Integrated Resource Planning

Roundtable 18-6

November 28, 2018

Meeting Logistics

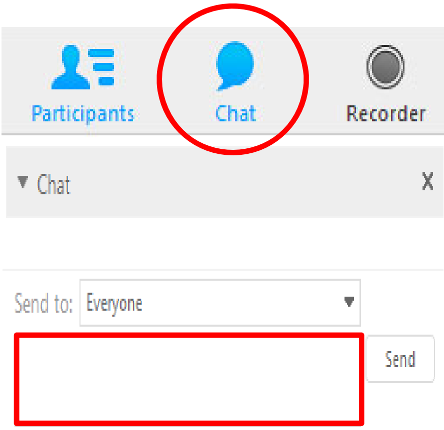
Local Participants:

- 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

- ❑ Portfolio & Scoring Update
- ❑ Flexibility Analysis
- ❑ Final DER Scenarios
- ❑ Need Update
- ❑ Experience Curve Analysis

Safety Moment

[Winter Preparation Safety Moment]

Portfolio & Scoring Update

Elaine Hart

Draft Portfolio & Scoring Caveats

Draft analysis does not reflect pending updates, including:

Update Needed	Draft Approach of 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
Finalized dispatch results	Draft analysis makes use of updated dispatch simulation results. Further refinements are ongoing.
Finalized flexibility analysis results	Draft analysis incorporates approximations of flexibility value for dispatchable resources, excludes variable renewable integration costs
Finalized cost and performance data	Draft analysis incorporates final renewable cost and performance data and High and Low capital cost futures based on learning curve analysis, except for Geothermal
Outcome of Renewables RFP	Draft analysis assumes a 100 MWa Gorge Wind addition in 2021, consistent with PGE’s 2016 IRP Revised Renewable Action Plan
Still to incorporate:	Refine REC bank characterization to align with 2017 RPS Compliance year; incorporate hydro futures into scoring risk metric calculations

Toward a Renewable Glide Path

- At Roundtable 18-5 on October 31st, PGE presented potential Renewable Glide Paths associated with various renewable portfolios
- Economic optimization tended to lead to very steep ramps in renewable procurement in the 2030s
- PGE proposed to impose a constraint in portfolio optimization to result in smoother Renewable Glide Paths to 2040
- PGE implemented two capacity addition constraints in the draft portfolios shown today
    - After 2025, total (across all resources) capacity additions are limited to 300MW per year. Note: unit sizes are not enforced post-2025.
    - Over 2022-2025, total (across all resources) capacity additions are limited to 300MWx4 = 1200MW, but no annual limit is imposed

Montana Wind Transmission Assumptions

- For the Montana Wind analysis in the 2019 IRP, PGE assumes availability of transmission to BPA's system
  - This assumption is made specifically for IRP modeling purposes and is not a forecast of actual future transmission availability
- Consistent with the MRDAP and the most recent transmission tariff filings from PSE and BPA, PGE has established the following transmission rates and losses for the Montana Wind resource:

Wheel	$/kW-mo	$/kW-yr	Losses	Notes
PSE CTS (Schedule 10)	0.99	11.91	2.7%	PSE rate is subject to waiver filing with FERC
MT Int	0.83	9.97	5.0%	
BPA	1.79	21.50	1.9%	
Total	3.62	43.39	4.6%	Excludes 5% losses per MRDAP
Incremental to Busbar	1.82	21.88	2.7%	

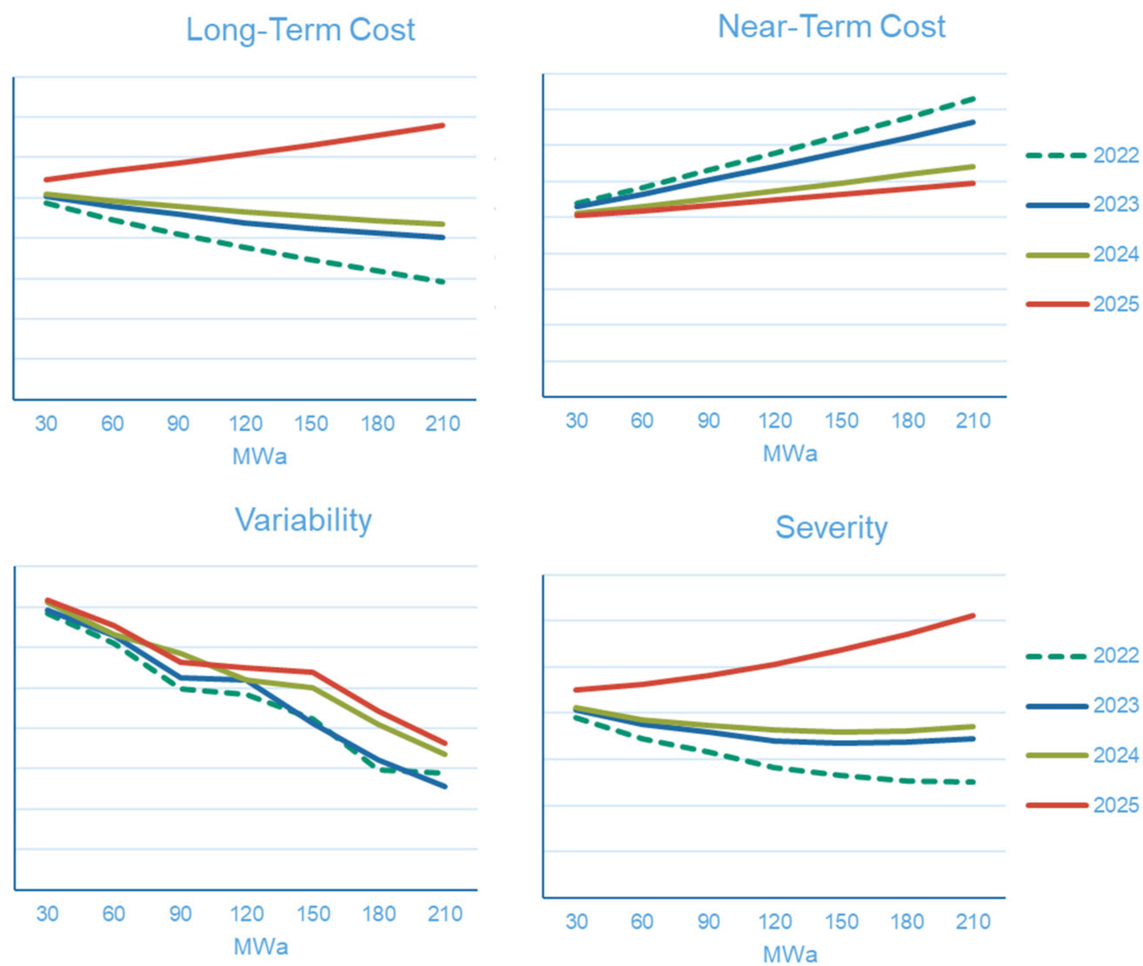
Note that these rates and losses are incremental to the rates and losses associated with wheeling from BPA to PGE, which are imposed on all non-distributed resources in IRP modeling

Renewable Size and Timing Portfolios

Draft Portfolios

Renewable Size and Timing Portfolios

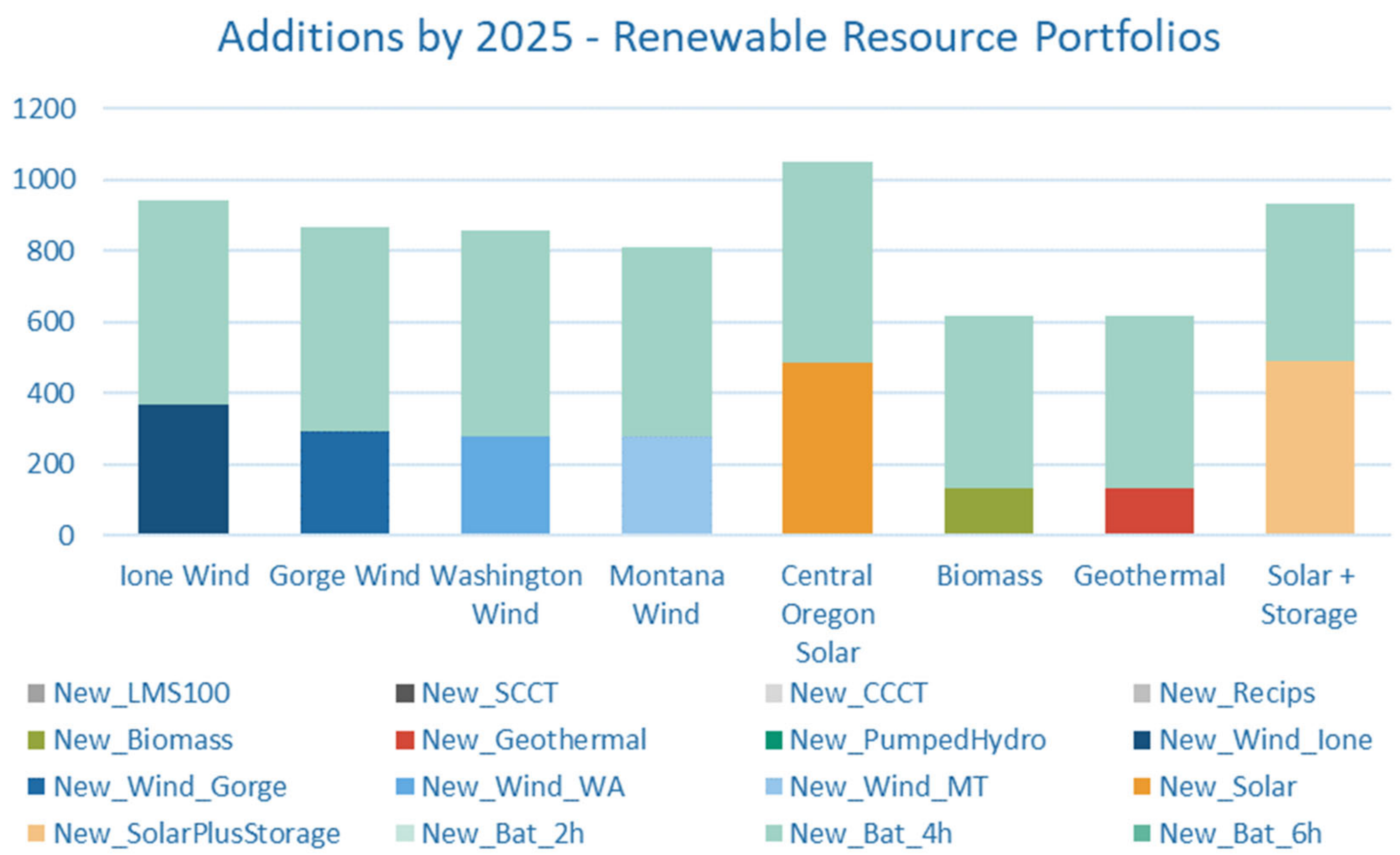
- Tests renewable resource economics as a function of both procurement size (MWa) and online date (COD)
- These portfolios require a specified amount of RPS-eligible energy to be procured in a specified year, but allow for the optimal selection of the RPS-eligible resource(s) within that requirement



