Integrated Resource Planning

Roundtable 18-3

August 22, 2018

Meeting Logistics

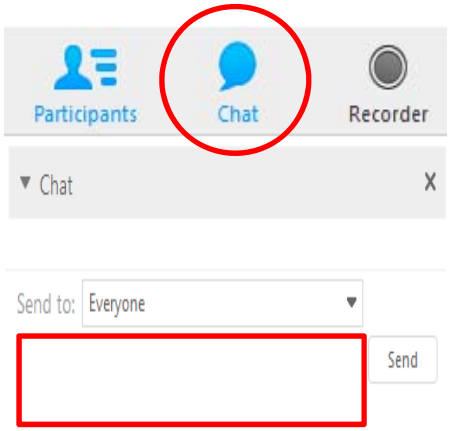
Local Participants:

- 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

- ❑ Welcome & Safety Moment
- ❑ Draft Navigant Study Results
- ❑ ROSE-E Carbon Constraints
- ❑ Montana Wind Workshop - Part 1
- ❑ Draft Market Prices
- ❑ Supply Side Options Studies

Safety Moment

Earthquake Safety References

https://www.statista.com/statistics/269648/number-of-earthquakes-by-country/

https://www.fema.gov/quakesmart

https://geology.com/articles/earthquake-safety.shtml

https://www.osha.gov/dts/earthquakes/index.html

http://www.wweek.com/news/2010/01/26/quake-up-call/

Draft Navigant Study Results

Navigant

DISTRIBUTED RESOURCE AND FLEXIBLE LOAD STUDY

ROUNDTABLE

AUGUST 22, 2018

TROVE™ PREDICTIVE DATA SCIENCE

NAVIGANT

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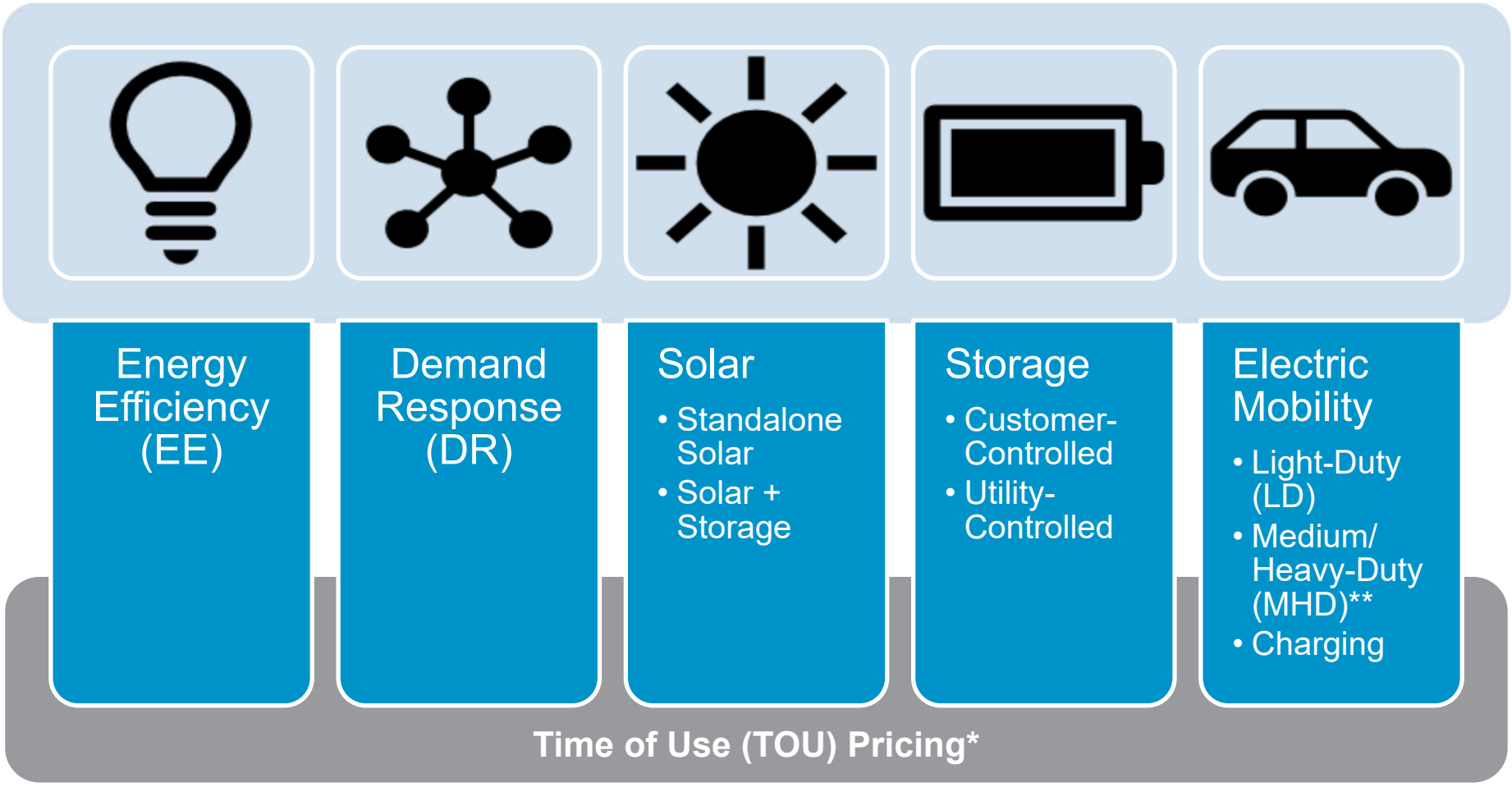
AGENDA

1. Introduction to Study
2. Base Case Methodologies and Inputs
3. Base Case Draft Results
4. Scenario Drivers
5. Next Steps

DISTRIBUTED RESOURCES ADDRESSED IN THE STUDY

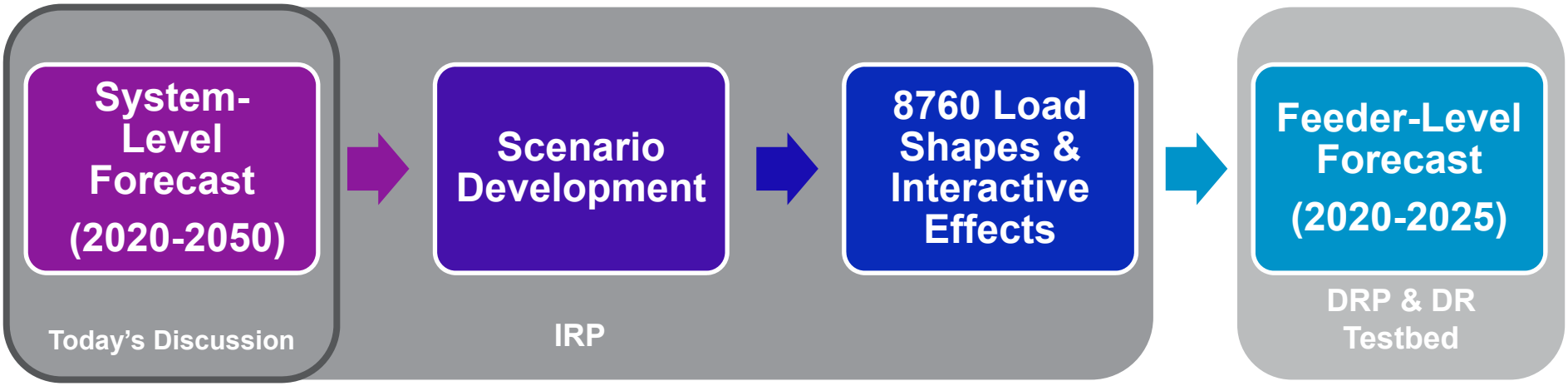
INTRODUCTION TO STUDY



** TOU for residential customers; not applied to EE or medium/heavy-duty. ** MHD assessed separately from results presented today.*

SCOPE AND APPROACH FOR DISTRIBUTED RESOURCES ASSESSMENT

INTRODUCTION TO STUDY



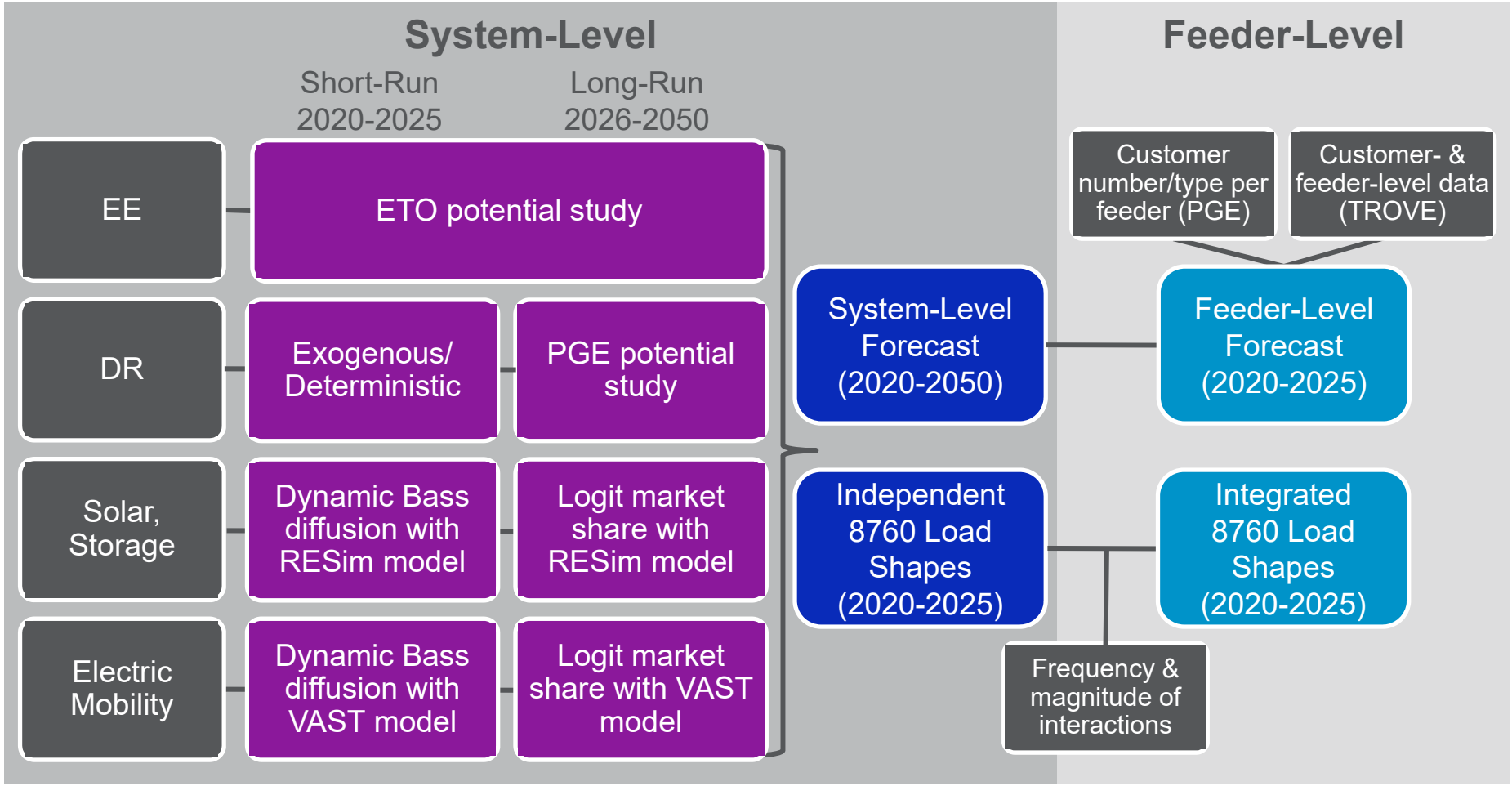
Customer Segments				
Residential – Single-Family (SF)	Residential – Multi-Family (MF)	Residential – Manufactured (Manu)	Commercial	Industrial

