Reliability Filing Requirements for Load Serving Entities' 2022 Integrated Resource Plans

Planning Reserve Margin Study Results

Energy Division

June 16, 2022

California Public Utilities Commission

Introduction

Introduction & Purpose

- These planning reserve margin (PRM) study results are the first among a set of reliability updates to be conducted this IRP cycle
  - Pursuant to Preferred System Plan decision (D.22-02-044) p.84: "the appropriate PRM to use for IRP, which may or may not be the same as used in resource adequacy, will be evaluated and discussed further with stakeholders in the upcoming IRP cycle"
  - Approach was presented at the April 7, 2022, Integrated Resource Planning (IRP) Modeling Advisory Group (MAG) Webinar
  - MAG webinar slides and recording are available on the IRP website[1]
- Near-term use case: LSE plan filing requirements to inform development of LSE plans due November 1, 2022
  - Pursuant to D.22-02-044 p.84: "the standard that LSEs should be using for future long-term planning... will be further considered when guidance is issued for filing requirements for the next individual IRPs to be submitted by LSEs"
  - These PRM results help define LSEs' reliability planning requirements
  - July 2022 release will complete the reliability information needed by LSEs: LSEs' peak demand and behind-the-meter (BTM) PV forecasts; final Resource Data Template (RDT) with resource accreditation metrics, including effective load carrying capabilities (ELCC), by resource type

1. https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/electric-power-procurement/long-term-procurement-planning/2022-irp-cycle-events-and-materials

Opportunity for Feedback

- Parties can informally comment on the PRM results to inform the work planning for reliability modeling that will be performed later this cycle
- It will not be possible for feedback to affect the near-term use case of LSE plan filing requirements
- Later use cases:
  - Updates to RESOLVE and SERVM, and IRP planning track more broadly, including for 2023 Preferred System Plan (PSP) development
  - Mid-to long-term procurement program, including reliability procurement need determination for 2025 and beyond
- To make informal comments parties can email IRPdatarequest@cpuc.ca.gov
- Staff expects there will also be an opportunity to formally comment later this year

Background

Opportunities to Improve IRP Reliability Planning

- **2017-18 IRP Cycle**
  - Optimistic import assumptions meant reliability planning was secondary
- **2019-21 IRP Cycle**
  - Changing assumptions led to two large procurement orders for new resources
    - Orders were not directly tied to loss of load probability (LOLP) modeling of reliability need
  - PRM assumed in RESOLVE to reflect Mid-Term Reliability (MTR) High Need scenario has led to portfolio that exceeds the reliability standard, per 2021 Preferred System Plan (PSP) analysis
- **2022-23 IRP Cycle**
  - I&A and LSE plan filing requirements present opportunity to refresh reliability planning inputs
  - Planning track PRM update for IRP modeling broadly
  - PRM for mid-to long-term procurement program

Topic	Current IRP Method	Potential Improvement
PRM	Shifting PRMs not tied to LOLP fundamentals → RESOLVE outputs are not matched to reliability results from loss of load modeling	SERVM-based PRM to meet reliability standard
Thermal resource accounting	NQC-based (installed capacity) → tips the scales in favor of gas plants vs. clean energy	Unforced capacity (UCAP) or ELCC-based to create a level playing field
ELCCs for RESOLVE	Solar + wind surface (RECAP) Storage ELCC curve (SERVM)	Solar + storage surface (SERVM) Wind ELCC curve (SERVM)
ELCCs for LSE Plans	Interpolation from RESOLVE outputs	SERVM-based ELCC forecast

Use Cases for Reliability Modeling in 2022-23 IRP Cycle

- The April 7, 2022, MAG webinar addressed the early stages of a broad set of reliability updates to be conducted this IRP cycle
- **Near-term use case**: **LSE plan filing requirements** due for release in June and July, 2022
  - Reliability planning requirement, including the planning reserve margin
  - Final Resource Data Template (RDT) with resource accreditation metrics, including effective load carrying capabilities (ELCC), by resource type
- **Later use cases**:
  - Updates to RESOLVE and SERVM, and IRP planning track more broadly, including for 2023 Preferred System Plan (PSP) development
  - Mid-to long-term procurement program, including reliability procurement need determination for 2025 and beyond
- **Approach**
  - Where possible, use consistent methodologies and inputs across all use cases; near-term deadline requires deferral of some items to later this cycle
  - Implement stakeholder feedback upfront where possible, otherwise addressing for later use cases

Summary of Proposed 2022 Approach

- **Modeling Approach**
  - Use the CPUC's SERVM model, with any appropriate updates, as the basis for need determination and resource accreditation
- **Need Determination**
  - System need calculated via a perfect capacity (PCAP) based total reliability need MW (TRN), translate into a planning reserve margin (PRM) above median gross peak
  - A PCAP-based approach means removing from the reserve margin an allowance for forced outages of firm resources, and accrediting all resource types at their respective ELCC i.e., their perfect capacity equivalent, based on simulations that consider their risk of outages, resource availability, and their interaction with load and other resource types
    - Discussed below in PRM Study Approach section
  - LSE-level need based on share of either total reliability need or marginal reliability need using new multi-year CEC LSE-level forecast
    - Discussed below in PRM Study Approach section, with final direction from staff to follow in July 2022 as part of final Resource Data Template (RDT) release
- **LSE Plan Resource Accreditation**
  - **Firm resources**: either an ELCC-based accreditation or a "calibrated" UCAP approach
  - **Non-firm resources**: ELCC-based accreditation using either marginal ELCCs or Delta Method-based average ELCCs
  - Discussed in April 7, 2022, MAG webinar[1], with final direction from staff to follow in July 2022 as part of final RDT release
- **RESOLVE Updates**
  - Align PRM and resource accreditation with LSE plan inputs
  - Change solar + wind ELCC surface to a solar + storage ELCC surface, include DR on the storage dimension
  - Develop a separate wind ELCC curve
  - Discussed in April 7, 2022, MAG webinar[1]

1. MAG webinar slides and recording are available on the IRP website: https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/electric-power-procurement/long-term-procurement-planning/2022-irp-cycle-events-and-materials

Summary of Proposed 2022 Approach

ELCC or Calibrated UCAP

	Current IRP Approach (RESOLVE)	Proposed 2022 IRP Approach (RESOLVE)	Proposed 2022 IRP Approach (LSE Plans)
Planning Reserve Margin	22.5% ICAP PRM above managed peak	Total Reliability Need based on 0.1 loss of load expectation (LOLE), translated into PCAP PRM over gross peak (i.e. managed peak + BTM PV)	Total Reliability Need based on 0.1 LOLE, translated into PCAP PRM over gross peak or share of marginal procurement need
Wind	ELCC (solar/wind surface w/ CF scaling)	ELCC (1-D curve w/ CF scaling or multiple curves)	ELCC**
Battery Storage	ELCC (1-D curve)	ELCC (solar/storage surface)	ELCC (paired generation/storage would use heuristic of solar + storage ELCCs)
Solar PV	ELCC (solar/wind surface w/ CF scaling)		ELCC
BTM PV	ELCC (solar/wind surface), after increasing need by IEPR peak shift		
BTM Storage	Load modifier via IEPR peak shift*	Load modifier via IEPR peak shift*	Load modifier via IEPR peak shift*
Pumped Hydro Storage	Installed capacity (Sept NQC)	ELCC (model on storage dimension of solar/storage surface)	ELCC
Demand Response	DR program capacity (NQC) for new + existing		
Hydro	Installed capacity (Sept NQC)	ELCC	
Bio/Geo/Nuclear		ELCC or Calibrated UCAP***	ELCC or Calibrated UCAP
Thermal (CT/peaker, CCGT, CHP, Coal)			

* Note: current peak shift from BTM storage in the IEPR has low implied capacity value.
** LSE plan ELCC study provides opportunity to break out sub-class ELCCs as desired; specific sub-classes to be detailed in the July 2022 RDT release.
*** Firm resource accreditation metrics will be finalized by July 2022 RDT release.

