A Comparison of Three Different Reserve Margin Methods in the Context of an Island System

Energy Systems Integration Group 2024
Spring Technical Workshop

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Energy+Environmental Economics

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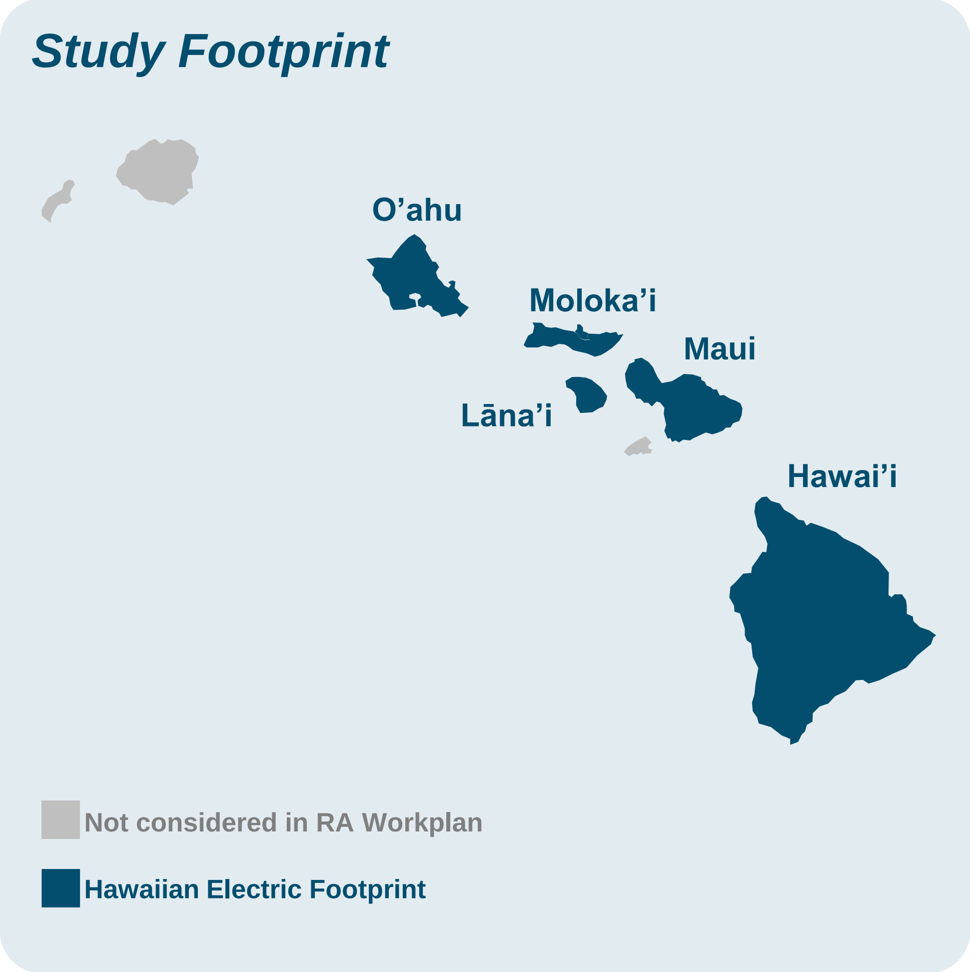
Agenda

+ Introduction to Hawaiian Electric Resource Adequacy Workplan Project
+ Methods for Evaluating Resource Adequacy
+ Testing three different methods for evaluating resource adequacy on O‘ahu
+ Results

Introduction to Hawaiian Electric Resource Adequacy Workplan Project

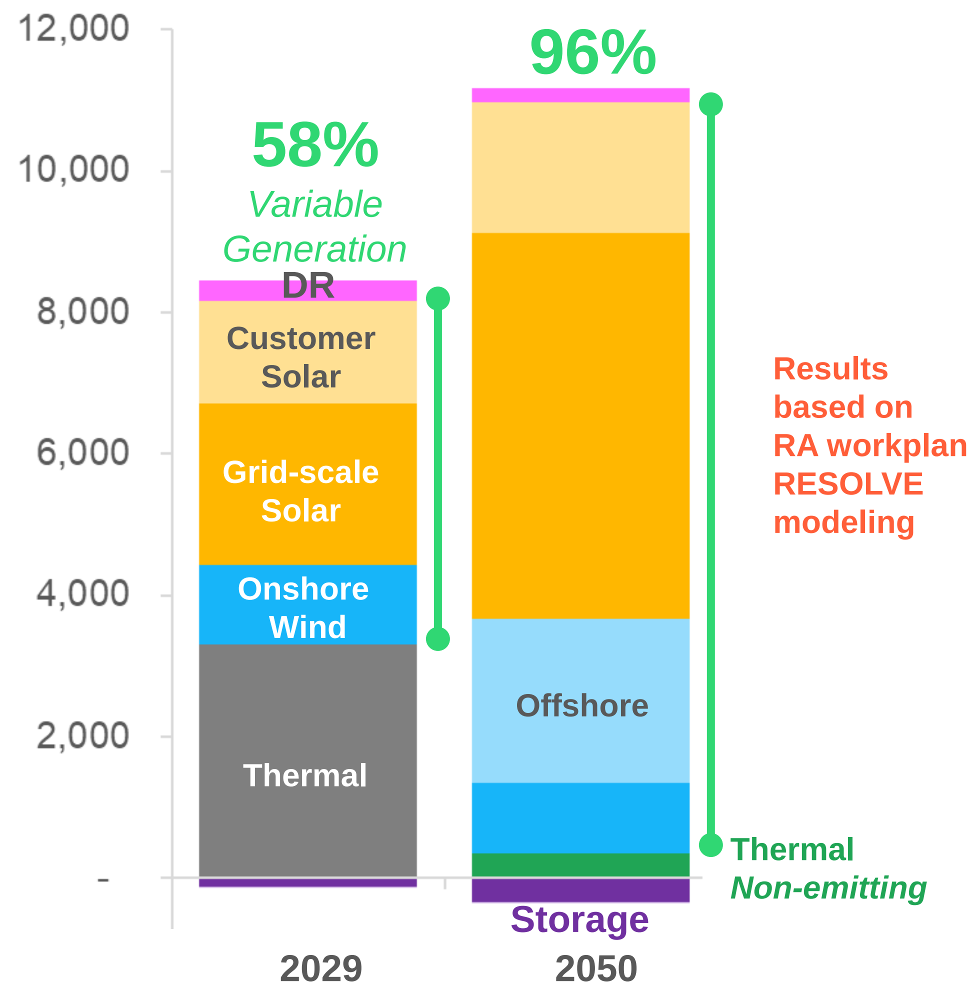


Energy+Environmental Economics

Hawai‘i PUC directed Hawaiian Electric to explore an ELCC-based resource adequacy framework

- **In the long-term, solar, wind, and storage resources will displace diesel generators in meeting O‘ahu’s resource adequacy needs, creating new reliability challenges**
- **In 2022, the Commission instructed Hawaiian Electric to explore an ELCC-based resource adequacy criterion for use in future rounds of its Integrated Grid Plan (IGP)**
- **In coordination with a Technical Advisory Panel (TAP), HECO + E3 explored three methods for incorporating RA need into capacity expansion modeling:**
  - ERM+HDC
  - ERM+HEC
  - PRM+ELCC