Impacts		
Energy	Demand	Vehicle Counts

Scenarios		
Low	Base	High

METHODOLOGY OVERVIEW

BASE CASE METHODOLOGIES AND INPUTS



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ELECTRIC MOBILITY: LD VEHICLES

BASE CASE METHODOLOGIES AND INPUTS

Inputs

- Navigant used registration data from Hedges and Oregon Department of Transportation to inform the current market penetration of LD PEV
- Analysis incorporates carbon pricing and TOU pricing assumptions

Calibration

- Navigant's Vehicle Adoption Simulation Tool (VAST) platform is calibrated to historical sales data for the state of Oregon by powertrain (BEV, PHEV) and class (passenger car, light truck), with estimates by vehicle ownership (individual, fleet)

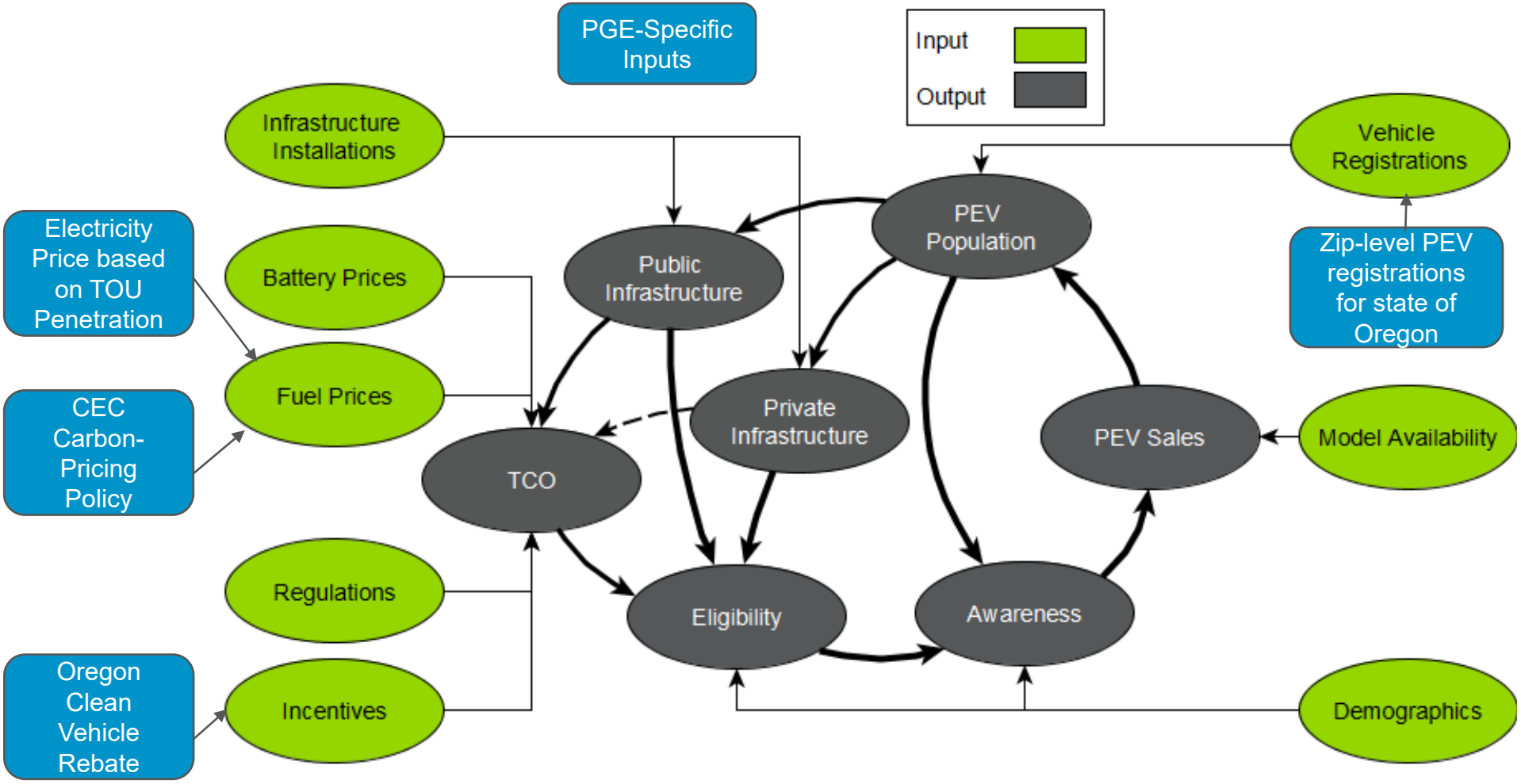
Base Case

- VAST forecasts vehicle adoption for the state of Oregon at the zip code-level, using a combination of Navigant's default parameters and PGE-specific inputs
- Results are filtered to PGE territory and aggregated to system-level

** PEV = plug-in electric vehicle; BEV = battery electric vehicle; PHEV = plug-in hybrid electric vehicle*

ELECTRIC MOBILITY: LD VEHICLES

BASE CASE METHODOLOGIES AND INPUTS



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ELECTRIC MOBILITY: CHARGING FORECAST

BASE CASE METHODOLOGIES AND INPUTS

- Forecast of System-Level charging infrastructure deployment is tied to the forecast of LD vehicles at the zip code level
  - Includes indication of type (i.e., public vs private)
  - Includes both existing and future charging sites

EE AND DR

BASE CASE METHODOLOGIES AND INPUTS

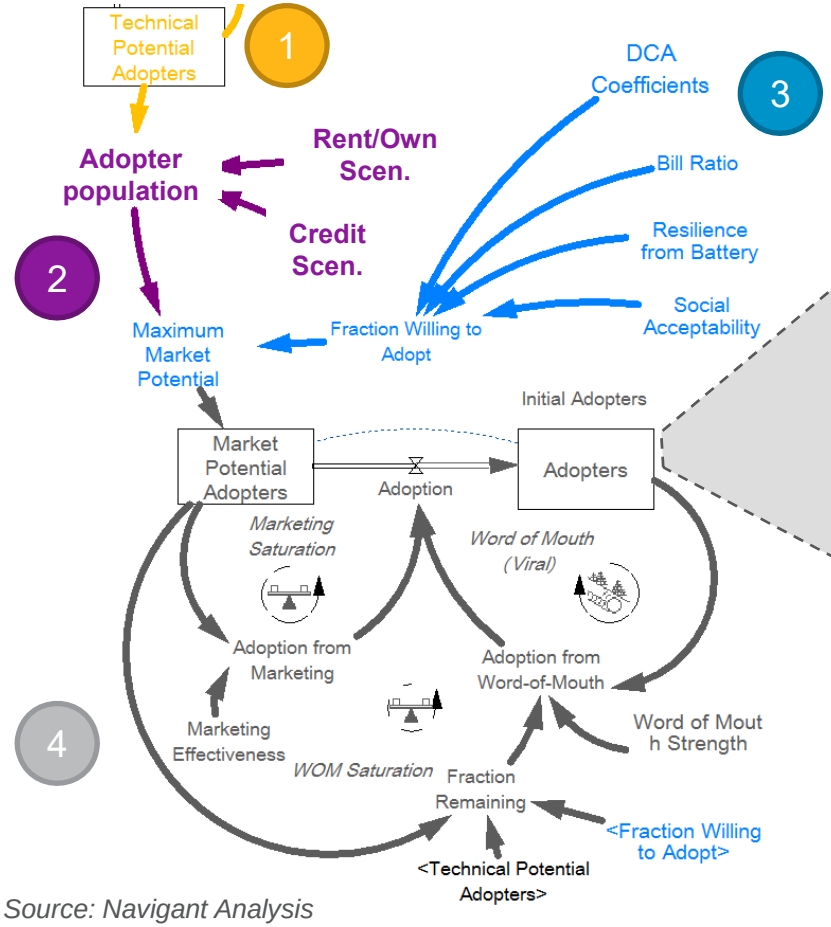
- Base Case EE and DR forecasts leverage existing ETO and PGE potential studies.
  - **EE:** Existing ETO forecast used as-is for system-level results
  - **DR:** Navigant updated PGE's most recent IRP DR forecast, originally based on the 2016 Brattle Study

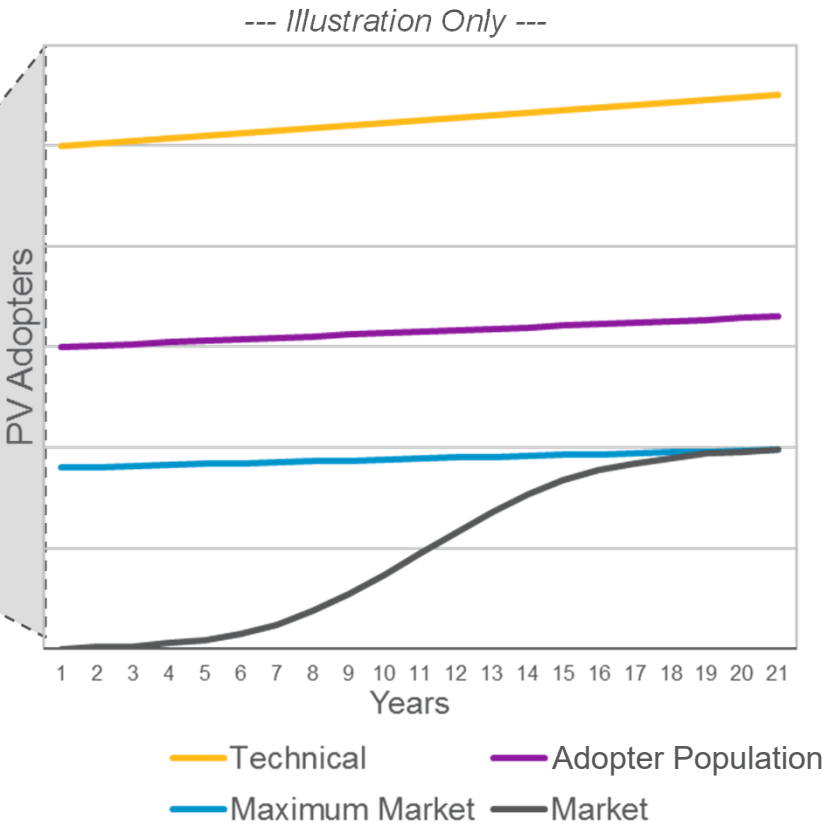
- Updates made to the DR forecast include:
  - Added/removed programs, based on PGE's projected portfolio mix
  - Revised smart technology penetration estimates
  - Updated customer count and peak load data, based on data provided by PGE
  - Calibrated impacts and participation estimates to expected program activity based on PGE's recent pilot program activities
  - Updated interactive effects to reflect assumptions about limited customer participation in multiple programs
  - Incorporated LD vehicle forecast to forecast potential for an EV DLC program *(pending)*

SOLAR AND STORAGE

BASE CASE METHODOLOGIES AND INPUTS

Navigant employs RESim, an enhanced version of a classic Bass diffusion model[1] using System Dynamics[2] to simulate market adoption of Solar PV, Solar + Storage, Stand-alone Storage.





