Integrated Resource Planning

Roundtable 19-1 | February 27, 2019

Meeting Logistics

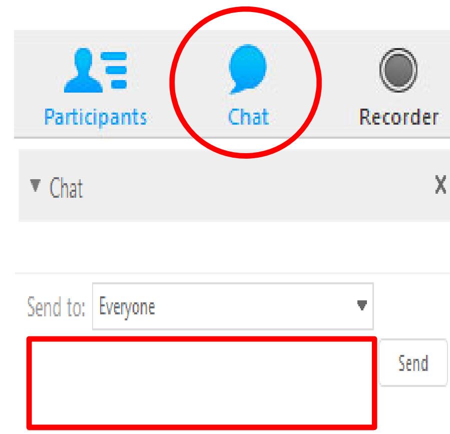
Local Participants:

- World Trade Center facility
- Wireless internet access
  - Network: 2WTC_Event
  - Password: 2WTC_Event$
- Sign-in sheets

Virtual Participants:

- Ask questions via ‘chat’ feature
- Meeting will stay open during breaks, but will be muted
- Electronic version of presentation: *portlandgeneral.com/irp*

>> *Integrated Resource Planning*



AGENDA

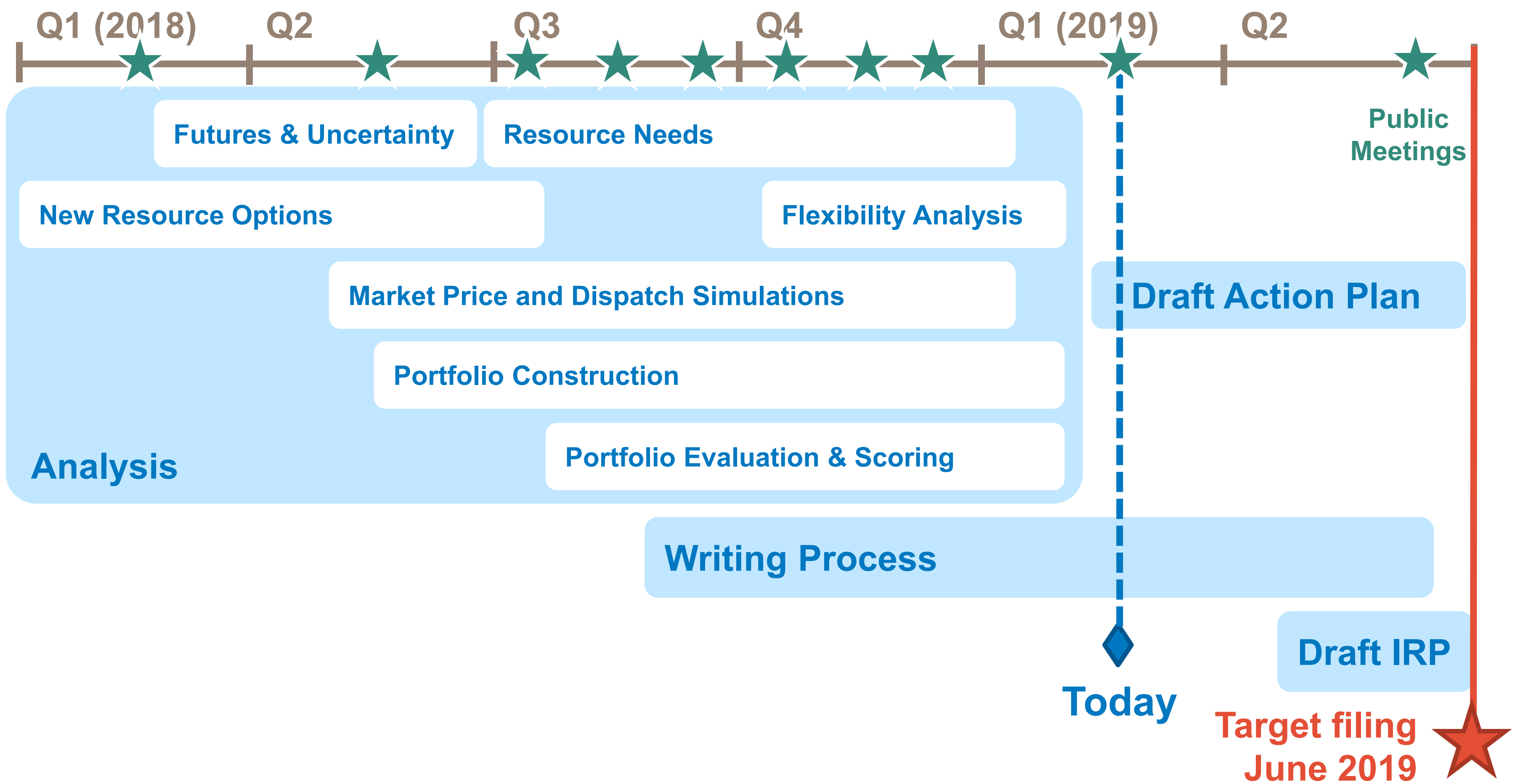
- ❑ Updated Need Assessment
- ❑ Updated Portfolio Analysis
- ❑ Draft Action Plan
- ❑ Updated Flexibility Analysis

Safety Moment

Preventing Eye Strain

2019 IRP Schedule

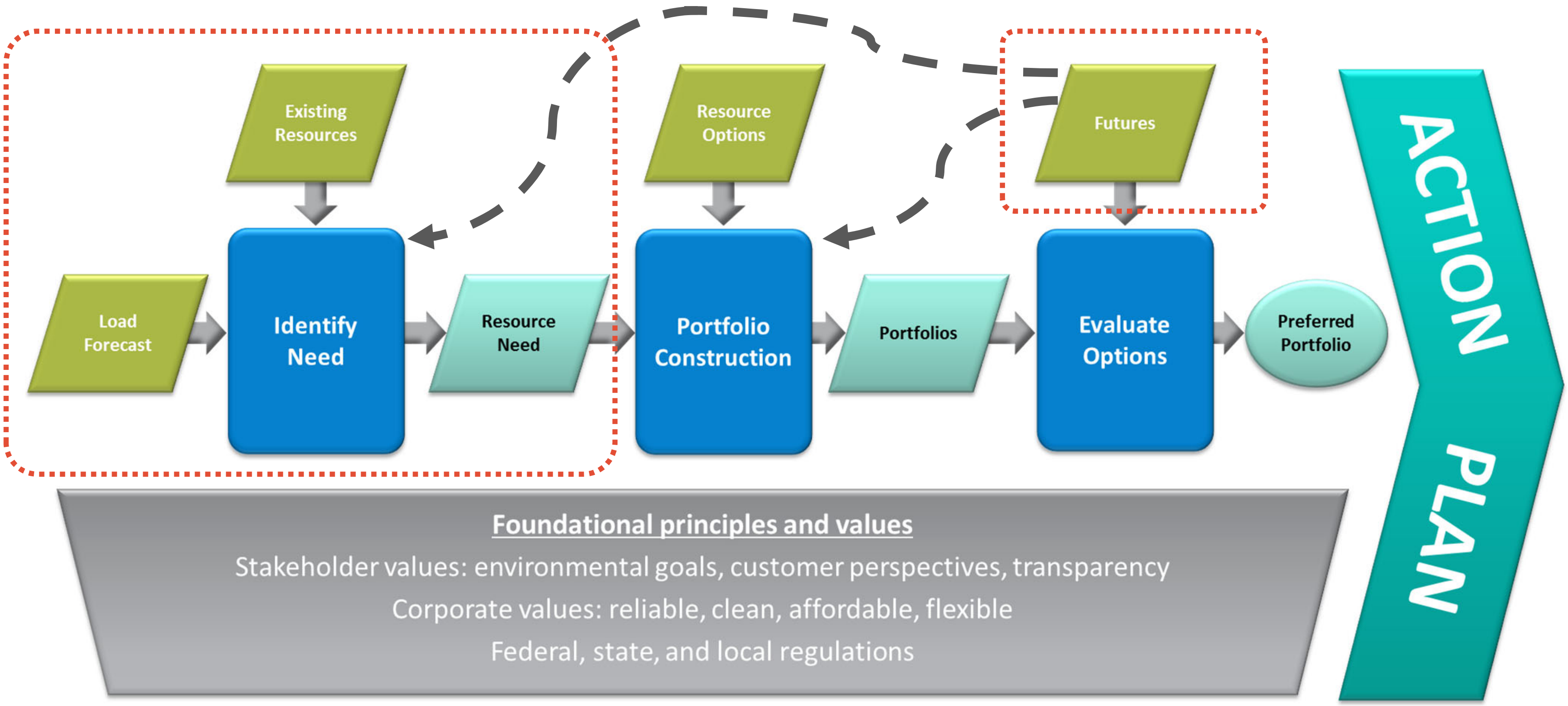
PGE is seeking feedback on the draft Action Plan as we finalize the draft 2019 IRP



Updated Need Assessment

Kate von Reis Baron

Needs Assessment

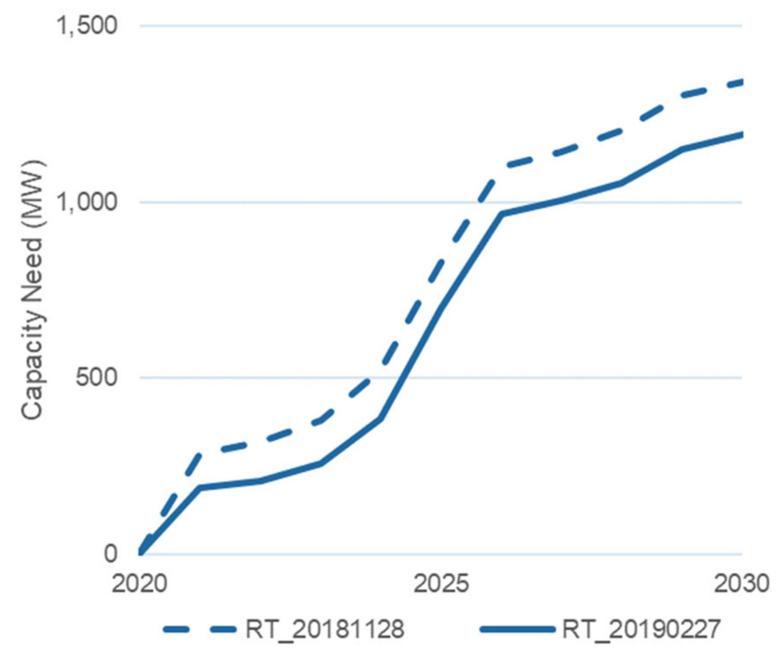


Need Assessments – Input Data

Item	Status
Load	• Final forecast, September 2018 • Low and high sensitivities
DER Study	• **Draft low/base/high from Navigant study** • **High EE in Low Need Future**
Market Capacity	• Winter and Summer on-peak from E3 Study (low, base, high) • **Off-peak unconstrained**
Qualifying Facilities	• **Snapshot from December 18, 2018**
New Resources	• **Wheatridge Renewable Energy Facility** • **HB 2193 storage resources** • **Dispatchable Standby Generation Study**
Existing Resources	• **Updates to more recent information**

Capacity Need - Reference

- Capacity need decreased in the updated snapshot compared to the view shared in the November 2018 Roundtable
- Need in the year 2025 decreased from approximately 828 MW to 699 MW
- Updates that reduced need include the addition of the Wheatridge Energy Facility, HB 2193 Energy Storage, updates to DER profiles, and updates to existing resources



All data is draft until filed.

New Resources

Wheatridge Renewable Energy Facility

- 300 MW of wind, 50 MW of solar, 30 MW of battery storage
- Wind online in 2020, solar and storage in 2021
- Located in Morrow County, OR

HB 2193 Storage

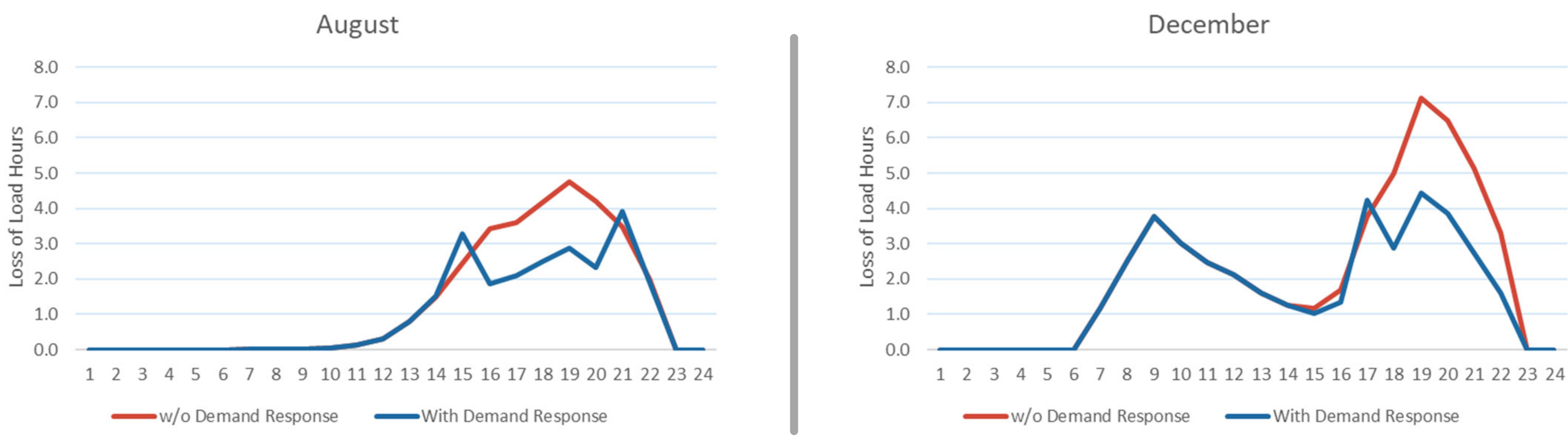
- Modeled in IRP as 23 MW (based on lower range of quantities proposed in OPUC Docket No. UM 18-290) and estimated as online by January 2021

All data is draft until filed.

Distributed Energy Resources

- High EE added to Low Need Future
- DER profiles refined
- More detailed program modeling than the 2016 IRP, but significant complexity added
- PGE plans to continue to develop this work in the next IRP

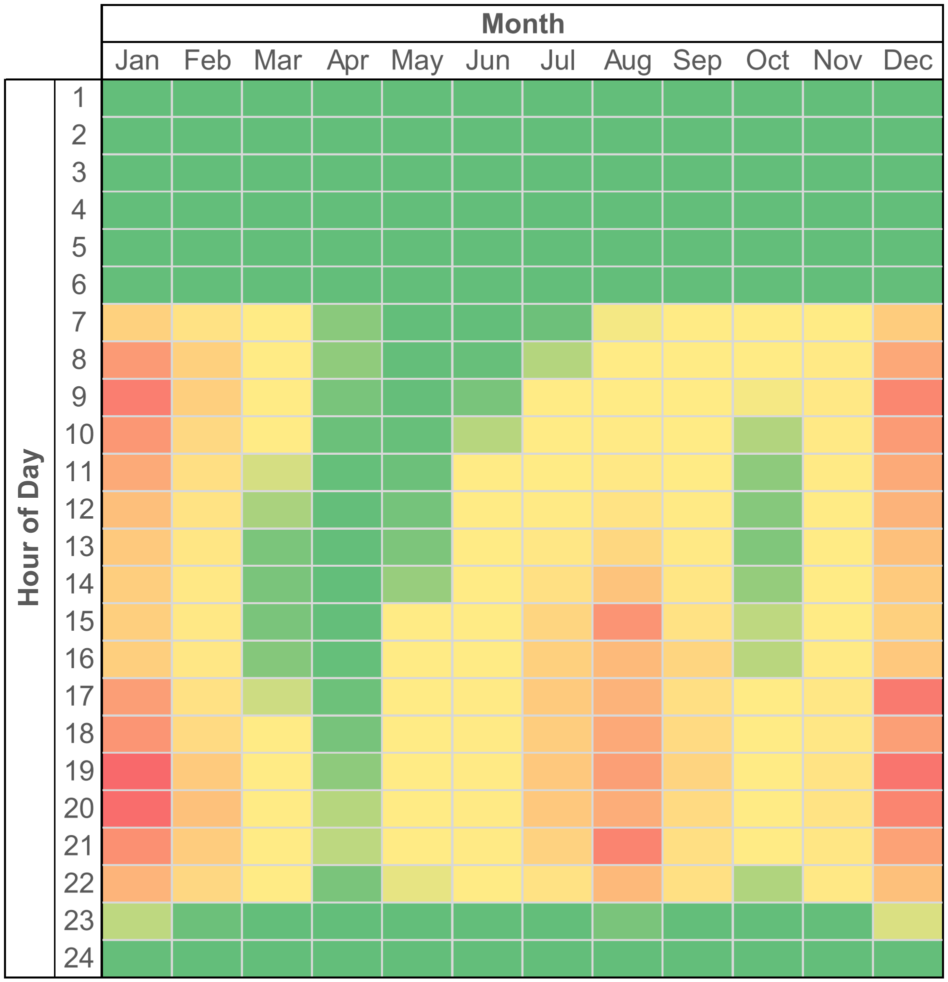
Loss of Load Hour Profiles with and without Demand Response*



** Simplified*

All data is draft until filed.

LOLH Heatmap – Year 2025



- Loss of Load Hours (LOLH) = 132 hr
- Adequacy target = 2.4 hr
- Includes impacts of DER, DSG, Wheatridge, HB 2193 Storage
- While summer peak loads are growing faster than winter, winter adequacy is a large and challenging issue
- Capacity need is 699 MW (Reference View, Reference Need)

All data is draft until filed.

Load Forecast is the top-down macro-economic forecast before the DER items.

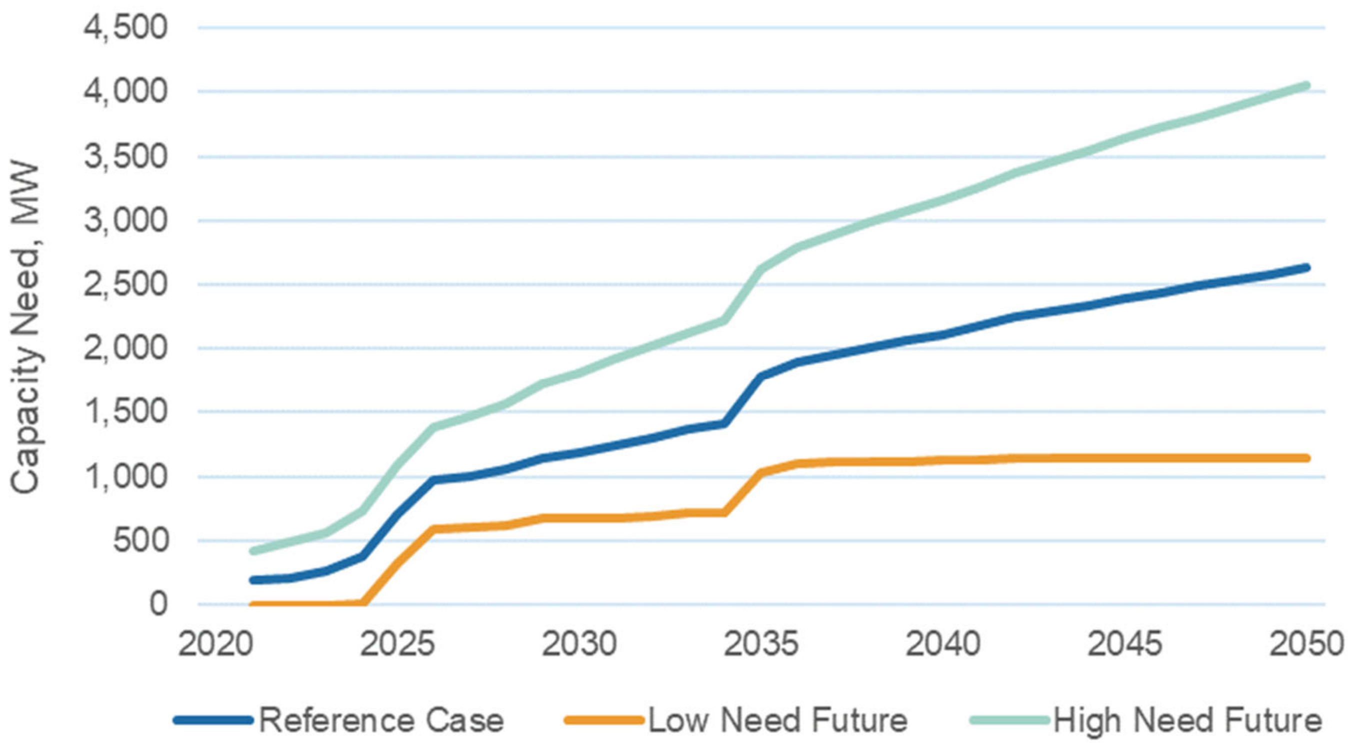
High EE is incremental to Energy Trust's Cost Effective Forecast.

Distributed PV and Distributed Batteries are customer-sited.

Need Futures

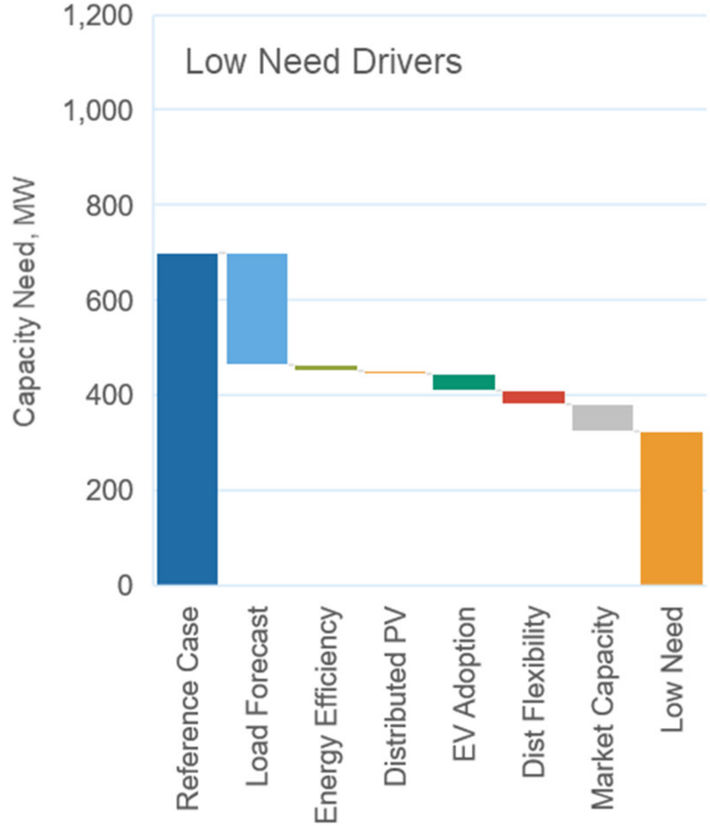
Item	Low	Ref	High
Load Forecast	-Econ-1SD	Ref	+Econ+SD
Energy Efficiency	High EE	Ref EE	Ref EE
Distributed PV	Nav High	Nav Base	Nav Low
EV + DLC_{EV}	Nav Low	Nav Base	Nav High
Demand Response	Nav High	Nav Base	Nav Low
Dist. Batteries	Nav High	Nav Base	Nav Low
Market Capacity	E3 Low Need	E3 Base Need	E3 High Need

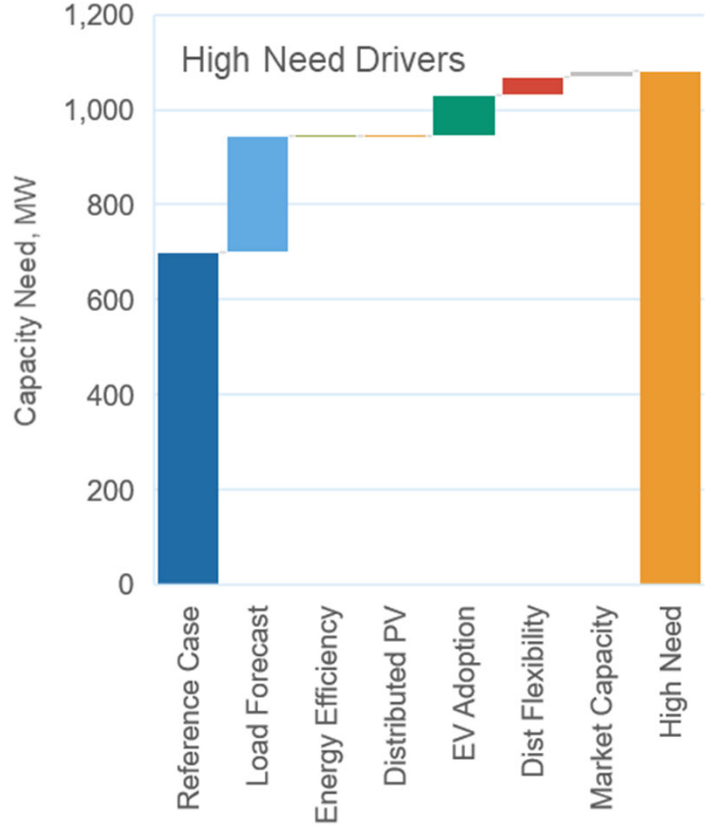
Capacity Need Futures



All data is draft until filed.

Need Future Drivers – Year 2025

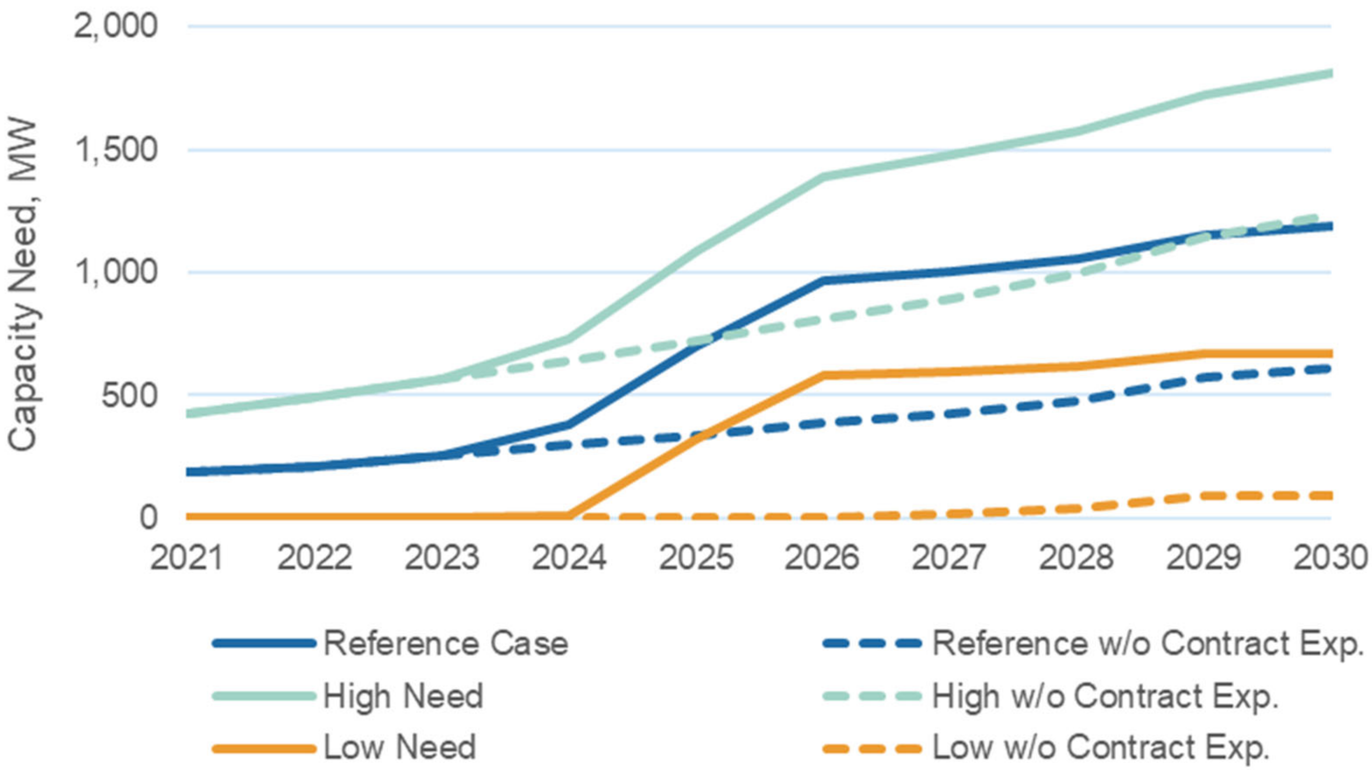




- Driver values are order dependent
- EE is incremental to cost effective forecast

All data is draft until filed.

Capacity Need



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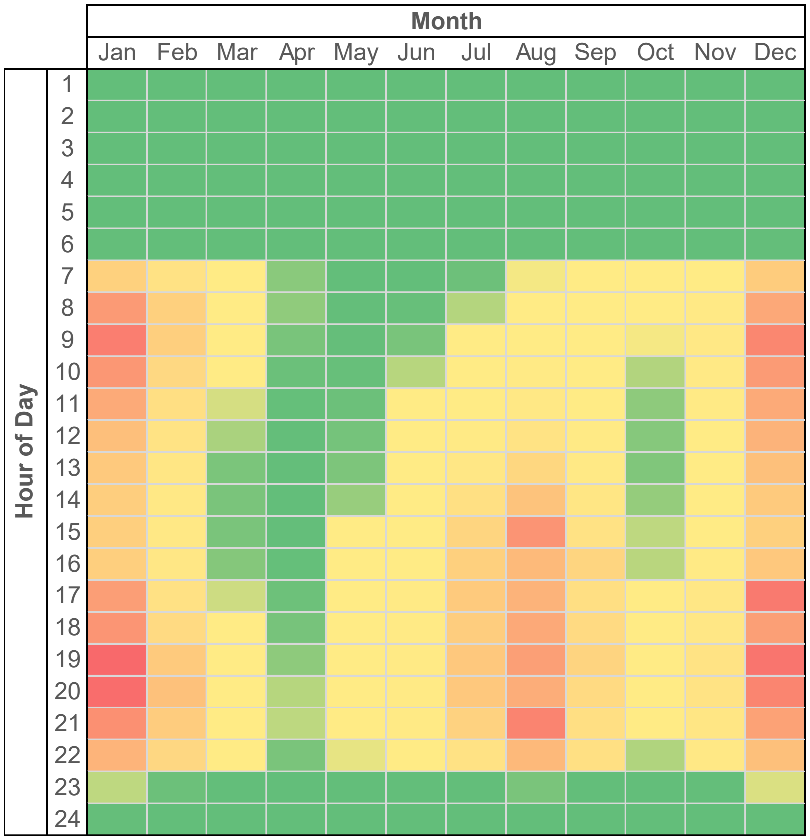
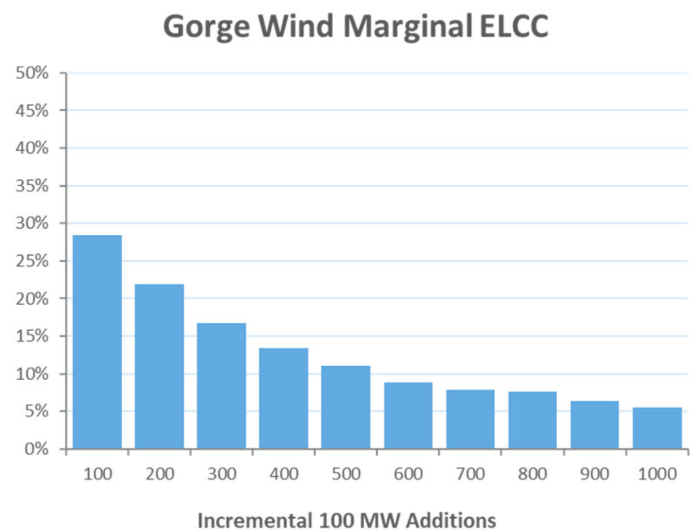
Capacity Contribution - ELCC

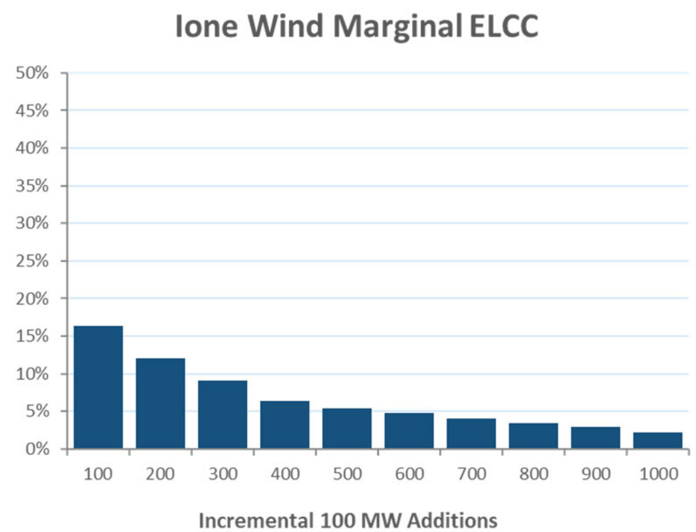


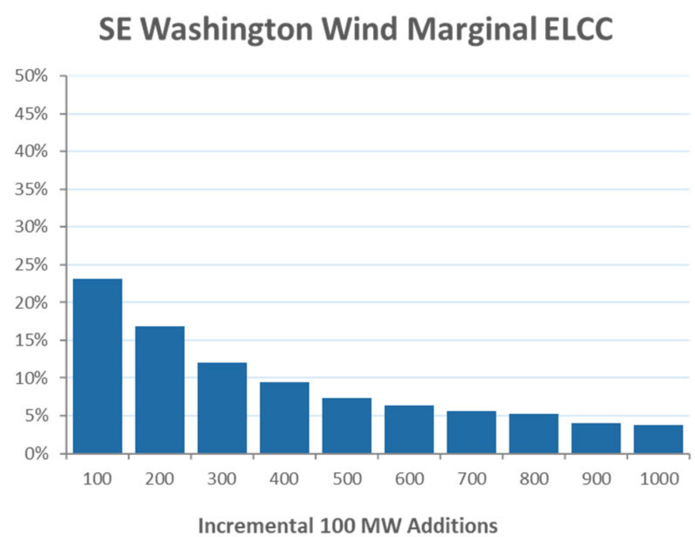
- **Capacity need** is expressed in terms of the amount of conventional capacity needed to achieve the annual adequacy target
- The conventional capacity resource in RECAP is an annual resource, available 24x7, has a 5% forced outage rate, and has a unit size of 100 MW
- The **capacity contribution** (effective load carrying capability or ELCC) of a resource addition is based on the amount of conventional capacity that can be avoided
- For example, if adding 100 MW of a wind resource reduces the need for conventional capacity by 25 MW, the wind resource's capacity contribution (ELCC value) is 25%

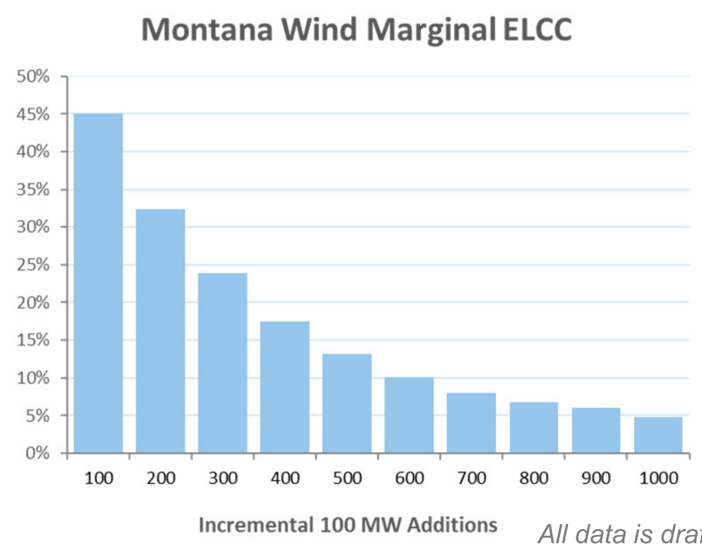
All data is draft until filed.

