“Perfect Capacity” and Other Design Considerations for Accreditation

NARUC Bulk Power System Learning Module
Accounting for a Changing Resource Mix: The Latest Developments in Capacity Accreditation

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Energy+Environmental Economics

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The resource adequacy “externality”

- **A resource adequacy construct is needed to ensure that all LSEs procure their share of the total system need and can’t lean on the system**
  - Resource adequacy is an “externality” because customers aren’t able to respond to market signals based on their own value of lost load (due to price caps, regulatory barriers, lack of information, etc.)
  - Regional construct provides benefits due to load and resource diversity across a large footprint
- **ISOs run an RA “markets” that provides the primary signal for investment in new resource adequacy capacity**
  - ISO sets the loss-of-load standard and allocates need to individual LSEs
  - ISO performs resource accreditation that determines how resources will be counted toward the need
  - States regulate *how* LSEs meet their allocated need using ISO rules
- **If the primary purpose of a capacity market is to provide the right incentives for economically efficient resource entry and exit, it must use marginal accreditation**
  - “Equity” among LSEs is a secondary purpose that may be in conflict with market efficiency

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*

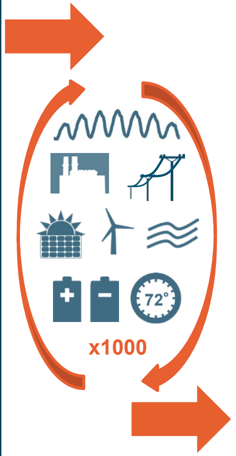
Dispatchable Generation
- *Capacity*
- *FOR*
- *Maintenance*

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

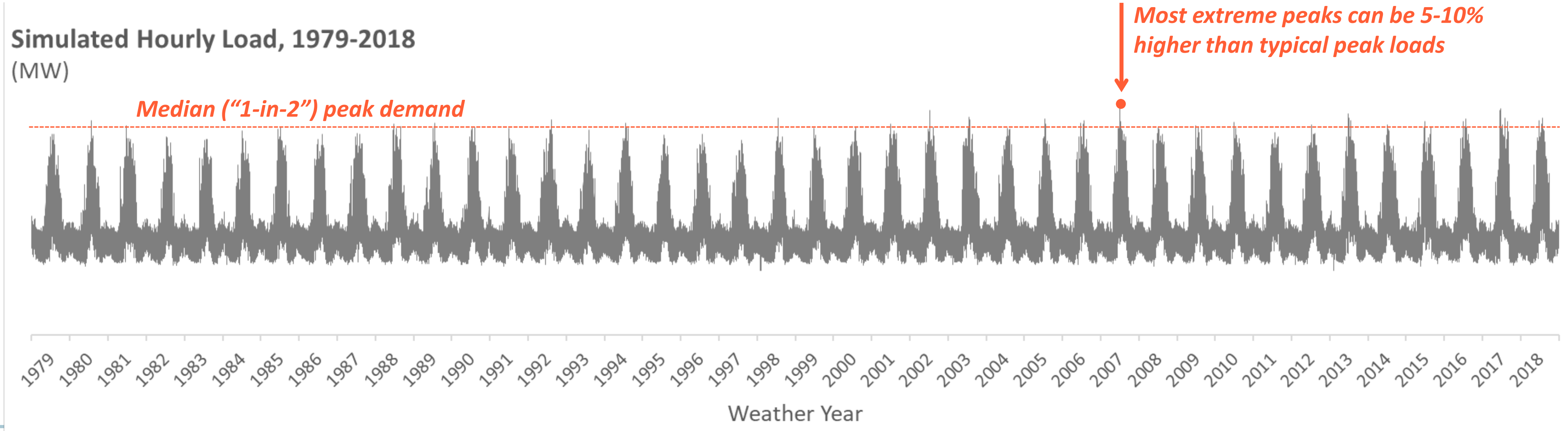
LOLE
- *Loss of load expectation*
- *days/yr of total expected lost load*

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*

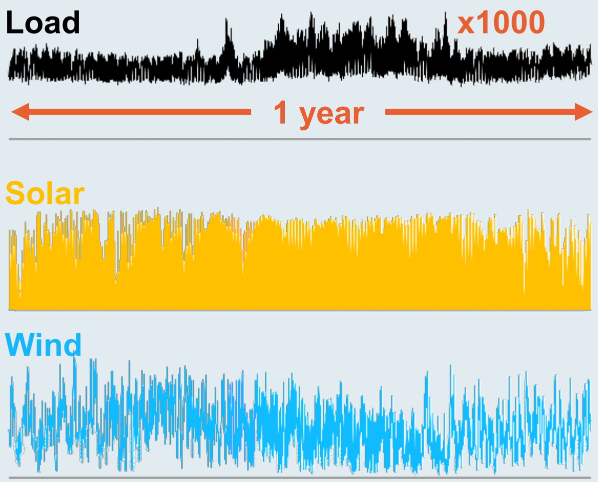
TPRM
- *Target planning reserve margin*
- *PRM required to achieve a specified reliability threshold (i.e. LOLE, ALOLP, or EUE)*