Source: Navigant Analysis

1. Bass, Frank (1969). "A new product growth model for consumer durables". *Management Science* **15** (5): p215–227.
2. Sterman, John D. *Business Dynamics: Systems Thinking and Modeling for a Complex World*. Irwin McGraw-Hill. 2000. p. 332.

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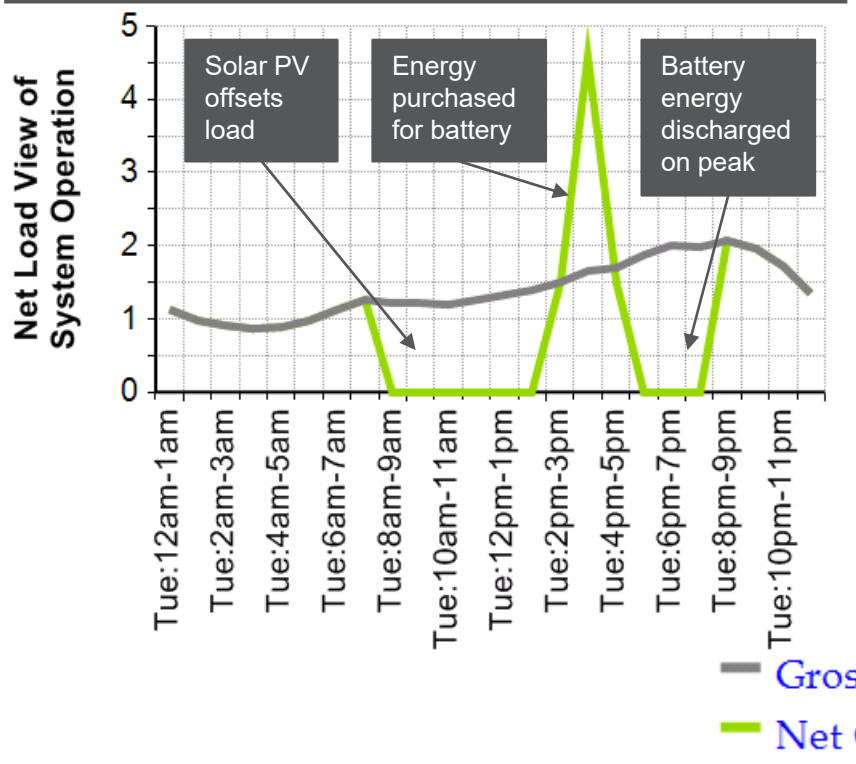
SOLAR AND STORAGE: CUSTOMER-CONTROLLED

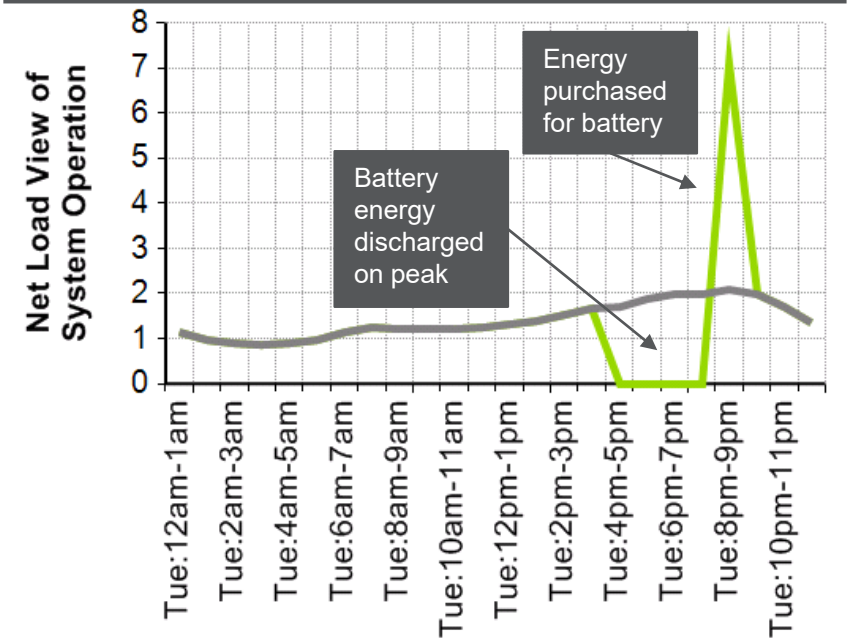
BASE CASE METHODOLOGIES AND INPUTS

The battery is controlled by dynamically storing electricity from Solar PV (if available) or the grid, and discharging to meet customer load or export to the grid. This simulated operation maximizes the value of the battery to the customer.

Net Load: Res Solar+Storage TOU



Net Load: Res Storage TOU



Gross Customer Load

Net Customer Load

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SOLAR AND STORAGE: CUSTOMER-CONTROLLED

BASE CASE METHODOLOGIES AND INPUTS

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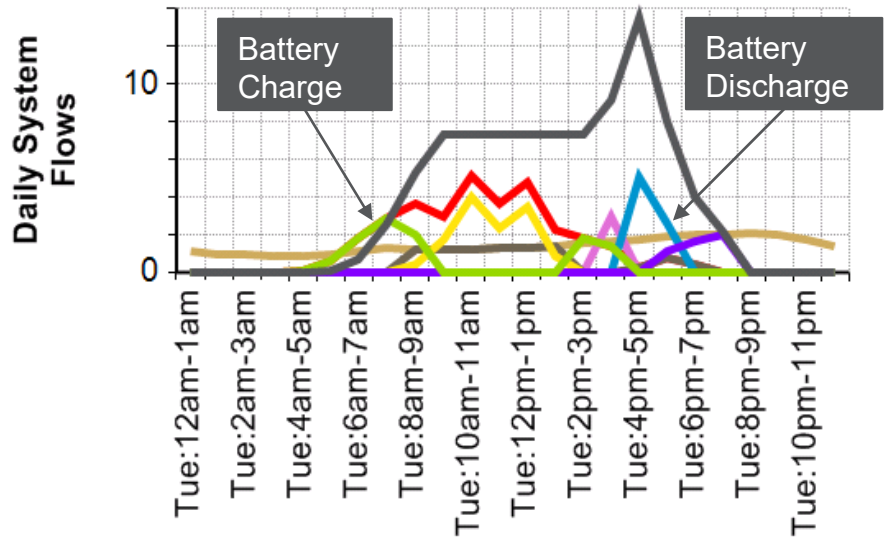
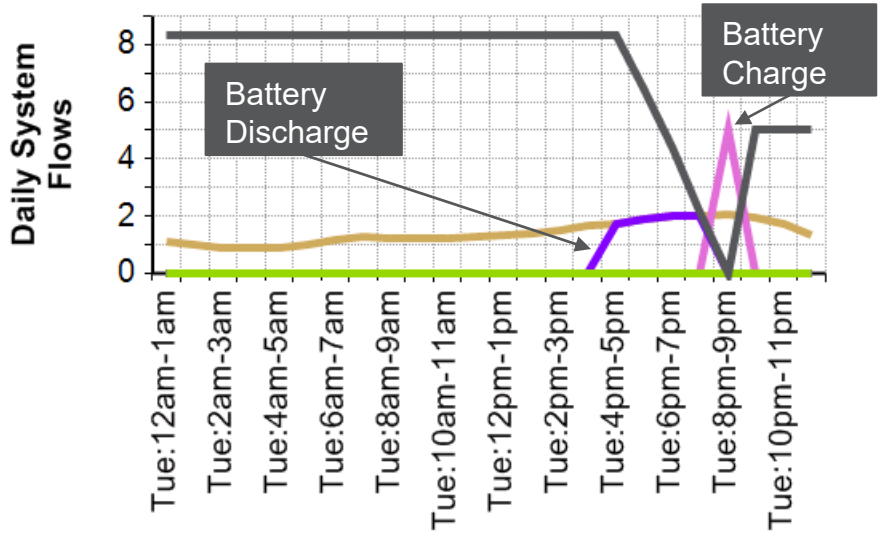
Energy Flows: Res Solar+Storage TOU



Energy Flows: Res Storage TOU

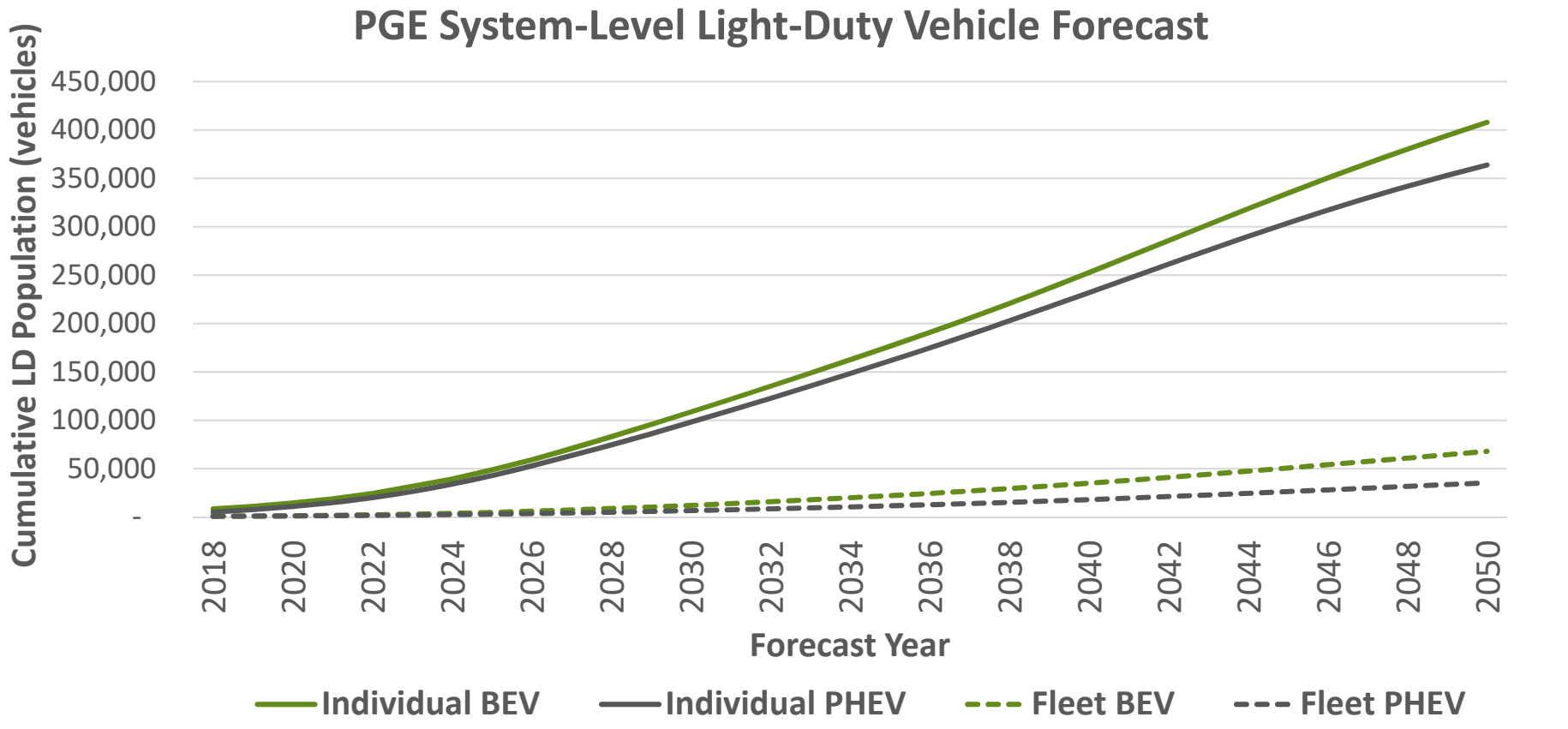


- State of Charge
- PV Elec for Storing
- Retail Discharge after Efficiency Loss
- Wholesale Discharge after Efficiency Loss
- Excess PV Generation
- PV at Retail
- Purchased Elec for Storing
- Cust Load by Opt Time Ext
- Lev Mthly Solar Gen by Opt Time

ELECTRIC MOBILITY: LD VEHICLES

BASE CASE DRAFT RESULTS

Light-duty vehicle adoption in PGE's system is forecast to grow by about 60x between 2018 and 2050, with BEV adoption expected to be slightly ahead of PHEV adoption.