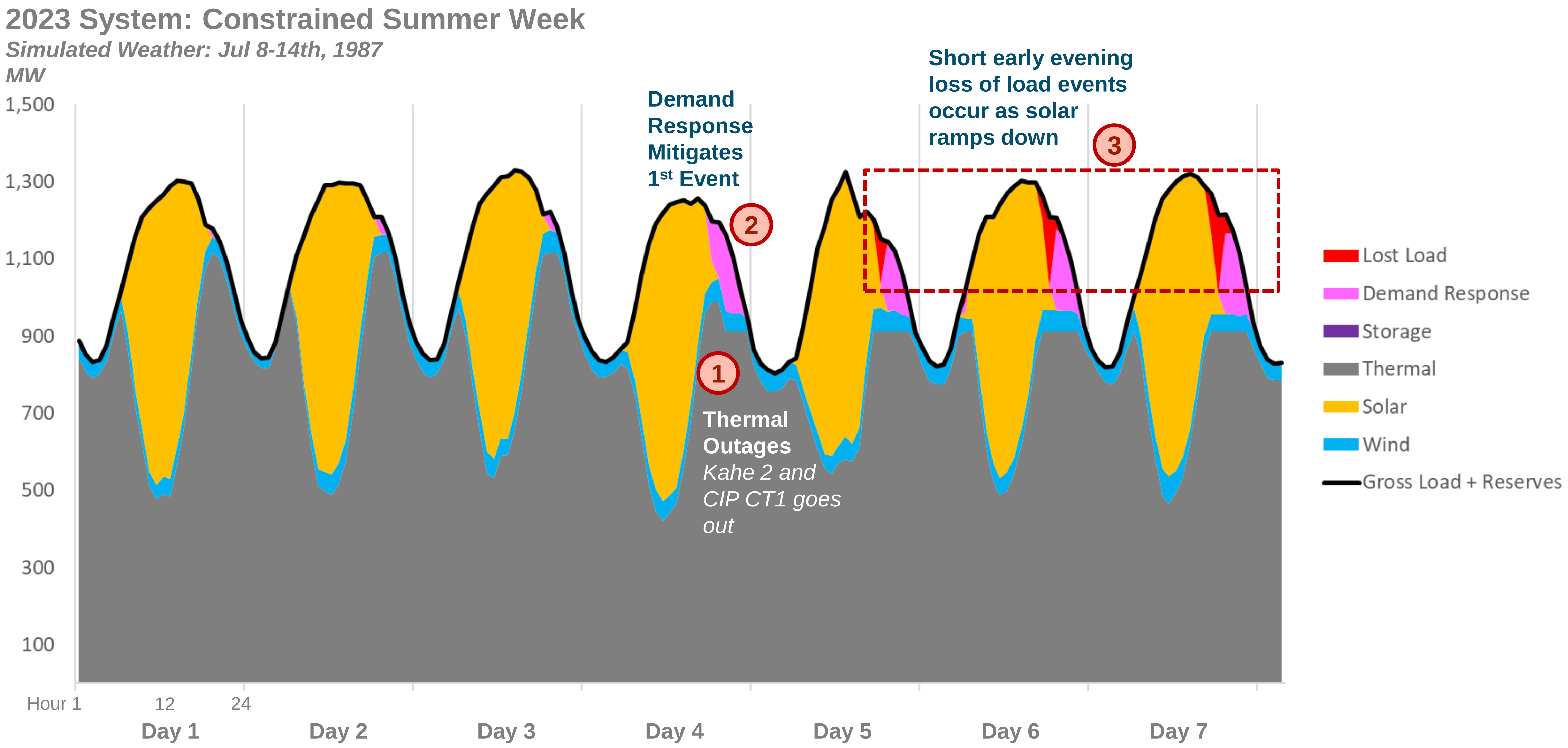
2029 vs 2050 Annual Generation on O‘ahu
GWh



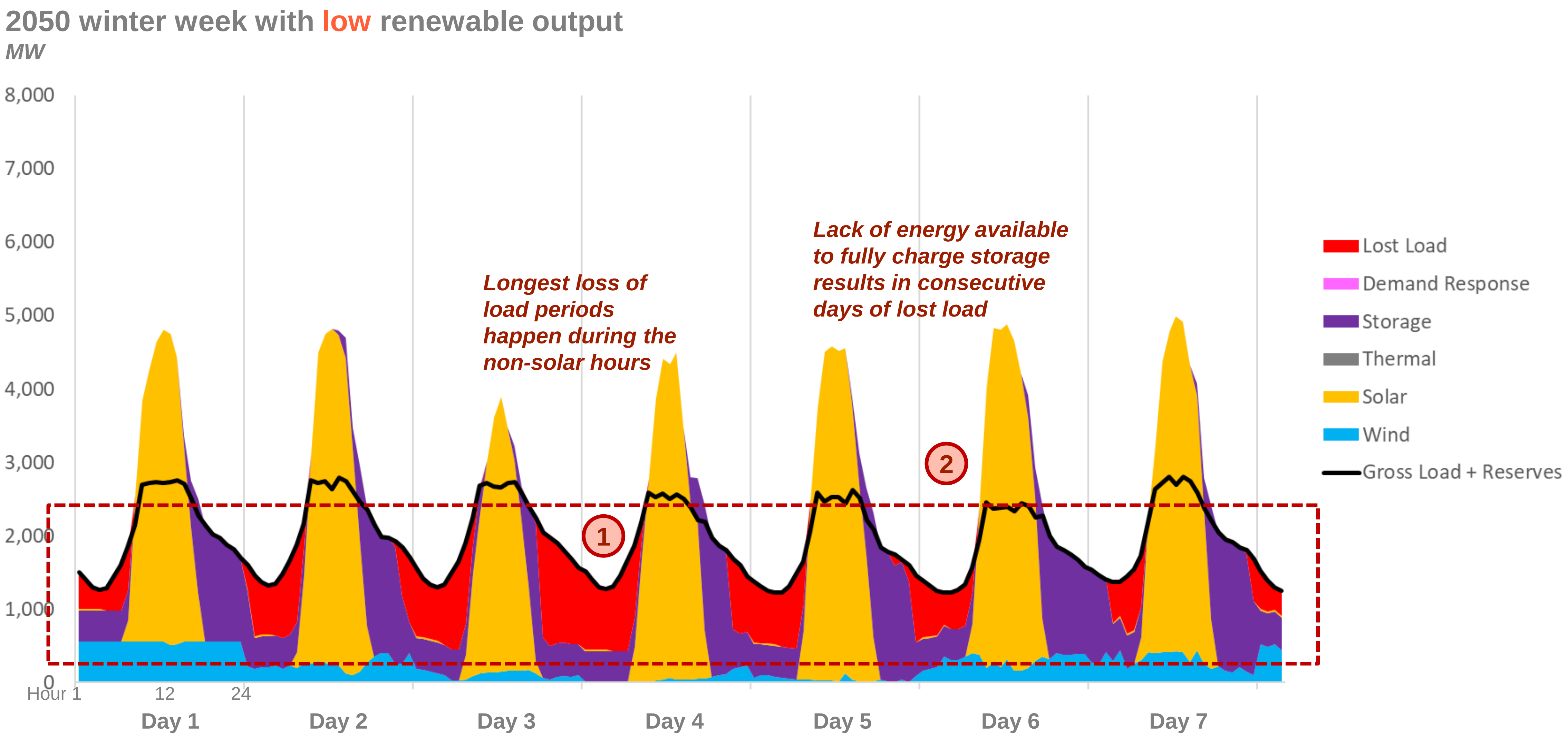
Technical Advisory Panel provided invaluable feedback to E3 and Hawaiian Electric

Name	Affiliation
Matthias Fripp	Environmental Defense Fund (EDF)
Aidan Tuohy	Electric Power Research Institute (EPRI)
Jo Ann Rañola	Electric Power Research Institute (EPRI)
Durgesh Manjure	Midcontinent Independent System Operator (MISO)
Jordan Bakke	Midcontinent Independent System Operator (MISO)
Andy Hoke	National Renewable Energy Laboratory (NREL)
Elaine Hale	National Renewable Energy Laboratory (NREL)
Gord Stephen	National Renewable Energy Laboratory (NREL)
Derek Stenclik	Telos Energy Group
Richard E. Rocheleau	Hawaii Natural Energy Institute (HNEI)
Terry Surles	Hawaii Natural Energy Institute (HNEI)

Today, reliability events occur during early evening, under high load and thermal plant outage conditions



In 2050, a high renewable system without firm capacity has insufficient energy available during low renewable periods

