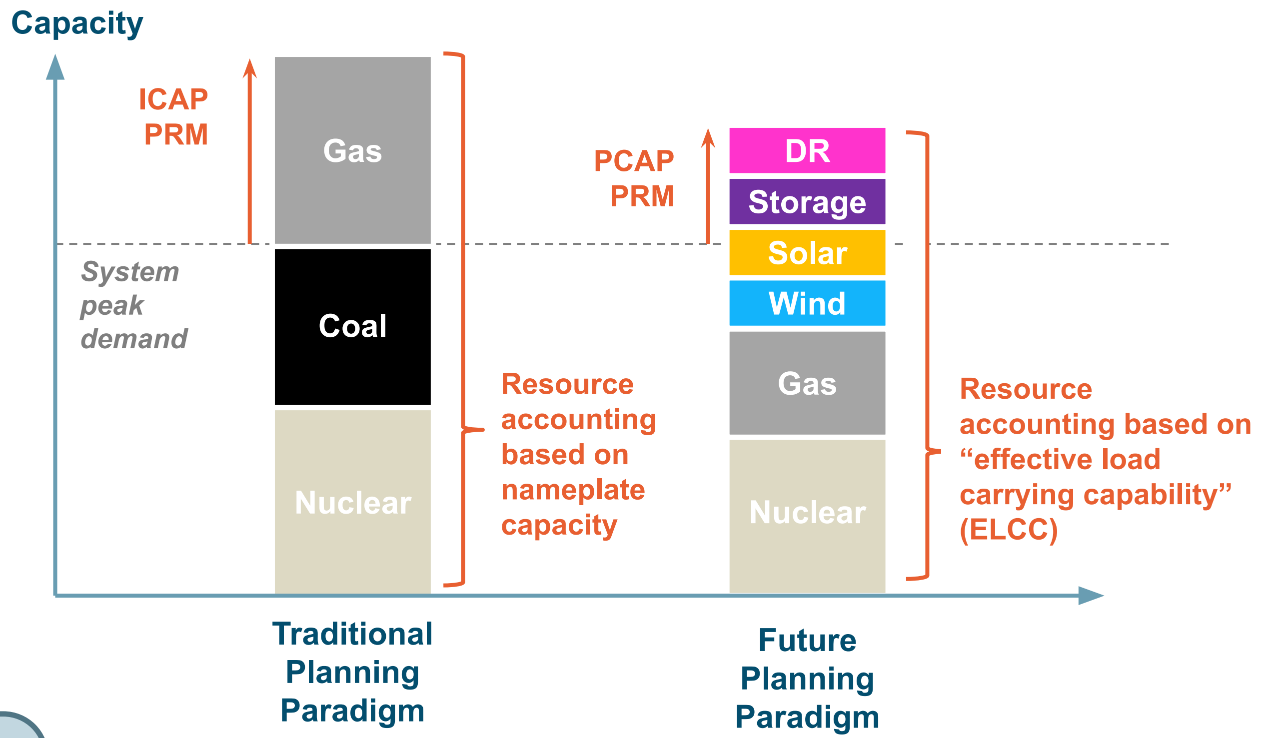
- **PRM defined based on Installed Capacity method (ICAP)**
  - Covers annual peak load variation, operating reserve requirements, and thermal resource forced outages
- **Individual resources accredited based on nameplate capacity**
  - Small differences in forced outage rates
  - No interactions among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



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

Adapting the PRM framework for a more 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 ELCC**
  - Large differences in availability during key hours
  - Significant interactions among resources
  - ELCC values are dynamic based on resource portfolio



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

Measuring ELCC of a portfolio and individual resources

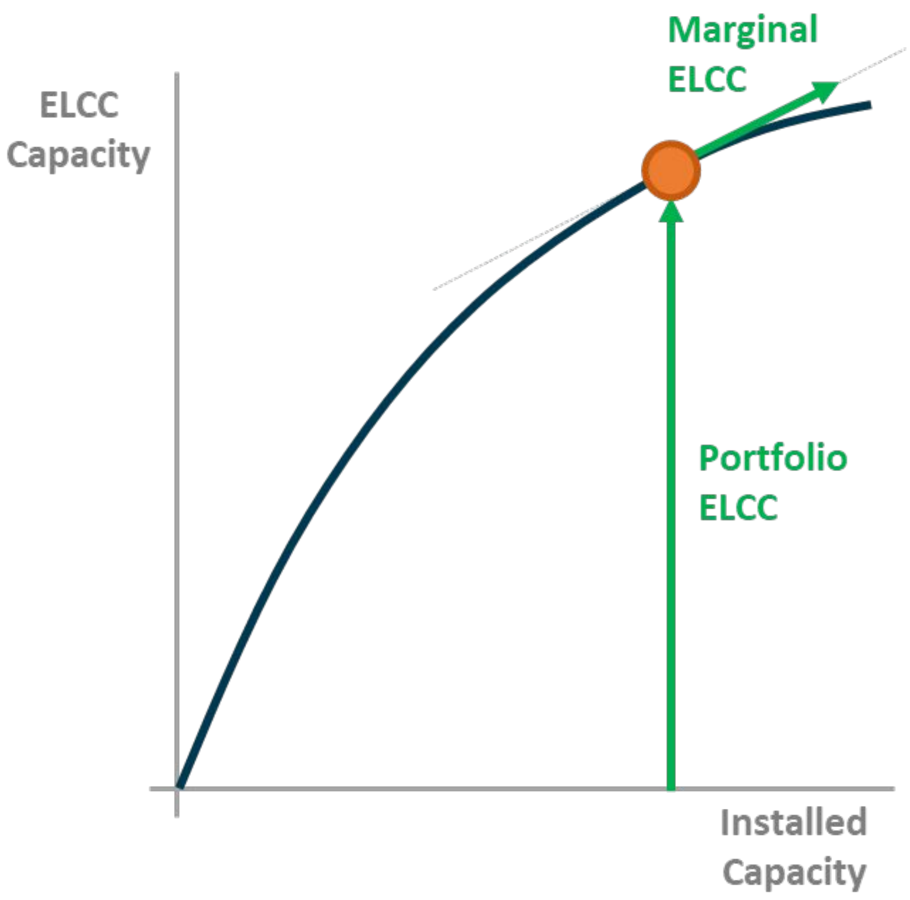
- **ELCC is a function of the portfolio of resources**
  - The function is a surface in multiple dimensions
  - The Portfolio ELCC is the height of the surface at the point representing the total portfolio