Key SERVM Modeling Updates

The following key updates were completed in May, 2022[1] and applied in this PRM study as part of comprehensive model updates scoped for the 2022-2023 IRP cycle. Recent studies for the 2021 IRP PSP and the RA proceeding (Dec 2021-Jan 2022) used assumptions from the prior IRP cycle.

- Weather Years now span 1998-2020 and determine the distribution of load, wind, solar, and hydro hourly shapes
- Demand forecast updated to CEC's 2021 IEPR mid-mid case
- Updated Preferred System Plan portfolio from RESOLVE using 2021 IEPR and updated resource costs and transmission zone limits
- PG&E Bay and Valley regions collapsed into one PGE region
- Only CAISO (PGE, SCE, SDGE regions) units explicitly modeled – transfers with neighbors modeled as fixed import shapes
- Updated forced outage rates
- Relaxed Path 26 transmission limits (to ensure congestion from unbalanced retirements or additions in N vs. S does not increase system reliability need)
- Ratio of fixed to tracking solar capacity aligned with RESOLVE assumptions
- BTM battery storage treated as a load modifier using 2021 IEPR shapes

1. Staff's input data for reliability modeling is available at https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/electric-power-procurement/long-term-procurement-planning/2022-irp-cycle-events-and-materials/unified-ra-and-irp-modeling-datasets-2022

PRM Study Approach

Overview of Approach to Study PRM for LSEs' IRPs

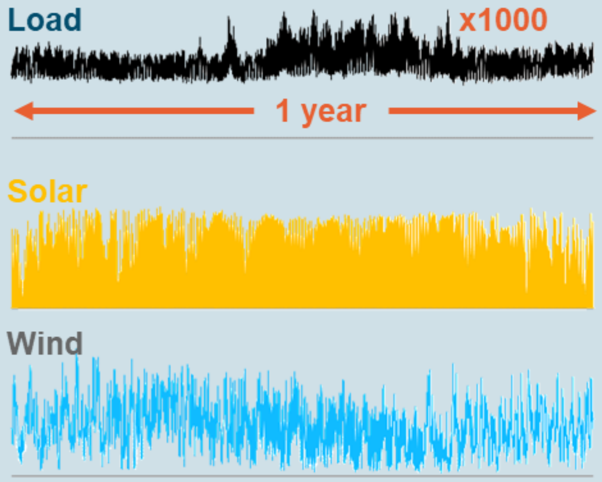
- Perfect capacity (PCAP) PRM is for use in LSEs' 2022 IRPs; this means removing from the reserve margin an allowance for forced outages of firm resources, and accrediting all resource types at their respective ELCC i.e., their perfect capacity equivalent, based on simulations that consider their risk of outages, resource availability, and their interaction with load and other resource types
- Given that PCAP PRM is less familiar to stakeholders than an installed capacity (ICAP) PRM, this study also calculates the ICAP PRM equivalent to the PCAP PRM
  - Information-only
  - Can be calculated relative to the managed peak (as well as the gross peak IRP uses), to enable more direct comparison to the historical 15% ICAP PRM
- In July 2022, when staff provides the final RDT with resource accreditation metrics (including ELCCs) by resource type, LSEs can determine the perfect capacity equivalent MW of their resources and compare this to their reliability need (based on their share of peak plus the PCAP PRM)

Key Steps for Reliability Planning using LOLP Modeling

Step 1: Model + Data Development

Develop a robust dataset of the loads and resources in a loss of load probability (LOLP) model

LOLP modeling evaluates resource adequacy across all hours of the year under a broad range of weather conditions

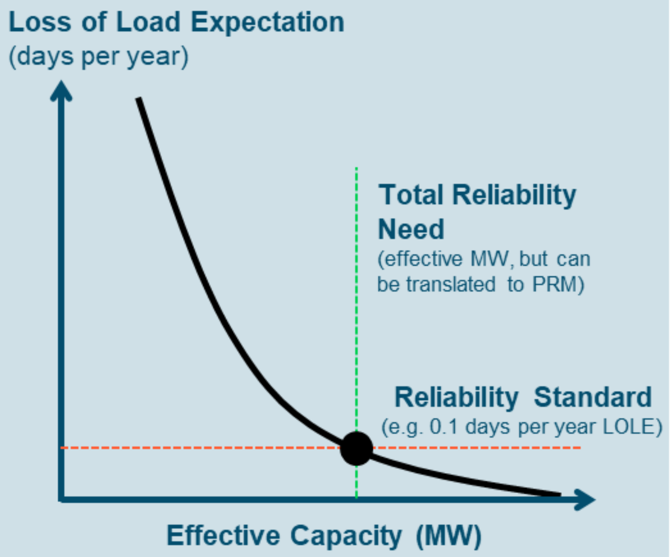


Robust probabilistic models + datasets are the foundation of any resource adequacy analysis

Step 2: Need Determination

Identify the Total Reliability Need to achieve the desired level of reliability

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

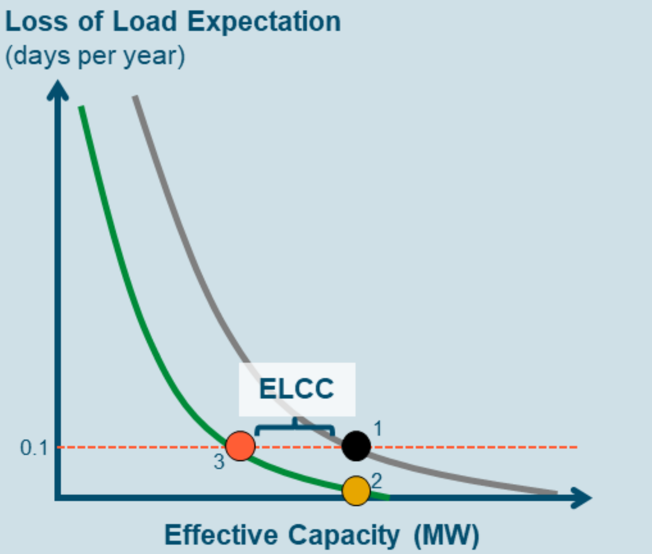


LOLP modeling provides <u>Total Reliability Need</u> in effective capacity MW to meet <0.1 days/yr LOLE, can be converted to a PRM

Step 3: Resource Accreditation

Calculate resource capacity contributions using effective load carrying capability

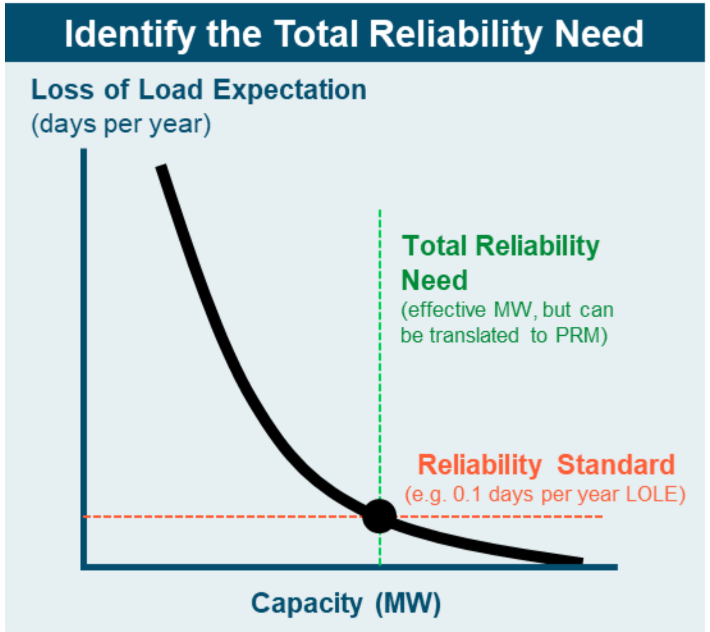
ELCC measures a resource's contribution to reliability needs relative to perfect capacity, accounting for performance across all hours