Renewable Resource Portfolios

Draft Portfolios

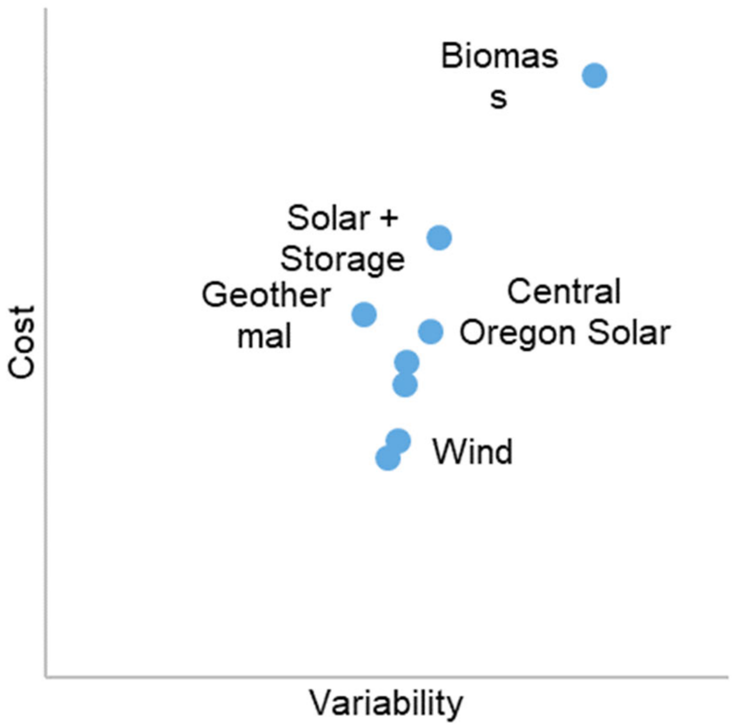
Renewable Resource Portfolios

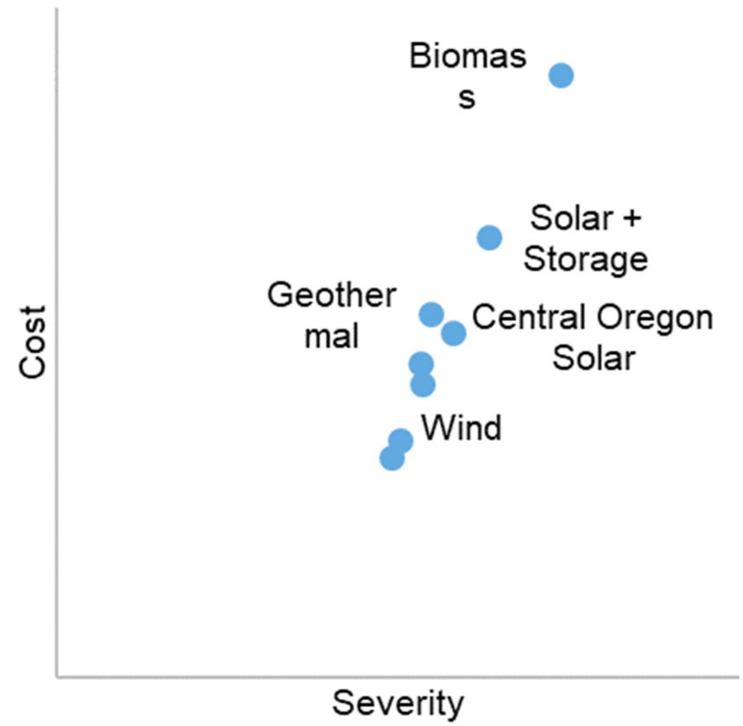


Draft Portfolios

Renewable Resource Portfolios

Portfolio performance across traditional metrics

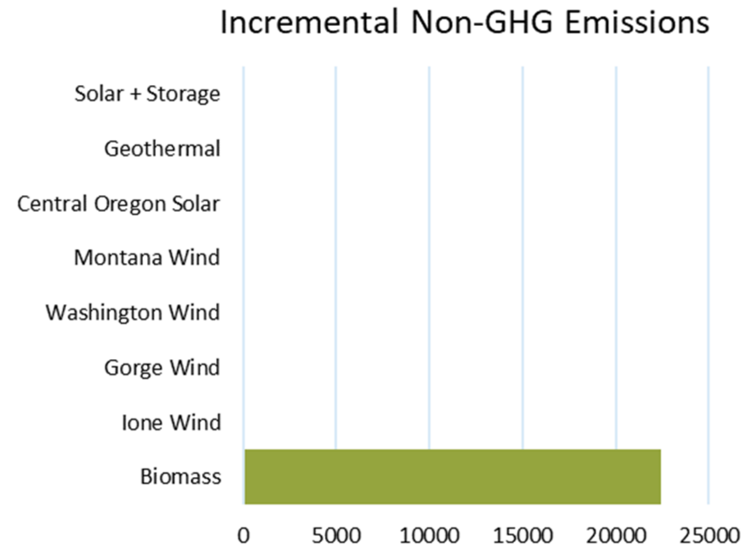


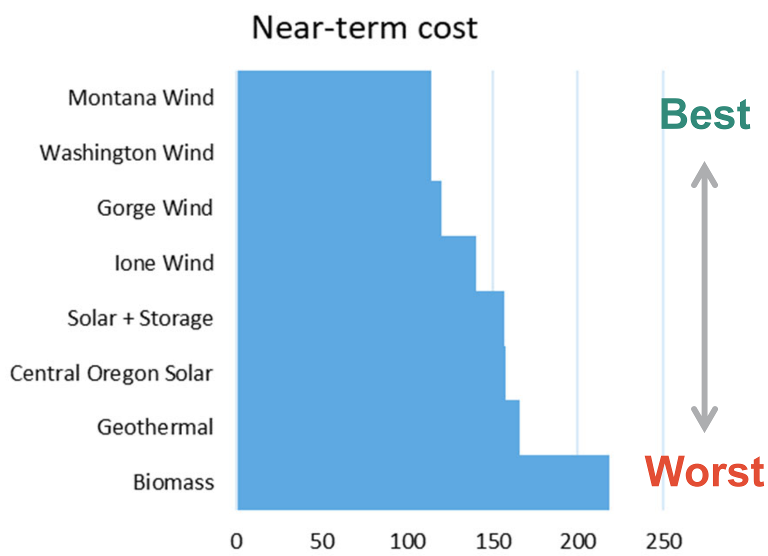


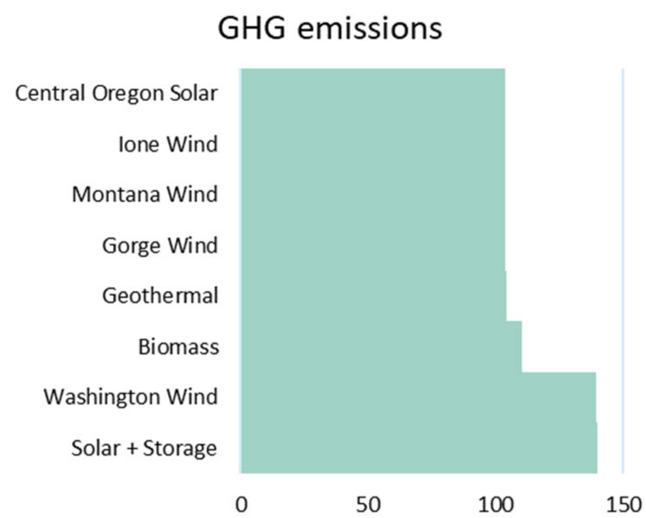
Draft Portfolios

Renewable Resource Portfolios

Portfolio performance across non-traditional metrics



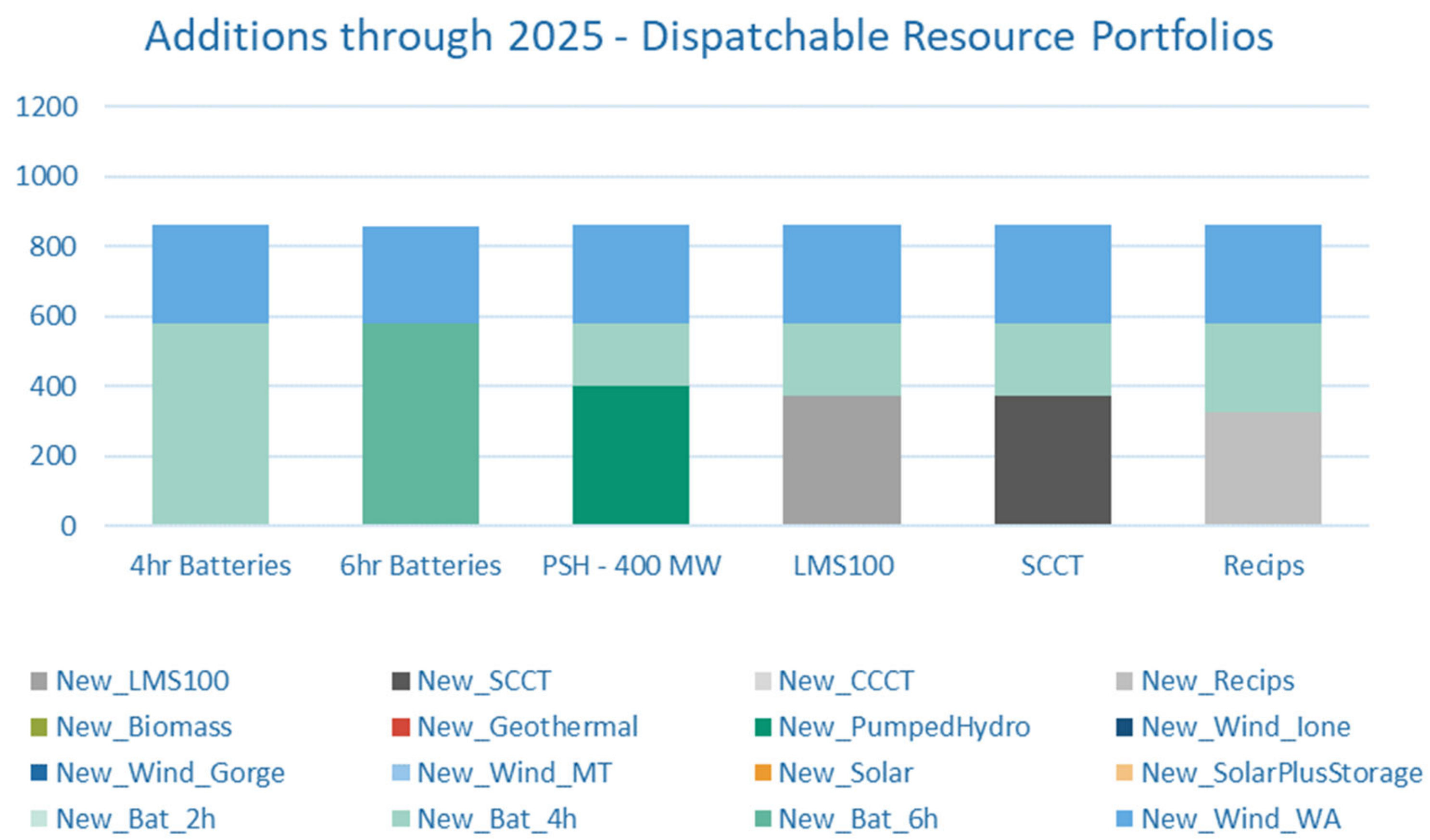




Dispatchable Resource Portfolios

Draft Portfolios

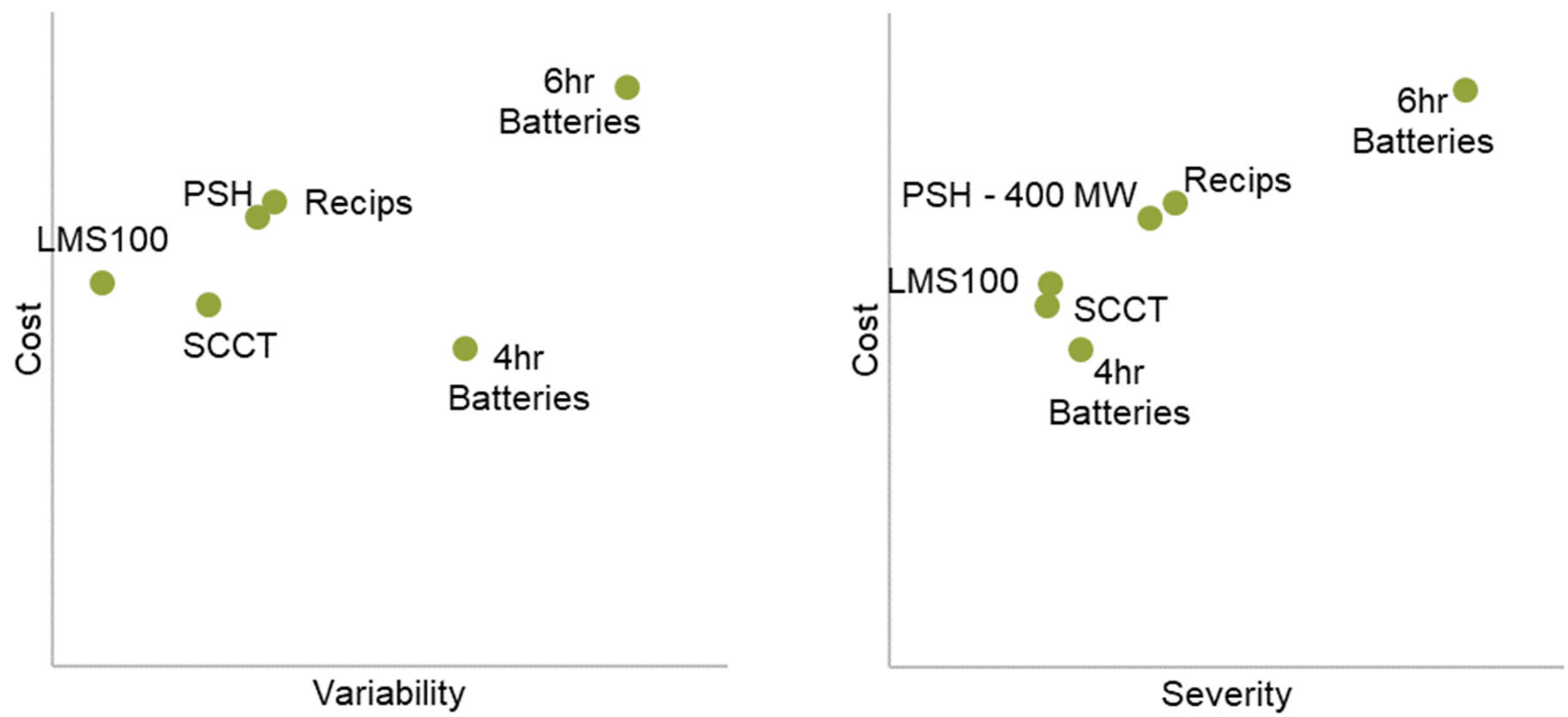
Dispatchable Resource Portfolios



Draft Portfolios

Dispatchable Resource Portfolios

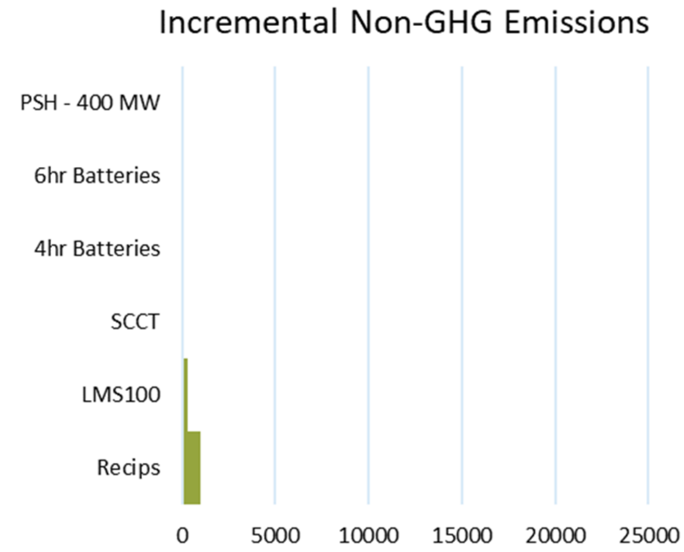
Portfolio performance across traditional metrics

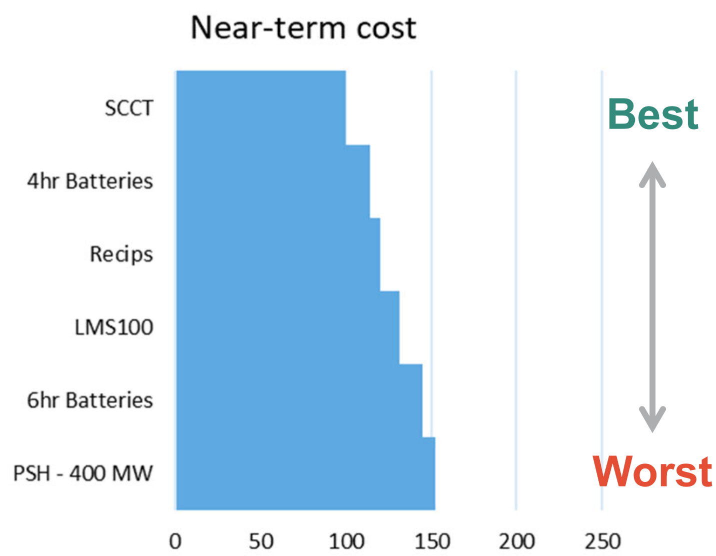


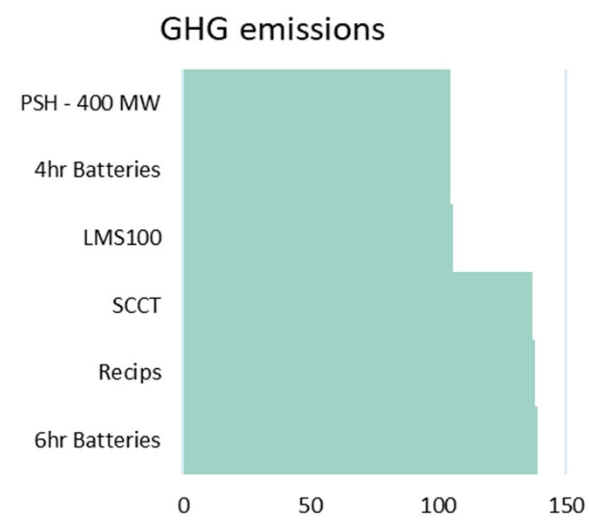
Draft Portfolios

Dispatchable Resource Portfolios

Portfolio performance across non-traditional metrics



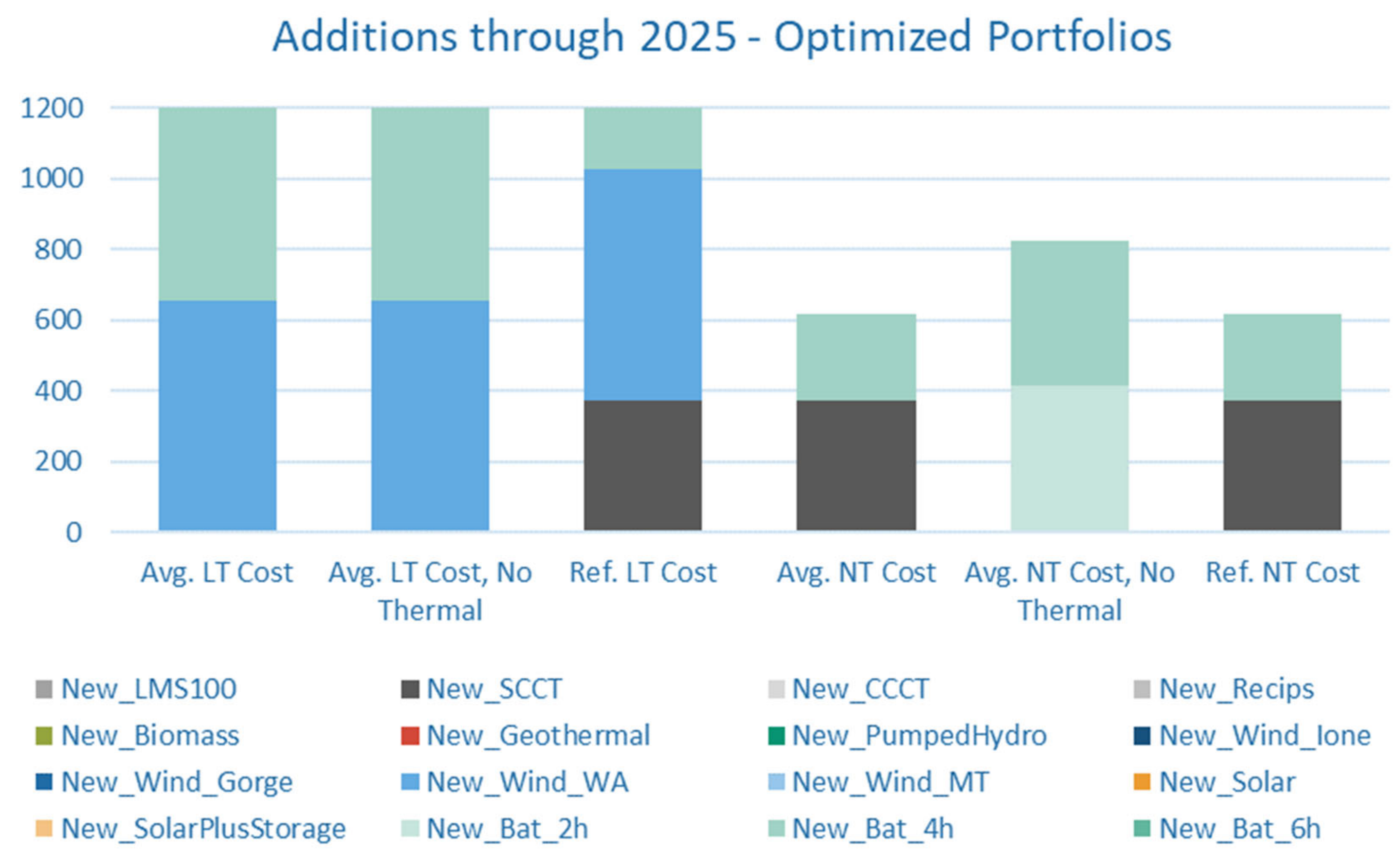




Optimized Portfolios

Draft Portfolios

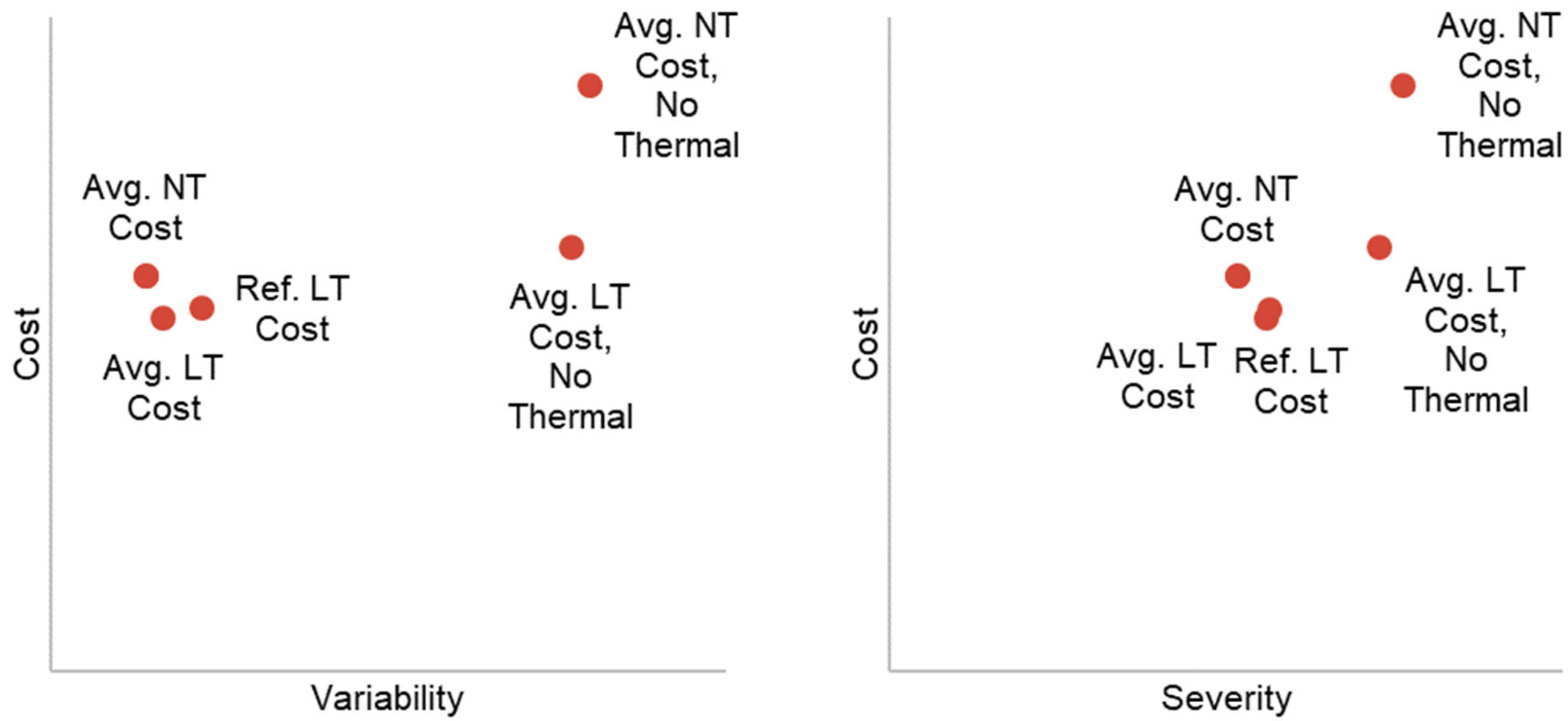
Optimized Portfolios



Draft Portfolios

Optimized Portfolios

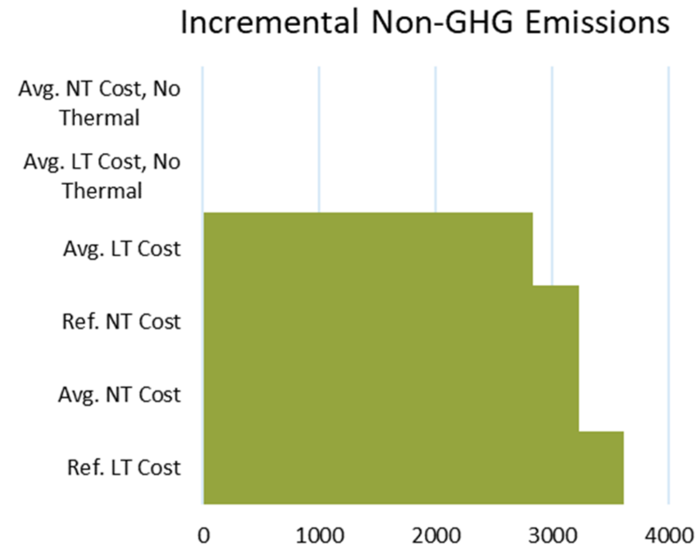
Portfolio performance across traditional metrics