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

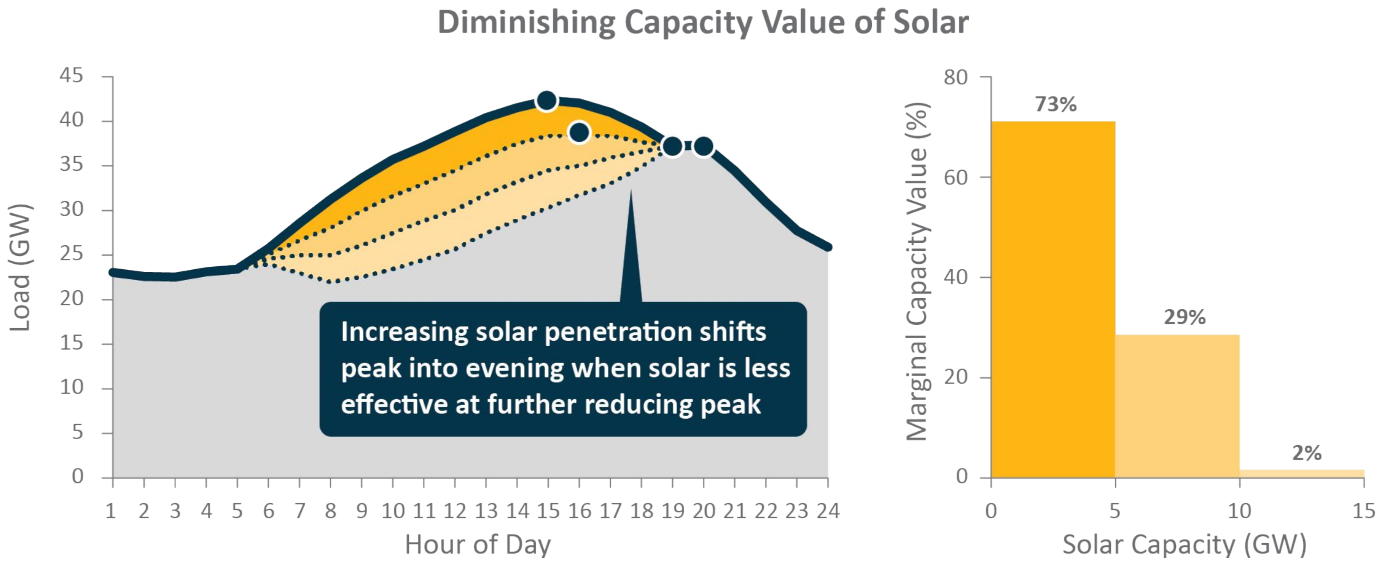
  - The Marginal ELCC of any individual resource is the gradient (or slope) of the surface along a single dimension – mathematically, the partial derivative of the surface with respect to that resource