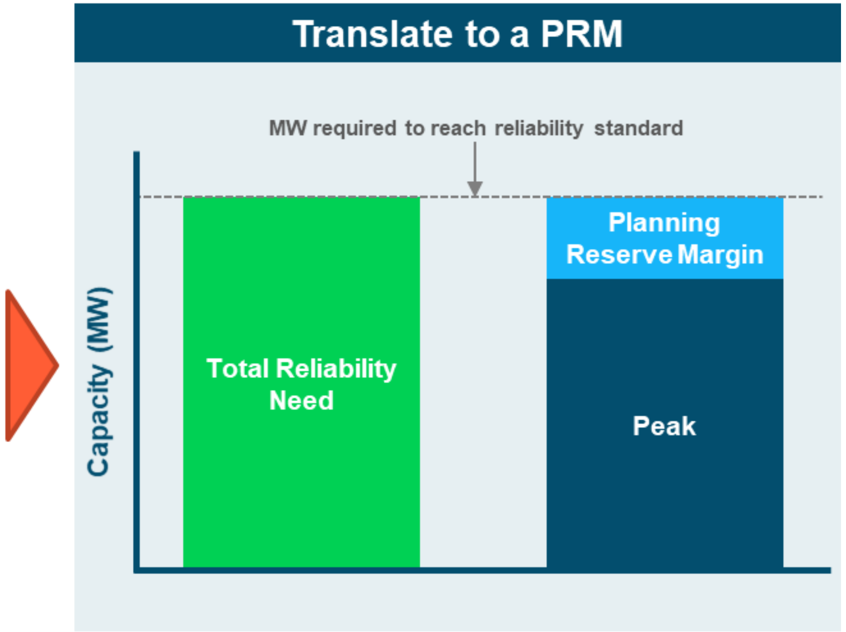
<u>Effective or "perfect" capacity based accounting</u> (UCAP or ELCC) counts all resources on a level playing field against that total reliability need

Using the Total Reliability Need (TRN) to Derive the PRM

- The Planning Reserve Margin (PRM) is a derivative value from the Total Reliability Need (TRN)
  - TRN is a MW value output from LOLP modeling
- The TRN/PRM can be defined using multiple approaches
  - E.g. resource accreditation methods (e.g. UCAP versus ICAP)



Total Reliability Need =
Total effective capacity (in MW) needed to maintain an adopted reliability standard (e.g. < 0.1 day/yr LOLE).



Planning Reserve Margin =
% margin above peak demand necessary to reach the TRN

$$PRM\ \% = \left(\frac{TRN}{Peak\ Demand}\right) - 1$$

Types of PRMs

- **Installed Capacity (ICAP) PRM –** ***calculated in this study for illustrative purposes only***
  - Measures resource MW using their installed capacity, accounting for forced outages in the reserve margin
- **Unforced Capacity (UCAP) PRM**
  - Measures resource MW using their unforced (i.e. outage de-rated) capacity, accounting for forced outages in resource accreditation
- **Perfect Capacity (PCAP) PRM –** ***for use in 2022 IRP LSE Plans***
  - Measures all resource MW using their perfect capacity equivalent (i.e. ELCC) capacity, accounting for forced outages and additional portfolio effects in resource accreditation

	Firm Resources	Non-firm Resources	Contributing Factors	Pros	Cons
ICAP	**Installed** capacity MW	ELCC MW	• Load/weather variability • Operating reserves • Forced outages	• Simpler firm resource accreditation	• "Tips the scales" in favor of firm resources
UCAP	**Unforced** capacity MW	ELCC MW	• Load/weather variability • Operating reserves	• Level playing field • Reliability need not impact by portfolio changes (retirements, etc.)	• UCAP may not reflect ELCC
PCAP	**ELCC** MW	ELCC MW	• Load/weather variability • Operating reserves		• More LOLP runs required

Why use the Perfect Capacity method for calculating a PRM?

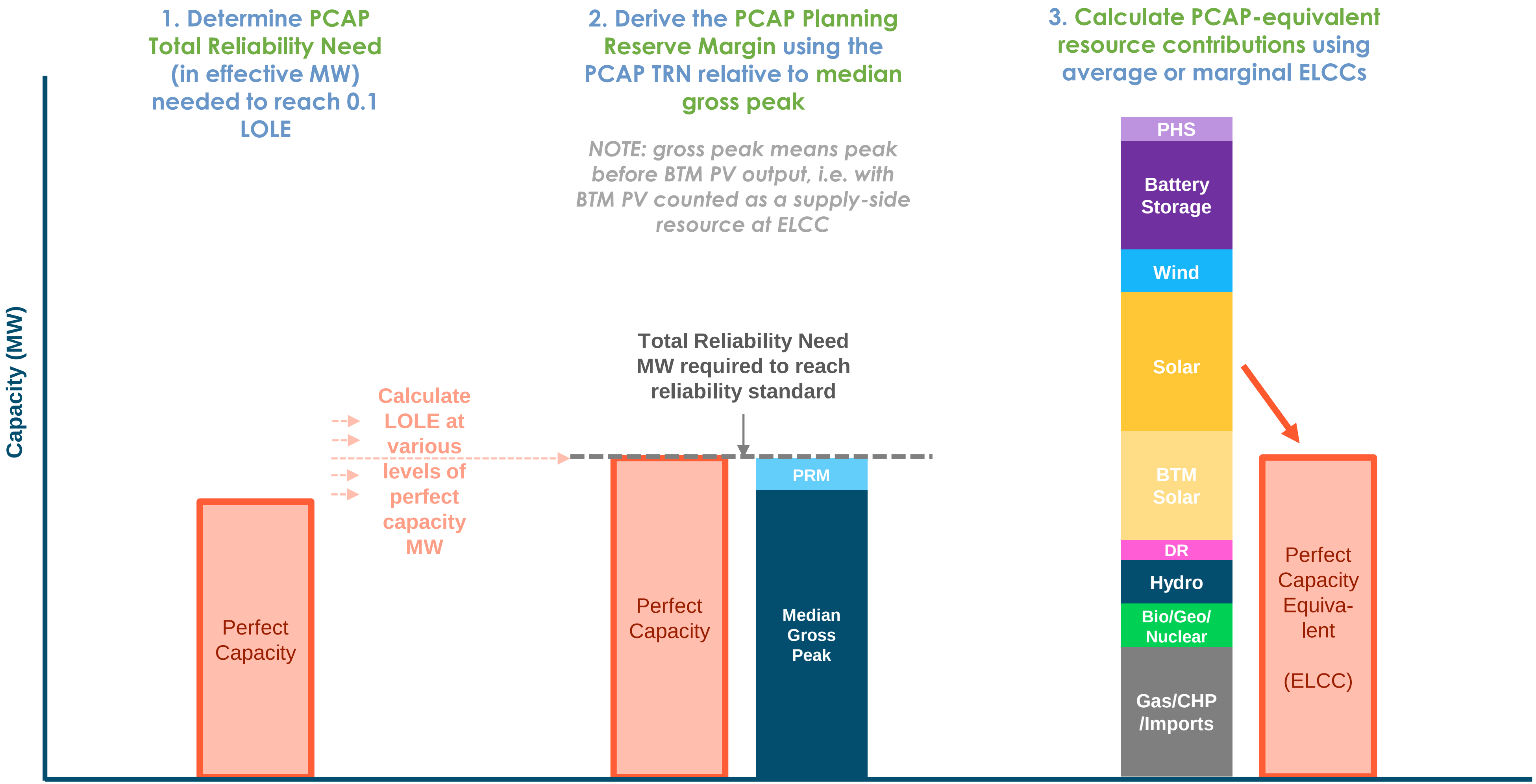
- Installed Capacity (ICAP) PRM has been widely used but is increasingly challenged at higher renewable penetrations
  - ICAP PRM is not stable over time because it is a **function of the portfolio**
  - ICAP accredits thermal generation at nameplate but derates gives variable and storage resources based on their inherent limitations, creating an **unlevel playing field** (e.g. thermal NQC vs. renewable/storage ELCC)
  - ICAP socializes the limitations of thermal generators (forced outages) by increasing the PRM, providing inefficient investment signals
- Most resource adequacy programs have moved away from ICAP to UCAP; PCAP represents a further improvement
- PCAP PRM helps meet key design objectives
  - **Reliability**: CAISO system should meet the established reliability standard
  - **Efficiency**: properly incentivizes least-cost portfolio to meet reliability needs
  - **Fairness**: fairly establishes LSE need and fairly credits resources (not relevant to need determination)
  - **Feasibility**: administratively simple and straightforward to comply with
  - **Durability**: reliability need definition is durable to portfolio changes

	Reliable	Efficient	Fair	Feasible	Durable
Perfect Capacity (PCAP)	✓	✓	✓	✓	✓ *
Unforced Capacity (UCAP)	✓	✓ **	✓ **	✓	✓
Installed Capacity (ICAP)	✓	✗	✗	✓	✗

* Updating PCAP/UCAP PRM regularly is still recommended, based on evolving load shapes (e.g. more EV loads) and updated historical weather year load variability.

