PNM 2020-2040
Integrated Resource Plan

September 15, 2020

Resource Adequacy Deep Dive, Final Modeling Updates
and Stakeholder Scenarios

Agenda

1. Welcome and Introductions
2. Safety and Ground Rules
3. Online Participation Instructions
4. Resource Adequacy in High Renewable/Deep Decarbonization Electric Systems (E3, Astrapé and PNM)
5. IRP Modeling Updates
6. Stakeholder Scenario Requests

Nick Phillips
Director, Integrated Resource Planning

Mr. Phillips manages the PNM Resource Planning department and is responsible for developing PNM resource plans and the regulatory filings to support those resource plans.

Prior to joining PNM, Mr. Phillips was involved with numerous regulated and competitive electric service issues including resource planning, transmission planning, production cost analysis, electric price forecasting, load forecasting, class cost of service analysis, and rate design.

Mr. Phillips received the Degree of Master of Engineering in Electrical Engineering with a concentration in Electric Power and Energy Systems from Iowa State University of Science and Technology, and the Degree of Master of Science in Computational Finance and Risk Management from the University of Washington Seattle.

Meeting ground rules

01

- Questions and comments are welcome – One Person Speaks at a Time

02

- Reminder; today's presentation is not PNM's plan or a financial forecast, it is an illustration of the IRP process

03

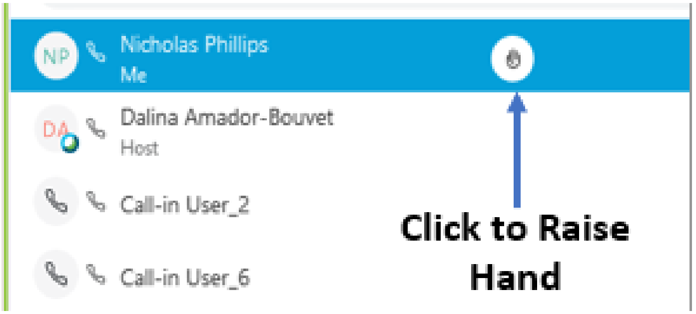
- Please wait for the microphone to raise your question or make your comment so we can ensure you are clearly heard and recorded. ***Only Q&A are transcribed for our filing package***.
- Questions and comments should be respectful of all participants

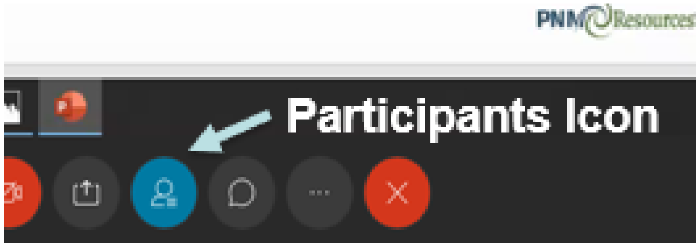
04

- These meetings are about the 2020 IRP, questions and comments should relate to this IRP. Any questions or comments related to other regulator proceedings should be directed towards the specific filing

Online Meeting Protocol

- All participants will be on mute upon entering the meeting, raise your hand to be unmuted or use the chat icon if you have a question.
- Participants asking questions are expected to identify themselves and the company they represent.
- All questions during this meeting will be public.





Disclosure regarding forward looking statements

The information provided in this presentation contains scenario planning assumptions to assist in the Integrated Resource Plan public process and should not be considered statements of the company's actual plans. Any assumptions and projections contained in the presentation are subject to a variety of risks, uncertainties and other factors, most of which are beyond the company's control, and many of which could have a significant impact on the company's ultimate conclusions and plans. For further discussion of these and other important factors, please refer to reports filed with the Securities and Exchange Commission. The reports are available online at www.pnmresources.com.

The information in this presentation is based on the best available information at the time of preparation. The company undertakes no obligation to update any forward-looking statement or statements to reflect events or circumstances that occur after the date on which such statement is made or to reflect the occurrence of unanticipated events, except to the extent the events or circumstances constitute material changes in the Integrated Resource Plan that are required to be reported to the New Mexico Public Regulation Commission (NMPRC) pursuant to Rule 17.7.4 New Mexico Administrative Code (NMAC).

Resource Adequacy in High Renewable/Deep Decarbonization Electric Systems

Nick Phillips

Director of Integrated Resource Planning

The Integrated Resource Planning Problem

$$\text{Minimize } c^{T}x = \sum_N c * x$$

$$\text{Subject to: } Ax \leq b$$

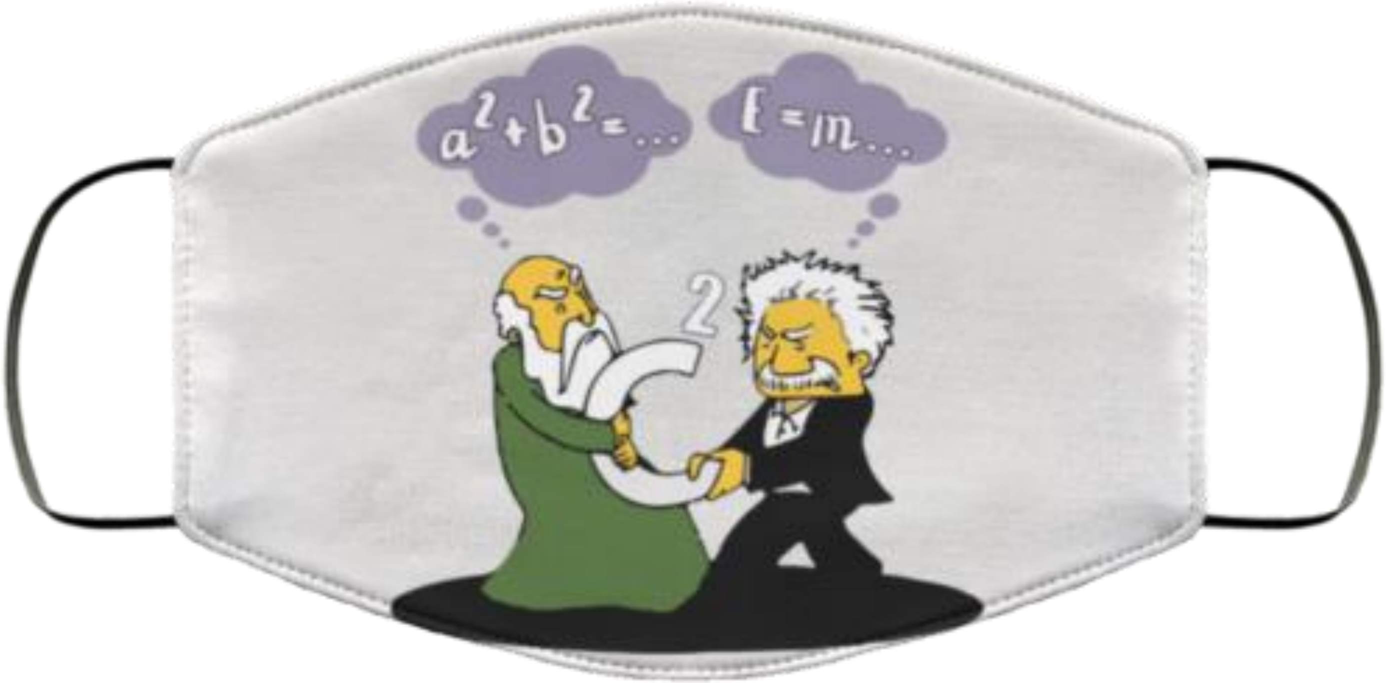
$$x_{1 \ldots n}\{0, 1\} \text{ (or integer)}$$

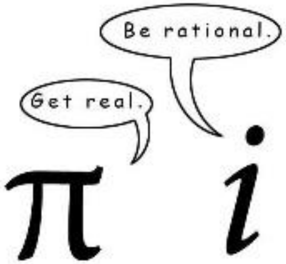
$$x_{n+1 \ldots N}\{\mathbb{R}, \geq 0\}$$

Reliability Requirements (Resource Adequacy) included here

- **Resource Planning Models Include Binary and Integer Decisions**
  - 0-1 Decision Variable to Represent a Choice about a Given Resource
  - Commitment Logic
  - Also Allows for logical constraints
  - New Assets cannot be fractional
- **Other Decisions are Linear (or semi-continuous)**
  - Power Output
  - Emissions
  - Transmission Flows
  - Etc.

Most Jokes Aside…





Yeah ok I get it – I'll stop being such a nerd, but lets all make sure to practice safe behaviors including face masks

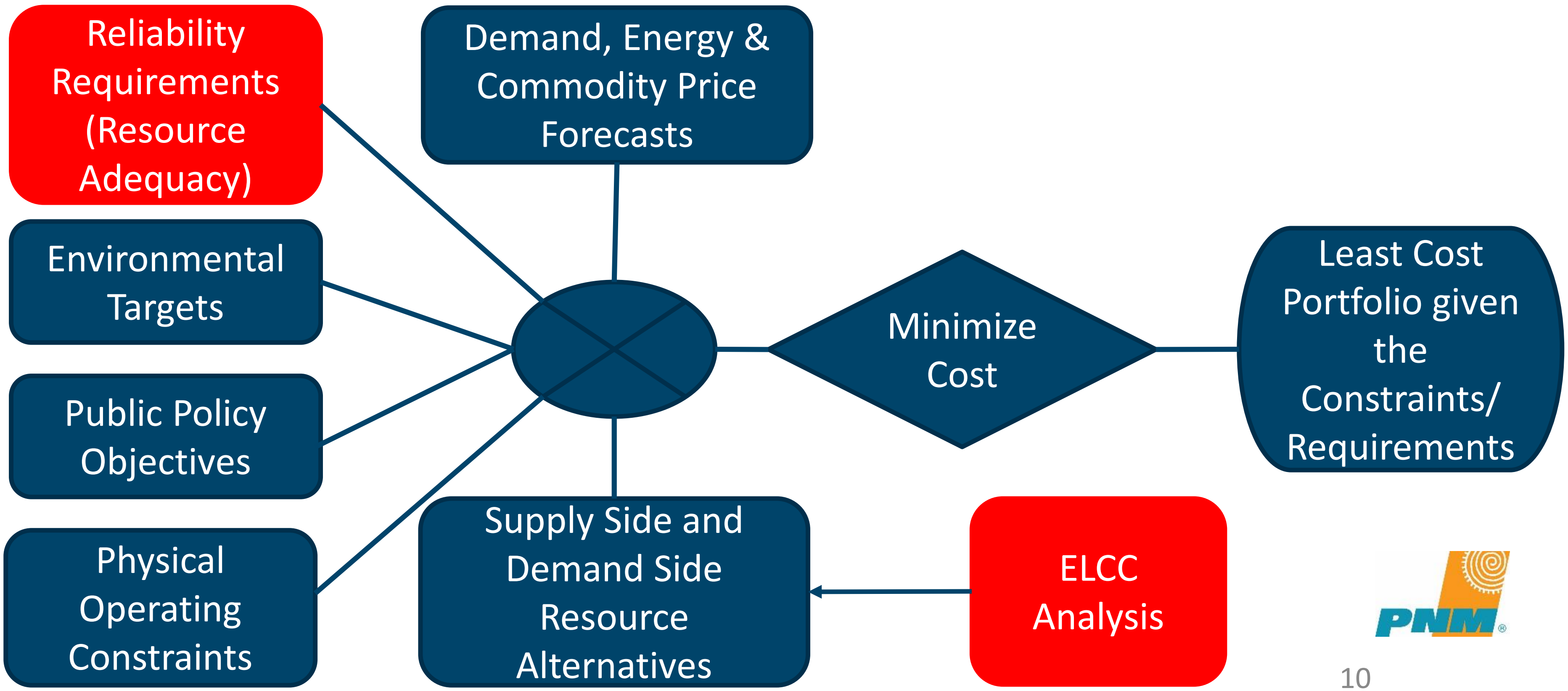
The Integrated Resource Planning Problem

Portfolio Objectives:

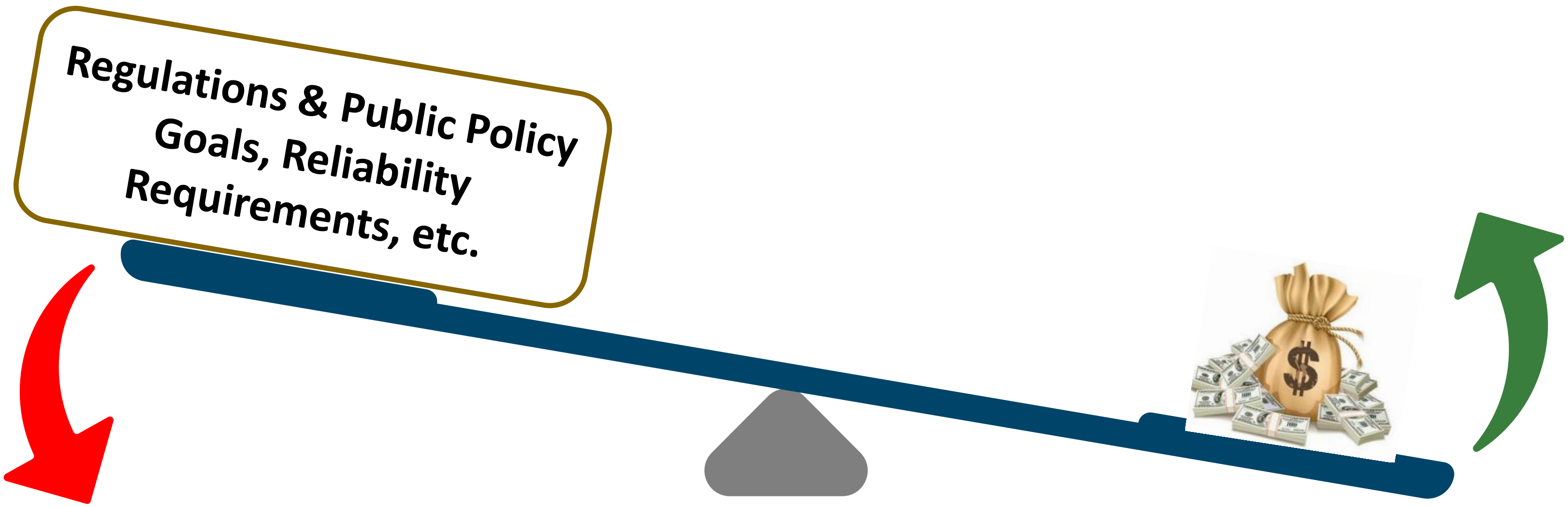
- Minimize Cost
- Meet Reliability Requirements
- Meet or Exceed Environmental Targets
- Meet Public Policy Objectives
- Operate within System Physical Limitations

Soft Constraint (Minimize Cost)

Binding constraints/requirements (remaining objectives)



A Planning Trade-Off

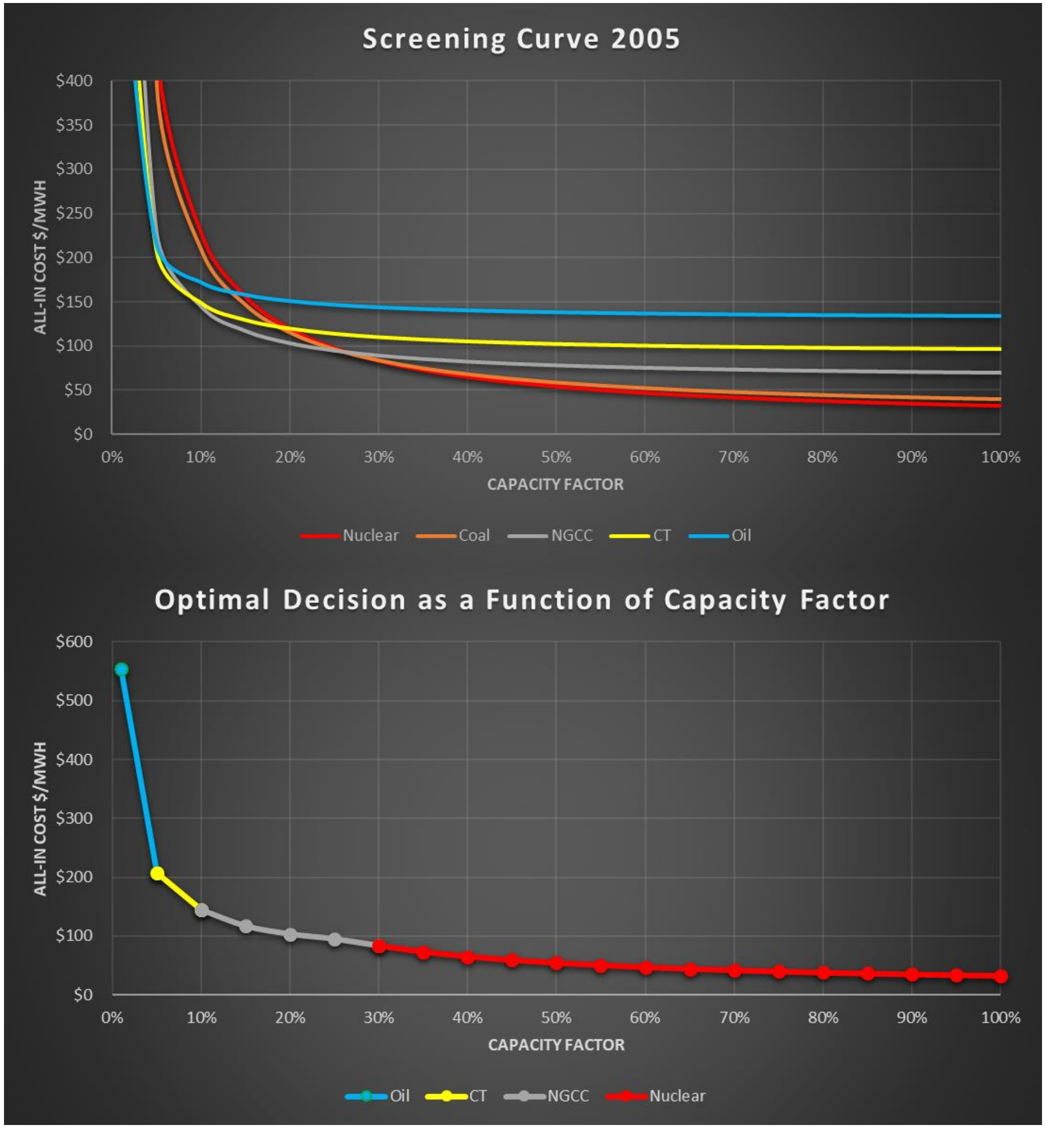


Portfolio Constraints

Increasing constraints on the portfolio due to regulations and public policy goals, such as RPS, Carbon Emission requriements, Communinty Solar, etc. reduce feasible economic alternatives, **possibly** adding to costs for customers.

Portfolio Costs

Historic Resource Planning (Illustrative)



- Prior to renewable resources, resource planning was simpler
  - (Most) all resources were dispatchable and provided 100% firm capacity relative to their nameplate, save for unplanned outages
  - The major question was how often was the resource expected to operate to assess the fixed vs. variable cost trade off

- Resource Adequacy (RA) was a much easier planning constraint than today as the risk was driven by system coincident peak demand

How would a renewable / energy limited resource show up on this plot?