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

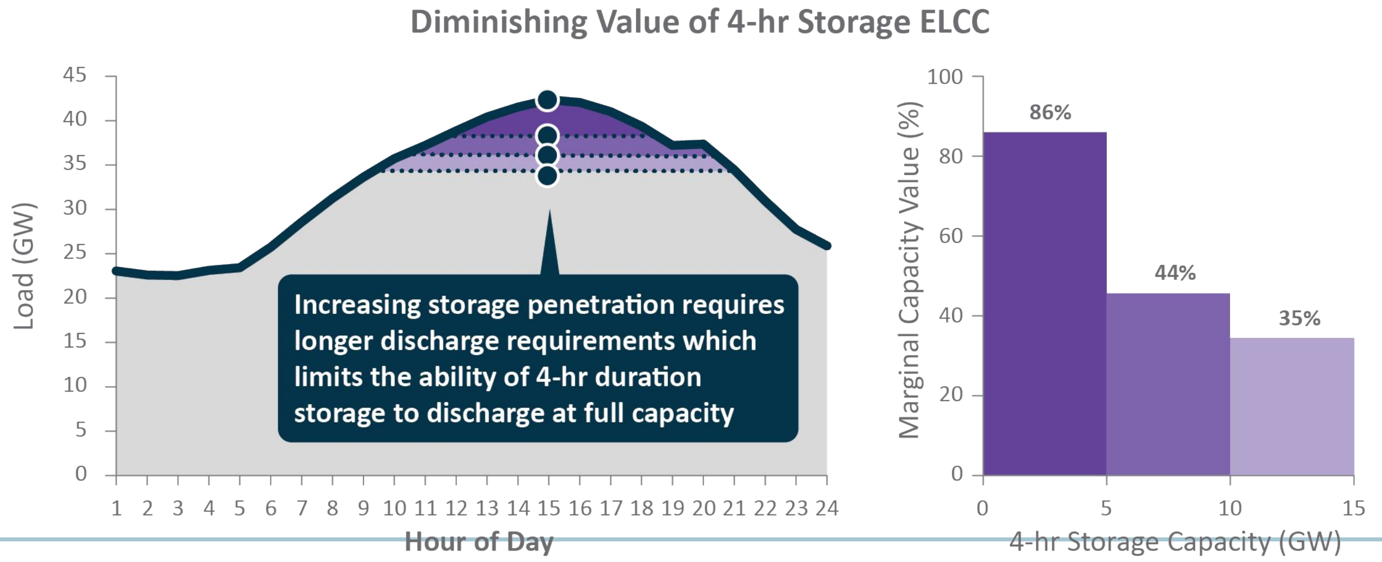
- **The functional form of the surface is unknowable**
  - Marginal ELCC calculations give us measurements of the contours of the surface at specific points
  - It is impractical to map out the entire surface



Interactive effect: The capacity contribution of variable and dispatch-limited resources diminishes at higher penetrations



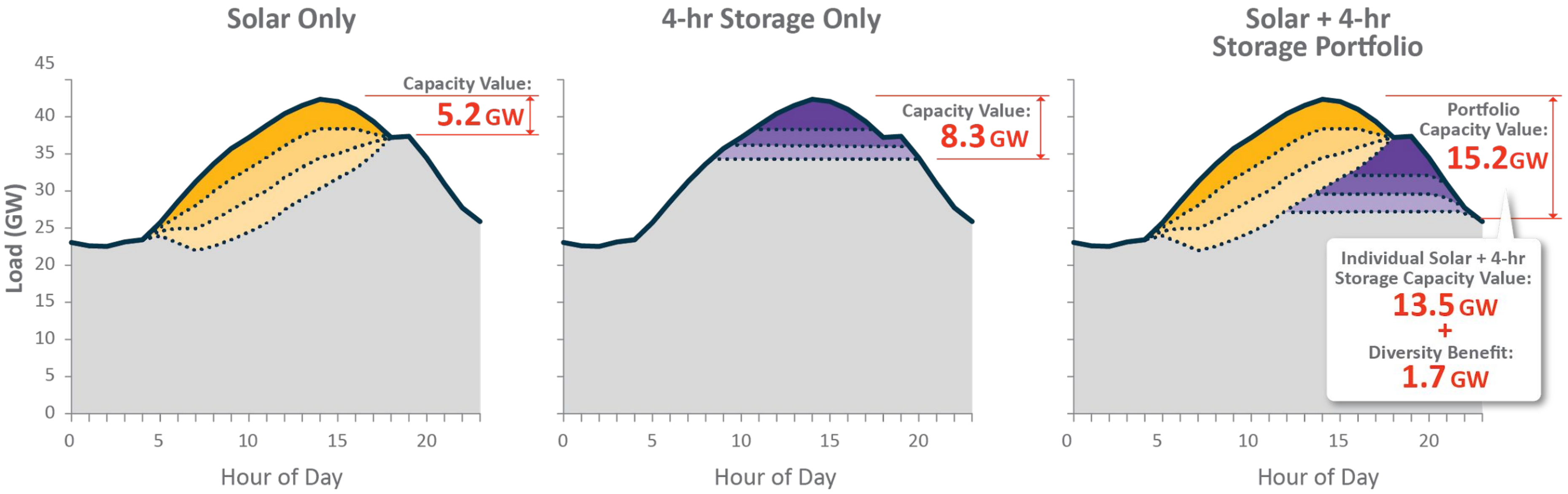
Solar and other **variable resources** (e.g. wind) exhibit declining value due to variability of production profiles



Storage and other **energy-limited resources** (e.g. DR, hydro) exhibit declining value due to limited ability to generate over sustained periods

Interactive effect: The capacity contribution of variable and dispatch-limited resources depends on the portfolio

- Resources with complementary characteristics produce the opposite effect, synergistic interactions (also described as a “diversity benefit”)
- As penetrations of intermittent and energy-limited resource grow, the magnitude of these interactive effects will increase and become non-negligible



- The existence of interactive effects means there is no mathematically unique way to calculate an average ELCC for multiple resource types

Resource interactions: synergistic or antagonistic pairings

Common Examples of Synergistic Pairings

Solar + Wind
The profiles for many wind resources produce more energy during evening and nighttime hours when solar is not available