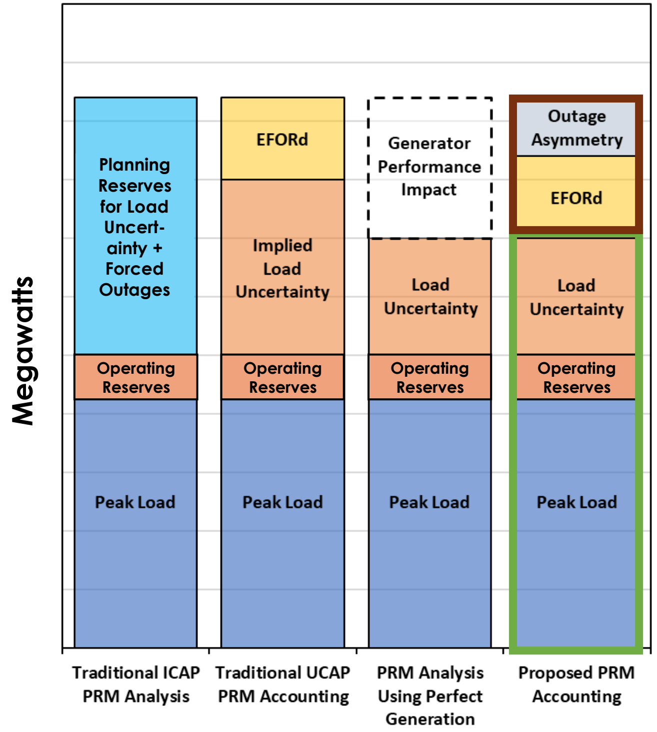
** UCAP has been considered a reasonable approximation of the ELCC for firm resources, but it does not necessarily capture their effective reliability value within a portfolio of resources

2022 IRP PCAP Planning Reserve Margin Study Method



Considering Firm Generator Outages in PRM Accounting

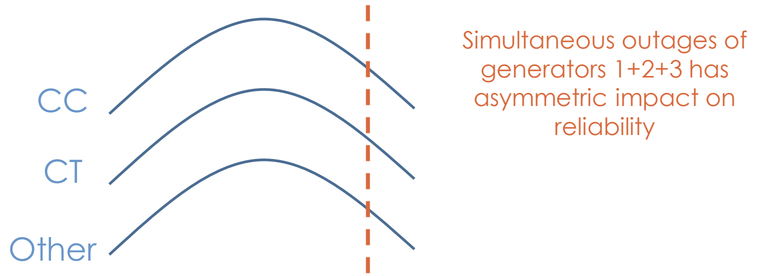
- UCAP accounting requires forced outage de-rate factors for each firm resource or resource class
  - E.g. UCAP = nameplate MW x (1 – EFORd %)*
  - UCAP PRM adjusted to remove forced outage impacts
  - However, EFORd changes as the firm fleet operations change, which would change the UCAP PRM as the resource mix changes
- Perfect capacity (PCAP) accounting utilizes *effective capacity* (i.e. perfect capacity equivalent = ELCC) accreditation for all resources, based on:
  - A. Their modeled performance
  - B. Interactive effects with other resources
- Firm generators can be accredited at their ELCC, providing consistency between firm and non-firm accreditation methods
- As an alternative, a forced outage de-rate heuristic can approximate ELCC… but requires an adjustment for generator performance impacts (a "calibrated UCAP")
  - EFORd represents a marginal de-rate for a single resource and may not capture interactive portfolio effects on its own
- **Staff is exploring both ELCCs and a "calibrated UCAP" method for firm resources and will release their counting values along with ELCCs for non-firm resources in July 2022**



Outages + interactive effects captured in **firm resource accreditation**

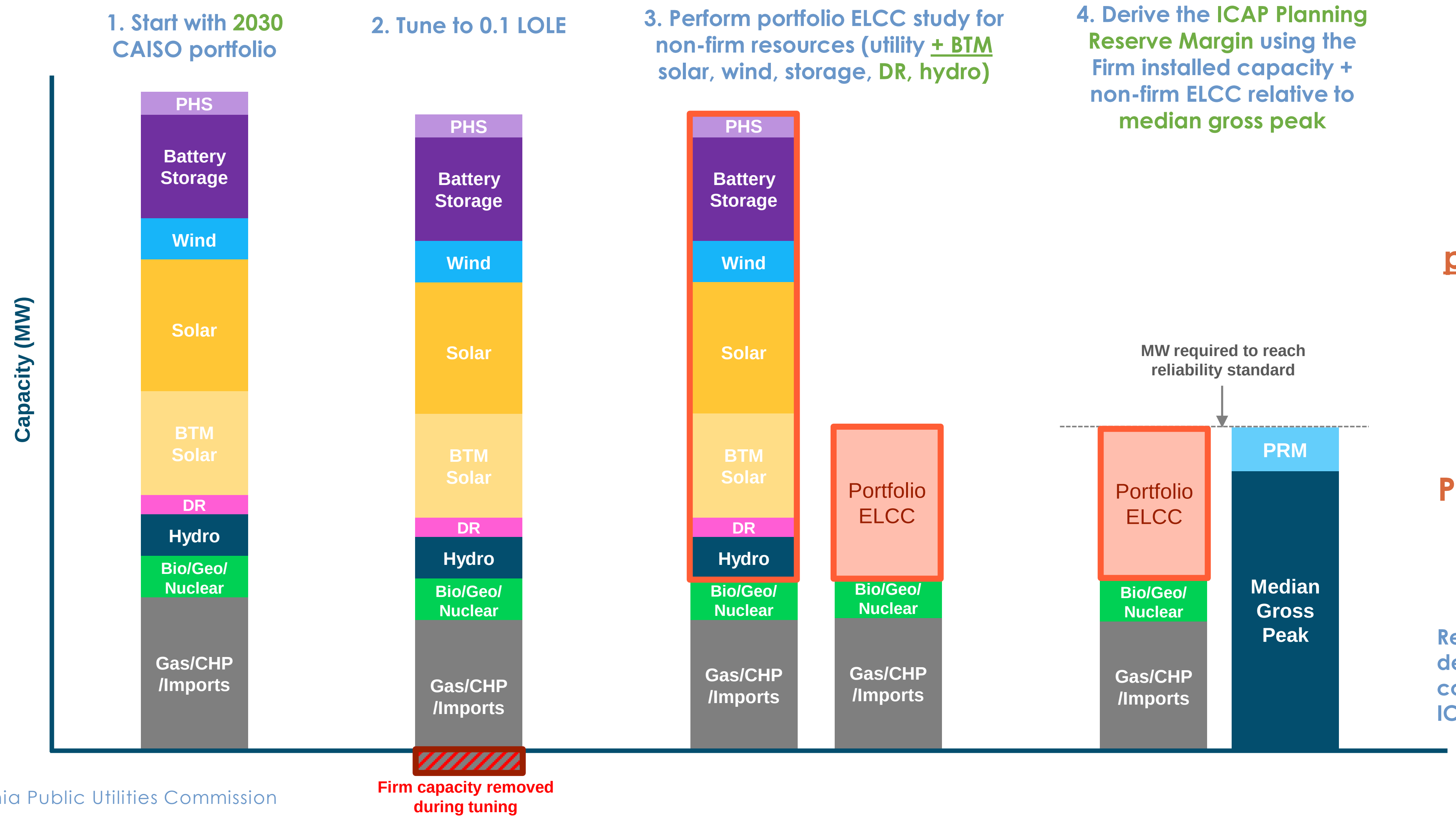
PCAP PRM based only on operating reserves + load uncertainty