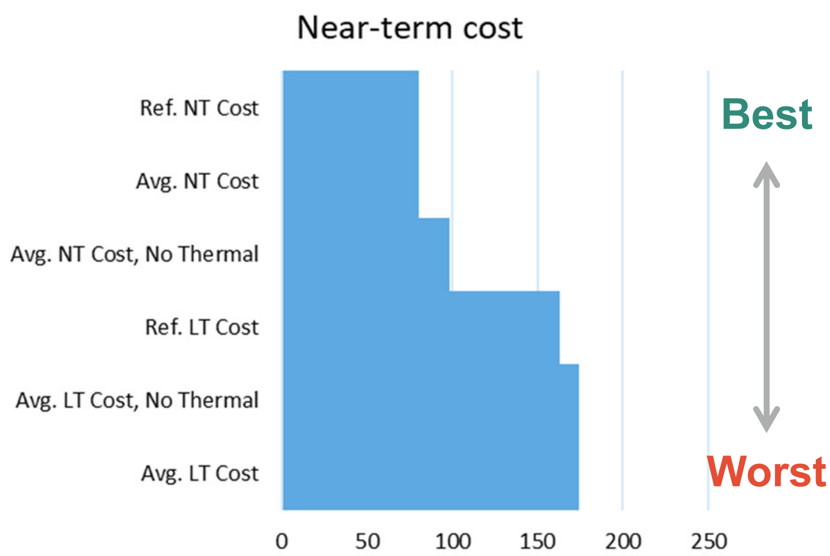


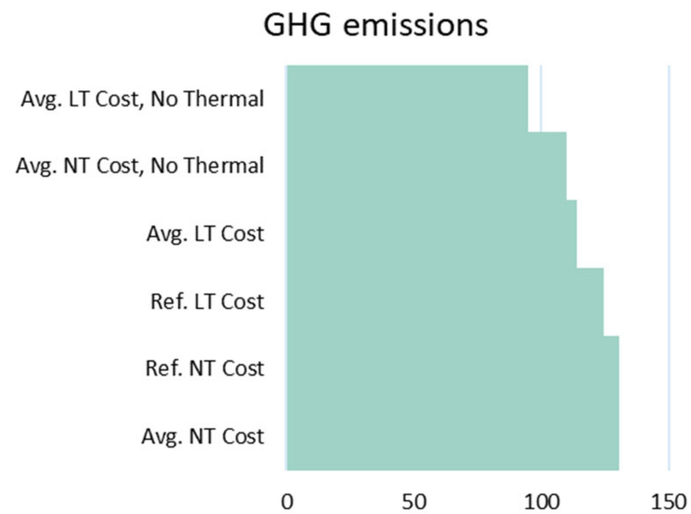
Draft Portfolios

Optimized Portfolios

Portfolio performance across non-traditional metrics

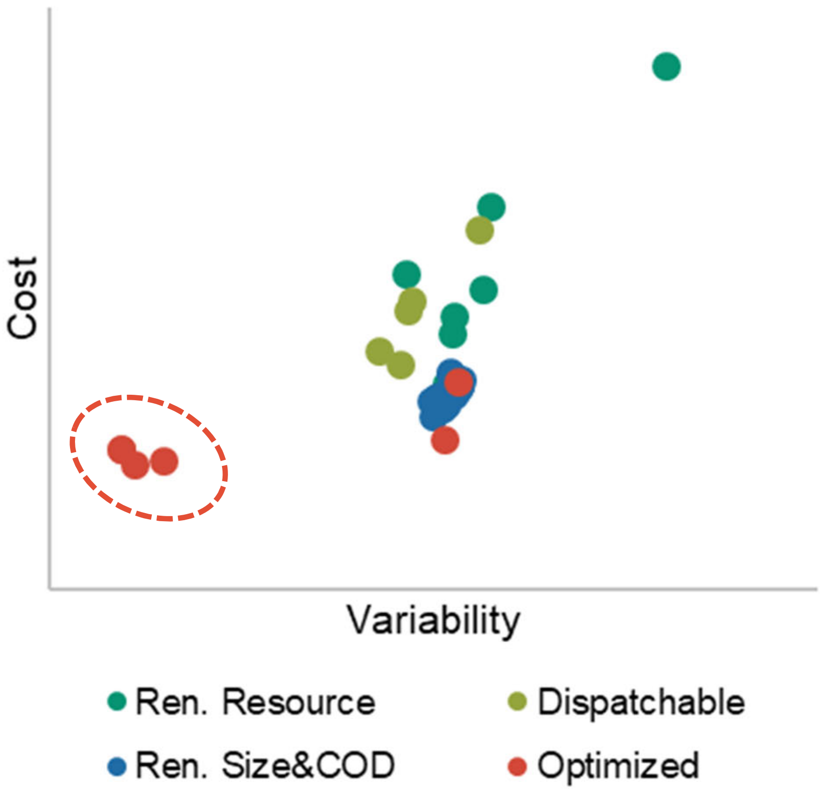


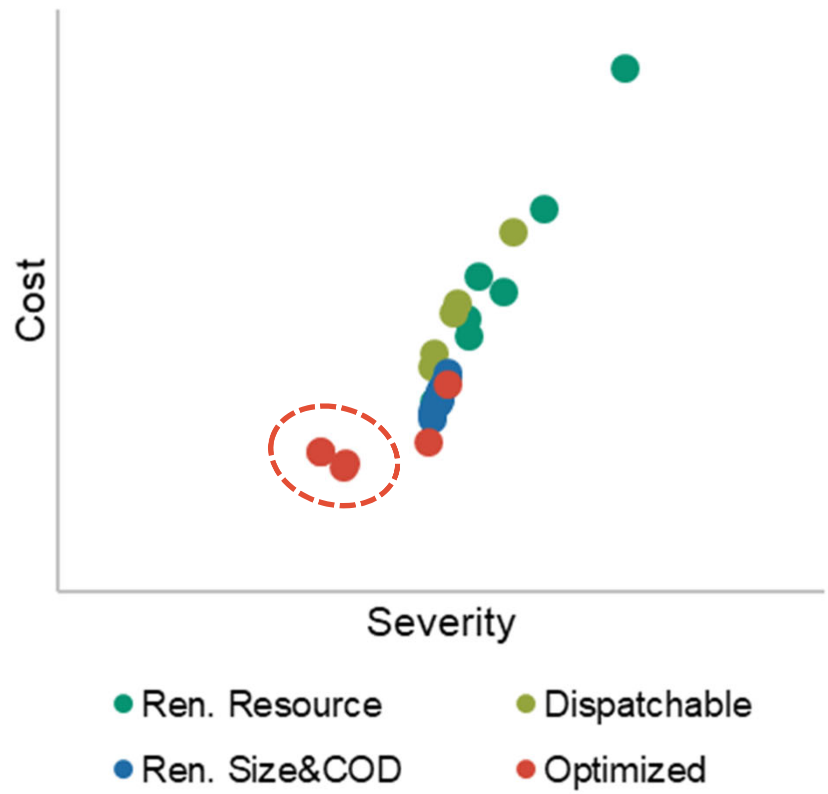




Draft Scoring Strawman

Bringing it all together…





Why not just pick an optimized portfolio?

Strawman Scoring Process

Step 1. Apply reasonable screens

Portfolios that perform the worst across the non-traditional metrics may be excluded from consideration for the Preferred Portfolio

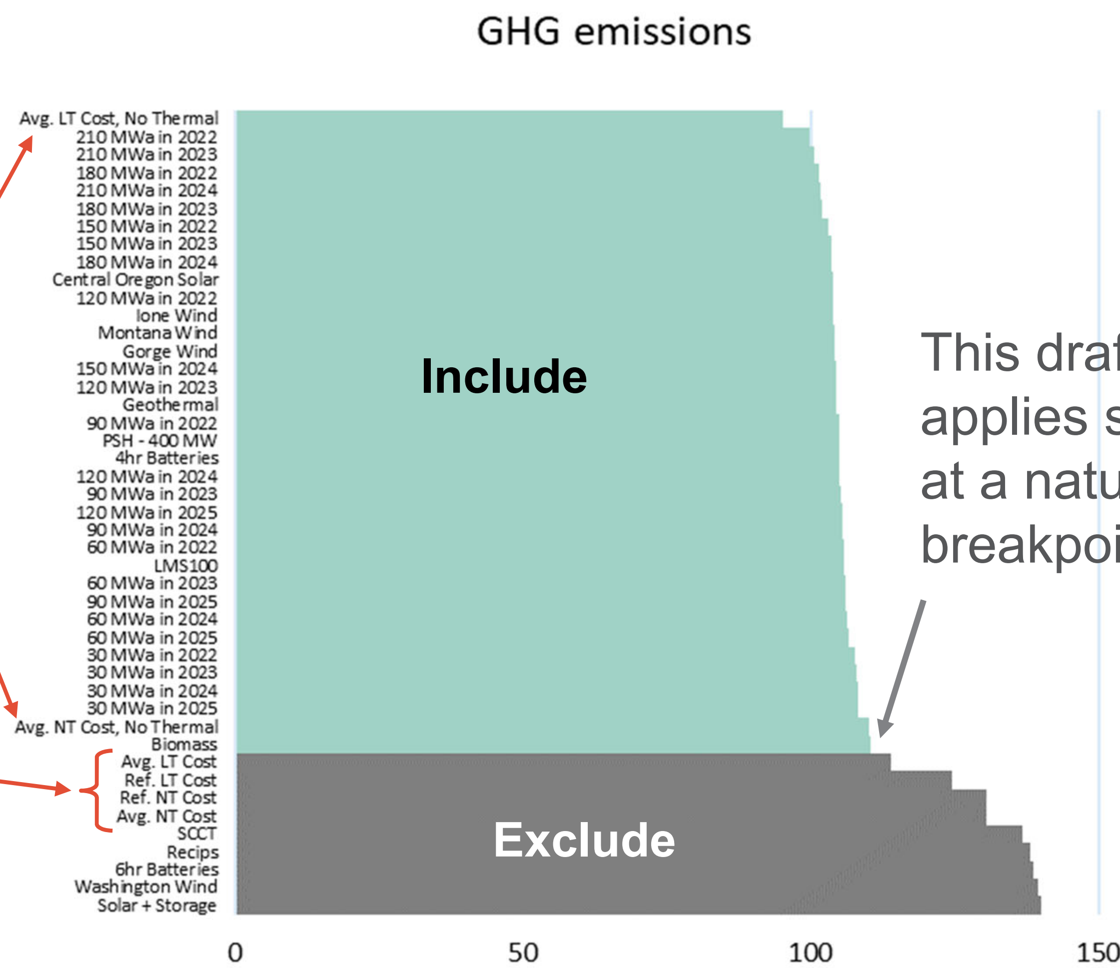
Step 2. Compare traditional cost/risk

Identify remaining portfolios that perform best on the basis of cost and risk

Screen #1 – GHGs

Optimized Portfolios
(no thermal)

Optimized Portfolios
(thermal allowed)

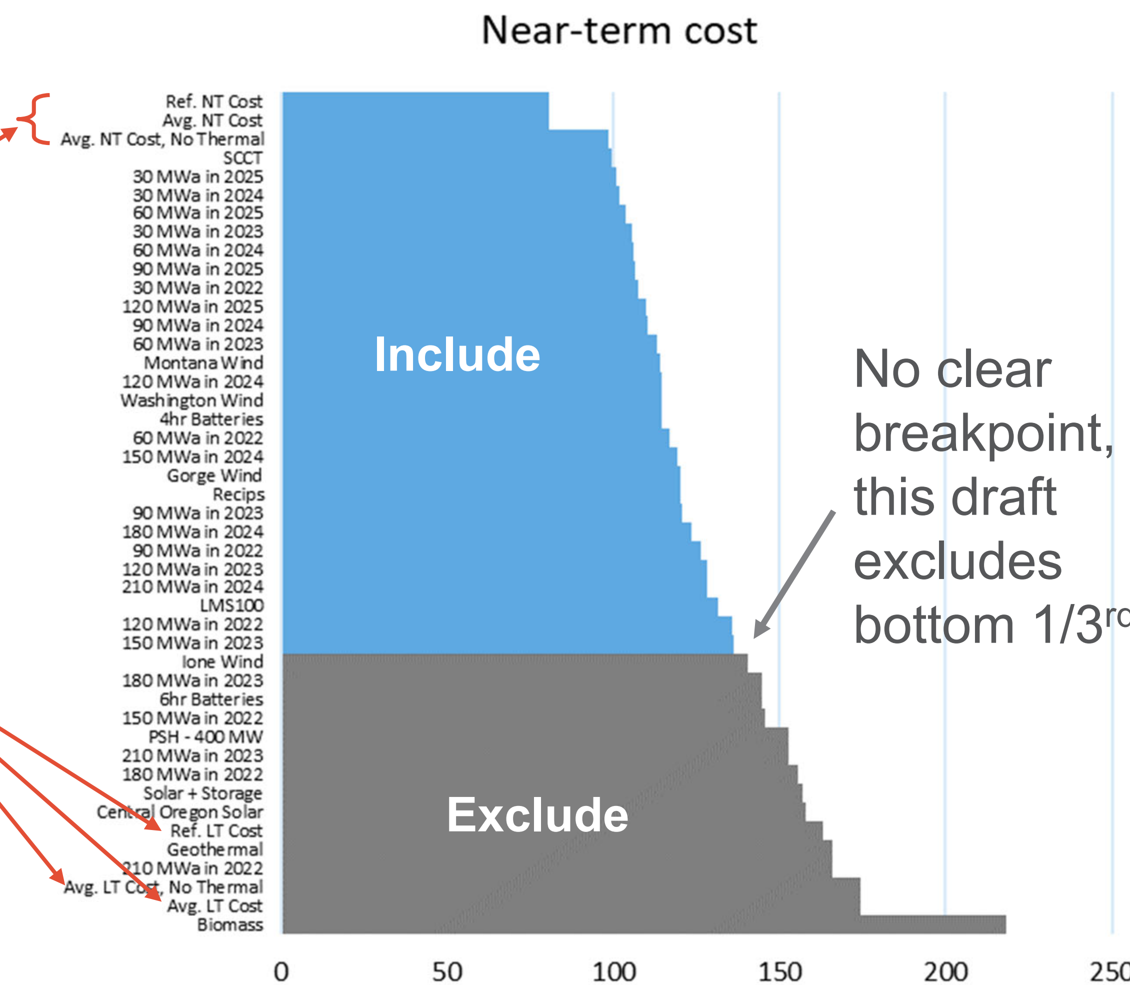


This draft applies screen at a natural breakpoint

Screen #2 – Near-term Cost

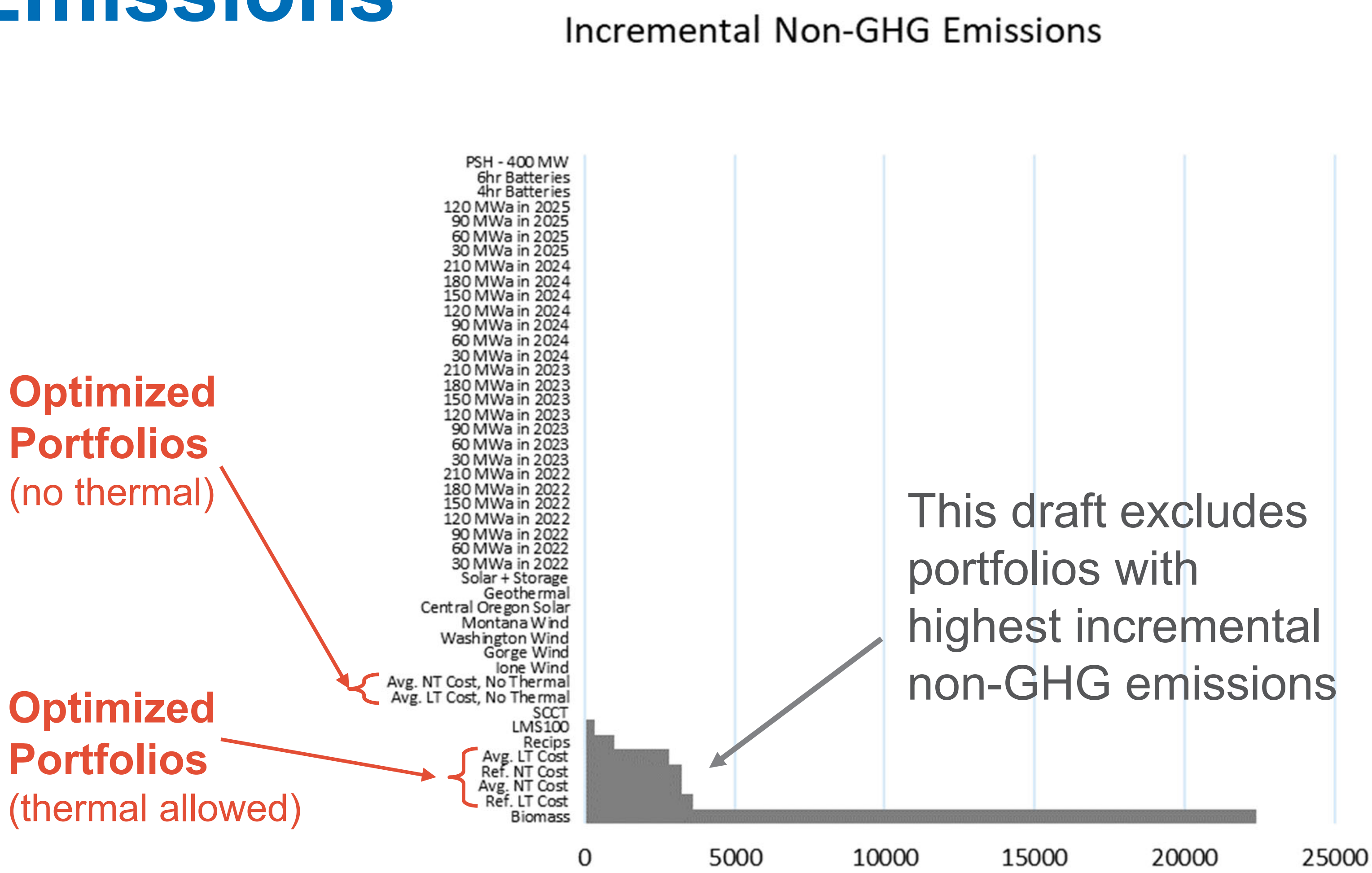
Optimized Portfolios
(minimized <u>near-term</u> cost)

Optimized Portfolios
(minimized <u>long-term</u> cost)



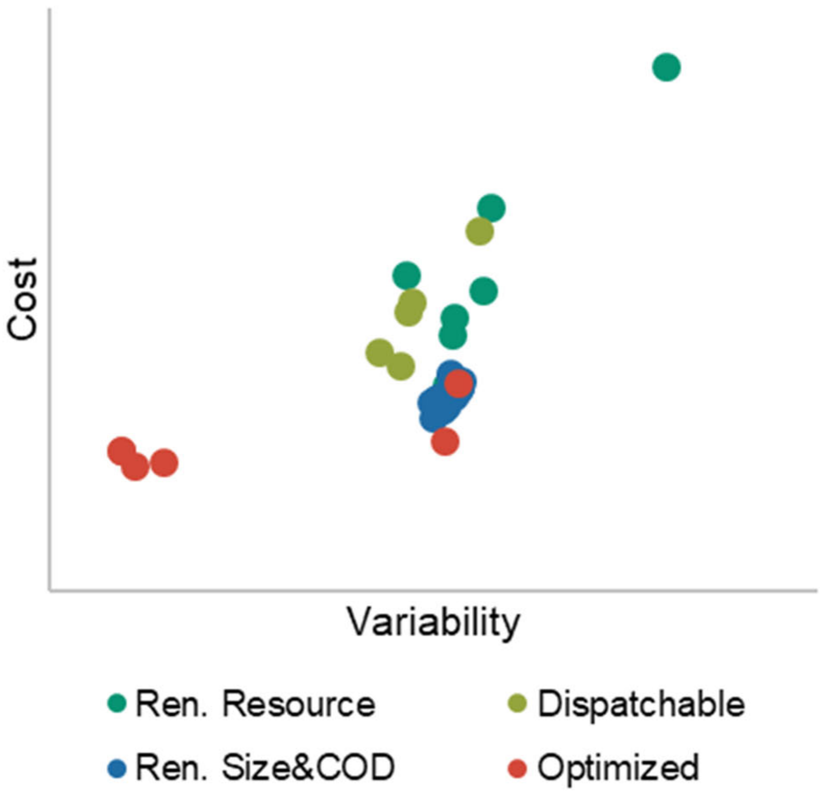
No clear breakpoint, so this draft excludes bottom 1/3rd

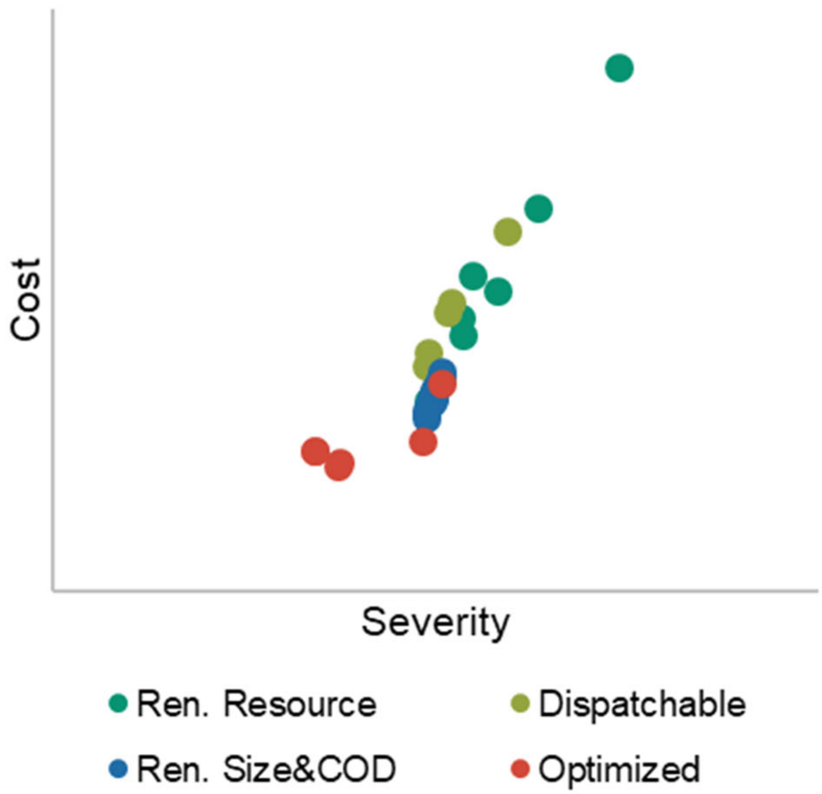
Screen #3 – Incremental Non-GHG Emissions