Variable Energy Resources, Energy Limited Resources & Net Load

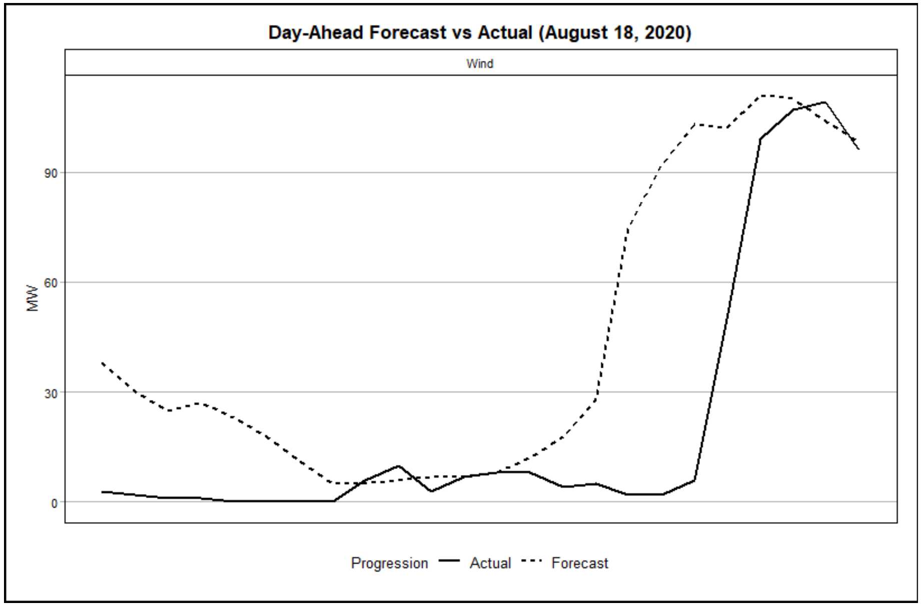
Variable Energy Resources (VER): Wind and Solar

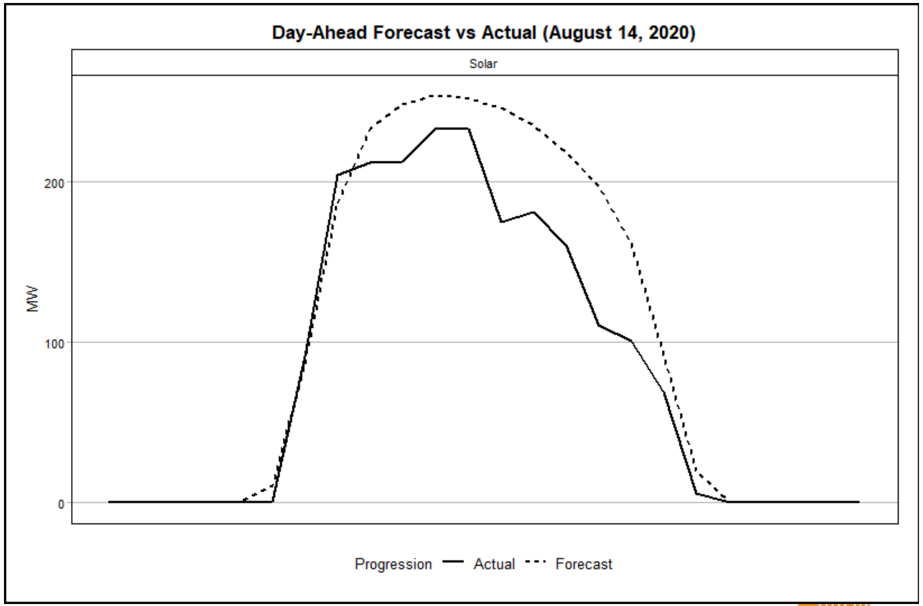
Uncertainty

- Wind and solar generators are not always available when needed
- Output is predicted by an imperfect (weather) forecast
- Actual output differ from forecasts

Variability

- Wind and solar generation vary with the intensity of their energy sources
- Several timescales of variability … intra-hour (regulation), inter-hour (ramping), daily, seasonal, inter-annual



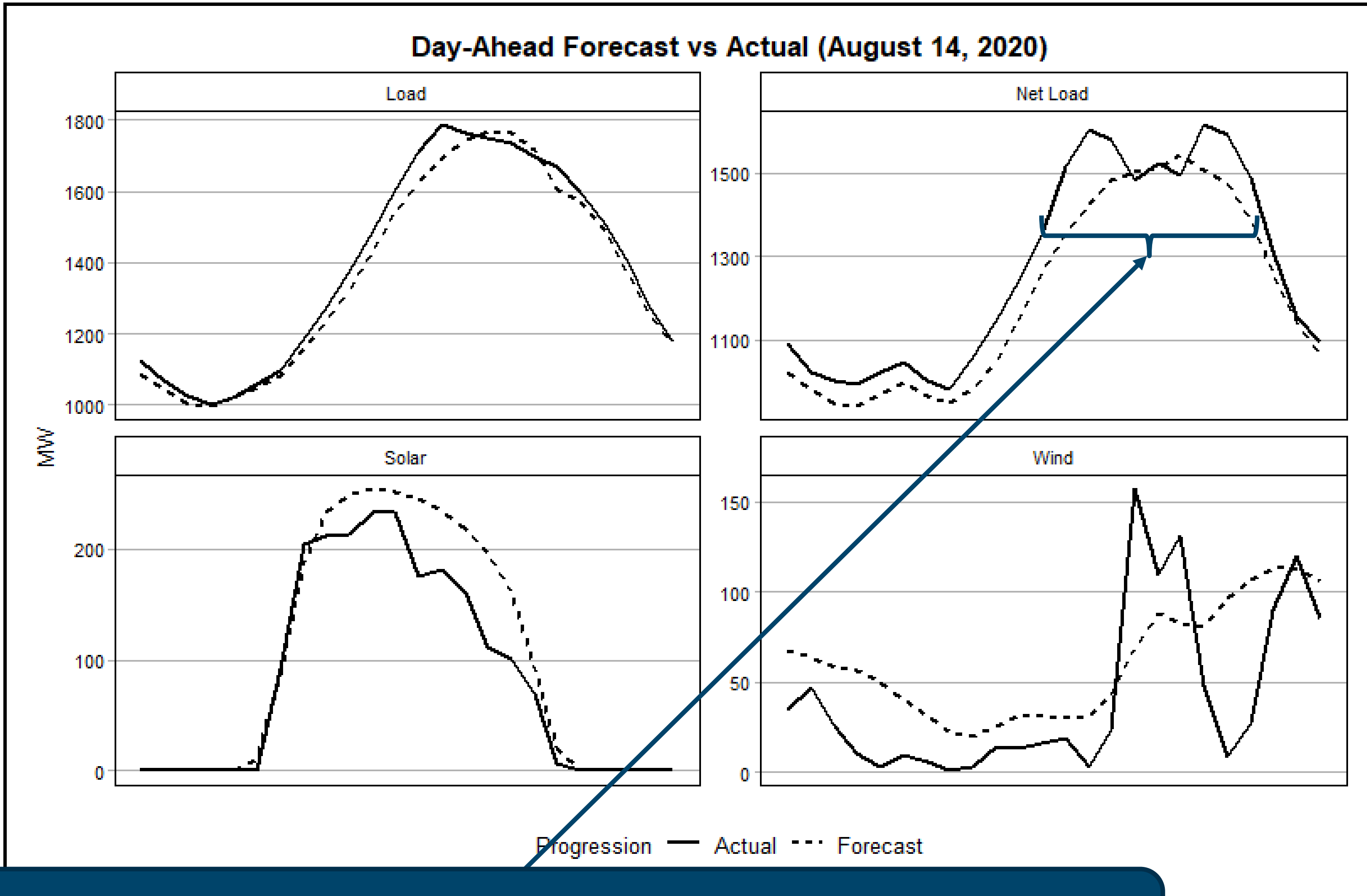


Perfect forecasts eliminate uncertainty, but variability remains

*Slide idea from Debra Lew, LLC WIEB/WIREB April 15,2020

Effects of Uncertainty and Variability

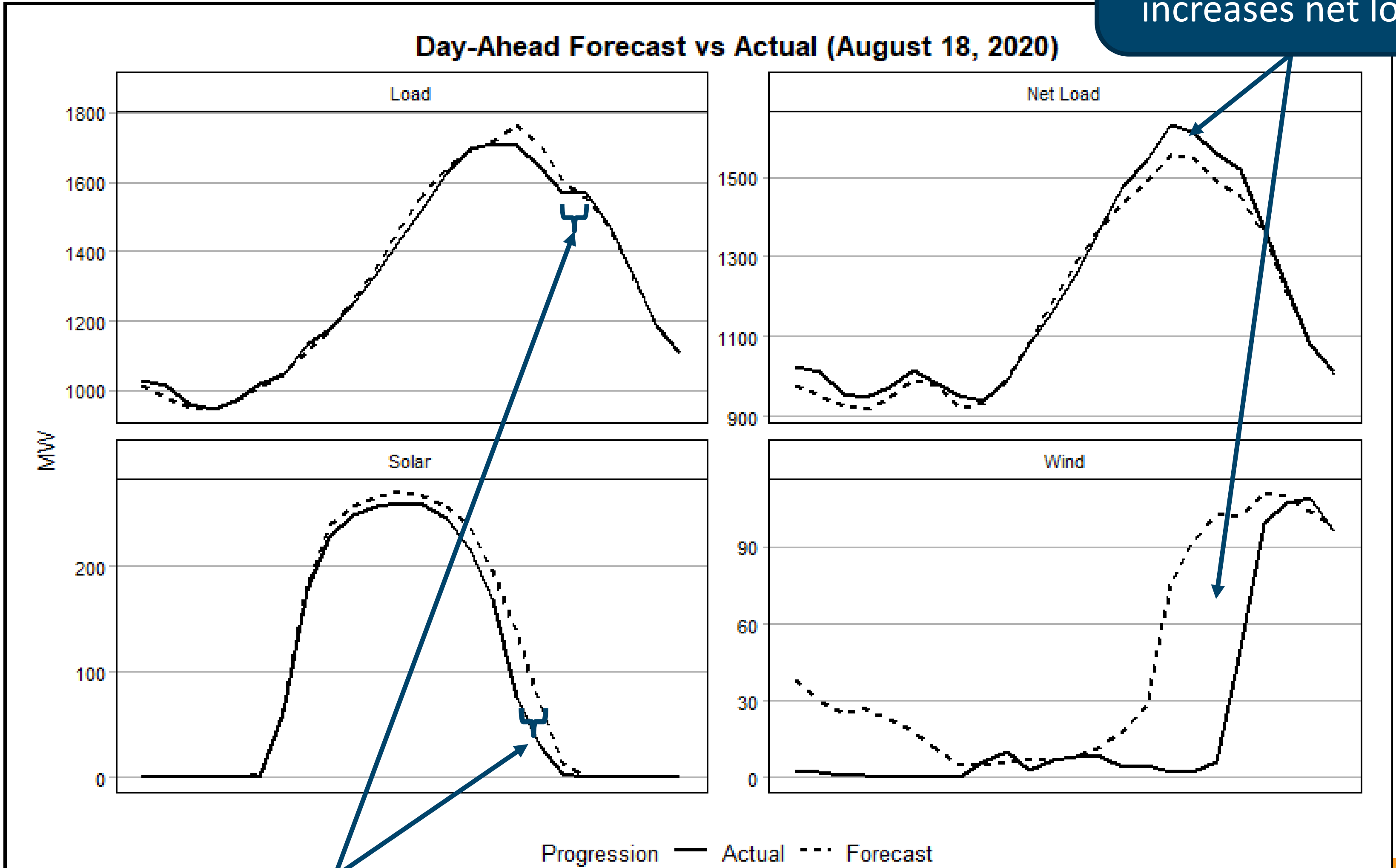
*Additional information in appendix slides XX-XX



Net Load = Gross Load – Solar – Wind
Uncertainty and variability lead to more volatile loads that must be served

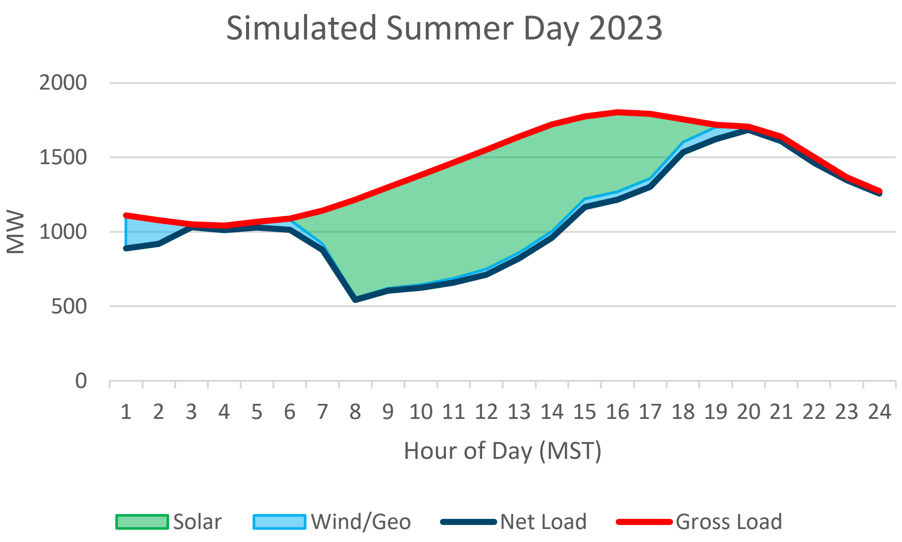
Effects of Uncertainty and Variability

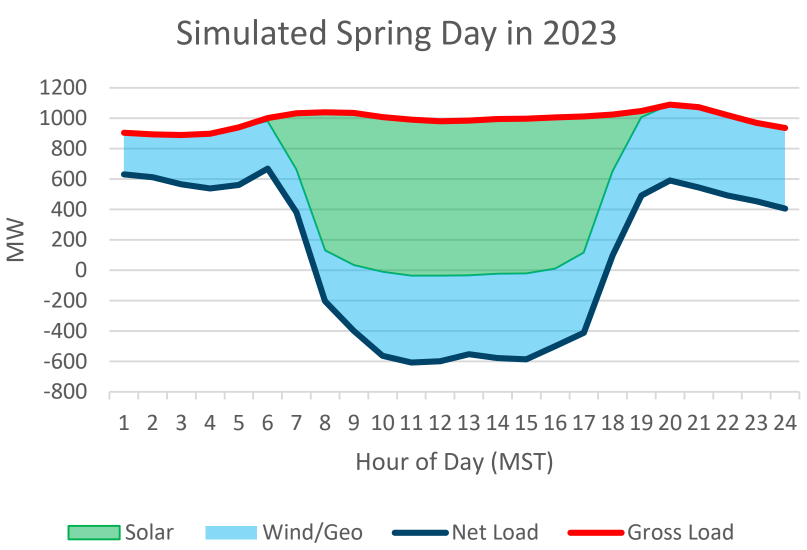
Absence of wind relative to forecasts increases net load

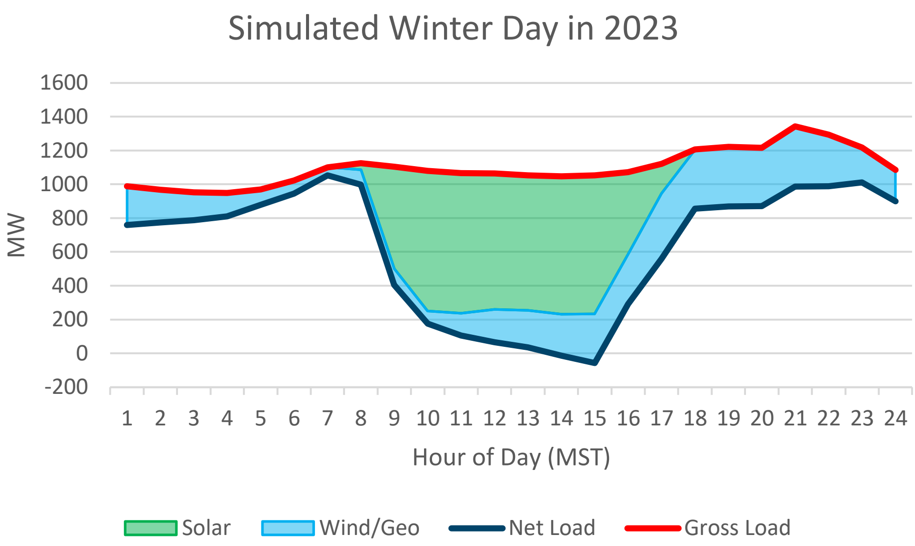


Reduction in Utility PV also corresponds to increase in load due to similar reductions from rooftop PV production. With high penetrations of distributed PV, it will be more accurate to explicitly model rooftop PV as generation.

Net Peak varies by Season







Energy+Environmental Economics

Resource Adequacy and ELCC Overview

Prepared for Public Service Company of New Mexico

August 31, 2020

Nick Schlag, Director
Andrew DeBenedictis, Director

Energy + Environmental Economics (E3) is assisting PNM for the IRP filing

- **Founded in 1989, E3 is a 70+ person leading energy consultancy with a unique 360-degree view of the industry built on the depth and breadth of their experts, projects, and clients**
- **E3's resource planning experts have led numerous analyses of how renewable energy and greenhouse gas policy goals could impact system operations, transmission, and energy markets**
  - Experience includes studies of deeply decarbonized and highly renewable power systems in California, Hawaii, the Pacific Northwest, the Desert Southwest, New York, New England, South Africa, and other regions

Arne Olson
Senior Partner

Nick Schlag
Director

Dr. Andrew DeBenedictis
Director

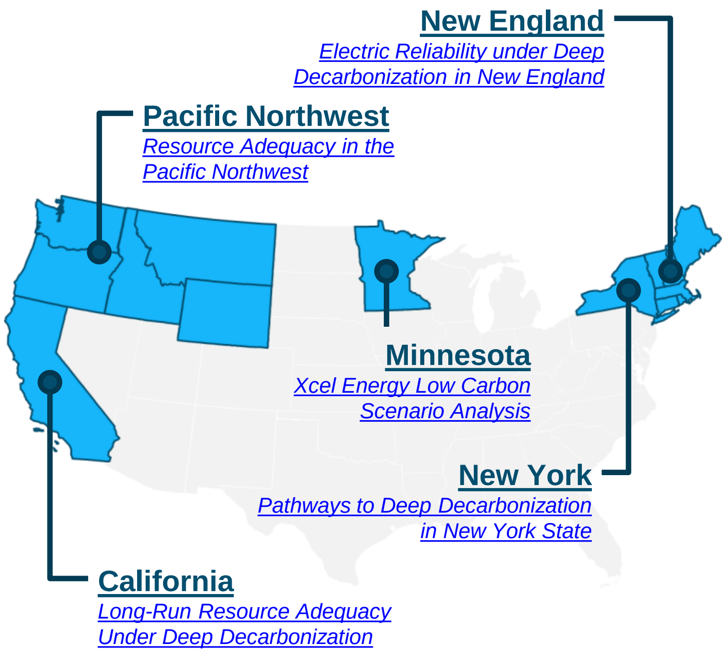
Outline

+ Overview of resource adequacy
+ Establishing a planning reserve margin requirement
+ Overview of “effective load carrying capability”
+ Implications for highly renewable electricity systems

E3 Experience Studying Resource Adequacy Under Deep Decarbonization

+ **E3's studies of resource adequacy under deep decarbonization use loss-of-load-probability modeling to study nature of resource adequacy challenges as wind, solar, and storage increase**
+ **Common findings include:**
  - Renewable and storage ELCCs decline with increasing levels of penetration
  - A diverse portfolio of resources can provide significantly higher capacity value than any single resource
  - At high renewable penetrations, reliability constraints shift to winter periods of sustained low renewable output
  - Some form of "firm" capacity – alongside renewables & storage – is needed to ensure reliability during these events

E3 has completed studies of resource adequacy needs under high renewable penetrations across the country

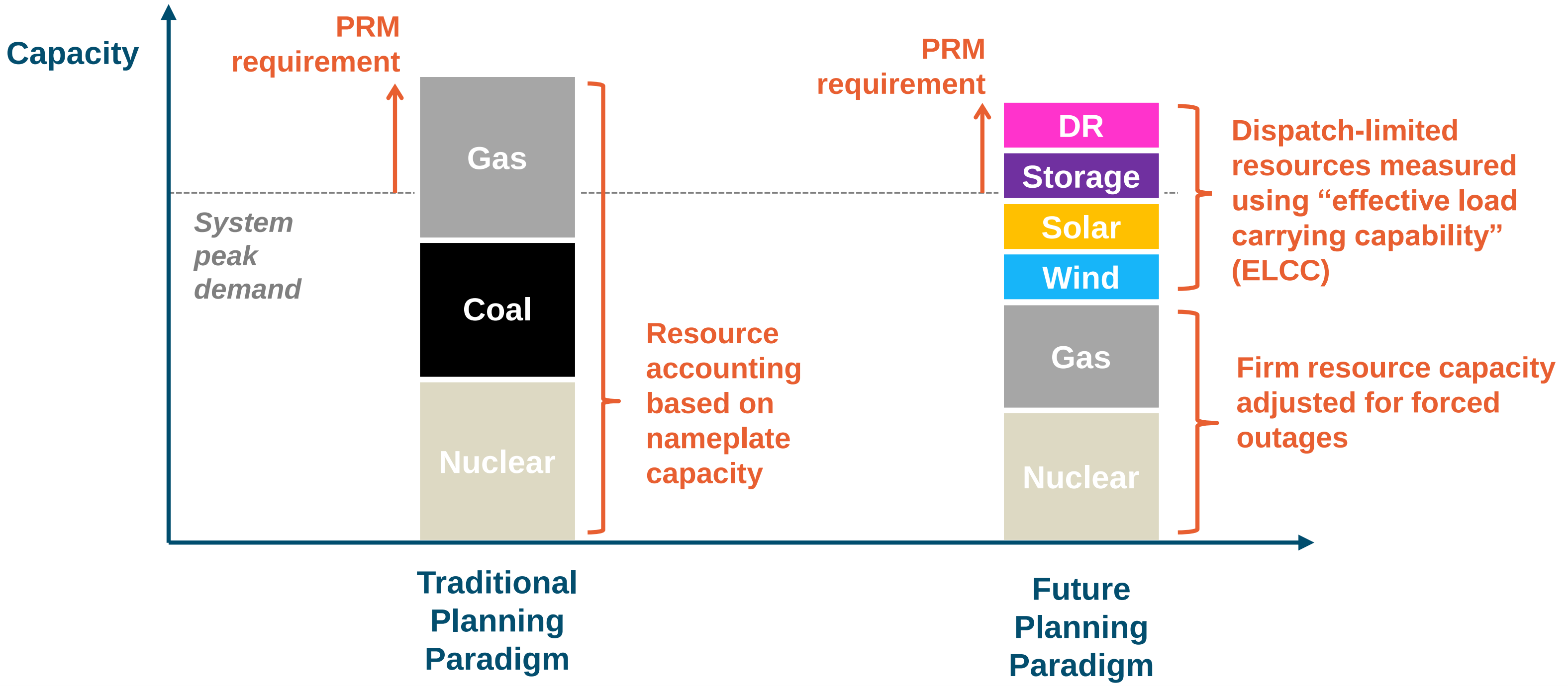


What is resource adequacy?