Outage Probability Distributions (illustrative)



* Equivalent Forced Outage Rate demand (EFORd) is a NERC index characterizing class average forced outage rates using generator performance data

2022 IRP ICAP Planning Reserve Margin Study Method



ICAP PRM calculated for illustrative purposes only, to compare to the historical 15% ICAP PRM…

IRP will use a PCAP PRM, not an ICAP PRM

Refer to Appendix for detail on methodology to compare PCAP PRM to ICAP PRM

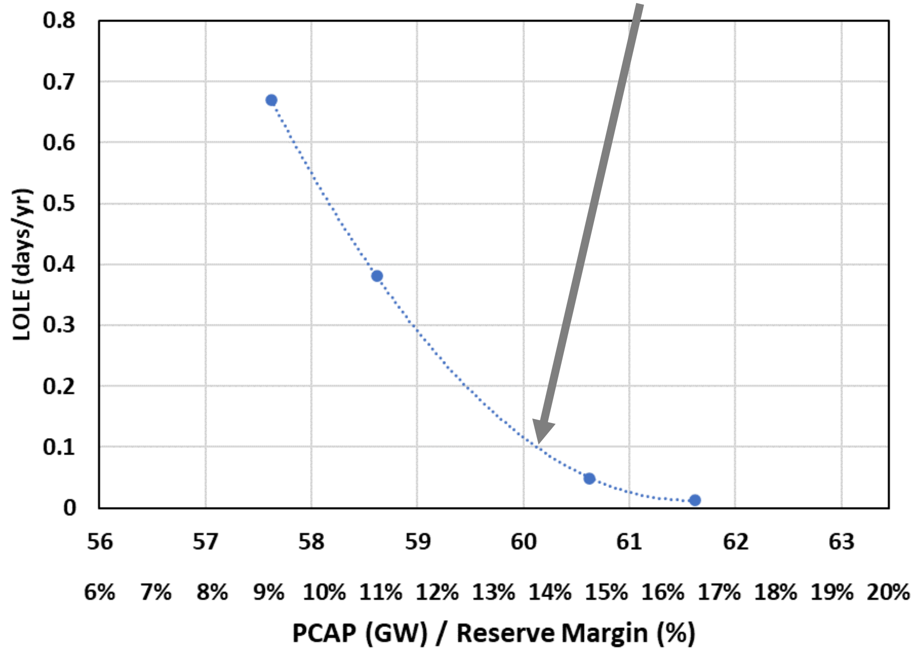
PRM Study Results

PCAP PRM Results

- A Perfect Capacity (PCAP) PRM analysis varies PCAP MW until 0.1 LOLE is achieved
- PCAP PRM is driven by
    A. Inter-annual load variability in historical weather dataset
    B. SERVM's load forecast error
    C. 6% operating reserves
- PCAP PRM was calculated for 2024, 2026, 2030, and 2035
- PRM is measured relative to median gross peak (i.e. BTM PV counted as a supply-side resource at ELCC)

SERVM's CAISO PCAP PRM Simulations (2024)

*LOLP simulations indicate an **13.8%** reserve margin needed to meet 0.1 days/year LOLE*

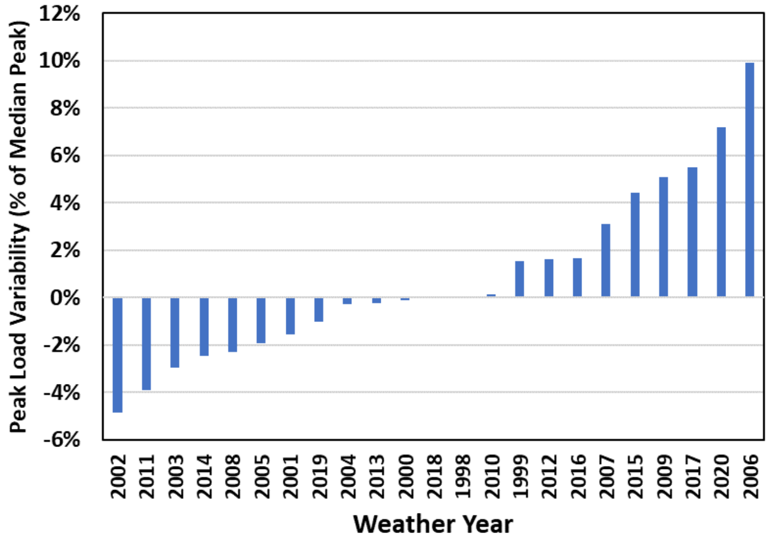


- *PCAP PRM simulations for years 2024, 2026, 2030 and 2035 ranged between 13.5-14.0%*
- *Equivalent 2030 ICAP PRM over gross peak is ~18-21.5%, depending on the share of resources counted at ELCC vs. installed capacity*
- *All PRMs calculated relative to CAISO median gross peak*

PCAP PRM Drivers

Inter-annual Load Variability

- Reserves required to meet load under extreme weather conditions



Load Forecast Error

- SERVM includes a symmetric stochastic load forecast error of +/- 2.5%
- However, the PRM impact is asymmetric
  - Higher load years drive more additional loss of load events that are avoided in lower load years, driving a small additional reserve margin need

Operating Reserves

- CAISO holds 6% operating reserves during load shedding events to avoid cascading blackouts
- Modeled in SERVM as:
  - 3% spinning reserve
  - 3% regulation up

PRM and ELCC Interaction

- A planning reserve margin % is a function of:
  - Operating reserves
  - Load forecast error
  - Load variability

  Directly impacts the total reliability need (perfect capacity MW) to reach 0.1 LOLE

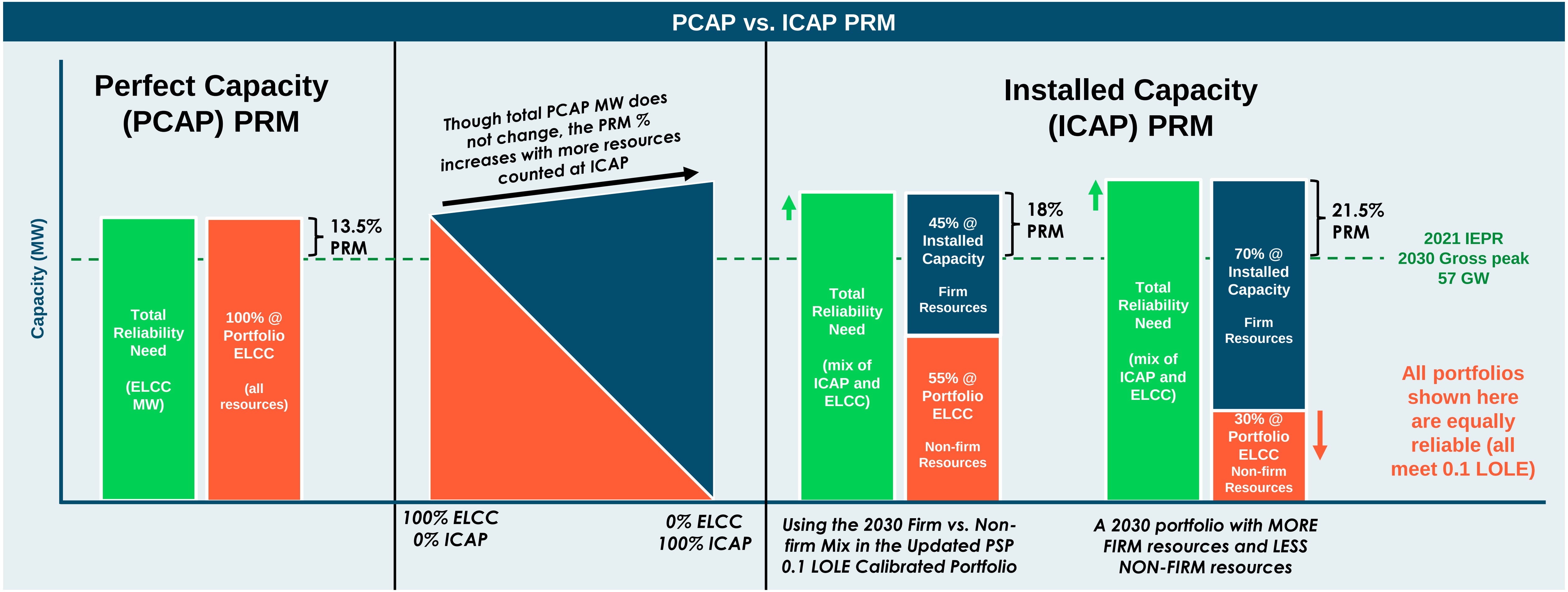
  - Median peak (managed vs. gross)