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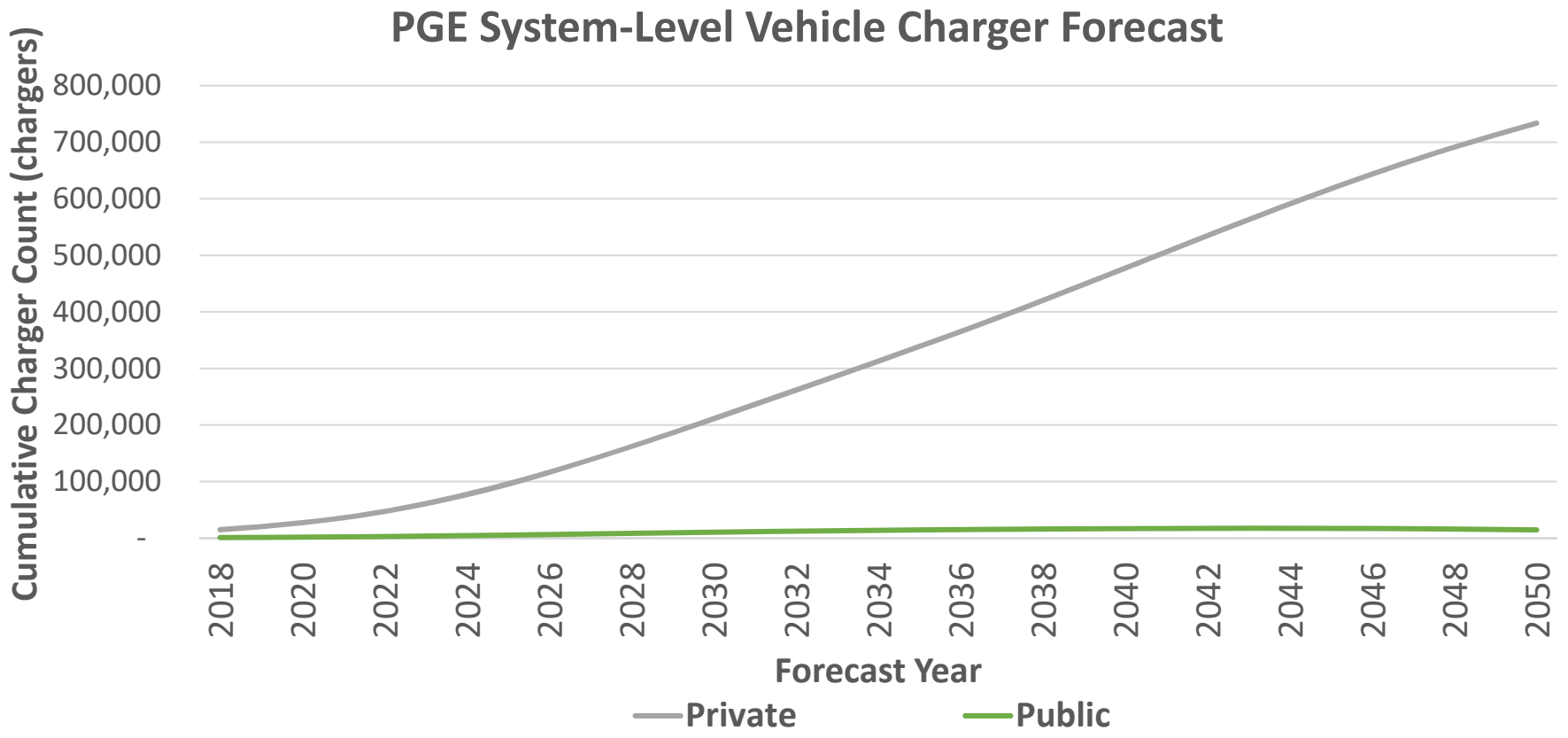
ELECTRIC MOBILITY: CHARGING

BASE CASE DRAFT RESULTS

Growth of private charging equipment is expected to far outpace public charging equipment as customers continue to primarily charge at home and workplaces.



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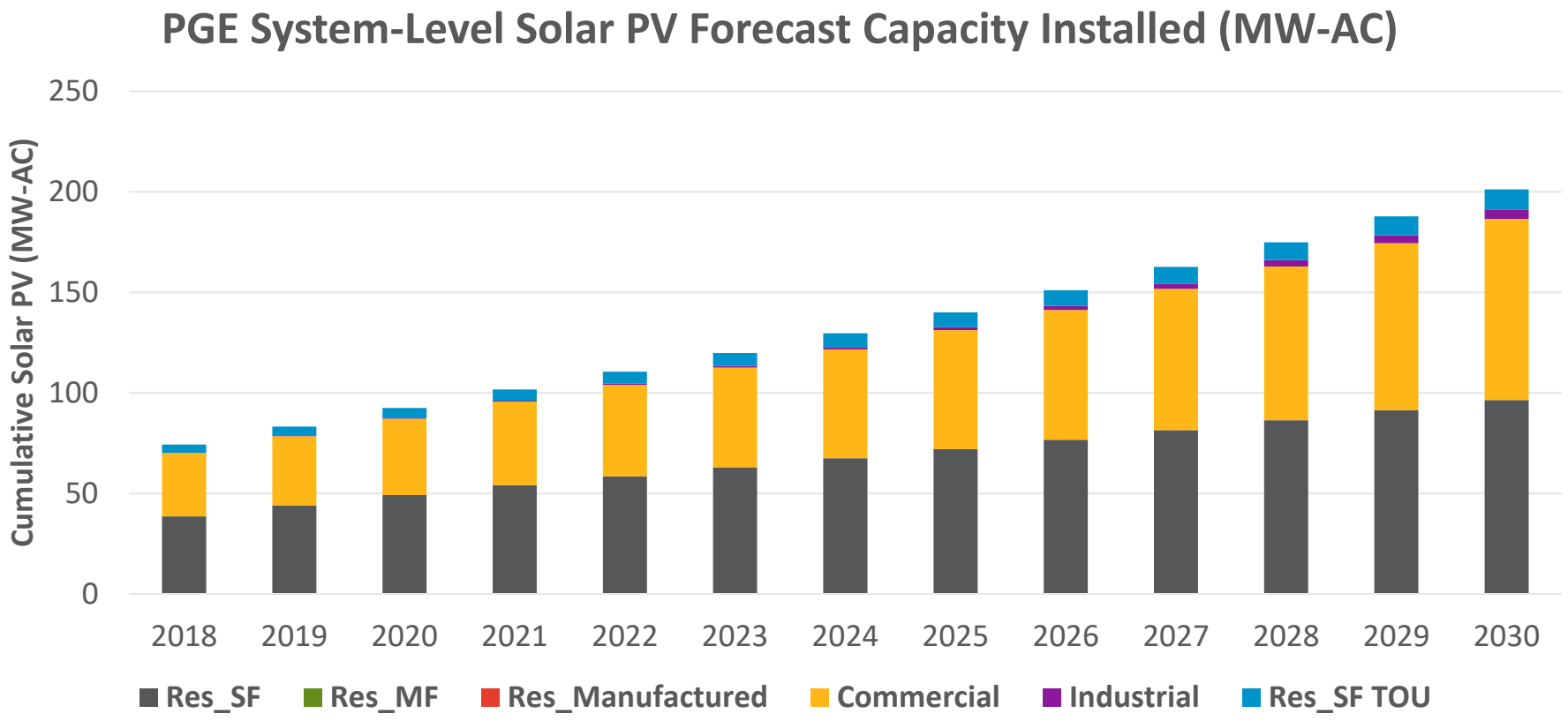
SOLAR BY CUSTOMER SEGMENT

BASE CASE DRAFT RESULTS

Solar PV growth is forecast to be driven primarily by Residential Single-Family and Commercial customers, given logistical limitations for other customer segments, with about 2.5x growth forecast before 2030.



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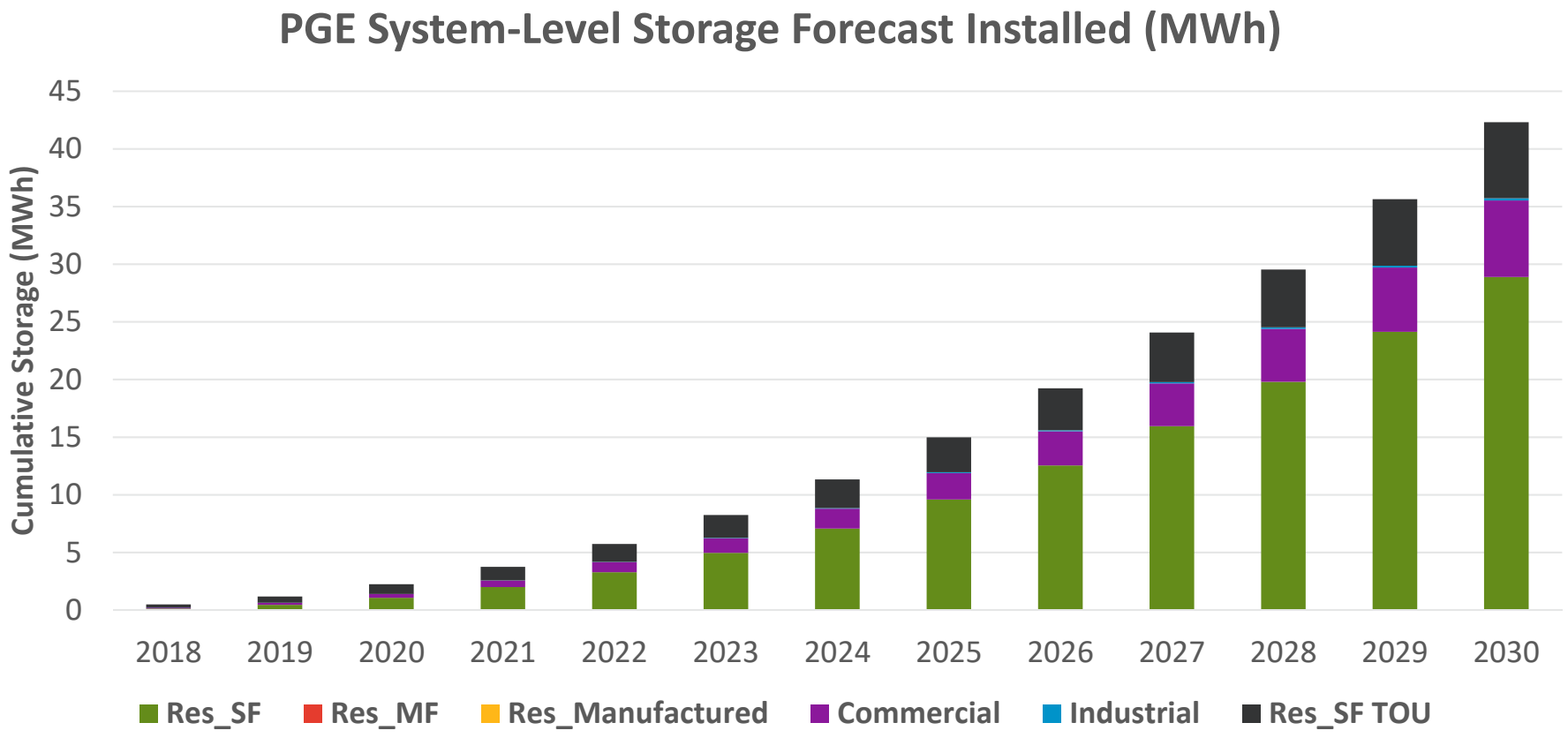
STORAGE BY CUSTOMER SEGMENT

BASE CASE DRAFT RESULTS

Storage PV growth is forecast to be driven primarily by Residential Single-Family customers with a TOU and Commercial customers, with significant growth forecast before 2030.