Overview of best practices in resource adequacy analysis

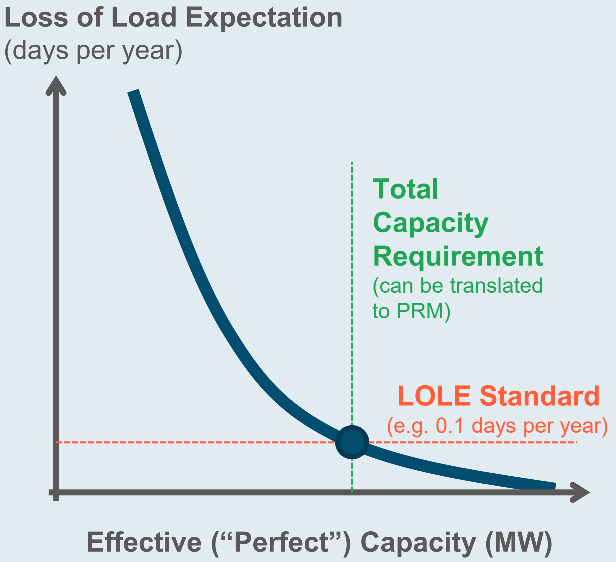
Develop a representation of the loads and resources of an electric system in a loss of load probability model

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



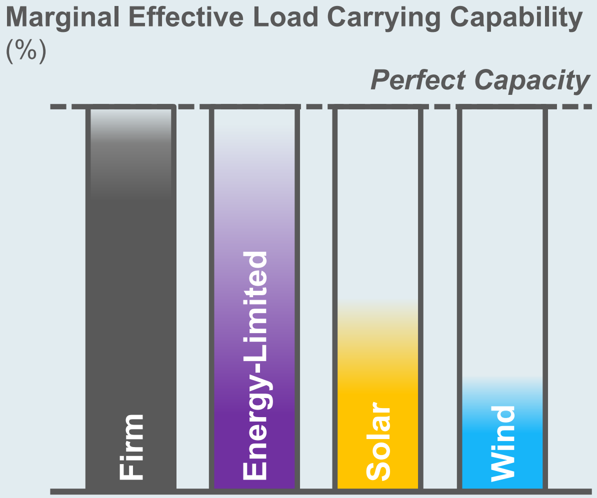
Identify the amount of perfect capacity needed to achieve the desired level of reliability

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



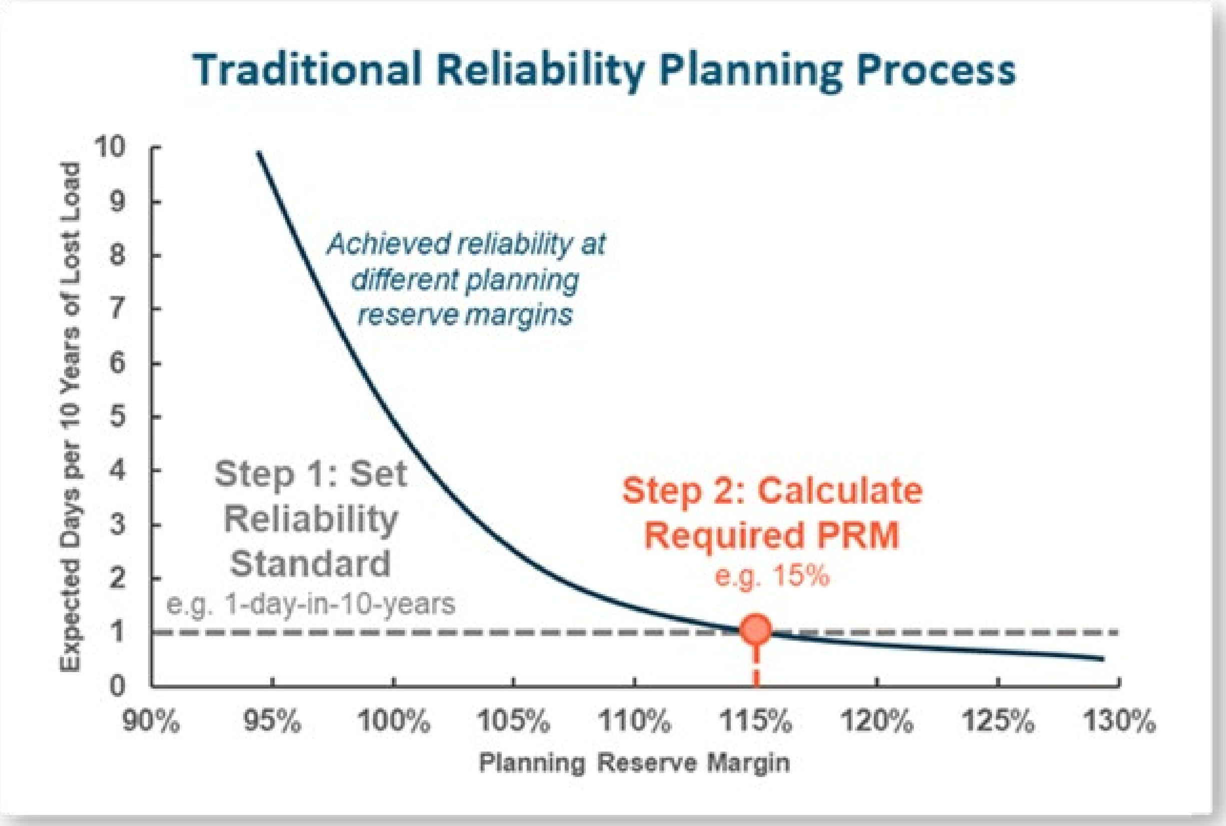
Calculate capacity contributions of different resources using effective load carrying capability