- **"Resource adequacy" refers to the ability of a portfolio of generation resources to meet a pre-defined standard for reliability**
  - Resource adequacy standards ensure that reliability events occur exceedingly rarely
  - Often measured using "loss of load expectation" (LOLE), expected number of days per year with unserved energy
- **Robust evaluation of resource adequacy relies on loss of load probability modeling**
  - A Monte Carlo simulation of load and resource availability across 100s (or 1000s) of years of conditions
- **Because of complexity of LOLP modeling, resource adequacy is often translated to a "planning reserve margin" (PRM) requirement**
  - Allows simpler and more transparent accounting of resource adequacy with a traditional load-and-resource table

Adapting the PRM framework for a high renewable future

- **Historically, utilities have relied upon a "planning reserve margin" (PRM) to ensure enough supply is available during peak periods**
- **Introduction of significant quantities of wind, solar, and storage present significant challenges to this accounting framework because:**
  - Availability of these resources during peak periods is likely lower than nameplate capacity
  - Increasing penetrations of renewables & storage will cause reliability needs to shift to other times of day/year
- **To continue using a PRM, we must revisit how we count capacity to ensure resources are measured based on their contributions across all hours – not just during peak periods**
  - A resource's effective load carrying capability (ELCC) reflects its contribution to reliability considering all hours of the year

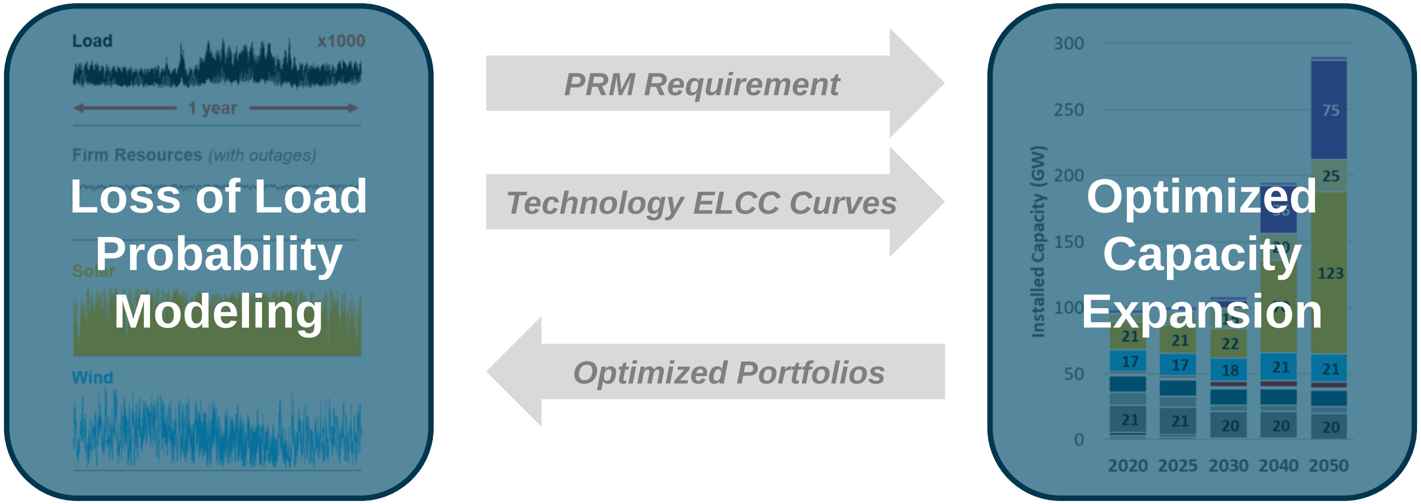


Robust resource planning combines capacity expansion and loss-of-load-probability modeling

The challenge: ensuring resource adequacy is a classic "needle-in-a-haystack" problem that requires analysis of thousands of years' worth of conditions to obtain a robust result, but optimized capacity expansion models typically consider a subset of representative days to identify optimal investments

The solution: pairing a capacity expansion model with loss-of-load-probability modeling provides a framework to capture the detail needed for resource adequacy without explicitly modeling all conditions in the capacity expansion model

1. Use LOLP model to quantify PRM requirement and "effective load carrying capability," which measures contribution of each resource to resource adequacy across 1000s of years



3. Use LOLP model to simulate performance of resulting portfolios across wide range of conditions, validating resource adequacy

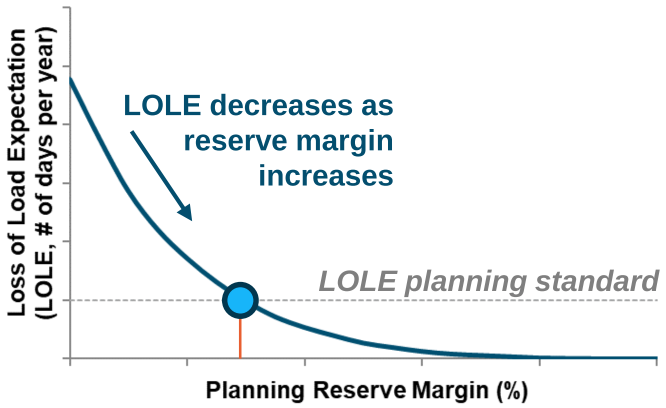
2. Use capacity expansion to optimize future portfolios to meet PRM requirement and clean energy goals while minimizing cost

Establishing a Planning Reserve Margin Requirement

Key drivers of the planning reserve requirement

1. What is the utility's reliability standard?

- No single standard required of utilities in North America – standards established by individual utilities/RTOs/regulators
- Most rely on a specified "loss of load expectation" – number of expected days per year with loss of load events



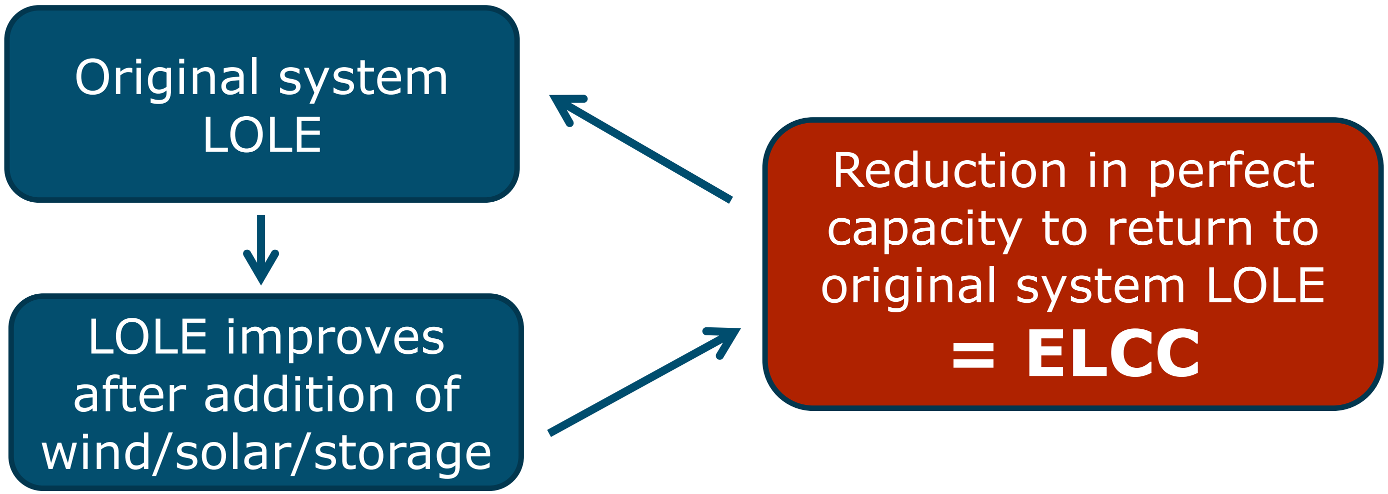
2. What conventions are used to count capacity towards the requirement?

- Utilities and resource adequacy program administrators use a variety of approaches to measure the contributions of different resource types towards the planning reserve margin:
  - Conventional resources: installed capacity vs. unforced capacity
  - Hydroelectric: installed capacity vs. historical output during peak time window
  - Wind & solar: effective load carrying capability vs. historical output during peak time window
  - Demand response: effective load carrying capability vs. expected peak demand impact
- Broad application of ELCC in PRM accounting provides the most consistent approach and will yield a more stable requirement even as resource mix changes
  - Contributions of all resources measured relative to "perfect capacity"

Overview of Effective Load Carrying Capability (ELCC)

Defining "effective load carrying capability" (ELCC)

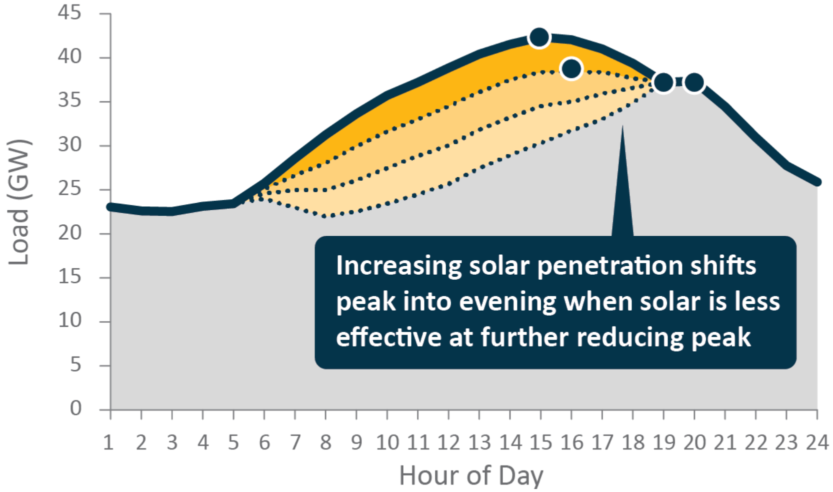
- Effective load carrying capability (ELCC) is the quantity of 'perfect capacity' that could be replaced or avoided with wind, solar, storage, etc. while providing equivalent system reliability

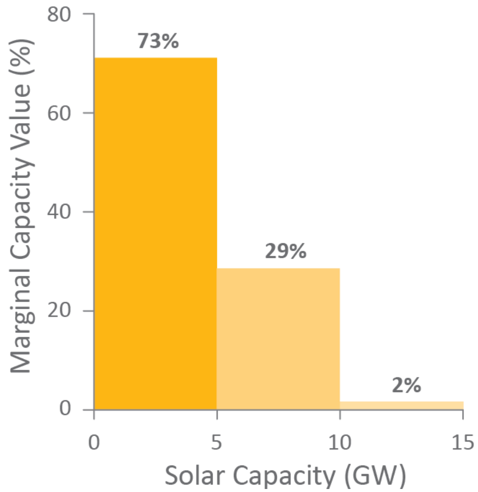


- ELCC is the most rigorous method for calculating qualifying capacity of energy-limited resources (solar, wind, storage, etc.)

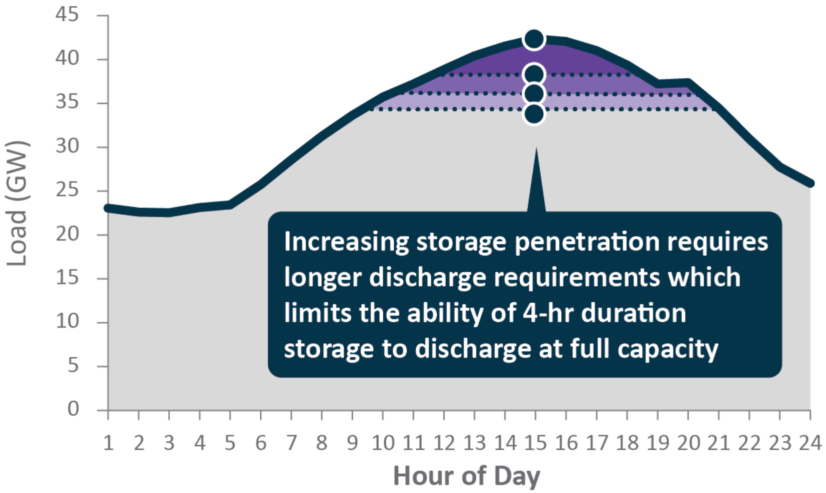
ELCC captures saturation effects with increasing resource penetration

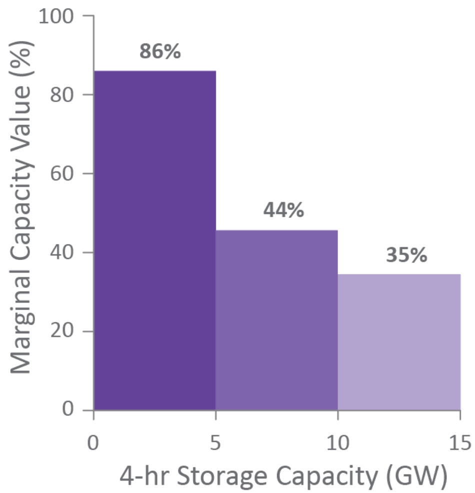
Diminishing Capacity Value of Solar





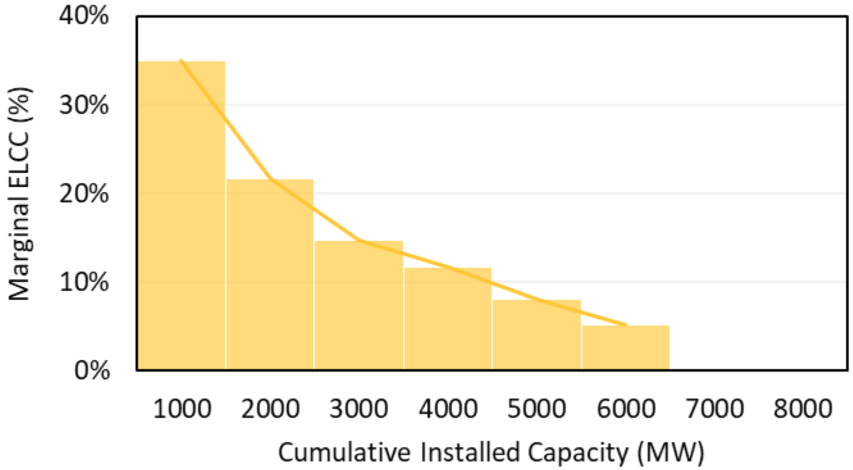
Diminishing Value of 4-hr Storage ELCC



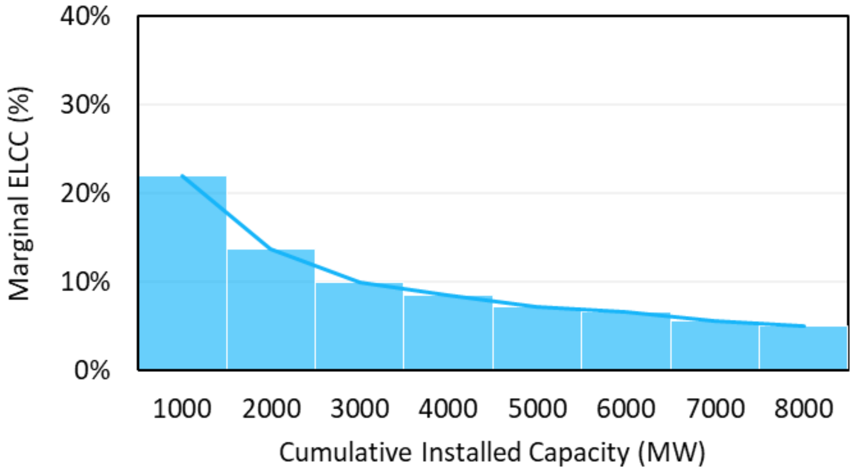


Example ELCC Curves
Xcel Energy (Upper Midwest System)