Applying Screens

Applying screens tends to remove cost/risk outliers





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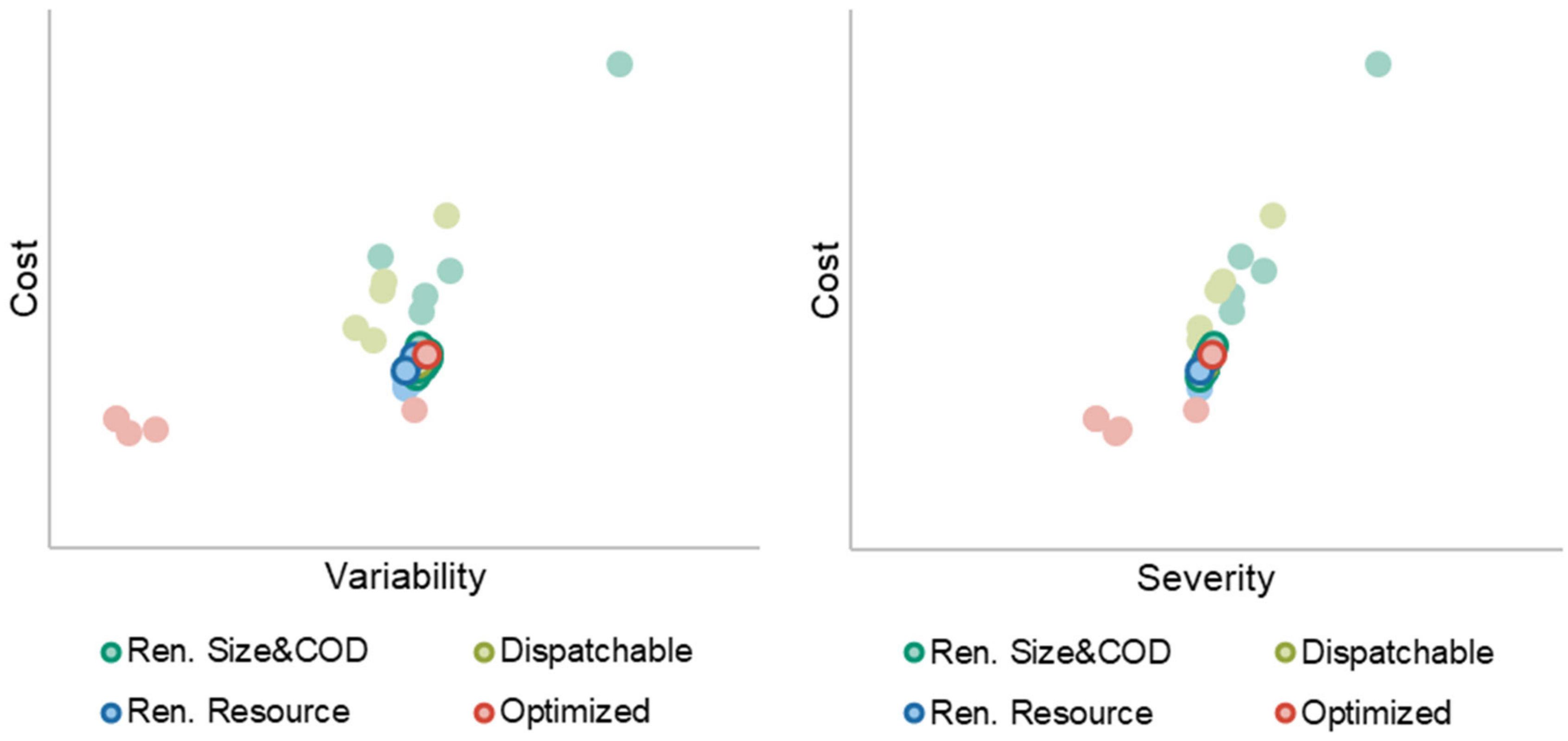
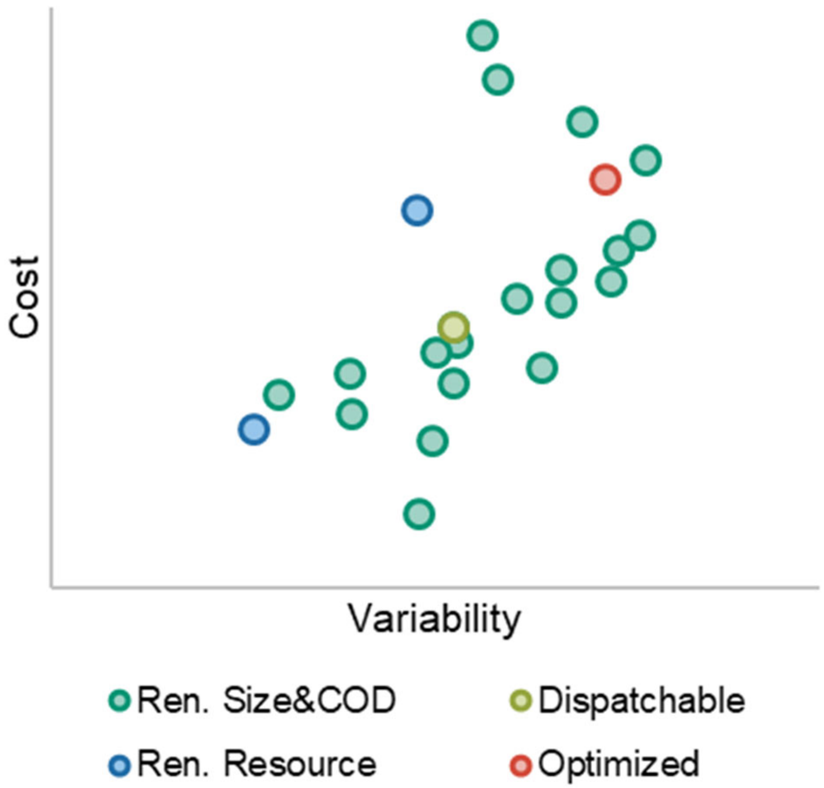
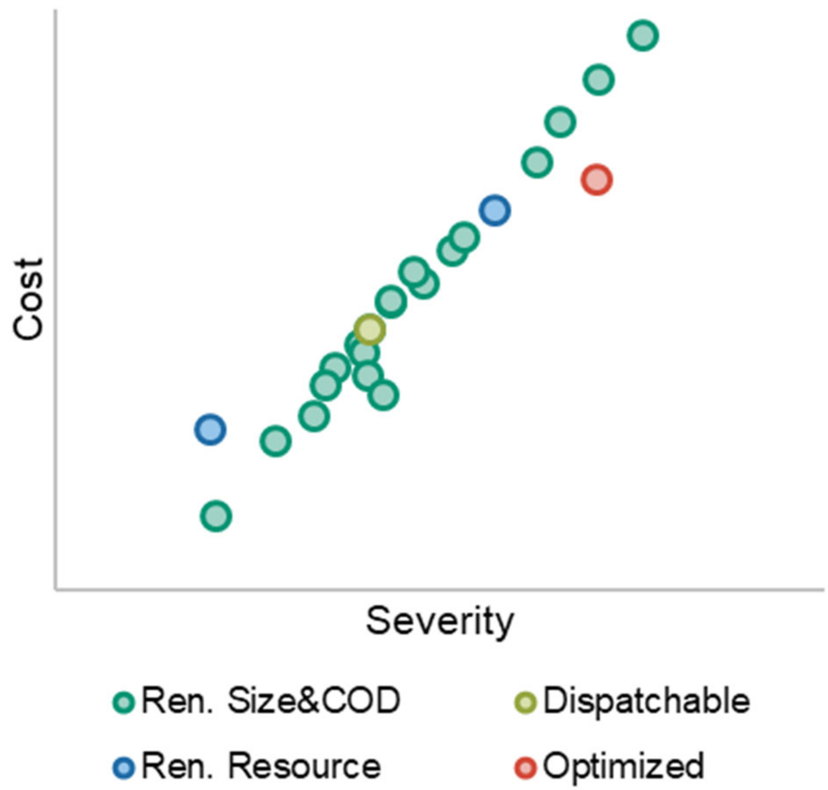


Applying Screens

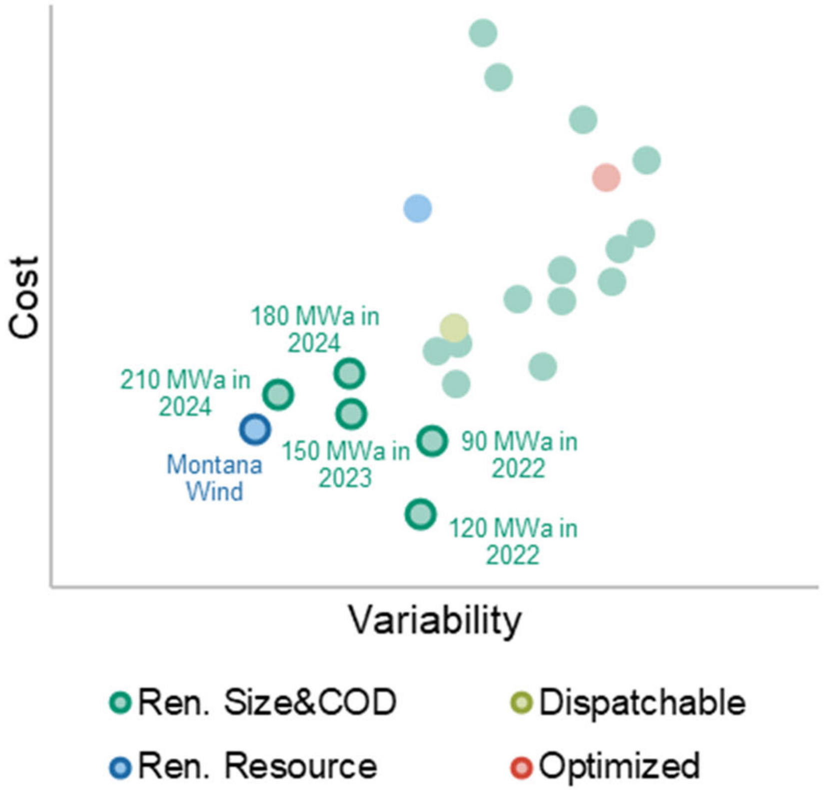
Zooming in…

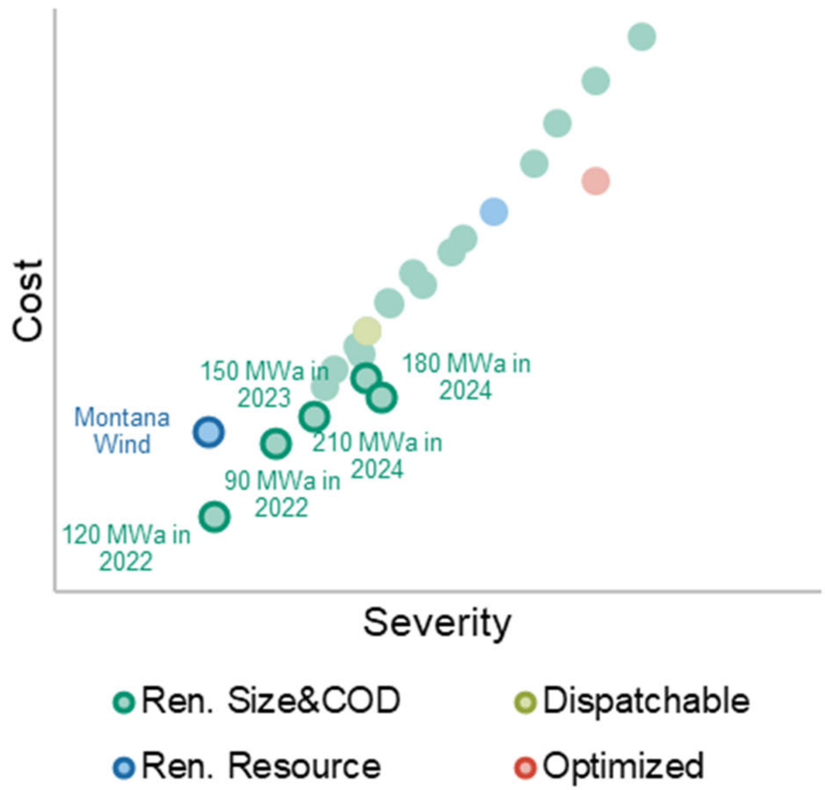




Applying Screens

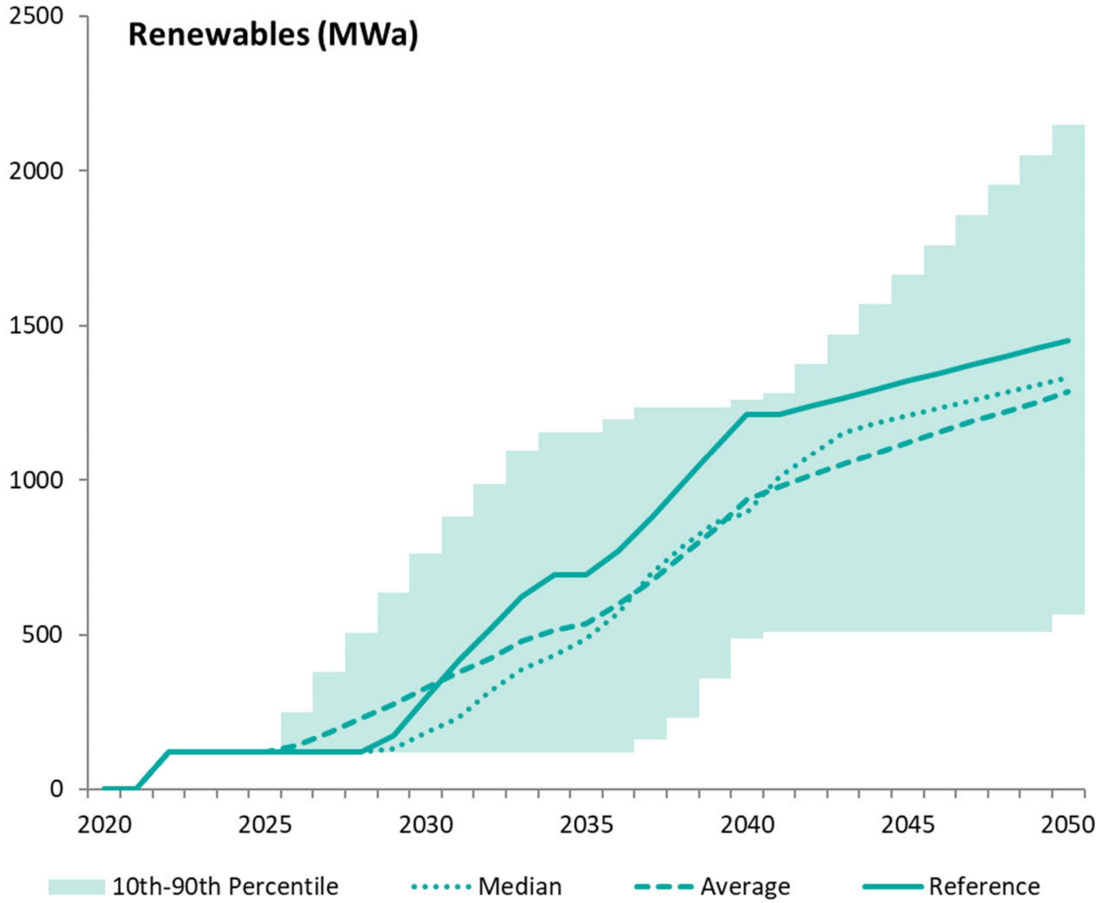
Identifying the draft portfolios that best balance cost and risk… so far!





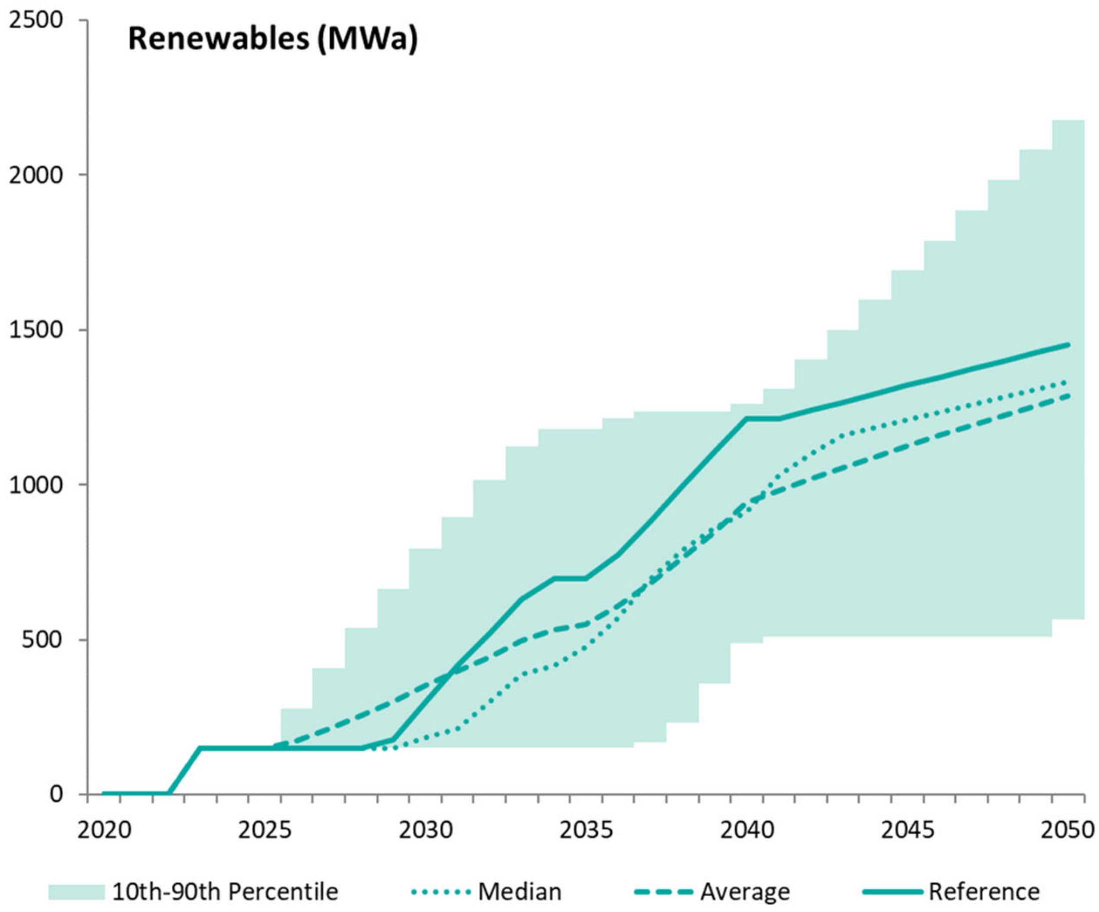
Updated Renewable Glide Path Analysis

Toward a Renewable Glide Path



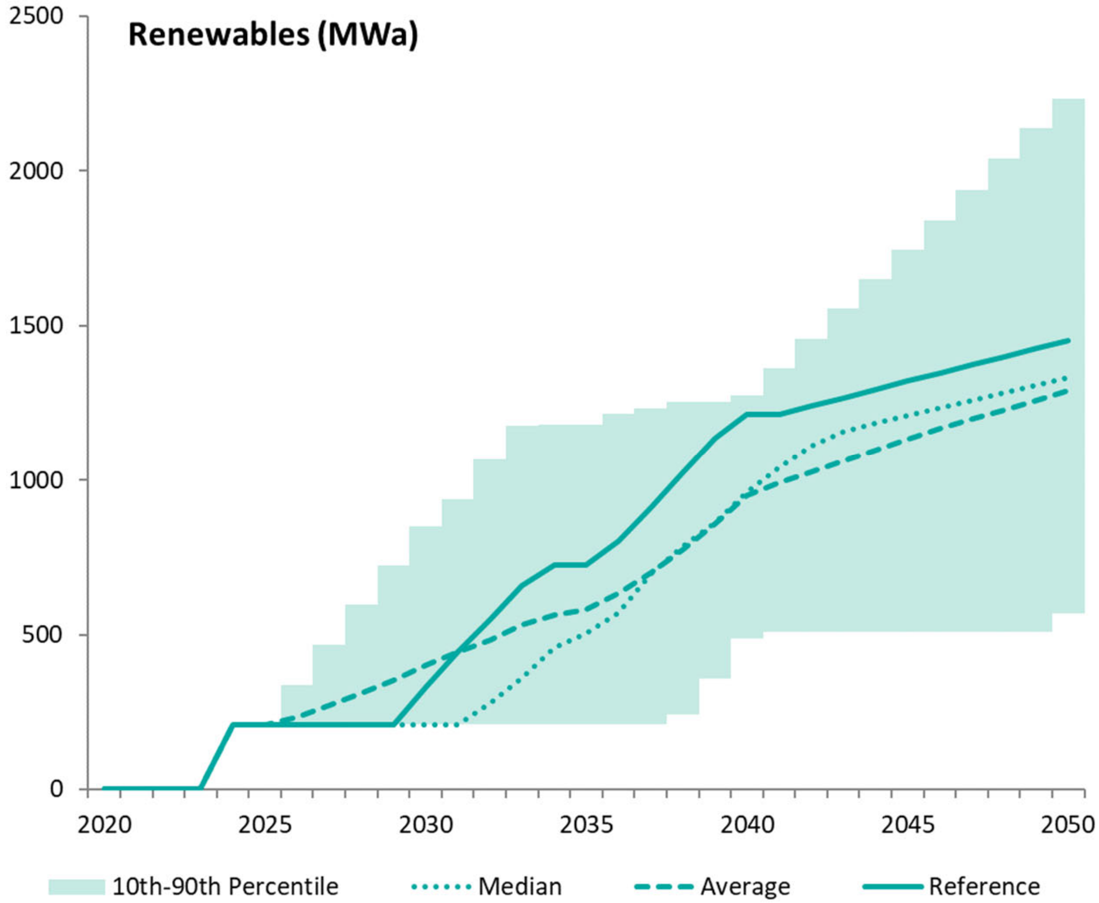
120 MWa of RPS-eligible resources added in 2022

