Integrating Capacity Expansion and Resource Adequacy Models: Key Concepts

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With thanks to Gord Stephen, whose framing of this topic in prior talks helped inform the structure of this presentation

Different models answer different planning questions

Capacity Expansion

Question: "What portfolio should we build"

Focus: Long-term investment

Resource Adequacy

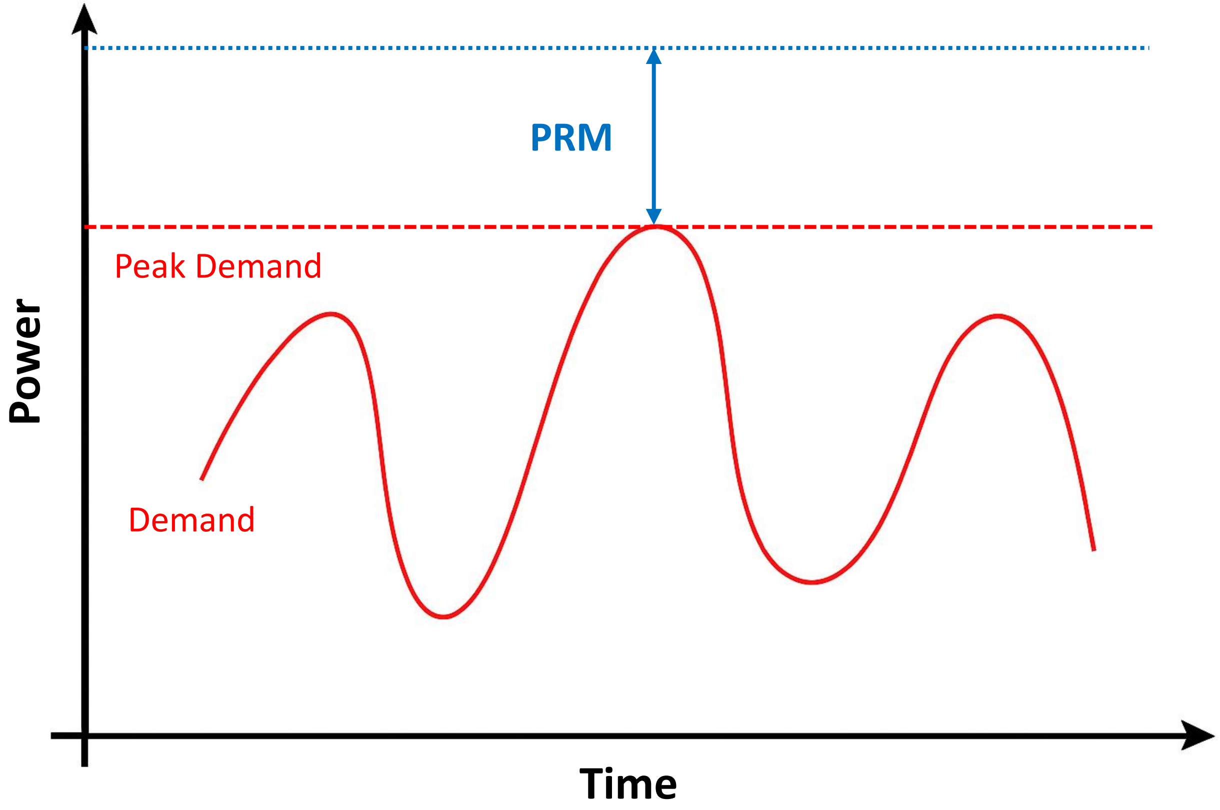
Question: "Is the system reliable?"

Focus: Risk and uncertainty

Modeling Dimension	Capacity Expansion	Resource Adequacy
Time horizon	Longer-term (ex: decades)	Shorter-term (ex: annual)
Hours modeled	Representative operating periods	All operating hours
Method	Optimization with integer variables	Probabilistic assessment, requiring many possible system realizations to be assessed
Linkage	Resource adequacy is a key constraint	System capacity buildout is a key input

How do we integrate long-term economic planning with hourly reliability assessments to achieve resource-adequate, cost-efficient portfolios within computational limits?