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

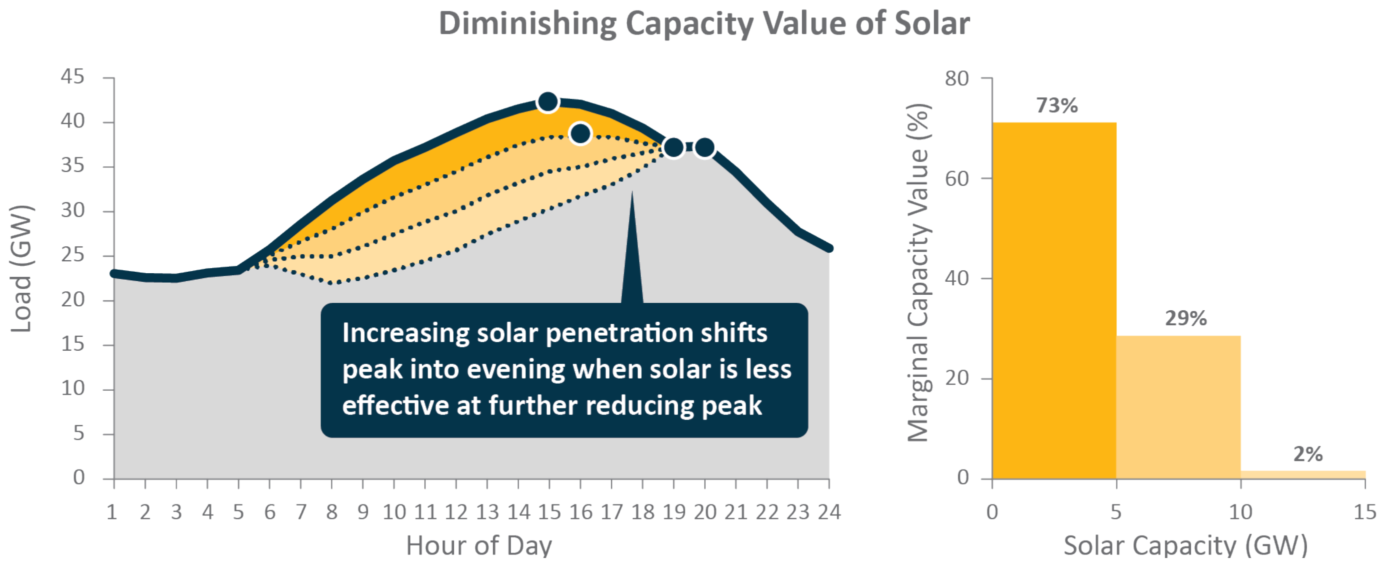


Total Resource Need (TRN) and Planning Reserve Margin (PRM)

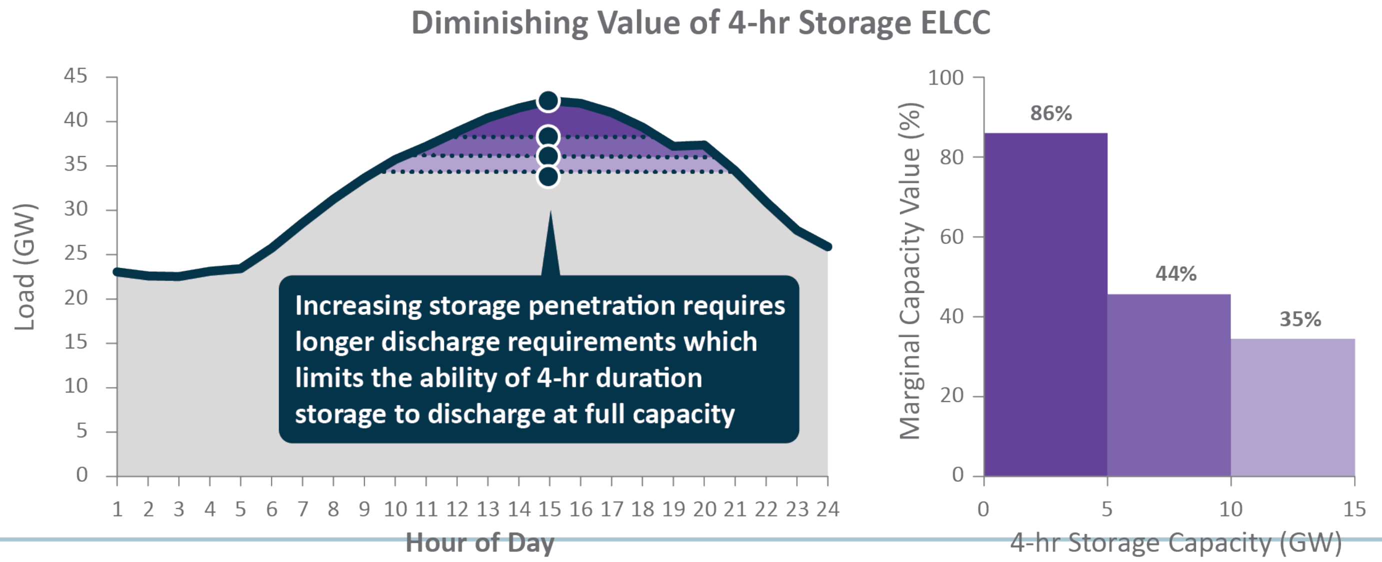
+ **Total Resource Need is the quantity of effective capacity needed to meet a defined reliability standard**
  - Typically defined as “1 day in 10 years” or 0.1 LOLE but other definitions may be useful
+ **PRM is measured as the quantity of capacity needed above the median year peak load to meet the 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*