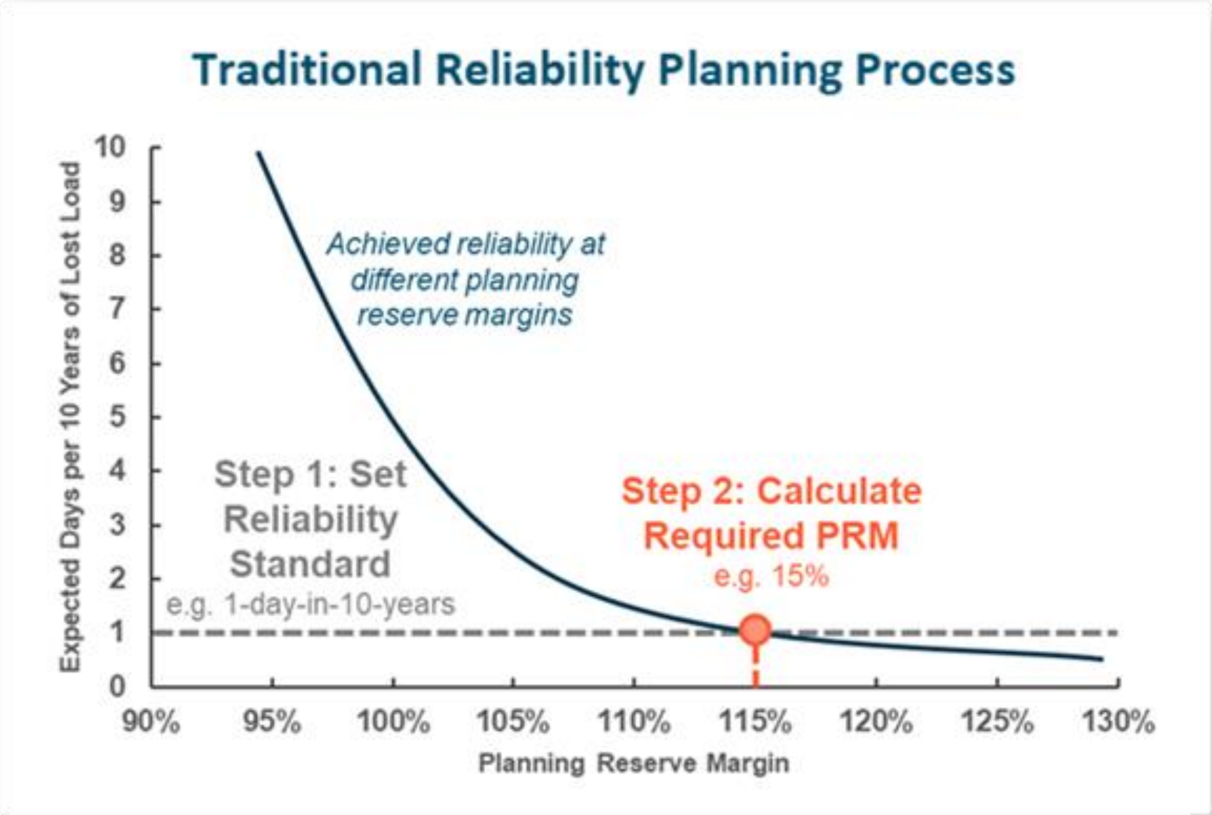


Due to lack of energy resources available in RESOLVE, this scenario is not calibrated to meet the 0.1 LOLE days/yr standard. It has a 228 MW effective capacity shortfall to reach the reliability standard, with an expected loss of load expectation of 65 days/yr.

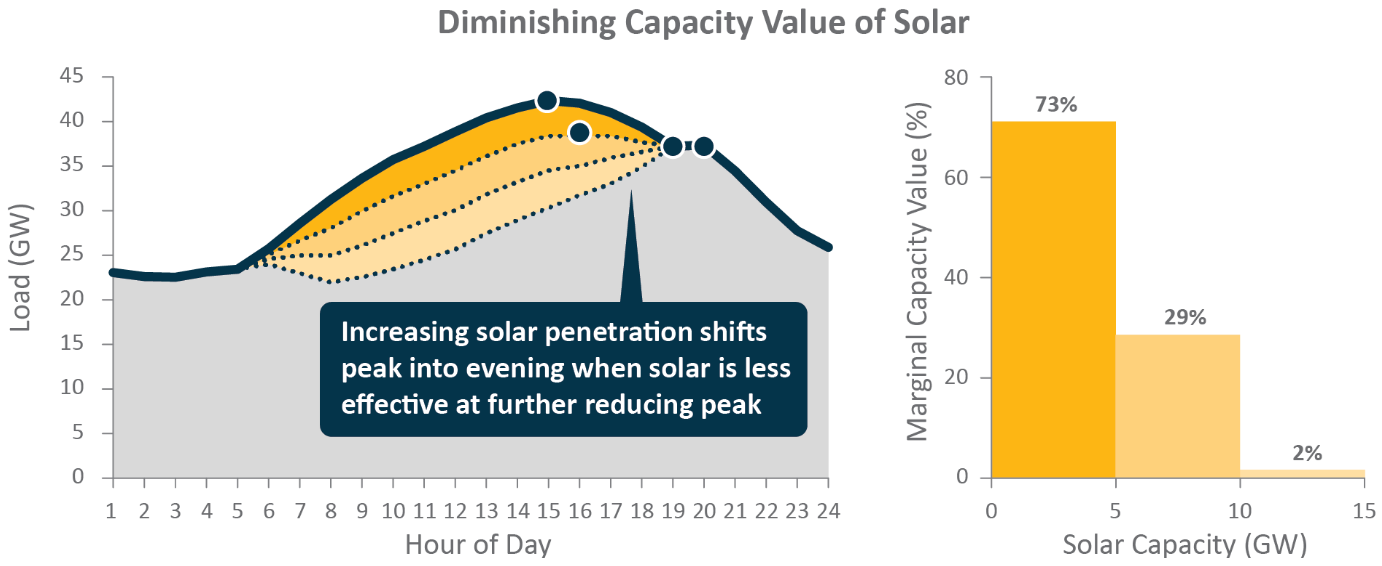
Methods for Evaluating Resource Adequacy

Total Resource Need (TRN) and Planning Reserve Margin (PRM) are the traditional metrics for resource adequacy need

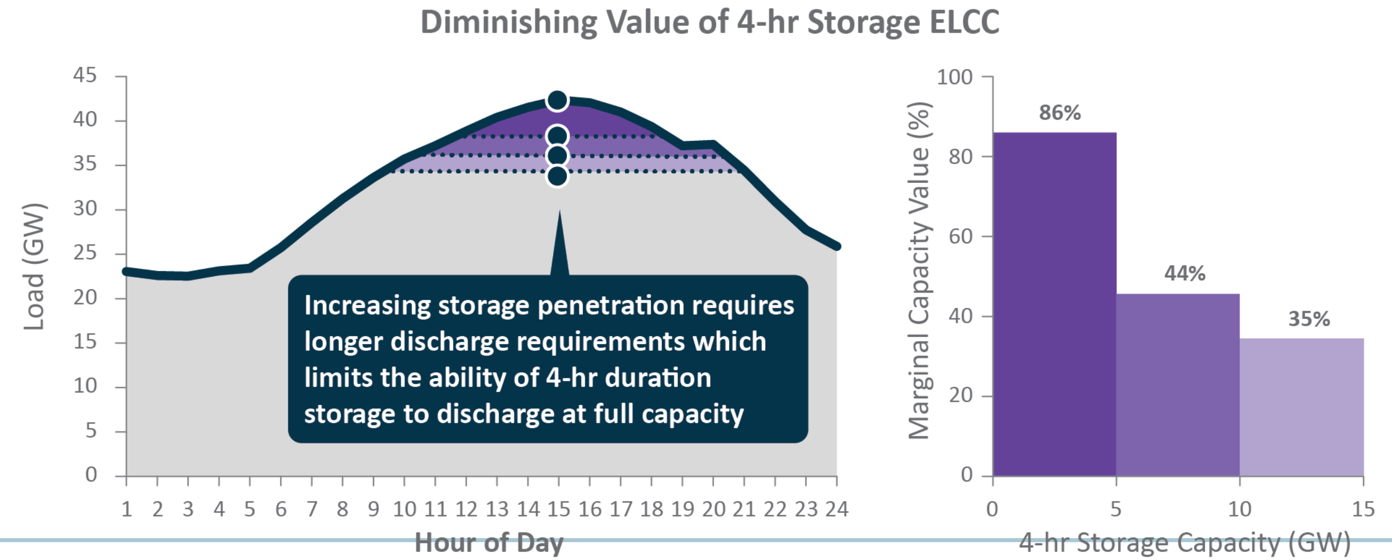
- **Total Resource Need is the quantity of effective capacity needed to meet a defined reliability standard**
  - Typically defined as “1 day in 10 years” or 0.1 LOLE but other definitions may be useful
- **PRM is measured as the quantity of capacity needed above the median year peak load to meet the LOLE standard**
  - Calculated as (TRN – Median Peak)/Median Peak
  - Serves as a simple and intuitive metric that can be utilized broadly in power system planning
  - Considers load and resource conditions during <u>*all hours of the year*</u>