Solar + Storage
Solar and storage each provide what the other lacks – energy (in the case of storage) and the ability to dispatch energy in the evening and nighttime (in the case of solar)

Solar/Wind + Hydro
Hydro is an energy-limited resource so increasing penetrations of solar or wind allows hydro to save its limited production for the most resource constrained hours

Common Examples of Antagonistic Pairings

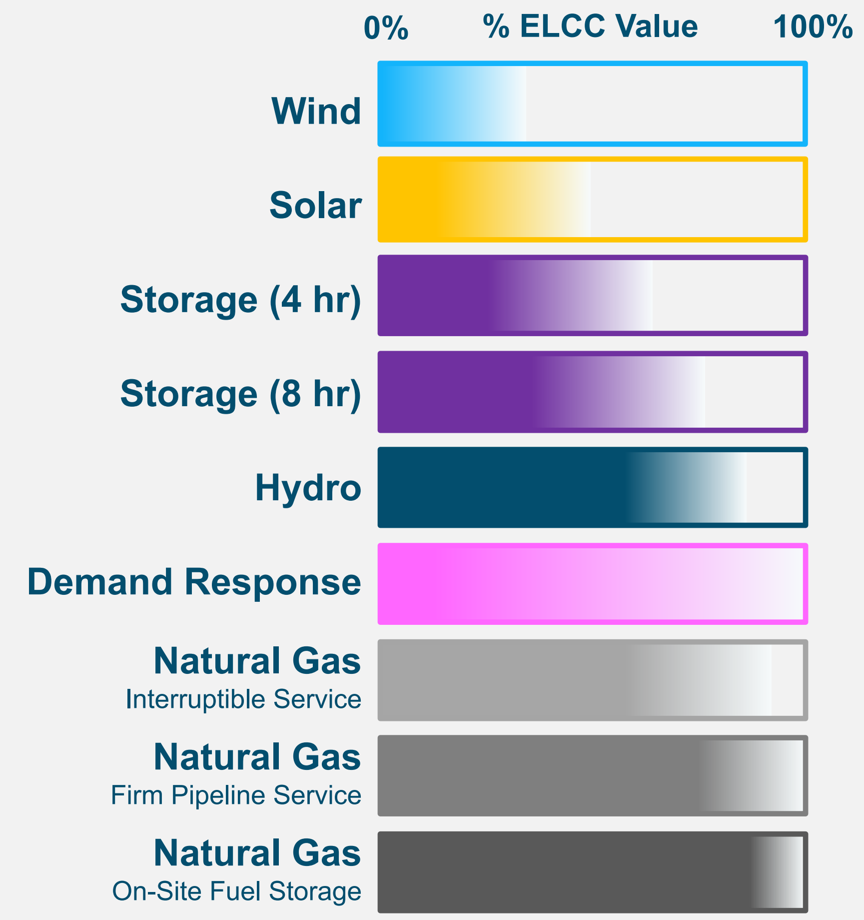
Storage + Hydro
Energy limitations on both storage and hydro require longer and longer durations after initial penetrations

Storage + Demand Response
Energy limitations on both storage and hydro require longer and longer durations after initial penetrations

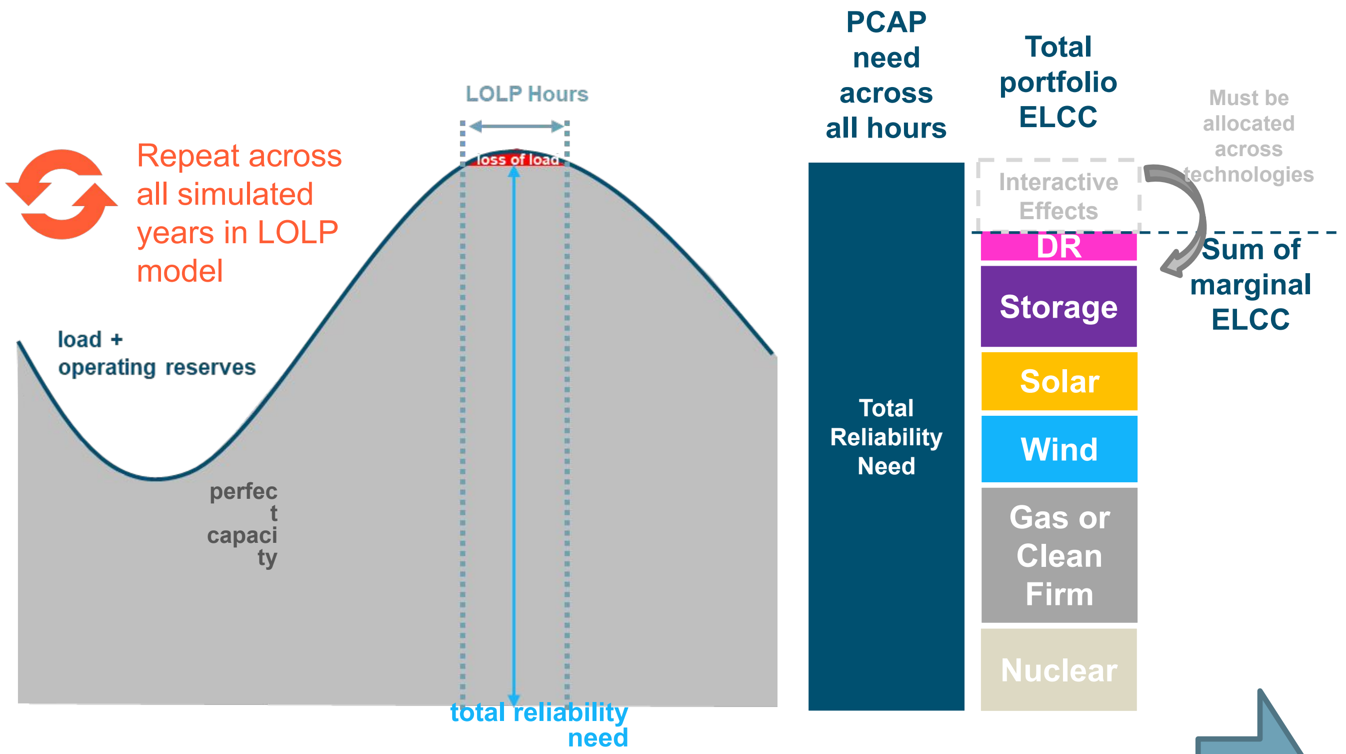
No resource is "perfect" – ELCC can and should be applied to all resources