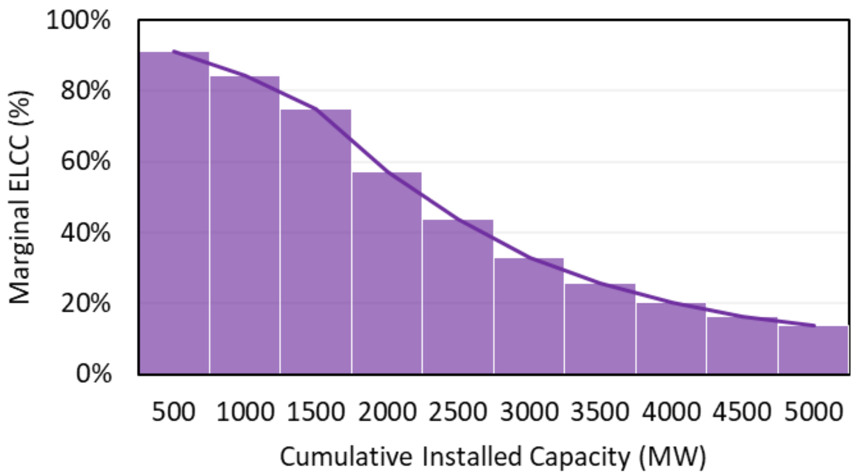
Marginal ELCC (%) - Solar



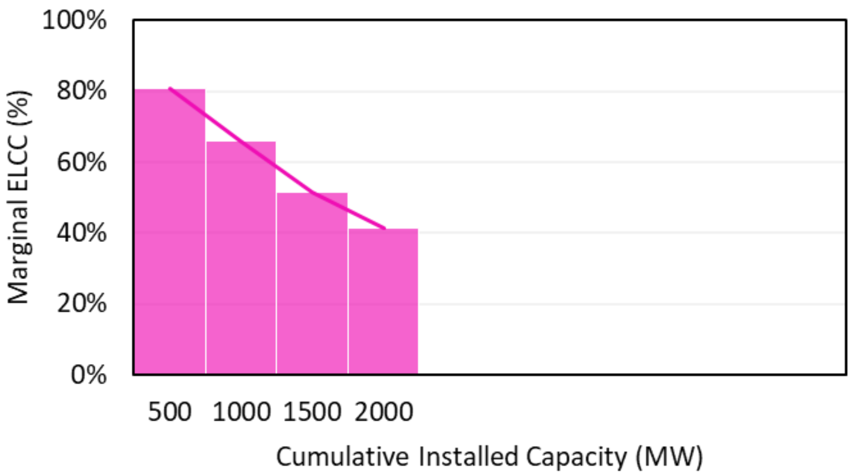
Marginal ELCC (%) - Wind



Marginal ELCC (%) – 4-hr Battery Storage

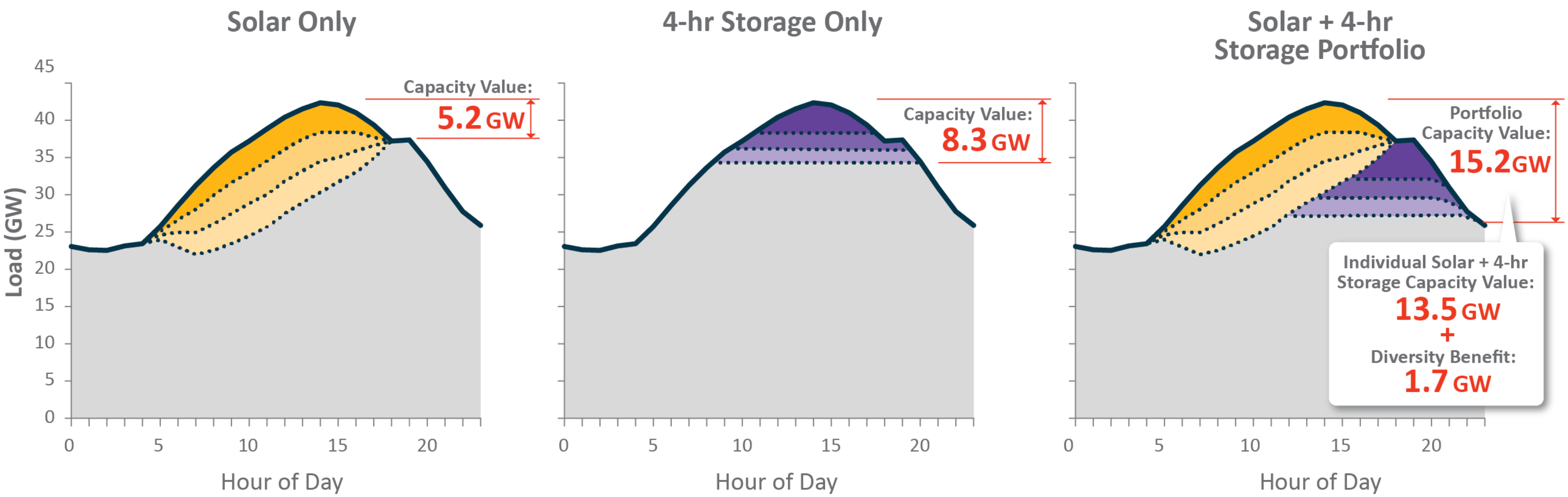


Marginal ELCC (%) – 4-hr DR



ELCC Captures Synergistic Interactive Effects Between Resources

+ **Resources with complementary characteristics produce a combined ELCC that exceeds the sum of individual resources' ELCCs, producing a "synergistic interaction"**
  - This effect has been described as a "diversity benefit" between resources



Common Examples of Synergistic or Antagonistic Pairings

+ **ELCC captures interactions between different resources which are an inherent feature of a decarbonized electricity system and will grow to be of profound importance**
  - This is what makes the calculation complex, but also what makes it valuable

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

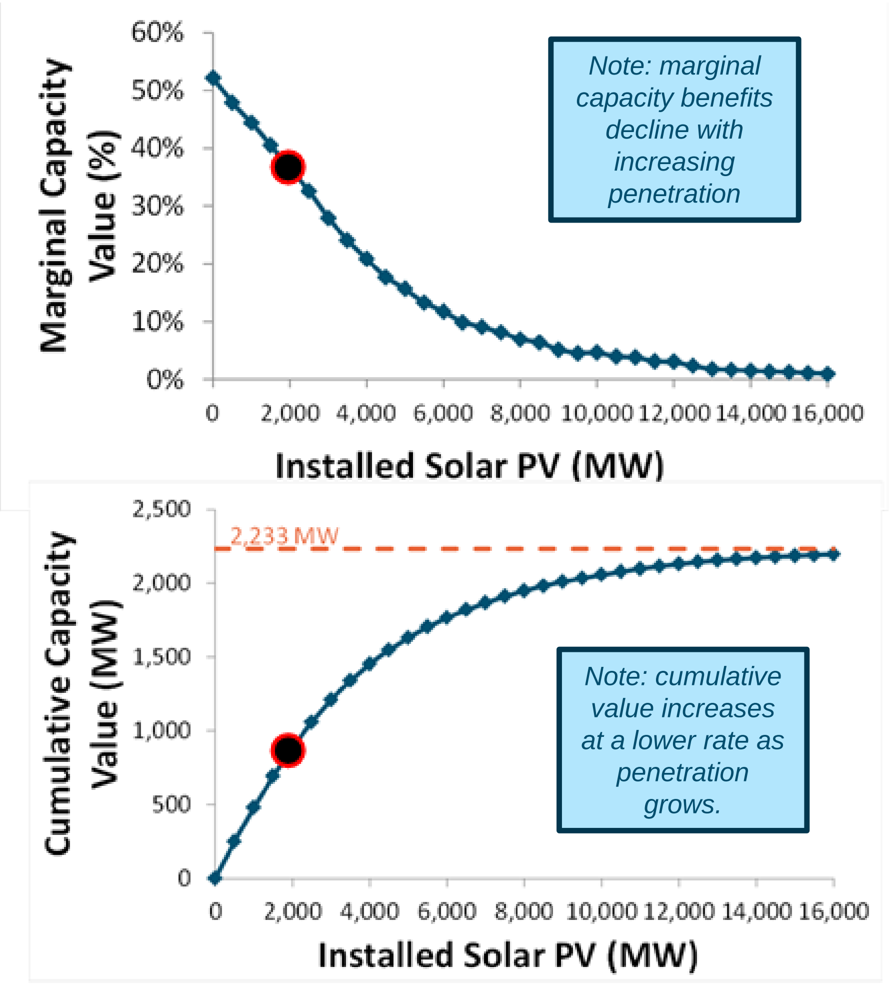
Storage + Demand Response
Energy limitations on both storage and hydro require longer and longer durations after initial penetrations

Average and marginal ELCC calculations

+ **Average and marginal ELCC metrics are useful for different purposes**

+ **Marginal ELCC:** incremental reliability benefit of adding one MW of capacity, useful for valuing future resources

+ **Total ELCC:** aggregate capacity credit (QC) for existing resources in RA program, useful for measuring total contribution of an existing portfolio



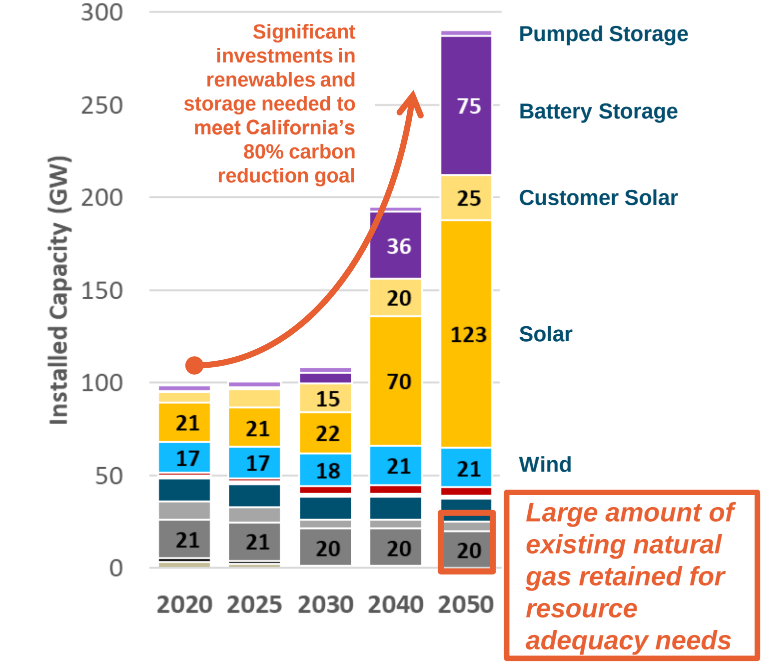
Energy+Environmental Economics

Implications for Highly Renewable Systems

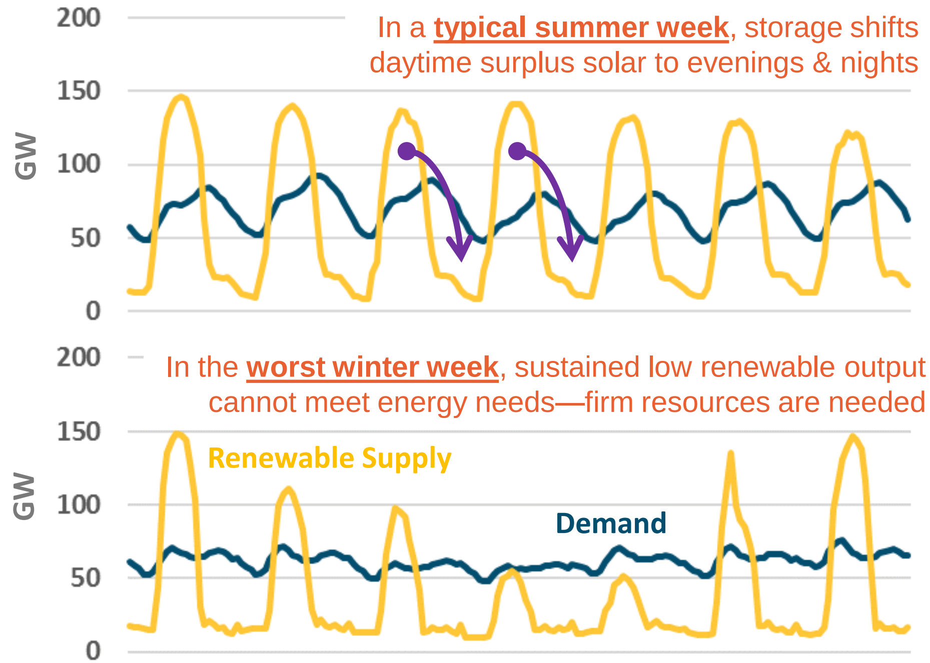
Case Study: Decarbonization & Reliability
Calpine Corporation

- Calpine Corporation retained E3 to conduct the first detailed reliability analysis of system needs under California's deep decarbonization goals
- <u>Key study finding:</u> Meeting California's greenhouse gas goals will require investment in >100 GW of solar and significant quantities of energy storage—but a significant quantity of firm resources are needed for reliability when solar is not available

Investment needs to meet California goals

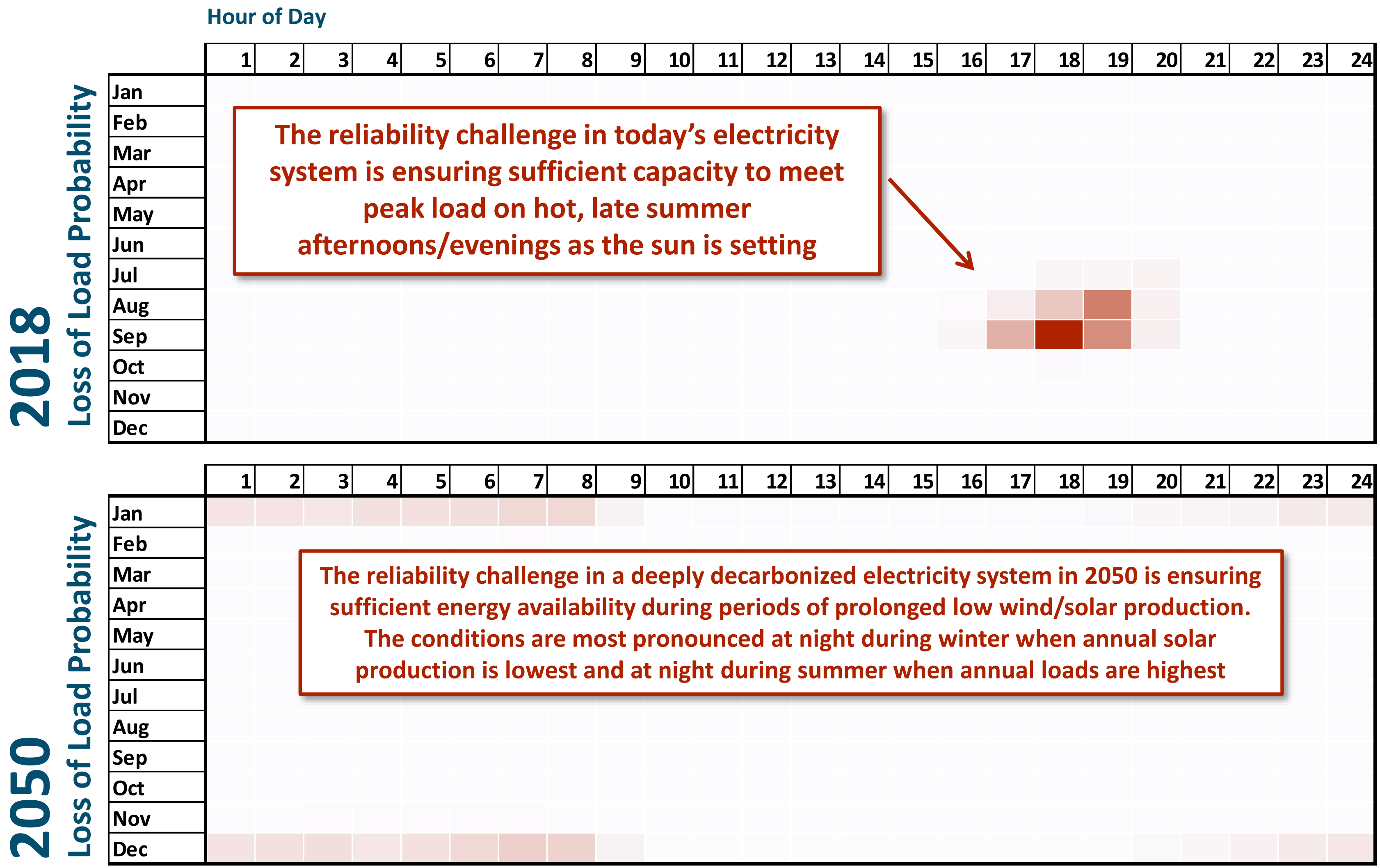


Diurnal balancing of solar becomes main challenge



Results from *Long Run Resource Adequacy Under Deep Decarbonization Pathways for California*, funded by Calpine Corp

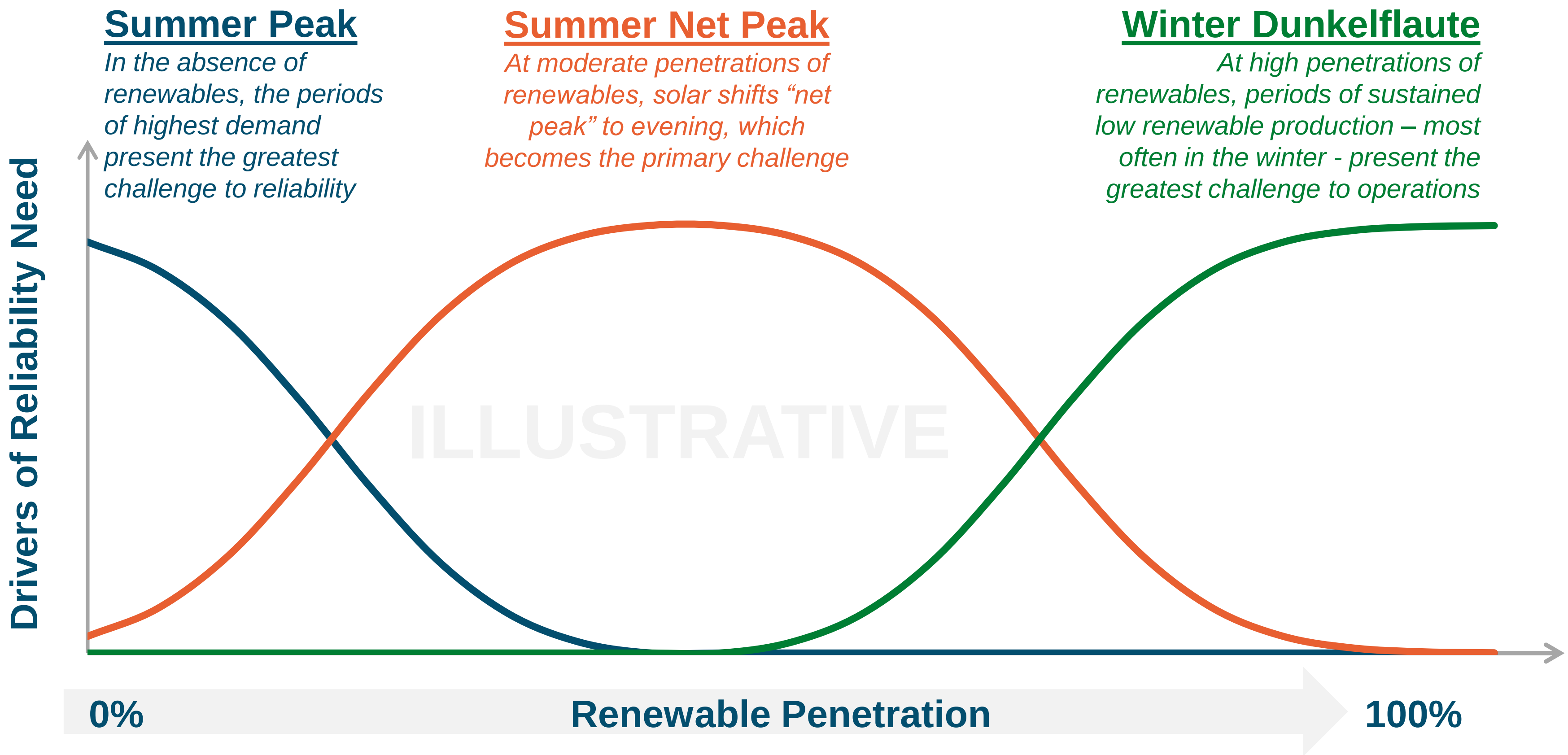
Focus of reliability planning shifts from a summer peak to winter “dunkelflaute”



Results from *Long Run Resource Adequacy Under Deep Decarbonization Pathways for California*, funded by Calpine Corp

Evolving grid challenges at increasing renewable penetrations

+ **Increasing levels of renewables will cause the timing of reliability challenges to shift to different times of day – and eventually to different times of year**