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



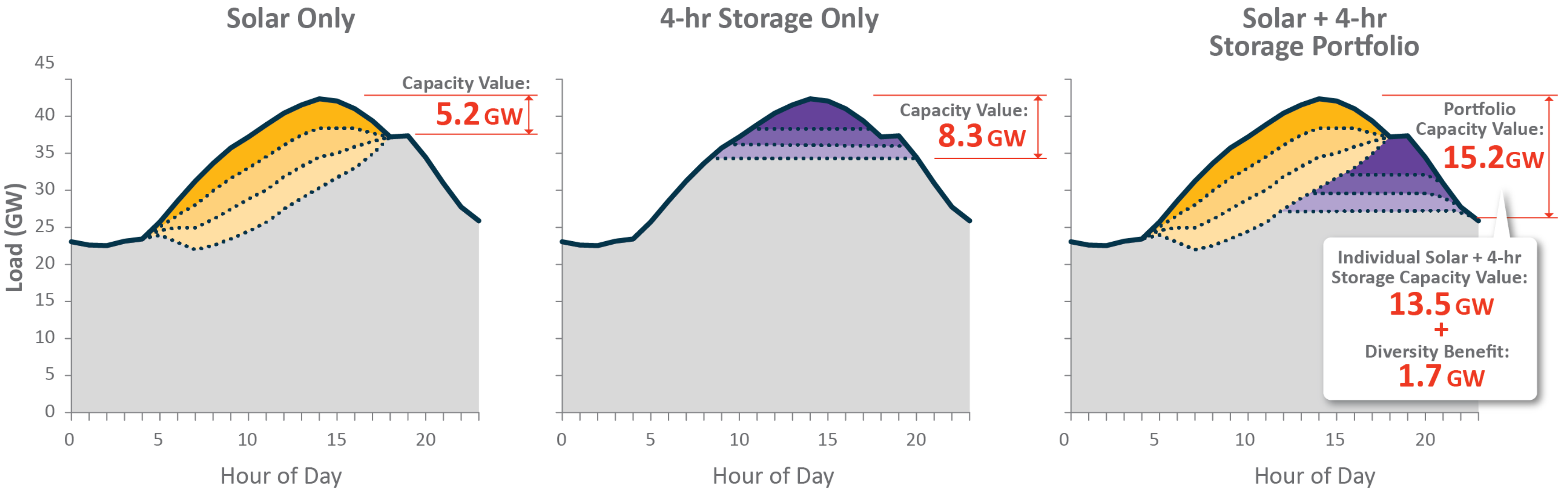
Solar and other **variable resources** (e.g. wind) exhibit declining value due to variability of production profiles



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

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

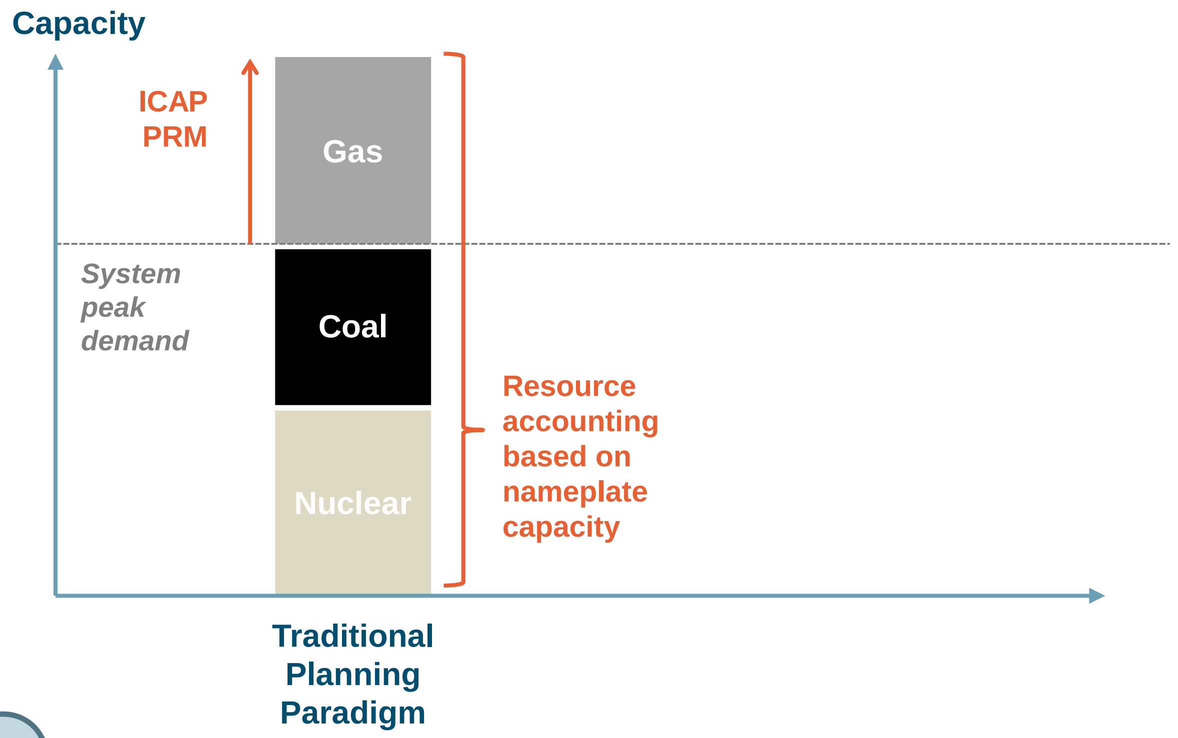
- Resources with complementary characteristics produce the opposite effect, synergistic interactions (also described as a "diversity benefit")
- As penetrations of intermittent and energy-limited resource grow, the magnitude of these interactive effects will increase and become non-negligible



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

Resource accreditation is simple in the traditional planning paradigm

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

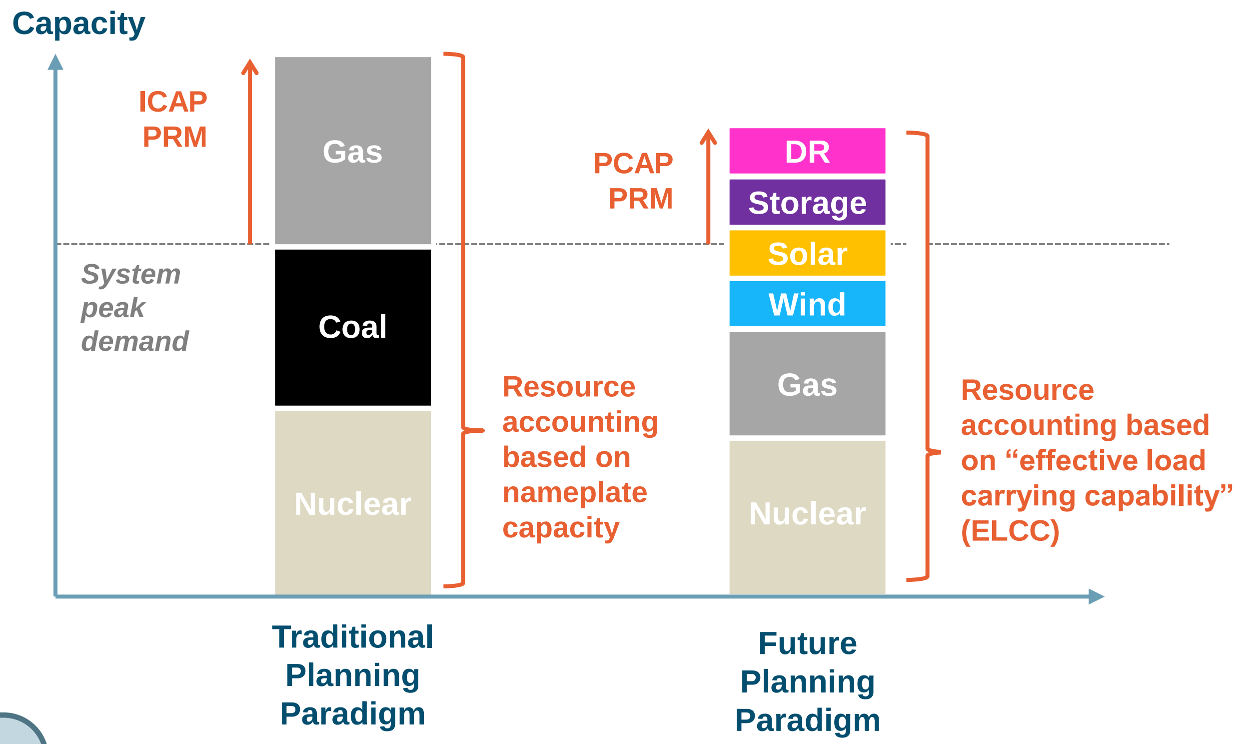


$$Installed\ Capacity = \sum_{i=1}^{n} G_i$$

Adapting the PRM framework for a more diverse resource mix

- **PRM defined based on need for Equivalent Perfect Capacity (PCAP)**
  - Covers annual peak load variation and operating reserves only; forced outages addressed in resource accreditation
- **Individual resources accredited based on ELCC**
  - Large differences in availability during key hours
  - Significant interactions among resources
  - ELCC values are dynamic based on resource portfolio