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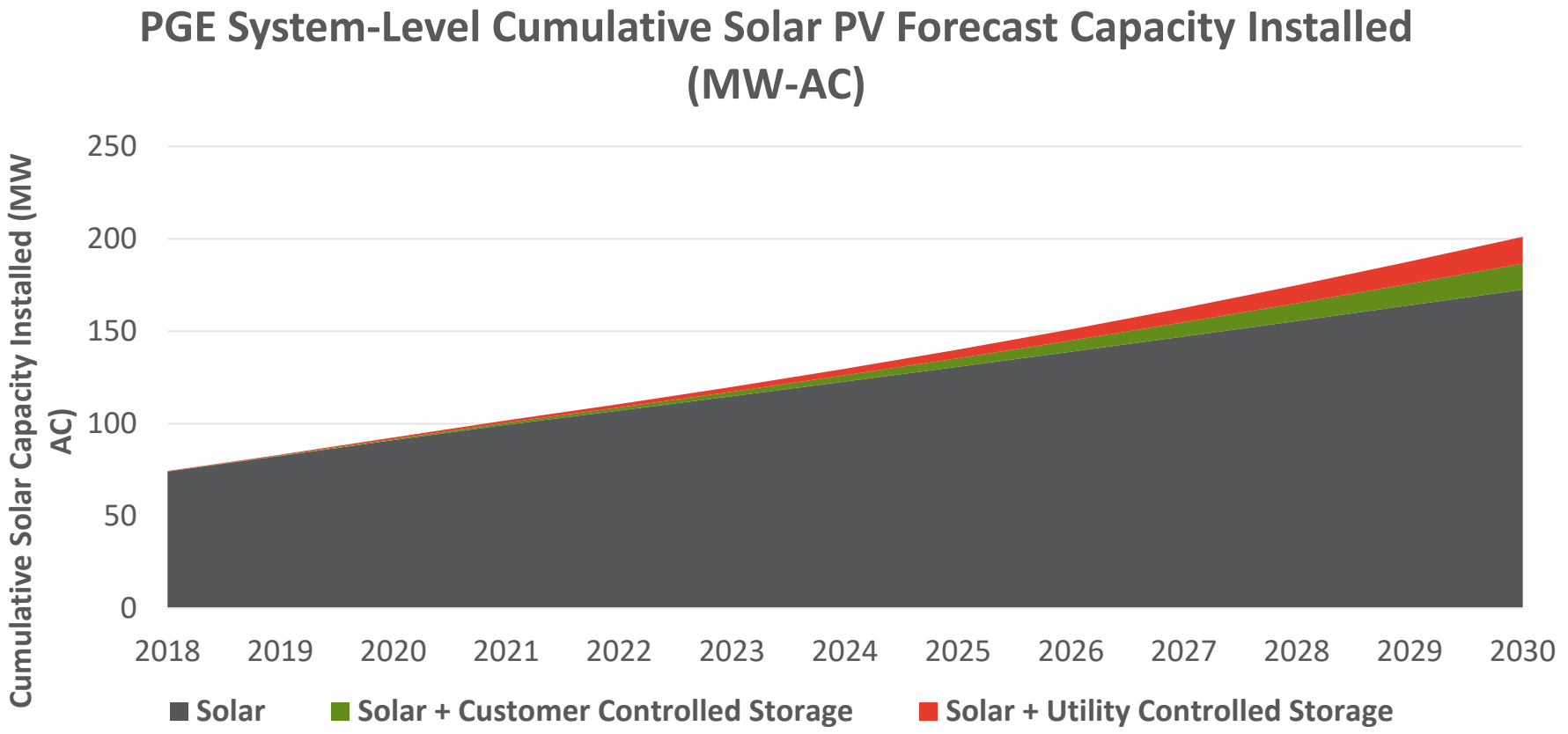
SOLAR BY USE CASE

BASE CASE DRAFT RESULTS

Solar PV growth is expected to continue around historical levels into the future. Solar + Storage comprises a much smaller market share, relative to standalone Solar PV alone. Customer operated Solar + Storage is expected to split the market, though this varies by sector.



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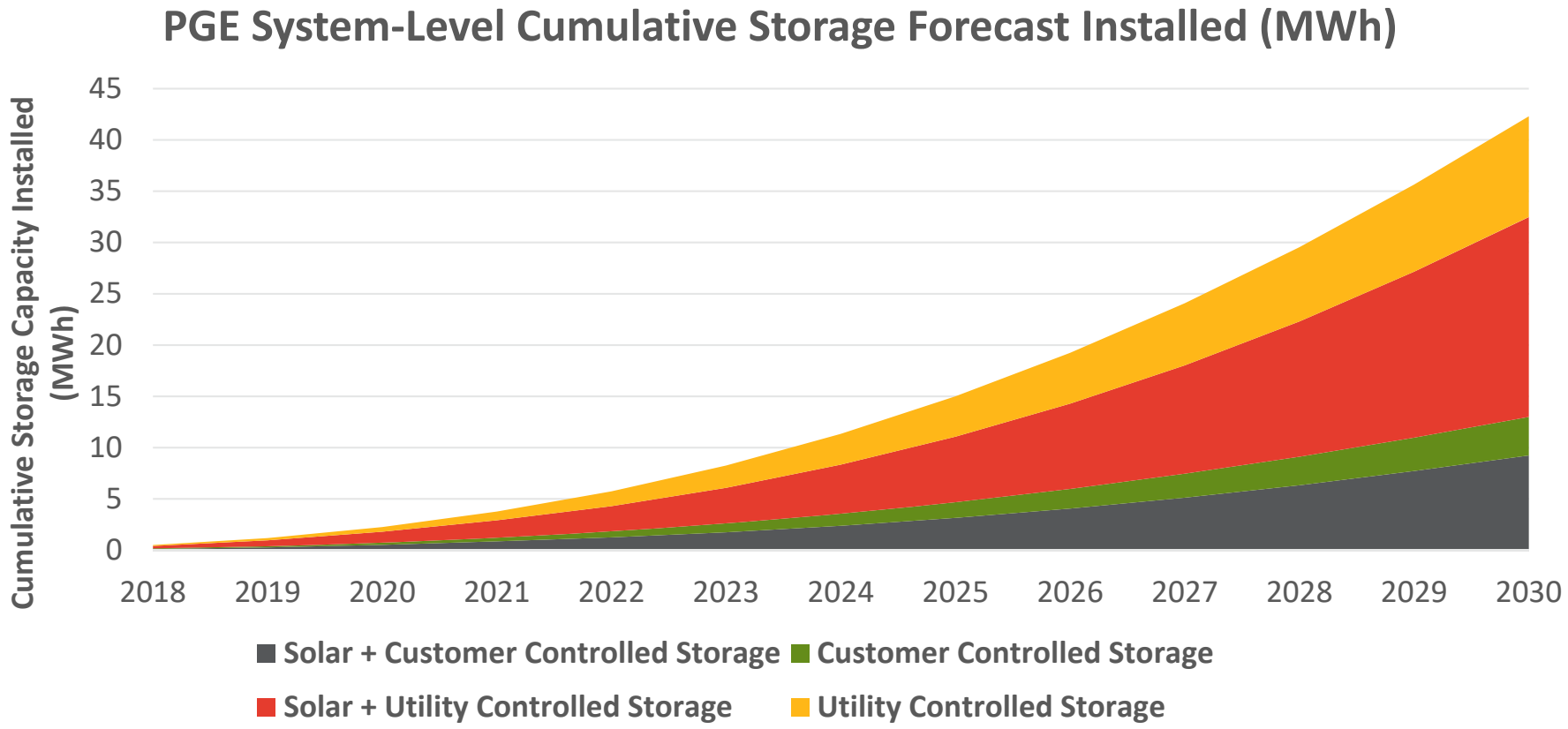
STORAGE BY USE CASE

BASE CASE DRAFT RESULTS

Customer-sited storage is expected to grow rapidly, but total installed capacity is limited by customer familiarity, economics, and competition with solar PV. Overall, utility controlled storage is expected to gain more market share than customer operated storage due to assumed incentive levels, though this varies by sector.