Planning reserve margin bridges that gap today



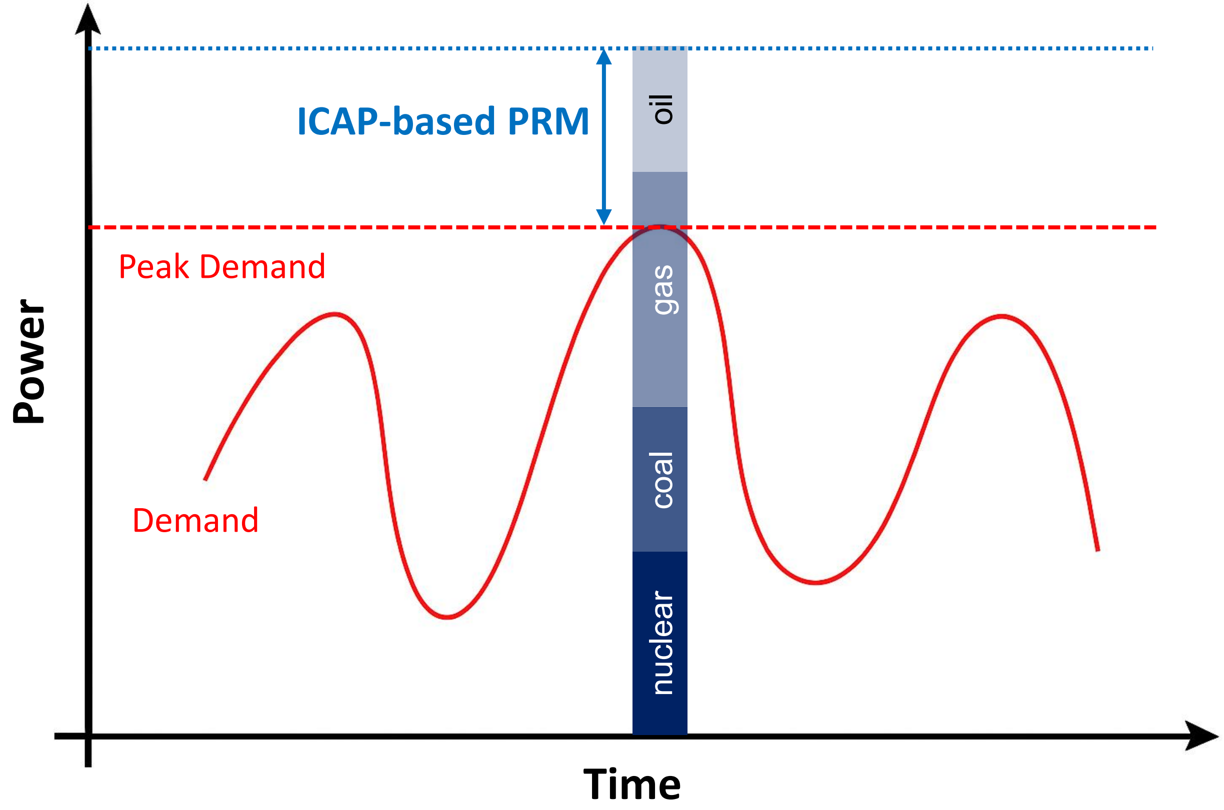
Planning Reserve Margin (PRM):
Percentage of extra capacity that a system plans to have above expected peak demand to ensure reliability.

$$PRM = \frac{Total\ Capacity\ - Peak\ Demand}{Peak\ Demand} \times 100$$

Key assumption implicit in this approach:
Peak load represents the highest-risk reliability period.

PRM is the industry's current, simplified mechanism for connecting long-term planning (capacity expansion) with short-term reliability (resource adequacy).