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



Measuring ELCC of a portfolio and individual resources

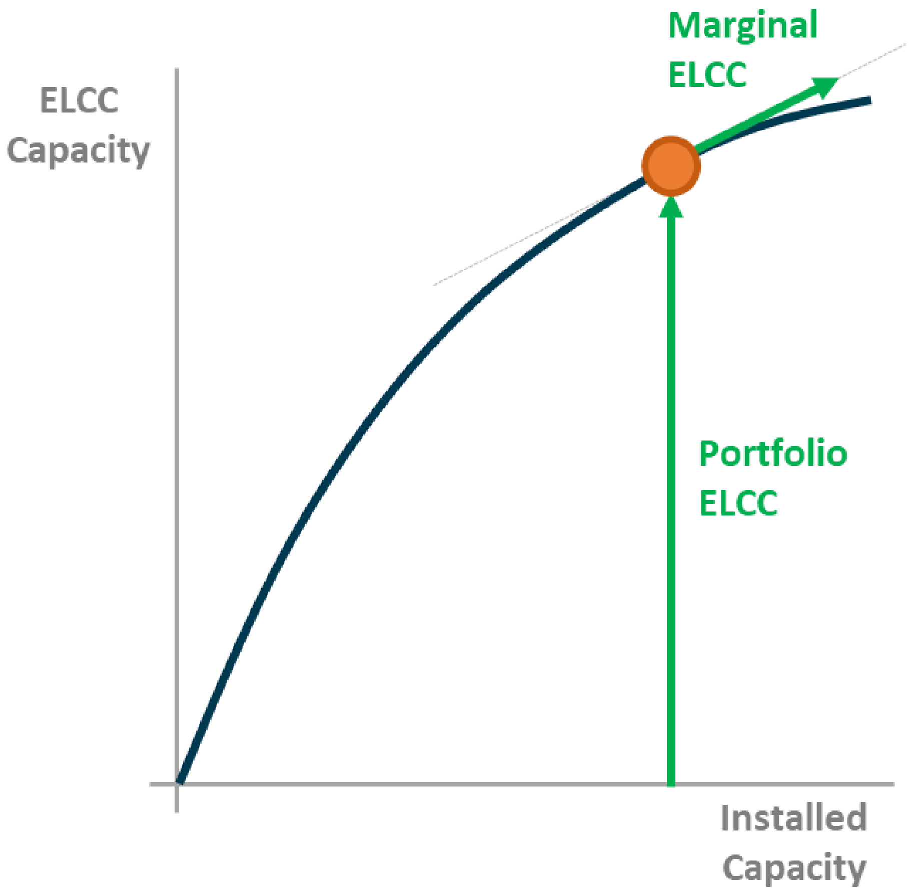
+ **ELCC is a function of the portfolio of resources**
  - The function is a surface in multiple dimensions
  - The Portfolio ELCC is the height of the surface at the point representing the total portfolio

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

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

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

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



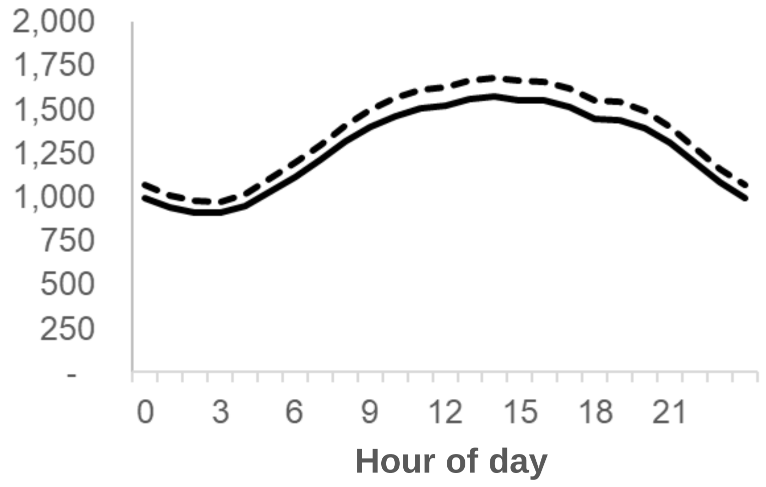
Testing three different methods for evaluating resource adequacy on O‘ahu

The incumbent method

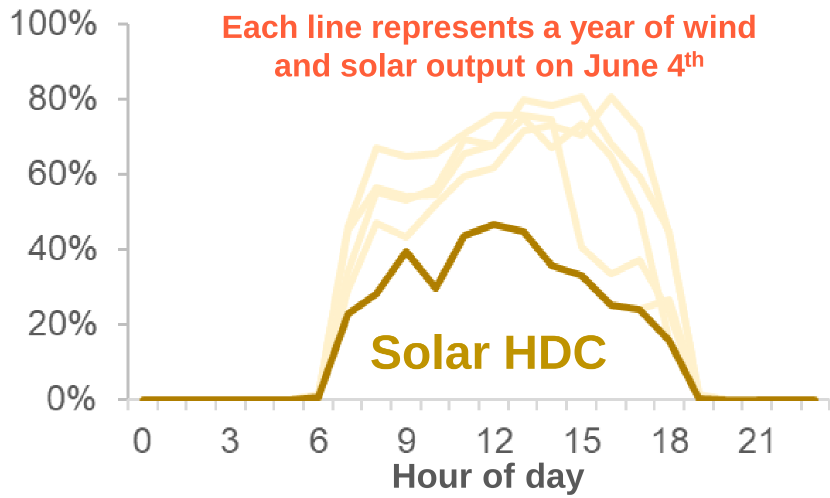
Hourly Energy Reserve Margin + Hourly Dependable Capacity

- **ERM+HDC is an hourly resource availability and load accounting methodology used by HECO**
- **For variable resources (e.g. renewables), Hourly Dependable Capacity (HDC) method uses historical / simulated hourly data from multiple years and determines the "1-in-5 worst output in each hour"**
  - Both load and resources inputs based on statistics and does not capture historical correlations between solar, wind, and load

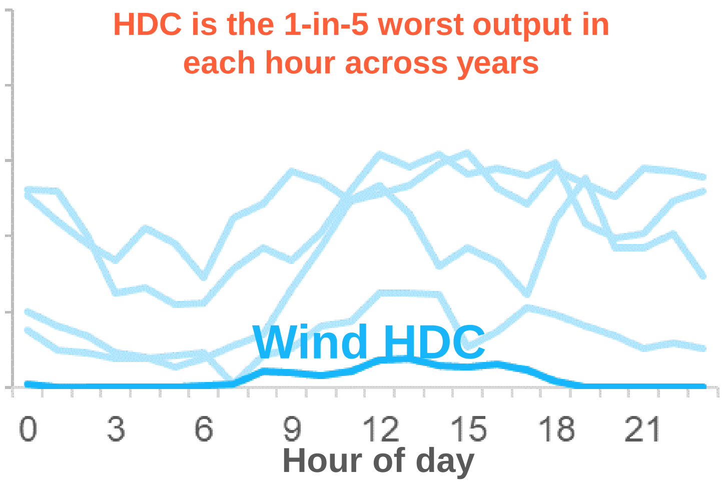
Hourly ERM Requirement on June 4th, 2015
MWs



Hourly Solar Production on June 4th
2015-2019 Historical Output
% of Nameplate



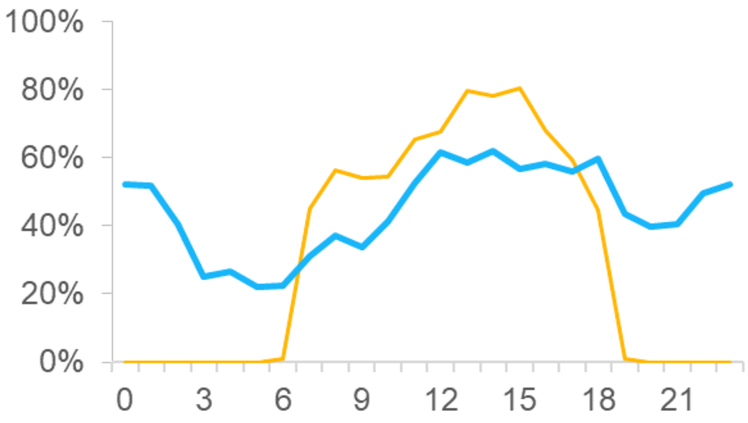
Hourly Wind Production on June 4th
2015-2019 Historical Output
% of Nameplate