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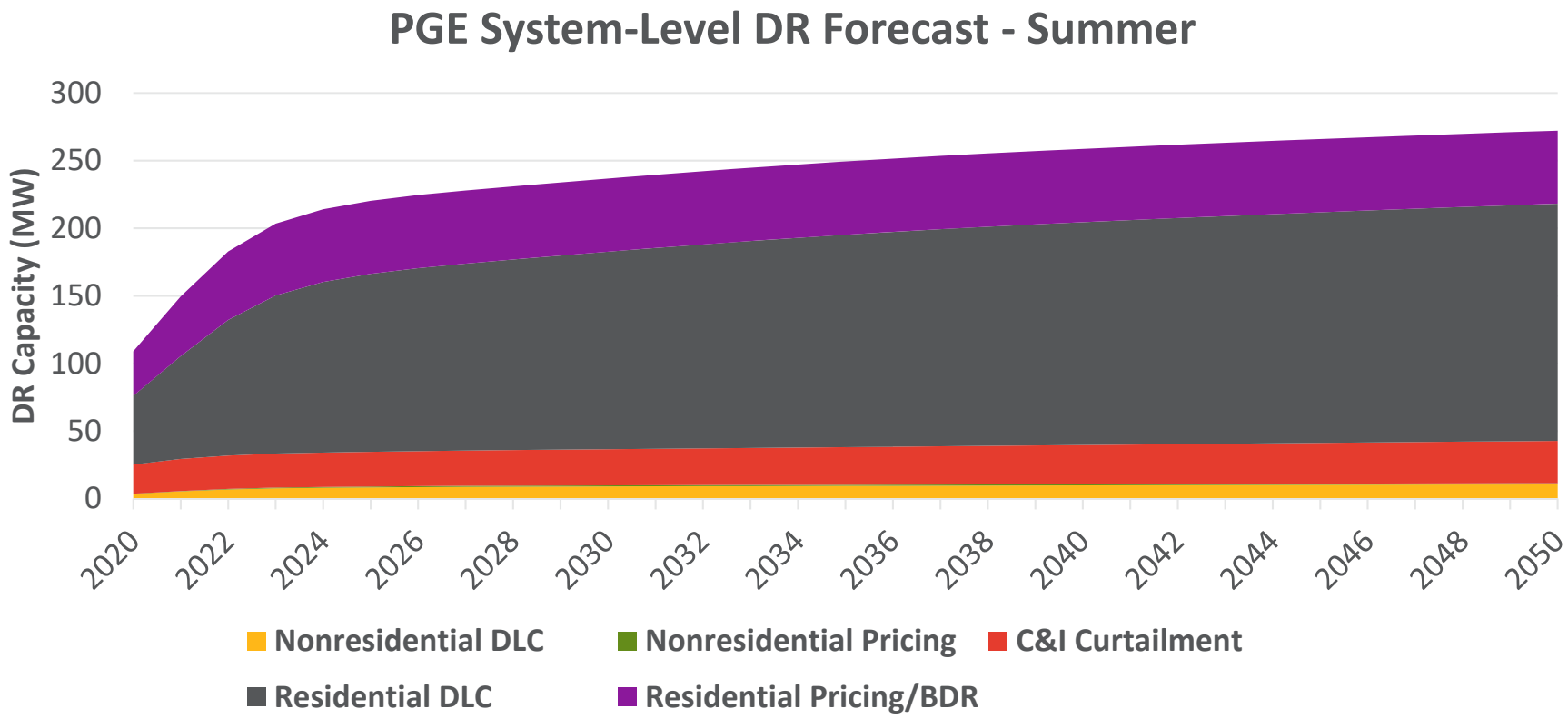
DR BY PROGRAM TYPE – SUMMER

BASE CASE DRAFT RESULTS

Summer DR is forecast to be largely from Residential DLC, with Residential Pricing/BDR also contributing a significant amount from TOU pricing and Peak-Time Rebate pricing.



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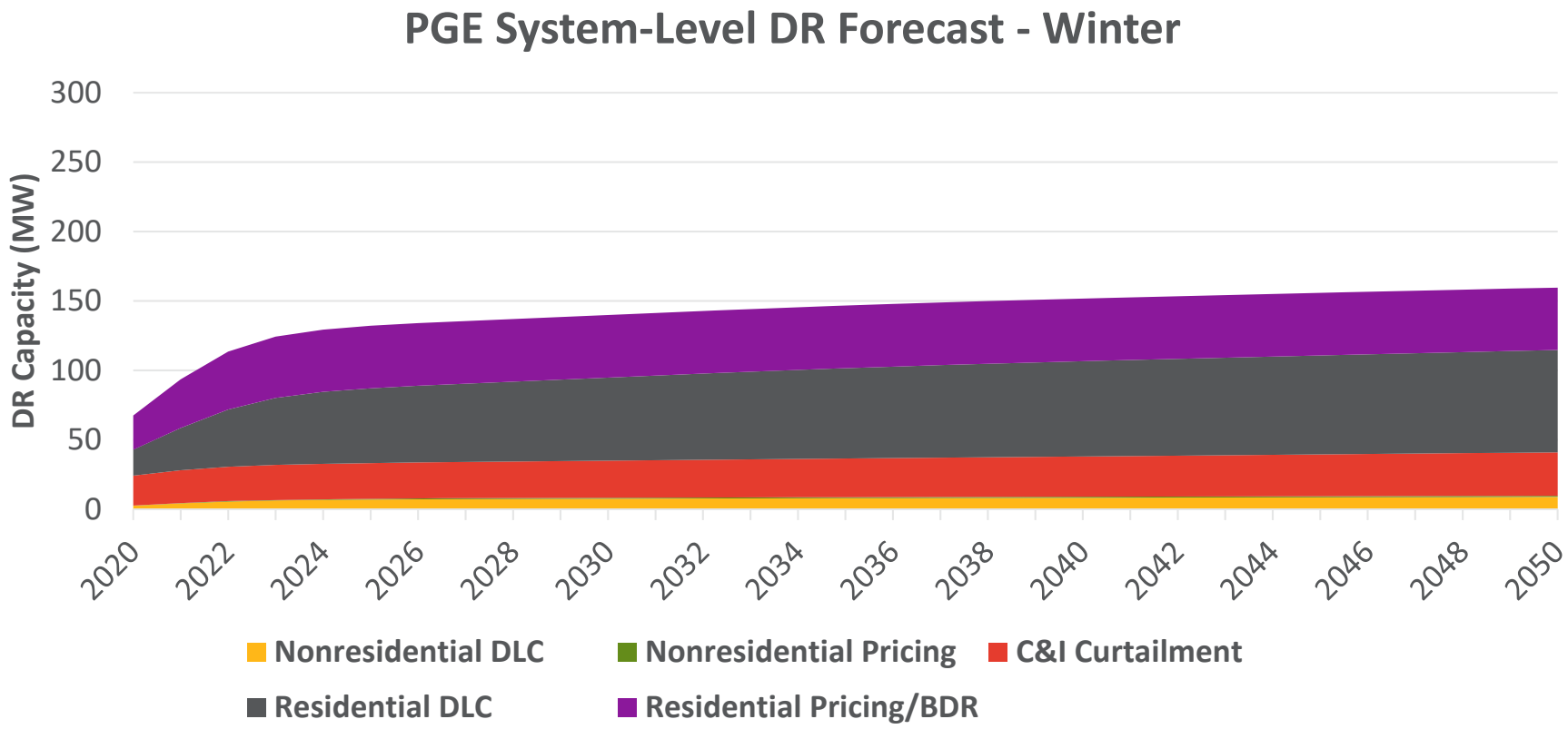
DR BY PROGRAM TYPE – WINTER

BASE CASE DRAFT RESULTS

Winter DR is forecast to be lower than Summer DR, given less potential from Residential DLC.



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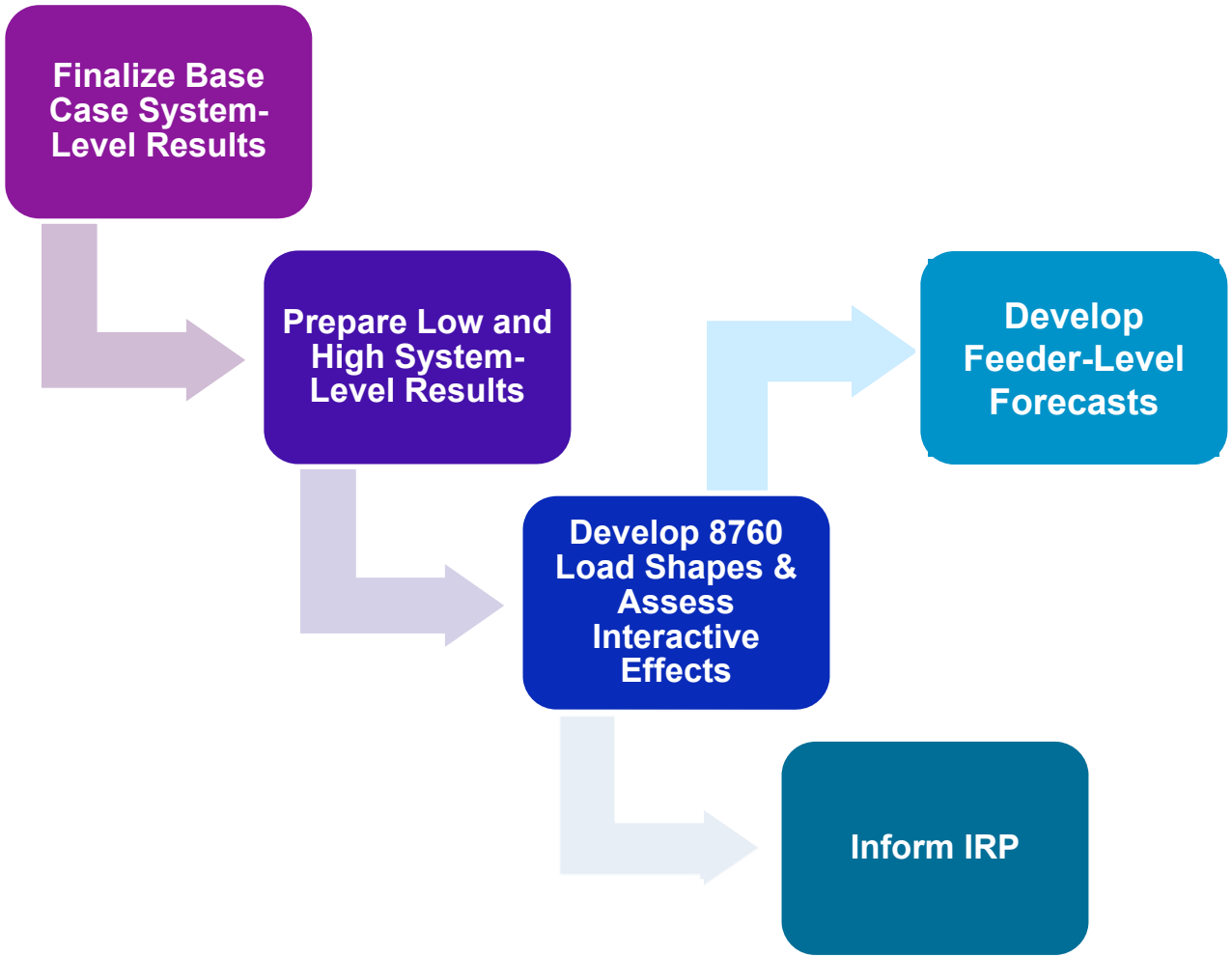
SCENARIO DRIVERS

- Looking forward, Low and High scenarios will be developed
- Scenario drivers will be directionally consistent across resources and reflect changes in assumptions for:
  - Distributed resource technology costs
  - Distributed resource policies
  - Carbon prices
  - TOU pricing participation rates

NEXT STEPS



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QUESTIONS?

NAVIGANT

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Carbon-Constrained Portfolios

Elaine Hart

PGE 2050 Clean Energy Vision

PGE is committed to reducing greenhouse gas emissions on our system by more than 80 percent by 2050.