ELCC - Wind









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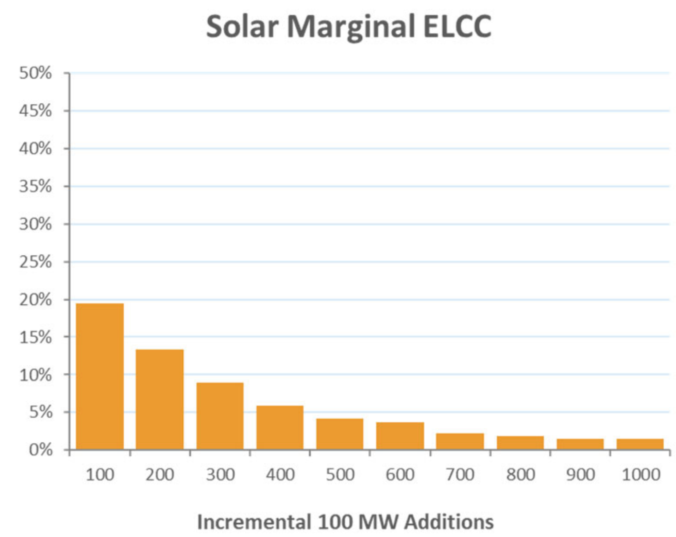
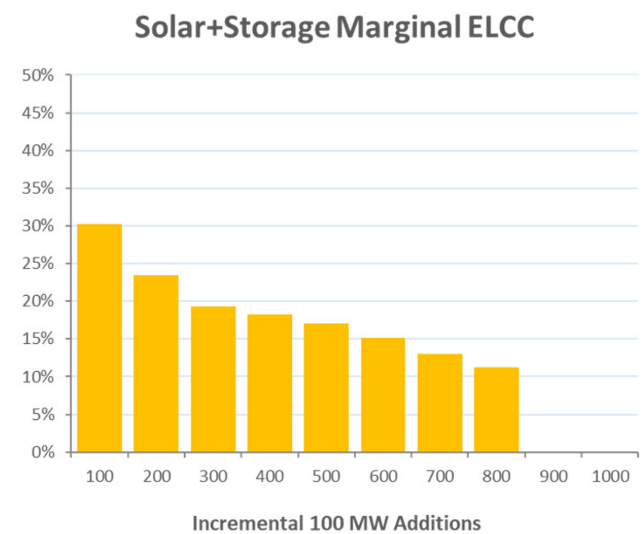
ELCC – Solar

- Central Oregon Single-axis Tracking Solar
- Solar+Storage has 25 MW of 4-hr batteries for each 100 MW of solar
- Battery can only be charged by solar





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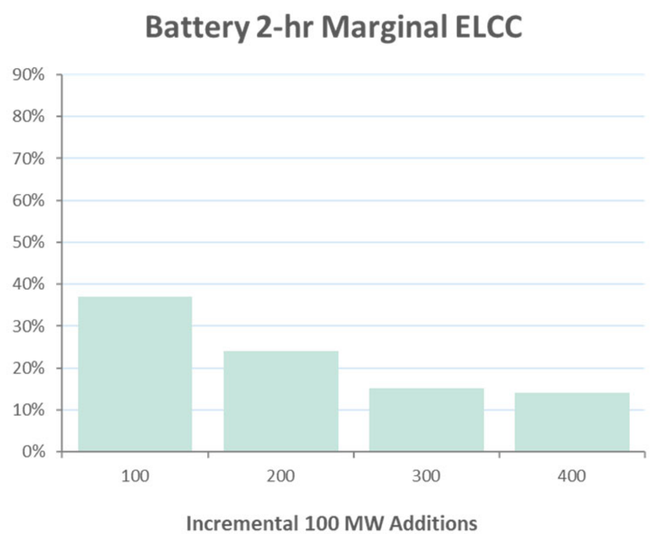
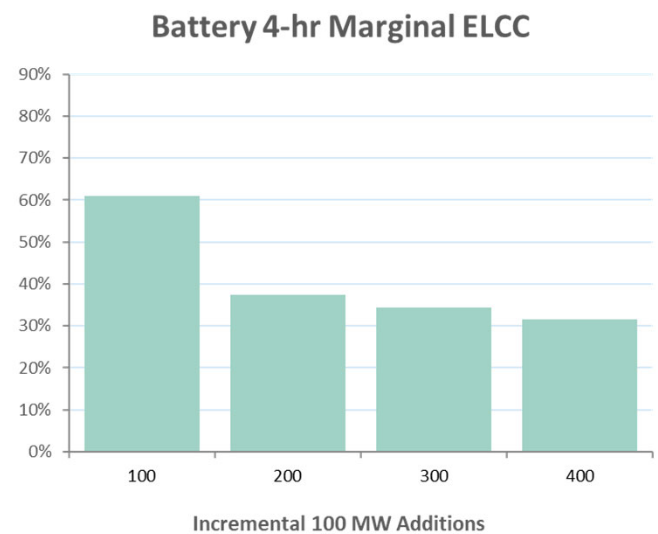
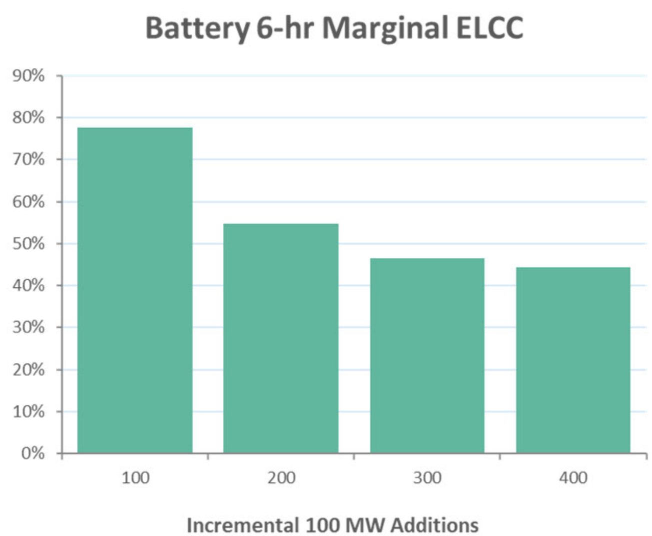
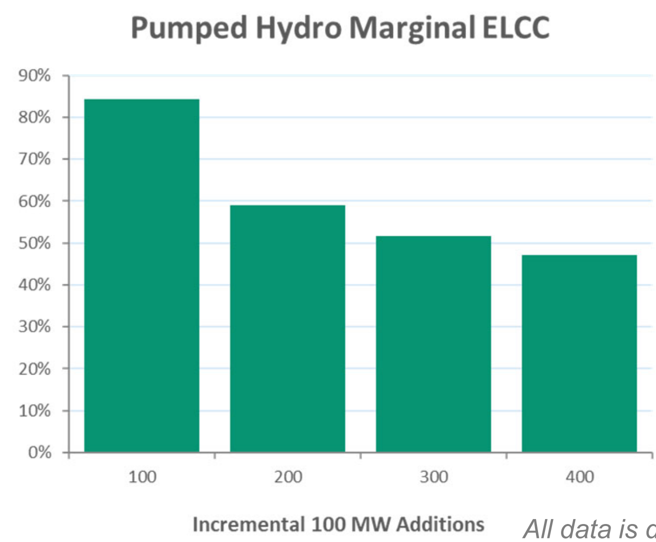
ELCC - Storage









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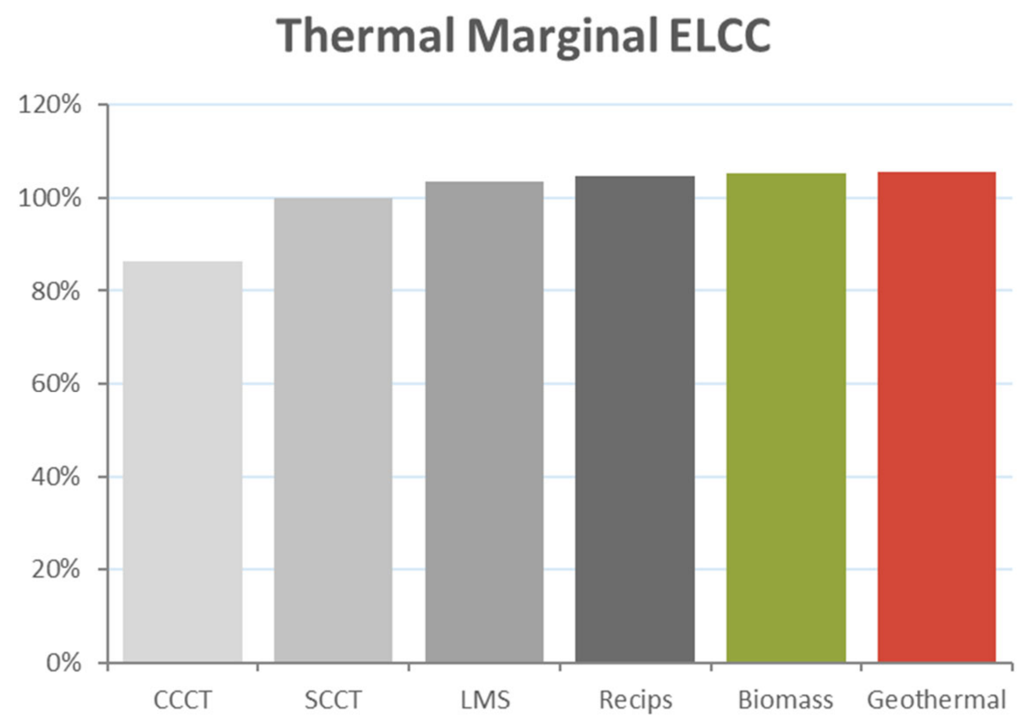
ELCC - Thermal

- Thermal ELCC values per unit addition
- ELCCs vary due to unit size, forced outage rates, and temperature profiles



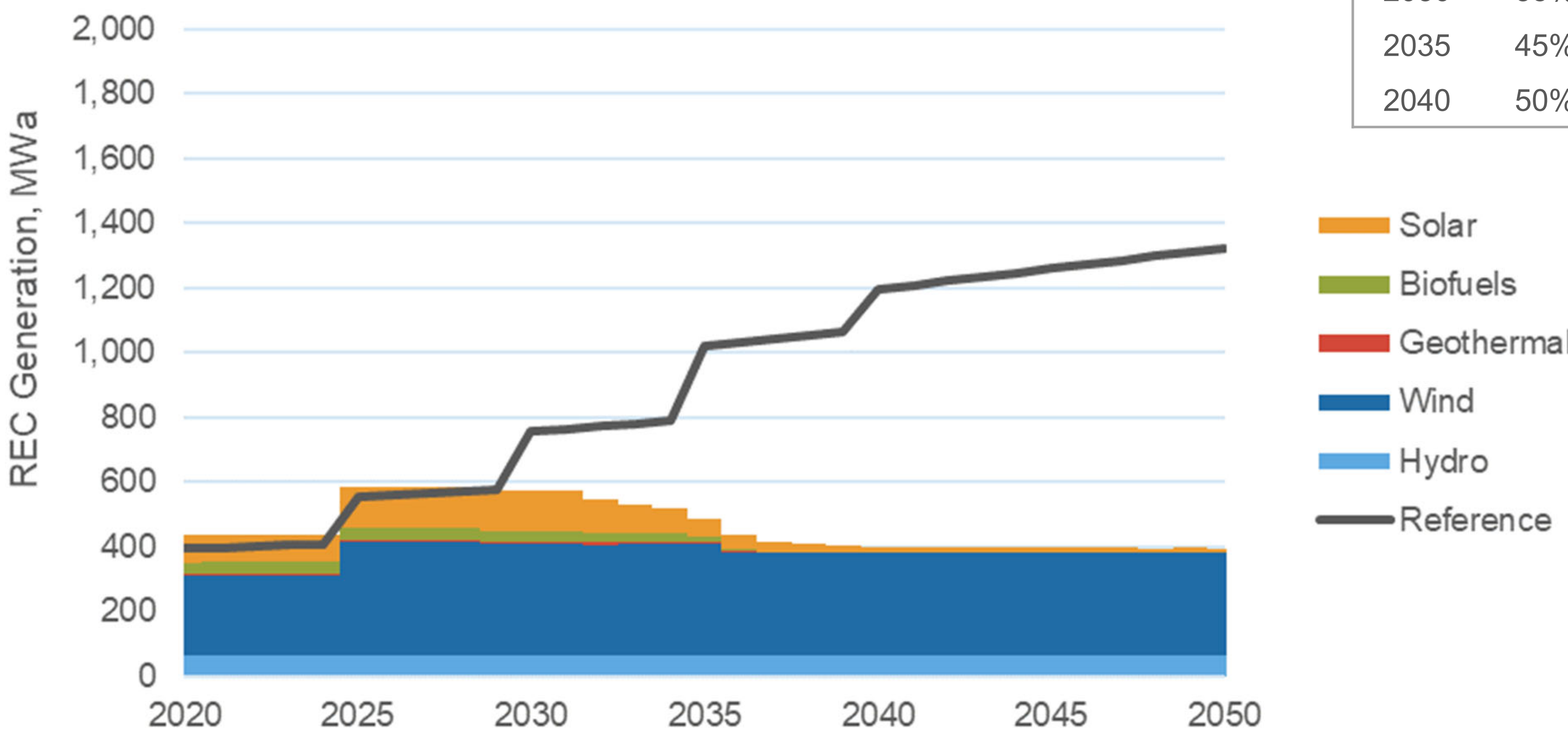
MW@55F	503	347	93	18	30	23

All data is draft until filed.

RPS Physical Compliance

- Reference line is RPS obligation in the Reference Need Future
- REC Generation includes Wheatridge Renewable Energy Facility

Year	RPS%
2020	20%
2025	27%
2030	35%
2035	45%
2040	50%



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RPS Physical Compliance is impacted by load, EE, distributed PV, and EV.

Load Forecast is the top-down macro-economic forecast before the DER items.

High EE is incremental to Energy Trust's Cost Effective Forecast.

Distributed PV and **Distributed Batteries** are customer-sited.

Need Futures

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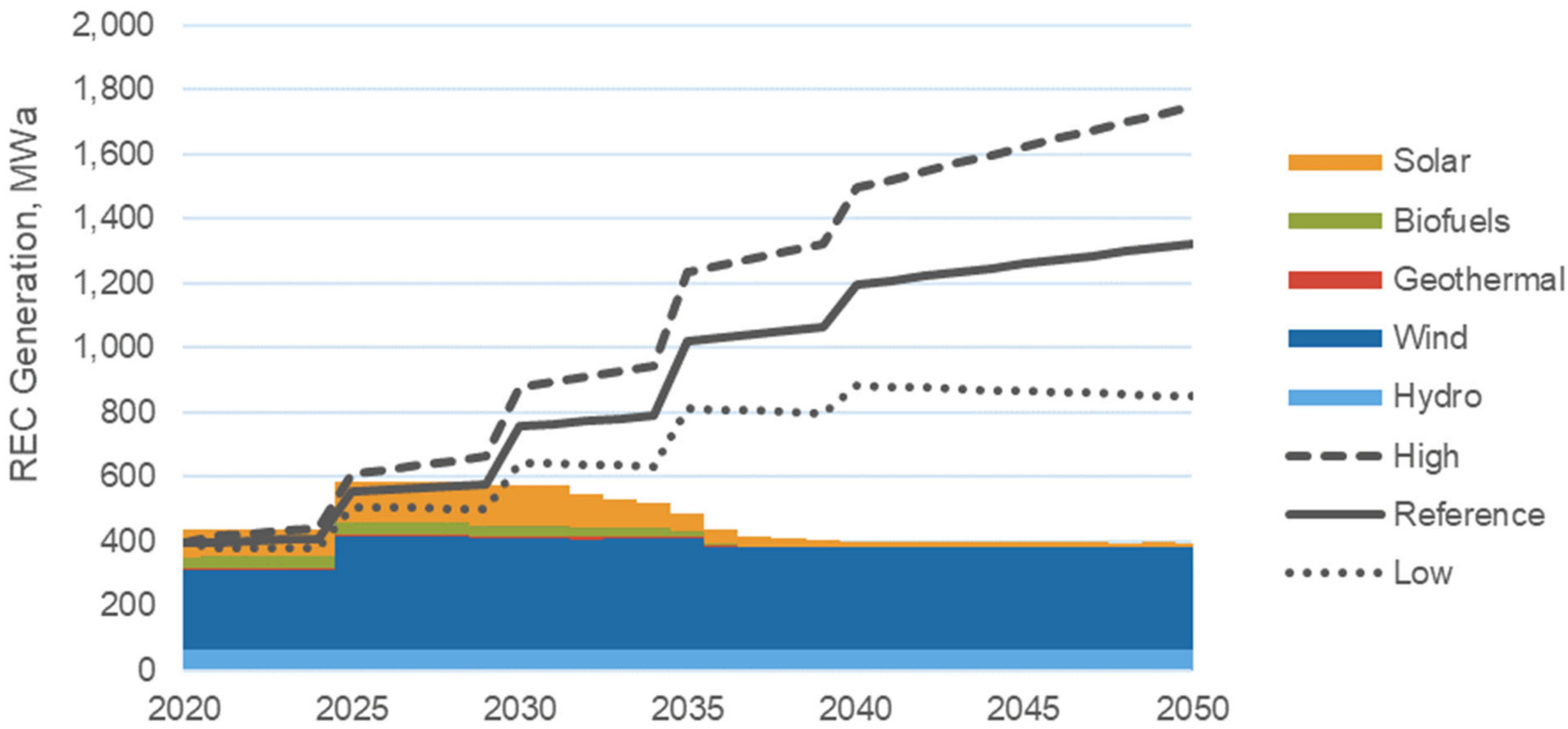
RPS Physical Compliance



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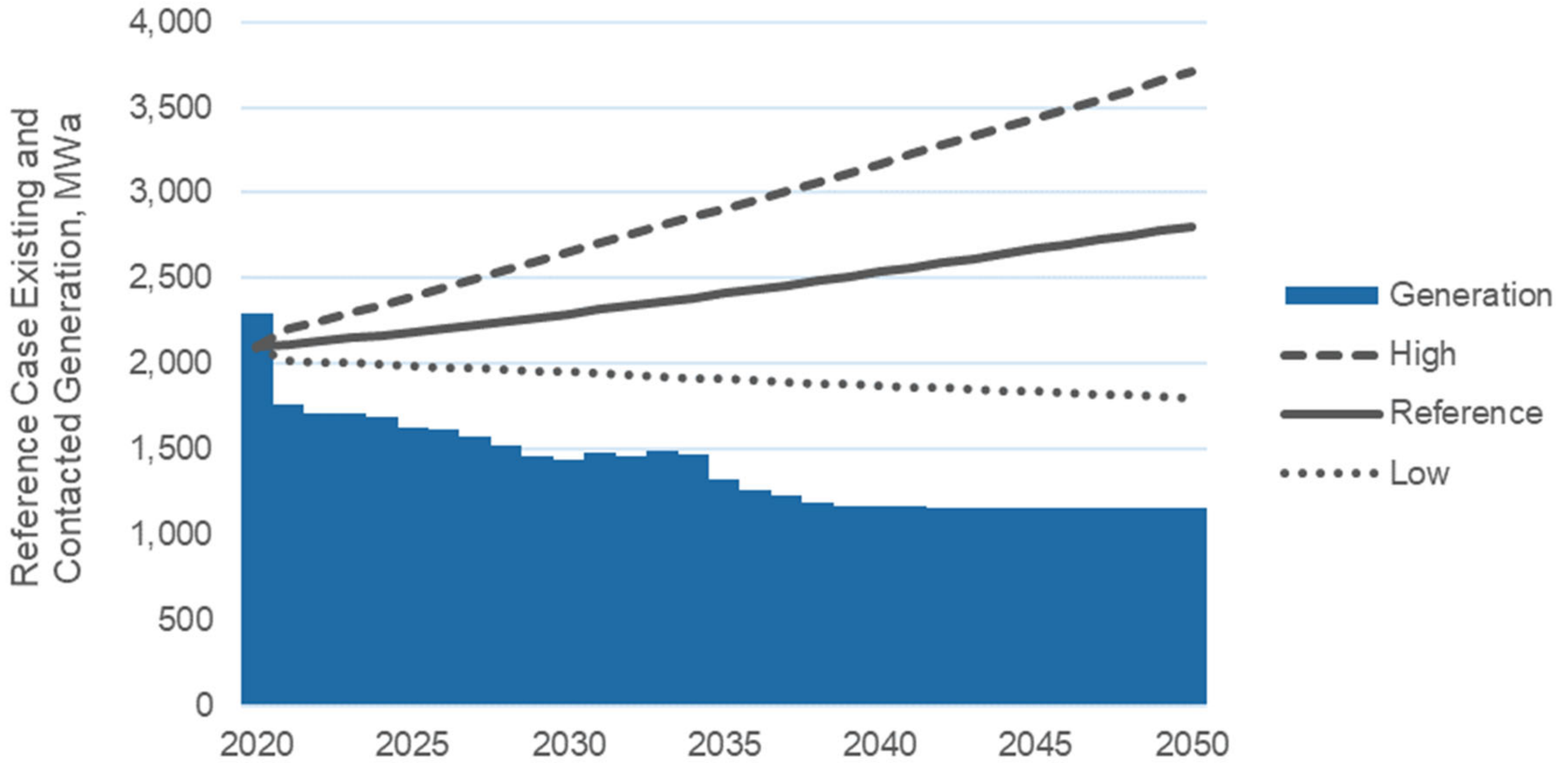
Energy – Economic Dispatch

Economic dispatch of existing resources (including Wheatridge) in the Reference Cost Future



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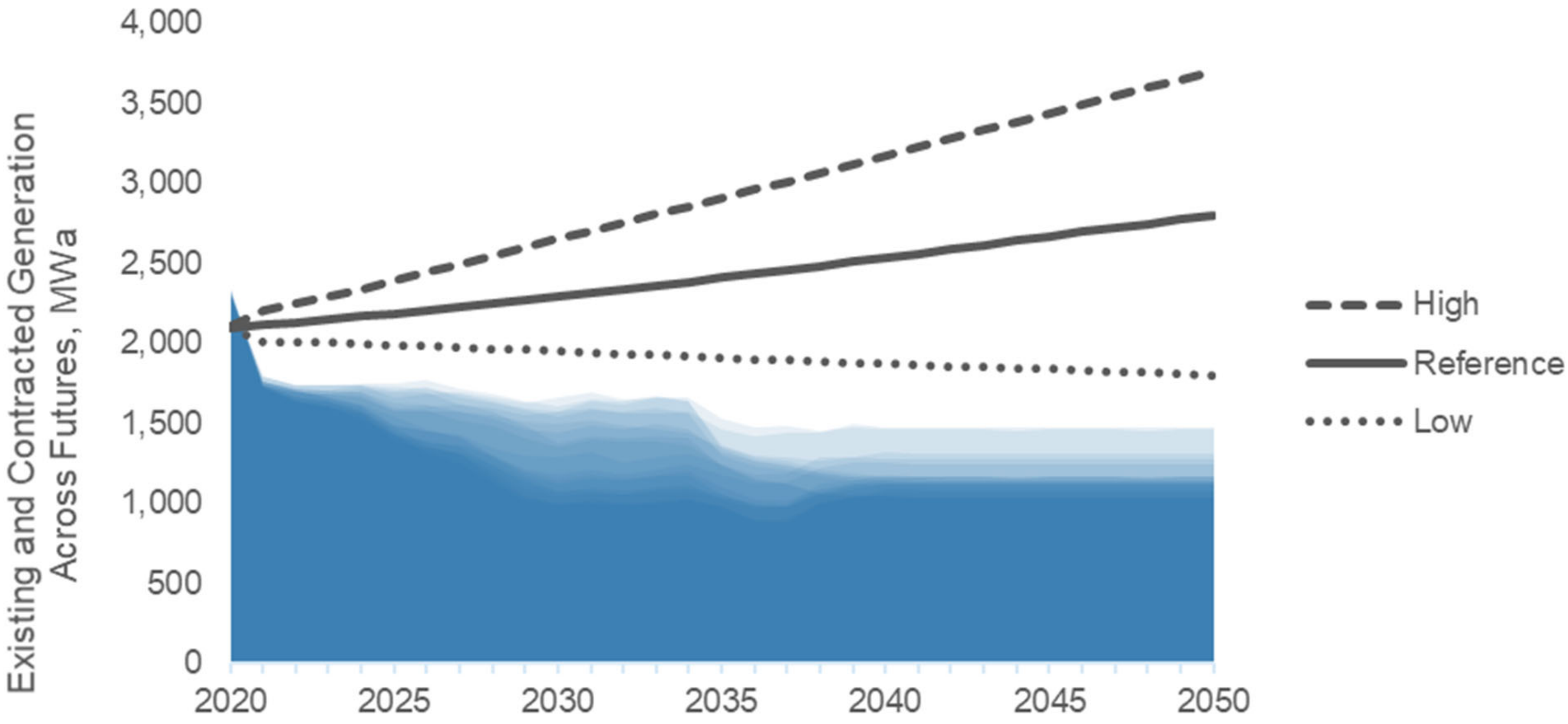
Energy – Economic Dispatch

Existing resources across all cost futures



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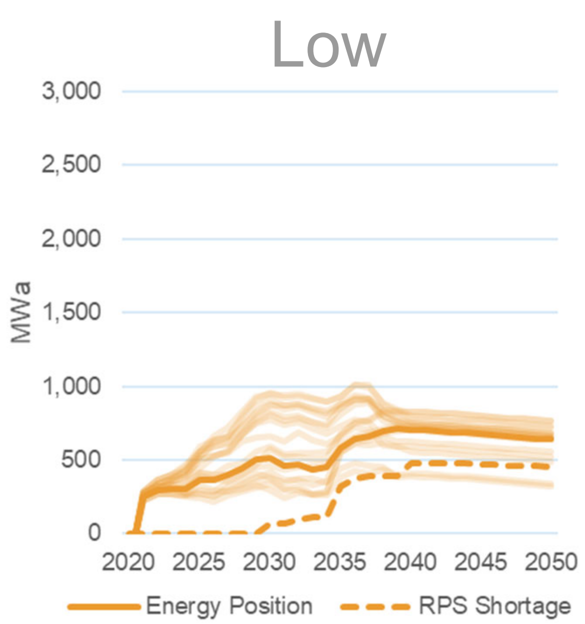
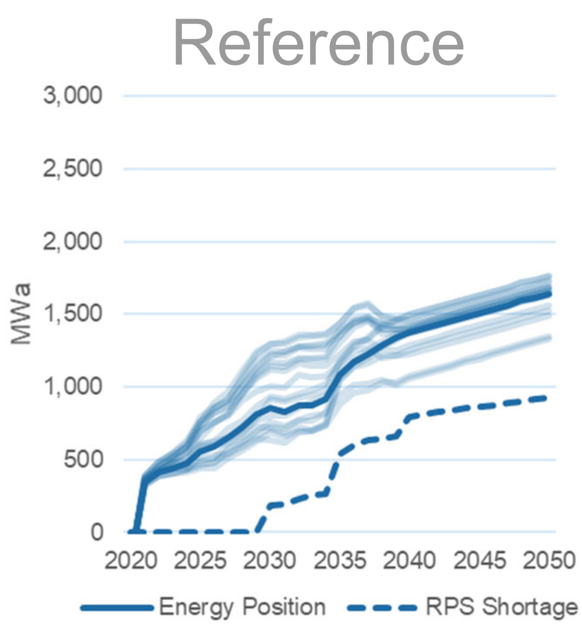
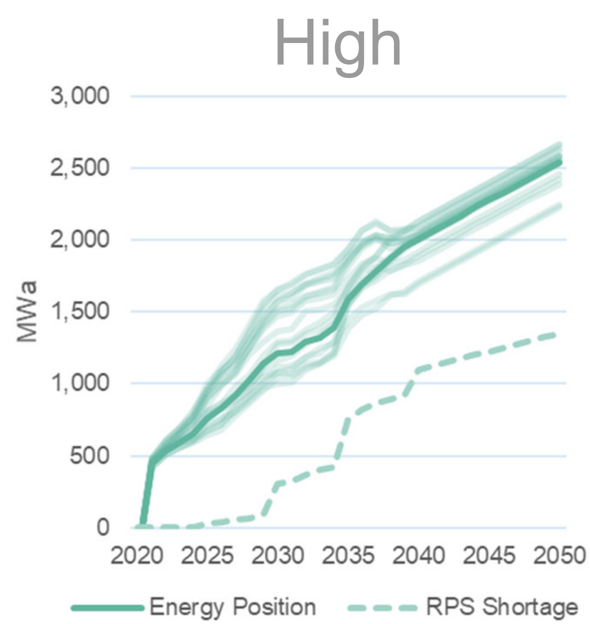
Energy and RPS

Net Market Purchases and Physical RPS Shortage across Need Futures







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Future Considerations

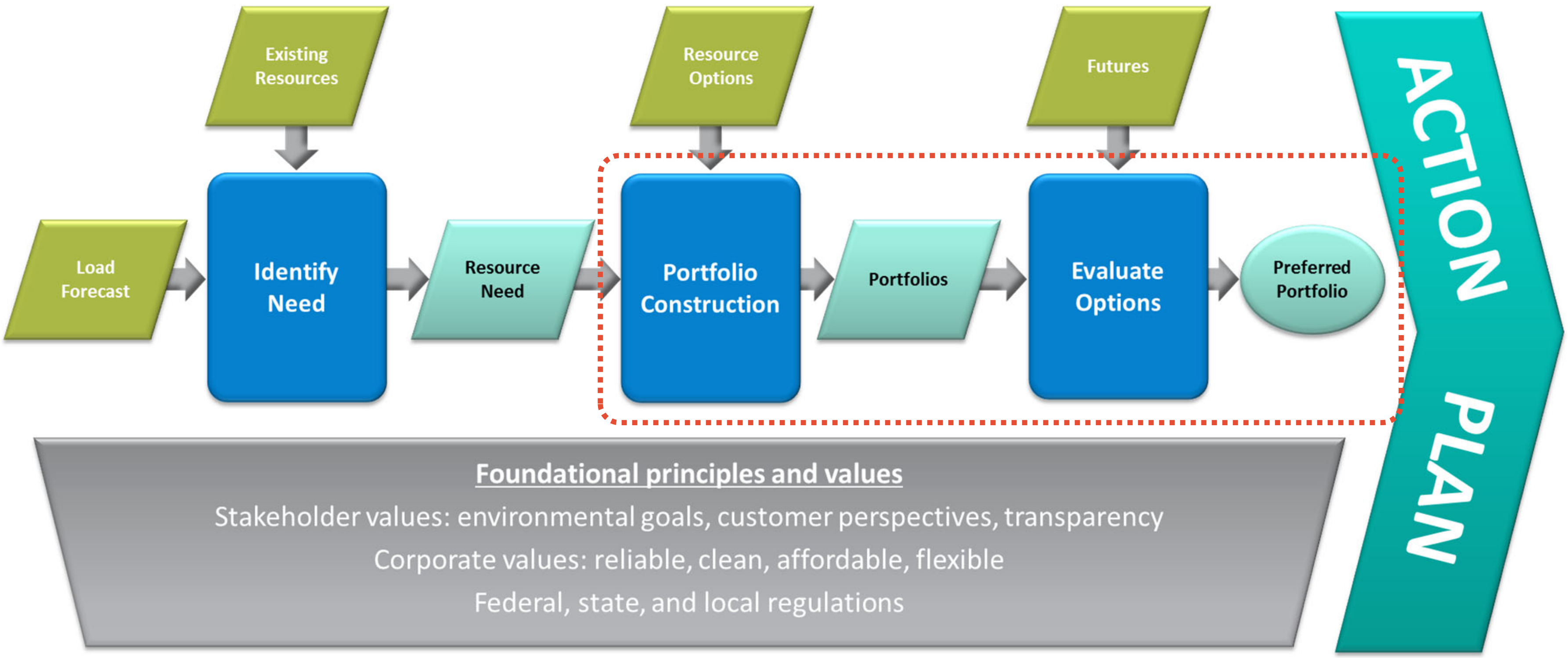
<u>**Capacity Adequacy and ELCC**</u>

- Improve modeling of energy-limited resources, including storage, demand response, and hydro
  - Consider time-sequential model
  - Build on development of profiles in this cycle
  - Continue to improve temperature impacts
- **Automate and reduce complexity while minimizing impacts on quality**