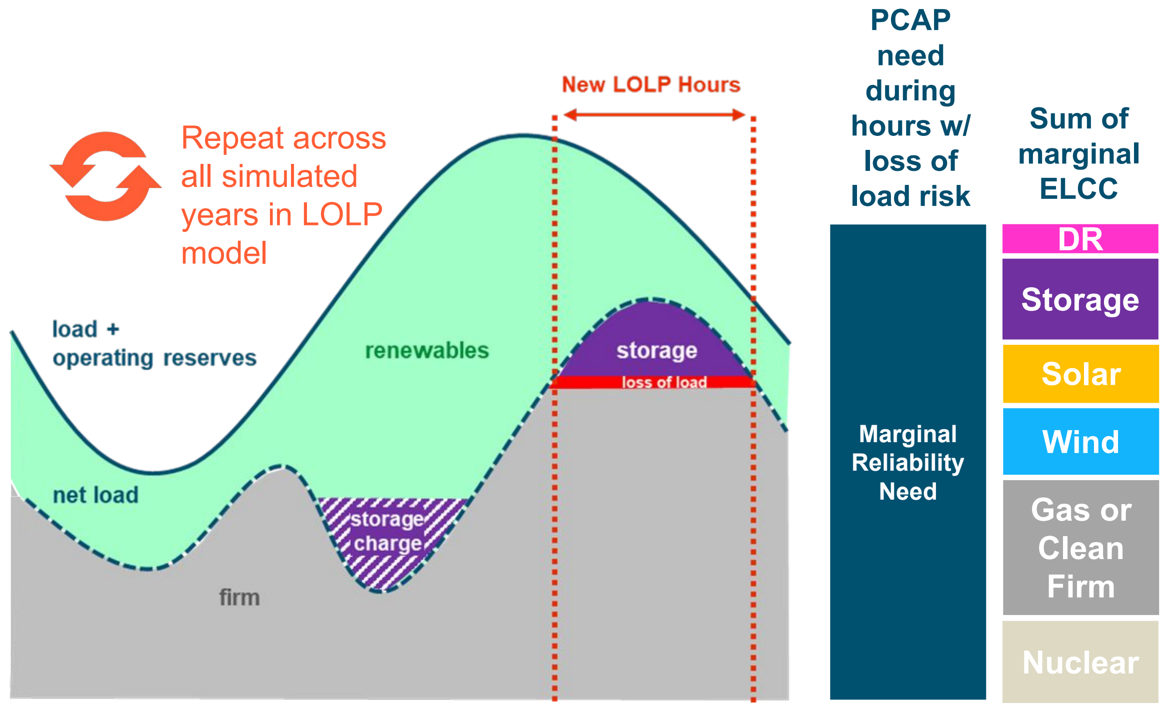
- **Marginal ELCC creates level playing field by measuring all resources against perfect capacity**
- **Can account for all factors that can limit availability:**
  - Hourly variability in output
  - Duration and/or use limitations
  - Seasonal temperature derates
  - Energy availability
  - Fuel availability
  - Temperature-related outage rates
  - Correlated outage risk, *especially under extreme conditions*
- **Use Perfect Capacity (PCAP) accounting as opposed to ICAP or UCAP**
  - Allocate need based on load during high-risk hours

Illustrative ELCC Values Across Technologies



Marginal ELCC based accreditation best informs decision making for market entry/exit