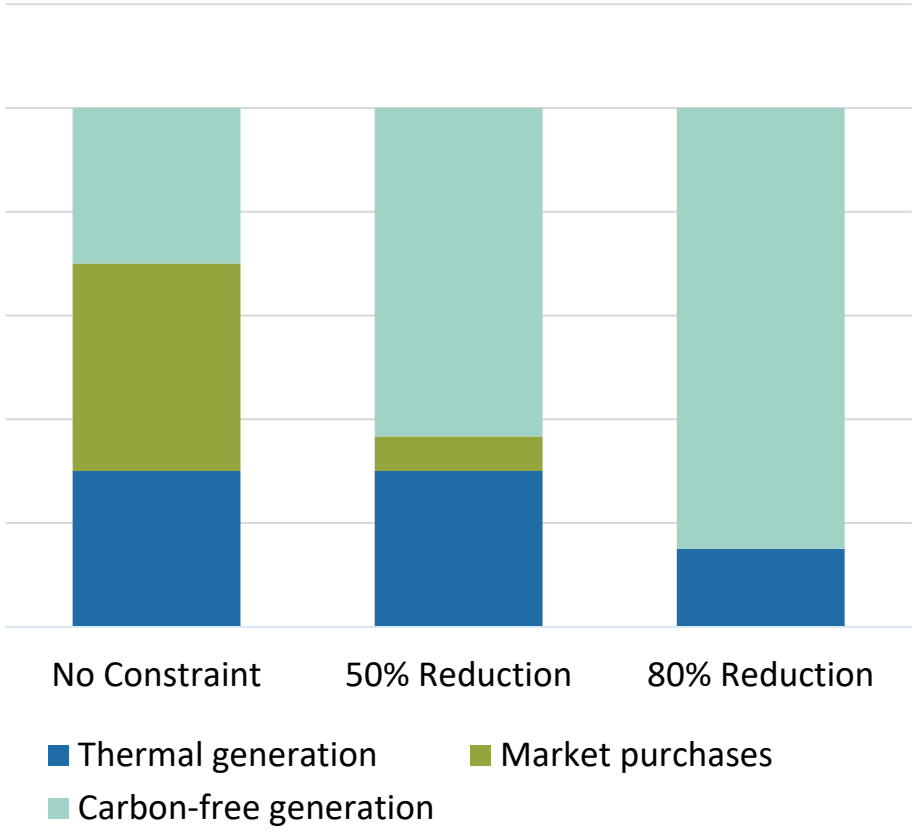
In the 2019 IRP, we will investigate this goal through simulating carbon-constrained portfolios.

Carbon Emissions in ROSE-E

Carbon emissions can be reduced by two mechanisms:

1. Procure renewable resources to offset market purchases

2. Curtail thermal generation and replace with renewable energy



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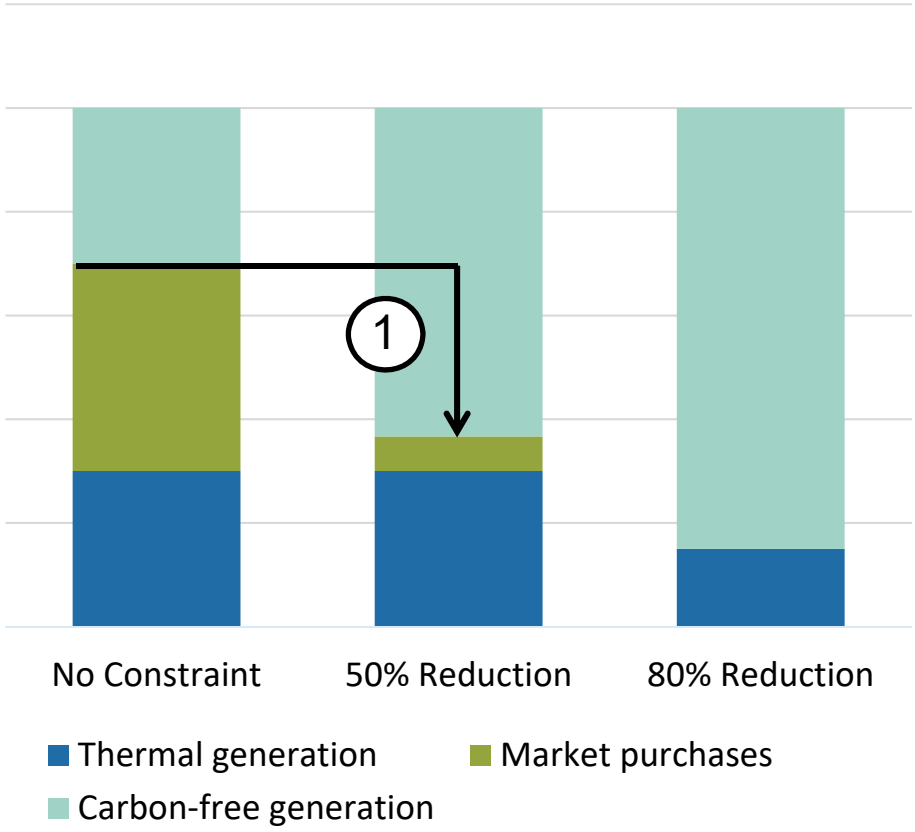

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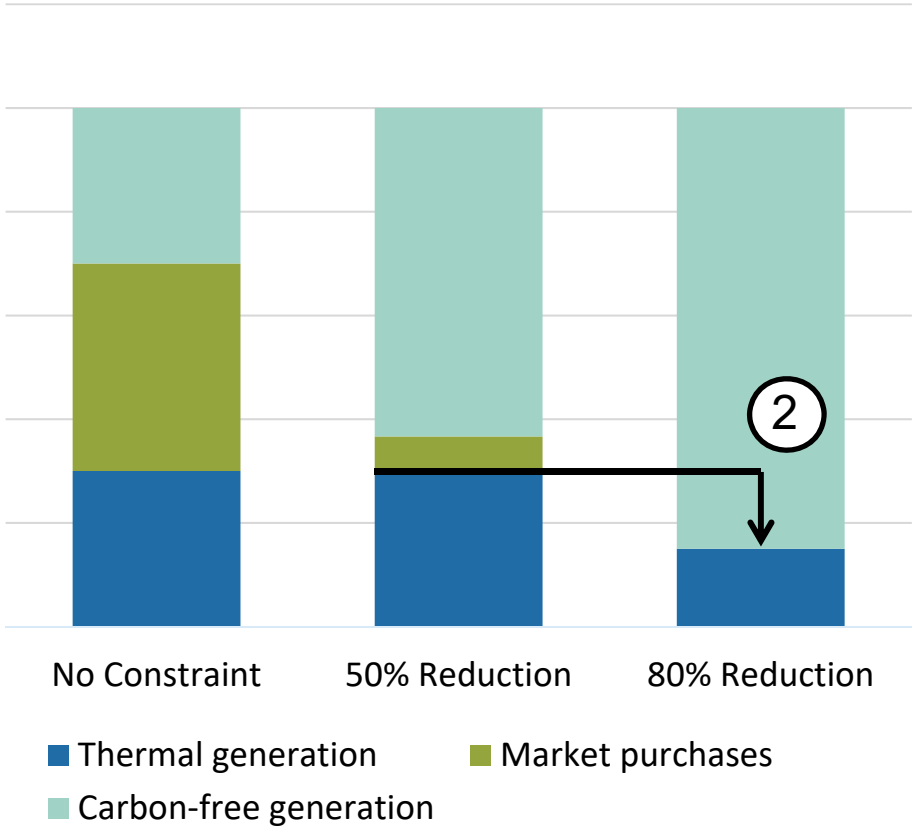
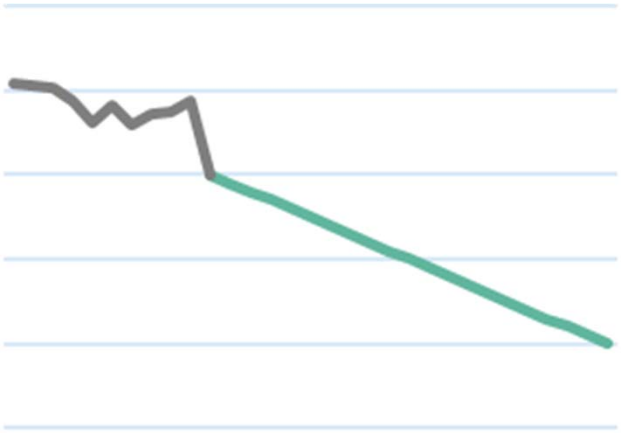


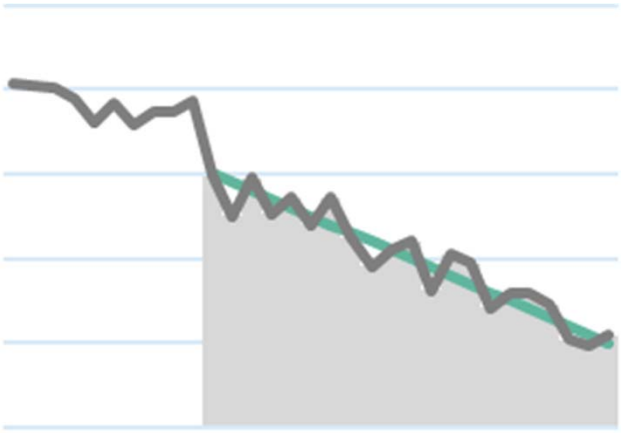
Options in 2019 IRP

Feedback on form of carbon constraint?

Trajectory constraint



Cumulative constraint



Illustrative – not indicative of PGE portfolio performance

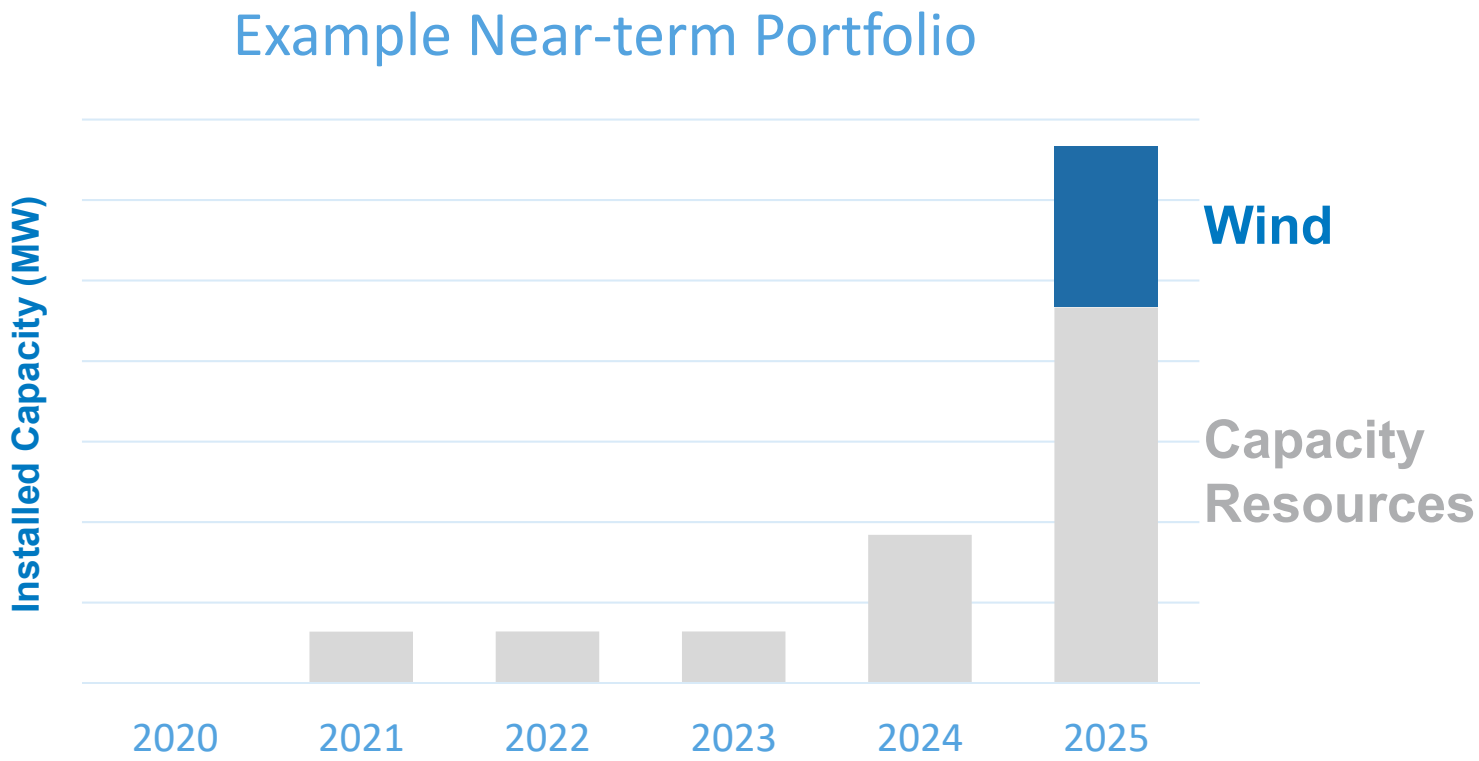
Strawman for 2019 IRP

Test portfolio performance with and without carbon constraint

- Recall that each portfolio will consist of a set of near-term actions
  - Long-term actions are allowed to flex across futures to capture the value of optionality
- This framework allows us to test the same near-term actions against different long-term constraints (i.e. with and without carbon constraints)
- Portfolio performance with carbon constraint would factor into portfolio scoring