Updated Portfolio Analysis

Elaine Hart

Portfolio Analysis



Portfolio Construction Overview

Portfolio Needs Data

Resource Cost & Performance Data

Portfolio Design Constraints

ROSE-E

Portfolio Optimization

- Solves for near-term actions based on expected portfolio performance across futures and through 2050
- Can use various constraints and objective functions to create a diverse set of portfolios

Near-term Additions

Scoring Optimization

- Minimizes net present value revenue requirement (NPVRR) through 2050 in each future

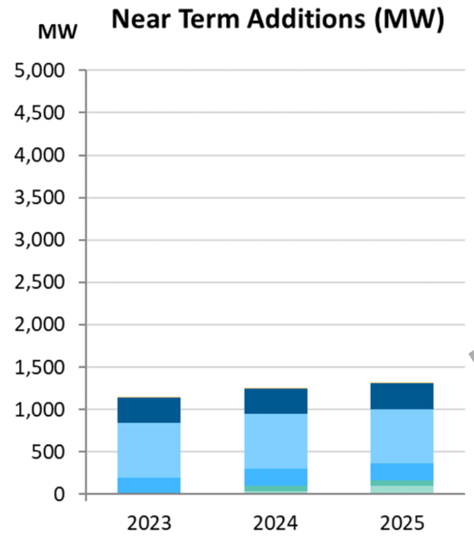
Portfolio Composition Across Futures

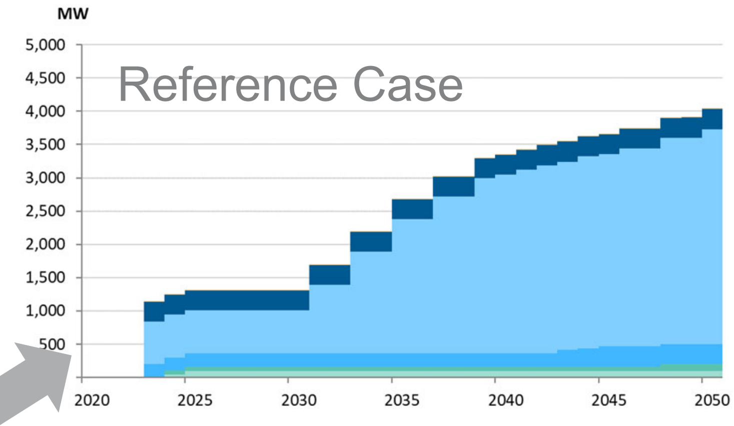
Portfolio Performance Across Futures

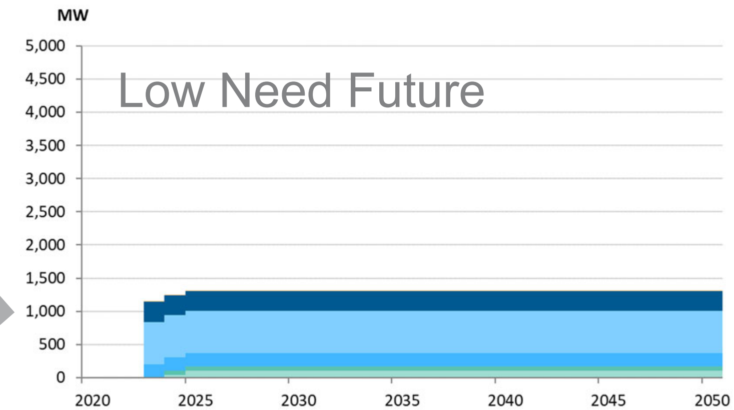
Portfolio Construction Example

Portfolios lock in near-term additions while allowing for flexibility in long-term plans

Portfolio that <u>minimizes cost and GHGs</u> and <u>excludes GHG-emitting resources</u>







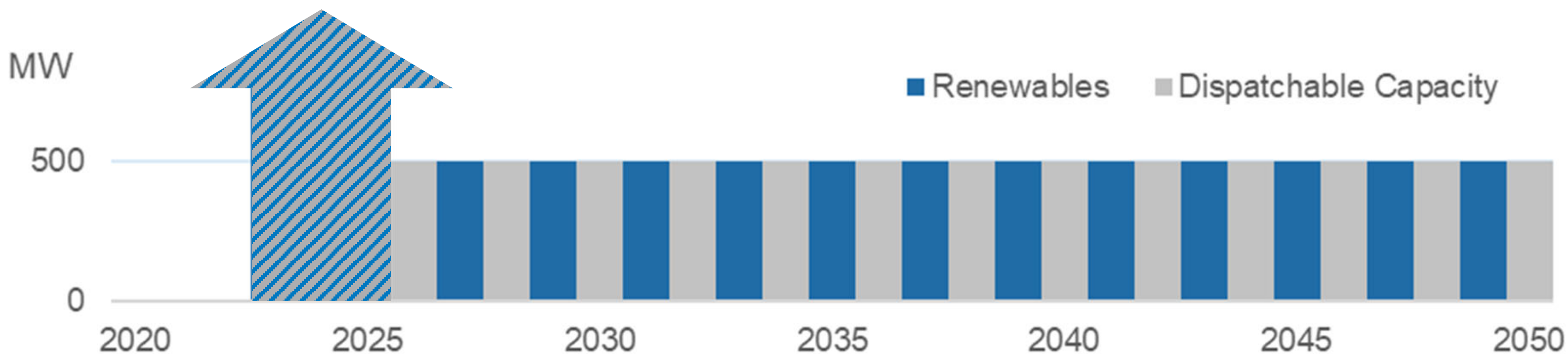
New_SolarPlusStorage, New_Solar, New_Wind_MT, New_Wind_WA, New_Wind_Gorge, New_Wind_Ione, New_PumpedHydro, New_Geothermal, New_Biomass, New_Bat_6h, New_Bat_4h, New_Bat_2h, New_Recips, New_CCCT, New_SCCT, New_LMS100

All data is draft until filed.

Portfolio Construction Updates

1. Procurement constraints

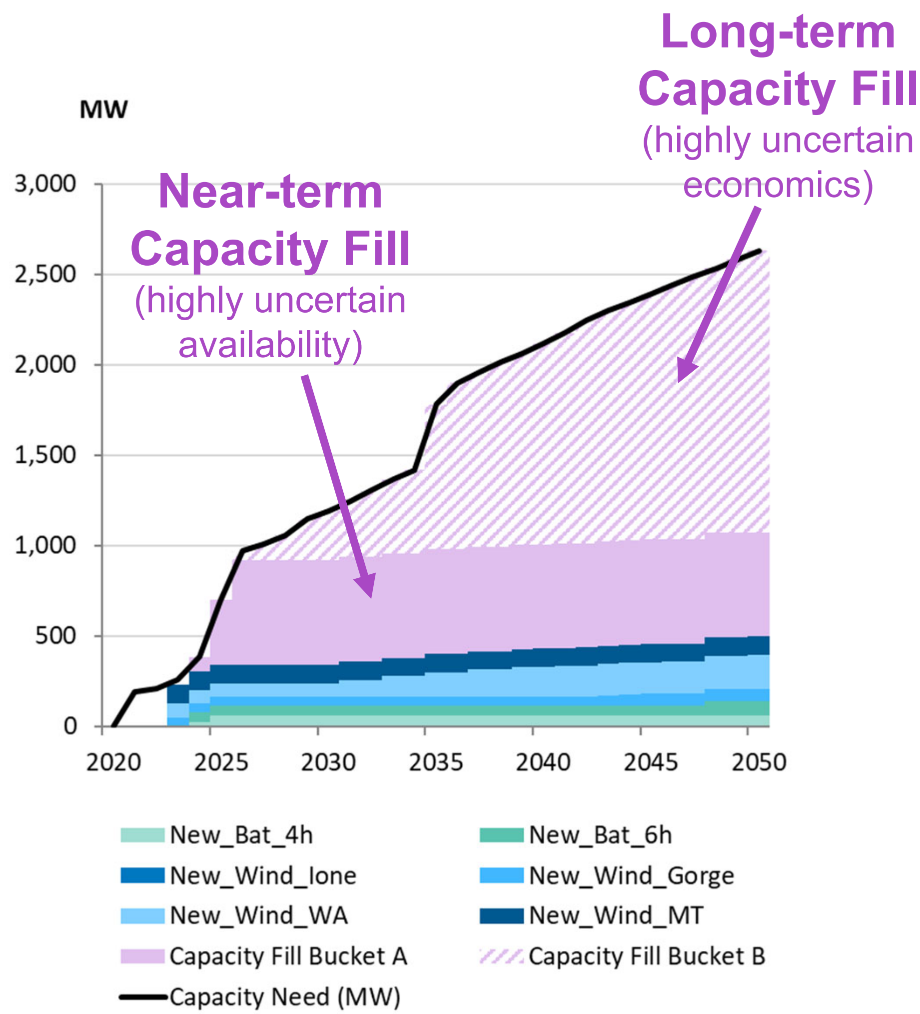
- Near term (through 2025): no constraints on resource additions
- Long term (2026-2050): implemented constraints to approximate realistic procurement cycles
  - Renewable procurement on a two-year cycle, resulting in renewable resource additions in odd years (this constraint is relaxed after 2040)
  - New capacity procurement on a staggered two-year cycle (additions in even years)
  - Maximum size of total additions in each year is capped at 500 MW



Portfolio Construction Updates

2. Capacity Fill

- May represent a combination of contracts, DER, or new resource additions where additional specificity is not possible or uninformative
  - Modeled as fixed price capacity call option
  - Allows portfolio design to focus on resource additions for which needs and economics are more certain
- Near term: limited to the portion of capacity needs driven by expiring contracts
- Long term: unconstrained
- **Action Plan must address all near-term needs even if portfolios rely on "Capacity Fill" in the near term**



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Additional Data Updates

Analysis presented today incorporates the following updates:

Input Data	Updates Implemented
September Load Forecast	Draft analysis incorporates September load forecast, including High and Low Load scenarios in High and Low Need Futures
DER Study output	Draft analysis incorporates draft treatment of outputs from DER Study in Low, Reference, and High Need Futures
Market Capacity Study output	Draft analysis incorporates recommendations from Market Capacity Study in Low, Reference, and High Need Futures
Dispatch results	Draft analysis makes use of updated dispatch simulation results
Finalized flexibility analysis results	Draft analysis incorporates final renewable integration costs and first draft of flexibility value for dispatchable resources
Finalized cost and performance data	Draft analysis incorporates updated renewable cost and performance data for Reference, Low, and High Technology Cost Futures
Outcome of Renewables RFP	Draft analysis incorporates Wheatridge Renewable Energy Facility
Existing and contracted resources.	Existing and contracted resource characterizations updated consistent with 2019 GRC. QFs executed through December 18, 2018 included. Existing and contracted resource fixed costs are draft.

Portfolio Overview

Portfolios

- Optimized Portfolios
- Renewable Size and Timing Portfolios
- Renewable Resource Portfolios
- Dispatchable Capacity Portfolios

Portfolio Scoring

Preferred Portfolio

Scoring Metrics

Traditional Metrics

- Cost – Net present value revenue requirement (NPVRR) through 2050
- Variability – Semi-deviation of NPVRR across futures
- Severity – TailVAR90 of NPVRR across futures

Non-Traditional Metrics

- Portfolio Cumulative GHGs
- Near-term cost
- New Resource Criteria Pollutants*
- GHG-constrained cost
- Cost in High Tech Future
- Energy additions through 2025

*The “New Resource Criteria Pollutant” metric is expressed as the sum of cumulative NO_2, SO_2, and Particulate Matter emissions from new resources through 2050, in short tons.

All data is draft until filed.

Optimized Portfolios

Optimized Portfolios

- Utilizes portfolio optimization to design portfolios that meet various objectives
  - **Min Avg LT Cost** – Minimizes average NPVRR through 2050 across futures
  - **Min Avg LT Cost, All Clean** - Minimizes average NPVRR through 2050 across futures with only GHG-free resources
  - **Min Ref LT Cost** – Minimizes Reference Case NPVRR through 2050
  - **Min Ref LT Cost, All Clean** - Minimizes Reference Case NPVRR through 2050 with only GHG-free resources
  - **Min Avg ST Cost** – Minimizes average NPVRR through 2025 across futures
  - **Min Avg ST Cost, All Clean** - Minimizes average NPVRR through 2025 across futures with only GHG-free resources
  - **Min Ref ST Cost** – Minimizes Reference Case NPVRR through 2025
  - **Min Ref ST Cost, All Clean** - Minimizes Reference Case NPVRR through 2025 with only GHG-free resources
  - **Min Risk** – Minimizes semi-deviation of NPVRR through 2050 across futures, subject to maximum Reference Case NPVRR
  - **Min Risk All Clean** - Minimizes semi-deviation of NPVRR through 2050 across futures with only GHG-free resources, subject to maximum Reference Case NPVRR
  - **Min GHG + Cost** – Minimizes the sum of the average NPVRR through 2050 across futures and the cumulative emissions across futures

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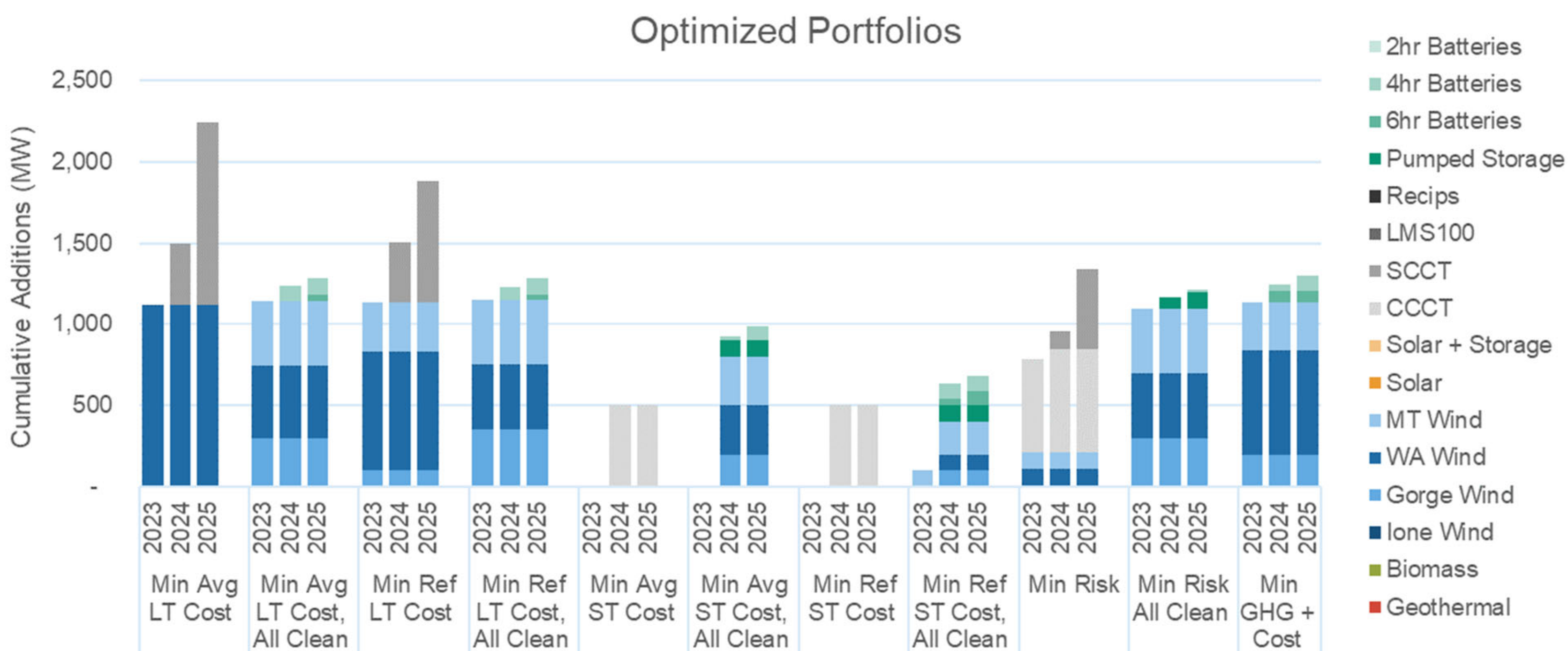
Optimized Portfolios

Utilizes portfolio optimization to design portfolios that meet various objectives



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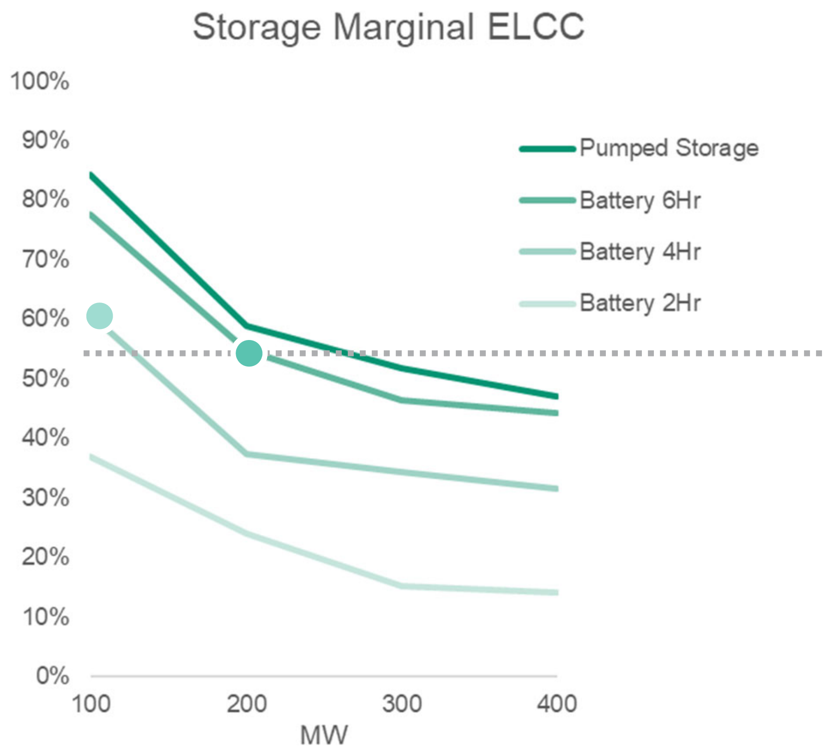
Portfolio Diversity

- Draft results approximate diversity benefits due to portfolio optimization methodology
- May overestimate diversity benefits for similar resources, may underestimate diversity benefits for complementary resources



Consider a portfolio that has selected 100 MW of 6-hr batteries.

For the next tranche of capacity, 100 MW of 4-hr batteries appears to have a higher capacity contribution than the next 100 MW of 6-hr batteries

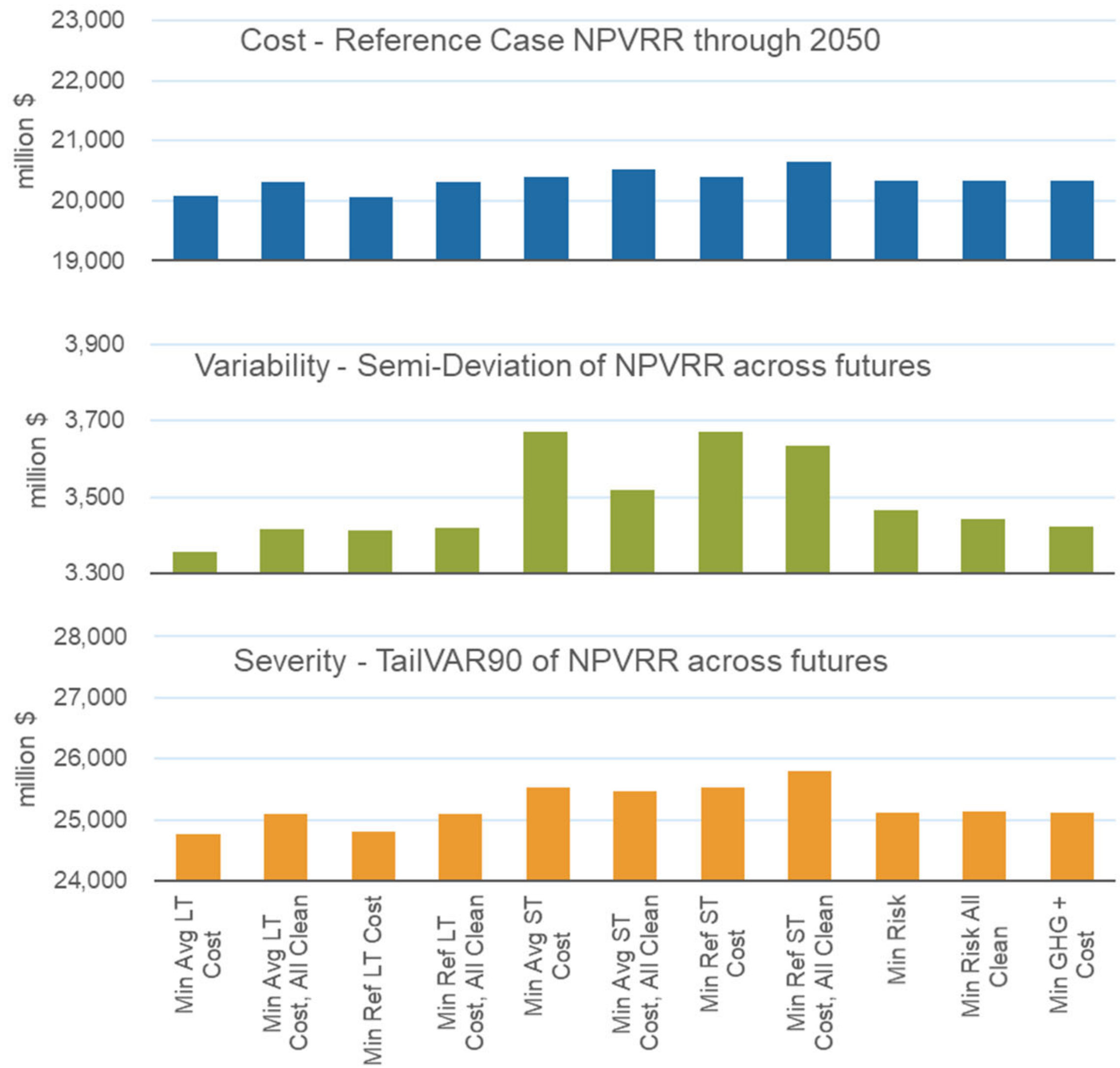
All data is draft until filed.

Optimized Portfolio Scoring

Cost metric is comparable across portfolios, but lower for those that are optimized on long-term cost

Variability is much higher for portfolios that prioritize reducing near-term cost

Severity follows similar but muted trend to Variability



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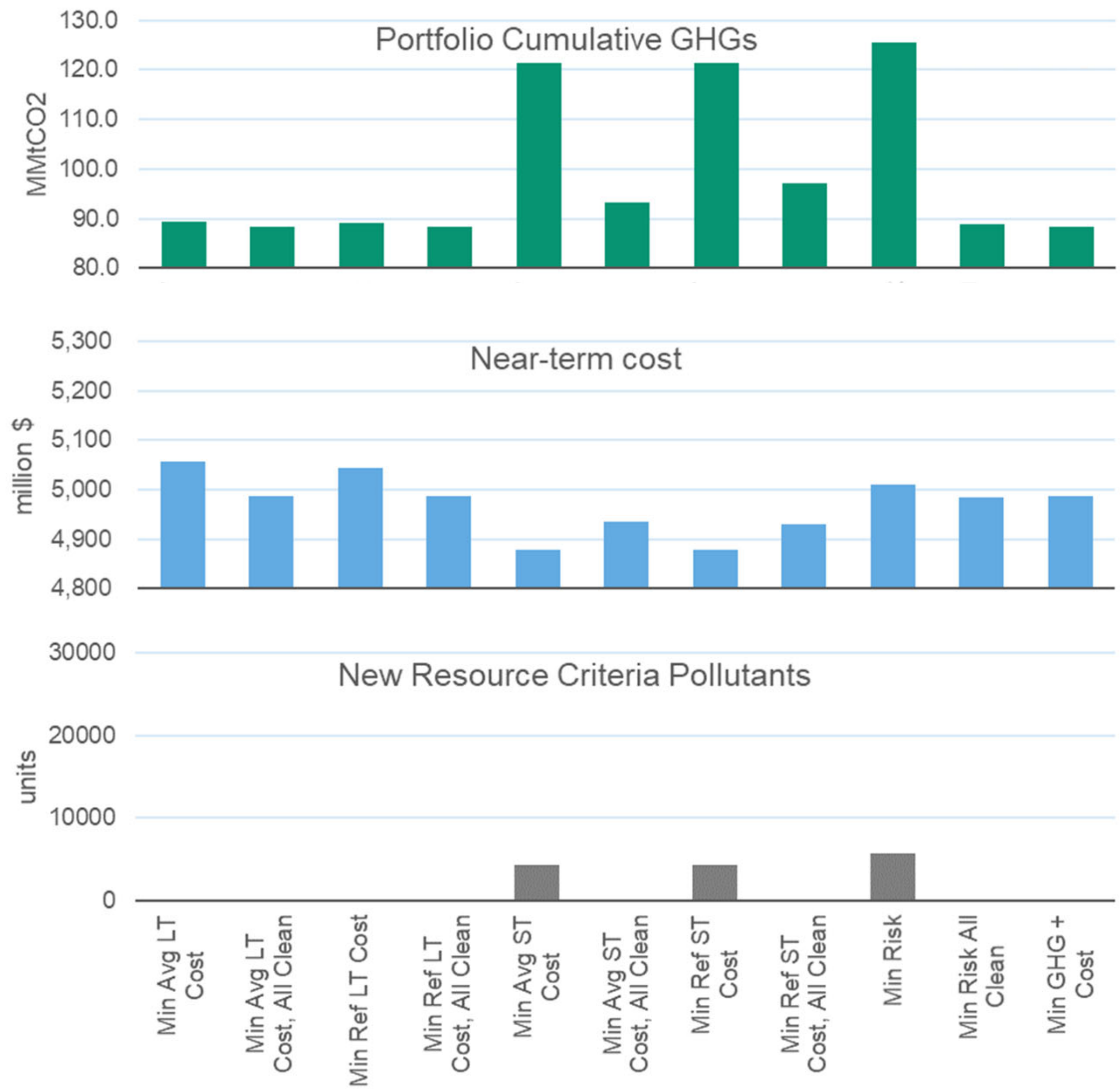
Portfolio GHGs and criteria pollutants are highest for optimized portfolios that include CCCT

Near-term costs are lower for portfolios that minimized near-term cost

Optimized Portfolio Scoring



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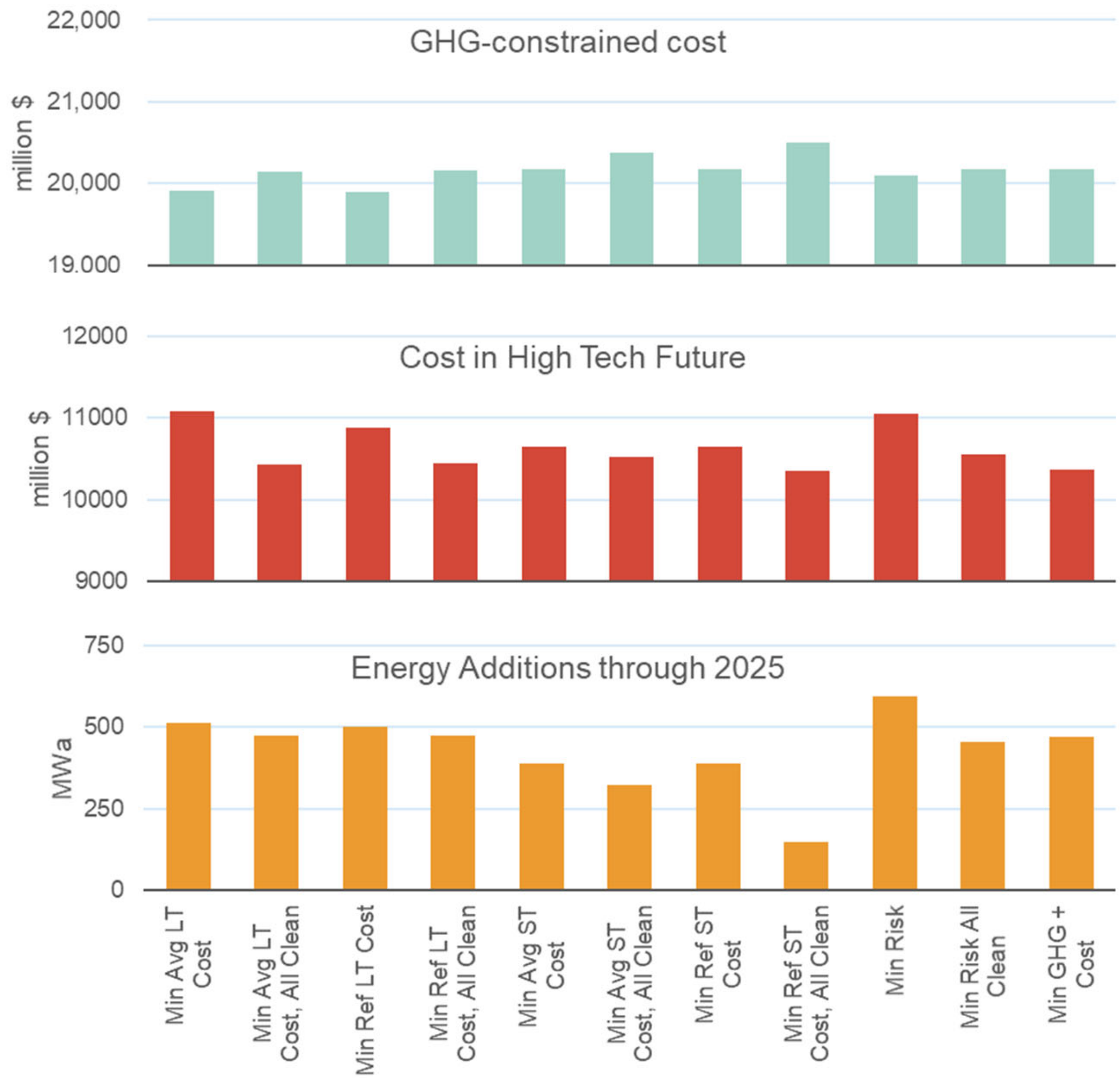
Optimized Portfolio Scoring

GHG-Constrained Cost reflect same patterns as traditional cost metric

Cost in the High Tech Future is relatively high across optimized portfolios, but lowest for those that exclude thermal resources



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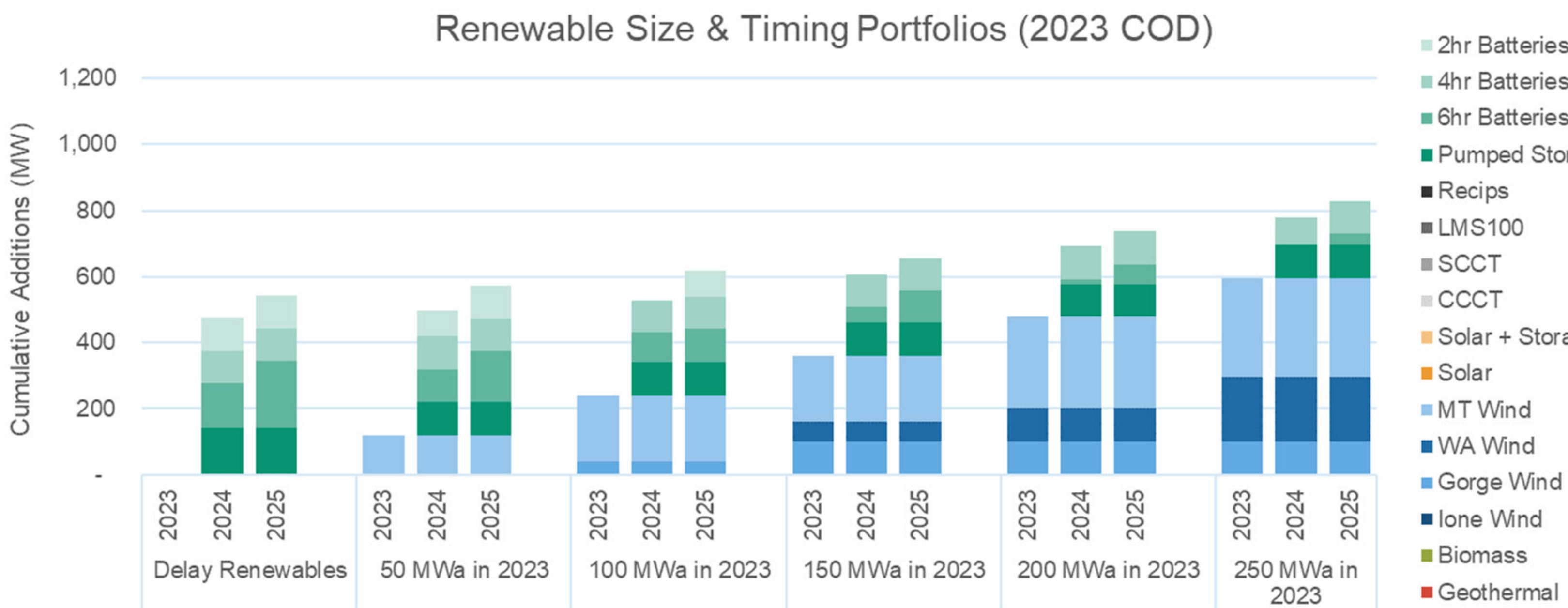
Renewable Size and Timing Portfolios