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



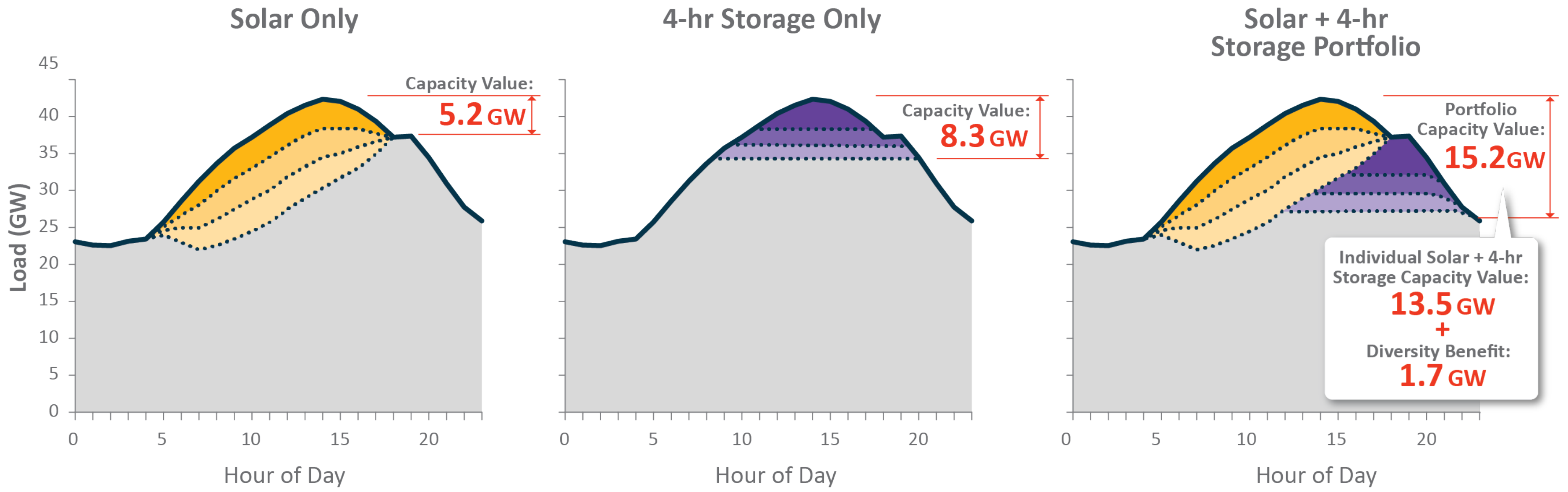
Solar and other **variable resources** (e.g. wind) exhibit declining value due to variability of production profiles



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

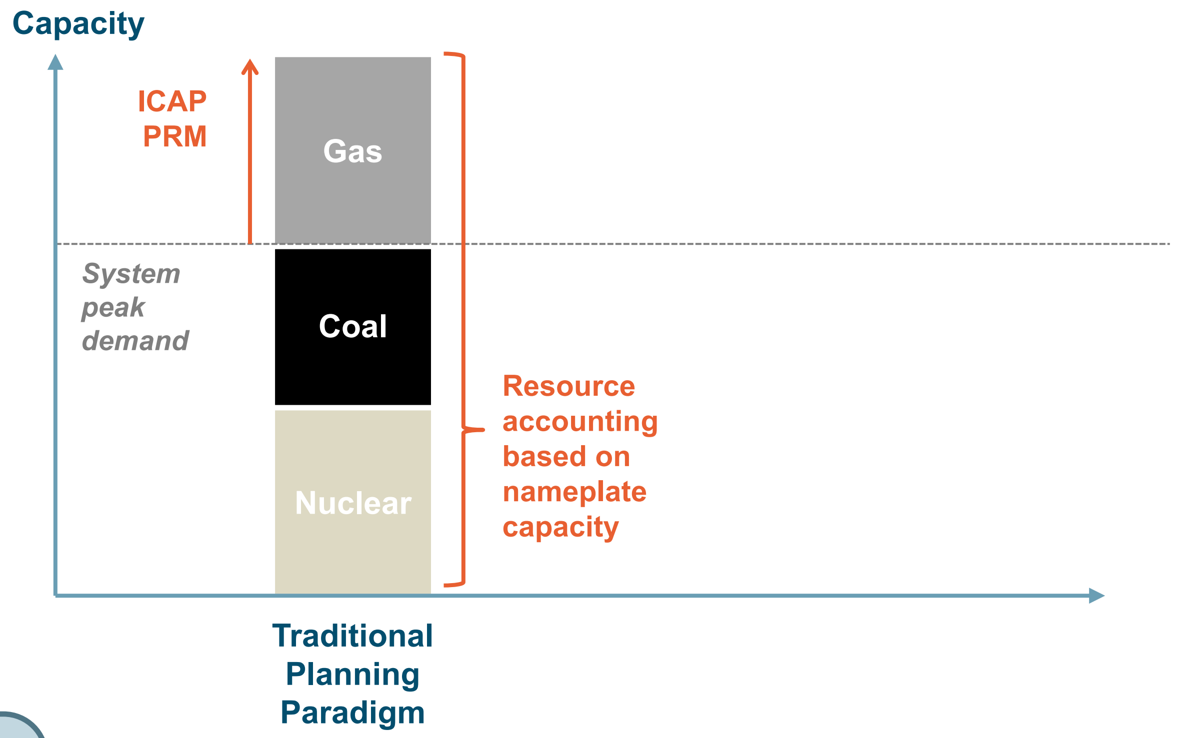
Common Examples of Antagonistic Pairings