Historically PRM was used alongside installed capacity…



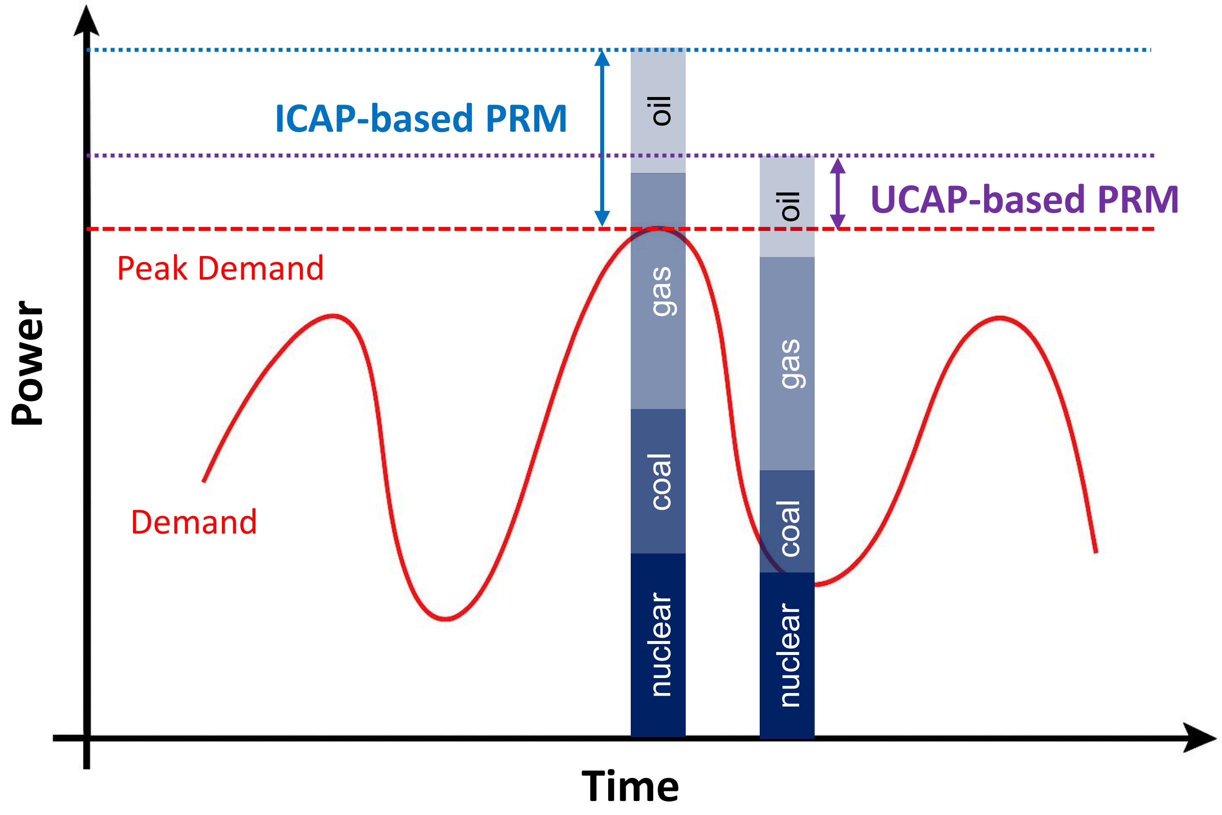
Installed Capacity (ICAP):
Generator nameplate rating

Key assumptions implicit in this approach:

- Resource outages are **independent** (no correlated failures).
- Resource availability is **constant over time** (no daily, seasonal, or extreme-weather variations).
- **Historical performance** is a reliable predictor of future behavior.
- **Energy constraints do not limit** a resource's ability to produce at full output during RA risk hours.
- **Transmission is unconstrained** during RA risk hours.

PRM in this approach must be set high enough to account for both demand forecast errors and generator forced outages.

Then alongside EFORd-based unforced capacity…



Unforced Capacity (UCAP):

Generator available capacity after accounting for its average forced-outage rate.

$$UCAP = ICAP \times (1 - EFORd)$$

UCAP does *not* capture:

- Hour-to-hour variability in outage risk
- Seasonal or weather-driven outage patterns
- Common-mode or correlated failures
- Multi-hour derating events
- Tail-risk events

PRM in this approach must be set high enough to account for both demand forecast errors and the variability in generator availability beyond what UCAP's average derate captures.