  Impacts the PRM % calculation that uses the TRN MW (a managed peak PRM is generally inconsistent with a PCAP approach)

  - Resource mix

  Does NOT impact a PCAP PRM since all resources counted at PCAP/ELCC…
  …but if a mix of PCAP-based and other methods used (installed capacity, exceedance heuristics, etc.), then the mix will impact the ICAP PRM

ICAP PRM Changes As the Resource Mix Changes

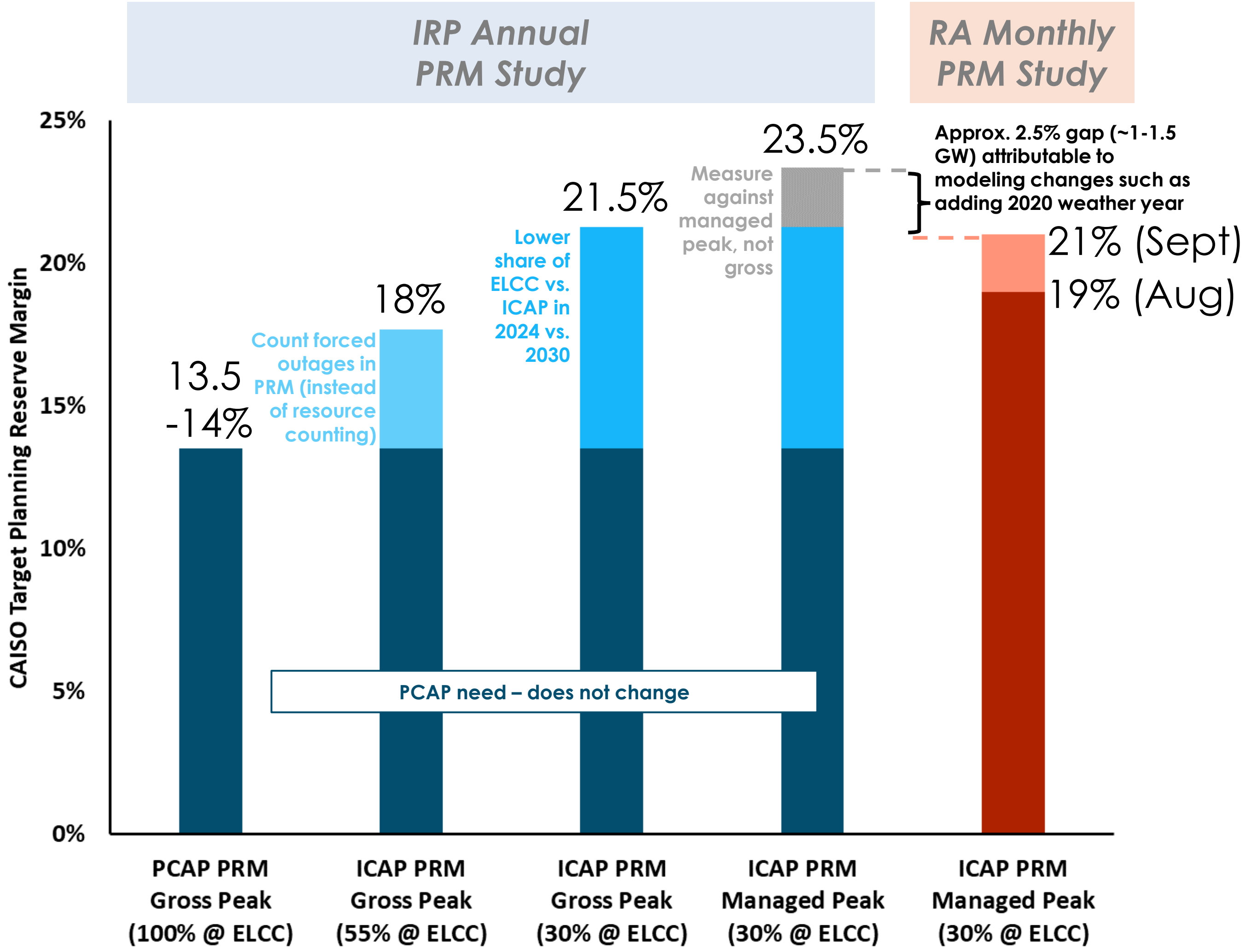


Defining the PRM Above Gross Peak (Before BTM PV Output) versus Managed Peak

- A PCAP PRM is derived from the perfect capacity needed to reach 0.1 LOLE
- This requires counting all resources at their perfect capacity equivalent MW (i.e. their ELCC) since the resources that would cause the managed peak and net peak to be lower than the gross peak are not included in the calculation of the PCAP PRM
- Therefore, the definition of the PRM relative to the gross peak (not managed peak) is consistent with the PCAP PRM method
  - It also provides the benefit of not changing the PRM % over time as the gross vs managed peak further shifts
  - It appropriately credits BTM PV for interactive effects like storage charging and does not inappropriately credit it with reducing the reserve margin needed to meet the TRN
- Note that a PRM % measured relative to the gross peak leads to a higher MW reserve margin versus the same PRM % applied to a lower managed peak

Comparing PRM Results to Recent RA Study

- Staff's February 2022 LOLE and ELCC Study[1] for the resource adequacy (RA) proceeding focused on defining a monthly ICAP and UCAP PRM above the CAISO managed peak
  - 2024 PRM = ~19-21% ICAP PRM over CAISO managed peak (for Jul-Sept)
- This IRP study focused on defining an annual PCAP PRM above the CAISO gross peak using an updated SERVM model including recent extreme weather conditions in August 2020
  - 13.5-14% PCAP PRM over CAISO gross peak
  - ~18% *ICAP PRM* over CAISO gross peak (2030 portfolio level of ELCC vs. ICAP)
  - ~21.5% ICAP PRM over CAISO gross peak (*2024 portfolio* level of ELCC vs. ICAP)
  - ~19.5-23.5% ICAP PRM over CAISO *managed peak*
    - Calculated by re-calculating the PRM after removing the IEPR peak shift from both the need and the median peak
  - (Refer to the Appendix for methodology to compare PCAP PRM to ICAP PRM)
- Since the RA study, this IRP study found up to an extra ~2.5% ICAP PRM (or approximately 1-1.5 GW) required over CAISO managed peak to address extreme weather in 2020 captured by adding weather years through 2020 to the model (and other less significant updates)