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

Resource accreditation is simple in the traditional planning paradigm

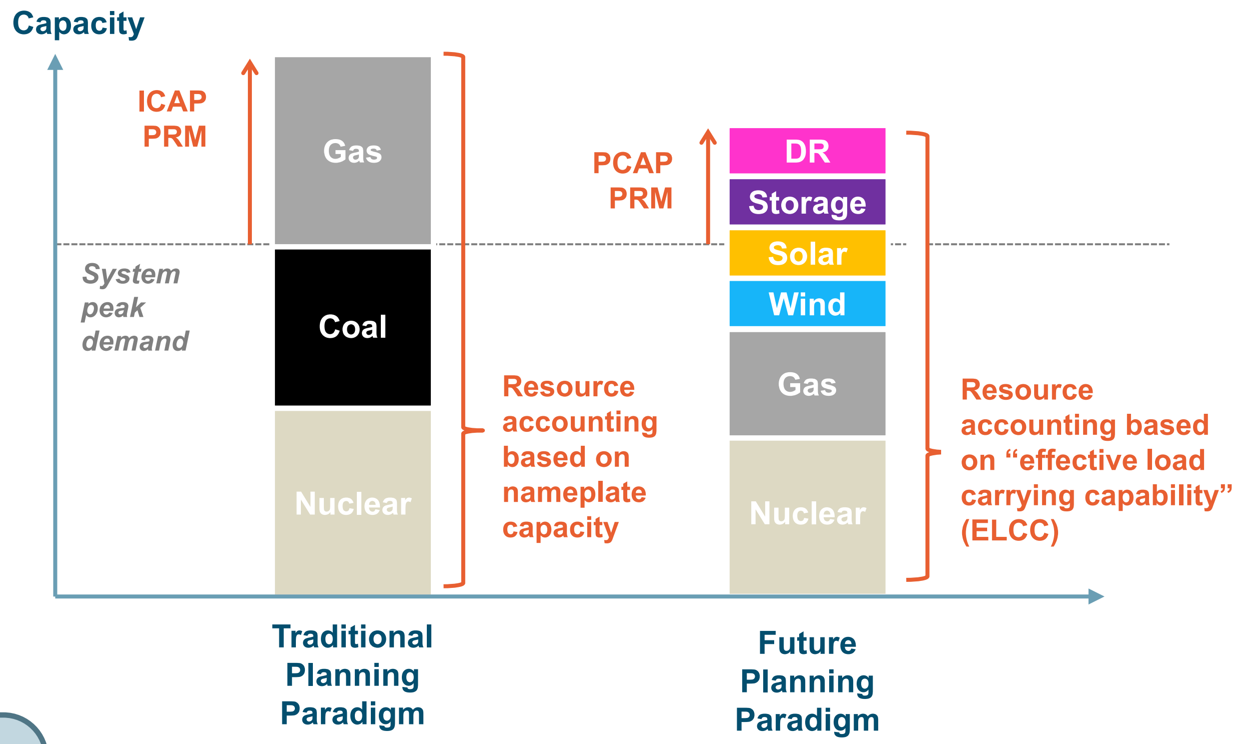
- **PRM defined based on Installed Capacity method (ICAP)**
  - Covers annual peak load variation, operating reserve requirements, and thermal resource forced outages
- **Individual resources accredited based on nameplate capacity**
  - Small differences in forced outage rates
  - No interactions among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