And now based on probabilistic capacity accreditation values

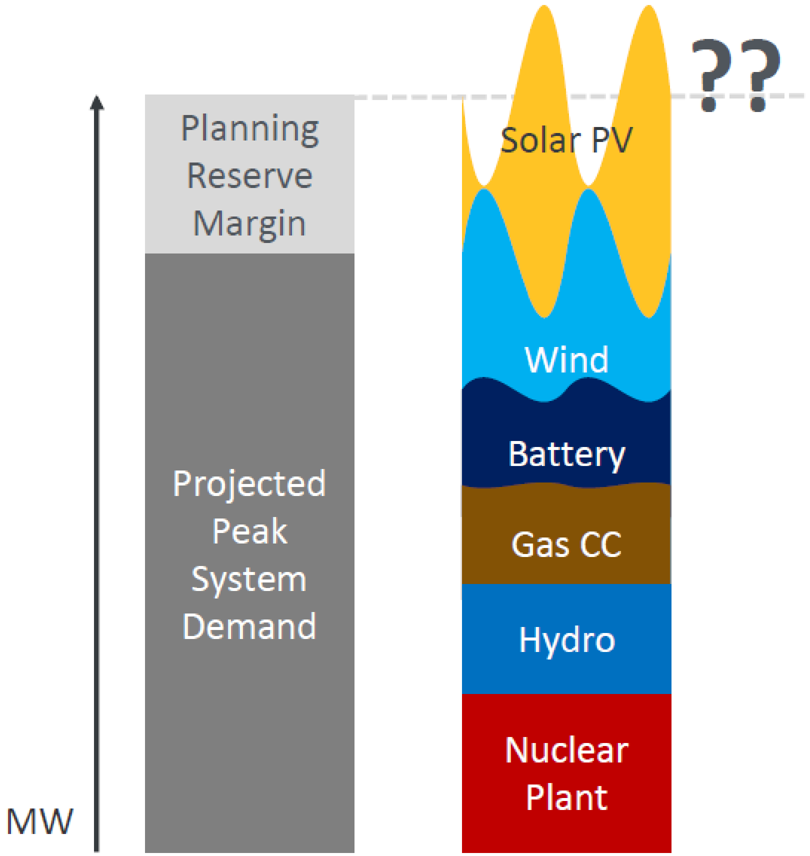


Image source: G. Stephen, EPRI RA Forum (July 2025)

Capacity Accreditation:

Amount of reliable capacity a resource contributes to meeting system adequacy needs.

↓

Often calculated using a probabilistic-based accreditation method such as Effective Load Carrying Capability (ELCC).

Key limitations of this approach:

- Static capacity values are valid only for small incremental additions to the existing system.
- Capacity values must be recalculated whenever the generation portfolio changes.

Under this approach, PRM could be very small or even negative because the highest-risk adequacy hours may occur below the system peak load.

How are PRM and capacity values incorporated into the capacity expansion model?

Capacity expansion models minimize total system cost (investment + operating costs) over the study horizon, subject to a set of constraints.

One key constraint ensures enough accredited capacity is built:

Σ (units × MW × capacity credit) ≥ peak load × (1 + PRM)

This embeds the PRM requirement directly into the optimization.