1. Available at: https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M452/K750/452750851.PDF

Conclusions from this PRM Study

- A 14% PCAP PRM over gross peak was found sufficient to meet 0.1 LOLE across multiple years
  - Corresponds to an ICAP PRM of 18-21.5% above gross peak or 19.5-23.5% above managed peak, depending on the CAISO system's proportion of resources counted at ICAP vs. counted with ELCC
  - All resources will be accredited at their PCAP equivalent MW (i.e. ELCC)
    - Corresponding ELCC values will be released in July 2022
- This PRM study incorporated recent extreme weather from 2020 into SERVM's weather year dataset
  - Result is to increase the total reliability need by ~1-1.5 GW relative to the RA proceeding study reported in February 2022
- RESOLVE portfolios from the updated PSP modeling were found to be more reliable relative to 0.1 LOLE
  - Planned updates as part of this cycle's I&A to RESOLVE's PRM and resource ELCCs are expected to better align RESOLVE inputs with SERVM LOLP modeling fundamentals

Next Steps

Next Steps for Reliability Filing Requirements for LSEs' IRPs

- These PRM results help define LSEs' reliability planning requirements, though further information is forthcoming:
  - June 15, 2022 - Ruling will formalize LSE IRP filing requirements
  - July 1, 2022 - Staff will send LSEs their final peak demand and BTM PV forecasts
  - July 2022 – Staff will post the final Resource Data Template (RDT), which will include
    - Resource accreditation metrics, including effective load carrying capabilities (ELCC), by resource type
    - Confirmation of use of average or marginal ELCCs
- Following these in July 2022, staff will host:
  - "Office hours" for each group of LSEs, by type, to answer questions and facilitate LSE IRP development
  - A MAG webinar to present these PRM results as well as the forthcoming ELCCs
    - Purpose will be to promote stakeholder understanding of reliability modeling inputs, methodology and results, support the development of LSEs' IRPs, and to gain feedback for informing modeling later this IRP cycle for updating the PRM for use in IRP modeling broadly, and as an input to the mid-to long-term procurement program

Next Steps for Potential Future Improvements to RESOLVE Inputs

- RESOLVE is designed to incorporate reliability assumptions from LOLP modeling
  - It is flexible to model any desired PRM and any set of ELCCs curves and/or surfaces
- Past RESOLVE versions partially aligned RESOLVE and SERVM
  - The 2019 IRP RESOLVE model used SERVM to derive a storage ELCC curve and a 2GW PRM adjustment factor
  - However, the combination of MTR High Need scenario-based assumptions (incl. a constant 22.5% ICAP PRM) and separate ELCC curves for solar and storage led the latest RESOLVE outputs to exceed the 0.1 LOLE standard
    - E.g. RESOLVE assumed solar marginal ELCCs "bottom out" at ~2%, when their marginal value likely increases from diversity benefits as storage penetration increases
- Updates planned in this cycle will fully align RESOLVE with a SERVM-based PRM and produce updated SERVM-based ELCCs that better capture solar and storage interactive effects
  - Reliability checks (and potentially portfolio iterations) between RESOLVE and SERVM will still be needed to ensure RESOLVE portfolios are sufficiently reliable across the planning horizon for modeled scenarios

Opportunity for Feedback

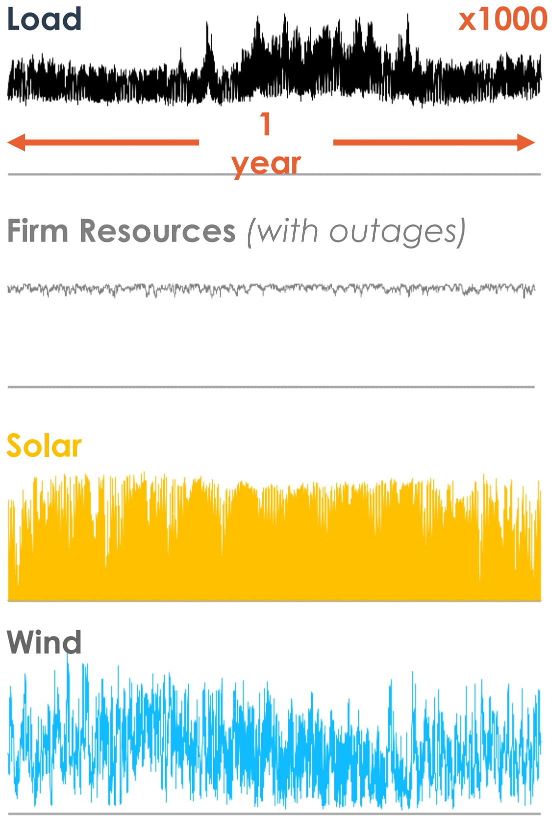
- Parties can informally comment on these PRM results to inform the work planning for reliability modeling that will be performed later this cycle, by emailing IRPdatarequest@cpuc.ca.gov
- Staff expects some parties will conduct their own reliability modeling to estimate the PRM and ELCCs
  - If parties' results are available in time for the July 2022 MAG webinar staff would like to discuss including them as presenters
  - Given the purpose of the webinar staff notes that modeling parties' results will not change the filing requirements for LSEs' IRPs
- Staff expects there will also be an opportunity to formally comment later this year

Appendix

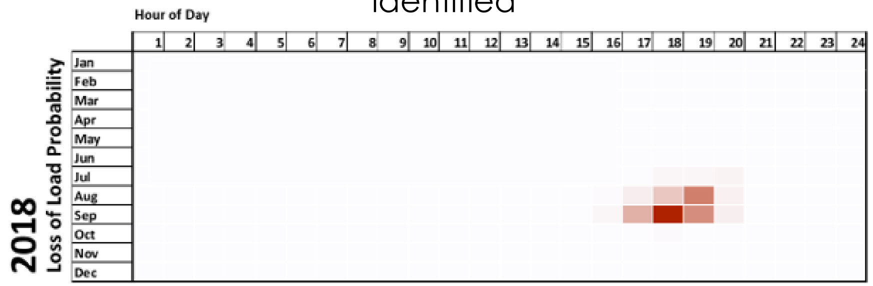
Loss of Load Probability Modeling

- Loss of load probability (LOLP) modeling is a probabilistic method to consider system reliability across a wide range of load and weather conditions
  - LOLP model inputs are tuned to historical correlations between weather, load, and renewable output
  - Monte-carlo simulations consider system operations across a range of weather conditions
- The CPUC IRP uses Astrapé's stochastic reliability model SERVM, which considers the following:
  - 23 years of historical weather conditions (1998-2020) to inform load, wind, and solar output
  - Economic-related load forecast uncertainty
  - Random unit-level forced outage draws
  - Regional market interactions

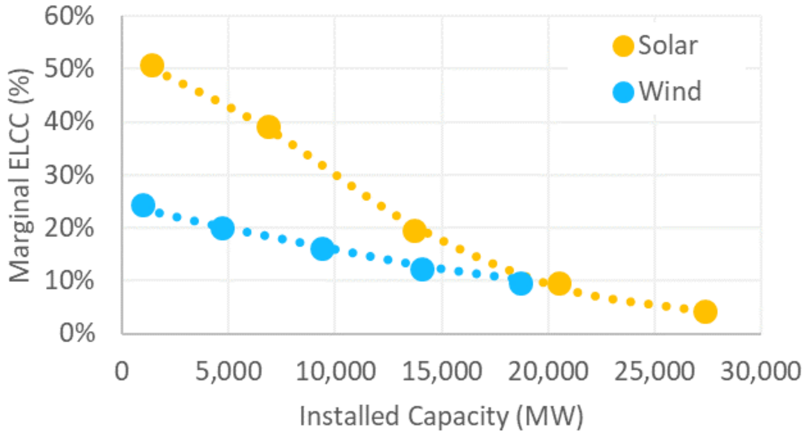
Monte Carlo simulation of loads, renewable profiles, and generator outages used to simulate 1,000 years of plausible system conditions



System reliability measured relative to "one day in ten year" standard; periods of high loss of load probability identified



Effective load carrying capability (ELCC) for a wide range of types of resources evaluated



Example RECAP result from *Long-Run Resource Adequacy under Deep Decarbonization Pathways for California* (Calpine, 2019)

LOLP Analysis Produces a Range of Useful Metrics

- Statistical reliability metrics: measures of the size, duration, and frequency of reliability events

Result	Units	Definition
Expected Unserved Energy (EUE)	MWh/year	Average total quantity of unserved energy (MWh) over a year due to system demand plus reserves exceeding available generating capacity
Loss of Load Probability (LOLP)	%	Probability of system demand plus reserves exceeding availability generating capacity during a given time period
Loss of Load Hours (LOLH)	hours/year	Average number of hours per year with loss of load due to system demand plus reserves exceeding available generating capacity
Loss of Load Expectation (LOLE)	days/year	Average number of days per year in which unserved energy occurs due to system demand plus reserves exceeding available generating capacity
Loss of Load Events (LOLEV)	events/years	Average number of loss of load events per year, of any duration or magnitude, due to system demand plus reserves exceeding available generating capacity
Total Reliability Need (TRN)	MW	***Total capacity MW necessary to maintain an adopted reliability standard*** (e.g. < 0.1 day/yr LOLE). Can be in effective MW (i.e. ELCC or perfect capacity equivalent) or defined relative to existing RA accounting (e.g. ICAP).