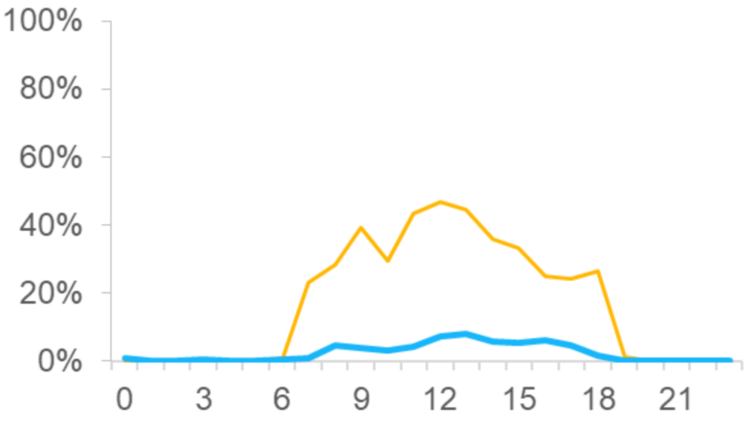
Hourly ERM + Hourly Expected Capacity for Solar and Wind

- **ERM+HEC is an hourly resource availability and load accounting methodology**
  - Hourly Expected Capacity (HEC) is an adaptation of HDC that E3 and Hawaiian Electric developed with the TAP
- **Hourly Expected Capacity (HEC) uses the same historical and simulated variable hourly profiles as HDC, but uses all the years directly as the resource accreditation in capacity expansion**
  - Instead of using an exceedances or averages, actual/simulated hourly production is used
  - Captures **both** high output and renewable drought periods

Summer day with high renewable output,
June 1, 2015
% of nameplate



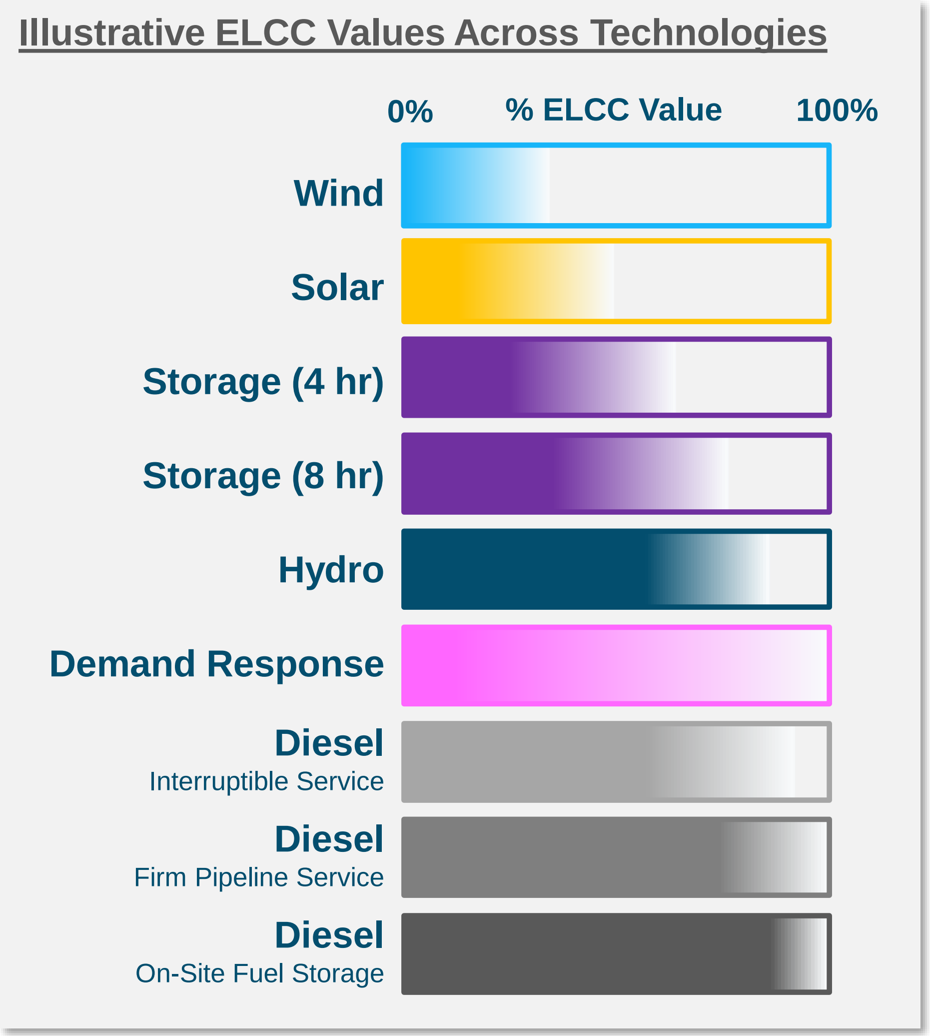
Winter day with low renewable output,
Jan 15, 2015
% of nameplate



A new approach for Hawaiʻi

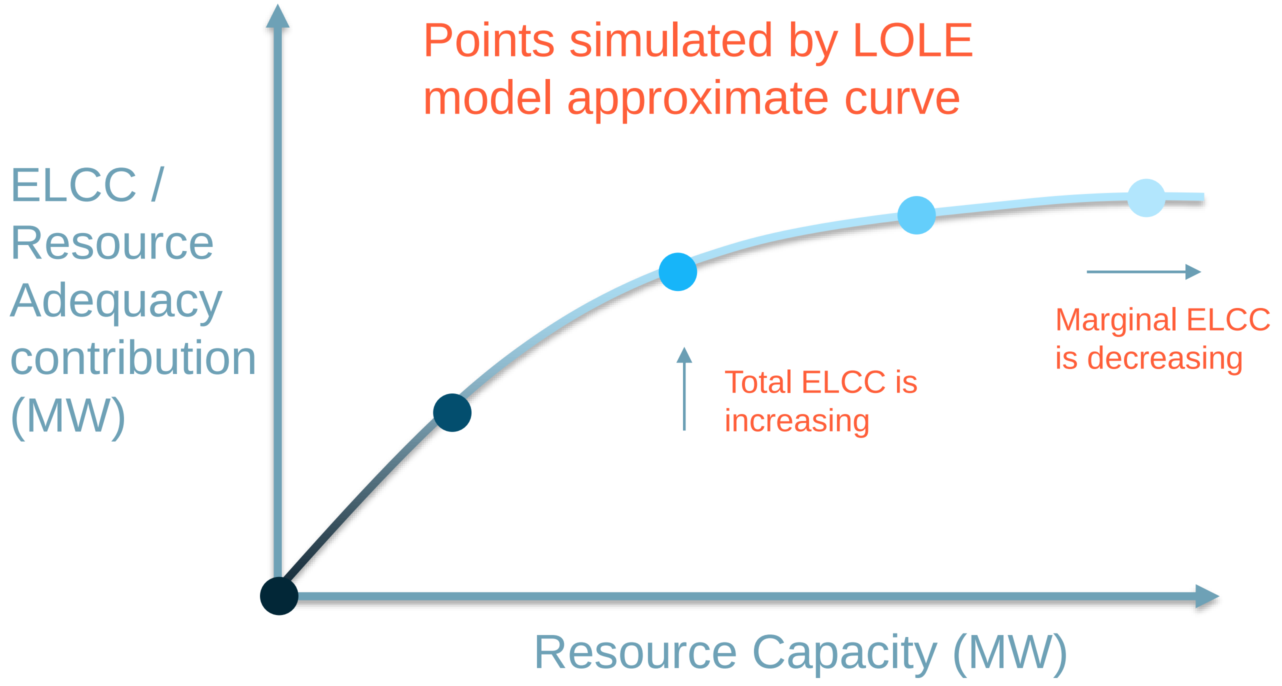
Planning Reserve Margin + Effective Load Carrying Capability

- **PCAP PRM+ELCC is an annual resource availability and load accounting methodology increasingly used on the mainland**
- **"ELCC for All" approach provides a simple and robust framework for resource adequacy accounting**
- **ELCC can account for all factors that can limit availability:**
  - Hourly variability in output
  - Duration and/or use limitations
  - Seasonal temperature derates
  - Temperature-related outage rates
  - Forced outages
  - Energy availability
  - Fuel availability
  - Correlated outage risk, *especially under extreme conditions*