Renewable Size and Timing Portfolios

- Tests renewable resource economics as a function of both procurement size (MWa) and online date (COD)
- These portfolios require a specified amount of RPS-eligible energy to be procured in a specified year, but allow for the optimal selection of the RPS-eligible resource(s) within that requirement



Note: Resources are assumed to come online by December 31st in the year prior to the listed COD to qualify for tax credits

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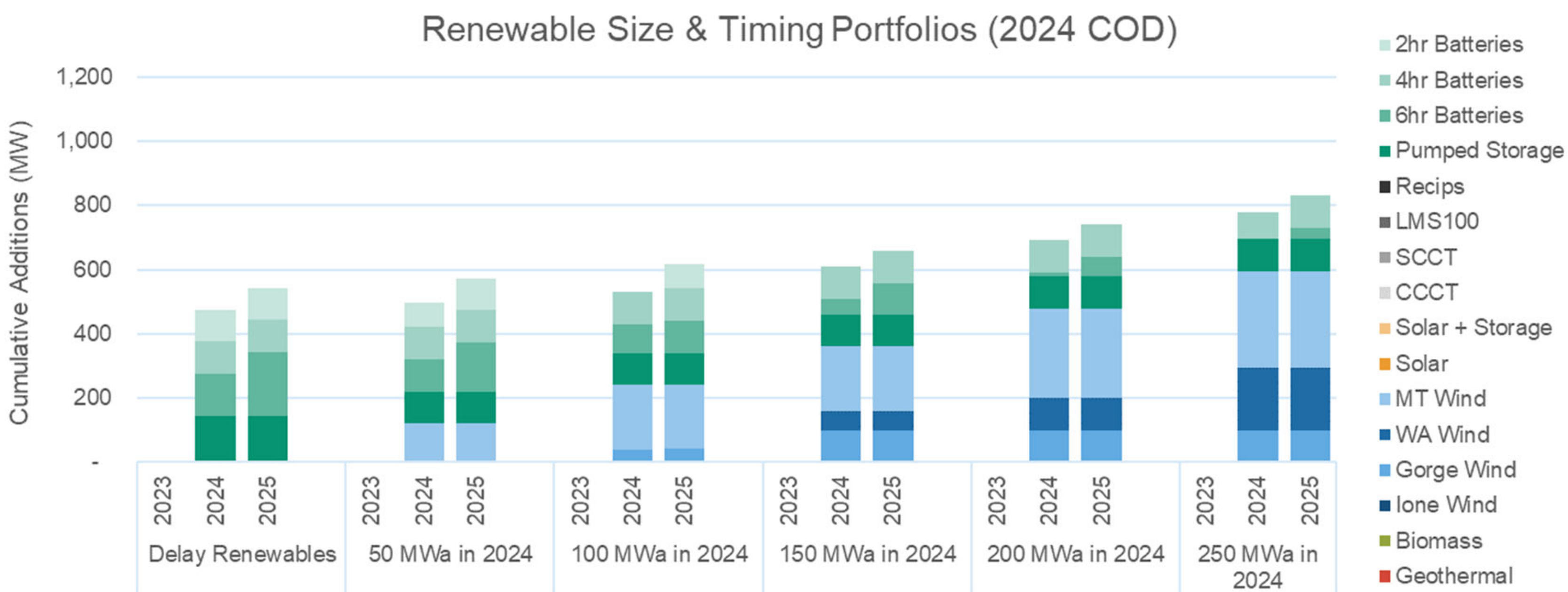
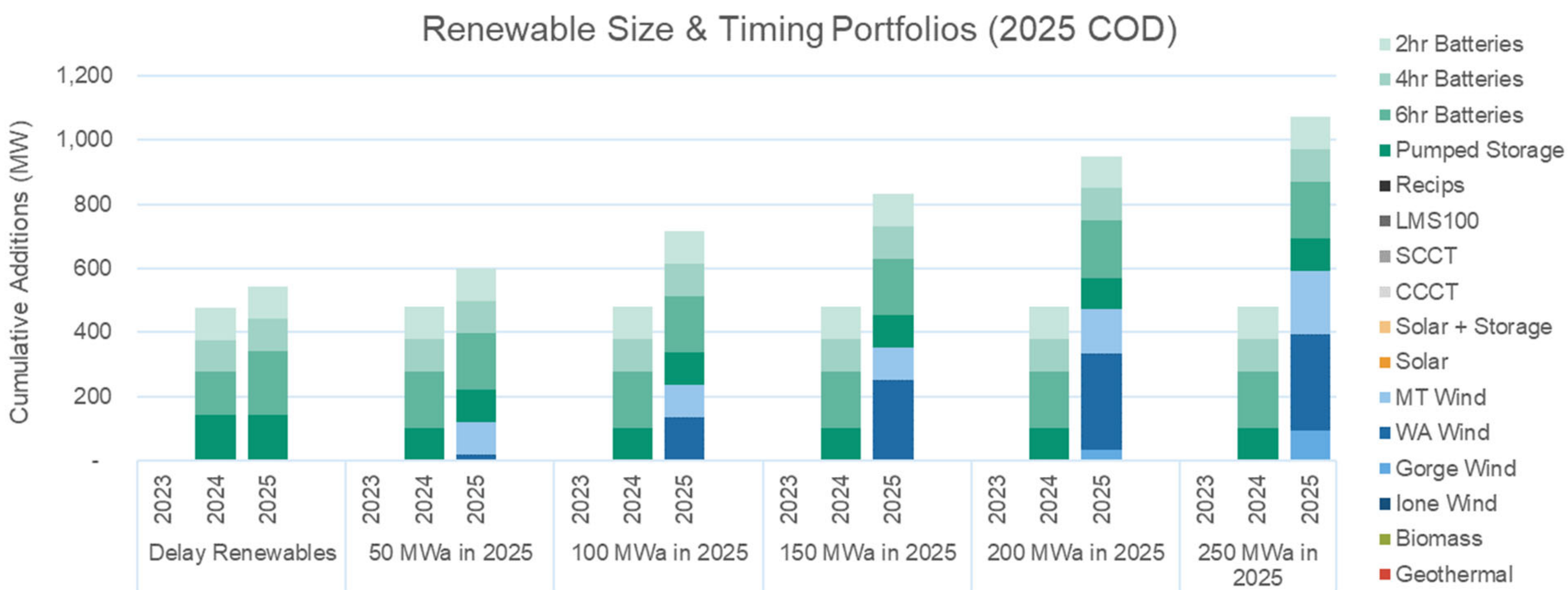


Note: Resources are assumed to come online by December 31st in the year prior to the listed COD to qualify for tax credits

All data is draft until filed.

Renewable Size and Timing Portfolios

- Tests renewable resource economics as a function of both procurement size (MWa) and online date (COD)
- These portfolios require a specified amount of RPS-eligible energy to be procured in a specified year, but allow for the optimal selection of the RPS-eligible resource(s) within that requirement



Note: Resources are assumed to come online by December 31st in the year prior to the listed COD to qualify for tax credits

All data is draft until filed.

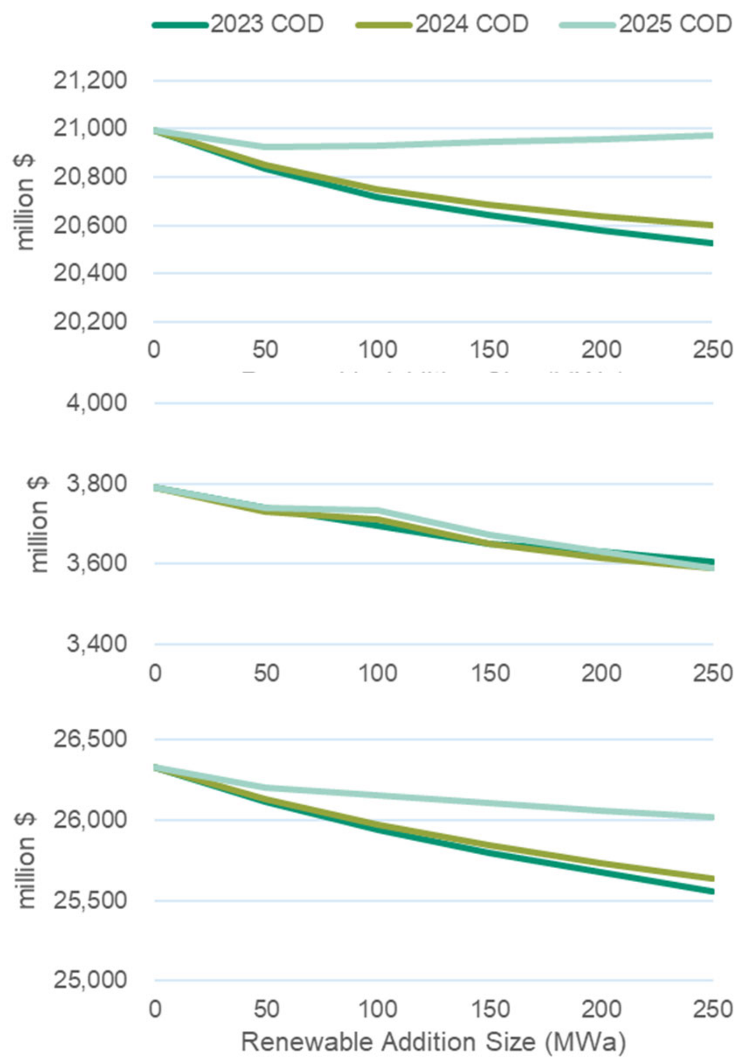
Renewable Size & Timing Scoring

Renewable procurements in 2023 and 2024 show benefits relative to delayed procurement across traditional cost and risk metrics due to expiring PTC and capacity benefits

Cost
Reference Case NPVRR through 2050

Variability
Semi-deviation of NPVRR across futures

Severity
TailVAR90 of NPVRR across futures



All data is draft until filed.

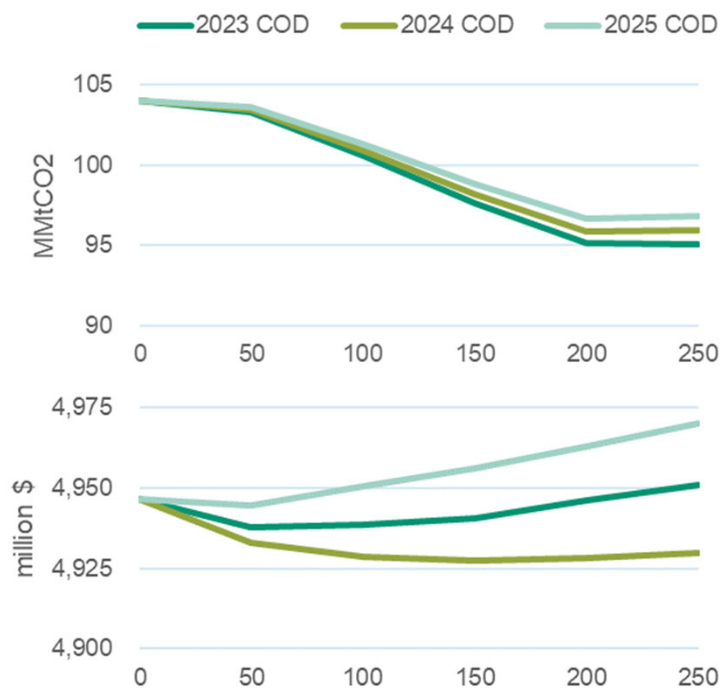
Early procurement and larger size has small impact on cumulative GHGs

Early renewable procurement appears to reduce near-term costs due to avoided need for near-term storage

Renewable Size & Timing Scoring

Portfolio cumulative GHGs

Near-term cost
NPVRR through 2025



New Resource Criteria Pollutants

[None – these portfolios are constrained to not add thermal resources]

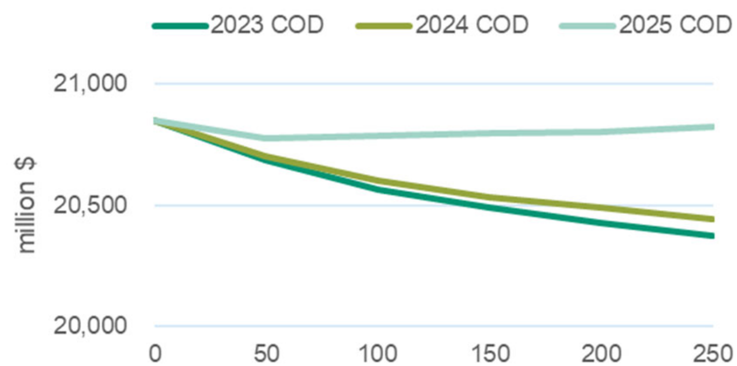
All data is draft until filed.

Renewable Size & Timing Scoring

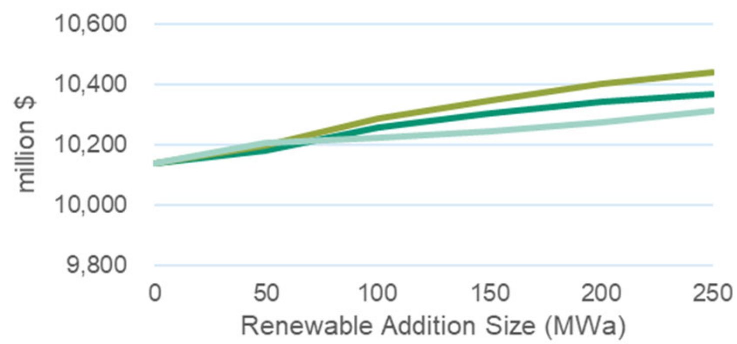
GHG-constrained costs reflect same patterns as traditional Cost metric

Cost in High Tech Future increases with addition size, 2024 COD highest cost for addition sizes larger than 50 MWa

GHG-constrained cost



Cost in High Tech Future

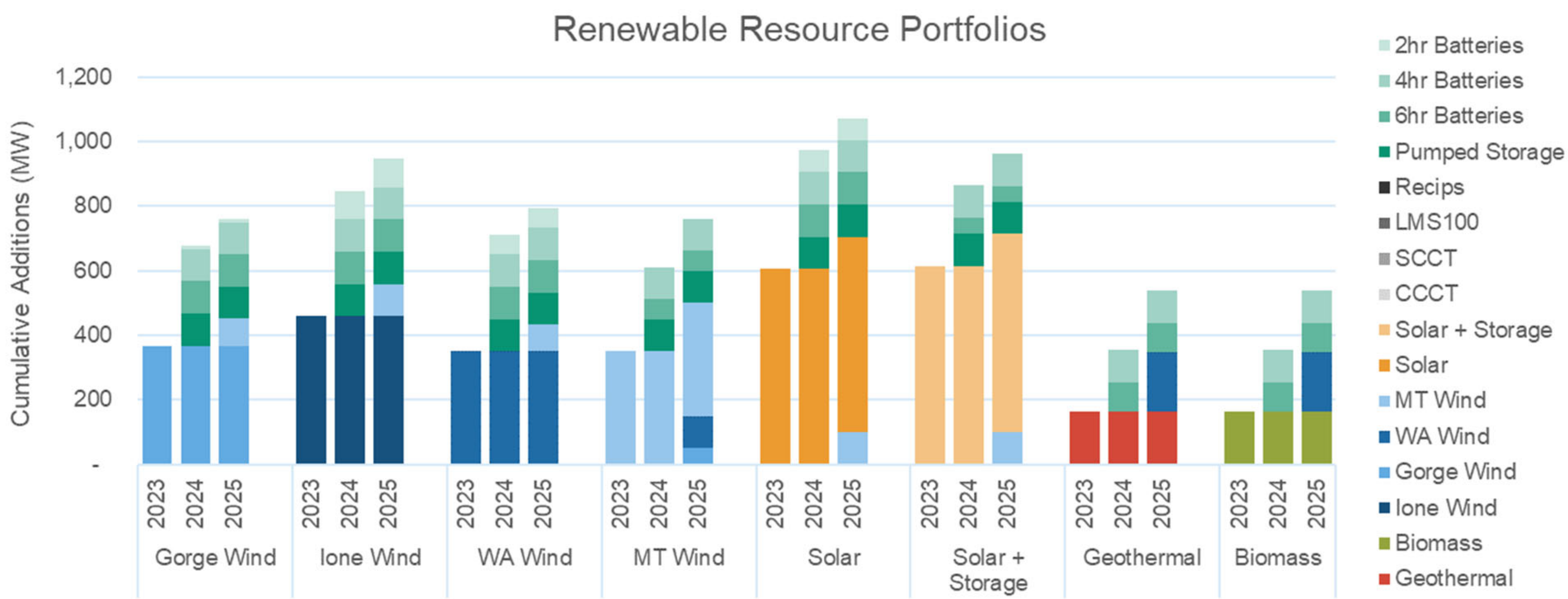


All data is draft until filed.

Renewable Resource Portfolios

Renewable Resource Portfolios

- Investigates resource economics across various renewable resource types
- Each portfolio assumes 150 MWa renewable addition by 2023 (December 31, 2022), excludes thermal generation

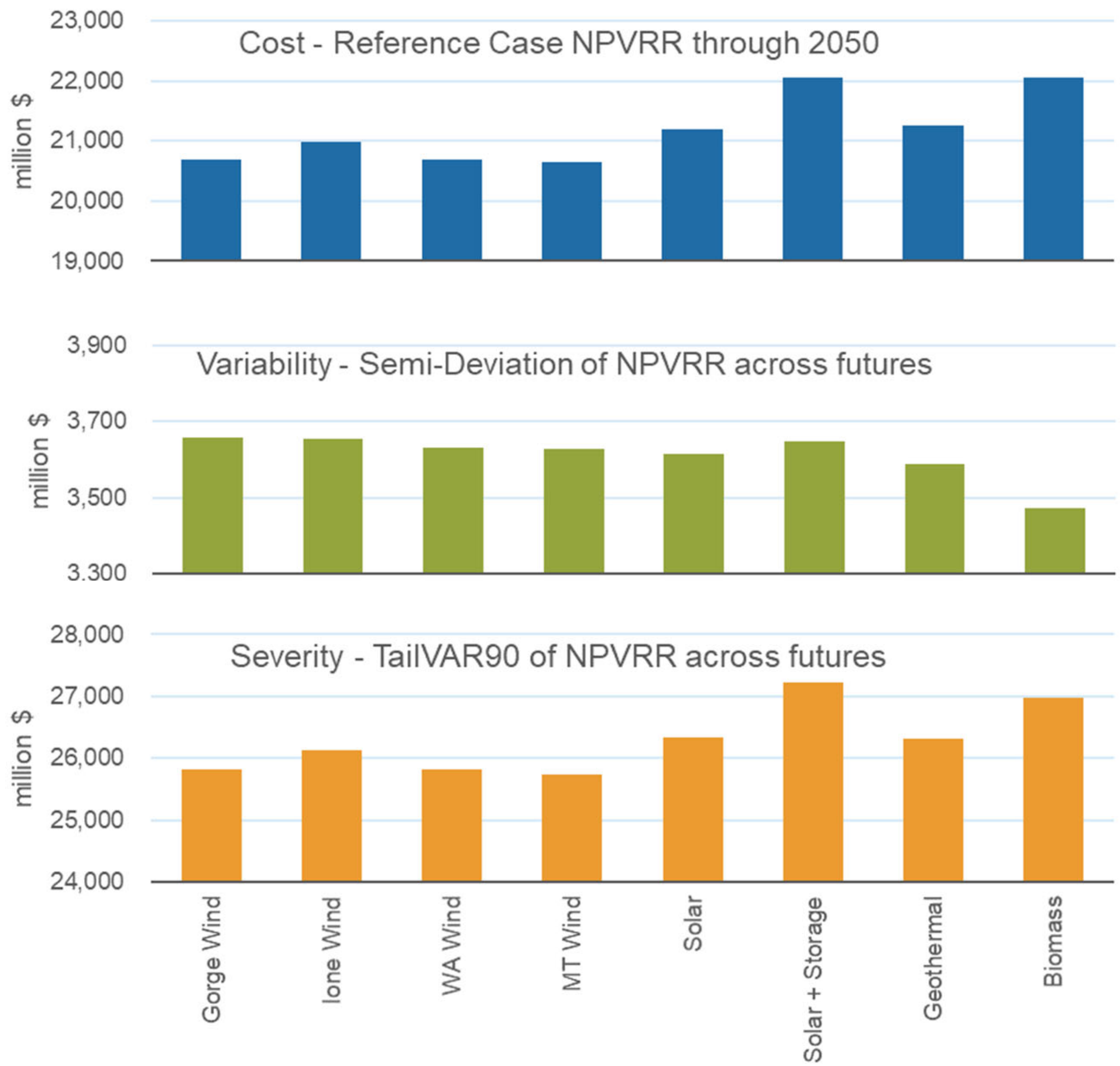


All data is draft until filed.

Renewable Resource Scoring

Wind portfolios perform the best with respect to Cost and Severity

Renewable resources have comparable Variability scores with the exception of Biomass



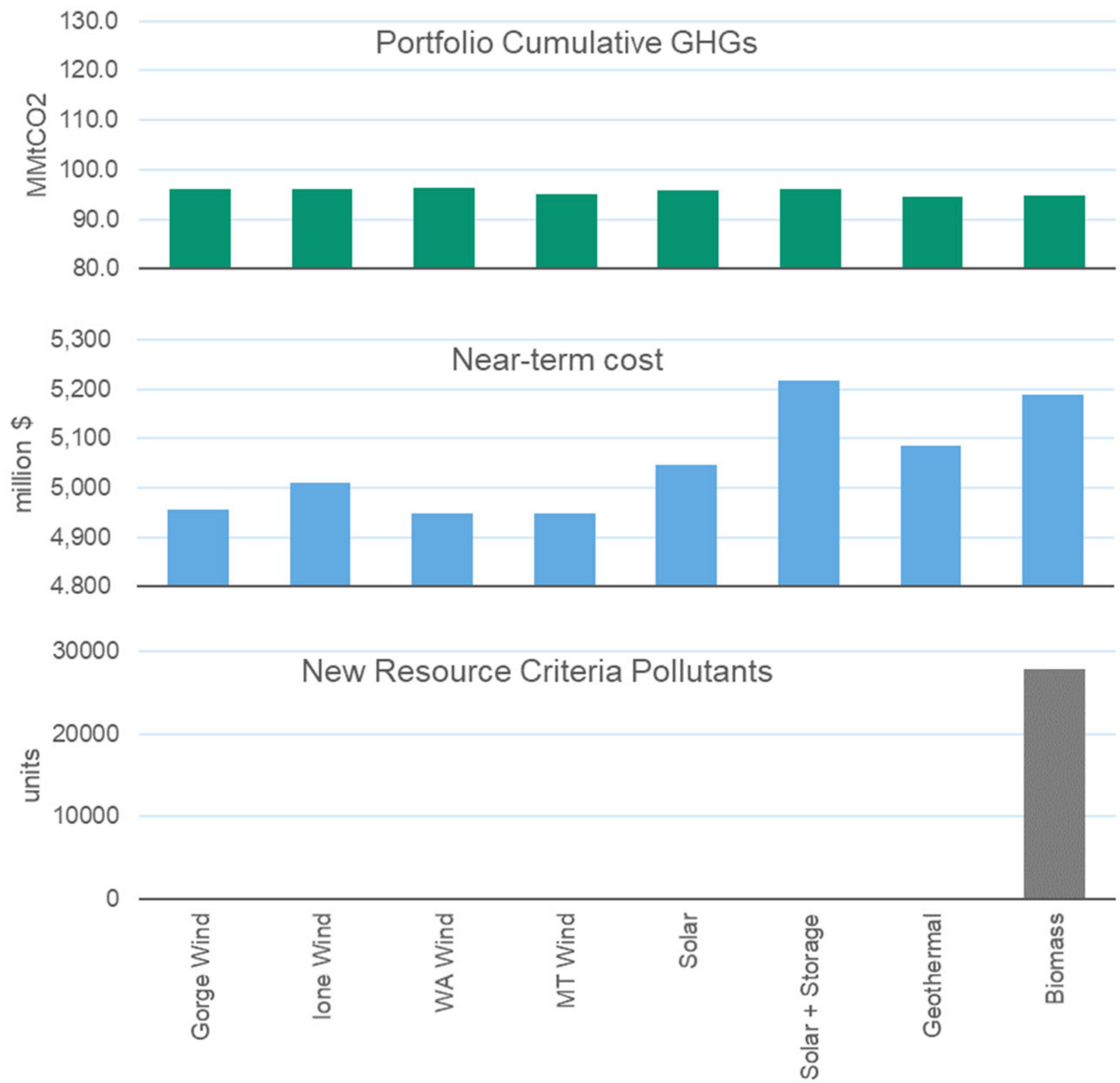
All data is draft until filed.

Renewable Resource Scoring

Similar GHG implications across renewable resource types

Near-term costs reflect same pattern as traditional Cost metric

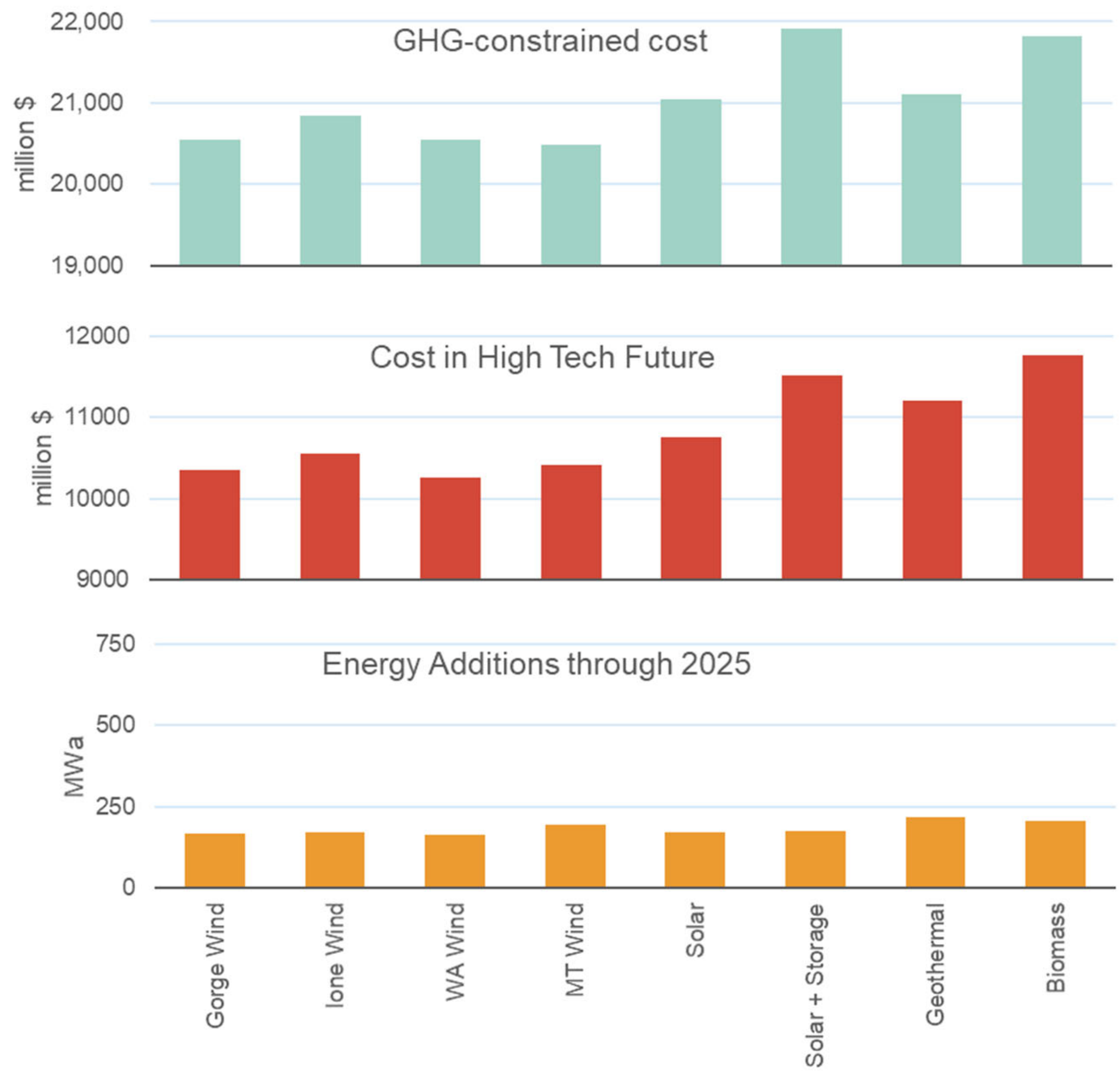
Biomass would have significant implications for criteria pollutants



All data is draft until filed.

Renewable Resource Scoring

GHG-Constrained Cost and Cost in High Tech Future reflect similar patterns to traditional cost metric

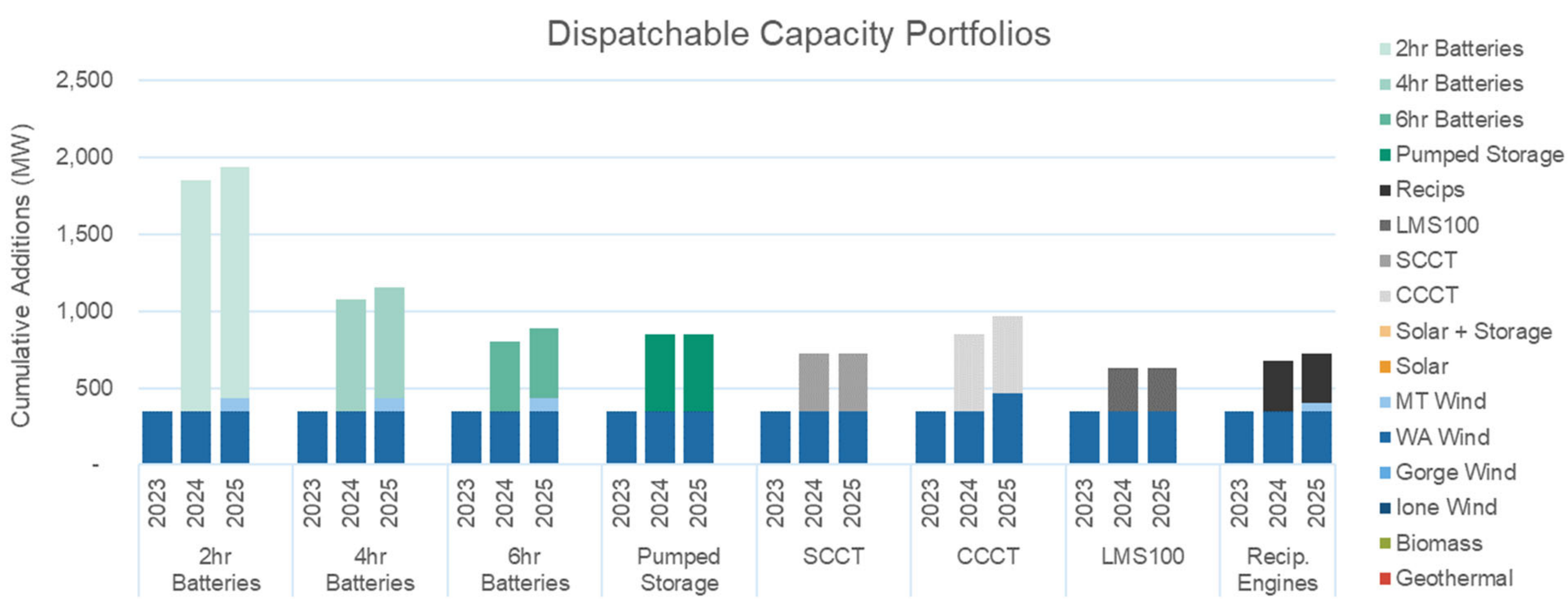


All data is draft until filed.