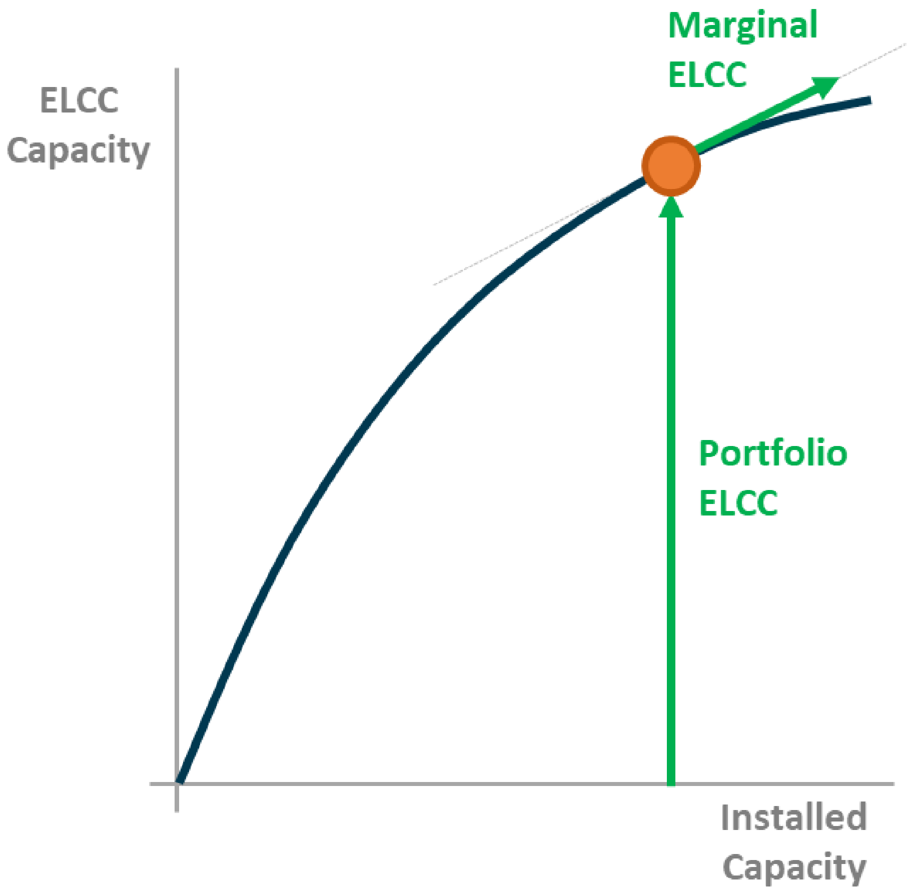
- **ELCC is a function of the portfolio of resources**
  - The function is a surface in multiple dimensions
  - The Portfolio ELCC is the height of the surface at the point representing the total portfolio

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

  - 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

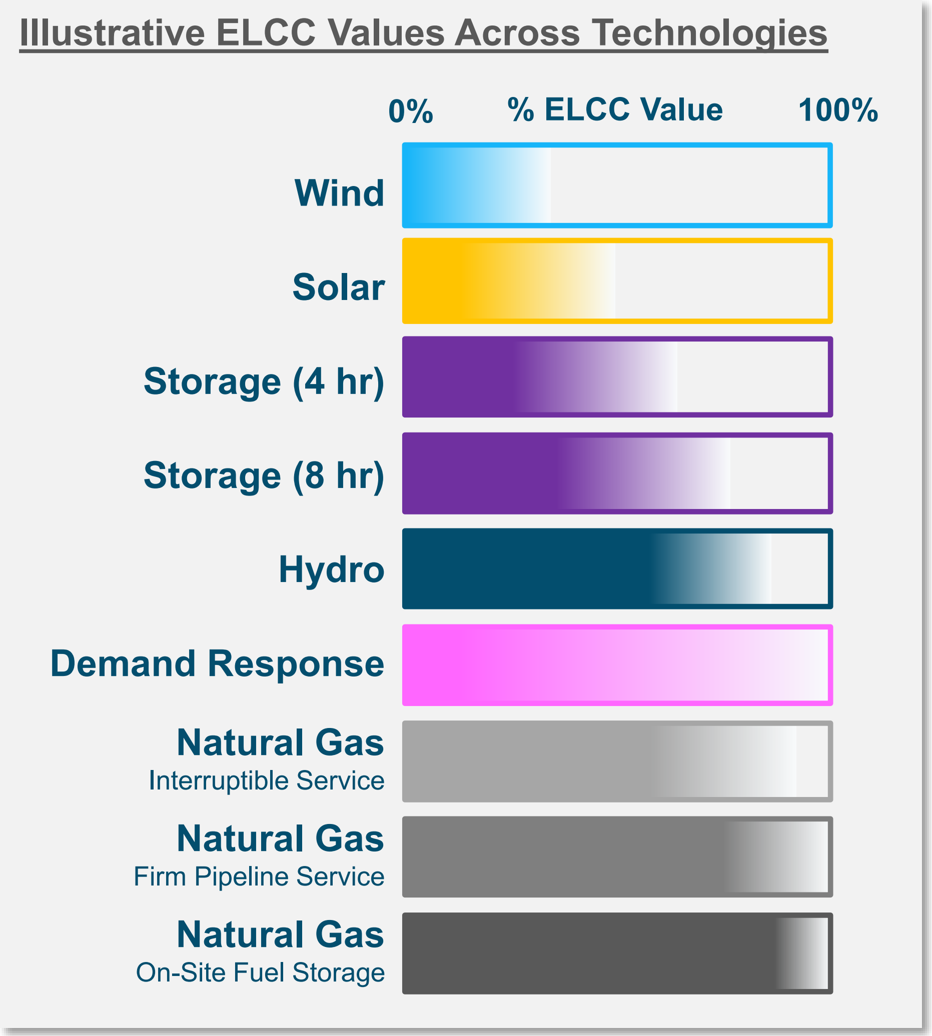
$$Marginal\ ELCC_{G_1} = \frac{\partial f}{\partial G_1}(G_1, G_2, \ldots G_n)\ (\%)$$