Toward a Renewable Glide Path



150 MWa of RPS-eligible resources added in 2023

Toward a Renewable Glide Path



210 MWa of RPS-eligible resources added in 2024

Next Steps

Finalize data and refine analysis of portfolios and scoring methodologies presented today

Draft additional portfolios:

- Risk-Minimizing Portfolios

Draft sensitivities:

- Renewable cost and performance uncertainties
- Storage cost uncertainties
- Colstrip sensitivities
- Contract renewal sensitivities

Flexibility Analysis

Nora Xu

Flexibility Analysis Scope Review

- An enabling 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

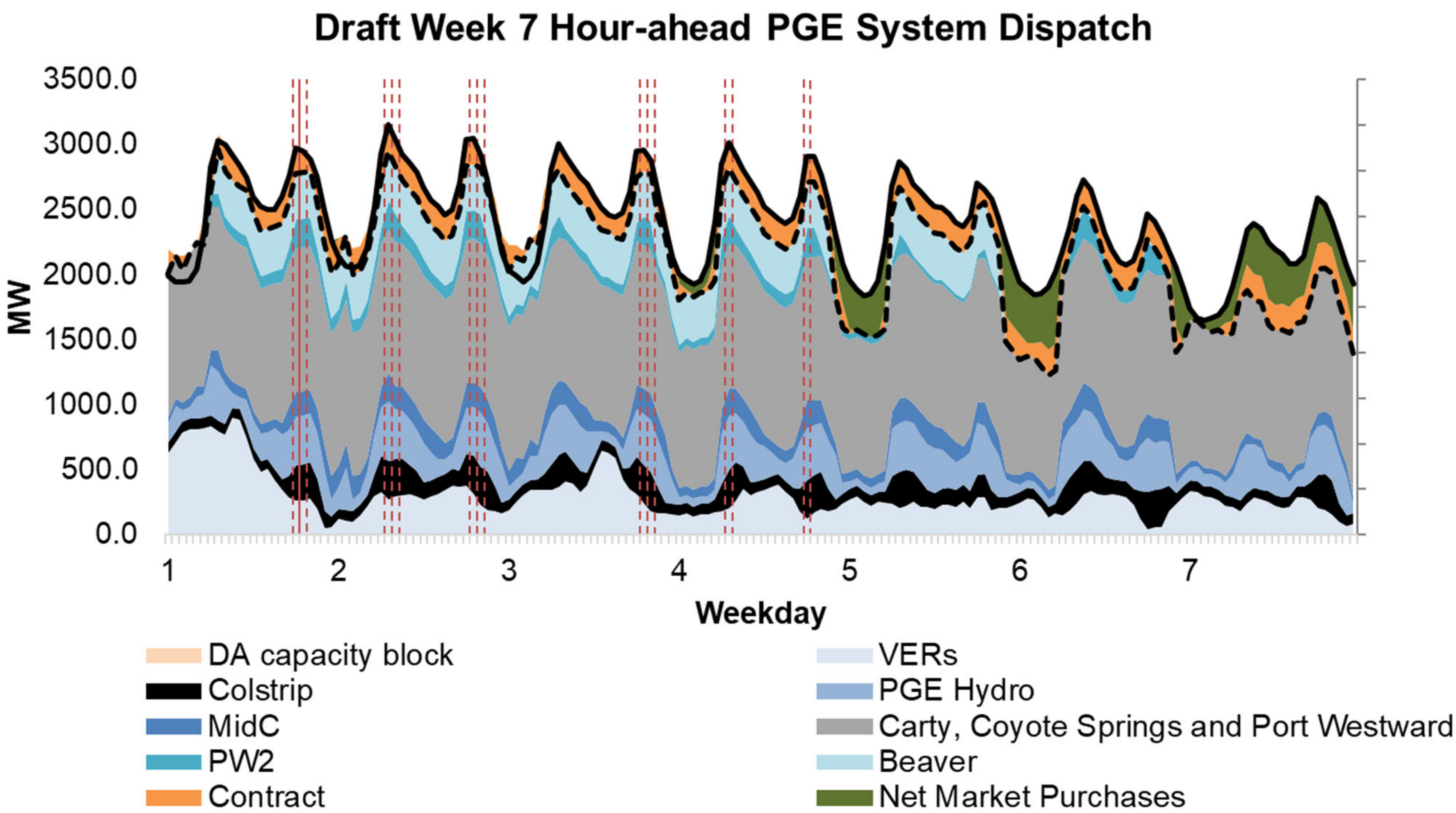
This component studies how much we value flexibility from different resources, such as energy storage, flexible loads, gas-based generators.

Flexibility Adequacy Study Updates

- ✓Updated and added base case inputs for 2019 IRP
  - ✓VER levels
  - ✓Load
  - ✓Reserves requirements (load following, regulation)
  - ✓Maintenance outage schedules
  - ✓Gas prices
  - ✓Market electricity prices
  - ✓Hydro characteristics
  - ✓Carbon pricing
  - ✓Existing contracts for 2025
  - ✓Market availability (no 2025 market access in summer and winter peak times aligned with draft E3 market capacity study and transmission limit in other times)
  - ✓Option to purchase 600MW on-peak DA capacity block in 100MW increments, aligned with draft RECAP

Flexibility Adequacy Study Updates

✓Run draft base case for 2019 IRP



Flexibility Adequacy Study Updates

- ❑ Ongoing Blue Marble Analytics assessment of baseline flexibility adequacy and analysis of supporting metrics
- ❑ Goal of draft completion by end of 2018

Variable energy resource (VER) integration costs

- Primary goal to provide new draft integration cost estimates for new resources of additional central OR solar, additional new WA wind, and new MT wind
- Seven draft model runs were conducted; all model runs assume:
  - 2025 test year
  - Existing fleet of wind resources (Biglow, Tucannon, RFP placeholder)
  - Existing on-system QF solar and off-system QF solar for associated reserves
  - Liquid sub-hourly market available for energy transactions only
  - Reference hydro, gas price, carbon price and renewable build market electricity prices and reference gas prices

Draft integration cost estimates

Case	VER (MWa)	Draft Integration Cost (2025 $/MWh)
New WA Wind	100	$0.34
New Central OR Solar	100	$1.6
New MT Wind	100	$0.09

Current flexibility values in ROSE-E

New Resource Option	Approximate draft Flexibility Value (2018$/kW-yr)
New_LMS100	~10
New_SCCT	~10
New_CCCT	~10
New_Recips	~20
New_Biomass	0
New_Geothermal	0
New_PumpedHydro	~40
New_Wind_Ione	0
New_Wind_Gorge	0
New_Wind_WA	0
New_Wind_MT	0
New_Solar	0
New_Bat_2h	~40
New_Bat_4h	~40
New_Bat_6h	~40

- An internal approximation based on modeling provides flexibility values currently used in ROSE-E

- ❑ ROM-based flexibility value estimates will be provided using the updated base case for:
  - Short-medium duration storage
  - Long duration storage
  - Thermal resources

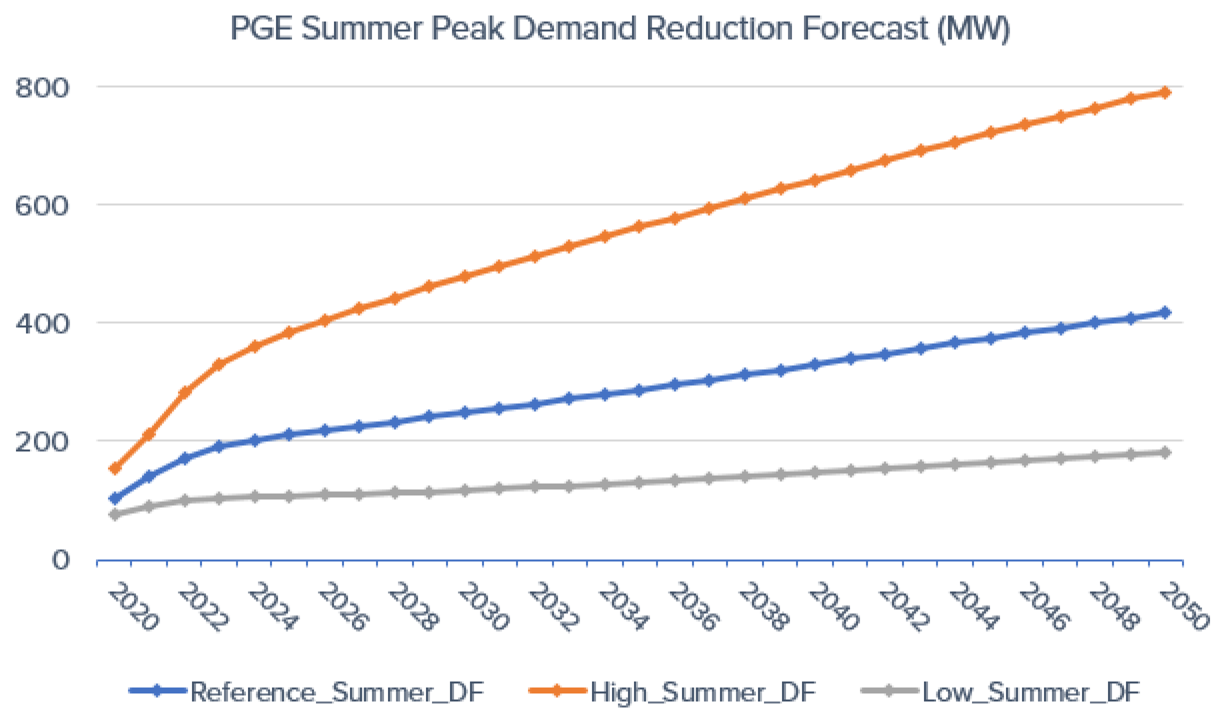
Final DER Scenarios

Shauna Jensen

Updates

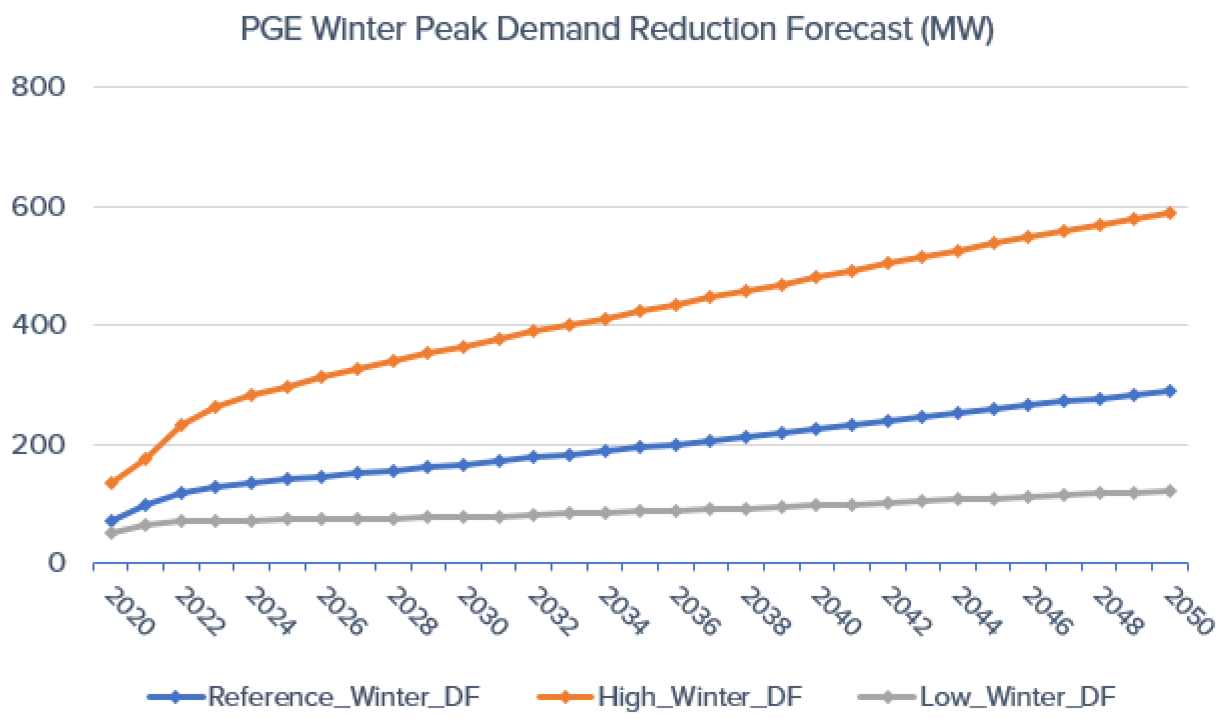
- Navigant DER Study Final Results
  - Distributed Flexibility
  - Distributed Solar
  - Distributed Storage
  - Electric Vehicles
  - Energy Efficiency
- Scenario Drivers
- Incorporation into IRP Models

Distributed Flexibility - Summer



	Technology Costs	Policies	Carbon Costs	Pricing
High Scenario	-50% cost by 2030	50% more favorable policy by 2030	No change (no energy impacts estimated)	Opt-out residential ToU
Low Scenario	+50% cost by 2030	50% less favorable policy by 2030	No change (no energy impacts estimated)	0% residential ToU

Distributed Flexibility - Winter



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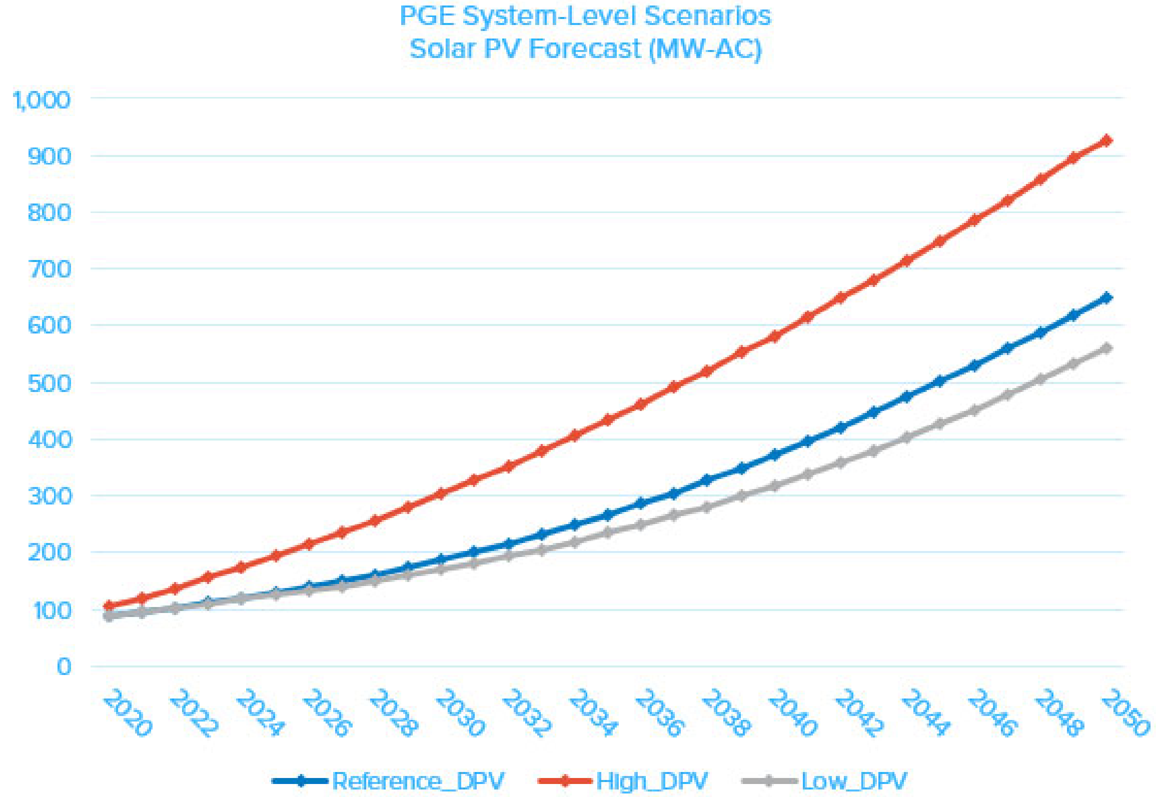
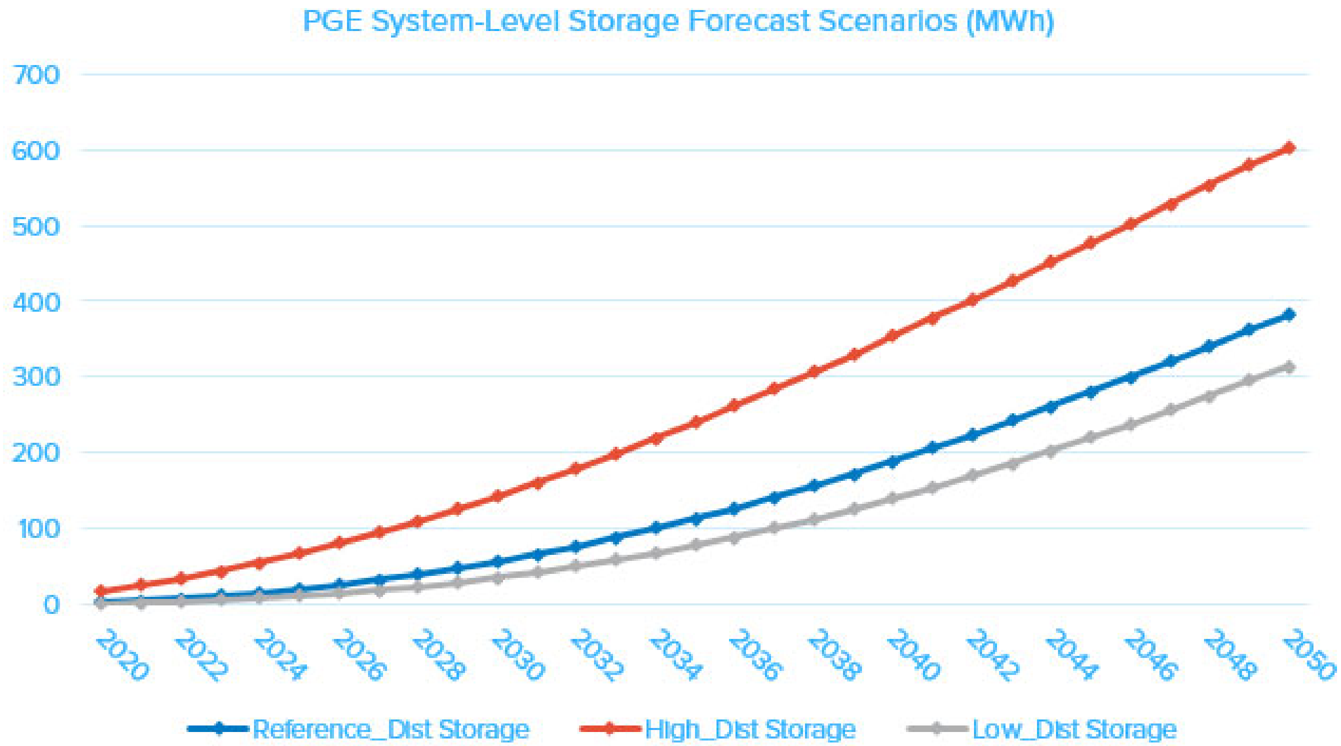
Distributed Solar



	Technology Costs	Policies	Carbon Costs	Pricing
High Scenario	Navigant low PV cost model	Navigant increased marketing model, and ITC extension through 2050	PGE high carbon price case	Opt-out residential ToU
Low Scenario	Navigant high PV cost model	Navigant decreased marketing model	PGE low carbon price case	0% residential ToU