Total Reliability Need Accreditation

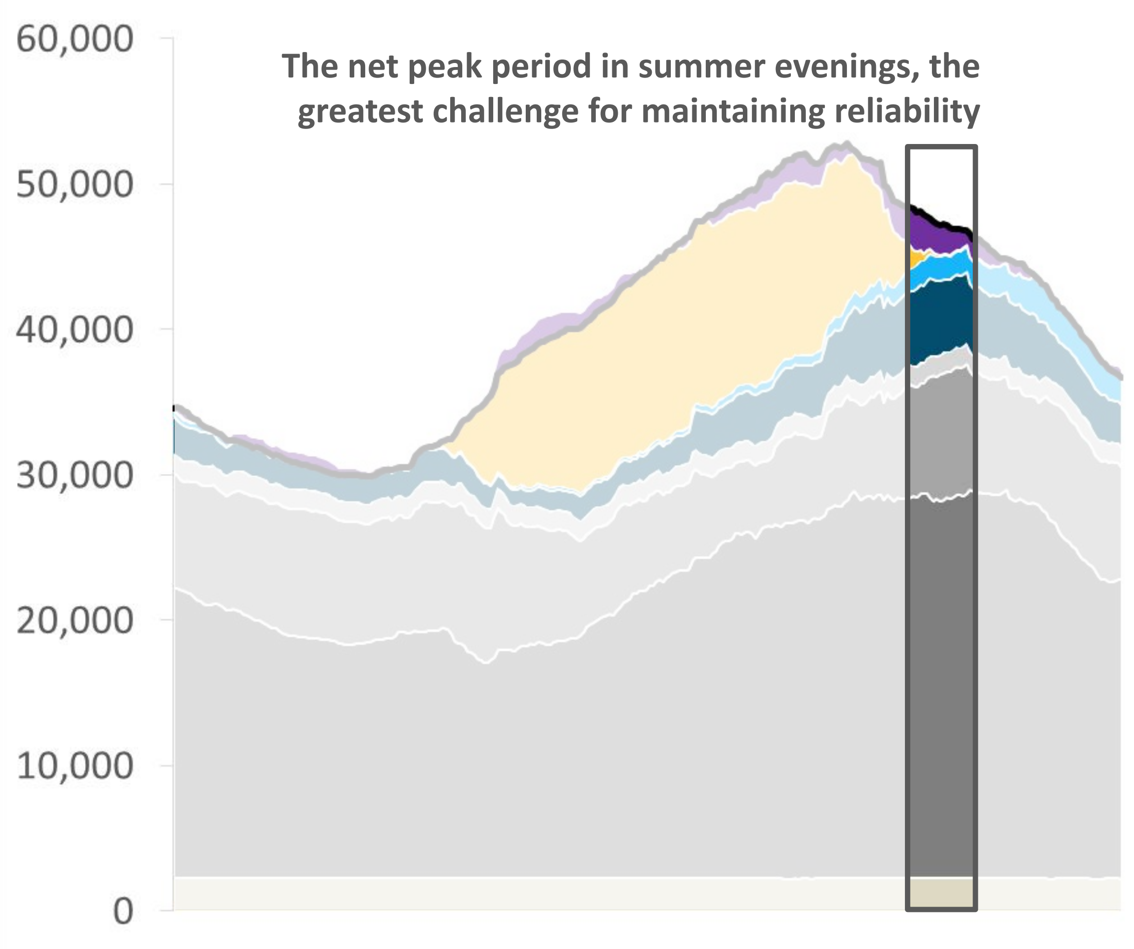
- Accredits the total portfolio reliability value using average ELCCs
- Not appropriate for resource accreditation / decision making
  - Sends incorrect investment signal for market entry/exit
  - Does not allocate need/costs w/ LSE marginal contribution
  - Requires arbitrary allocation of interactive effects

Marginal Reliability Need Accreditation

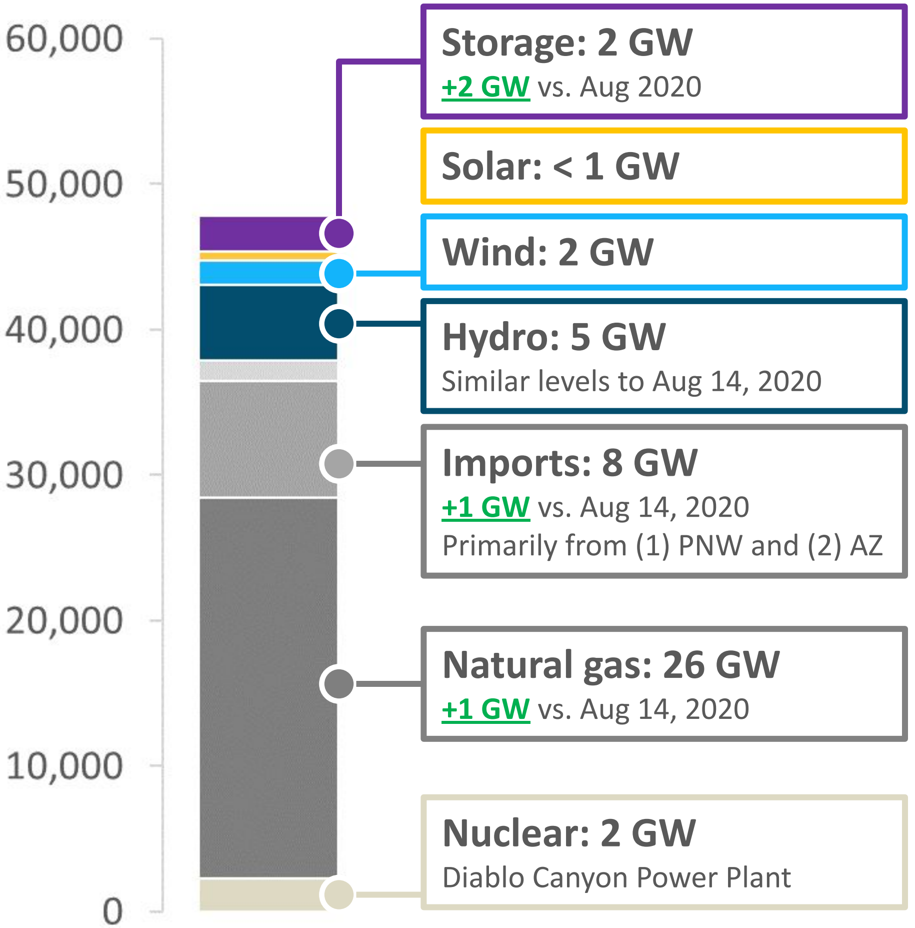
- Accredits the marginal reliability value of each resource <u>during hours with loss of load risk</u>
- <u>Useful for capacity markets</u>, whereby market entry/exit occurs to meet reliability needs
- Need is portfolio dependent, evolving as resource mix changes