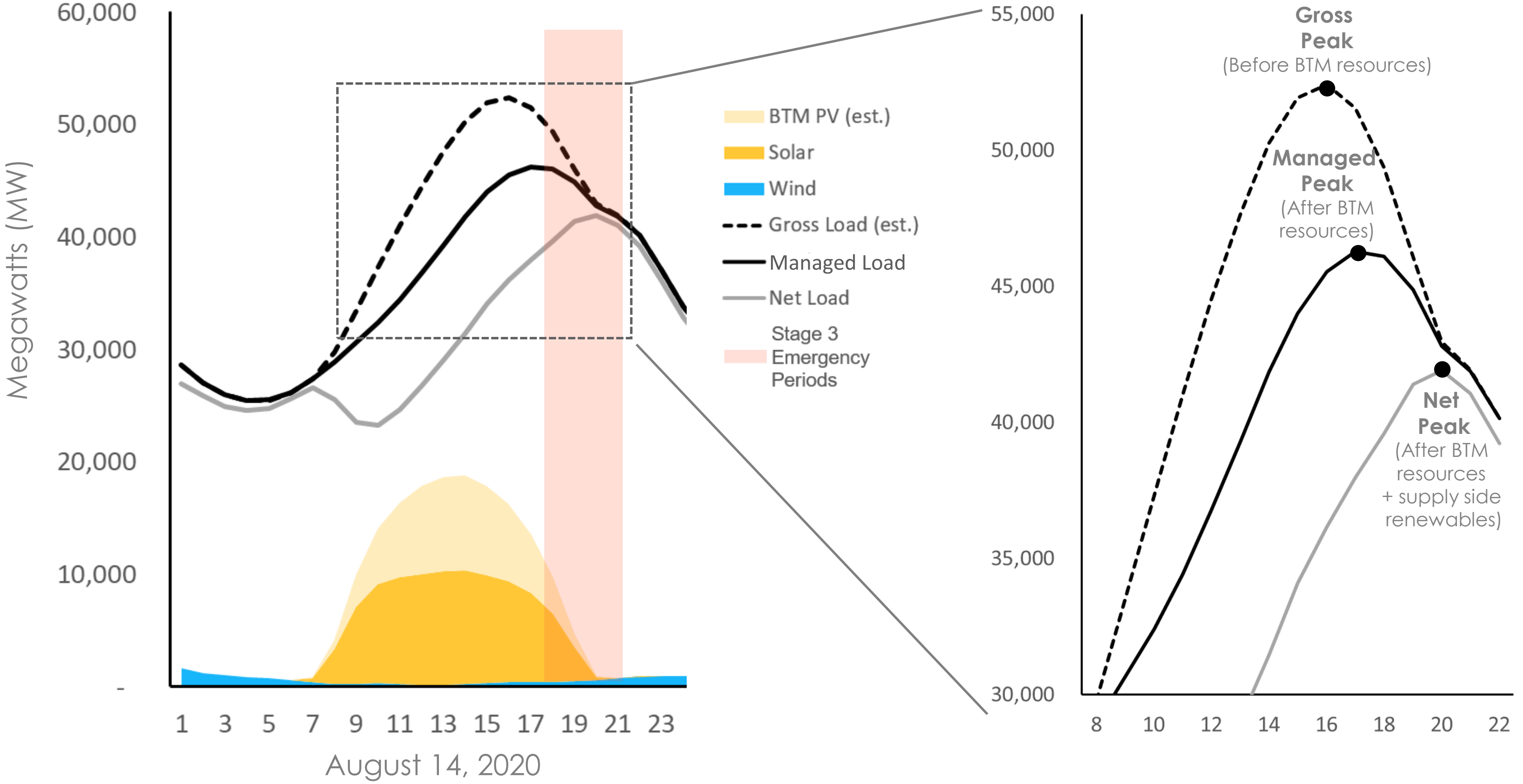
- Derivative metrics: additional useful measurements that can be derived from LOLP analysis

Result	Units	Definition
Planning Reserve Margin Requirement (PRM)	% 1-in-2 peak load	The planning reserve margin needed to achieve a given reliability metric (e.g., 1-day-in-10-years LOLE)
Effective Load-Carrying Capability (ELCC)	MW	Effective "perfect" capacity provided by energy-limited resources such as hydro, renewables, storage, and demand response
Residual Capacity Need	MW	Additional "perfect" capacity needed to achieve a given reliability metric

Why Switch from a "Managed Peak" Load Basis?

PRM % over Managed Peak changes as BTM resources change

Total Reliability Need MW to meet 0.1 LOLE does not change depending on the load determinant
...but if measured against a lower load, the required PRM % will increase



Gross Peak + 15% = 7.9 GW reserve margin

Managed Peak + 15% = 6.9 GW reserve margin

To reach the same 7.9 GW reserves, a 17% PRM is required over managed peak

Defining PRM above gross/consumption peak avoids this issue
BTM PV treated as a resource via ELCC (per current IRP methods) and its growth does not change the PRM % required

Loss of Load Heatmaps for 0.1 Tuned System from this ICAP PRM Study

2024

Hour

Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1																								
2																								
3																								
4																								
5																								
6																								
7																			0%					
8													0%			0%	0%		3%	3%	4%	7%	0%	
9																		29%	47%	3%	2%	2%	0%	
10																								
11																								
12																								

Risk concentrated in the early evening (HE 18-19) as solar drops off

Capacity shortfalls drive early evening risk

2026

Hour

Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1																								
2																								
3																								
4																								
5																								
6																								
7																			0%					
8																0%			1%	1%	7%	11%	1%	0%
9																		17%	51%	3%	2%	5%	1%	0%
10																								
11																								
12																								

2030

Hour

Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1																								
2																								
3																								
4																								
5																								
6																								
7																			0%				0%	
8																0%			2%	6%	14%	18%	13%	2%
9	0%																	9%	16%	0%	1%	9%	10%	1%
10																								
11																								
12																								

Risk extends and shifts later into the evening (HE 21-24) when storage runs out of charge

Capacity shortfalls still drive early evening risk…

… but energy shortfalls also drive late evening risk

Heatmap shows the share of annual expected unserved energy occurring in each month/hour.

Methodology to Compare PCAP PRM to ICAP PRM

- The following steps were taken to compare the PCAP PRM to the ICAP PRM from the February 2022 RA study:
  1. Calculate the PCAP PRM in 2030 required to reach 0.1 LOLE
  2. Calculate the ICAP PRM in 2030 required to reach 0.1 LOLE
     - An ELCC study was used to calculate the non-firm fleet ELCC MW
  3. Adjust the ICAP PRM to align with the 2024 resource portfolio mix assumed in the RA study
     - ELCC MW were replaced with ICAP MW, so that the ELCC share of total capacity was reduced from the 2030 share of ~55% to the 2024 RA study share of ~30%
  4. Adjust the ICAP PRM to be calculated over managed peak instead of gross peak
     - Remove the IEPR BTM PV peak shift from the numerator (total MW to reach 0.1 LOLE) and the denominator (peak demand MW) of the PRM calculation
  5. Compare (4) above to the Jul-Sept monthly target PRM from the RA study