Distributed Storage



	Technology Costs	Policies	Carbon Costs	Pricing
High Scenario	Navigant low lithium ion cost model	Navigant increased marketing model, and ITC extension through 2050	PGE high carbon price case	Opt-out residential ToU
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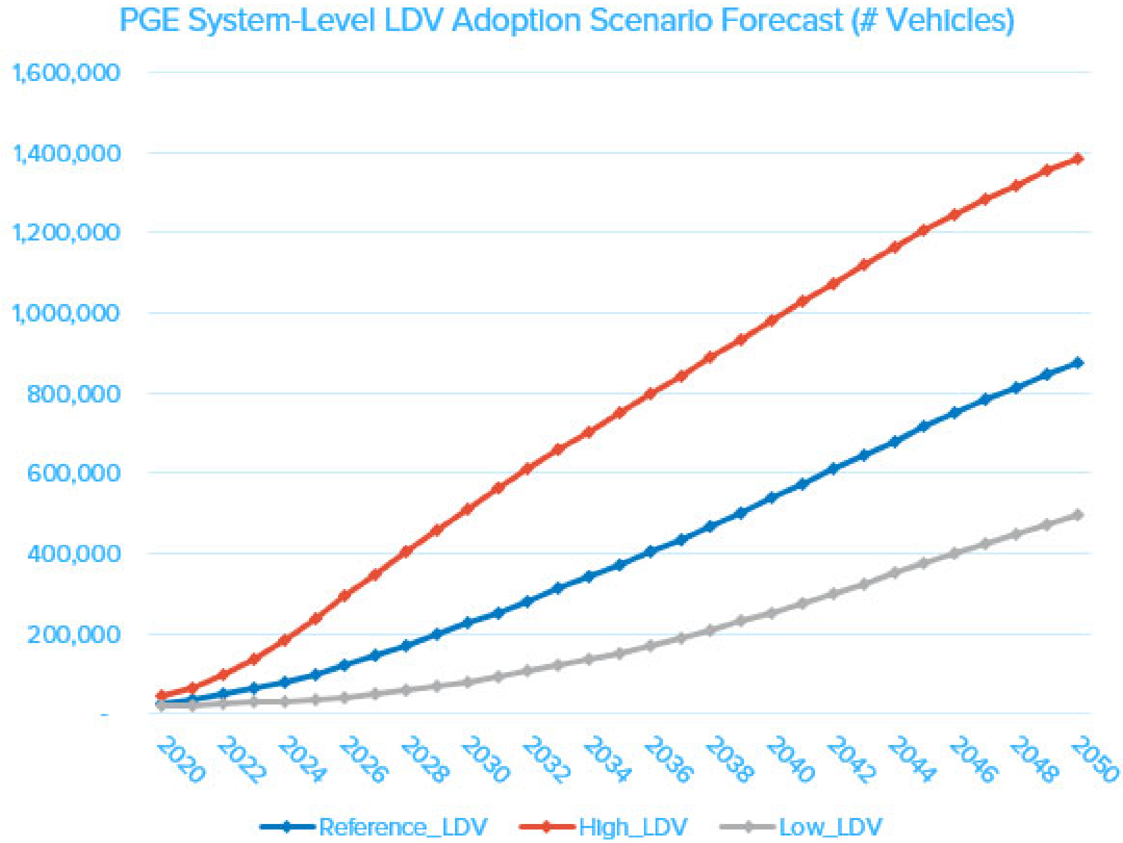
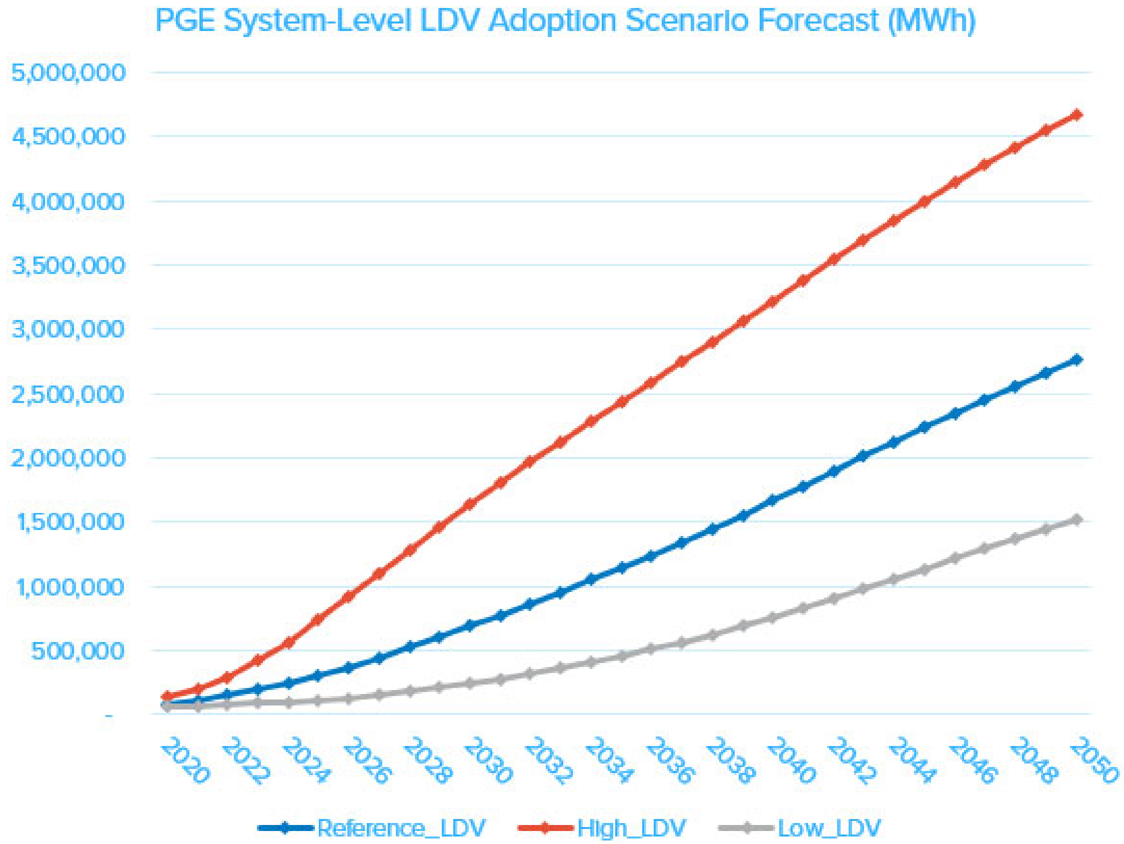
Electric Vehicles - Adoption



	Technology Costs	Policies	Carbon Costs	Pricing
High Scenario	Navigant low lithium ion cost model	Navigant increased vehicle availability, production and marketing model	PGE high carbon price case	Opt-out residential ToU
Low Scenario	Navigant high lithium ion cost model	Navigant decreased vehicle availability, production and marketing model	PGE low carbon price case	0% residential ToU

Electric Vehicles – MWh Impact



	Technology Costs	Policies	Carbon Costs	Pricing
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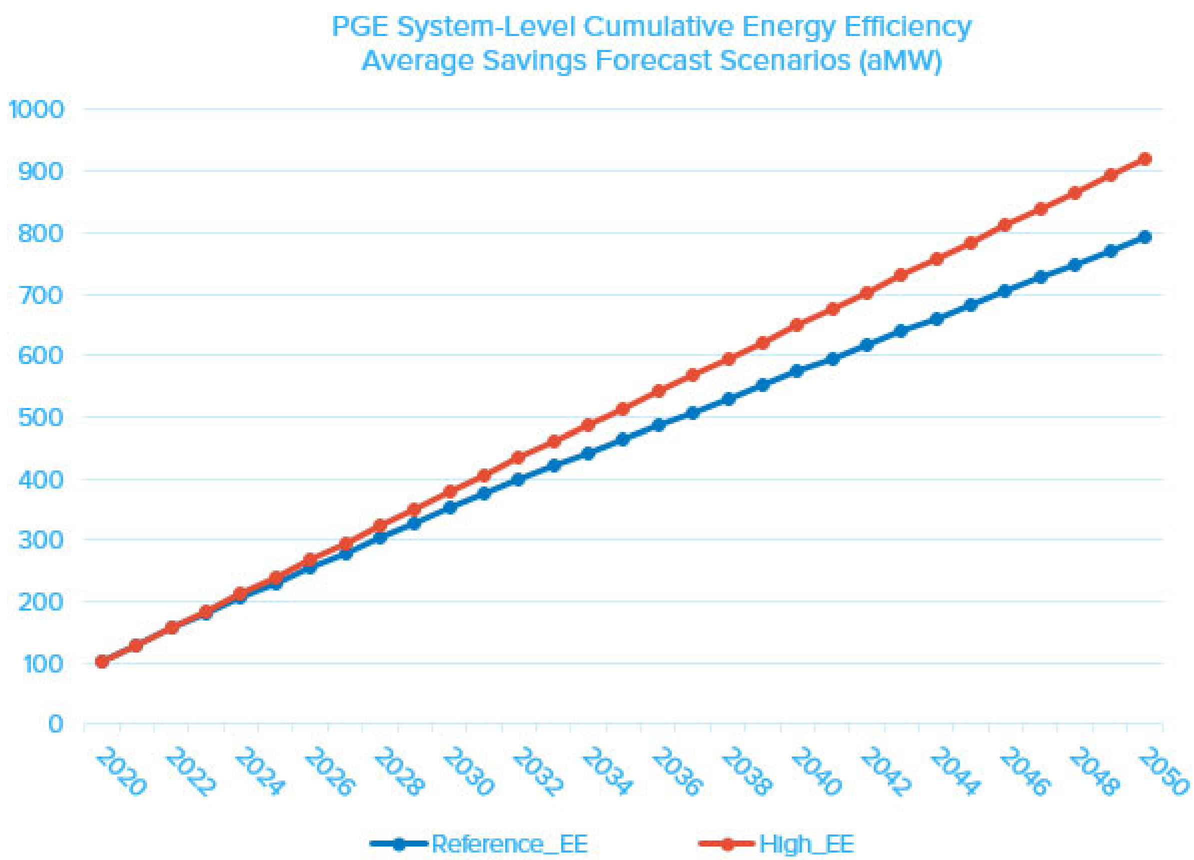
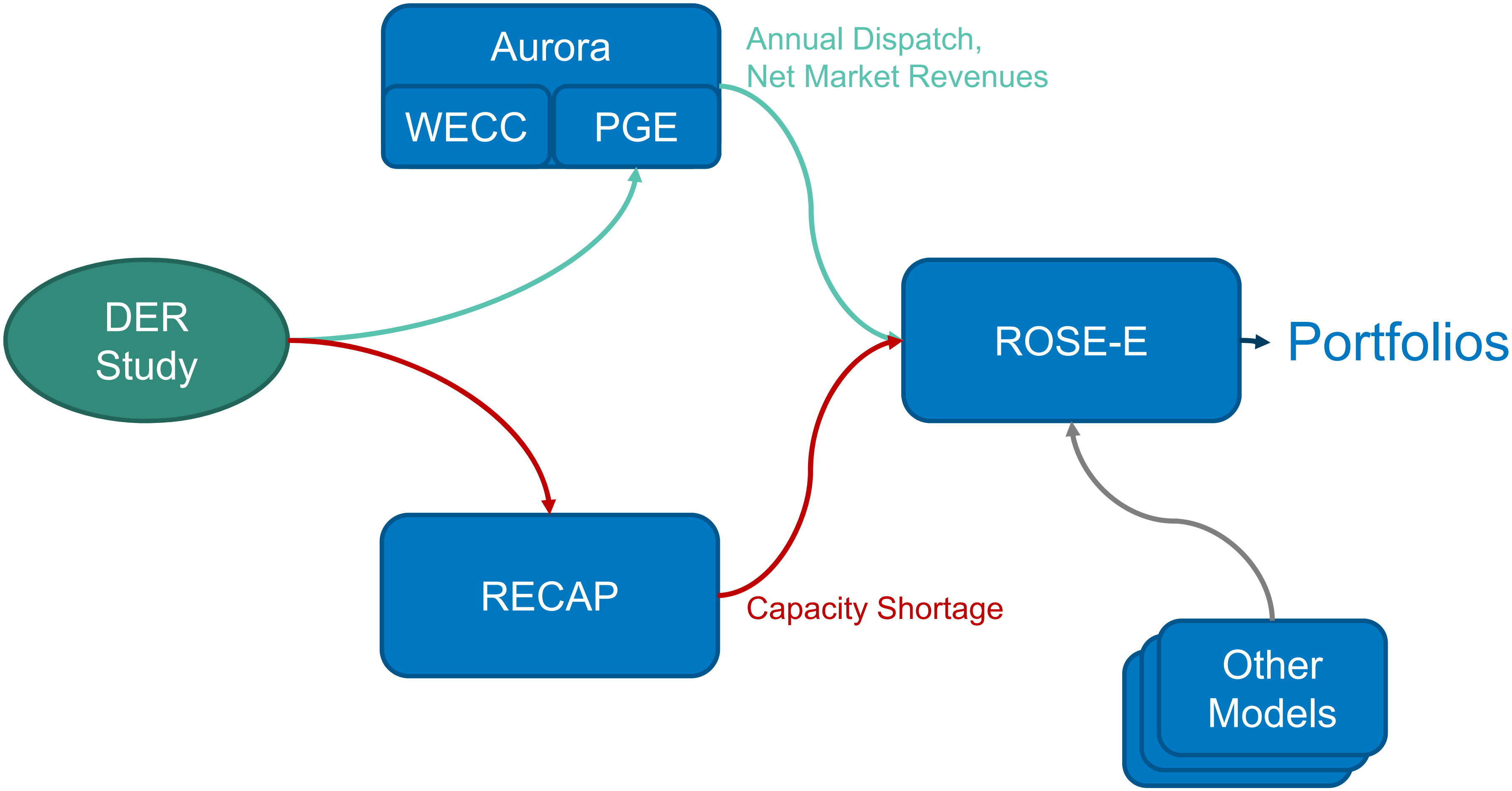
Energy Efficiency



- Reference Case
  - ETO Cost Effective Forecast
- High Case
  - ETO All Achievable Forecast

DER Data in PGE Models



Need Update

Kate von Reis Baron

Draft Need Assessments

Draft analysis includes some placeholder data

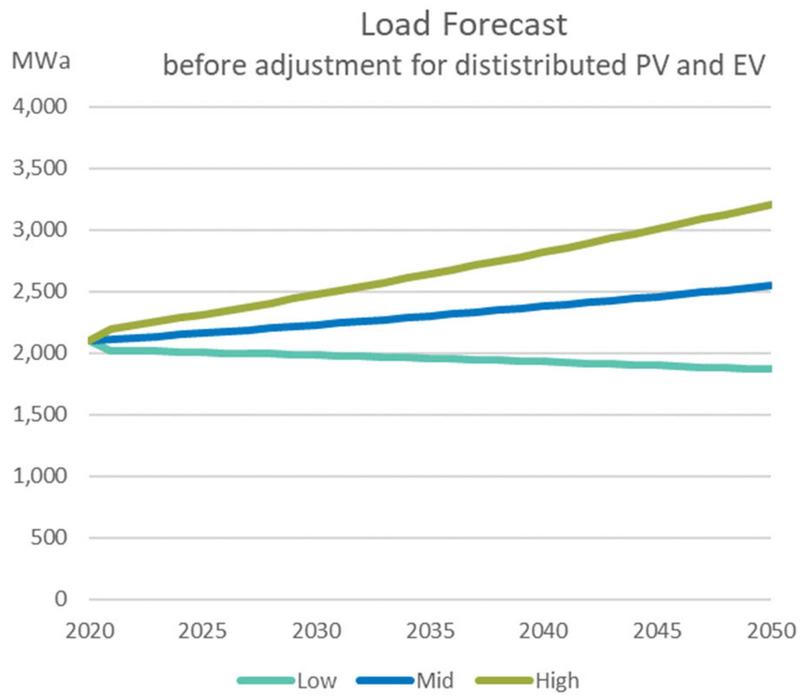
Item	Status
Load	• Final forecast, September 2018 • Low and high sensitivities
DER Study	• Draft low/base/high from Navigant study • High EE pending for Low Need Future
Market Capacity	• Low/base/high from E3 Study
Qualifying Facilities	• Snapshot from June 27, 2018
RFP	• Placeholder included in some views (100 MWa PNW Wind)
Existing Resources	• Pending minor updates for some resources

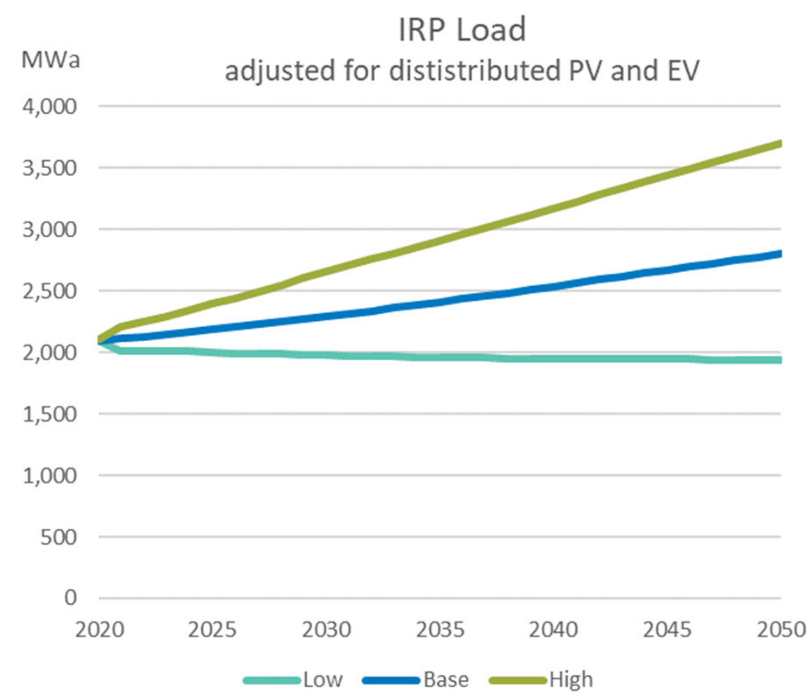
Need Futures - Draft

Item	Low	Base	High
Load Forecast	-Econ-1SD	Ref	+Econ+SD
Market Capacity	E3 Low Need	E3 Base Need	E3 High Need
EV + DLC_{EV}	Nav Low	Nav Base	Nav High
PV distributed	Nav High	Nav Base	Nav Low
Storage dist.	Nav High	Nav Base	Nav Low
Dist. Flexibility	Nav High	Nav Base	Nav Low
Energy Efficiency	High EE (pending)	Ref EE	Ref EE

Load Forecast – Cost of Service, MWa

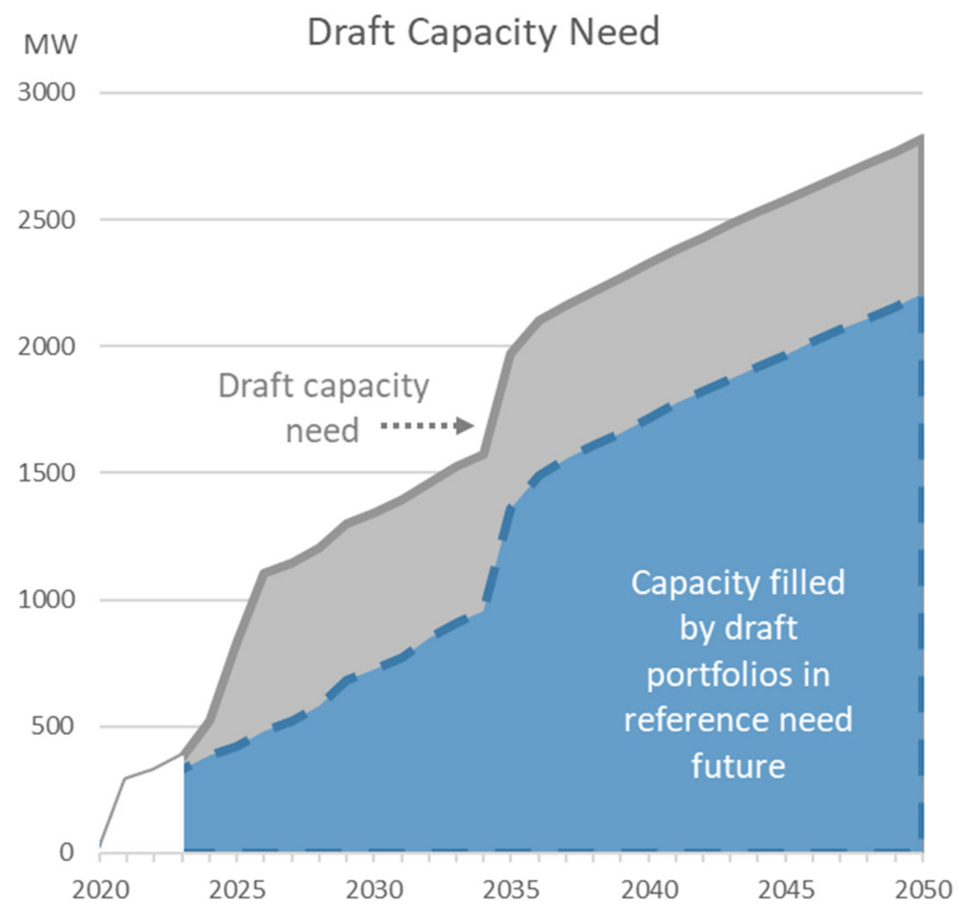
- The low and high load sensitivities capture the economic and migration drivers discussed in RT-5 and one standard deviation of model regression error
- The “IRP Load” views include the impacts from the Navigant low/base/high forecasts for distributed PV and light duty EVs