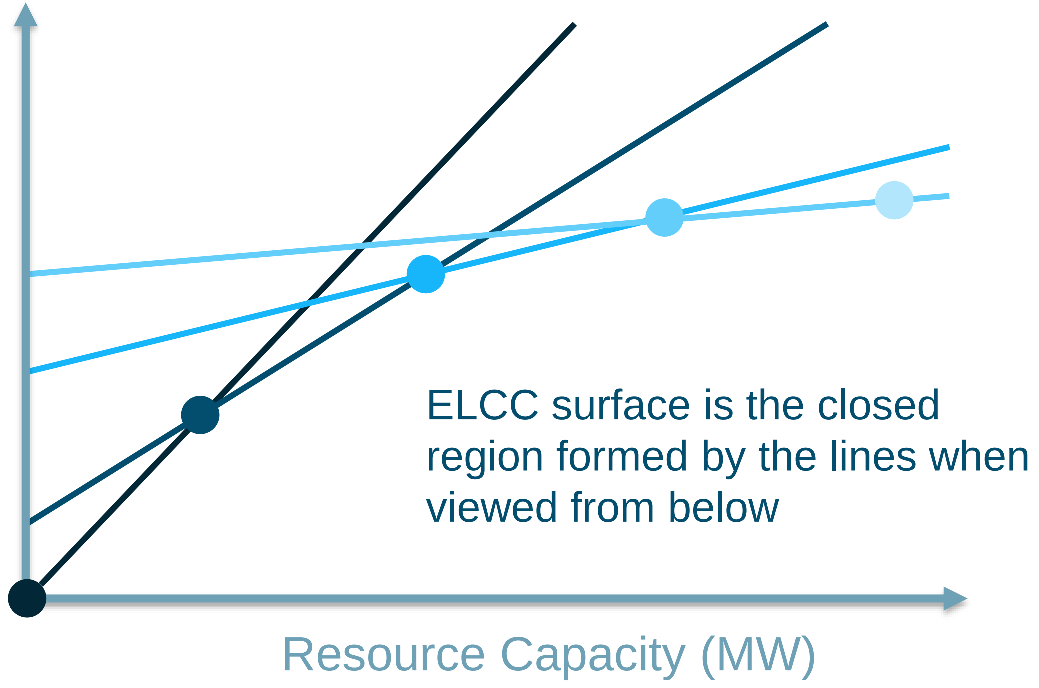


Building an ELCC surface in one dimension for use in Long-Term Capacity Expansion Model

Calculate ELCC at Different Levels of Penetration



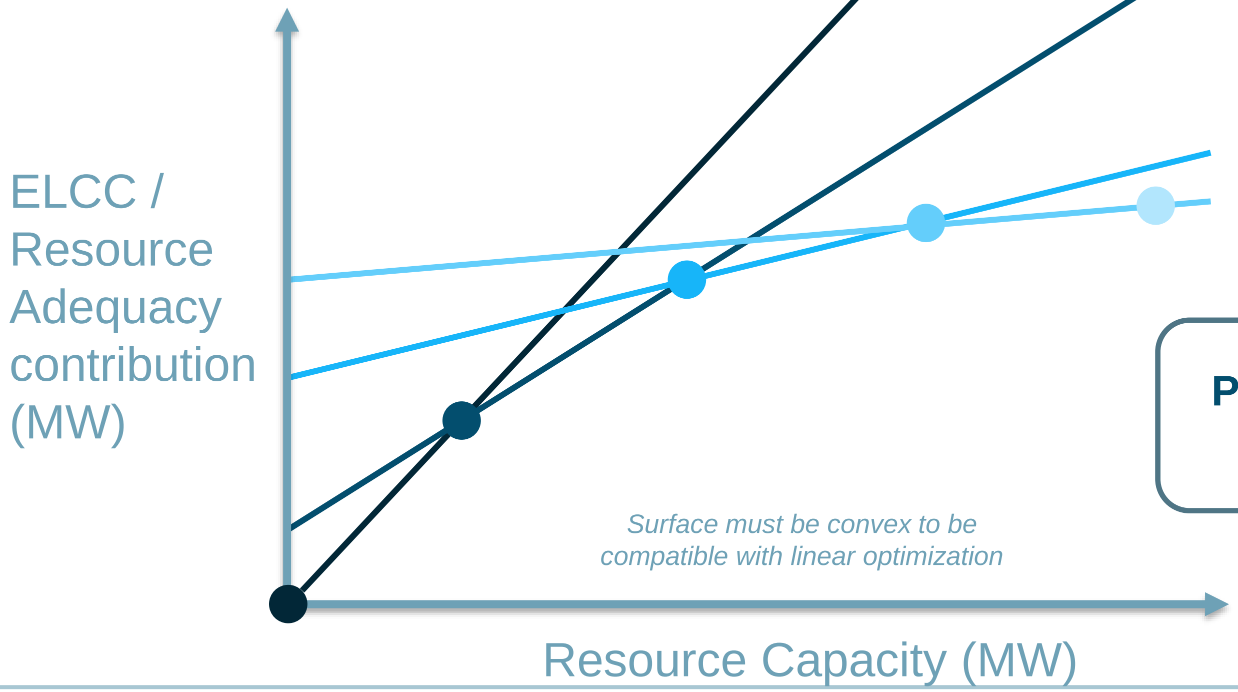
Linear equations to approximate ELCC curve



Implementing in capacity expansion model

All equations implemented in capacity expansion linear optimization <u>simultaneously</u>

>> Only one will be binding each year



ELCC <= 1 * ResCap + 0

Example values

ELCC <= 0.7 * ResCap + 80

ELCC <= 0.3 * ResCap + 200

ELCC <= 0.1 * ResCap + 300

Portfolio ELCC	**<=**	**Incremental Capacity Value**	*****	**Resource Capacity**	**+**	**Line Intercept**

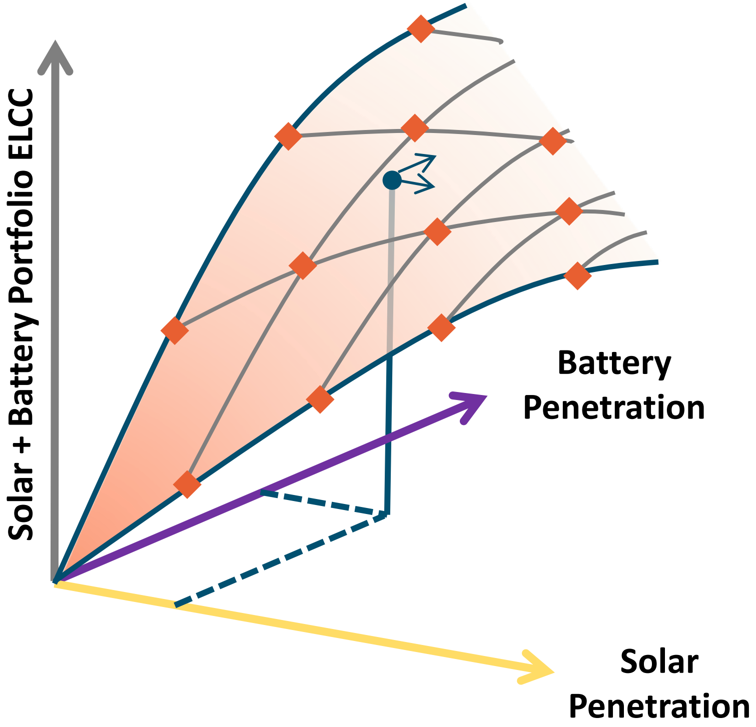
General form of equation

Now in two dimensions....

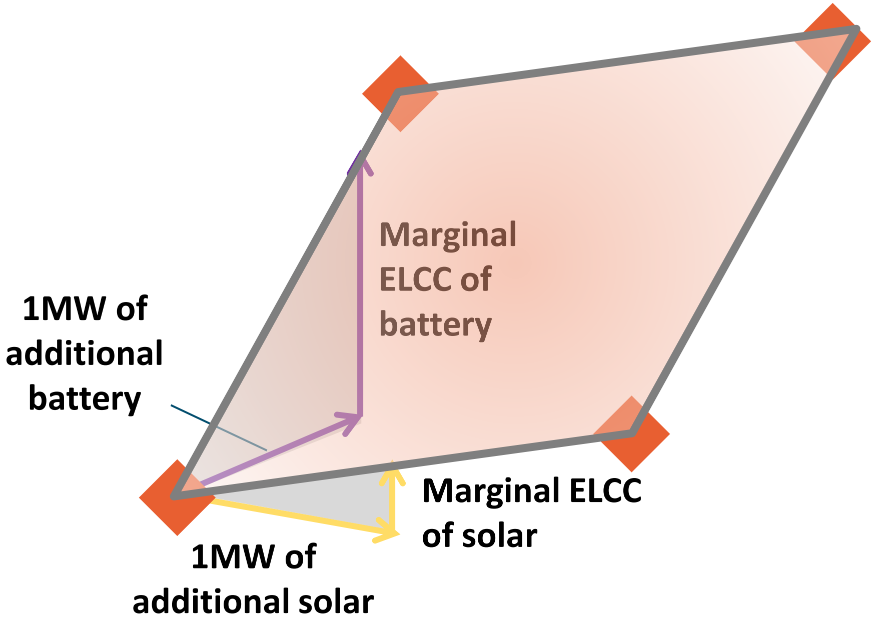
+ E3 developed a two-dimensional ELCC surface representing the combined capacity contribution of different quantities of solar and battery storage