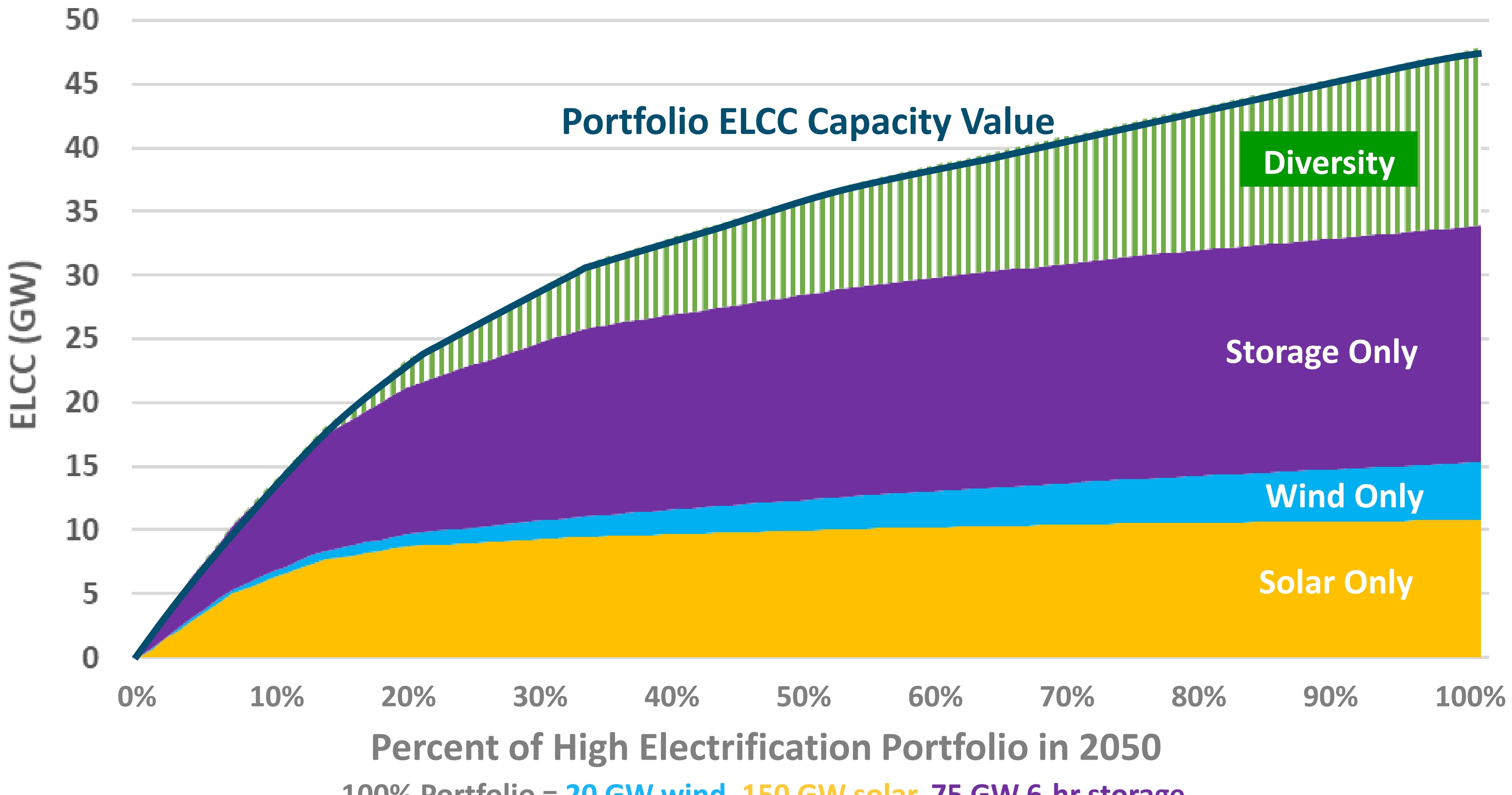
Appendix

Factors Affecting the ELCC of Variable Resources

+ **Coincidence with load**
  - Positive correlation with load means higher capacity value
+ **Existing quantity of other resources**
  - Same or similar resource types have diversity penalty
  - Complementary resource types have diversity benefit
+ **Production variability**
  - Statistically, the possibility of low production reduces the value of a resource
+ **Reliability target**
  - Effective capacity does not have linear relationship with system LOLE

Limited Potential for Wind, Solar, and Storage Despite Interactive Diversity Effects

+ The resources needed to meet California's decarbonization goals include approximately 150 GW of solar, 75 GW of storage, and 20 GW of wind – which together provide the same capacity value as <u>47 GW of perfect capacity</u>



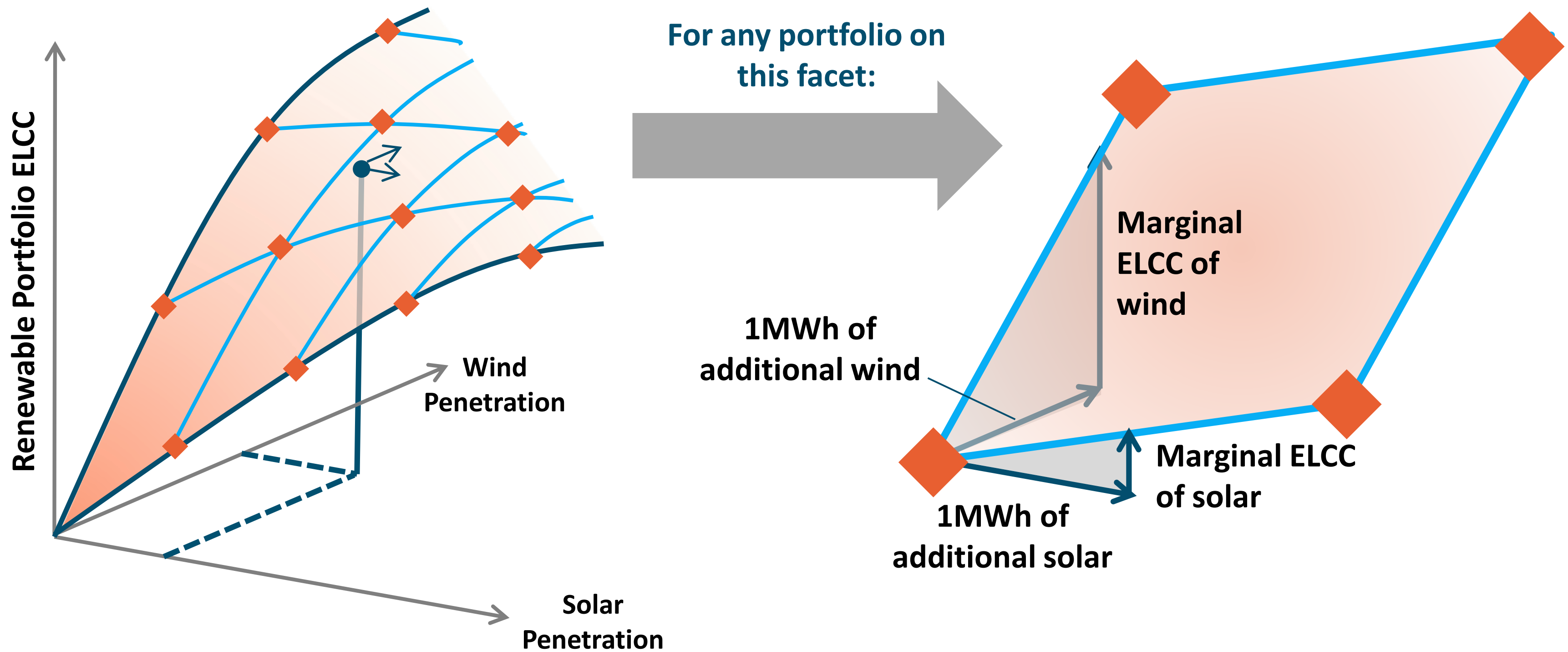
Options for conventions for planning reserve margin accounting

+ **Moving towards ELCC-style accounting for all resources in the portfolio will lead to a more durable and robust PRM, but results in departures from some well-established historical conventions**

Resource Type	"Traditional" Approach	"Advanced" Approach
Conventional	**Rated Capacity** ✓ Consistent with common IRP practice ✓ Simple to evaluate & understand ✗ Doesn't capture value of improved outage rates	**Unforced Capacity** ✓ More consistent with ELCC ✗ Change from common IRP practice ✗ Optics challenges due to "lower" PRM
Variable Renewable	**Time Window Approach** ✓ Easy to calculate and understand ✗ Fails to capture declining marginal value	**Effective Load Carrying Capability** ✓ Emerging best practice for utility IRPs ✓ Most robust measure of capacity value ✗ Computationally complex
Storage	**Rules of Thumb** based on duration ✓ Simple to implement ✗ Unsophisticated measure of value	**Effective Load Carrying Capability** ✓ Emerging best practice for utility IRPs ✓ Most robust measure of capacity value ✗ Computationally complex
Demand Response	**Peak Load Impact** ✓ Consistent with common IRP practice ✓ Simple to evaluate & understand ✗ Not "apples-to-apples" with ELCC ✗ Ignores interactive effects	**Effective Load Carrying Capability** ✓ More durable accounting convention ✗ Change from prior IRP

Conceptualizing an ELCC "Surface"

+ **Within RESOLVE—E3's capacity expansion model—this ELCC surface is expressed as a piecewise linear function of multiple variables (e.g. wind and solar penetration)**
  - Current formulation includes two dimensions (wind & solar); surface may be expanded to include additional dimensions if necessary



Resource Adequacy Overview

Nick Wintermantel

Chase Winkler

Astrapé Consulting

September 2020

ASTRAPÉ CONSULTING
innovation in electric system planning

Astrapé Consulting

- **Energy consulting firm with a focus on Resource Adequacy and Resource Planning**
  - Performs resource adequacy studies for utilities throughout the U.S. and internationally including California, MISO, SPP, ERCOT, TVA, Southern Company, Duke energy and others
    - Target Reserve Margin Studies
    - ELCC Studies for solar, wind, and battery
    - Renewable Integration Studies
    - Licenses and provides consulting services using proprietary SERVM model

Nick Wintermantel

Principal

Chase Winkler

Consultant

ASTRAPÉ CONSULTING
innovation in electric system planning

Topics

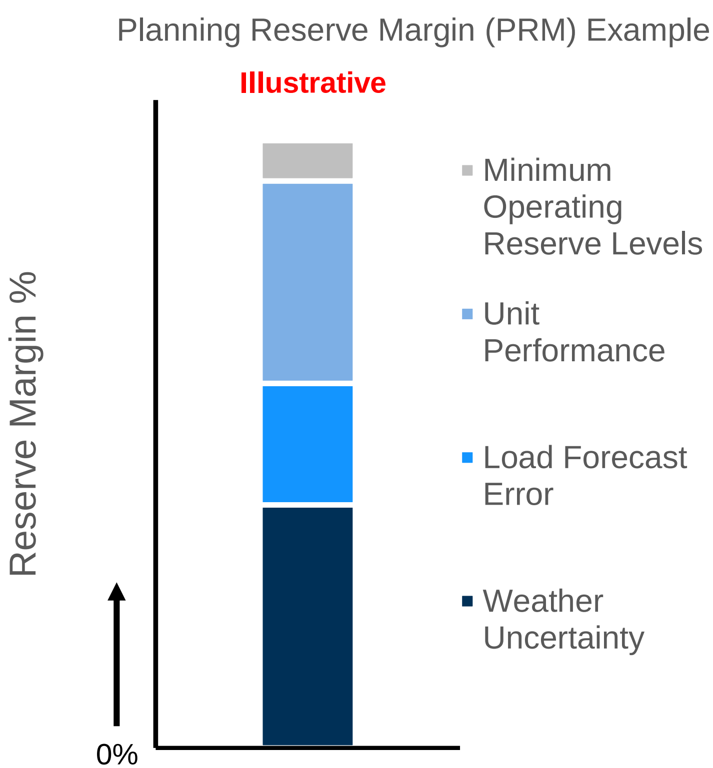
- **Define Resource Adequacy**
- **Resource Adequacy Drivers**
- **Physical Reliability Metrics**
- **Modeling Practices**

Resource Adequacy

- **The ability of supply-side and demand-side resource to meet the aggregate electrical demand (including losses)**
  - Traditionally refers to balancing authorities maintaining enough generating capacity during peak periods to keep the lights on
  - Planning reserve margins are determined by regulators in individual regions or balancing authorities based on resource adequacy studies
- **Different from distribution customer outages caused by storms or trees falling which are much more frequent than customer outages caused by capacity shortages**

Resource Adequacy Drivers

- **Why do entities need to carry more capacity then their peak load forecast?**
  - Weather Uncertainty
  - Load Forecast Uncertainty
  - Unit Performance
  - Minimum Operating Reserves
- **Outside external assistance, if modeled, decreases the above calculation depending on the amount modeled**
  - For example, PJM allows for up to 3,500 MW of import capability in its Resource Adequacy Study (~2.3% of peak summer load)
  - Recent California experience.



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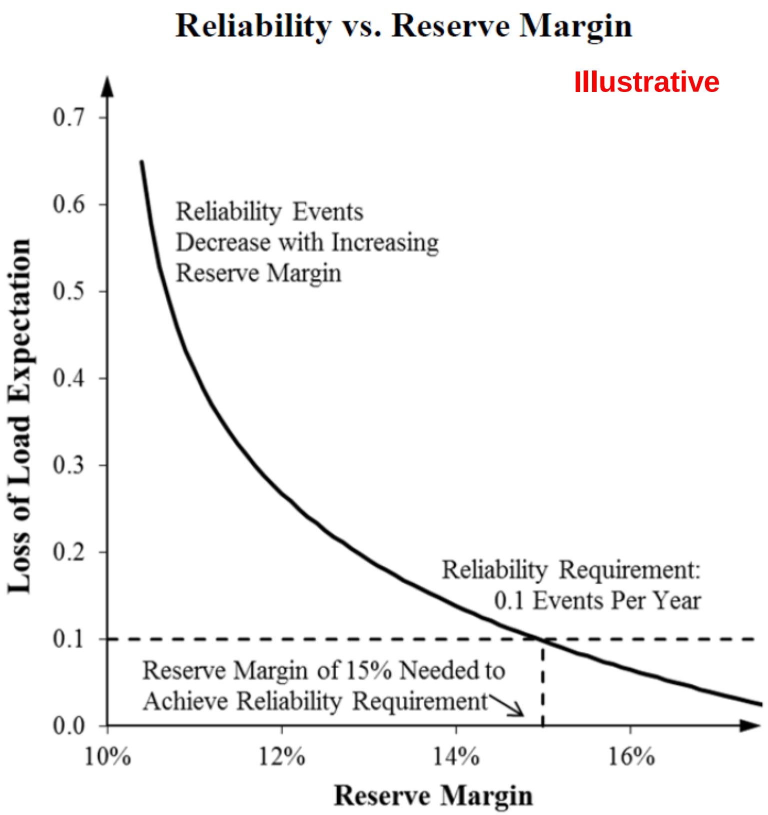
Physical Reliability Metrics

- **Loss of Load Expectation (LOLE)**
  - Counts the number of days load was not met
  - 1-day-in-10-year Standard
    - Most used metric by RTOs, Utilities, and Commissions
    - Equates to 0.1 days per year for modeling purposes
    - Allows 1 day (1 event) every 10 years
- **Additional Metrics**
  - Loss of Load Hours (LOLH)
    - Counts the number of hours load was not met
  - Expected Unserved Energy
    - The amount of load in MWh not met



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Survey Summary

Survey of Resource Adequacy Criteria Across U.S. and Canadian Power Systems

Region	Standard	Model	Notes
PJM[a]	0.1 LOLE	PRISM and GE-MARS	The LOLE based target reserve margin and various other calculations provide key inputs into the PJM capacity market.
MISO[b]	0.1 LOLE	SERVM	Performed Annually by the ISO. Regional reserve margin of 16.7% but after diversity allows its load serving entities to carry an 11.3% reserve margin.
NYISO[c]	0.1 LOLE	GE-MARS	Resulted in a reserve margin of 16.1% for the period May 2012 to April 2013. Reserve Margin calculation includes nameplate of all resources including wind. Results are adapted to derated UCAP for implementation in the NYISO capacity market.
ISO-NE[d]	0.1 LOLE	GE-MARS	2012 ICR report calculates the requirement needed to meet its 1 day in 10 year standard, load uncertainty considers weather but not economic forecast error. Results used capacity market.
SPP[e]	0.1 LOLE	SERVM	Capacity margin criterion of 12% for RTO members that are steam based and 9% for hydro based; results in capacity margin criterion above the 1 day in 10 year definition.
Maritimes [f]	20% RM and 0.1 LOLE	NPCC uses MARS	Maritimes uses a 20% reserve margin criterion for planning purposes but at the same time adheres to the NPCC requirement of not shedding firm load more than 1 day in 10 years.
Quebec[g]	0.1 LOLE	NPCC uses MARS	Based on an LOLE of 0.1, Quebec requires a 10% reserve margin for the 2012/2013 winter peak. By the 2015/2016 winter peak, Quebec requires a 12.2% reserve margin. Because of its dependence on hydro generation, Quebec also imposes an energy requirement to withstand 2 consecutive years of low water inflows.
IESO[h]	0.1 LOLE	NPCC uses MARS	The target for 2013 to meet the one day in 10 year target is 19.7% in which the region meets easily with an anticipated reserve margin of 40.1%.
Saskatchewan[i]	EUE Standard		Sask Power uses a 13% RM based on probabilistic analysis of Expected Unserved Energy.
Manitoba[j]	Both RM and energy standards due to hydro dependence		The energy criterion requires adequate energy resources to supply firm energy demand in the event that the lowest recorded coincident river flow conditions are repeated. The capacity reserve margin is at least 12%.
MAPP[i]	1 day in 10 years (LOLE of 0.1)		Some MAPP members self-impose a planning reserve margin of 15% based on the results of an LOLE study performed in 2009.
SERC/ General	No mandatory requirement		RA targets set by individual load serving members subject to regulatory review. With this approach, the criteria and final reserve margins vary across the region.
SERC/SoCo[k]	0.1 LOLE/ Economics	SERVM	The target is based on analyzing LOLE and customer costs

https://www.ferc.gov/sites/default/files/2020-05/02-07-14-consultant-report.pdf
Survey was performed in 2014 and has been updated for known changes

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Survey Summary

Region	Standard	Model	Notes
SERC/Duke Energy Carolinas[l]	0.1 LOLE and Economic Assessment	SERVM	Set minimum RM based on LOLE values but base target RM on an economic assessment, which is slightly higher than the LOLE target.
SERC/ Progress Energy Carolinas[m]	1 day in 10 years (LOLE of 0.1) and Economic Assessment	SERVM	Set minimum RM based on LOLE values but base target RM on an economic assessment, which is slightly higher than the LOLE target.
SERC/TVA[n]	Economics	SERVM	The target is based on minimizing customer costs.
SERC/Santee Cooper[o]	Economics	SERVM	The target is based on minimizing customer costs.
SERC/ LGE&KU[p]	Economics	SERVM	The target is based on minimizing customer costs.
SERC/ Entergy[i]	1 day in 10 years (LOLE of 0.1)	ERAILS	
SERC/ SCE&G[q]	12–18% RM		
FRCC[r]	0.1 LOLE	Tiger	"The FRCC has a resource criterion of a 15% minimum Regional Reserve Margin based on firm load. The FRCC assesses the upcoming ten-year summer and winter peak hours on an annual basis to ensure that the Regional Reserve Margin requirement is satisfied. Since the summer of 2004, the three Investor Owned Utilities (Florida Power & Light Company, Progress Energy Florida, and Tampa Electric Company) are currently maintaining a 20% minimum Reserve Margin planning criterion, consistent with a voluntary stipulation agreed to by the FPSC. Other utilities employ a 15% to 18% minimum Reserve Margin planning criterion."
ERCOT[s]	0.1 LOLE target (not mandatory)	Internal Model	ERCOT operates as an energy-only market and so does not mandate a RM; but performs one day in 10 year standard assessment to inform ERCOT and
WECC/ General[t]	No mandatory requirement		Individual balancing areas within WECC determine their own resource adequacy requirements in various ways and are subject to review by state regulators
CAISO[u]	15% RM		In January 2004, the CPUC established a long-term Resource Adequacy framework (D.04-01-050). This decision adopted a 15% to 17% planning reserve margin (PRM) and directed that each LSE is responsible for acquiring sufficient reserves to meet its own customer load. CAISO has since performed LOLE studies but the studies have not impacted the decision made in 2004 to maintain at a minimum 15% reserve margin

https://www.ferc.gov/sites/default/files/2020-05/02-07-14-consultant-report.pdf
Survey was performed in 2014 and has been updated for known changes

Survey

Region	Standard	Model	Notes
Northwest/ BPA[v]	Loss-of-Load Probability (LOLP) of 5%; and conditional value at risk (CVaR) to evaluate energy not served (ENS) events	Genesys Model	A completely different method from 1 day in 10 years. Method was developed in cooperation with the Northwest Council to take into account the predominantly hydro resource mix of the Northwest. For this use, LOLP is not defined as hours per year. It is instead a percentage of iterations that contain any EUE. The target allows no more than 5% of all iterations to contain EUE.
Southwest/ APS[w]	0.1 LOLE		APS 2012 IRP states that at 15% planning reserve margin criterion, LOLE is less than 1 day in 10 years.
Southwest/ PNW[x]	NM State Commission set target at 13%		Notes that reserve margin would likely increase if a one day in 10 year standard were used.
Southwest/ NV Energy[y]	1-in-10		Definition of 1 day in 10 years is not reported.
Alberta	No RA requirement		Intervention possible if expected EUE over a two-year outlook increases above 1,600 MWh.