Capacity Need - Draft

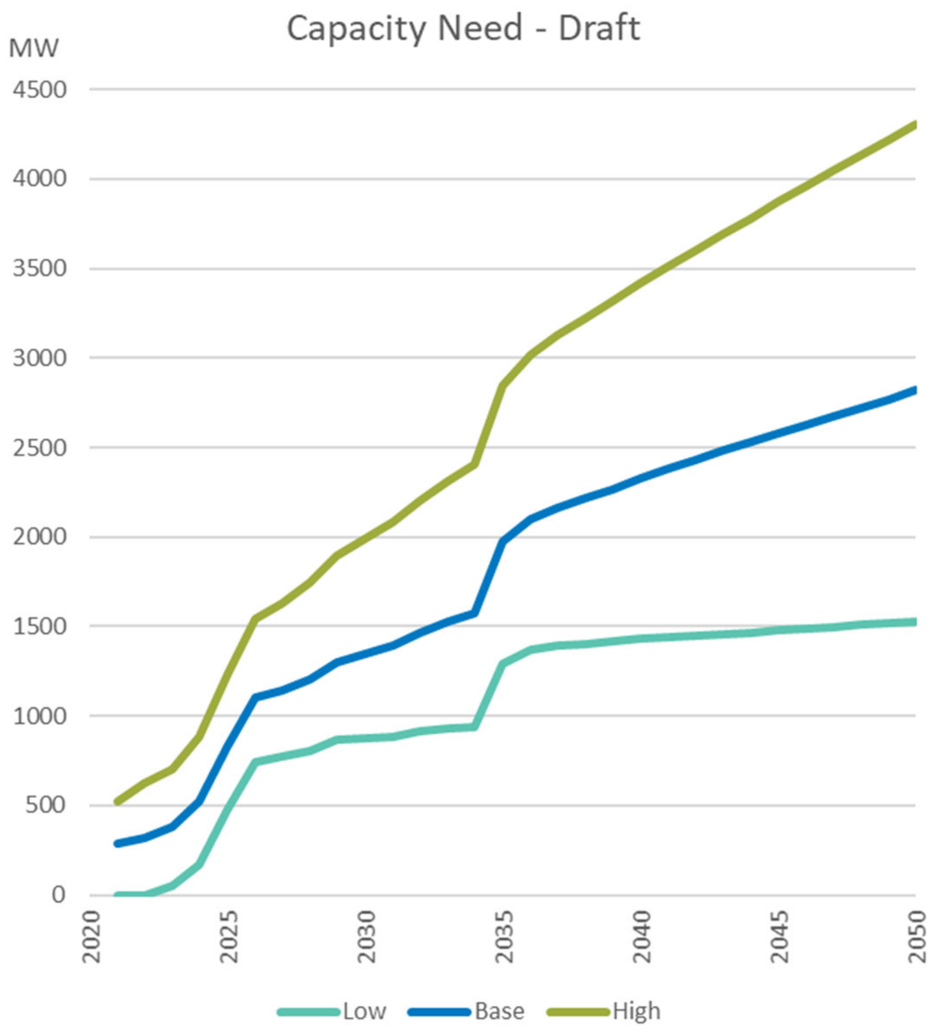
- The draft capacity need begins at 284 MW in 2021, increasing to 1103 MW in 2026. The increase is mainly due to contract expirations.
- Draft portfolios examine a portion of the capacity need beginning in 2024 that excludes the need associated with these contract expirations and includes a placeholder RFP resource.



Notes

1. Consistent with 2016 IRP, capacity needs in the 2021-2023 time frame may be met through short- and mid-term activities.

Capacity Need - Draft

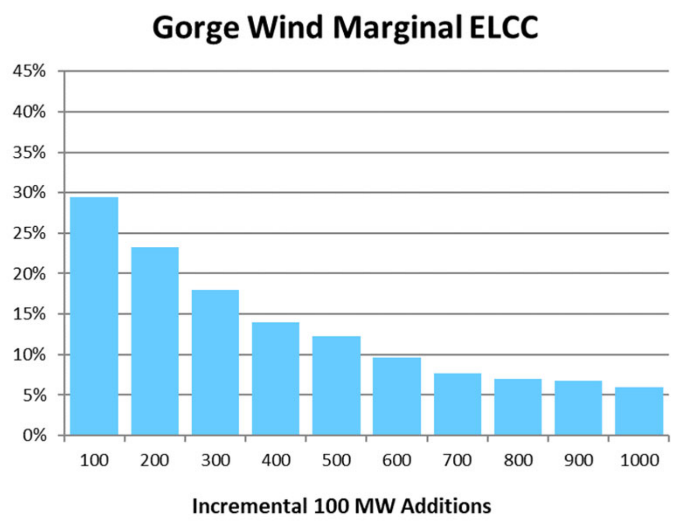


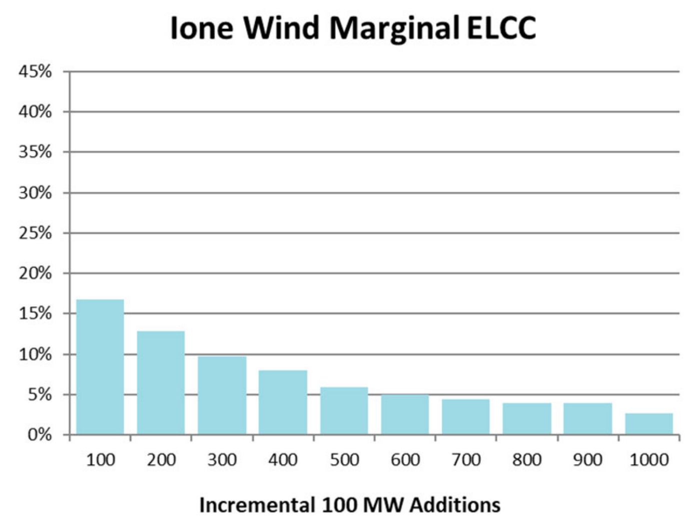
- These views reflect near-term contract expirations and do not include a placeholder for an RFP resource

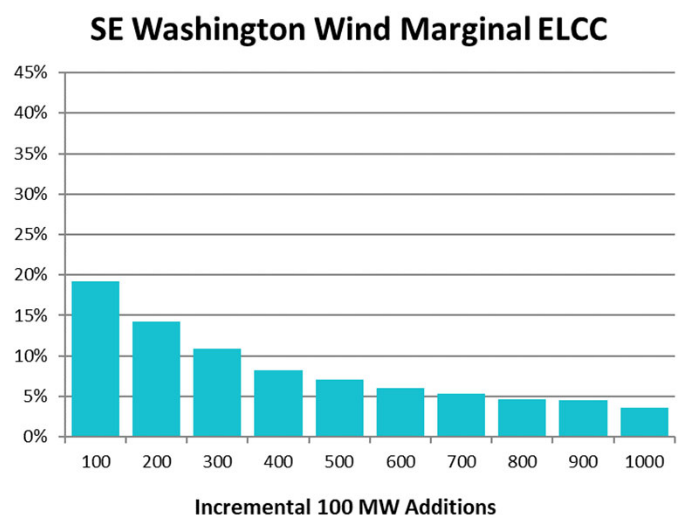
Draft Capacity Need, MW

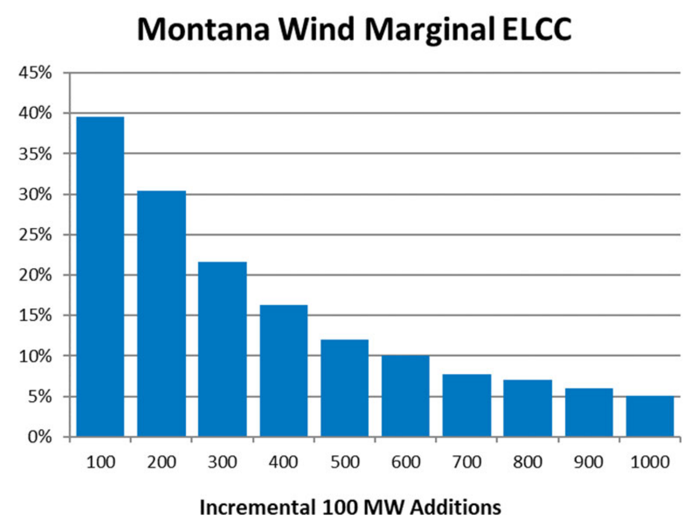
Year	Low	Base	High
2025	474	828	1227
2030	875	1343	1990
2035	1288	1971	2848
2040	1431	2326	3416
2045	1478	2578	3873
2050	1530	2819	4308

Capacity Contribution - Draft

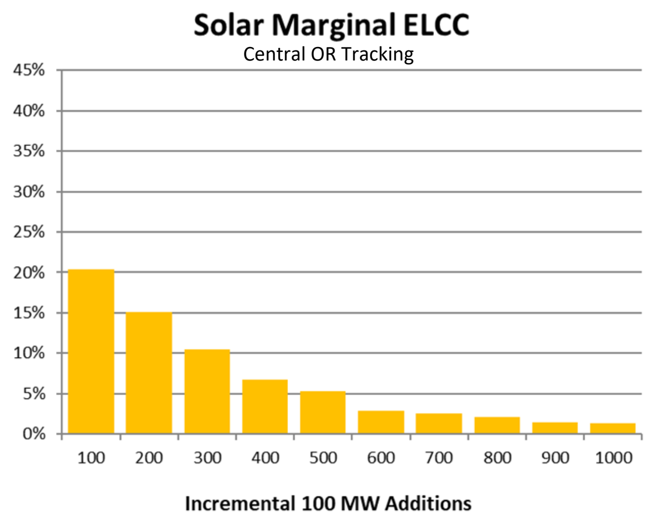








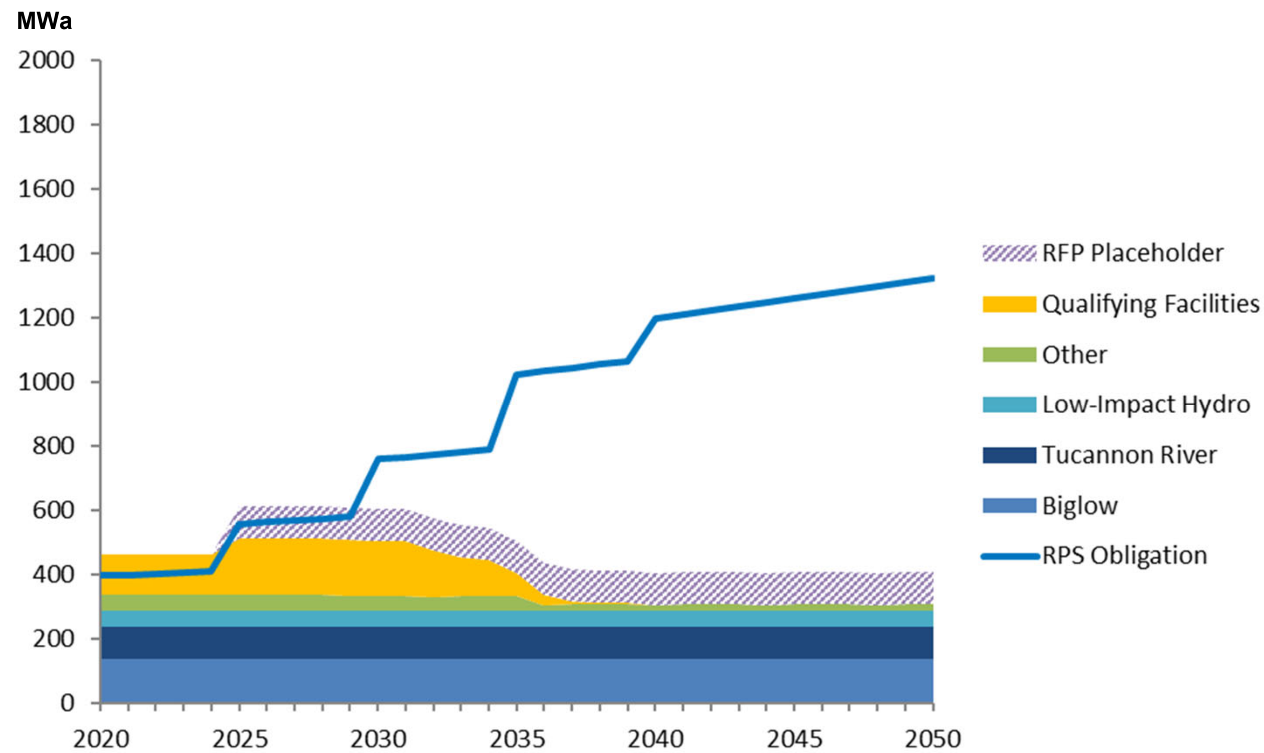
Capacity Contribution - Draft



RPS Need - Draft

Forecast Physical RPS Position

Year	RPS%
2015	15%
2020	20%
2025	27%
2030	35%
2035	45%
2040	50%

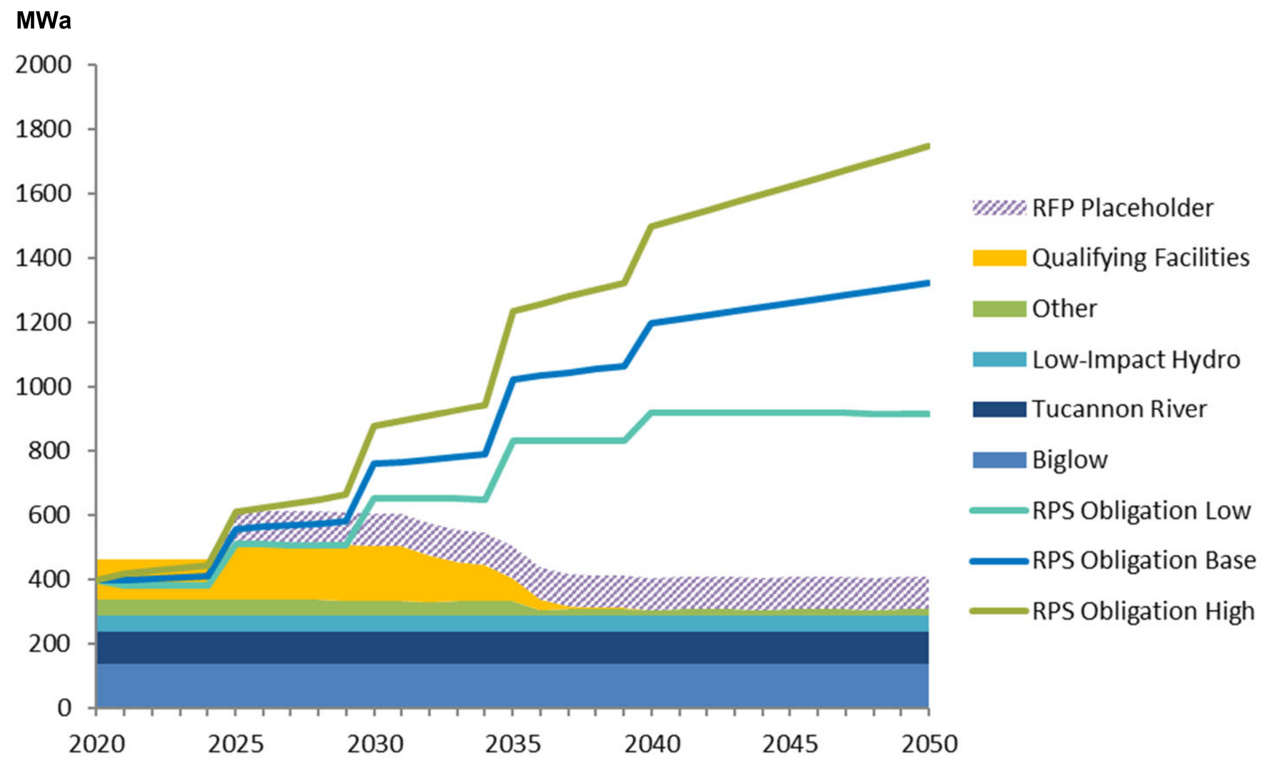


Note: Draft RPS Need slide in RT-5 was missing the impact of incremental EE.

RPS Need - Draft

Forecast Physical RPS Position

Year	RPS%
2015	15%
2020	20%
2025	27%
2030	35%
2035	45%
2040	50%



Experience Curve Analysis

Jessie Lee

Experience Curve Analysis

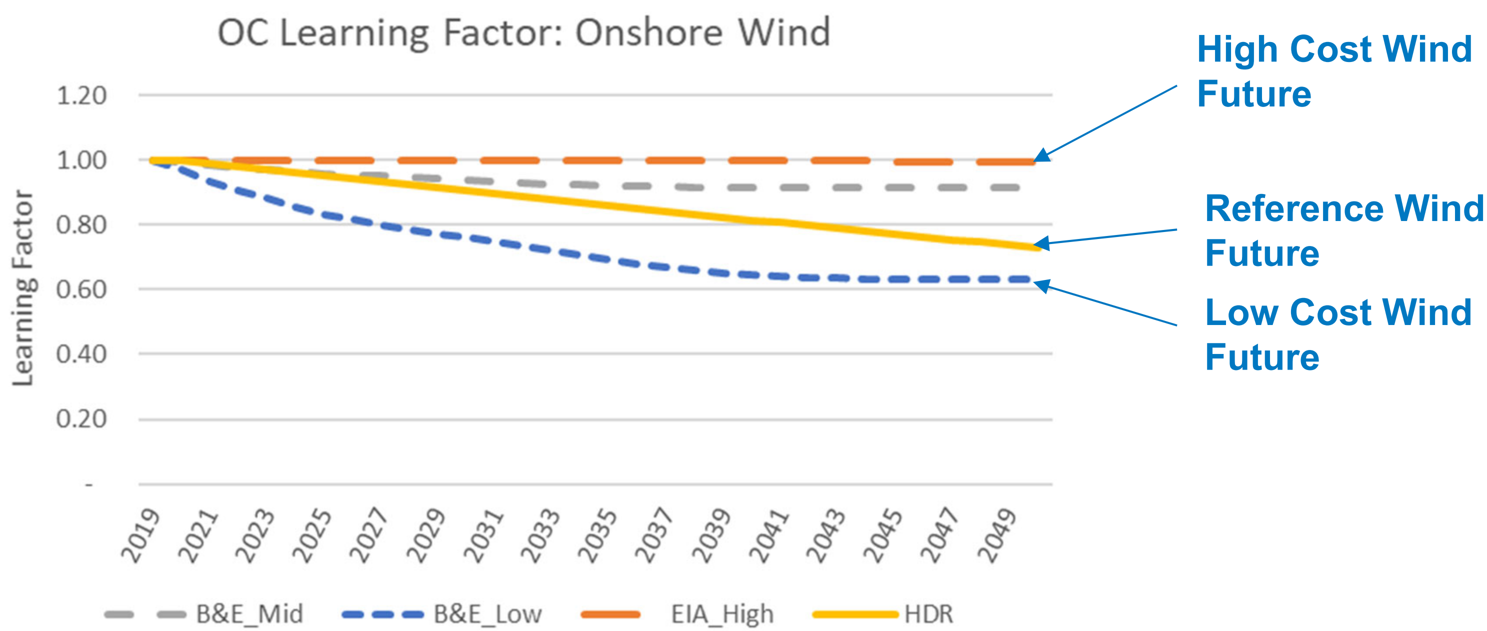
Used to contextualize Technical Maturity Outlook curves from HDR and to develop Low and High capital cost futures