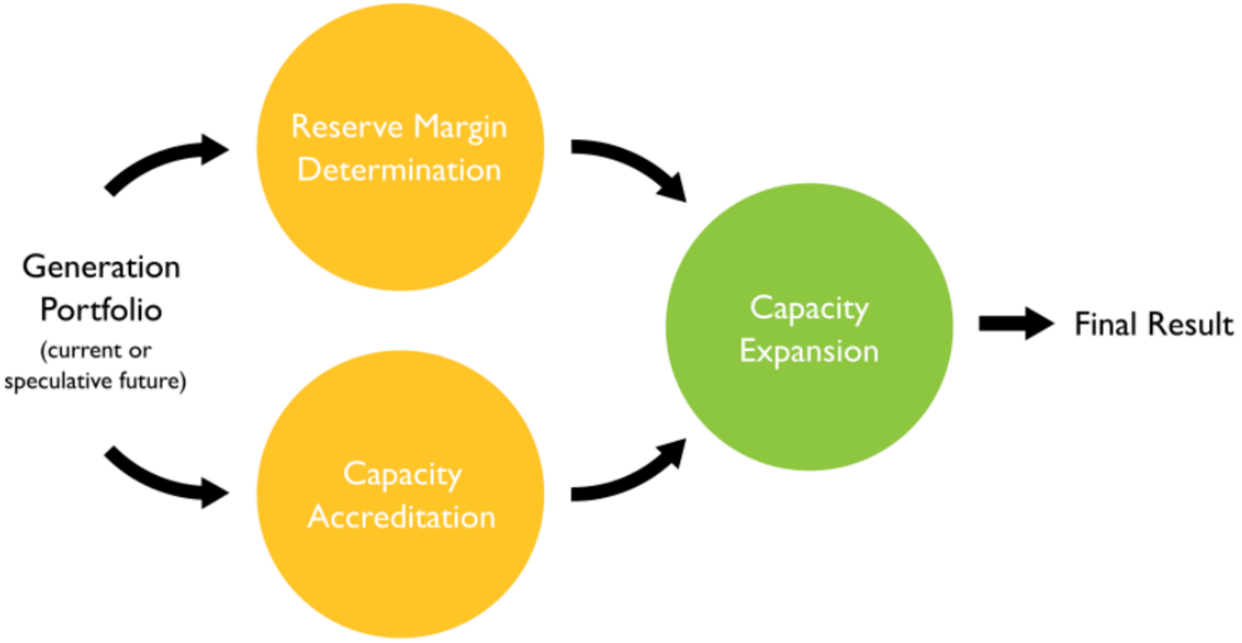


Image source: J. Kuna, et al., Beyond Capacity Credits: Adaptive Stress Period Planning for Evolving Power Systems (2024)

Why this is so challenging…

Critical adequacy hours are increasingly decoupled from peak load hours and instead are driven by high net peak load and extreme weather events.

Resource saturation
Leads to diminishing marginal capacity credit

Synergistic pairings
Some resources increase each other's accreditation value

Antagonistic pairings
Some resource combinations reduce each other's accreditation value

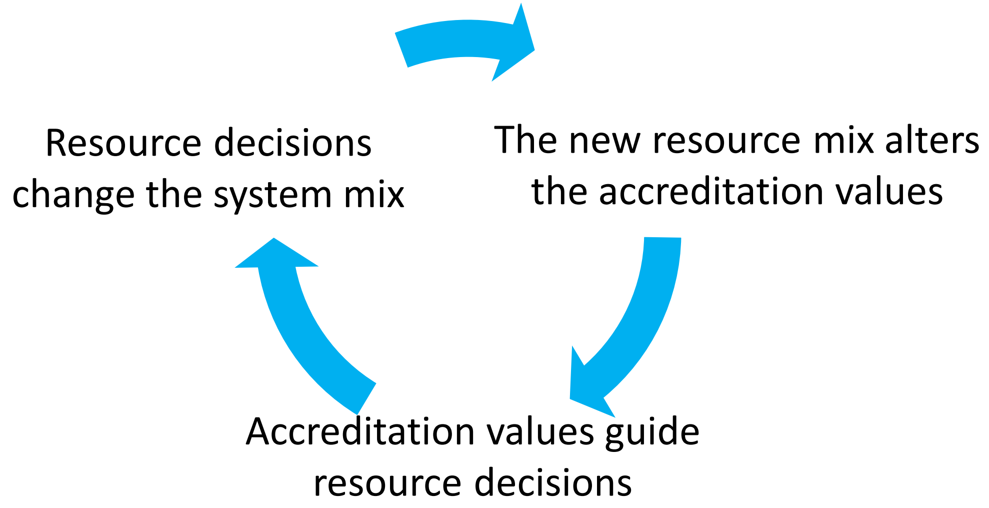
→ **Capacity value depends on the evolving resource mix**

Why this creates challenges

Capacity expansion models still plan to meet a PRM, which is defined in terms of peak load.

Current methods require accreditation values to be continually updated.
System changes directly affect the marginal contribution of each resource.

There is also a built-in circularity:



Conclusions

Increasing system complexity has transformed the resource planning question:

Before:

How much capacity should we build?

→

Now:

What types of capacity should we build — and how much of each?

The upcoming presentations introduce emerging approaches to improve this decision process and ensure capacity expansion models have the information needed to guide efficient investments.

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