https://www.ferc.gov/sites/default/files/2020-05/02-07-14-consultant-report.pdf
Survey was performed in 2014 and has been updated for known changes

Probabilistic Modeling Framework

- Modeling captures the following distributions for a future year and typically consists of running 1000’s of simulations for a single year.
  - Weather Distributions
    - Impact on Load and Resources
  - Load Forecast Error (LFE)
    - Typically done with load multipliers
  - Stochastic Generator Outages
- In Astrapé’s SERVM Modeling, below is a typical representation for a single Study Year:

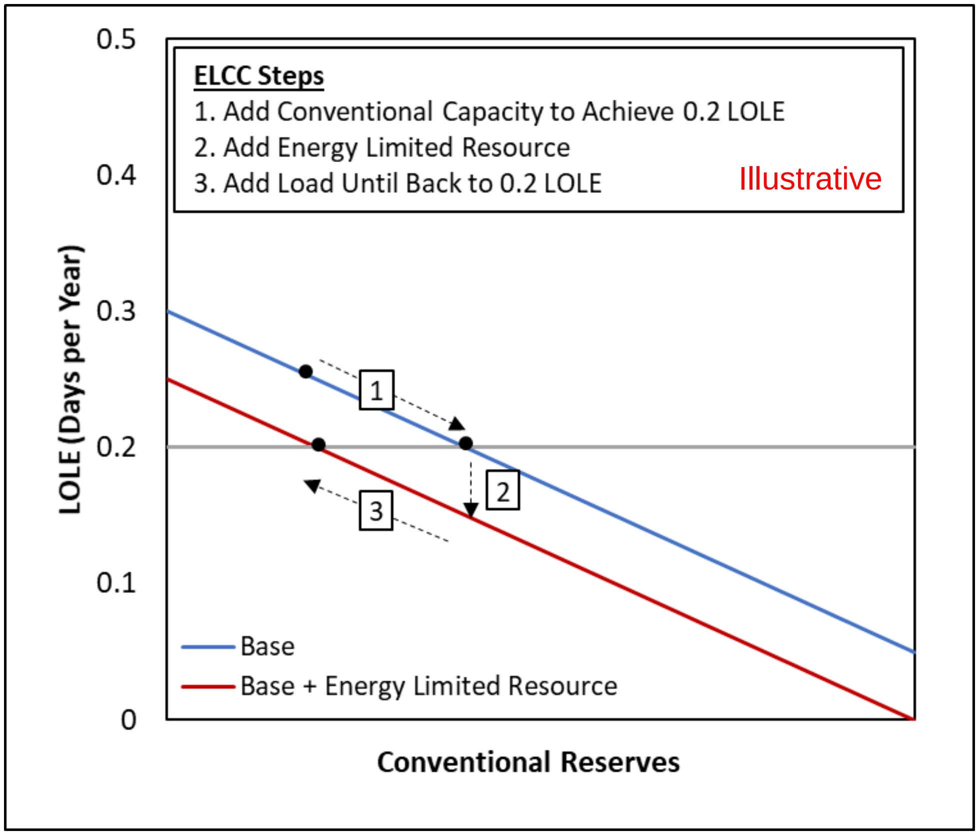
39 **Weather Years** (Equal Probability)	x	**5** **LFE Points** (Associated Probabilities)	=	**195** **Load Scenarios** (Associated Probabilities)
195 **Load Scenarios**	x	**10** **Unit Outage Draws**	=	**1,950** **8760 Hour Simulations**

Resource Adequacy is Evolving Due to Intermittent and Energy Limited Resources

- **Intermittent resources**
  - Wind and solar resources modeled with hourly shapes
  - Not always available during peak periods
- **Energy limited resources**
  - 2-hour, 4-hour storage/battery resources
  - Solar/battery hybrid resources with charging restrictions
  - Demand Response resources with limited number of calls per year or per day
- **Resource Adequacy analysis has become more complex**
  - Capacity accounting for wind, solar, and storage resources
  - Economic commitment and dispatch models are required to understand battery storage
  - Expansion planning models and resource adequacy models are working more in an iterative process to ensure resource adequacy is met

Effective Load Carrying Capability

Effective Load Carrying Capability (ELCC) describes the reliability contribution of an energy limited or non-dispatchable resource



Effective Load Carrying Capability (ELCC) analysis adds load to offset the reliability contribution of the resource type under study. For example, an energy limited resource may be added to the system to improve reliability. This may be offset with load until the reliability target is achieved to quantify the reliability benefit.

The same process may be performed on a non-dispatchable resource.

0.2 Loss of Load Expectation (LOLE) is utilized as the reliability target and equates to 2 days with generation shortage every 10 years.

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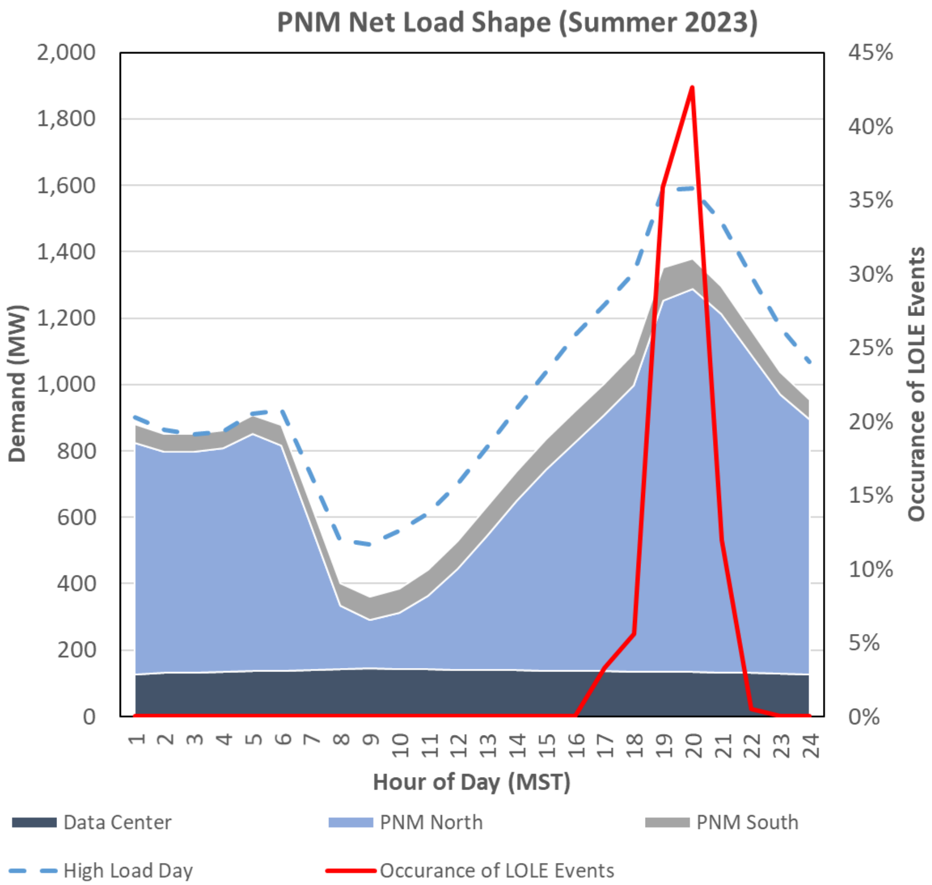
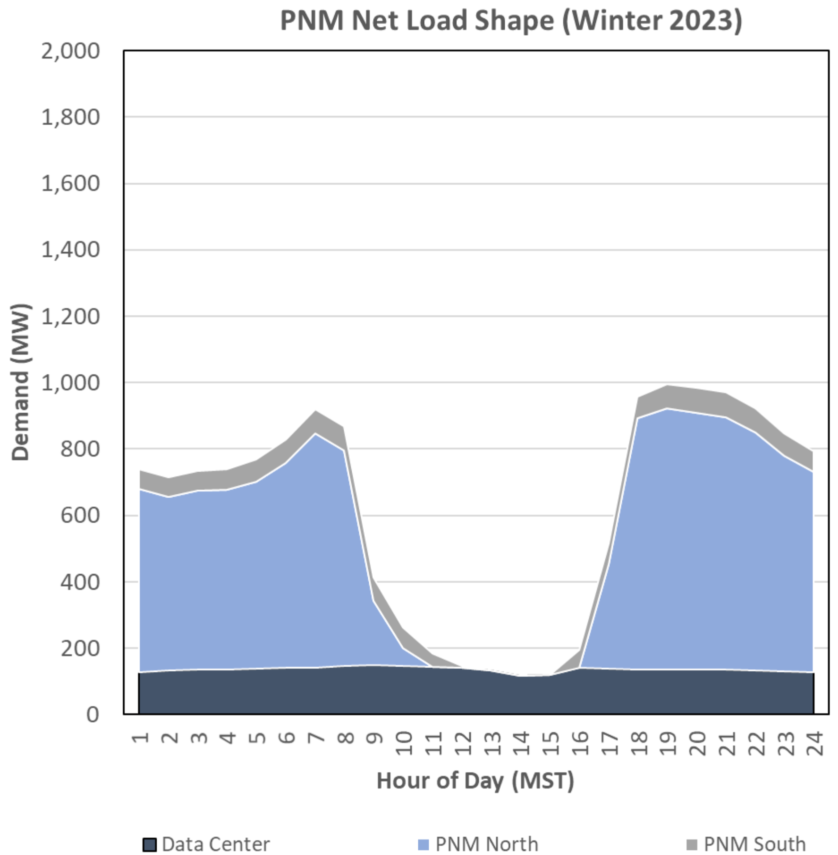
PNM Net Load and Reliability Hours

By 2023, the reliability risk hours shift to 19-20 due to increased solar penetration





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Preliminary ELCC Results

Wind Nameplate Capacity	Capacity Value MW	Average ELCC	Marginal ELCC of Tranche
607	175	28.9%	28.9%
1,000	217	21.7%	10.7%
1,500	262	17.5%	9.0%
2,000	273	13.7%	2.2%
2,500	283	11.3%	1.9%
Solar Nameplate Capacity	**Capacity Value MW**	**Average ELCC**	**Marginal ELCC of Tranche**
1,026	172	16.7%	16.7%
1,200	183	15.3%	6.6%
1,500	199	13.3%	5.3%
2,000	210	10.5%	2.2%
2,500	211	8.4%	0.2%
Battery Nameplate Capacity[1]	**Capacity Value MW**	**Average ELCC**	**Marginal ELCC of Tranche**
300	287	95.6%	95.6%
500	472	94.4%	92.6%
700	641	91.6%	84.5%
1,000	825	82.5%	61.4%
1,500	945	63.0%	23.9%
DR Nameplate Capacity	**Capacity Value MW**	**Average ELCC**	**Marginal ELCC of Tranche**
56	52	92.5%	92.5%
106	92	87.2%	81.3%
106[2]	87	86.8%	70.0%

1. Assumes 4 hour Battery. First 300 MW must charge from associated solar
2. Incremental 50 MW DR available only on weekdays

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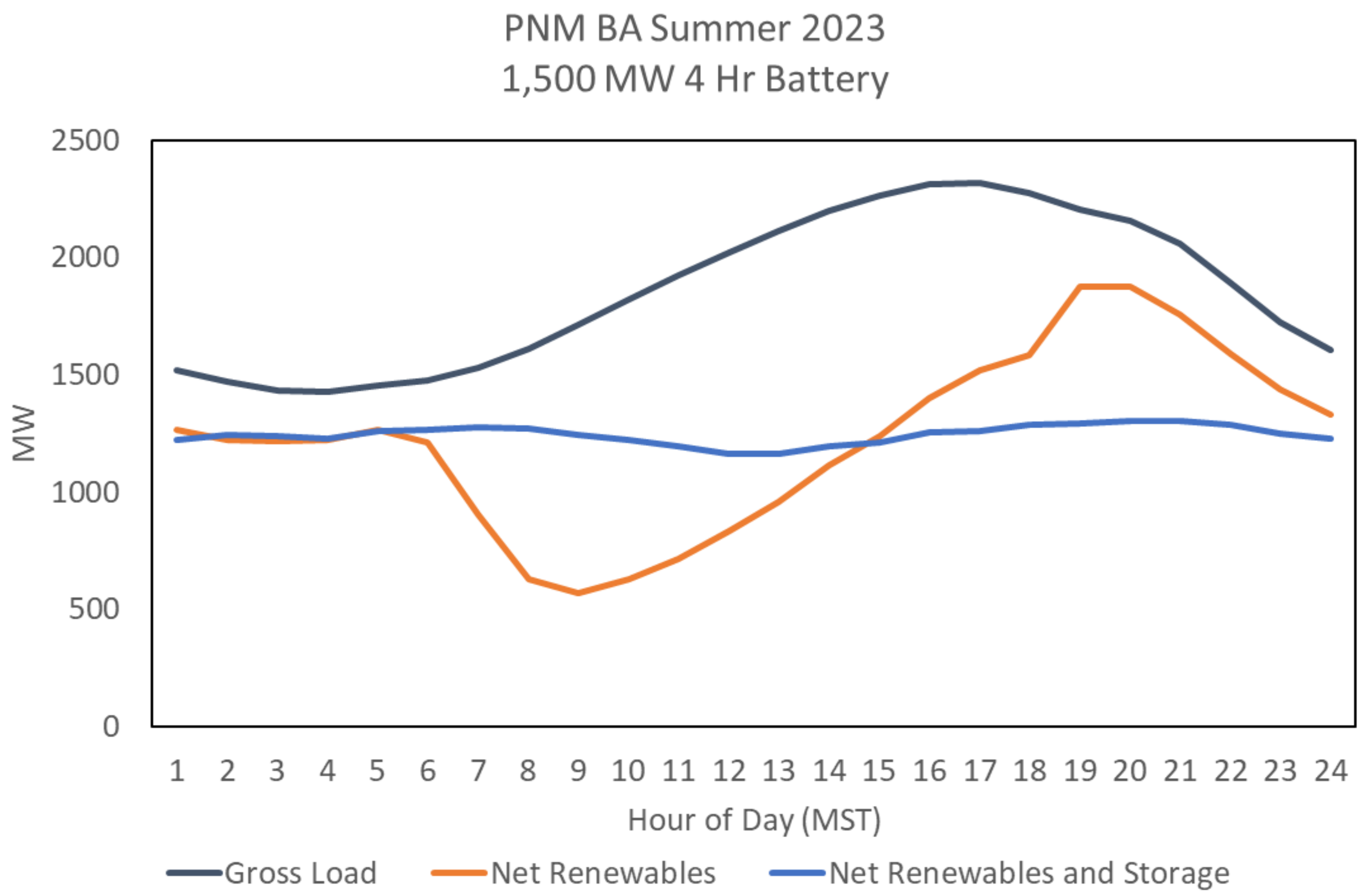
Preliminary ELCC Results – incremental 2 hour, 4 hour, and 6 hour storage

2 Hr	Capacity Value MW	Average ELCC	Marginal ELCC
300 - 4 hour	287	95.6%	95.6%
500	440	88.0%	76.7%
700	562	80.3%	61.2%

4 Hr	Capacity Value MW	Average ELCC	Marginal ELCC
300 – 4 Hour	287	95.6%	95.6%
500	472	94.4%	92.6%
700	641	91.6%	84.5%
1,000	825	82.5%	61.4%
1,500	945	63.0%	23.9%

6 Hr	Capacity Value MW	Average ELCC	Marginal ELCC
300 - 4 hour	287	95.6%	95.6%
500	476	95.3%	94.8%
700	647	92.5%	85.5%
1,000	837	83.7%	63.3%
1,500	1000	66.7%	32.5%

Storage Illustration



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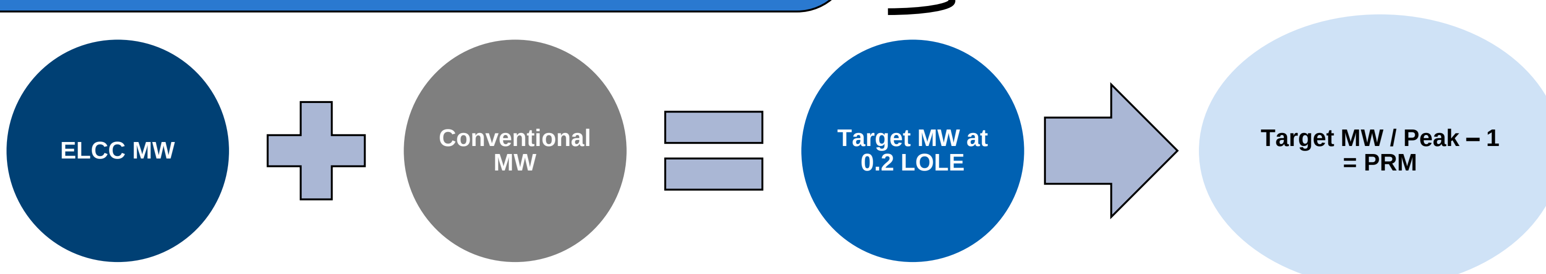
Tying it all together

SERVM ELCC Analysis
Isolates the capacity contribution of non-dispatchable / energy limited resources

LOLE analysis
Determines any MW adjustments to the portfolio necessary to meet 0.2 LOLE

Analysis Includes:
Load and Generation
Probabilistic outages,
Renewable profiles,
DER units,
market assistance, and
other inputs



LOLE and ELCC analyses models all hours of the year and allows reliability metrics to be reflective of system conditions

PNM Reserve Margin Calculations and ELCC

PNM Fleet					Calculation Assuming Market Access*	
Unit Category	Installed	ELCC %	EFOR (%)		ICAP	UCAP
EE	16	100	-		16	16
CC	419	100	4		419	402
CT	408	100	3		408	395
DR	56	92	-		52	52
Geothermal	12	100	24		12	9
Nuclear	402	100	2		402	394
Solar	1,026	17	-		171	171
Solar Battery	300	96	-		287	287
ST Coal	200	100	20		200	160
ST Gas	154	100	3		154	149
Wind	607	29	-		175	175
Total	3,600				2,294	2,208
LOLE					0.2	0.2
Peak					2011	2011
PNM PRM	**80%**				**14%**	**10%**