- **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



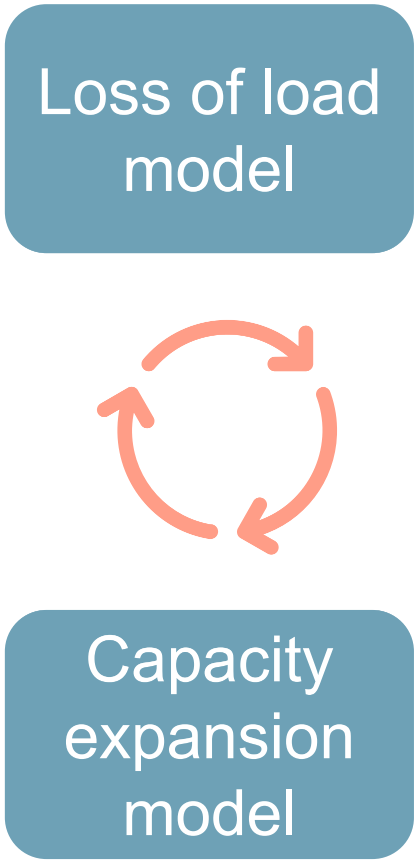
No resource is "perfect" – ELCC can and should be applied to all resources

- **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



Utilities should use "surfaces" of marginal ELCC values for resource planning and procurement

- **Capacity expansion models enforce resource adequacy constraints when planning power systems**
  - Accredited capacity (total ELCC) ≥ Total need
- **For utilities in organized markets, the model should use forecasts of need allocated from the market operator and forecasts of market ELCC values**
- **For utilities outside of organized markets, the utility should conduct its own loss-of-load modeling to calculate total need and resource ELCC values**
  - ELCC "surfaces" to reflect interactive effects (both saturation and diversity effects)
  - Should use marginal ELCC for conventional resources to create a level playing field with variable resources and storage
  - Calculate the ELCC values of demand-side resources such as demand response, VPPs, flexible loads, etc.



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 operate**
  - Capacity products are denominated in MW and have no specific runtime (MWh) requirements
  - There is no such thing as "clean capacity"
- **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

+ Defining appropriate reliability standard

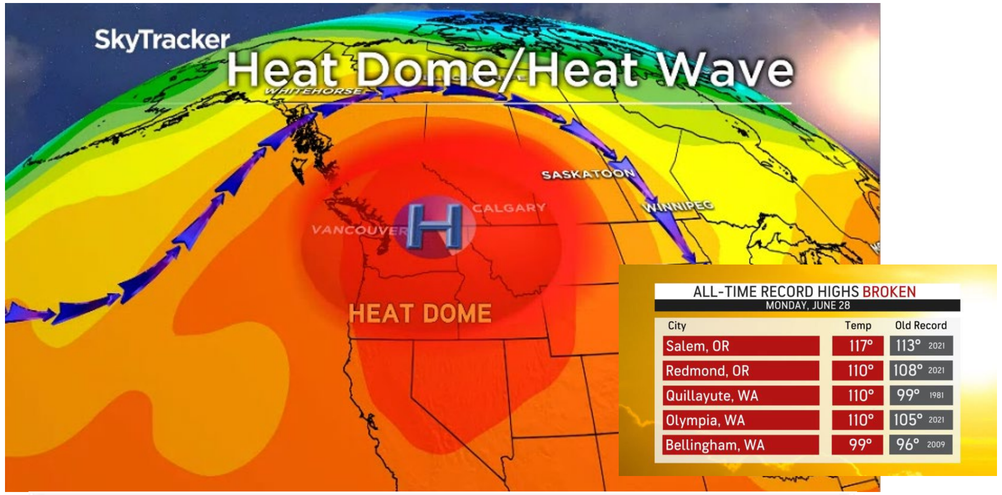
- ❑ No solid analytical foundation for 1-day-in-10-years
- ❑ What is the value of lost load?
- ❑ Bending the demand curve with price responsive demand

+ Adapting weather data for climate change

- ❑ Past performance is not indicative of future results

+ Addressing fuel limitations in thermal accreditation

- ❑ Thermal resources without firm fuel supplies should get lower ELCC accreditation, but it is difficult to develop appropriate statistical information
- ❑ “Common mode failure” such as pipeline disruption or temperature driven fuel supply interruptions