Dispatchable Capacity Portfolios

Dispatchable Capacity Portfolios

- Investigates resource economics across various dispatchable capacity technologies
- Each portfolio assumes 150 MWa Washington Wind addition in 2023



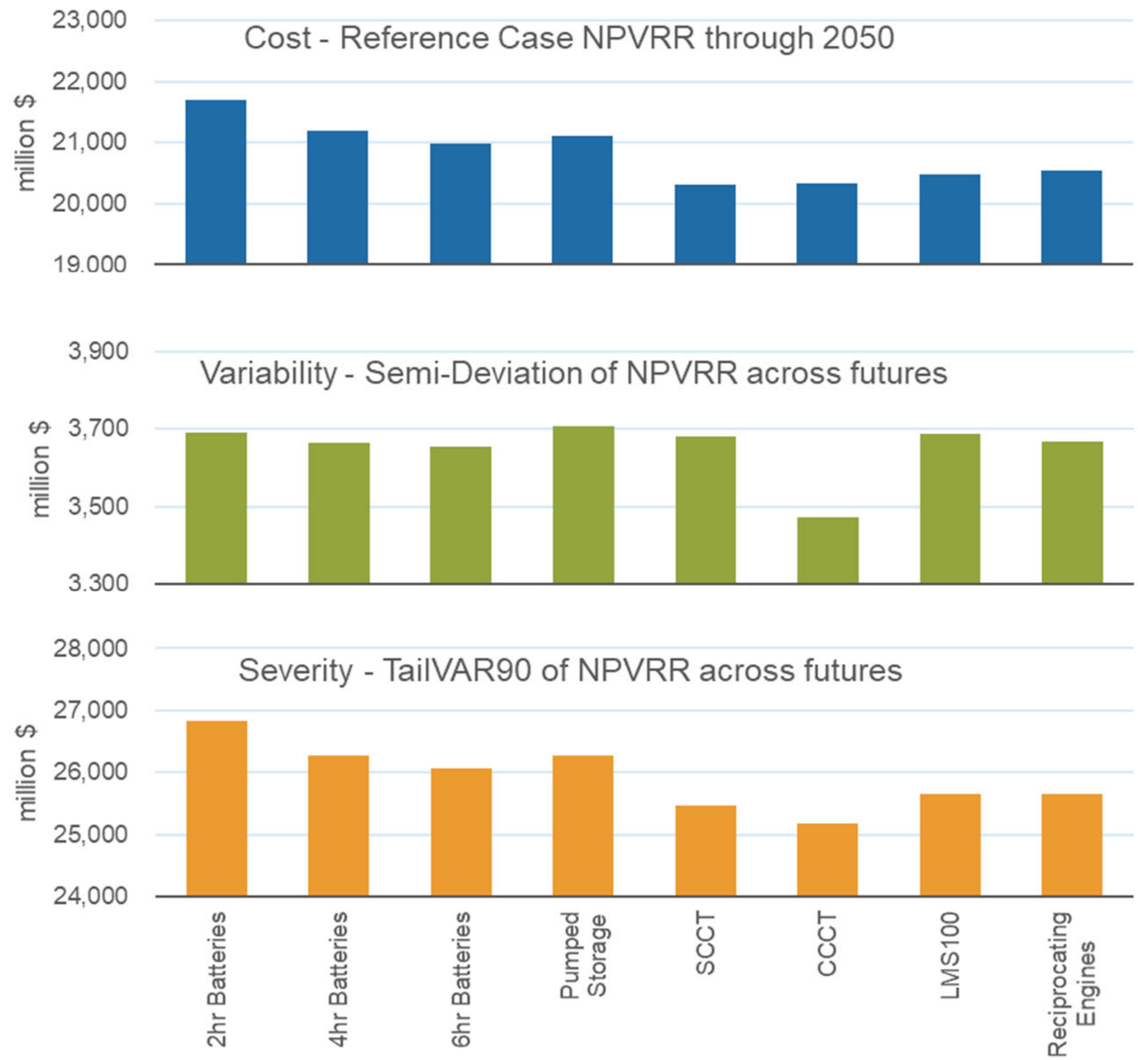
All data is draft until filed.

Dispatchable Capacity Scoring

Cost metric is comparable between 4hr, 6hr batteries and pumped storage, lower for thermal technologies

Variability is similar across technologies, except CCCT

Severity follows similar trends to Cost metric



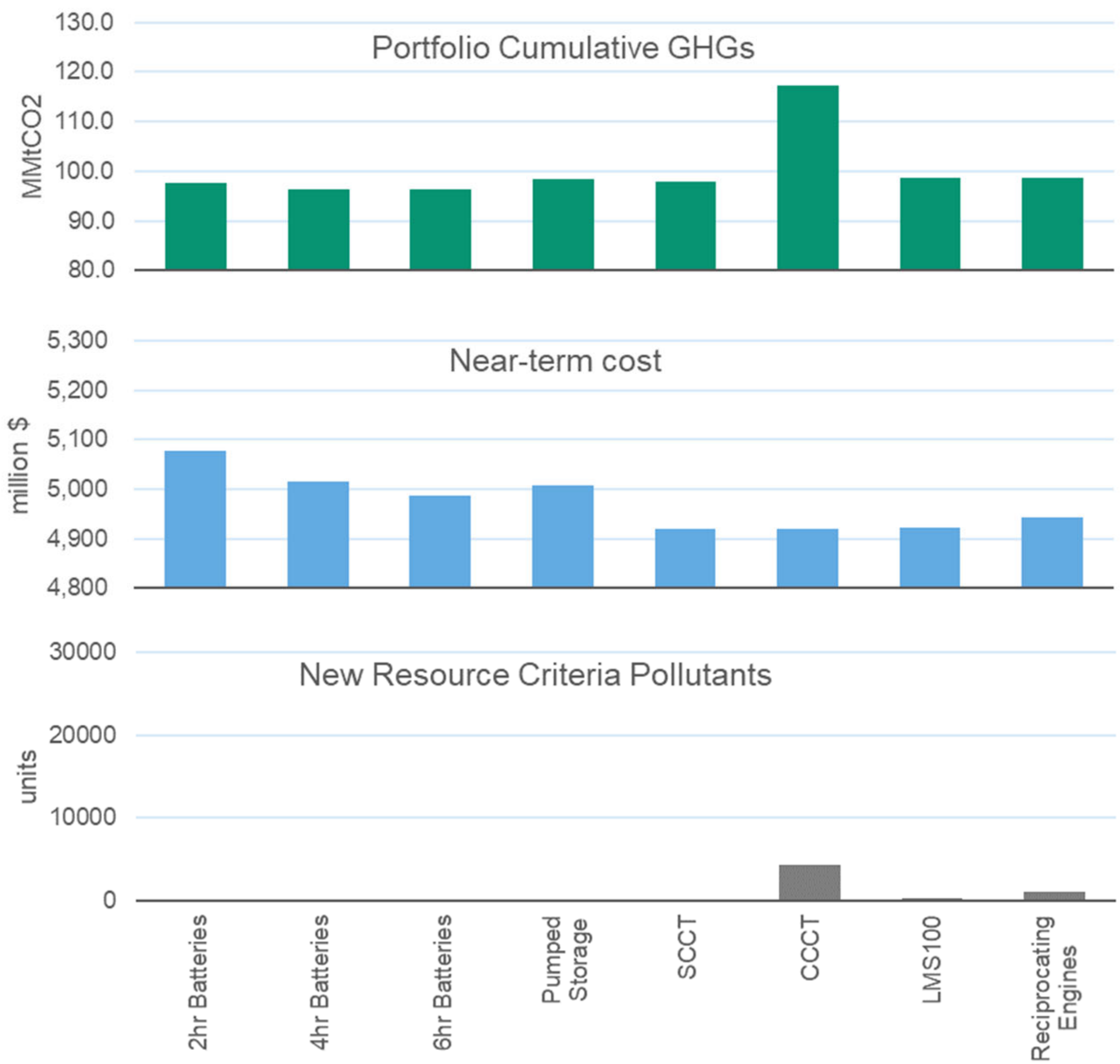
All data is draft until filed.

Dispatchable Capacity Scoring

CCCT results in significantly higher cumulative GHG emissions

Near-term costs reflect same pattern as traditional Cost metric

Thermal resources result in additional criteria pollutants, but not as significant as Biomass

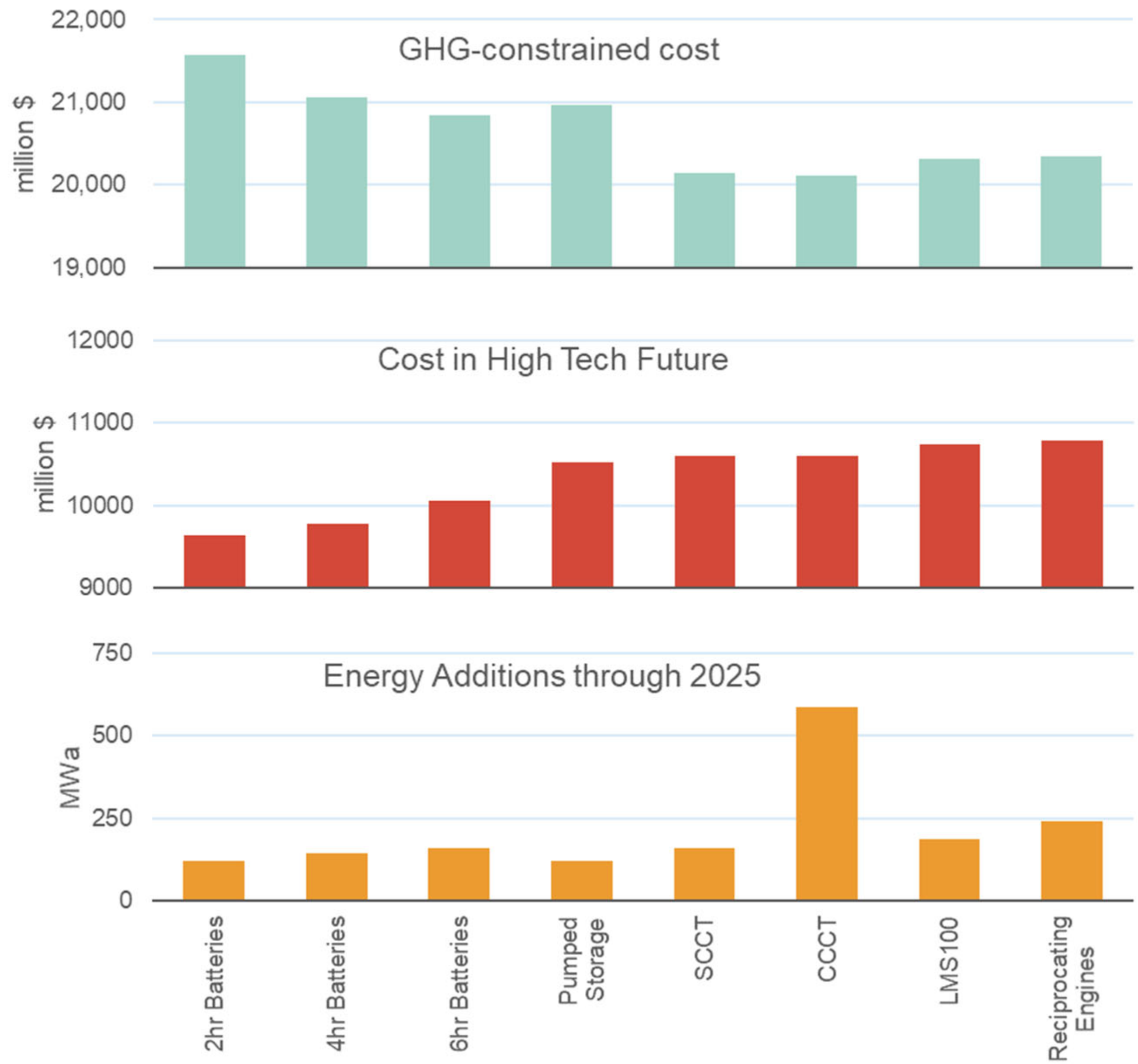


All data is draft until filed.

Dispatchable Capacity Scoring

GHG-Constrained Cost reflects same patterns as traditional cost metric

Batteries are lower cost than thermal resources in High Tech Future

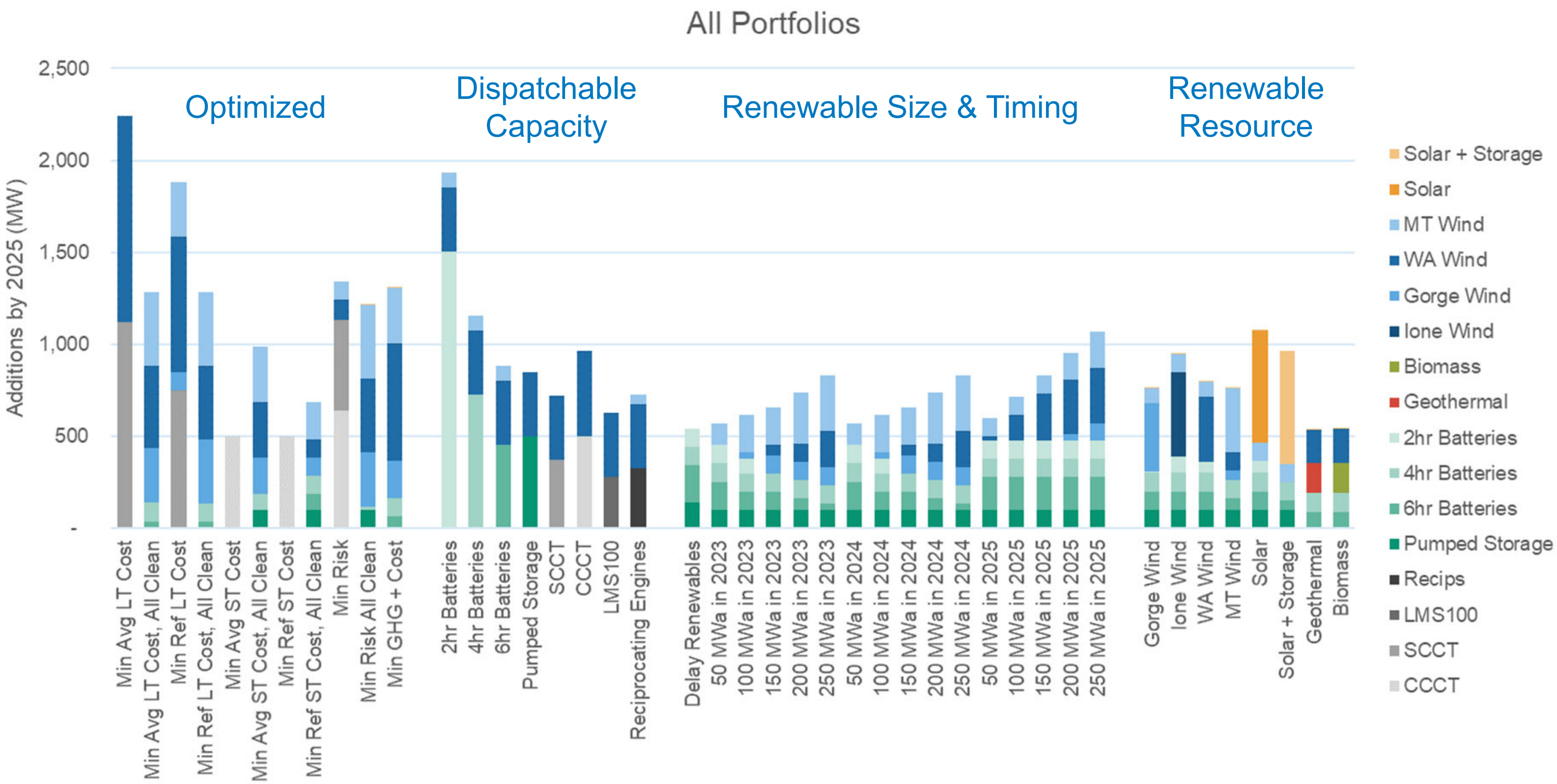


All data is draft until filed.

Portfolio Scoring

Portfolio Scoring

Goal is to interpret portfolio performance across 40+ portfolios to select a Preferred Portfolio and to motivate an Action Plan



All data is draft until filed.

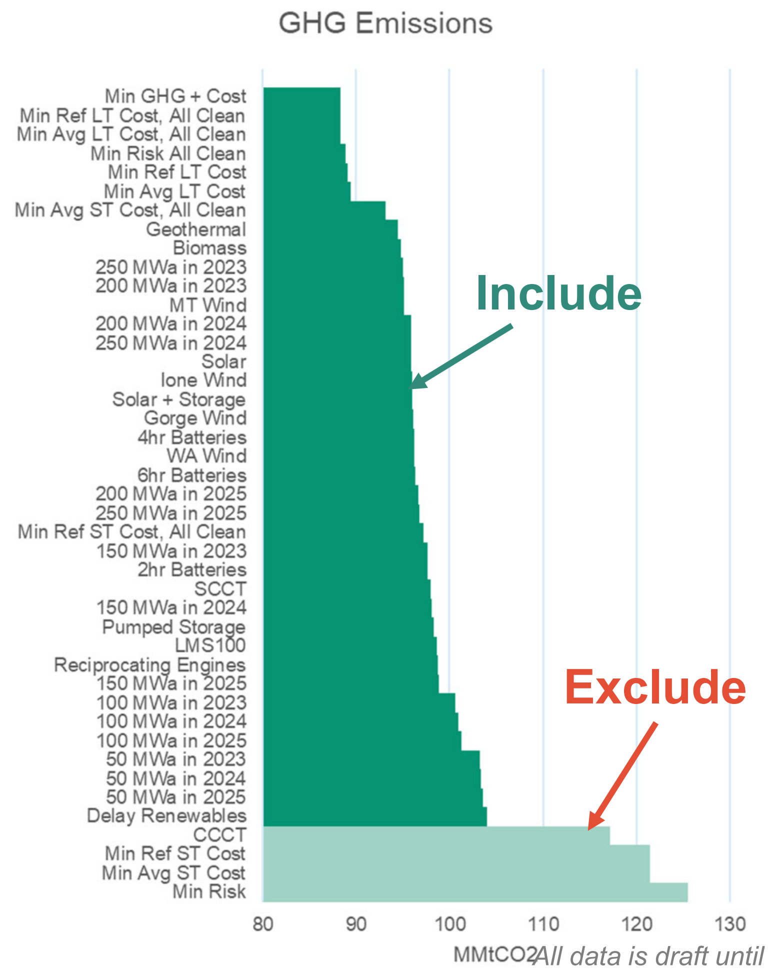
Portfolio Scoring Overview

1. **Screening** based on performance across Non-Traditional Scoring Metrics
2. **Evaluation** based on Traditional Cost and Risk Metrics
3. **Identification** of common aspects of well-performing portfolios
4. **Selection** of a Preferred Portfolio

Screening

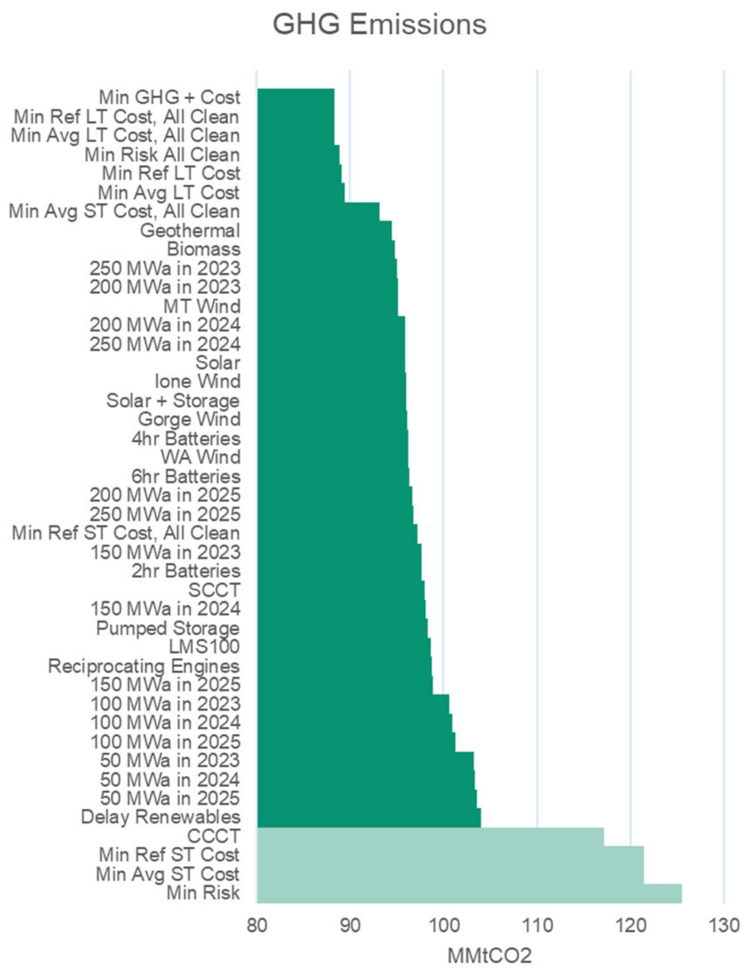
Based on performance across Non-Traditional Scoring Metrics

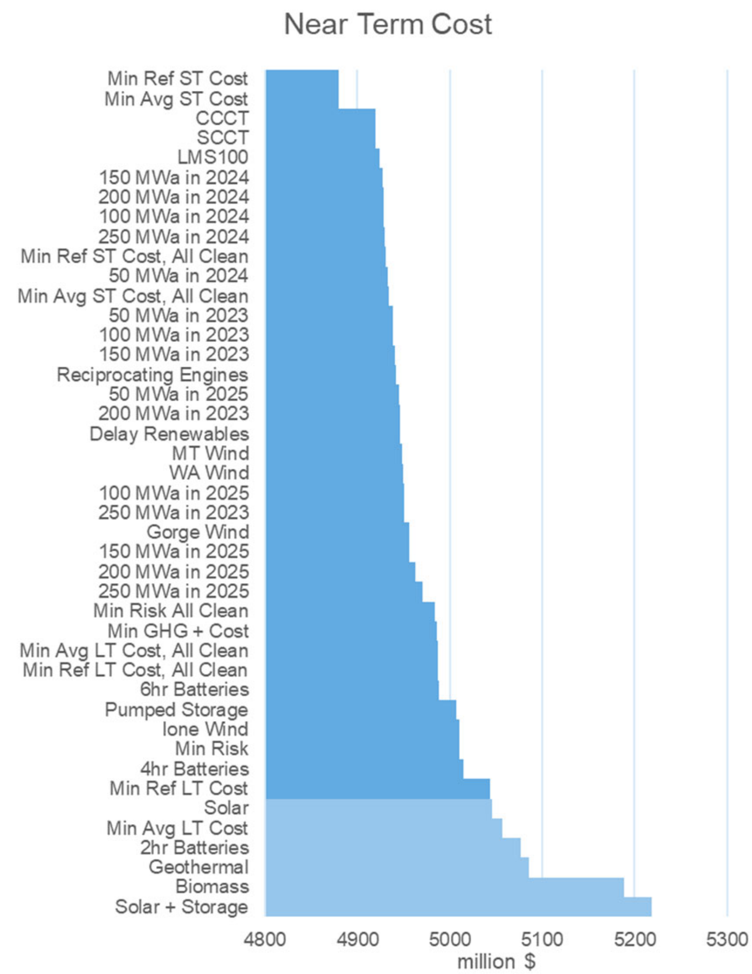
- For each Non-Traditional Metric, portfolios that score worse than one standard deviation above the mean (higher score = worse performance) are screened out
  - Scores will be shown for screened portfolios, but they will not be considered in the Selection of the Preferred Portfolio
- Example at right would screen out the following portfolios:
  - CCCT
  - Min Ref ST Cost
  - Min Avg ST Cost
  - Min Risk



All data is draft until filed.

Screening (1)





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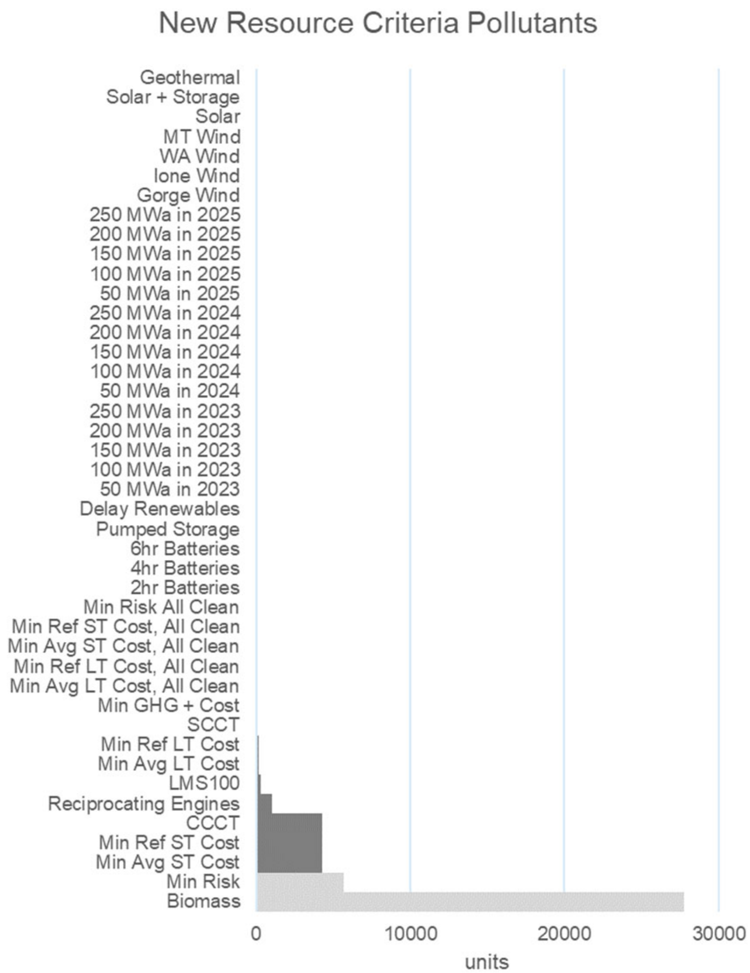
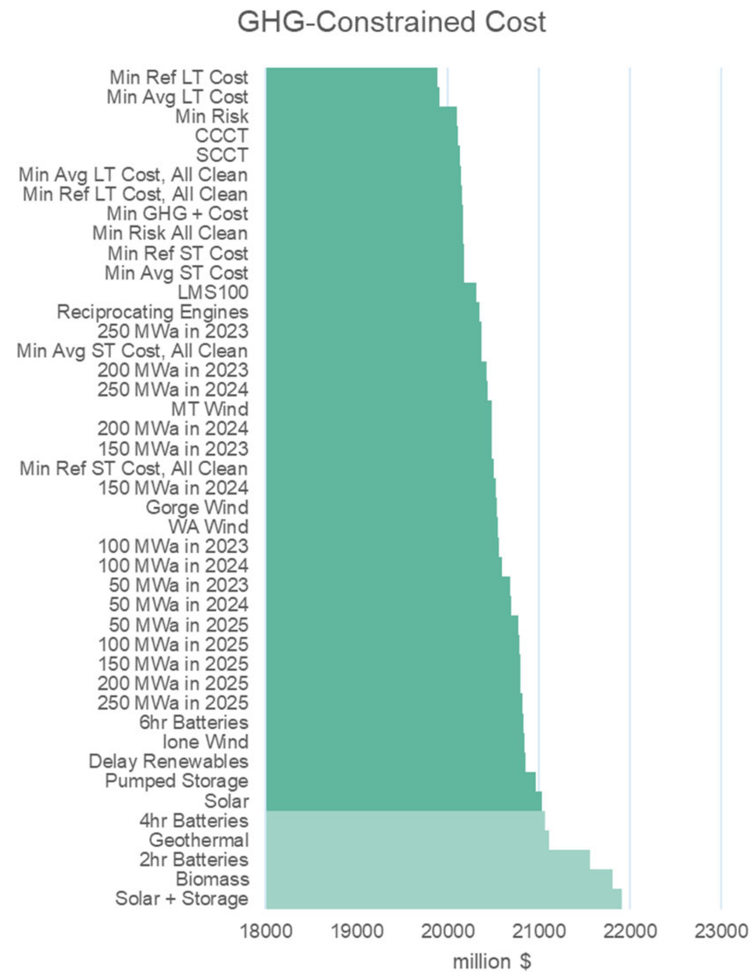
Screening (2)

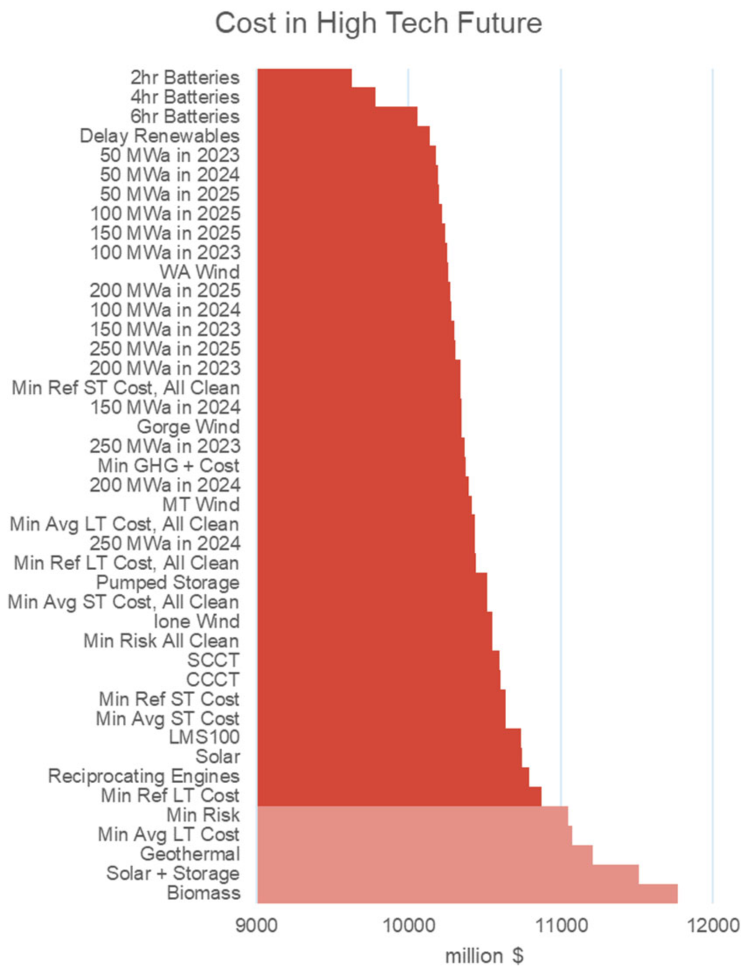


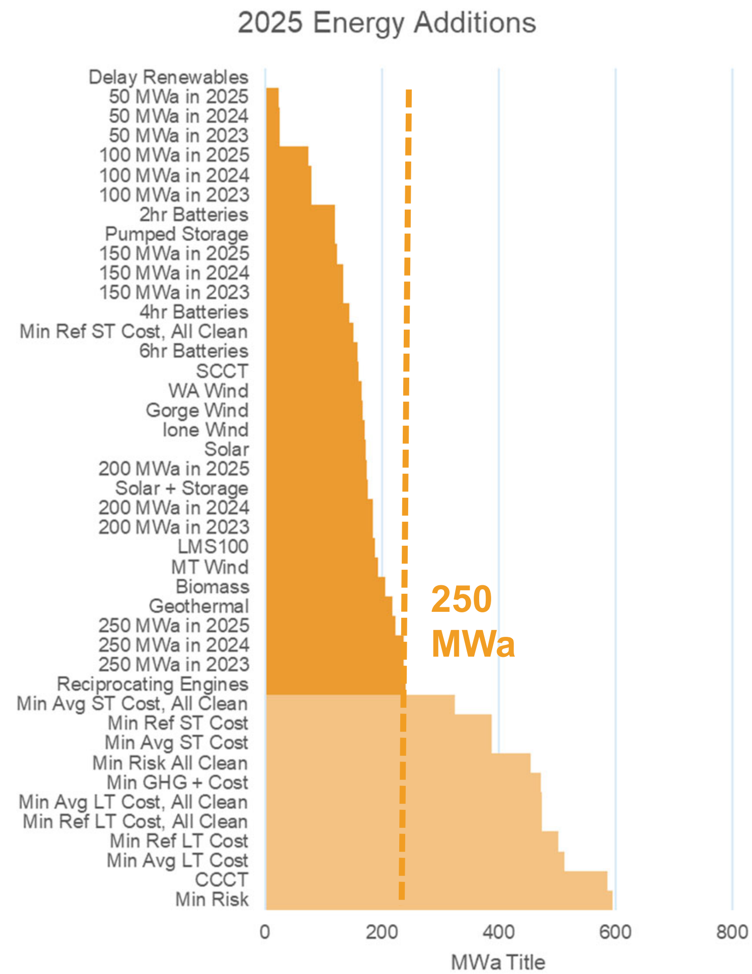


*The "New Resource Criteria Pollutant" metric is expressed as the sum of cumulative NO_2, SO_2, and Particulate Matter emissions from new resources through 2050, in short tons.

All data is draft until filed.