- **Theory**
  - Technology costs are assumed to decrease over time as the industry gains more experience. The cost decline per cumulative production ("the Experience Curve") was developed by Bruce D. Henderson and the Boston Consulting Group and has been widely used in industry.
  - The learning rate ("LR") shows how much costs decline for every doubling of cumulative capacity.
  - Formula: $OC_n = k \cdot C^{\alpha}$

    where:

    - k is a parameter calculated from the initial overnight capital cost
    - OC_n is the overnight capital cost for year n
    - C is the cumulative volume of the capacity
    - α is the experience curve gradient with regard to doubling the capacity
      - $\alpha = \ln(1 - LR) / \ln(2)$
- **Applications in 2019 IRP** : Wind, Solar, and Batteries

Wind



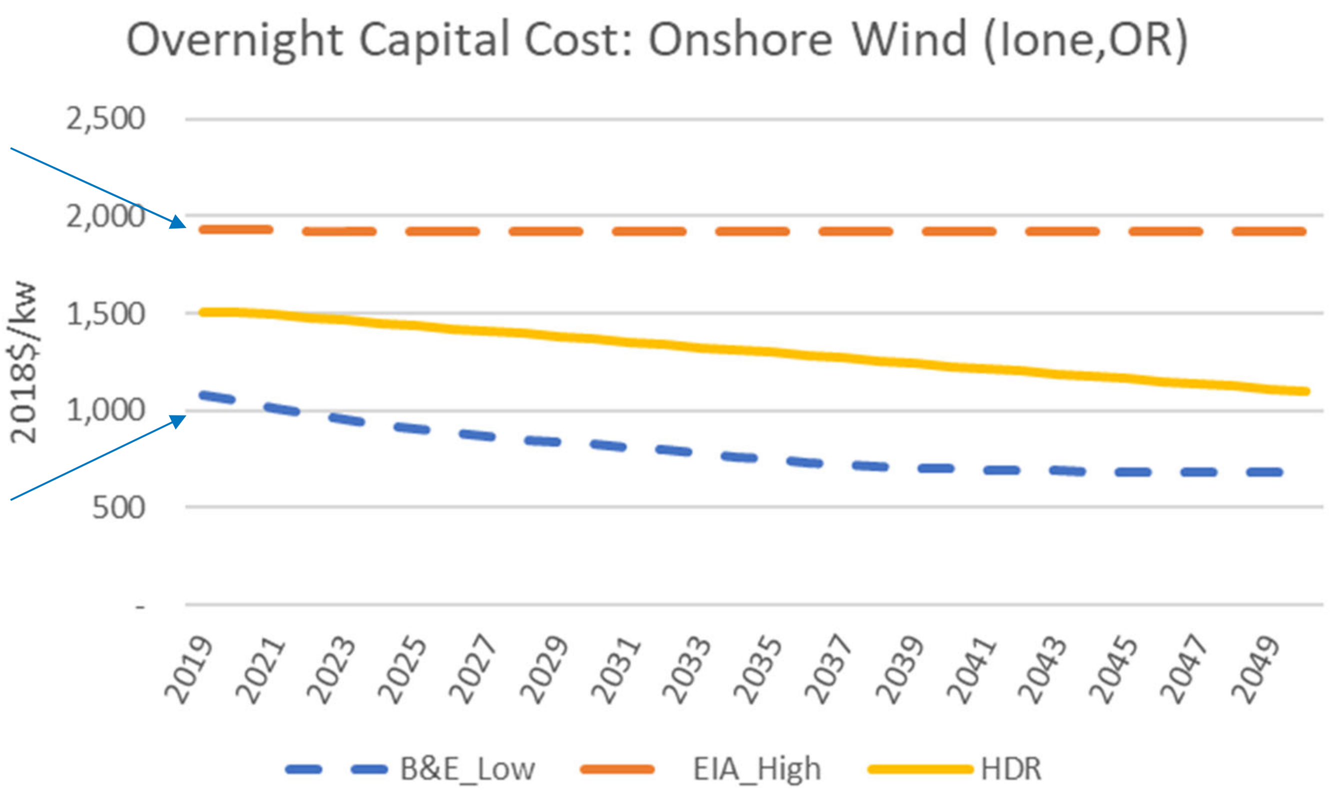
BNEF / EIA	B&E_Low	B&E_Mid	EIA_High
Cumulative Capacity	BNEF NEO 2018 Global	BNEF NEO 2018 Global	AEO 2018 Reference
Learning Rate	20%	5% to 1%	1%
Learning Rate Source	AEO 2018 (Offshore Wind)	AEO 2018 (Minimum by 2035 then Mature)	AEO 2018 (Mature)

Sources: Bloomberg New Energy Finance (BNEF), U.S. Energy Information Administration, HDR Inc., and PGE calculations

Wind

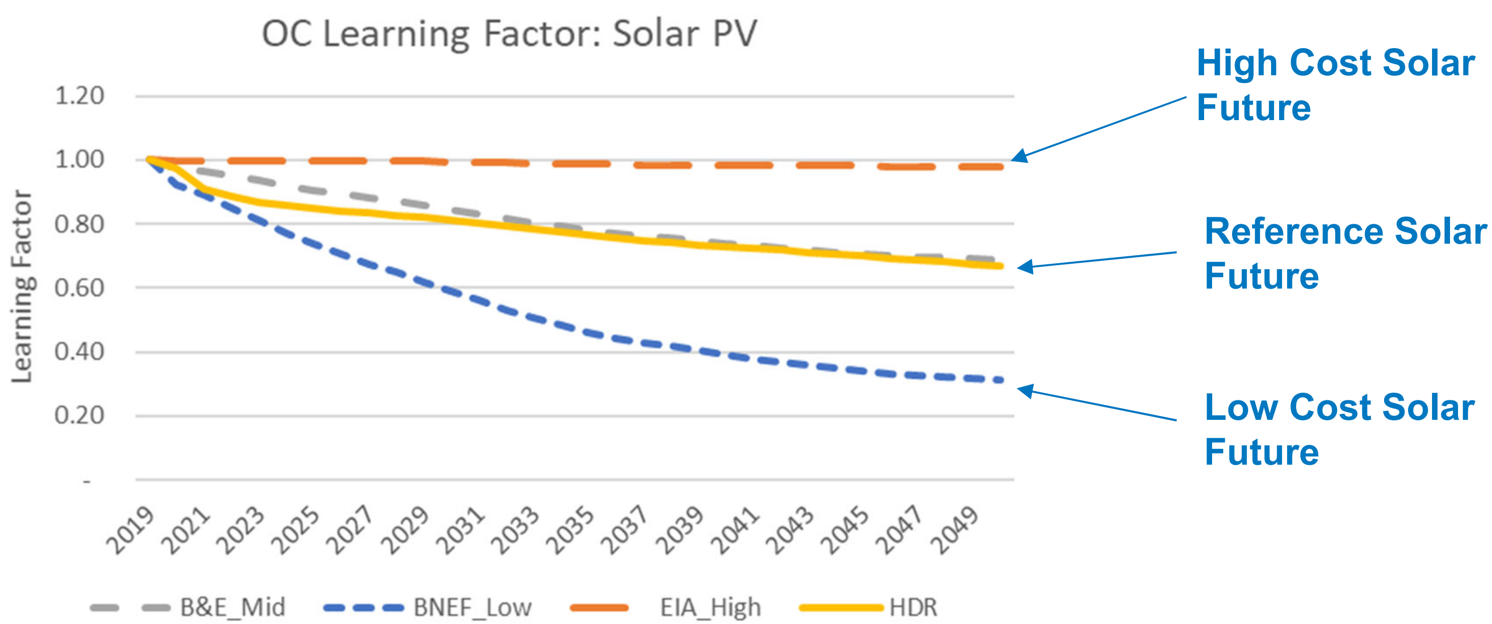
High Capital Cost (+σ)

Low Capital Cost (−σ)



Sources: Bloomberg New Energy Finance (BNEF), U.S. Energy Information Administration, HDR Inc., and PGE calculations

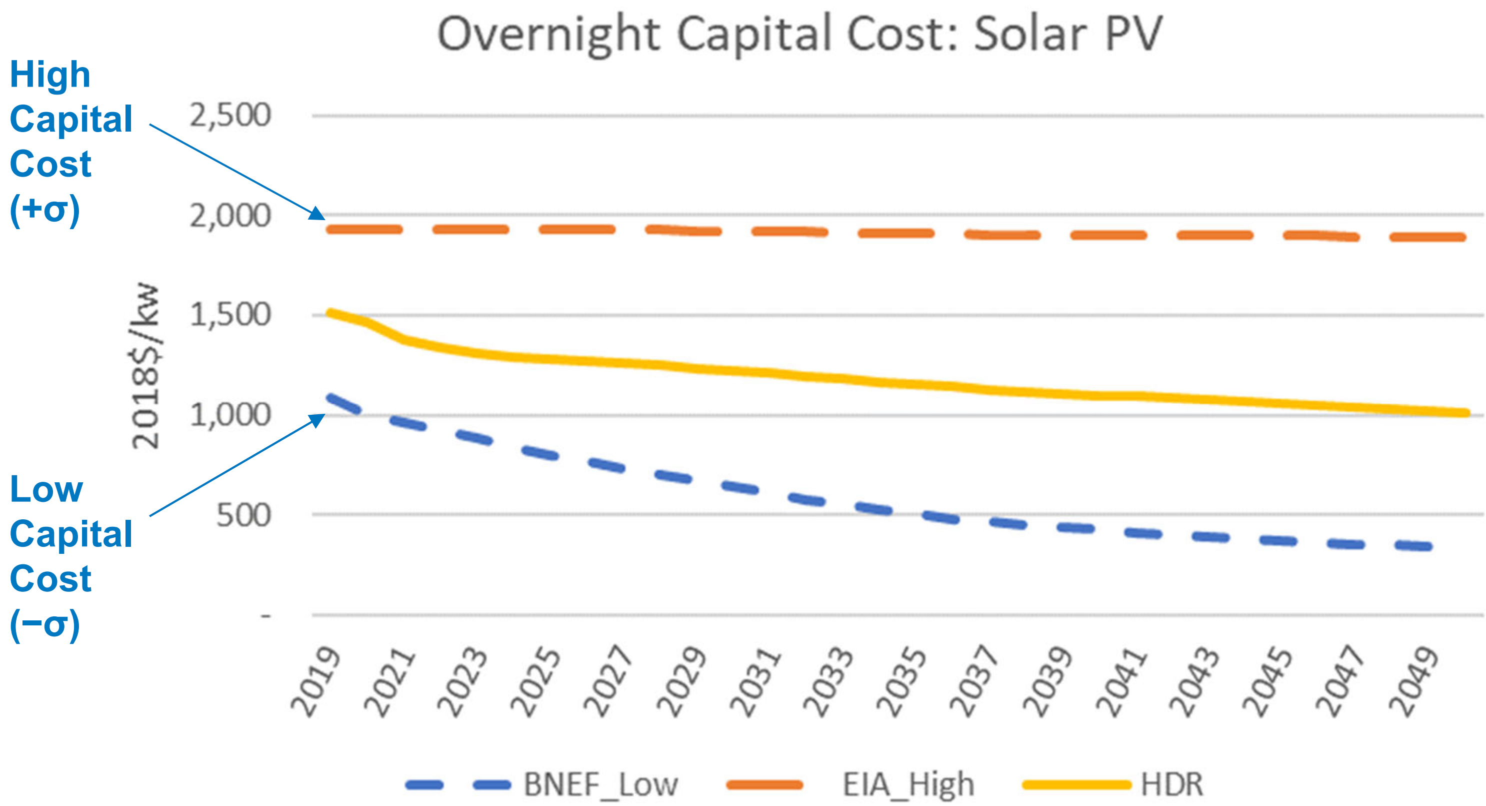
Solar



	BNEF_Low	B&E_Mid	EIA_High
Cumulative Capacity	BNEF NEO 2018 Global	BNEF NEO 2018 Global	AEO 2018 Reference
Learning Rate	28%	10%	1%
Learning Rate Source	BNEF (1H 2017)	AEO 2018 (Evolutionary)	AEO 2018 (Mature)

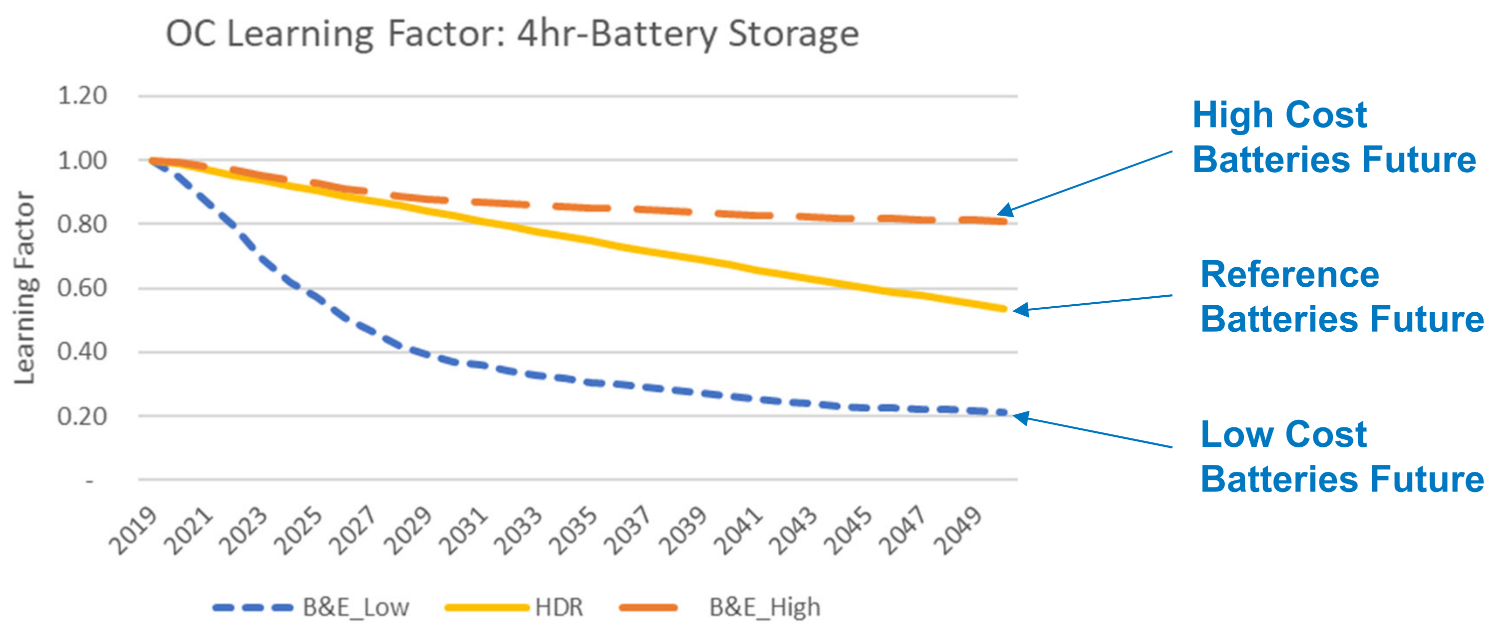
Sources: Bloomberg New Energy Finance (BNEF), U.S. Energy Information Administration, HDR Inc., and PGE calculations

Solar



Sources: Bloomberg New Energy Finance (BNEF), U.S. Energy Information Administration, HDR Inc., and PGE calculations

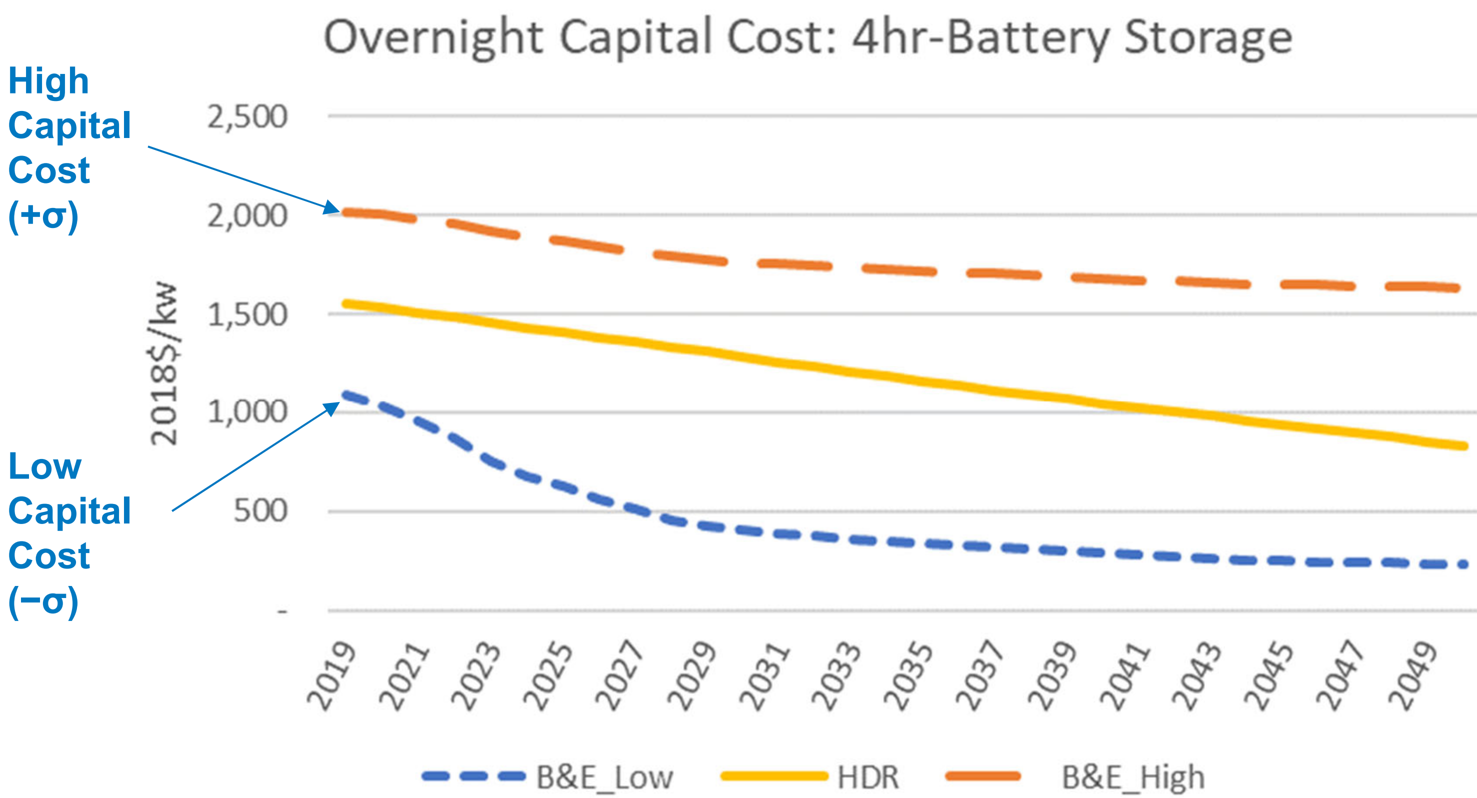
Batteries



	B&E_Low	HDR	B&E_High
Cumulative Capacity	BNEF 2018 NEO Global	HDR	BNEF 2018 NEO Global
Learning Rate	20%	-	3%
Learning Rate Source	AEO 2018 (Revolutionary)	-	AEO 2018 (Mature + 2%)

Sources: Bloomberg New Energy Finance (BNEF), U.S. Energy Information Administration, HDR Inc., and PGE calculations

Batteries



Sources: Bloomberg New Energy Finance (BNEF), U.S. Energy Information Administration, HDR Inc., and PGE calculations

Wrap up

Elaine Hart

Upcoming 2018 Roundtables

Roundtable 18-7 Wednesday, December 19, 2018 (9:00 am - 1:00 pm PST) 2 World Trade Center, Sky Bridge A & B 121 SW Salmon St., Portland, OR 97204	AGENDA ▪ Distribution Resource Planning ▪ Transmission

https://www.portlandgeneral.com/our-company/energy-strategy/resource-planning/integrated-resource-planning/irp-public-meetings

Wrap Up

- Thank you for your participation today!
- **Questions or Feedback -** If you would like to provide feedback on PGE's 2019 IRP or the IRP process
    - Complete the IRP Online Form (https://www.portlandgeneral.com/forms/pge-stakeholder-feedback)
    - Email IRP@pgn.com