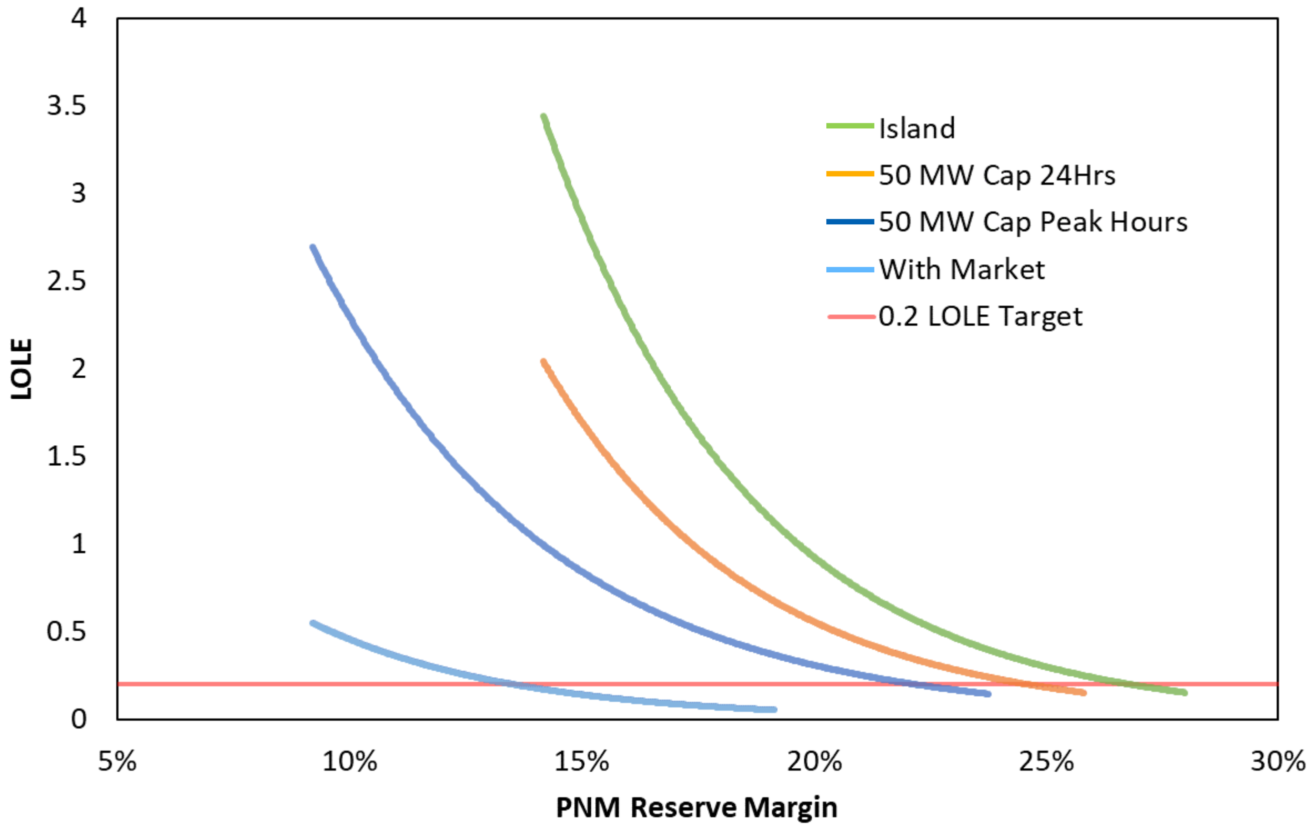
*Market access of 200-300 MW during peak hours

PNM Reserve Margin Calculations and ELCC

Market Configuration	PNM PRM ICAP	PNM PRM UCAP
Island	27%	23%
50 MW Cap 24Hrs	25%	20%
50 MW Cap During Peak Hours	22%	18%
200 - 300 MW During Peak Hours	14%	10%

Above reserve margin calculations using ELCC for solar, wind, DR, and battery capacity.
PNM Island Scenario is simulated as BA with Tri State
Market provides between 2 and 13% in reserve margin reduction based on assumption during peak periods

Reserve Margin Curves



Island - PNM BA as an islanded system
50 MW Cap 24Hrs - 50 MW limit on imports at all times
50 MW Cap Peak Hours - a 50 MW limit during peak hours of 16-22 and 200-300 during high load hours
With Market – 200-300 MW limit during high load hours

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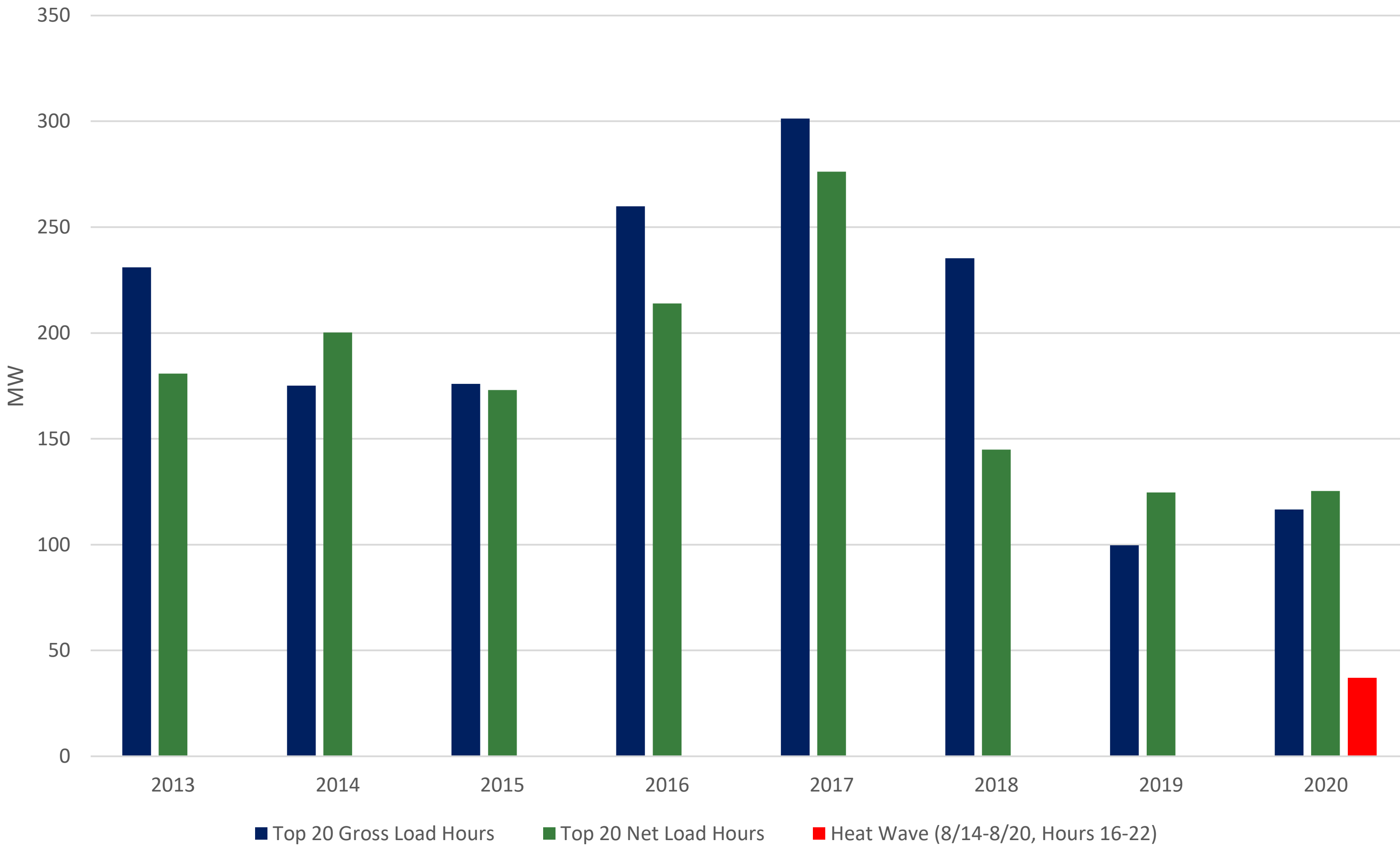
Questions?

Thank you!

Resource Adequacy Key Takeaways

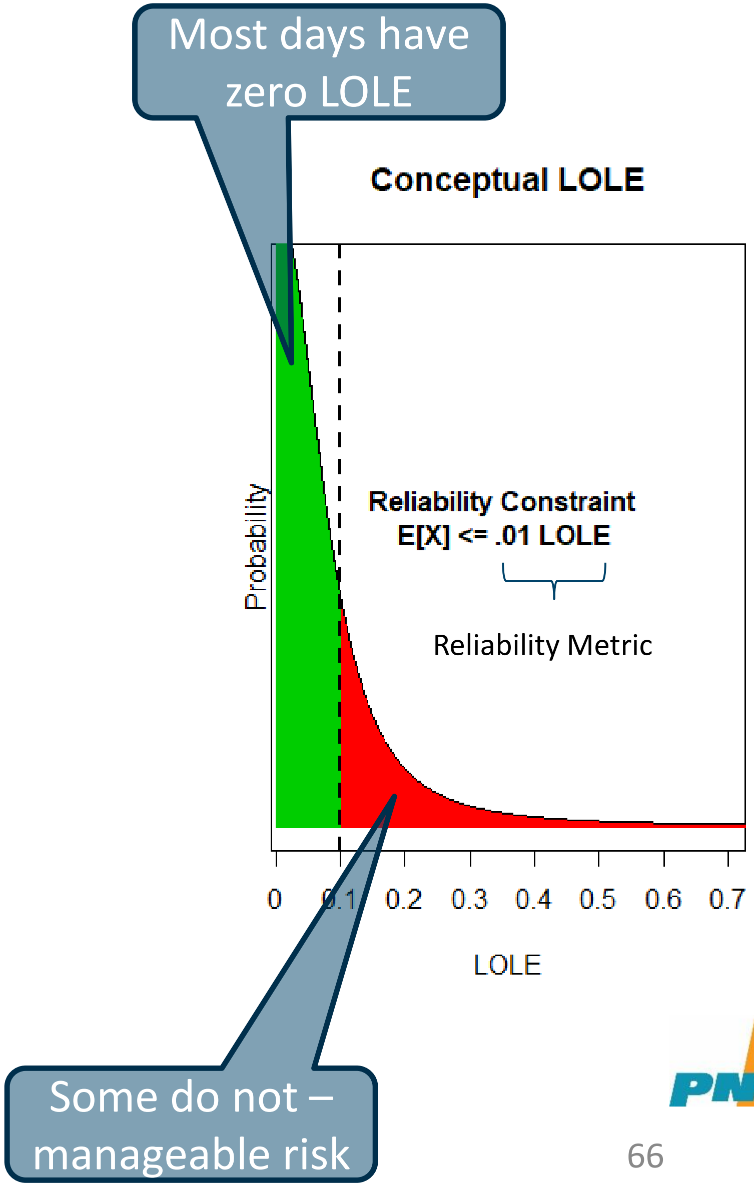
Historic market purchases by PNM



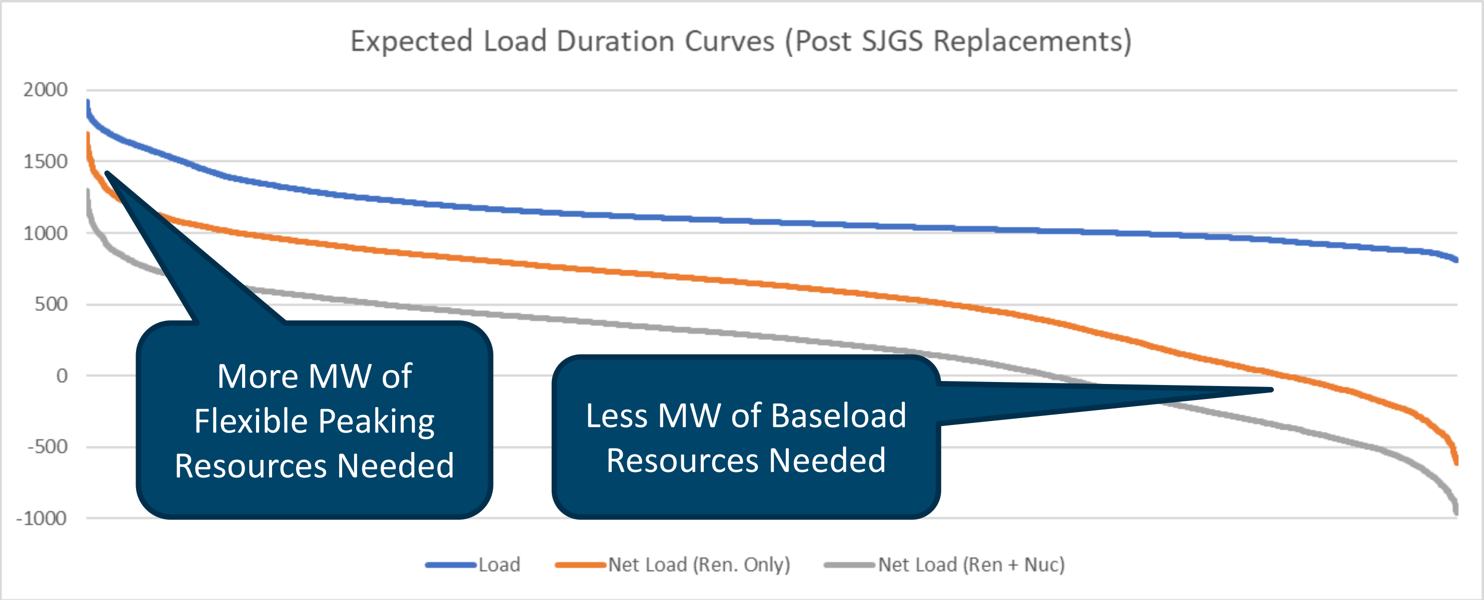
PNM's ability to purchase power during periods of system stress is decreasing.

Loss-of Load Calculations

- Resource Adequacy is about Probability/Risk
- LOLE (**Probabilistic**) is data intensive
  - LOLE is the fundamental tool for assessing resource adequacy
  - LOLE is dynamic, as the system changes so the hours driving LOLE risk
- Planning Reserve Margin (**Deterministic**) (PRM) is easy to use and understand
  - LOLE used to calculate (and re-calculate) ELCC to meet required reliability metric as the system changes
  - LOLE used to establish (and re-establish) PRM to meet required reliability metric as the system changes
  - PRM then used for resource planning
- There is a reliability vs cost trade-off



As VER Increase, Resource Planning Becomes More Complex



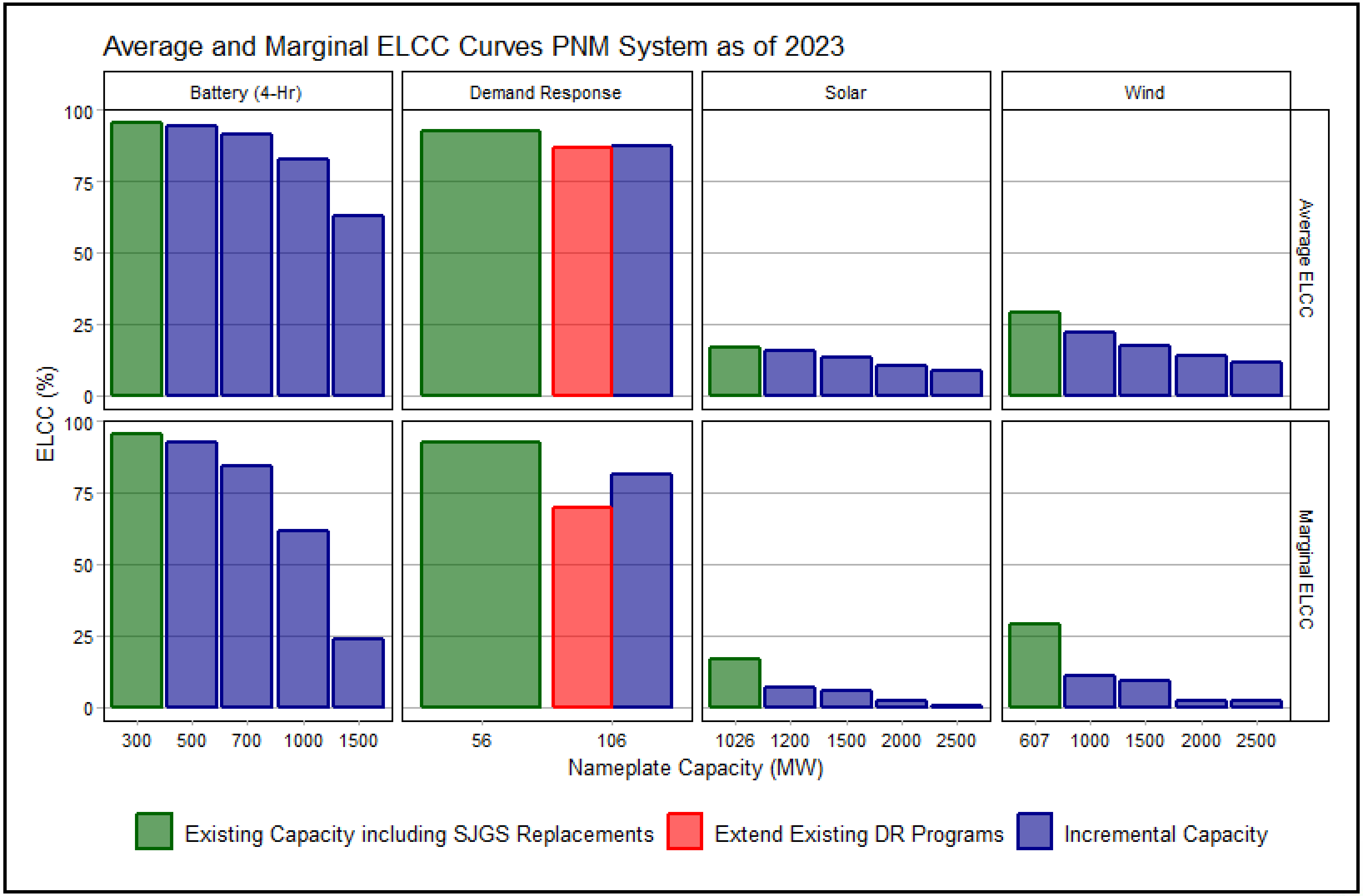
- Inflexible generators may be able to meet peak demand but not accommodate changes in wind/solar/load
- Ramping, minimum generation levels, and start times all become important parameters
- Example: California has **flexible** resource adequacy requirements to accommodate high solar
- There can also be **local** capacity requirements due to transmission constraints

- Volatility of the net load greater than either the gross load or the renewable output (small positive correlation ~ 12.5%)
- Must include flexibility assessment/metric for reliability analysis

σ_{load} = 195 MW
$\sigma_{renewable}$ = 384 MW
$\sigma_{net\ load}$ = 409 MW

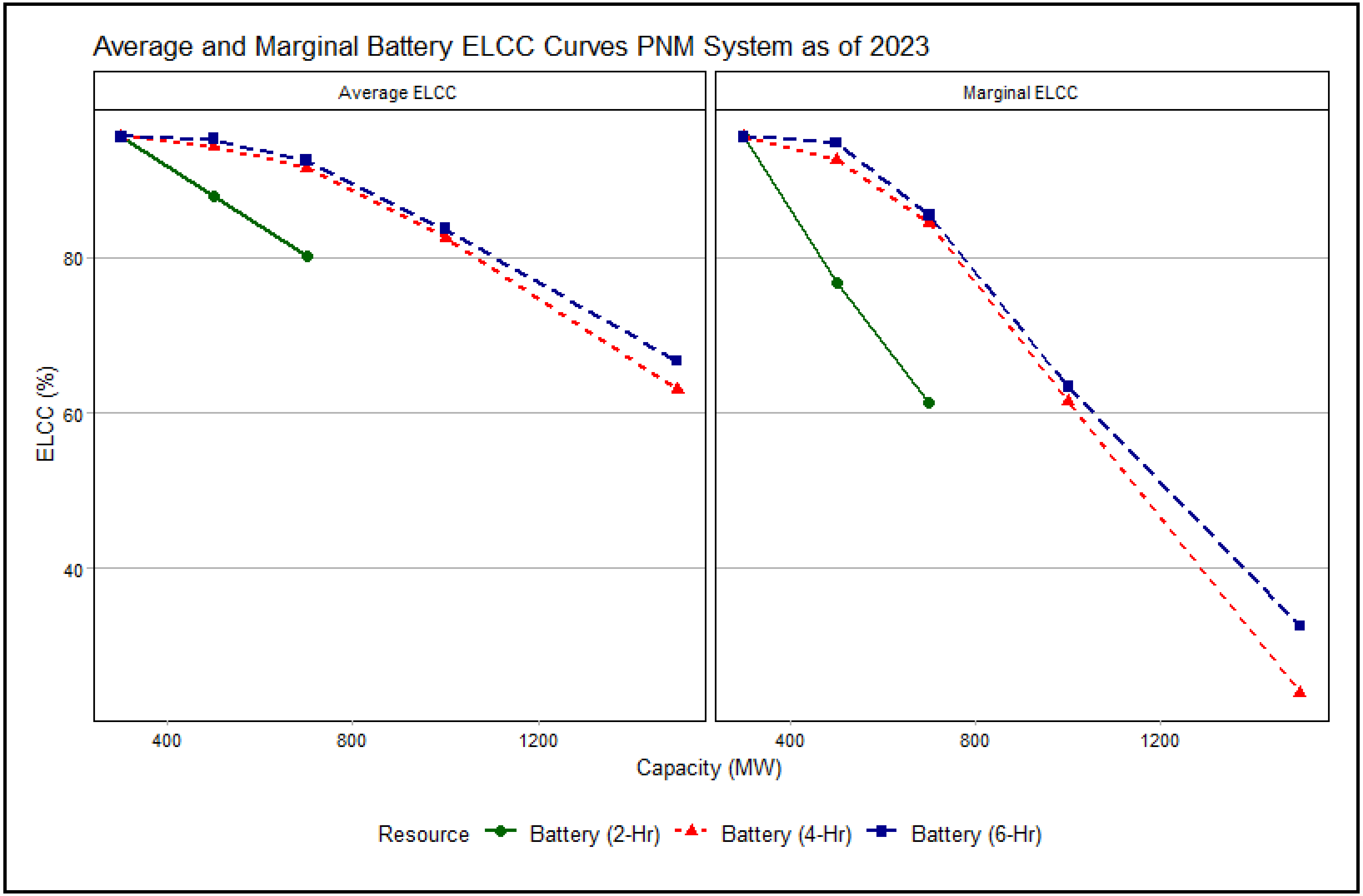
*Slide idea from Debra Lew, LLC WIEB/WIREB April 15,2020