The height of the orange dots gives the total solar + storage portfolio ELCC

The slope between each point gives the marginal capacity value of solar and storage at a given capacity



For any plane on the surface:



Portfolios developed under each framework are calibrated to common reliability standard using E3's RECAP Model

Portfolio calibration process for each RA framework to ensure each portfolio meets 0.1 LOLE

Optimal portfolios are fed into RECAP

RESOLVE (LTCE)

Find Optimal Portfolio

Develop portfolios using the 3 different RA frameworks with a capacity expansion model

Continue iterating until portfolio meets reliability target

RECAP (LOLP)

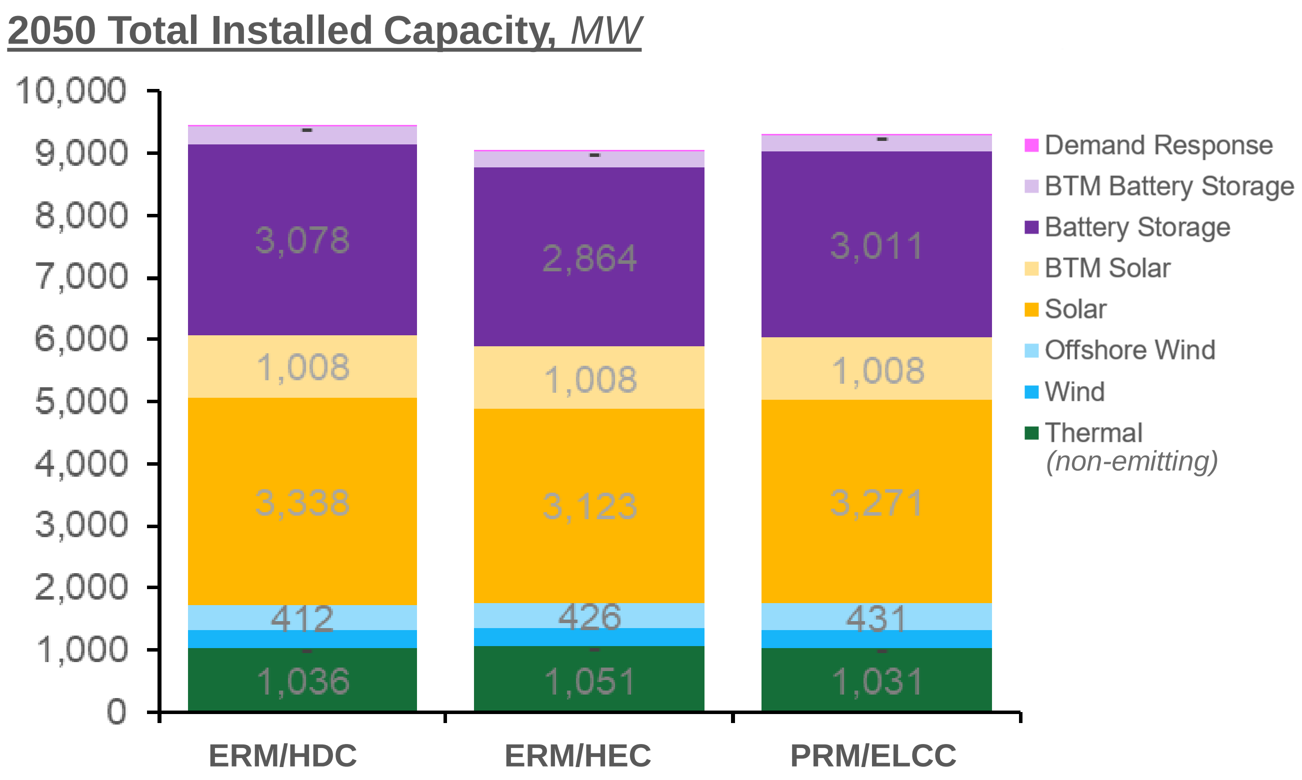
Test Portfolio Reliability

Check reliability to ensure portfolios meet reliability target with an LOLP (Loss of Load Probability) Model

Re-run capacity expansion to fill any gap
(may still be required for different scenarios or model years)

Results

Quantitatively, each RA framework achieves similar costs and reliability… but with varying levels of modeling challenges



Total Storage Energy Capacity	9,007 MWh	8,490 MWh	8,876 MWh

Result	Units	HDC	HEC	ELCC
GHG Emissions	*MMT*	**0**	**0**	**0**
Loss of Load Expectation	*days/ year*	**0.1**	**0.1**	**0.1**
Reserve Margin	*% above load*	**10%** Above Hourly	**-2%** Above Hourly	**16%** Above Annual Peak
Modeled Cost	*$Mil*	**812**	**811**	**806**
Expected Unserved Energy	*MWh or NEUE*	**239**	**247**	**214**
Iterations	*Model Runs*	**1**	**8**	**2**

Because portfolios results are similar, differences in qualitative goals will help decide the appropriate framework for HECO

Evaluating each framework

+ To achieve workplan goals as described by the commission's order, E3 and Hawaiian Electric borrowed from ESIG's recent paper *Ensuring Efficient Reliability: New Design Principles for Capacity Accreditation*

If quantitative evaluations all similar, differences in qualitative goals will help decide the appropriate framework for HECO

Qualitative Metrics

Non-Discriminatory	Transparent	Complexity*	Predictable
Accreditation is applied to all resources using a similar methodology.	*Accreditation can be effectively communicated to stakeholders, and data are readily available for decision making.*	*Accreditation process does not create undue burden to grid planners and stakeholders*	*The process is repeatable and consistent. It does not yield volatile or unexplained changes year to year*

Quantitative Metrics

We should expect each framework to achieve these goals

Reliable	Least Cost*	Robust
Accreditation accurately measures performance during real scarcity events.	*Accreditation sends the correct marginal investment signals to meet reliability at least cost*	*Accreditation continues to work as the resource mix, load patterns, and system risk change over time.*

***Least cost and complexity are additional criteria for this workplan**

Adapted from ESIG's *Ensuring Efficient Reliability: New Design Principles for Capacity Accreditation* (source)

Qualitative Method Comparison Summary Matrix

	ERM + HDC	ERM + HEC	PRM + ELCC
Robustness	2/5 • ERM depending on resource portfolio • Statistical representation masks real system dynamics	2/5 • ERM depending on resource portfolio • ERM volatility produces counterintuitive results	5/5 • PRM is dependent on load only • Stable PRM throughout modeling
Non-discriminatory	1/5 • Different metrics for each resource • Historical statistics used	3/5 • Different metrics for each resource • Actual output used	5/5 • Same metric across resources • Historical statistics used
Transparent	2/5 • Clear approach but needs statistical representation, which hides information	2/5 • Clear approach • Simple representation in capacity expansion	2/5 • "Black box" model • Results tied to resources' contribution to reliability
Complexity	3/5 • More iteration required • Relatively intuitive results metric	2/5 • More iteration required • Interpretation of results difficult • Could results in non-intuitive results metric	3/5 • Less iteration required • Results metrics industry standard
Predictability	3/5 • Repeatable process • Less Volatile ERM results YoY	2/5 • Repeatable process • Risk of volatile ERM results YoY	5/5 • Repeatable process • Stable PRM • Stable ELCCs

E3 recommends the PRM/ELCC methodology for future IGPs

- For PRM/ELCC's main benefit is its fairness across all types of resources (whether variable, use-limited, or firm) and its predictability and stability in marginal investment signal
- Most utilities and capacity markets have moved or are moving to a PRM/ELCC-like framework for their long-term planning
- This RA study showed that PRM/ELCC can capably address Hawai'i's unique carbon-free energy focused planning challenges
  - With other entities and markets using a PRM/ELCC framework, the growing body of knowledge and experience worldwide will only enhance and strengthen the way Hawaiian Electric plans for resource adequacy in its IGP process
- Using an industry-standard resource adequacy approach also facilitates increased stakeholder engagement for those stakeholders engaged across multiple utility planning processes

Resource Adequacy Frameworks

ERM + HDC
Energy Reserve Margin + Hourly Dependable Capacity

ERM + HEC
Energy Reserve Margin + Hourly Expected Capacity

PRM + ELCC
Planning Reserve Margin + Effective Load Carrying Capability

Thank you!

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