Screening (3)

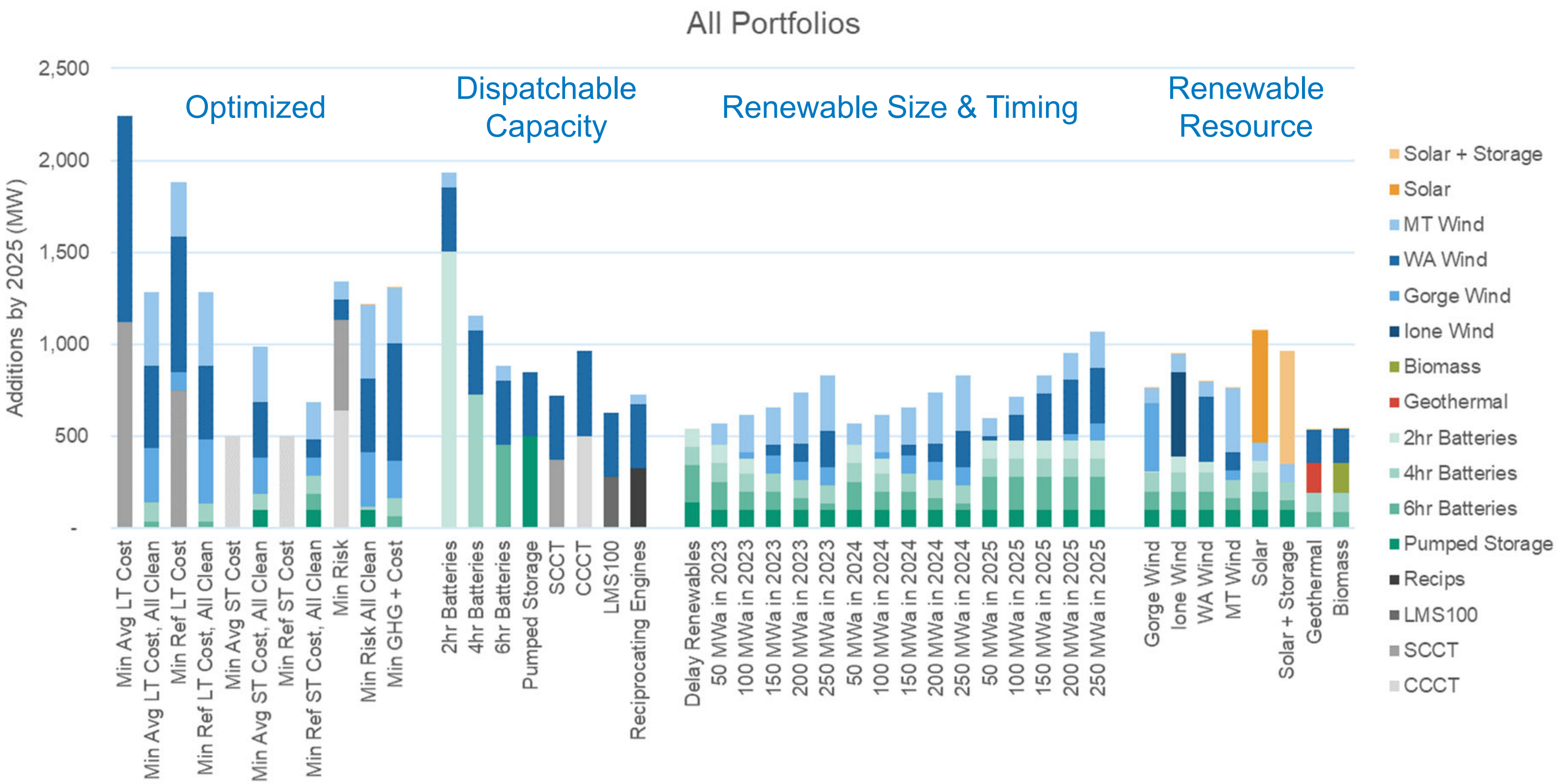




All data is draft until filed.

Screening Results

Screening reduces the number of portfolios under consideration for the Preferred Portfolio from 43 to 26



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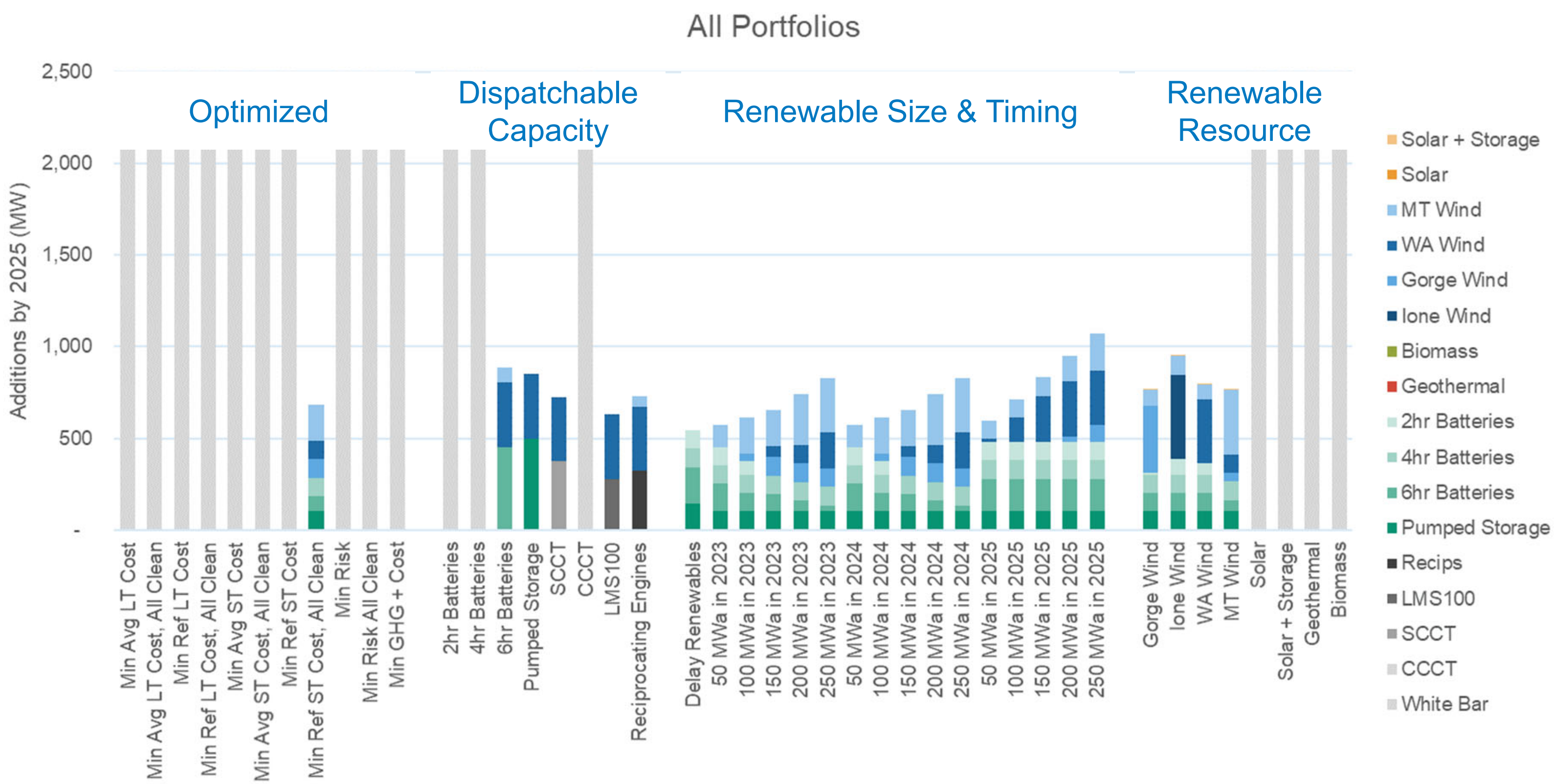


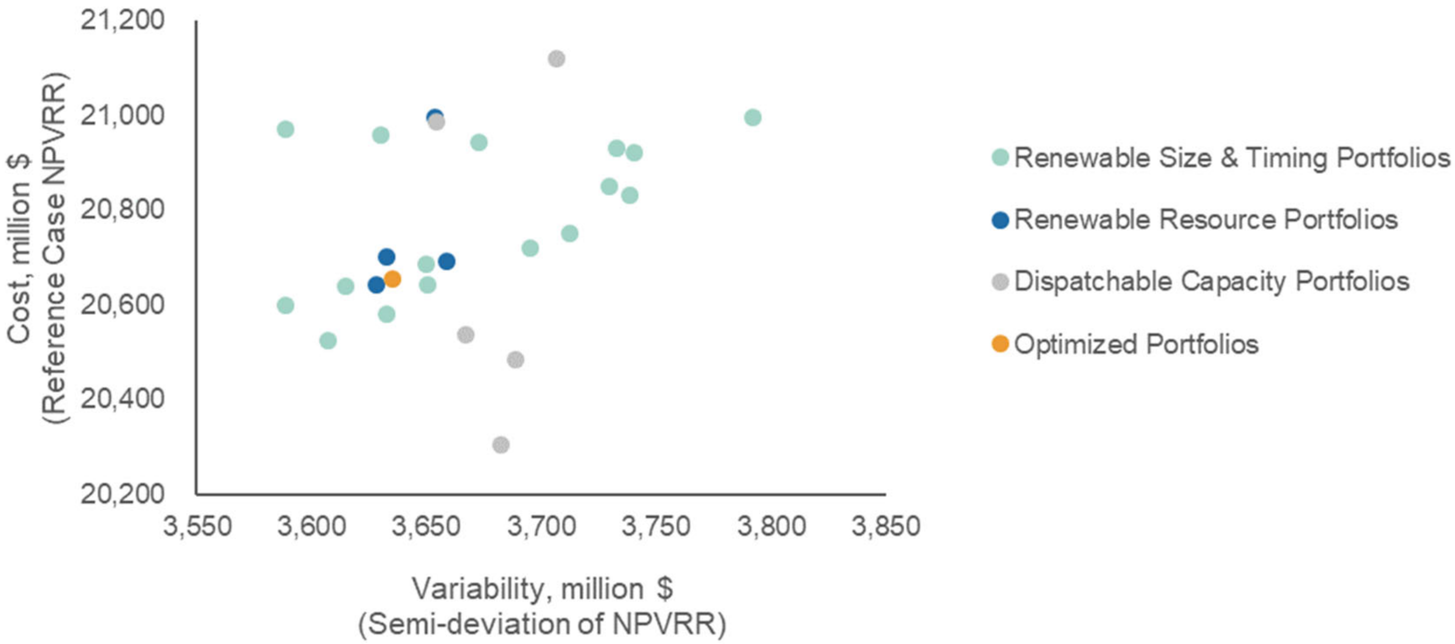
All data is draft until filed.

Evaluation

Based on Traditional Cost and Risk Metrics

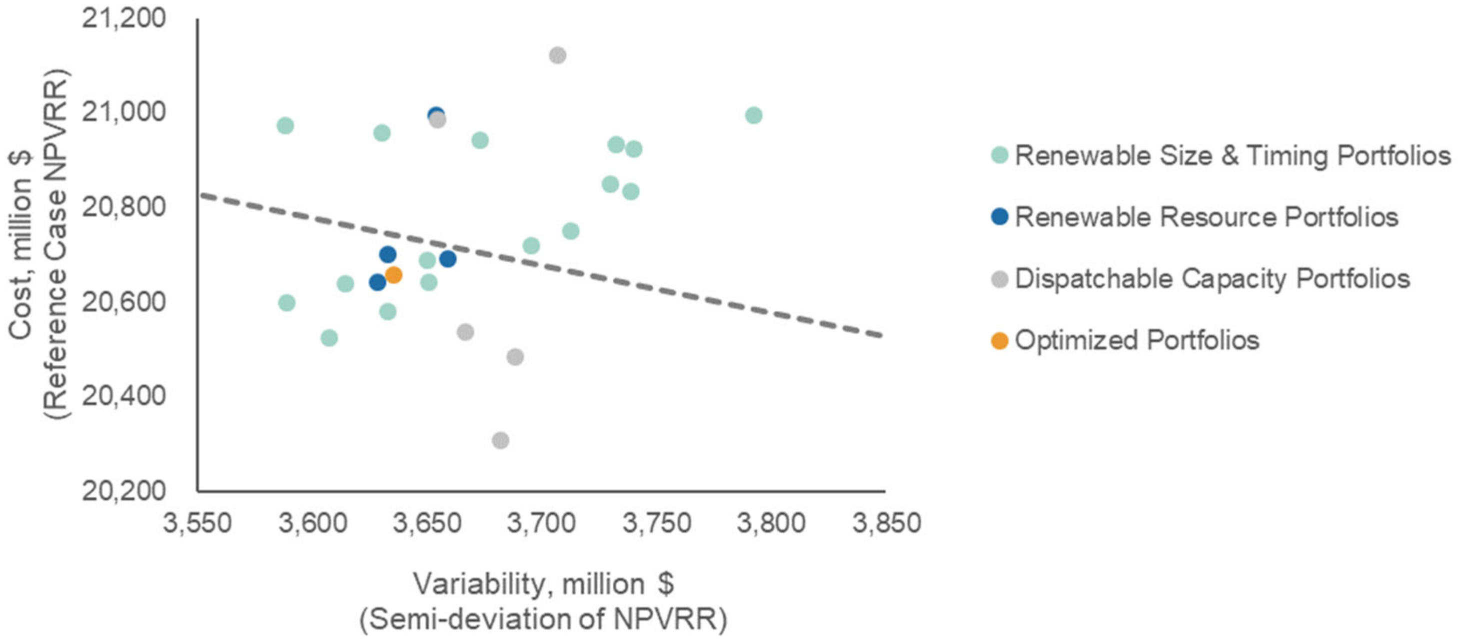
- The remaining portfolios are compared on the basis of the Cost, Variability, and Severity metrics, with the goal of identifying those that best balance cost and risk

Evaluation – Cost and Variability



All data is draft until filed.

Evaluation – Cost and Variability



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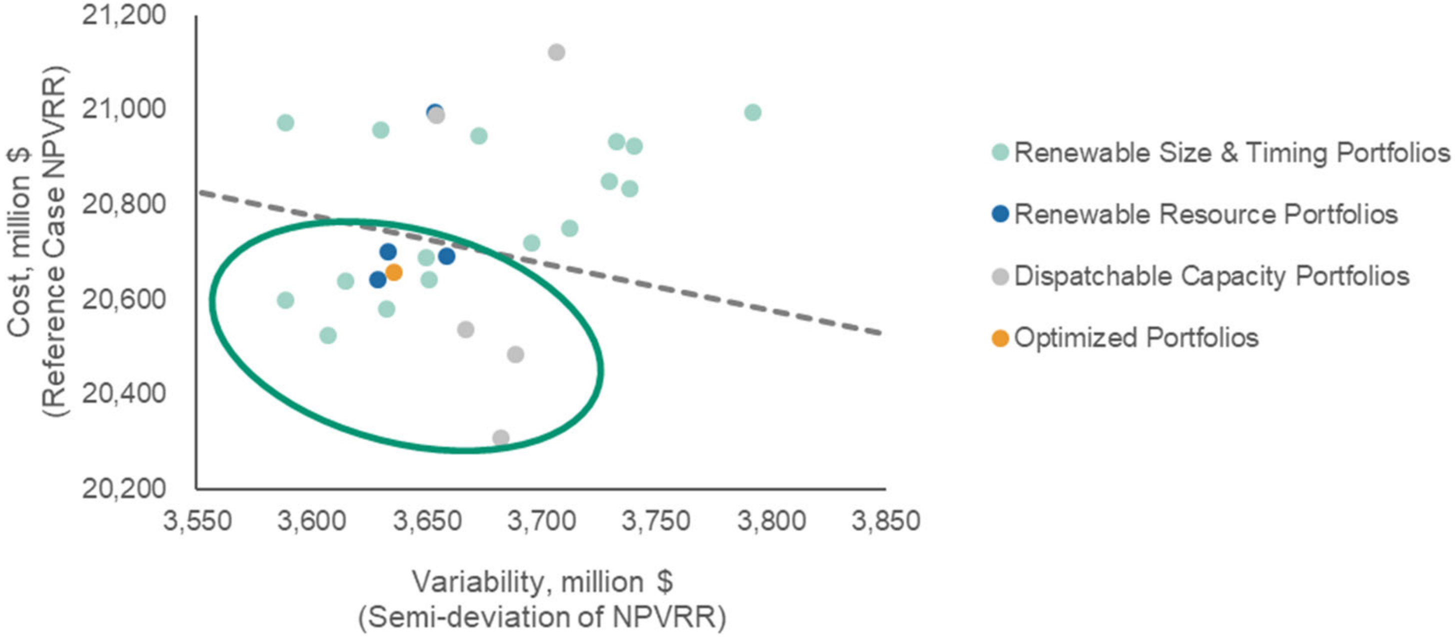
Evaluation – Cost and Variability



Best performing portfolios:

Renewable Size & Timing Portfolios: 150-250 MWa in 2023; 150-250 MWa in 2024.

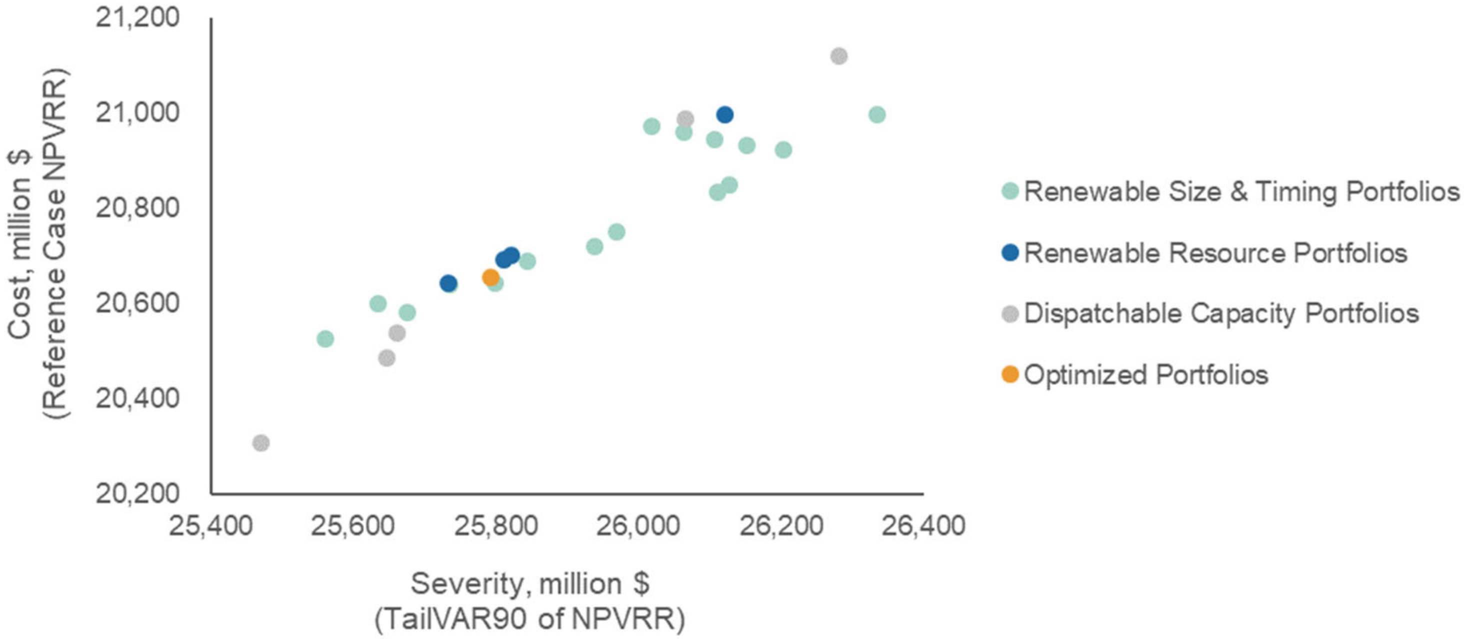
Renewable Resource Portfolios: MT Wind; WA Wind; Gorge Wind.

Dispatchable Capacity Portfolios: SCCT; LMS100; Reciprocating Engines.

Optimized Portfolios: Min Ref ST Cost, All Clean.

All data is draft until filed.

Evaluation – Cost and Severity



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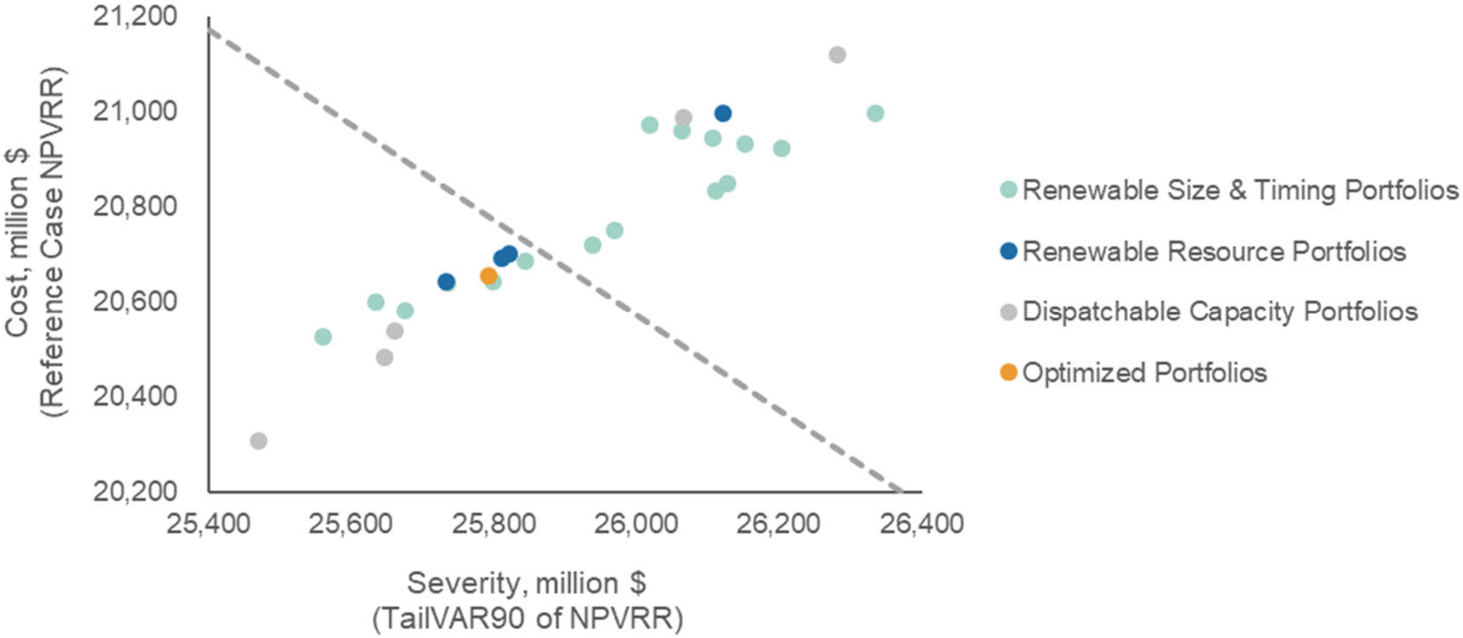

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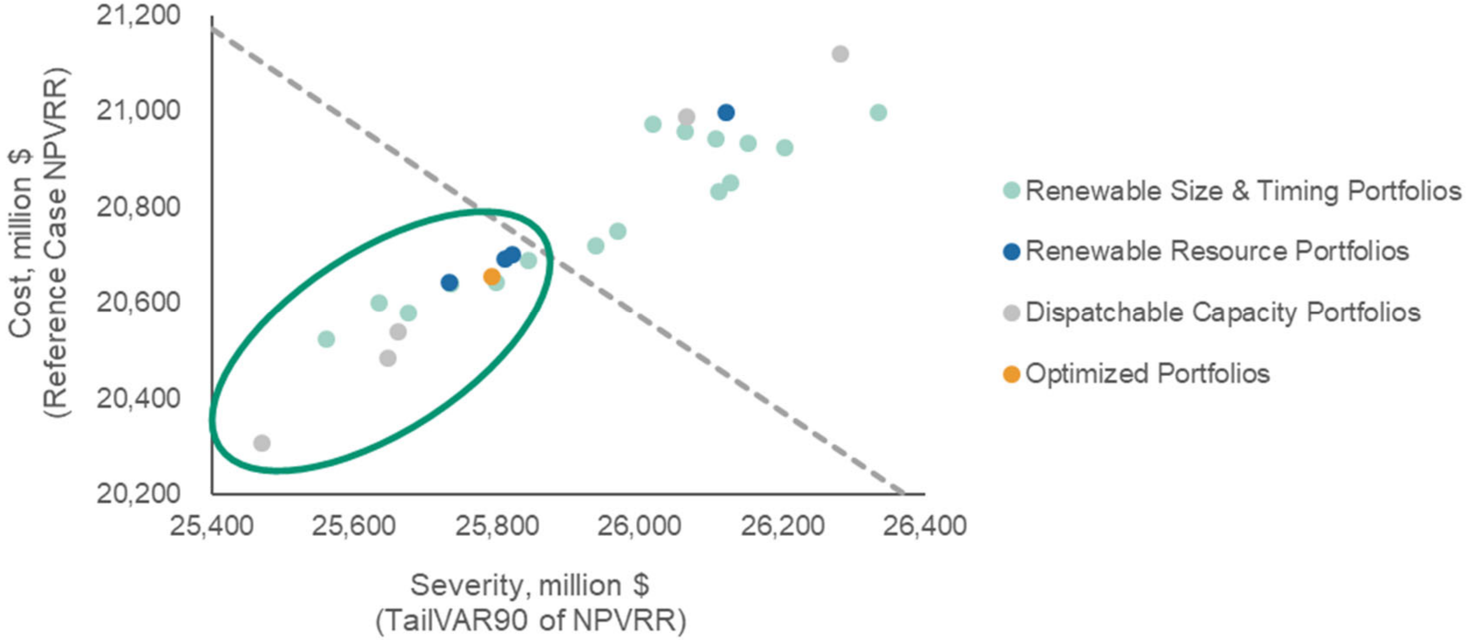

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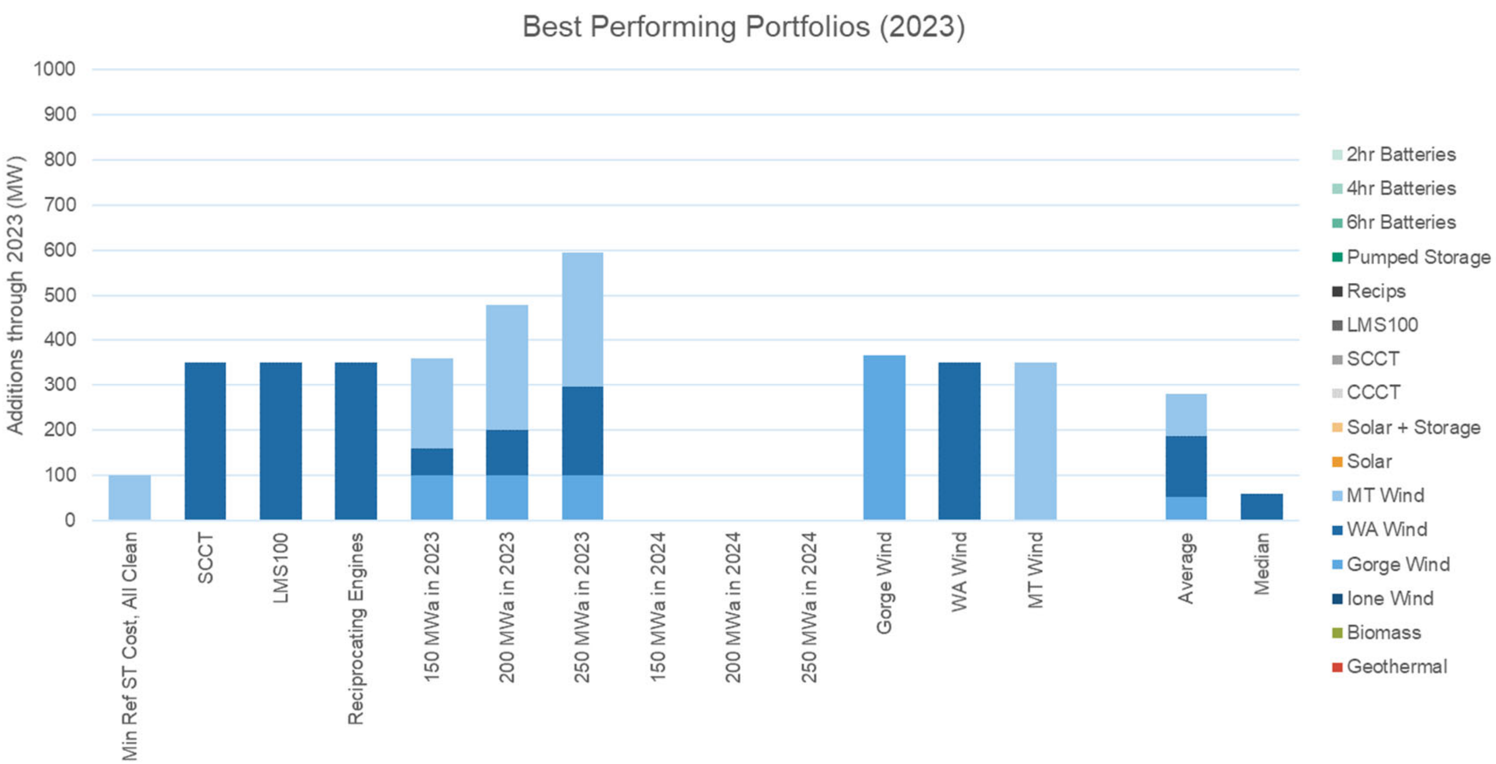
Optimized Portfolios: Min Ref ST Cost, All Clean.

All data is draft until filed.

Identification

Of common aspects of well-performing portfolios

Resource additions by 2023:

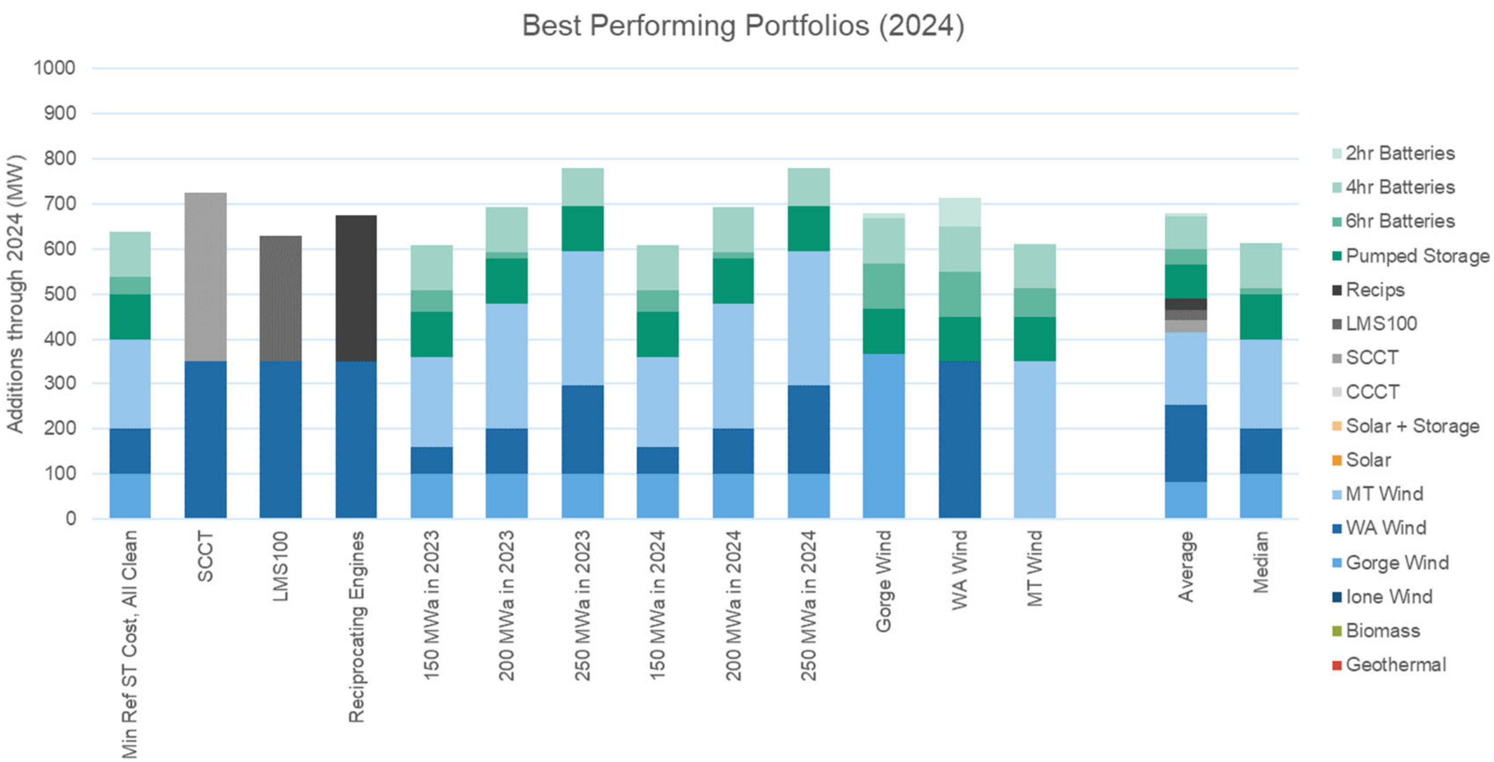


All data is draft until filed.