California, September 6, 2022: All hands on deck!

CAISO System Operations on September 6, 2022
(MW)



Generation During Hour of Highest Net Load
(MW)



Most organized market operators are moving toward a marginal accreditation framework

Market	Accreditation
NYISO Installed Capacity (ICAP) Market	Marginal ELCC by zone
PJM Reliability Pricing Model (RPM)	Marginal ELCC
MISO Planning Resource Auctions (PRA)	Direct LOL, which is a form of marginal ELCC
ISO-NE Forward Capacity Market (FCM)	Moving toward marginal ELCC
SPP Resource Adequacy Requirement (RAR)	Average ELCC with declining curves by load zone
ERCOT proposed Performance Credit Mechanism (PCM)	Similar to marginal ELCC
CPUC/CAISO RA Program	Average ELCC, moving toward Slice of Day

Example load-resource table under ICAP and PCAP methods

Resource Type	Nameplate	ICAP + Average ELCC	PCAP + Marginal ELCC
Gas CCGT	5,000 MW	5,000 MW	4,750 MW
Gas CT	5,000 MW	5,000 MW	4,750 MW
Solar	4,000 MW	2,000 MW	600 MW
Batteries	1,000 MW	1,000 MW	900 MW
Portfolio Effect			1,000 MW
Total	15,000 MW	13,000 MW	12,000 MW

Load Type	Nameplate	ICAP + Average ELCC	PCAP + Marginal ELCC
Peak Load	10,000 MW	10,000 MW	10,000 MW
PCAP Need	12,000 MW	12,000 MW	12,000 MW
PRM Achieved		30%	20%

Example load-resource table under ICAP and PCAP methods

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Over-accreditation of thermal resources under ICAP

Saturation effects for non-firm resources under PCAP

Peak load to net peak load shift impact under PCAP

Load Type	Nameplate	ICAP + Average ELCC	PCAP + Marginal ELCC
Peak Load	10,000 MW	10,000 MW	10,000 MW
PCAP Need	12,000 MW	12,000 MW	12,000 MW
PRM Achieved		30%	20%

Illusion of capacity surplus under ICAP

Resource adequacy is largely distinct from environmental policy

- **Any overlap between resource adequacy requirements and environmental policy goals is limited and case-specific**
- **Environmental harm happens when fossil generators run**
  - Capacity products are denominated in MW and have no specific runtime (MWh) requirements
  - There is no such thing as “clean capacity”, only clean energy!
  - Batteries charge from thermal generation on days with high risk of reliability events
- **As a general rule, gas generators only run when no other resources are available**
  - Sometimes needed to avoid loss of load
  - Climate policy can work to reduce fossil generator runtime by forcing cleaner alternatives into the market

Current and future challenges in resource adequacy

Encouraging adoption of advanced practices

- Stakeholder education and acceptance can be challenging

Adapting weather data for climate change

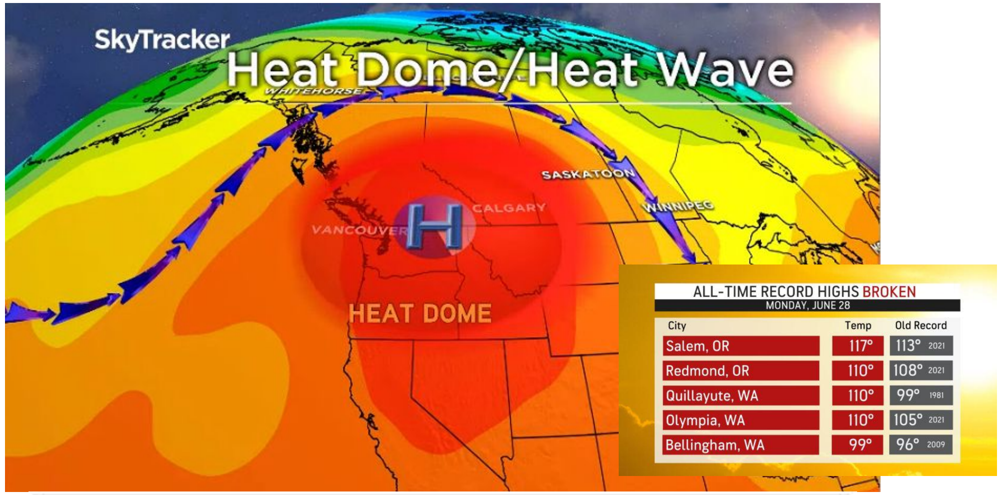
- Past performance is not indicative of future results