Preliminary ELCC Results for PNM System



Battery and DR ELCC's assume perfect forecasting/optimal dispatch

Preliminary ELCC Results for PNM System

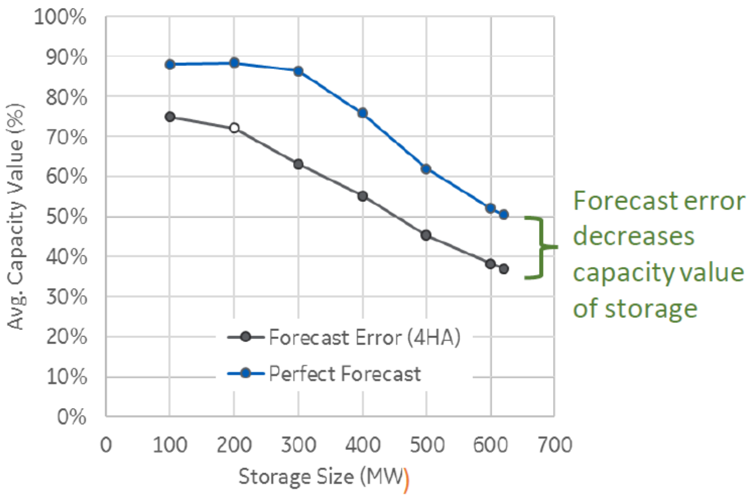


Battery ELCC's assume perfect forecasting/optimal dispatch

Resource Variability Requires Improved Forecasting

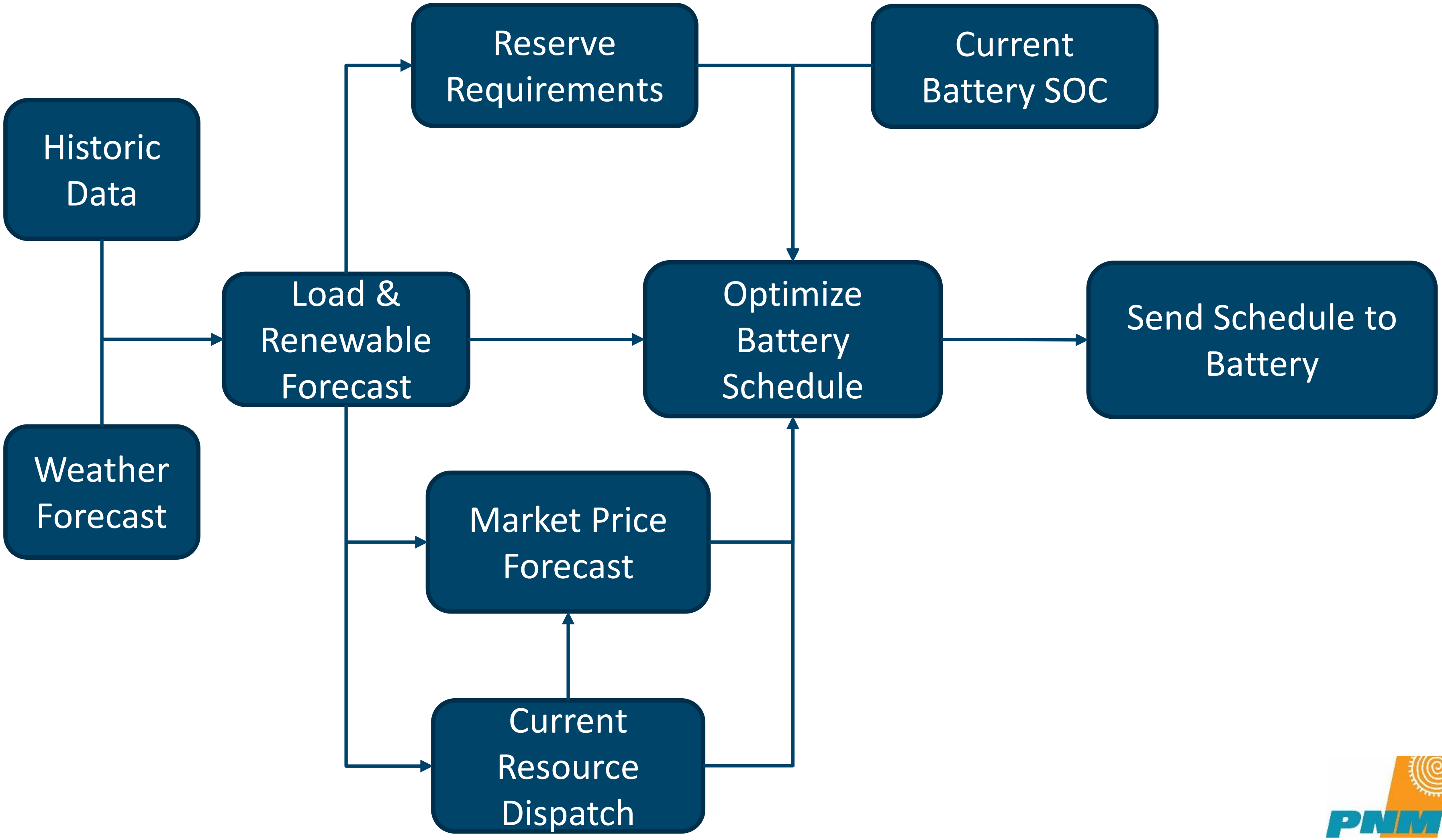
- Improved renewable and storage forecasting tools and processes will help support optimization of existing and future technologies
- PNM is currently implementing improved tools in order to better predict utility-scale and rooftop solar output and to improve predictive wind forecasting
- As PNM integrates more battery resources, better tools will be needed to optimize charge and discharge patterns
- PNM is also evaluating more advanced load forecasting models for real-time, not just day-ahead, forecasting

Forecast errors affect storage value

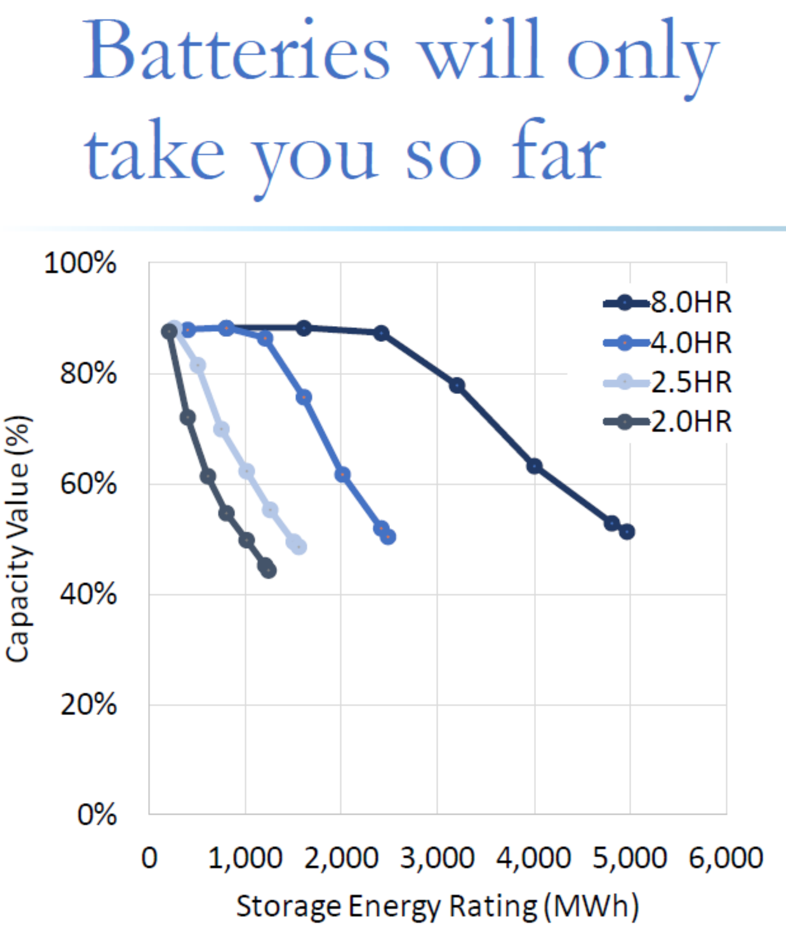


Stenclik, et al., "Energy Storage as a Peaker Replacement," IEEE Electrification Magazine, September 2018

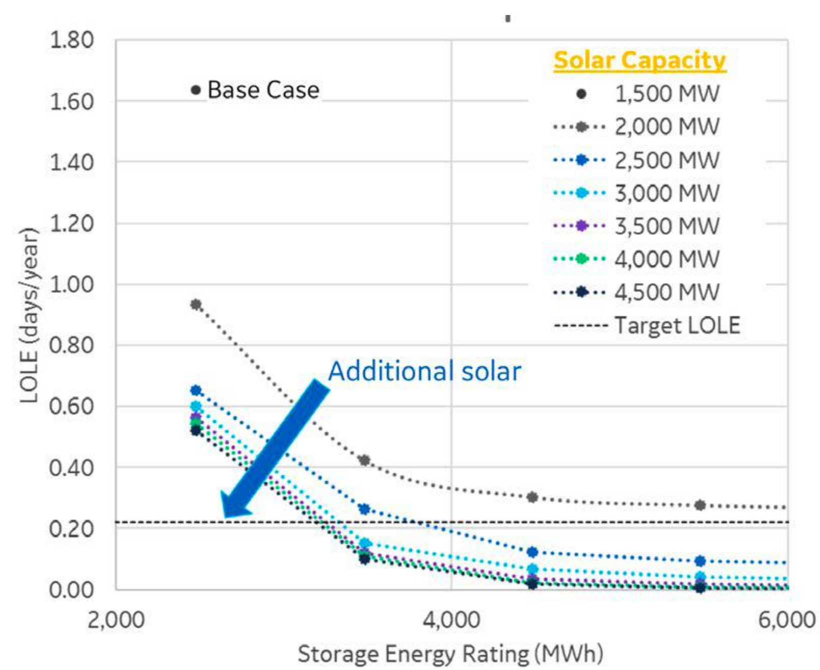
Resource Variability Requires Improved Forecasting



Capacity vs Energy in Deep Decarbonization



2,500 MW solar & 3,800 MWh storage
Or…
3,000 MW solar & 3,400 MWh storage
Or…
115 MW of firm capacity

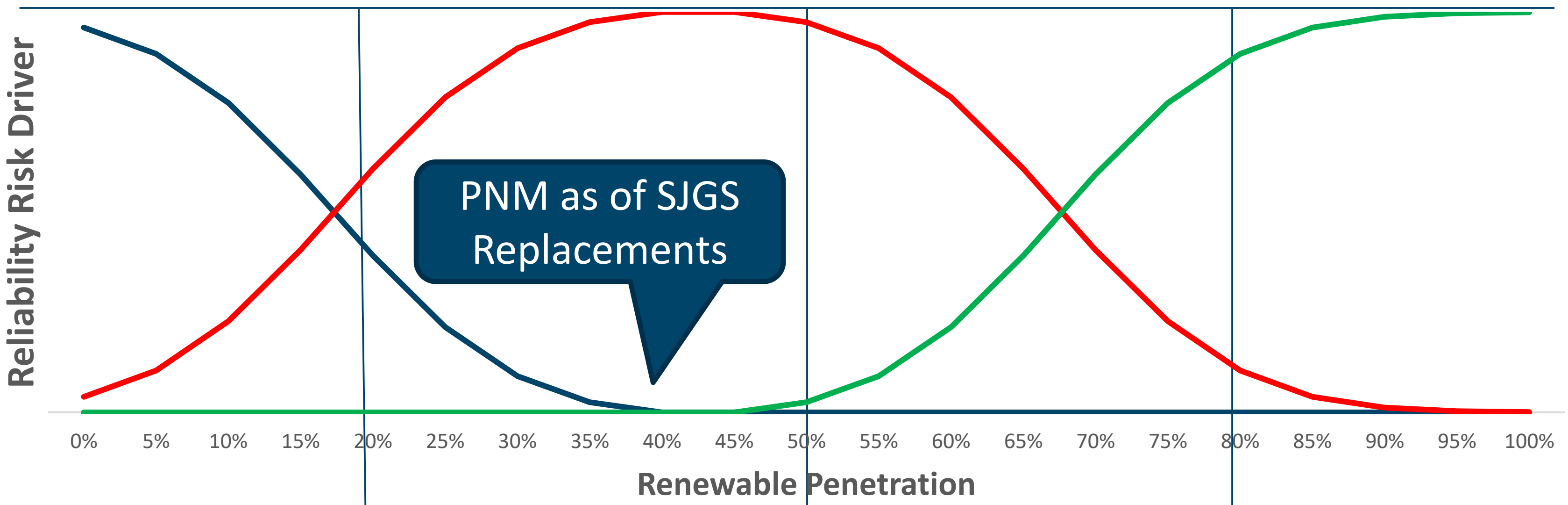


Eventually, the problem becomes an energy problem, not a capacity problem

Stenclik, et al., "Energy Storage as a Peaker Replacement," IEEE Electrification Magazine

*Slide idea from Debra Lew, LLC WIEB/WIREB April 15,2020

Resource Planning Complexity Further Increases Post-2030



Expected technology progression to meet RPS and CO2 requirements. If technologies mature quicker they will be considered earlier in time based on cost-effectiveness. This is not an exhaustive list, the list of technologies is still growing and evolving. At this point nothing should be prematurely excluded.

2020-2030

- Wind
- Solar PV
- Natural Gas
- Lithium Ion (2-6 hr)
- Transmission
- Demand Response

2030-2040

- Compressed Air Storage
- Pumped Hydro Storage
- Thermal Storage
- Liquified Air Storage
- Flow Batteries
- Gravitational Storage

2040+

- Hydrogen
- Synthetic Gas (Non-Carbon Emitting)
- Small Modular Reactors

PNM

Key Takeaways for Resource Planning Challenges in the Transition to Zero Carbon

- Continuing the near-term transition required by the Energy Transition Act is attainable with existing technologies at reasonable cost without compromising reliability but extra attention must be paid to ensure resource adequacy
- As we move from 40% renewable to 50% renewable by 2030, the transition will also be aided by improvements in better forecasting technologies as well and transmission and distribution system support
- To move beyond 50% renewable and into the next major phase of the transition up to 80% renewable, technological improvements are crucial in the form of longer duration storage to cost-effectively balance the system during periods of sustained low renewable output; during this time gas will still play a pivotal role in reliability and backup generation
- Transmission expansion is also critical to this transition in order to geographically diversify renewable resources
- To fully achieve 80% renewable and ultimately 100% carbon-free, a firm, non-carbon-emitting dispatchable resource such as hydrogen or seasonal storage will be required to avoid significant overbuilds and cost increases and maintain reliable service

Questions from August 25, 2020

Questions received as a follow up to last meeting

- How are the batteries charged?
- Solar, wind or fossil fuel?
- How long to charge from what depletion state to full capacity?
- Cost of charging equipment?

Modeling Updates

Modeling Updates

1. ELCC modeling based on inputs developed by Astrapé implemented and tested
   - Currently using “soft constraints” rather than “hard constraints” to reduce computation time
2. Transmission Expansion
   - 4 Candidate Projects based on September 6, 2019 Presentation
   - Costs modeled as Network Costs
   - Projects are “all or nothing” – no fractional transmission.
   - There is interplay with ELCC inputs and the number of resources which are leading to high computation times – if this becomes limiting, transmission modeling may be removed.
3. Commodities & Market Assumptions
   - Commodity and Market forecasts developed in consistent and similar manner to previous IRPs.
4. Energy Efficiency Bundles / DSM
   - No issues with EE Bundling methodology in our tests
   - Revising existing DR program modeling characteristics
   - DSM RFP bids were due September 14, 2020

PNM

Technology Review & Candidate Resources

- Renewable Resources
  - Wind
  - Solar PV (Single-Axis Tracking)

- Dispatchable Storage / Energy Limited Resources
  - Lithium-Ion Batteries
  - Flow Batteries
  - Compressed Air Storage
  - Liquified Air Storage
  - Pumped Hydro Storage
  - Gravitational Storage
  - Thermal Energy Storage**

- Dispatchable Resources (Not Energy Limited Resources)
  - Natural Gas (Aero Derivative)
  - Natural Gas (Aero Derivative) with Hydrogen Conversion
  - Small Modular Reactors
  - Natural Gas with CCUS**

**Likely will not be modeled based on recommendations from Technology committee. PNM will continue to monitor these technologies and consider in future IRPs.

Additional resources may be added data/technologies become known to PNM during the IRP evaluation. Some technologies may be grouped together for modeling to improve computation time.

Stakeholder Scenarios

Audience Future, Scenario & Sensitivity Ideas (Received to Date)

- Economic Cycles / Tax Policies*
- EV's & Home Batteries*
- Ancillary Service Rates#
- Additional DC Interconnects #,^
- Carbon Free by 2030 #
  - PSH
  - Thermal Storage
- Major Carbon Pricing*

*PNM believes these are captured within PNM futures and scenarios, but would appreciate audience discussion and feedback

#Requires additional discussion/clarification

^Likely not possible under the existing modeling framework

Audience Future, Scenario & Sensitivity Ideas (Received to Date)

- Economic Impact of Environmental Regulations vs Least Cost#
- Climate Change Scenario #,^
- Demand Flexibility*
- Market Purchases *

*PNM believes these are captured within PNM futures and scenarios, but would appreciate audience discussion and feedback

#Requires additional discussion/clarification

^Likely not possible under the existing modeling framework

Audience Future, Scenario & Sensitivity Ideas (Received to Date)

- Expand Interconnection to EPE System#,^
- Replace PVNGS with All Renewables based on results from SJGS RFP#,^
- Transmission Expansion that would allow all renewables from last RFP that passed initial viability review*,^
- Replace FCPP with All Renewables by 2027 based on RFP bids from SJGS RFP*,^

All the above should assume transmission costs are network costs and spread across the system rather than assigned to specific generators.

*PNM believes these are captured within PNM futures and scenarios, but would appreciate audience discussion and feedback

#Requires additional discussion/clarification

^Likely not possible under the existing modeling framework

Tentative Meeting Schedule Through November 2020

July 31:	Kickoff, Overview and Timeline
August 20:	The Energy Transition Act & Utilities 101
August 29:	Resource Planning Overview: Models, Inputs & Assumptions
September 6:	Transmission & Reliability (Real World Operations)
September 24:	Resource Planning “2.0”
October 22:	Demand Side/EE/Time of Day
November 19:	Battery and Energy Storage; Sandia National Laboratory Guest Presentation
January 14:	Technology Review
August 25, 2020:	Current Events, Commodities Forecast, Load Forecast, Modeling Updates, ELCC Study, Process and Scenario Update
September 15, 2020:	Resource Adequacy Deep Dive, Modeling Updates & Stakeholder Scenarios
October 20, 2020:	Process Update
November 25, 2020:	Draft IRP Completed

*NOTE: Date Change

** NOTE: Topic Change

Registration for Upcoming Sessions

Please register for each upcoming session separately. You will receive a reminders two days in advance and the day of the event.

To access documentation presented so far and to obtain registration links for upcoming sessions, go to:

www.pnm.com/irp

Other contact information:

irp@pnm.com for e-mails

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THANK YOU