Identification

Of common aspects of well-performing portfolios

Resource additions by 2024:

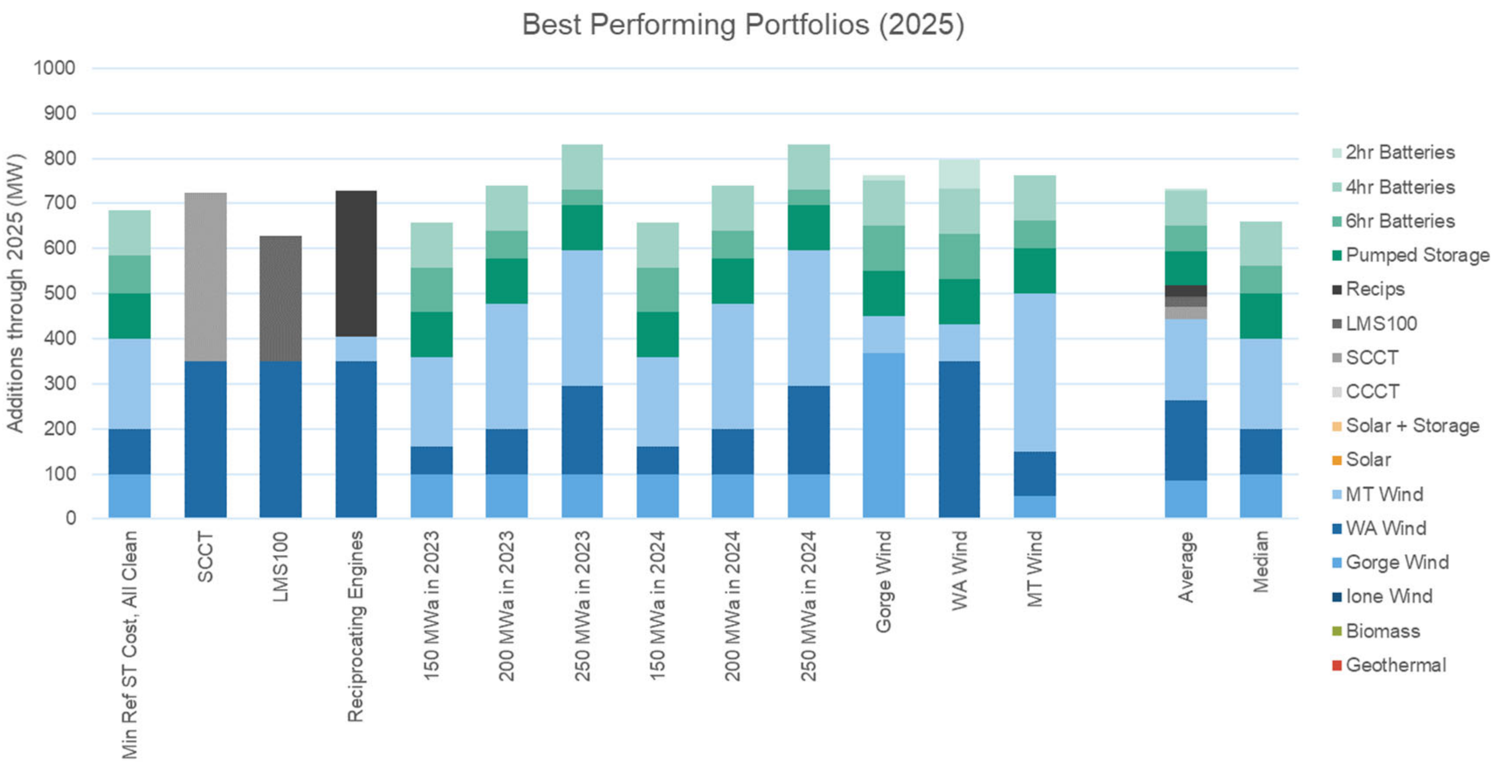


All data is draft until filed.

Identification

Of common aspects of well-performing portfolios

Resource additions by 2025:

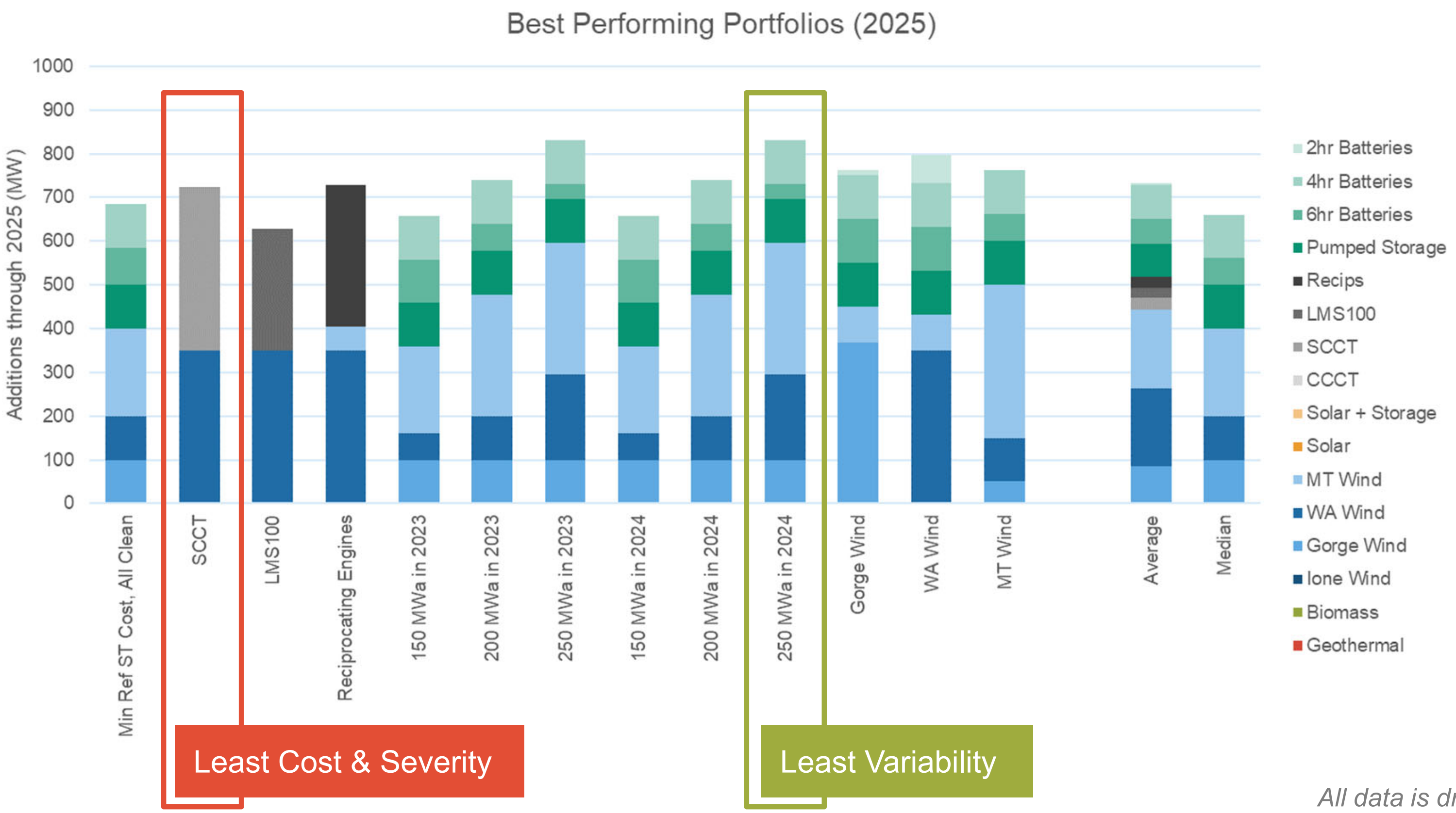


All data is draft until filed.

Identification

Of common aspects of well-performing portfolios

Resource additions by 2025:



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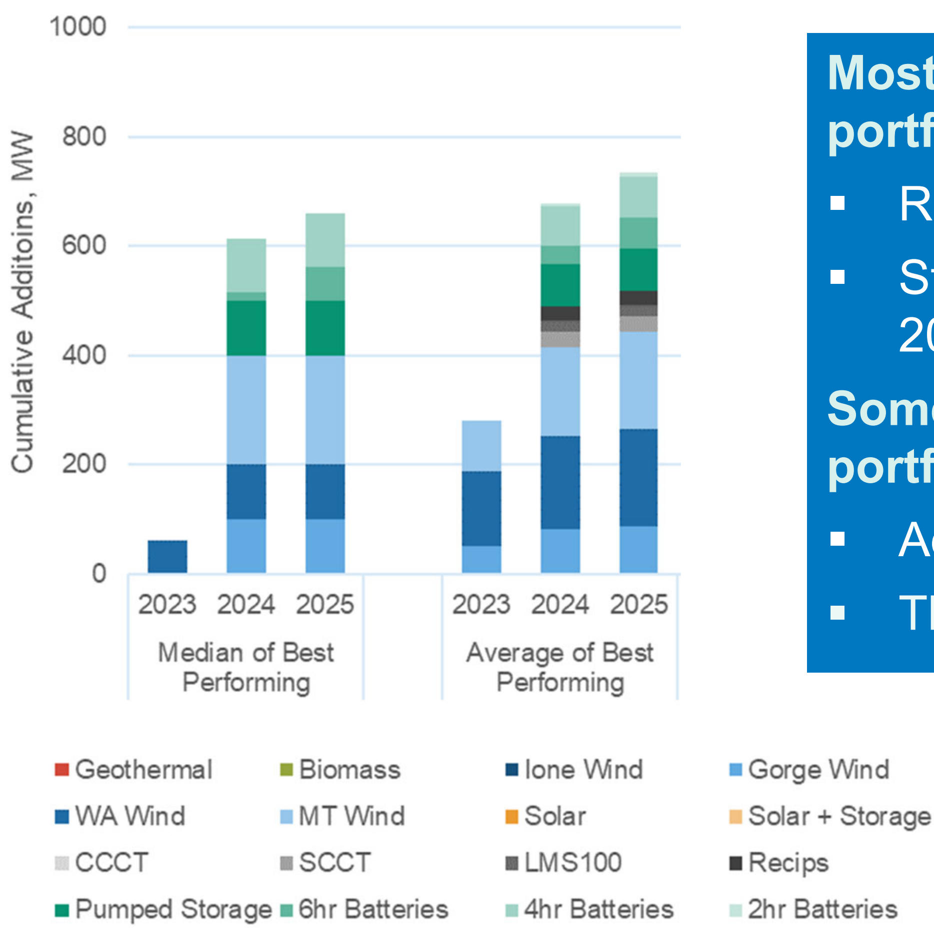
Identification

Of common aspects of well-performing portfolios



Most of the best performing portfolios include:

- Renewable action in 2023
- Storage (4+ hour duration) in 2024 and 2025

Some of the best performing portfolios include:

- Additional renewables in 2025
- Thermal resources

All data is draft until filed.

Selection of a Preferred Portfolio

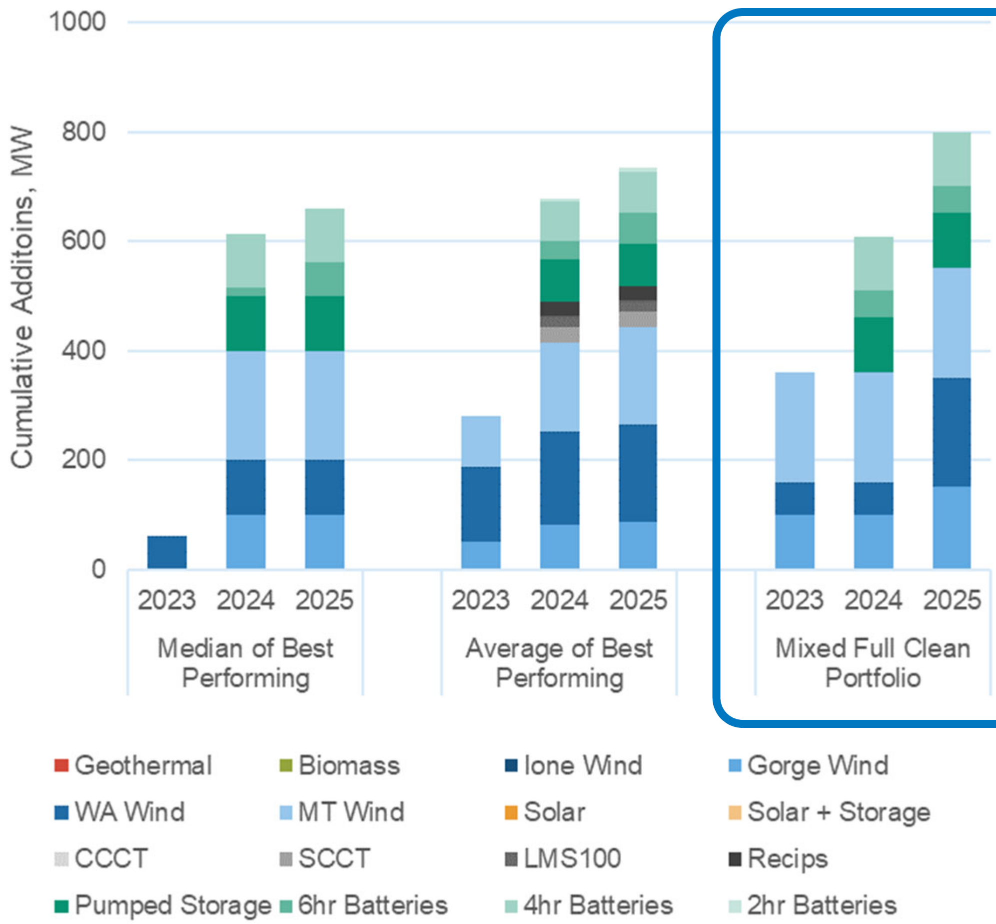
Based on the portfolios that perform the best on the basis of cost and risk, PGE designed the **Mixed Full Clean Portfolio**

- Includes 150 MWa renewable addition by 2023
- Allows for additional renewables in 2025, if economic, consistent with a two-year renewable procurement cycle
- Adds only non-GHG resources

PGE

All data is draft until filed.

Preferred Portfolio



Mixed Full Clean Portfolios includes:

Diverse portfolio of wind resource additions in 2023

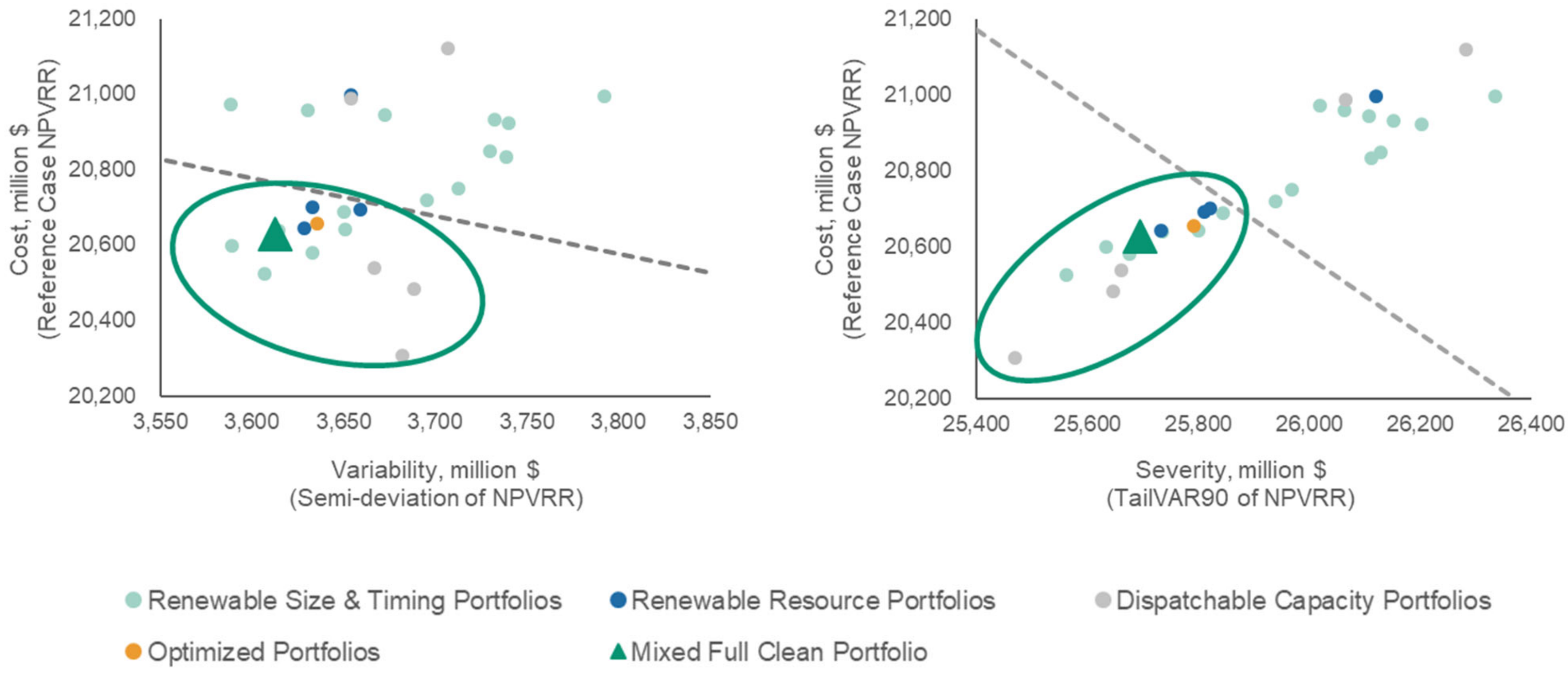
Additional wind in 2025

Storage (4 hour duration and longer) to meet remaining capacity needs

All data is draft until filed.

Preferred Portfolio

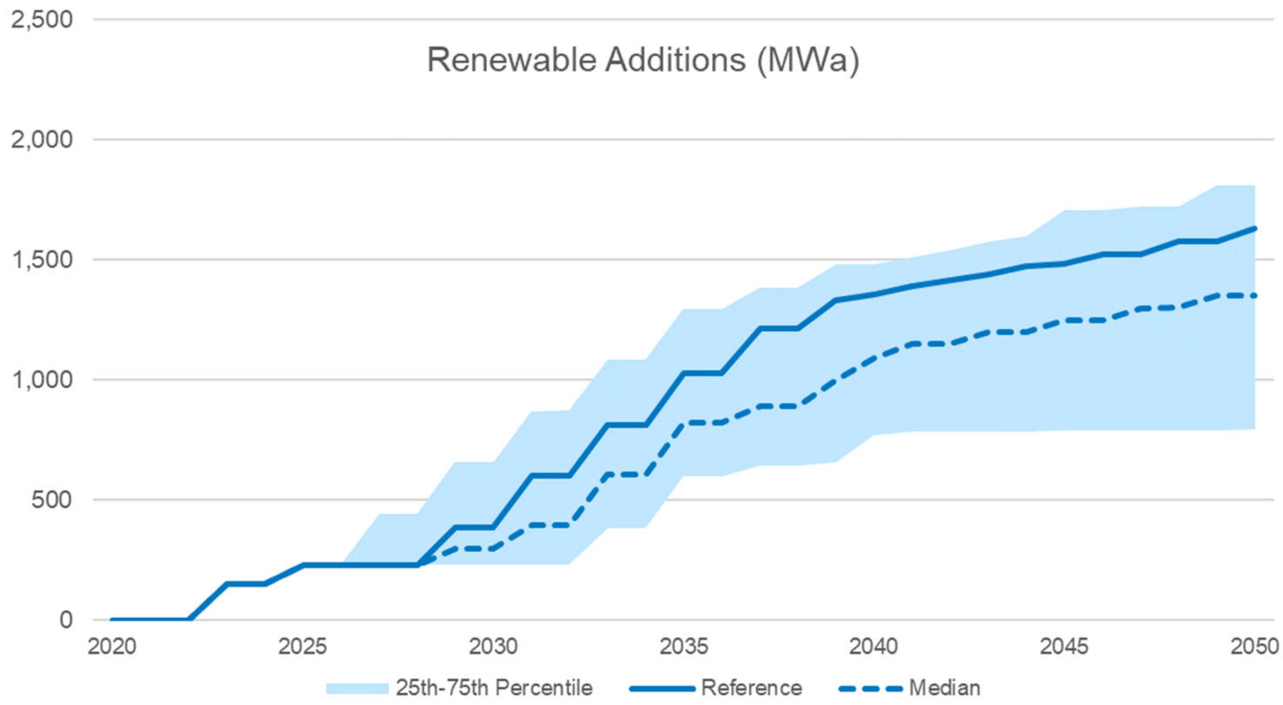
Mixed Full Clean Portfolio performs well relative to the portfolios that perform the best on the basis of cost and risk



All data is draft until filed.

Renewable Glide Path

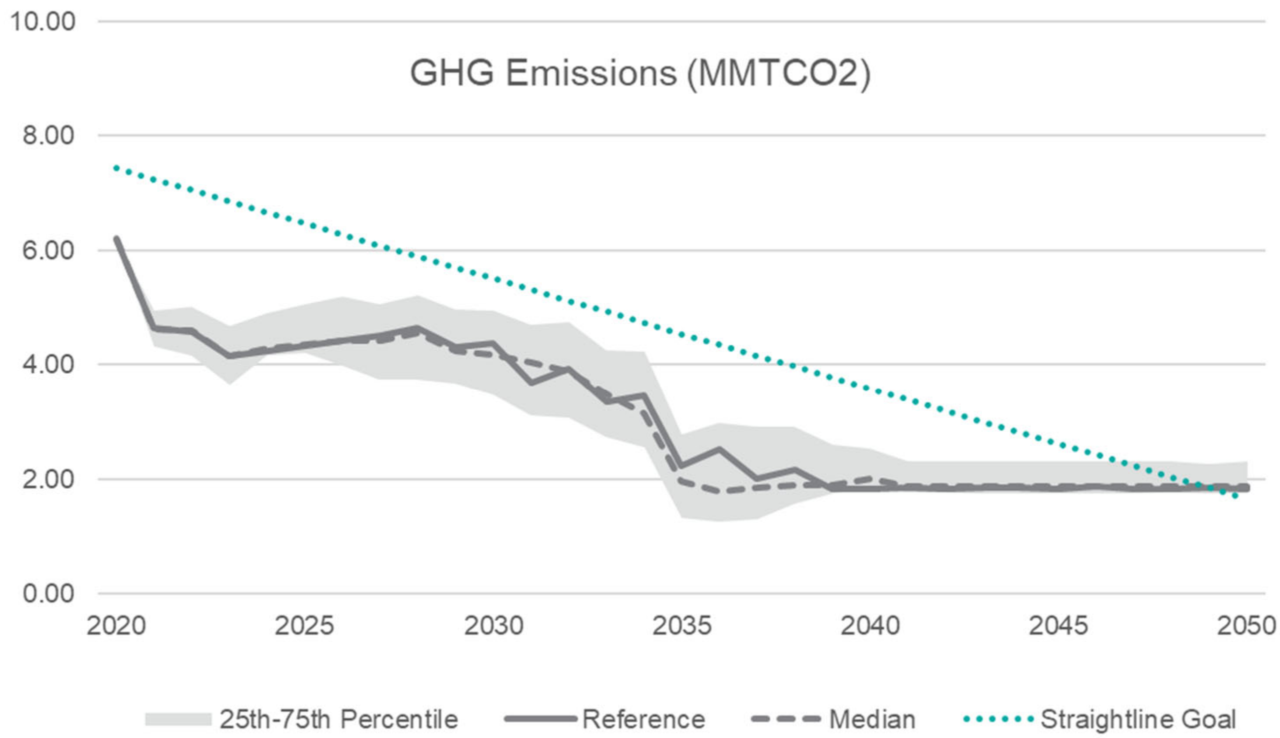
The **Mixed Full Clean Portfolio** takes advantage of near-term economic opportunities to pursue cost competitive renewables while layering in subsequent renewable acquisitions over time to cost effectively decarbonize PGE's energy supply



All data is draft until filed.

GHG Reductions

The **Mixed Full Clean Portfolio** would help PGE to make significant progress toward our goal to reduce GHGs by 80% by 2050.



All data is draft until filed.

Draft Action Plan

Elaine Hart

Draft Action Plan
Customer Resources

1.A. Acquire all cost-effective energy efficiency, currently forecasted to be ~190 MWa by 2025

1.B. Acquire all cost-effective distributed flexibility, currently estimated to include, by 2025:

- ~140 MW (Low: 77 MW, High: 222 MW) of winter demand response
- ~200 MW (Low: 114 MW, High: 342 MW) of summer demand response
- ~2 MW (Low: 1.3 MW, High: 4.4 MW) of dispatchable customer storage

All information is draft until filed.

Draft Action Plan
Renewable Resources

2. Conduct a Renewables RFP in 2020, seeking ~150 MWa of RPS-eligible resources, online before January 1, 2023

- Timing allows PGE to capture ≥60% PTC for customers
- Propose cost containment screen similar to the 2018 Renewables RFP
- Propose to return value of RECs generated prior to 2030 to customers

All information is draft until filed.

Draft Action Plan
Dispatchable Capacity

3. Pursue a staged procurement process to secure capacity to maintain resource adequacy, while considering the impact of uncertainties

- **A.** Pursue cost competitive existing capacity in the region via bilateral negotiations
- **B.** Update the OPUC and stakeholders on PGE's resource needs in 2020
- **C.** Conduct a Non-Emitting Capacity RFP in 2021 for capacity needs remaining after above action

All information is draft until filed.

Feedback

PGE is seeking the first round of feedback on this Draft Action Plan by March 22, 2019

Email informal comments to IRP@pgn.com.

Thank you!

PGE

Updated Flexibility Analysis

Nora Xu

Flexibility Analysis Scope Review

- A set of studies that aim to assess flexibility needs, value and costs
- Using ROM, a PGE system multi-stage optimal commitment and dispatch model

Flexibility Adequacy

This component seeks to model flexibility adequacy with production cost models and develop initial methodologies to evaluate how different resources affect it.

Variable Energy Resource (VER) Integration Costs

This component continues to estimate costs of integrating additional VERs into the system.

Flexibility Value

This component studies how much we value flexibility from different resources, such as energy storage, flexible loads, gas-based generators.

All data is draft until filed.

Flexibility Modeling Tools: Resource Optimization Model (ROM)

- What is ROM?
  - Mixed integer programming optimal commitment and dispatch model
  - Multi-stage

  - Includes generator representations, fuel constraints, market availability, regulation and load following reserve requirements
- What resources can be represented in ROM?
  - Current PGE generation portfolio
  - Potential new additions (thermal, storage, renewables)
- ROM does not model capital costs, revenue requirement modeling, loss of load expectation

All data is draft until filed.

Flexibility Analysis ROM Inputs

Input	Comments
Time frame	Updated to 2025
Existing contracts	Updated
Gas prices	Reference
Carbon prices	Reference
Electricity prices	Reference (RRRR)
Load	Updated to 2025, average year
VER generation	Updated to 2025, average year
Reserves	Load following, regulation, spin, non-spin
Capacity Availability	Day-ahead, block capacity that is more expensive than existing system generation available depending on study

All data is draft until filed.

Flexibility Analysis ROM Inputs

	Flexibility Adequacy	Integration Cost	Flexibility Value
Market Availability	Consistent with E3 Market capacity study ▪ Limited in on-peak summer and winter ▪ Unconstrained in off-peak and non-winter and summer peak	Unconstrained	Unconstrained
Day-ahead (DA) Capacity Availability	DA block capacity that is more expensive than existing system generation available	-	-

All data is draft until filed.

Flexibility Adequacy of the PGE System

Ana Mileva

Blue Marble Analytics

Portland General Electric IRP Public Meeting

Feb 27, 2019

Portland, Oregon

About

- Independent consultant
- Extensive experience with power-system modeling
- Experience in 2016 PGE IRP

All data is draft until filed.

Agenda

- Flexibility metrics literature review
  - What is “flexibility” and how do we measure it?
  - What is “flexibility adequacy?”
- ROM flexibility adequacy analysis for PGE’s system
  - Base Case analysis
  - Battery analysis

All data is draft until filed.

Flexibility Metrics

Literature Reviewed

Entity	Study	Type	Flexibility Metrics
PGE	2016 IRP	IRP	Reliance on intra-day capacity product; curtailment
Puget Sound	2017 IRP	IRP	Unserved energy; reserve shortages; curtailment
PNM	2017 IRP	IRP	LOLE Flex, EUE Flex; curtailment
CAISO	Final Flexible Capacity Needs Assessment 2019	Planning	Max 3-hour net load ramps by season
NWPCC	Seventh Power Plan	Planning	Upward flexibility (headroom) over different time horizons (e.g. by month, time of day, etc.)
BPA, EPRI, NWPCC	2015 Flexibility Assessment Methods DRAFT	Thought-leadership	Upward flexibility (headroom) over different time horizons (e.g. by month, time of day, etc.)
EPRI	Various	Thought-leadership	Periods of flexibility deficit; insufficient ramping resource expectation; expected unserved ramping
LBNL	Flexibility Inventory for Western Resource Planners	Thought-leadership	Flexibility "inventory" & demand-supply balance screening
CES-21 Program	Flexibility Metrics and Standards Project	Thought-leadership	LOLE Flex (multi-hour and intra-hour)
IEA	Harnessing Variable Renewables	Thought-leadership	Flexibility "inventory"
LLNL	Flexibility Metrics to Support Grid Planning and Operations	Thought-leadership	Literature review
NREL	Advancing System Flexibility for High Penetration Renewable Integration	Thought-leadership	Literature review
Anderson and Matevosyan (2017)	"Flexibility studies in system planning at ERCOT," IEEE	Academic	Headroom; expected unserved ramp
Lannoye et al. (2012)	"Evaluation of Power System Flexibility," IEEE	Academic	Insufficient Ramping Resource Probability
Various		Academic	

All data is draft until filed.

Summary

- We use the term “flexibility” to describe the system’s ability to adapt to the variability and uncertainty of net load
- Traditional reliability metrics (i.e. LOLE) address the probability of reliability events as a result of generator outages or weather excursions, but assume no additional reliability shortages due to insufficient operational flexibility

- **No widely-used and accepted metrics of flexibility and flexibility adequacy exist**
- **No industry standard for flexibility adequacy similar to capacity adequacy 1-in-10 LOLE standard**

All data is draft until filed.

Other Takeaways

- Few IRPs have considered flexibility explicitly
- Flexibility is often thought of in terms of economics (less flexible systems yield higher system costs)
- Various entities define/calculate flexibility demand over different time horizons
  - What are the time horizons of interest for PGE's system?
- Several entities have observed seasonal trends in flexibility demand
  - Are there seasonal trends in flexibility demand-supply balance for PGE's system?
- Production-cost simulation is most commonly used for flexibility analysis

All data is draft until filed.

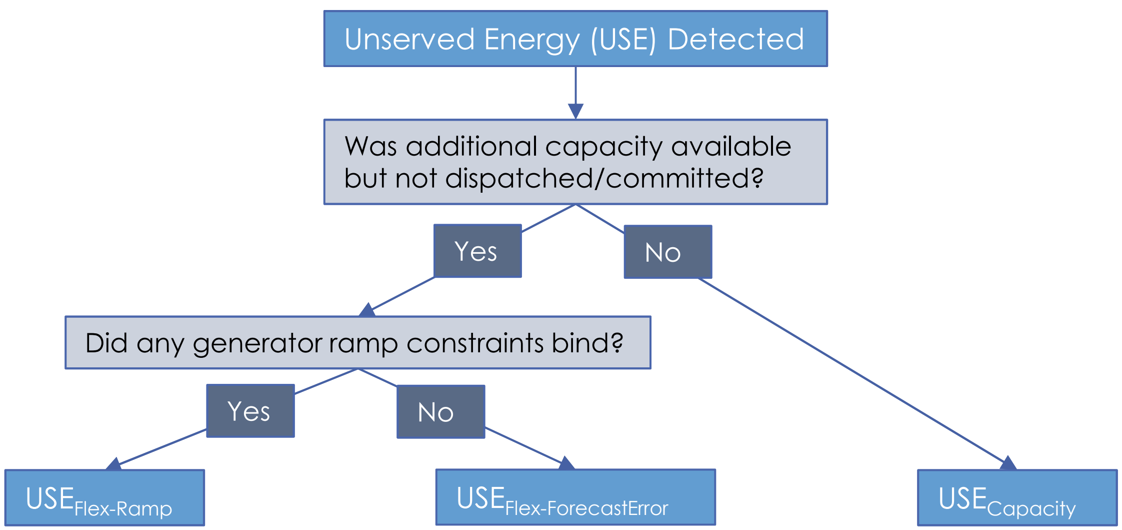
Using Production-Cost to Measure Flexibility

- Traditional metrics available from production cost simulation results can be used to indicate insufficient flexibility in the power system (e.g. unserved energy, reserve shortfalls, curtailment, price spikes)
  - Important to distinguish between events attributable to insufficient flexibility and those due to insufficient capacity
- Metrics of grid flexibility stress can provide useful information on the state of the system, even if no shortages are observed
  - We're interested in the magnitude and seasonal distribution of these indicators

All data is draft until filed.

Metric 1: LOLE Flex (USE Flex)

- Used by CES21 study, PNM IRP study
- Measures loss of load due to flexibility shortages as opposed to capacity shortages
- Distinguishes between uncertainty- and variability-related events

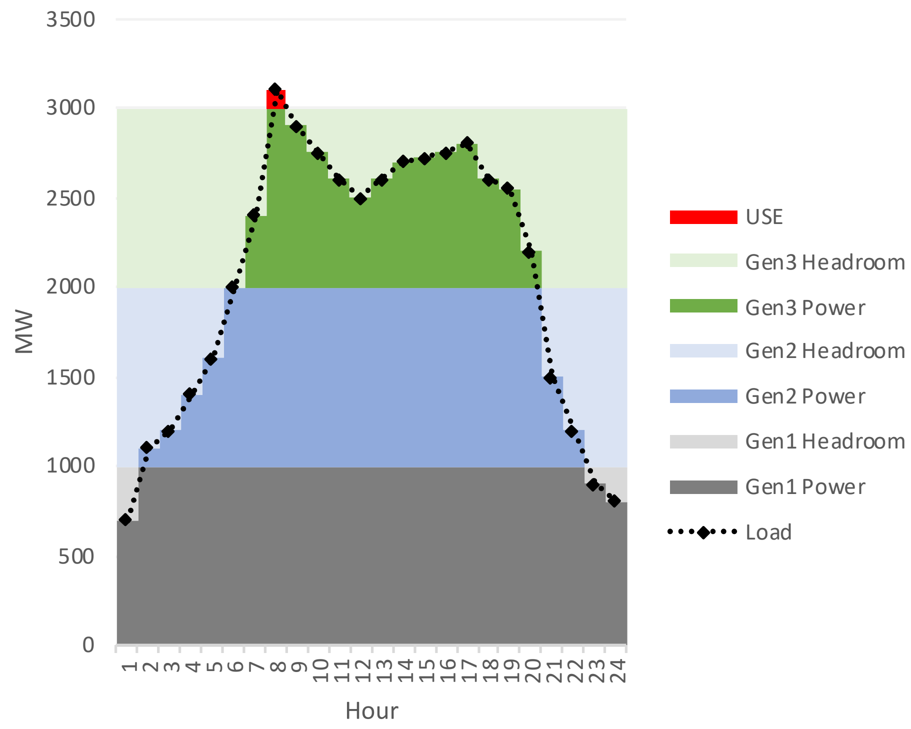


All data is draft until filed.