Addressing fuel limitations in thermal accreditation

- Lower accreditation for thermal resources without firm fuel supplies, but difficult to develop appropriate statistical information
- “Common mode failure” such as pipeline disruption or temperature driven fuel supply interruptions

Defining appropriate reliability standard

- No solid analytical foundation for 1-day-in-10-years
- What is the value of lost load?
- Bending the demand curve with price responsive demand



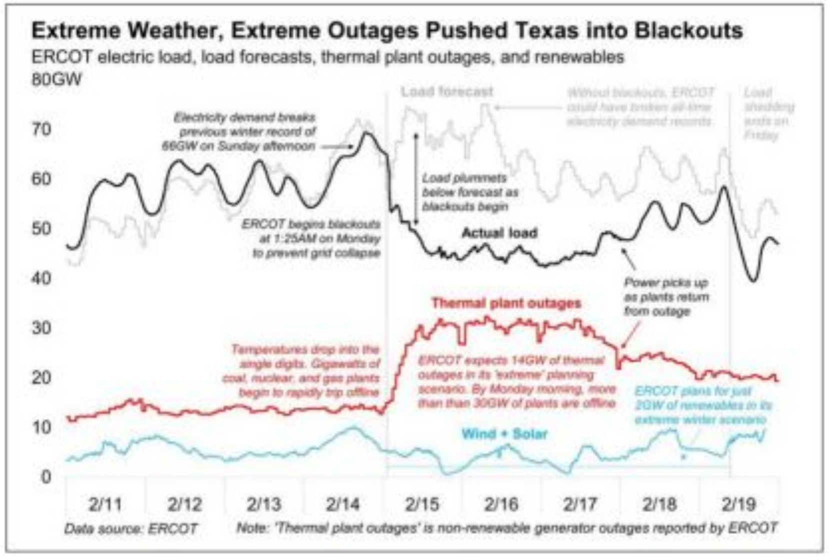


Figure 1. ERCOT data posted to Twitter by Brian Bartholomew (@BPBartholomew)

Thank you!

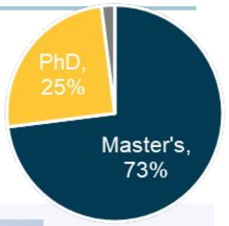
Arne Olson, Senior Partner (arne@ethree.com)

Energy+Environmental Economics

Who is E3?

Thought Leadership, Fact Based, Trusted.

100+ full-time consultants | 30 years of deep expertise | Engineering, Economics, Mathematics, Public Policy…



San Francisco

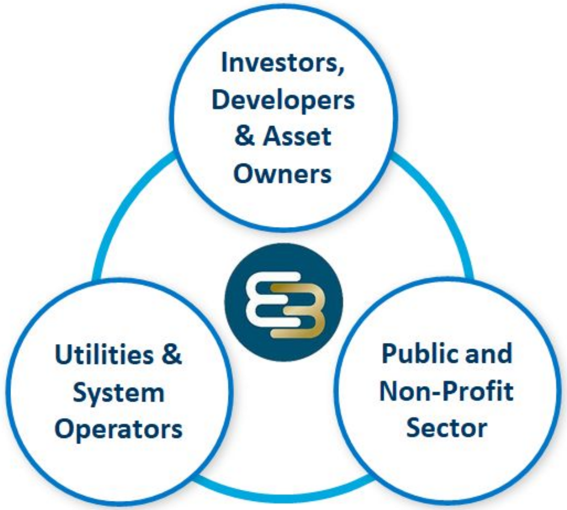
New York

Boston

Calgary

E3 Clients

300+ projects per year across our diverse client base



Recent Examples of E3 Projects

Buy-side diligence support on several successful investments in electric utilities (~$10B in total)

Acquisition support for investment in a residential demand response company (~$100M)

Supporting investment in several stand-alone storage platforms and individual assets across North America (10+ GW | ~$1B)

Acquisition support for several portfolios and individual gas-fired and renewable generation assets (20+ GW | ~$2B)

United Nations Deep Decarbonization Pathways Project

California: 100% clean energy planning and carbon market design for California agencies

Net Zero New England study with Energy Futures Initiative

New York: NYSERDA 100% clean energy planning

Pacific Northwest: 100% renewables and resource adequacy studies for multiple utilities

E3 has extensive experience supporting utilities and market operators in studying resource adequacy

- **Rapid transformation of electric supply portfolios have led many utilities to revisit their approaches to ensuring resource adequacy**
- **E3 has worked with utilities across North America to design and implement modernized frameworks to meet future resource adequacy needs**
- **Considerations include:**
  - Establishing a planning reserve requirement tied to fundamental loss-of-load-probability modeling
  - Valuing contributions of non-firm resources (renewables and storage) using effective load carrying capability (ELCC)
  - Accounting for changing system needs under deep decarbonization

E3 has worked directly with utilities across North America to study resource adequacy needs