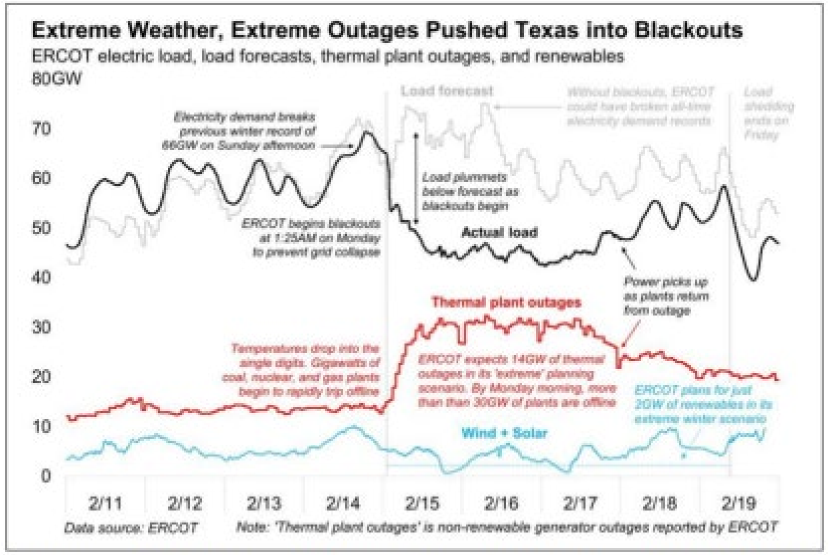


Figure 1. ERCOT data posted to Twitter by Brian Bartholomew (@BPBartholomew)

Thank you!

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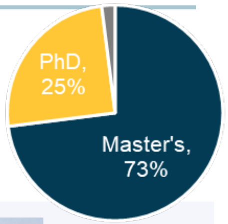
Energy+Environmental Economics

Who is E3?

Thought Leadership, Fact Based, Trusted.

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



San Francisco

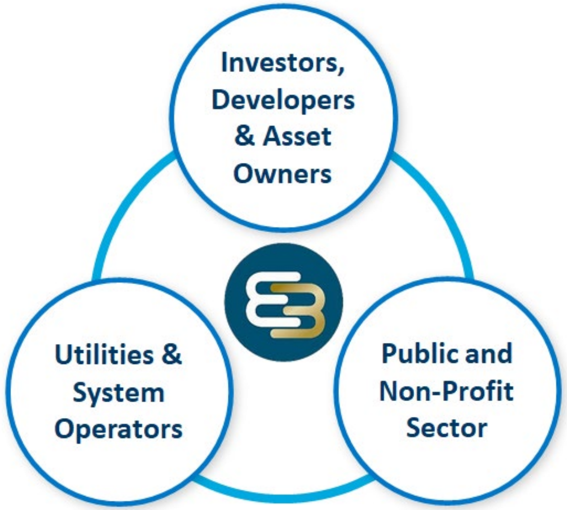
New York

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

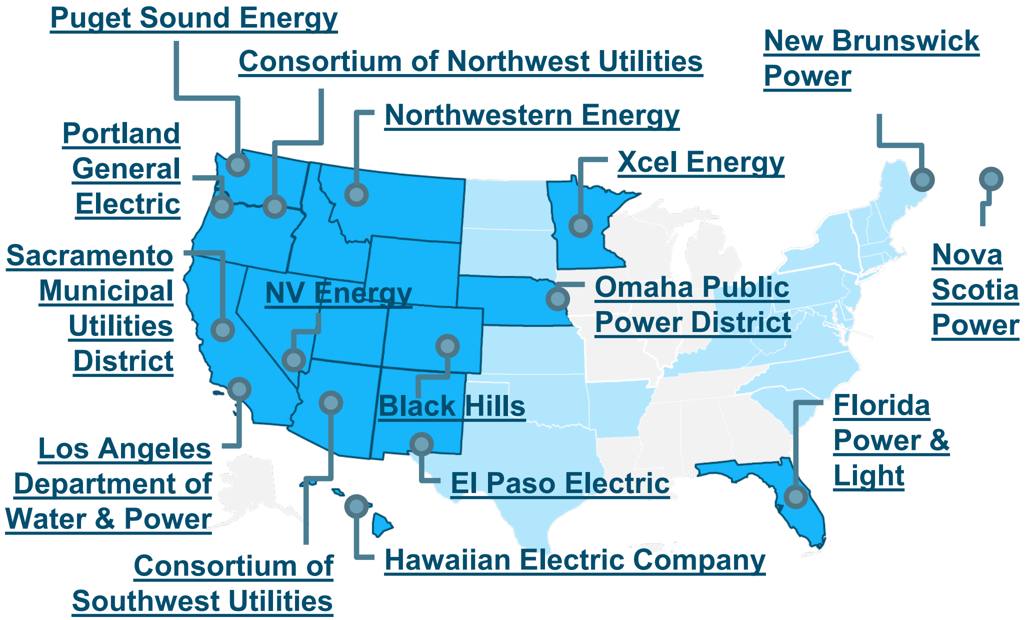
New York: NYSERDA 100% clean energy planning

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



States where E3 has provided direct support to utilities to develop resource adequacy frameworks

Areas where E3 has worked with non-utility clients to examine issues related to resource adequacy