Figure adapted from CES21 Flexibility Metrics and Standards Project

Metric 2: Net Upward Capability

- Used by EPRI, ERCOT, NWPCC 7th Power Plan
- Measures the magnitude of available upward (downward) flexibility, i.e. headroom (footroom), for a given time horizon
- Can provide useful indication of system stress even when no reliability events are present



All data is draft until filed.

PGE Flexibility Adequacy Analysis

Unserved Energy in the Base Case

Real Time Unserved Energy (USE)	
# Timepoints	57
% Timepoints	0.16%
Total MWh	800
Max MW	178

- All realized USE occurs during times when the DA capacity was not fully committed
  - USE is caused by insufficient flexibility, not capacity shortages
- Ramping constraints don't bind during the times with USE
  - Flexibility events are caused by forecast error, not insufficient ramping capability

All data is draft until filed.

Seasonal Distribution of USE in Base Case

Hour Ending

MWa USE

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Jan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	3	21	1	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0
Mar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0	0	0	0	0	0
Jul	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aug	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sep	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dec	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

% Time with USE

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Jan	0%	0%	0%	0%	0%	0%	0%	4%	0%	0%	0%	0%	0%	0%	0%	0%	1%	2%	2%	0%	0%	0%	0%	0%
Feb	0%	0%	0%	0%	0%	0%	5%	25%	4%	0%	0%	0%	0%	0%	0%	0%	0%	1%	4%	3%	0%	0%	0%	0%
Mar	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Apr	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
May	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Jun	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Jul	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%
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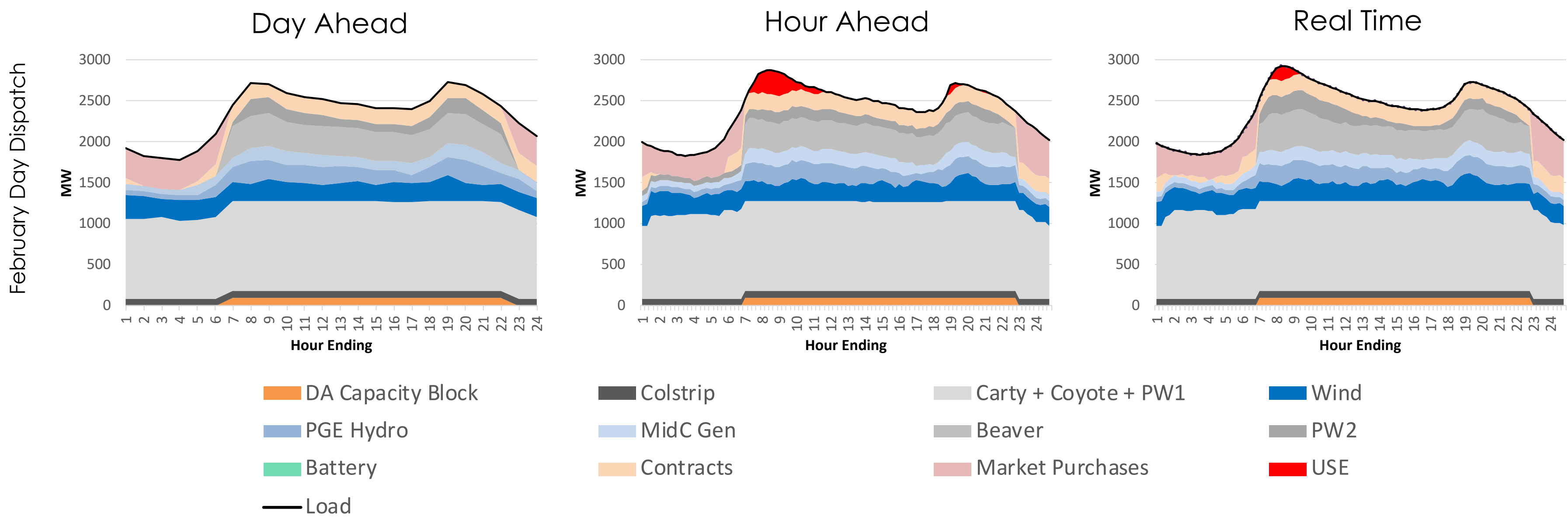
Nov	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Dec	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

- USE is concentrated during the winter morning peak

All data is draft until filed.

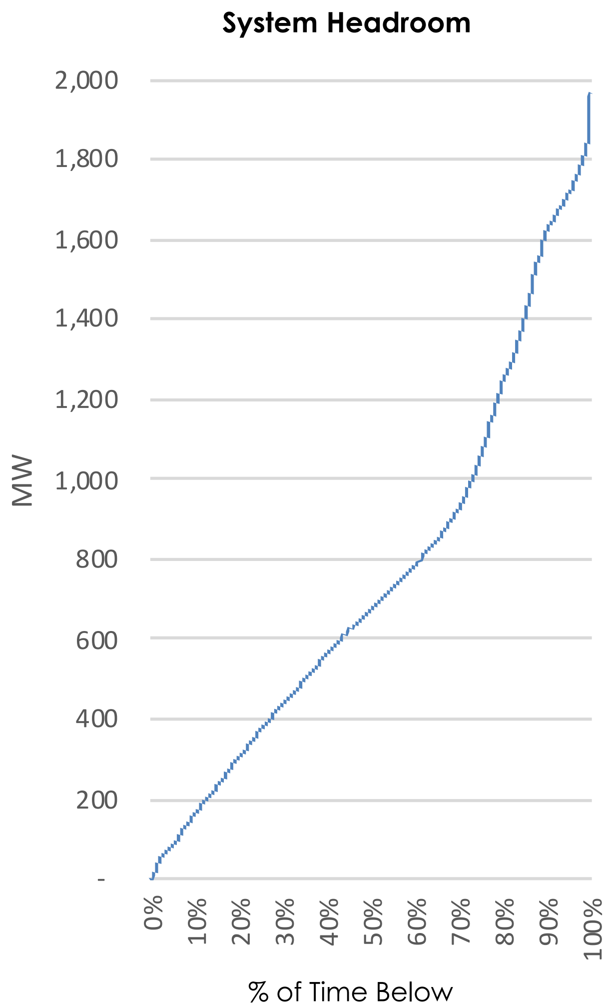
USE Caused by Under-Commitment of DA Capacity



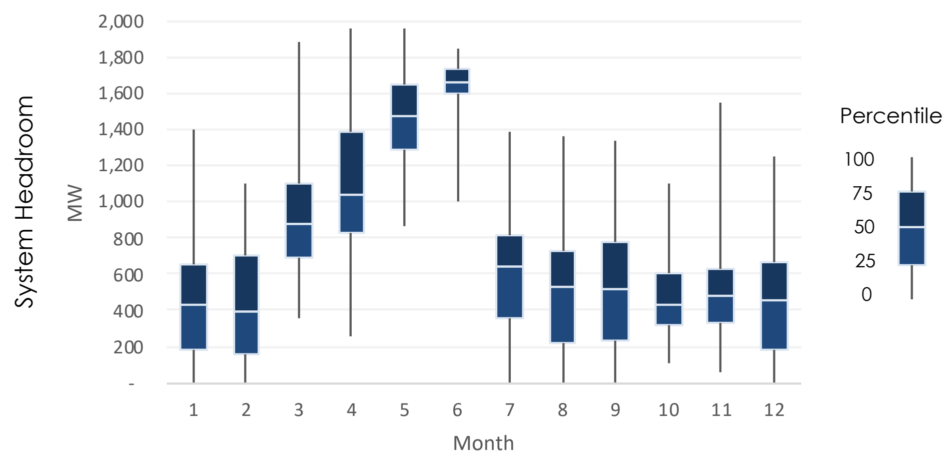
- Only 100 MW of DA capacity committed
- Net load forecast error between DA and RT stage during hours 7, 8, and 9 results in unserved energy in those hours
- This is a flexibility event caused by the inability to re-commit DA capacity within the day

All data is draft until filed.

System Headroom in the Base Case



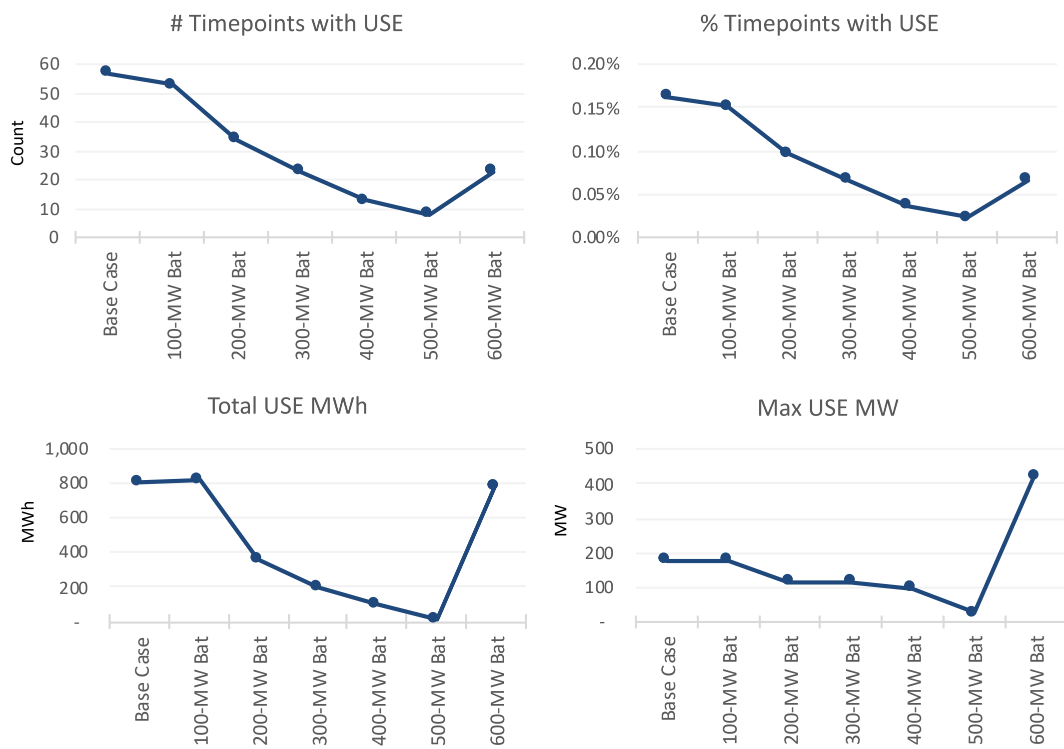
- PGE's system is most headroom-constrained in the winter months
- Headroom during the summer months also drops to 200 MW or below around 25% of the time
- Headroom is plentiful in the spring



All data is draft until filed.

Addressing Forecast Error with Batteries

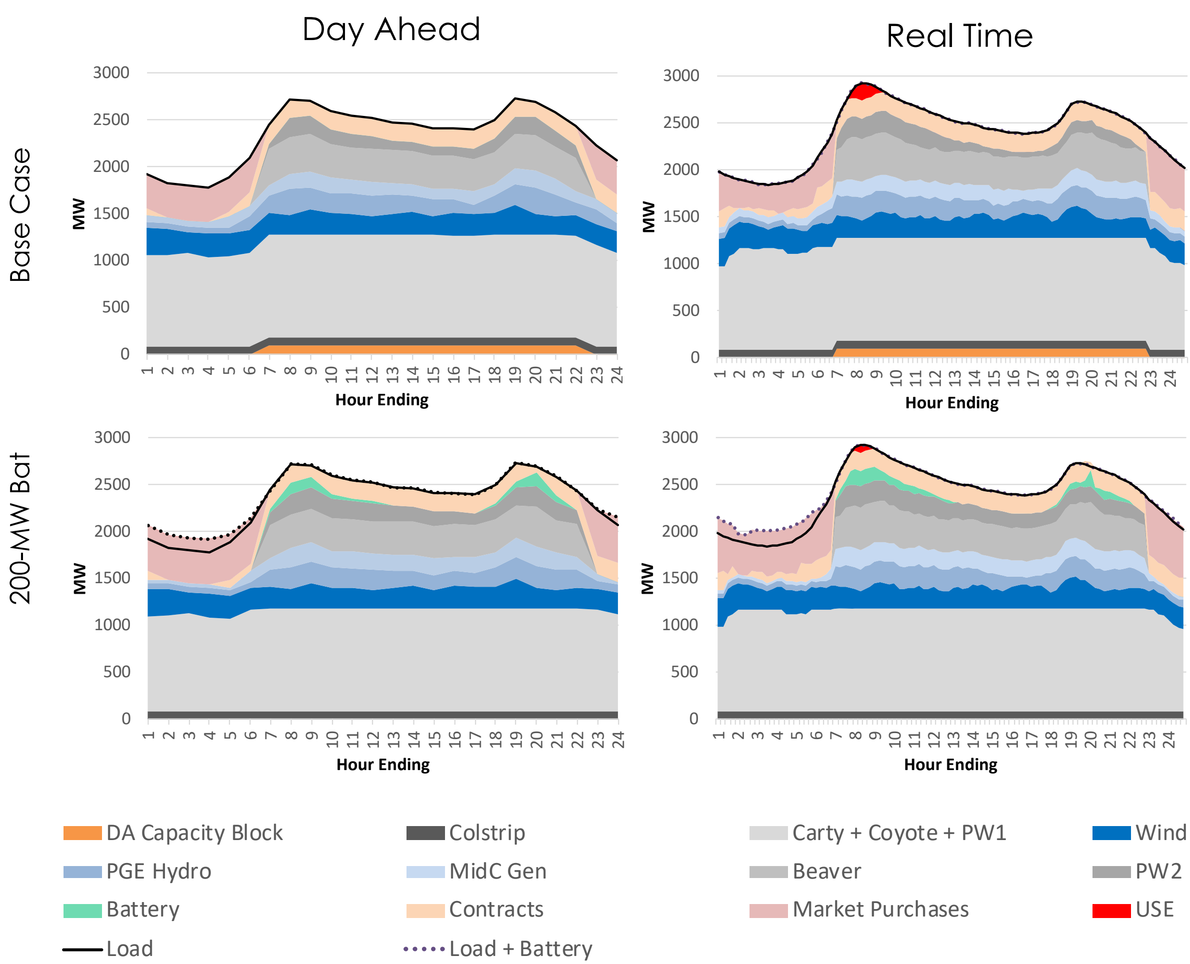
- USE decreases with battery size until 500 MW (4-hour duration), then sharply increases



All data is draft until filed.

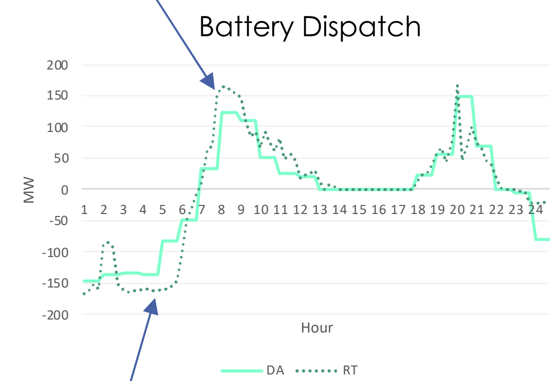
The Flexibility Value of Batteries

February Day Dispatch



- A battery is capable of adjusting its schedule within the day

Battery increases output to compensate for higher load

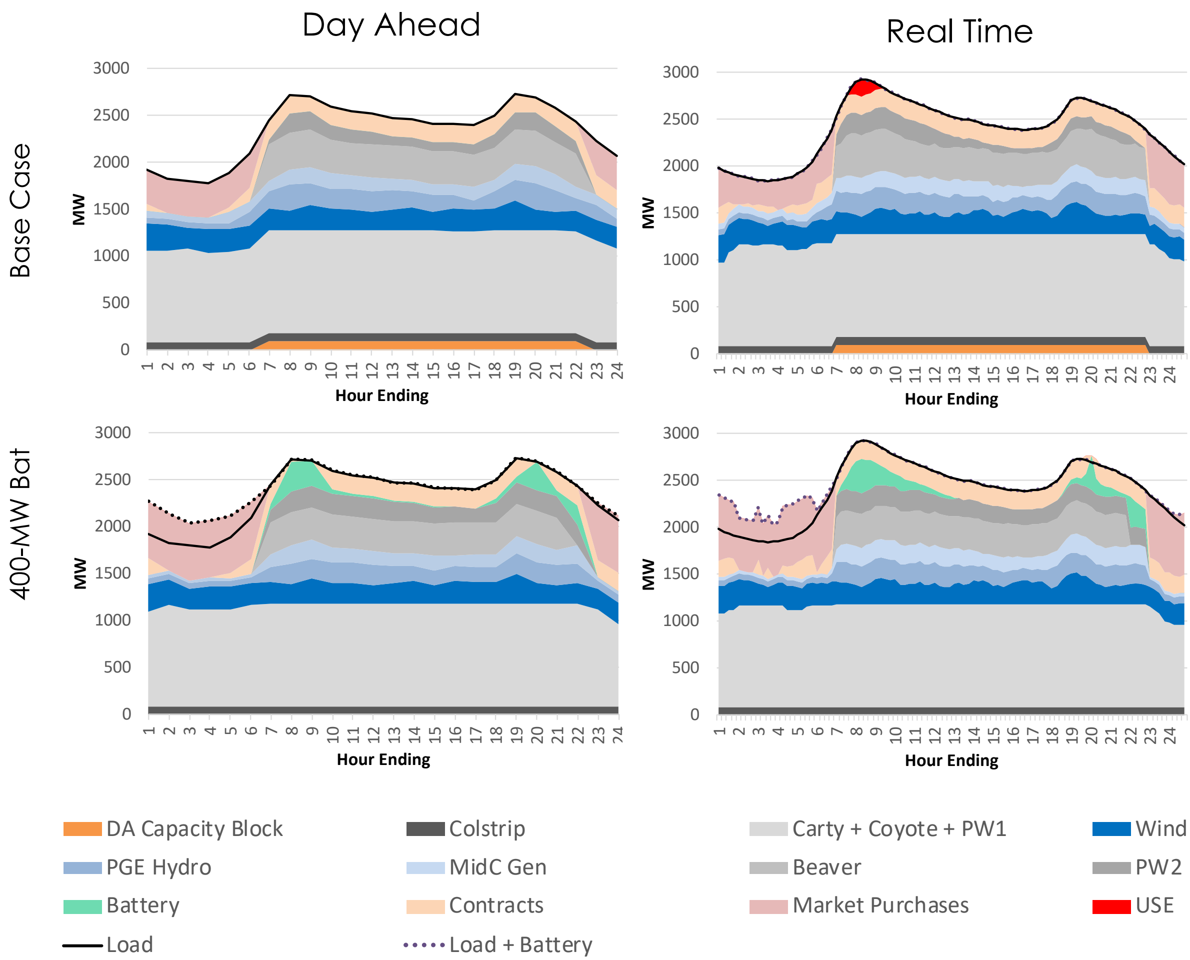


Battery charges up more in RT than in DA

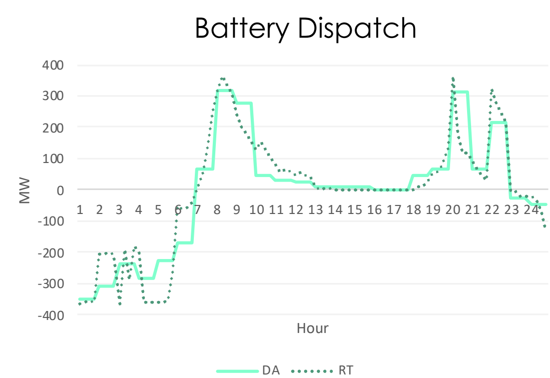
All data is draft until filed.

The Flexibility Value of Batteries

February Day Dispatch



- A battery can shape energy, potentially freeing up other resources to deal with forecast error

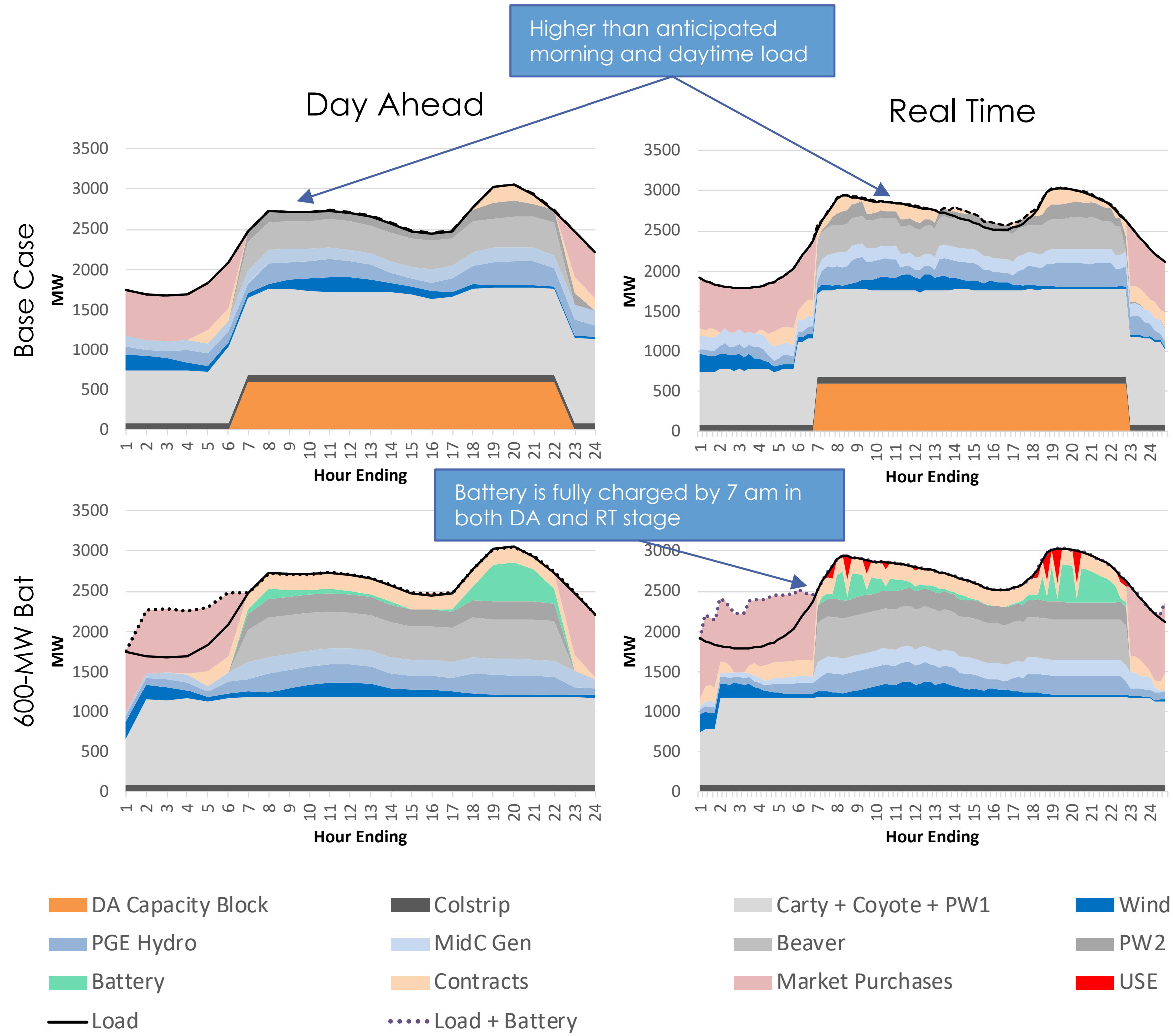


Battery dispatch is similar between RT and DA – value is in the ability to allocate energy more efficiently than the DA capacity block

All data is draft until filed.

"Energy Adequacy" of Larger Batteries

- Batteries are an energy-limited resource and rely on other resources to charge
- As more DA capacity is replaced with battery capacity, the system can become energy-limited on some days



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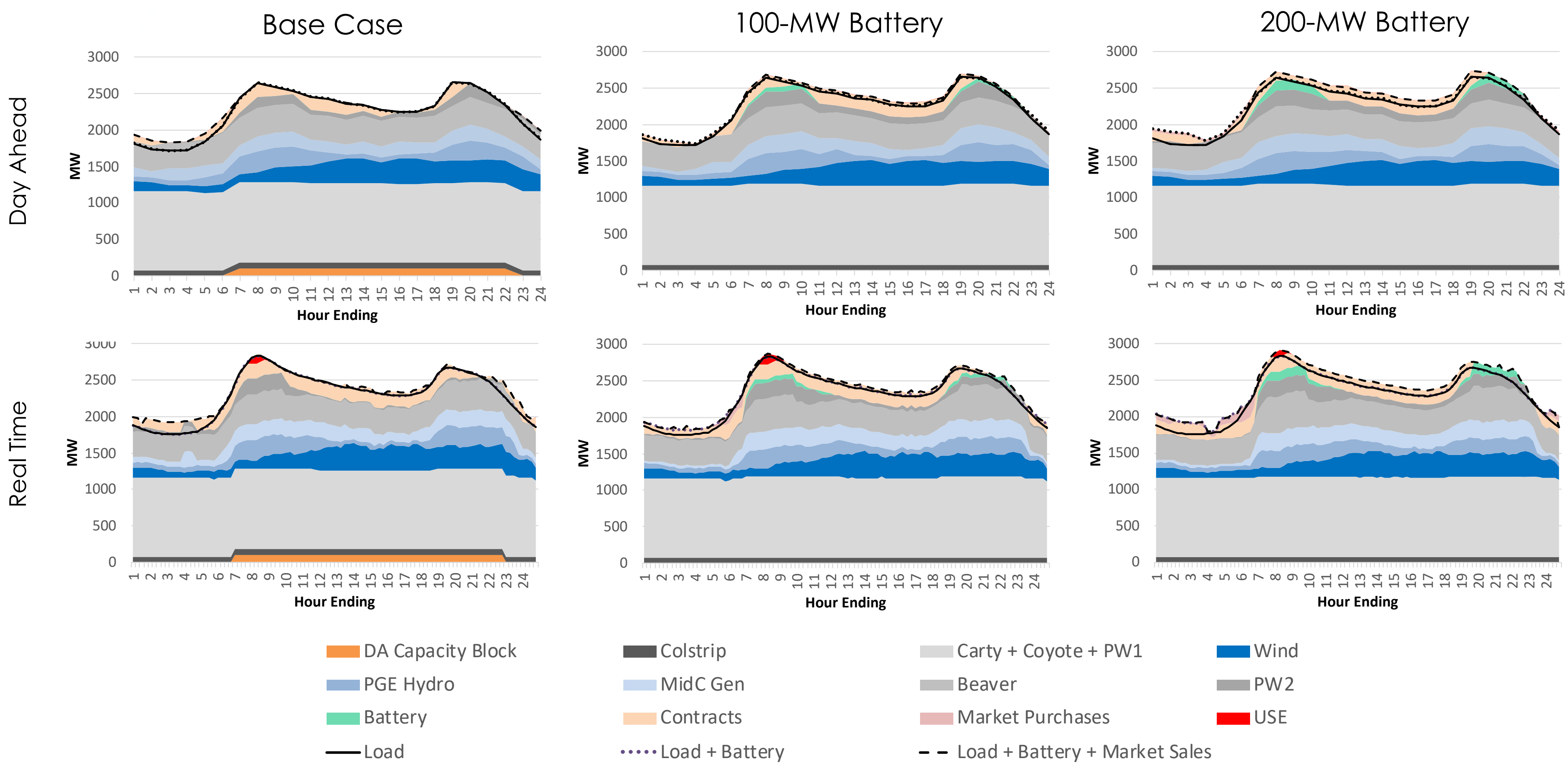
Can a Battery Exacerbate Forecast Error?



- On some days, the battery makes it possible to sell into the market in the DA stage to lower system cost
- However, if net load is under-forecast, the additional commitment may exacerbate USE intra-day

All data is draft until filed.

Thank You

Contact:

ana@bluemarble.run

Flexibility Adequacy Study Takeaways

- We continue to think it is important to better understand how to assess flexible capacity adequacy in our system
- In future work, aim to continually improve and add incremental progress to flex adequacy assessment
- Flexible capacity additions on a system and their implications for system flex adequacy are complex

Flexibility Value

Objective: estimate operational flexibility value of different new resources when added to the PGE system in 2025

- New resource additions to the system bring two types of operational value: energy value and flexibility value
- A case is run with and without each potential new resource
  - System cost savings between the two cases includes both energy value and flexibility value
  - We remove the energy value from the system cost savings to isolate flexibility value and calculate them on a $/kw-year basis
- Marginal flexibility benefits decrease as more flexible resource capacity is added to the system

All data is draft until filed.

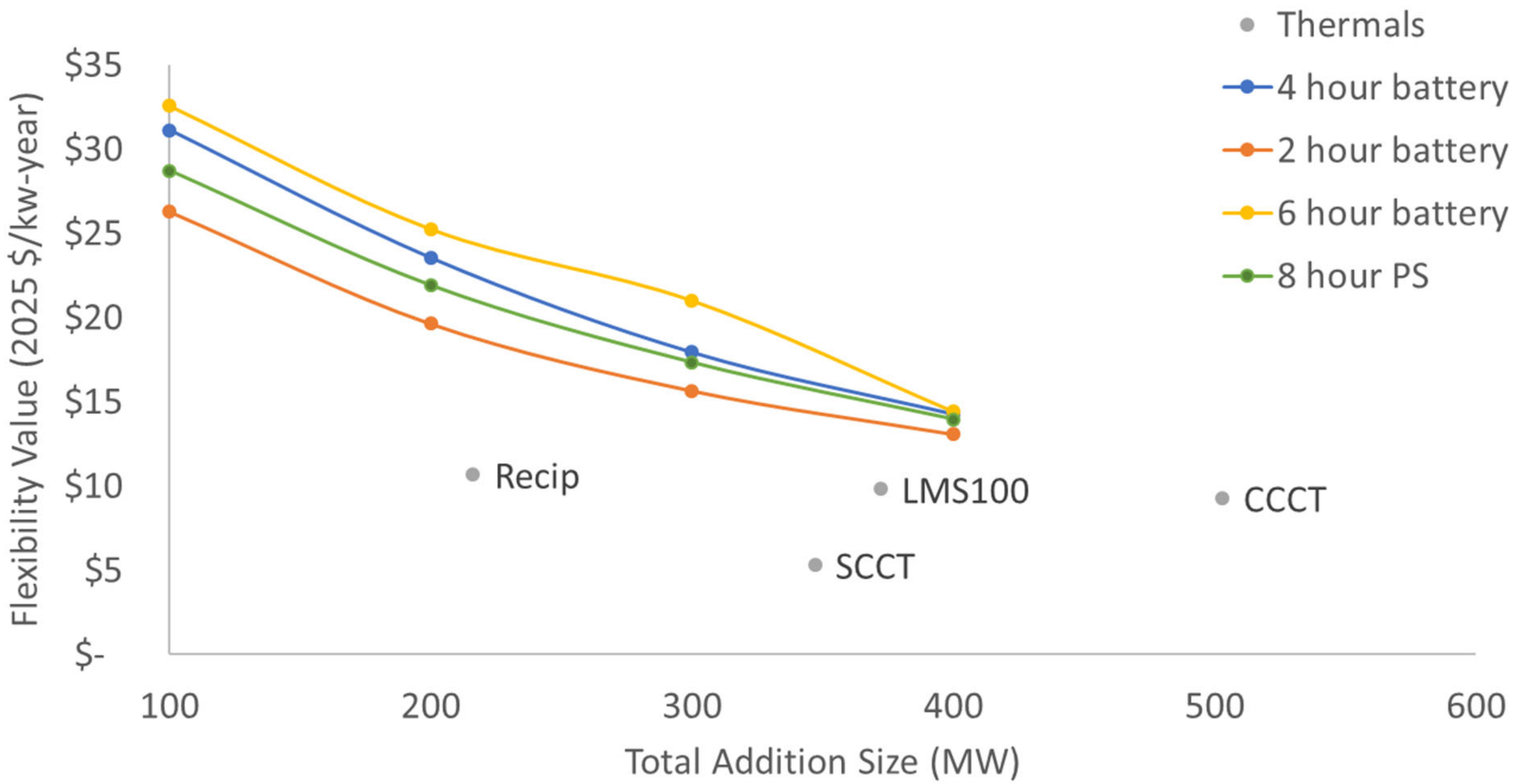
Flexibility Value: New Resources

Storage resource	Round trip efficiency
2 hour battery	82%
4 hour battery	87%
6 hour battery	89%
Pumped storage	80%

Description	Unit Size	Number of units	Total additions (MW)
SCCT	347	1	347
Recip	18	12	216
CCCT	503	1	503
LMS100	93	4	372

All data is draft until filed.

Flexibility Value Results



All data is draft until filed.

VER Integration Costs

Objective: estimate updated integration cost of different new resources when added to the PGE system in 2025

	Solar	MT wind	WA Wind
Integration cost (2025$)/MWh	1.51	0.14	0.28

- 100 aMW of each new resource (solar, MT wind and WA wind) is added to the system in separate runs
- Incremental costs estimated from the system cost difference between two cases:
    1. PGE system does not integrate new resource
    2. PGE system integrates new resource

All data is draft until filed.

Wrap up

Elaine Hart

Next Steps

2019 IRP Process

- Analytical refinements are ongoing
- Seeking informal feedback from stakeholders on Draft Action Plan by March 22, 2019
- Targeting April 2019 for release of Draft 2019 IRP
- Targeting June 2019 for filing of 2019 IRP

Roundtable and Public Meetings

- PGE is planning a Community Listening Session to receive additional feedback on the Action Plan, targeting May 2019
- PGE will continue to hold Roundtable Meetings in 2019 to provide updates as needed

RFP Process

- In parallel with the IRP, PGE will initiate a separate process to support the design of the next Renewables RFP

Thank you!

Contact us at:
IRP@pgn.com