Strawman for 2019 IRP

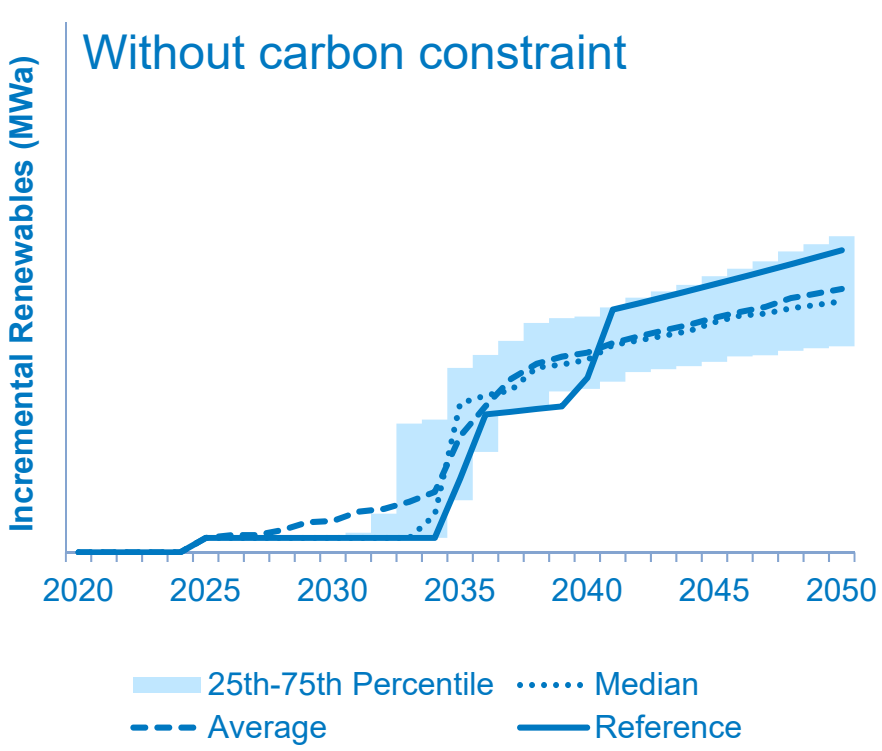
Example: 2025 wind addition with and without long-term carbon constraint

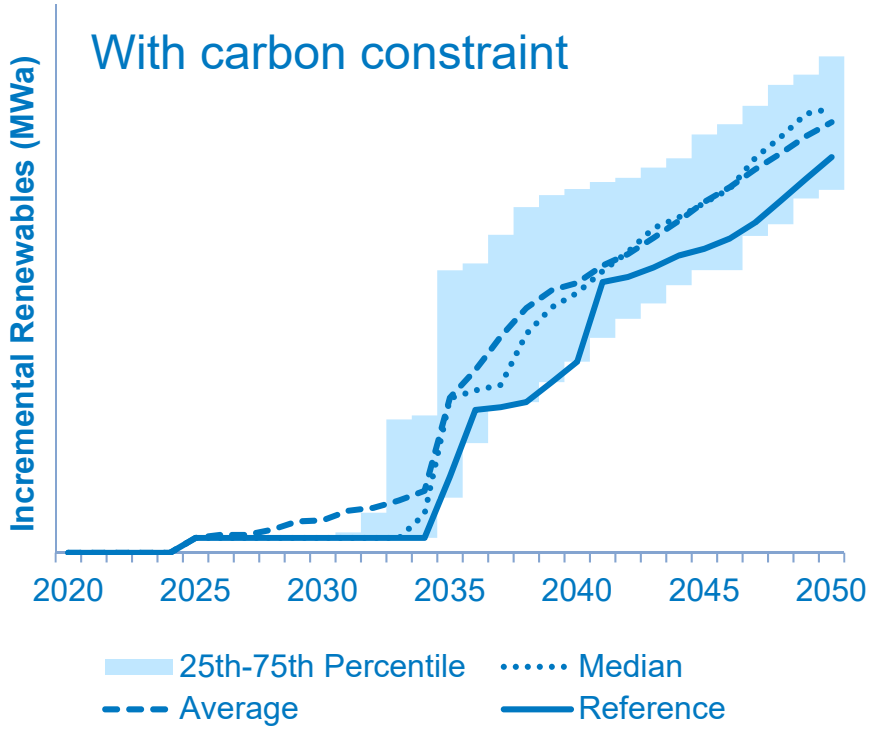


Illustrative – not indicative of PGE resource needs

Strawman for 2019 IRP

Example: Renewable glide path with 2025 wind addition

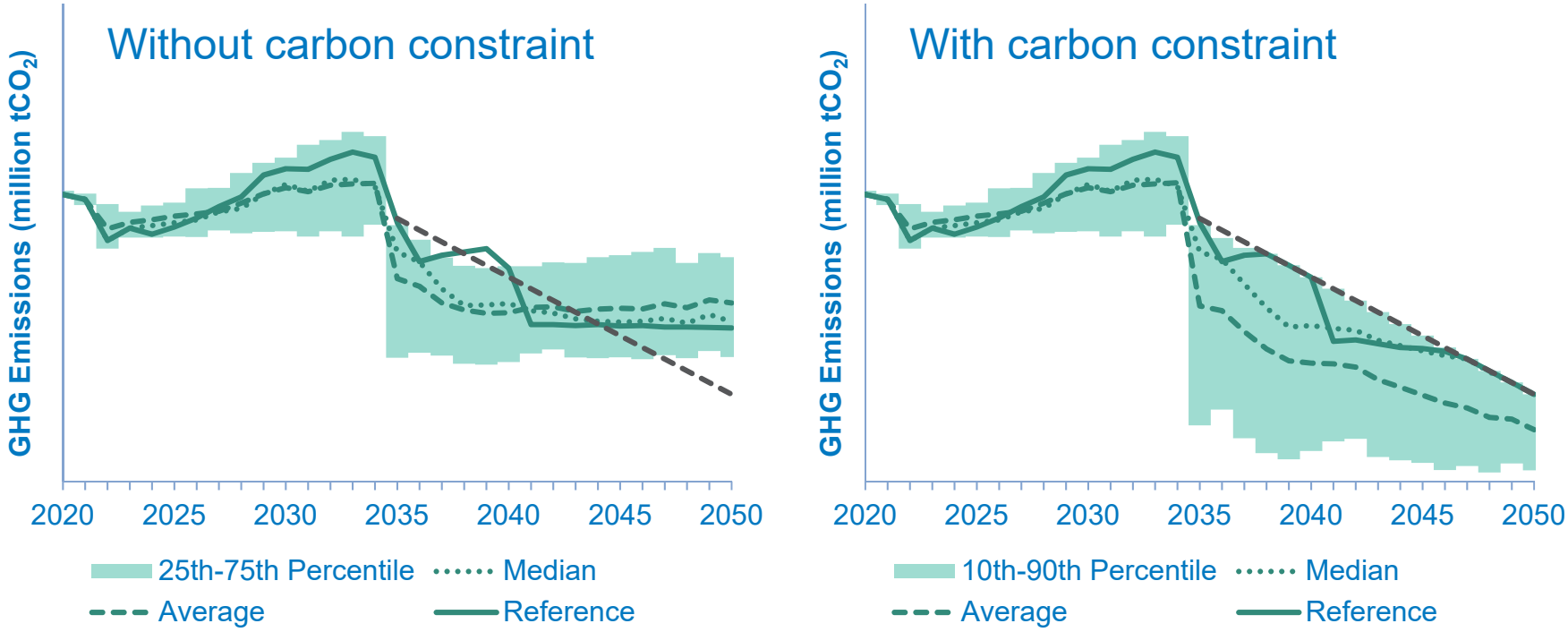




Illustrative – not indicative of PGE resource needs, carbon target, or portfolio performance

Strawman for 2019 IRP

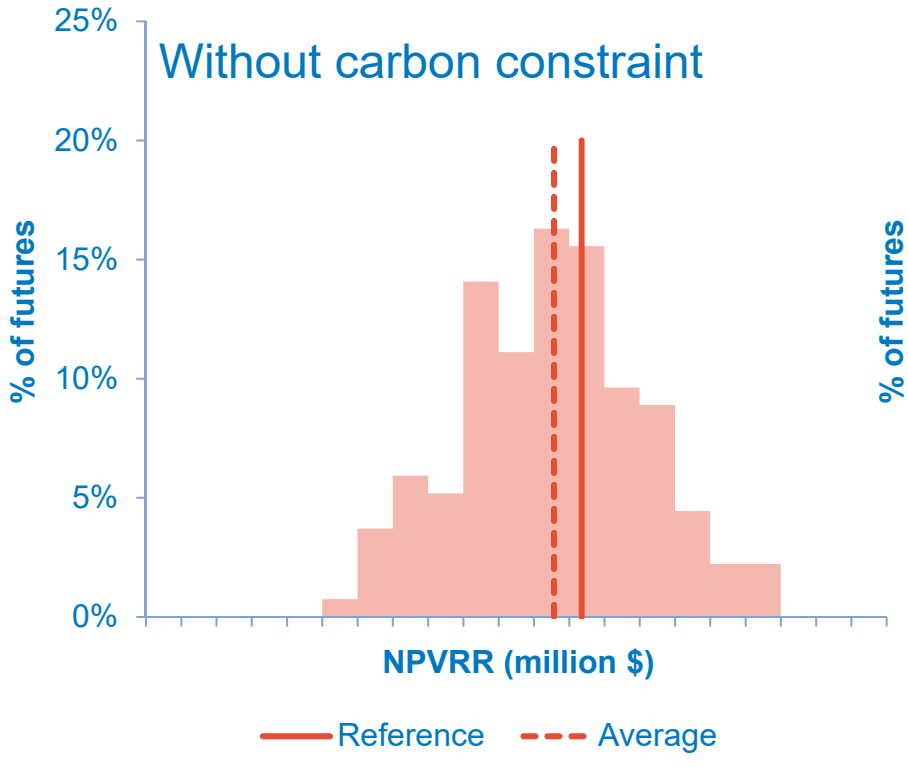
Example: Emissions with 2025 wind addition

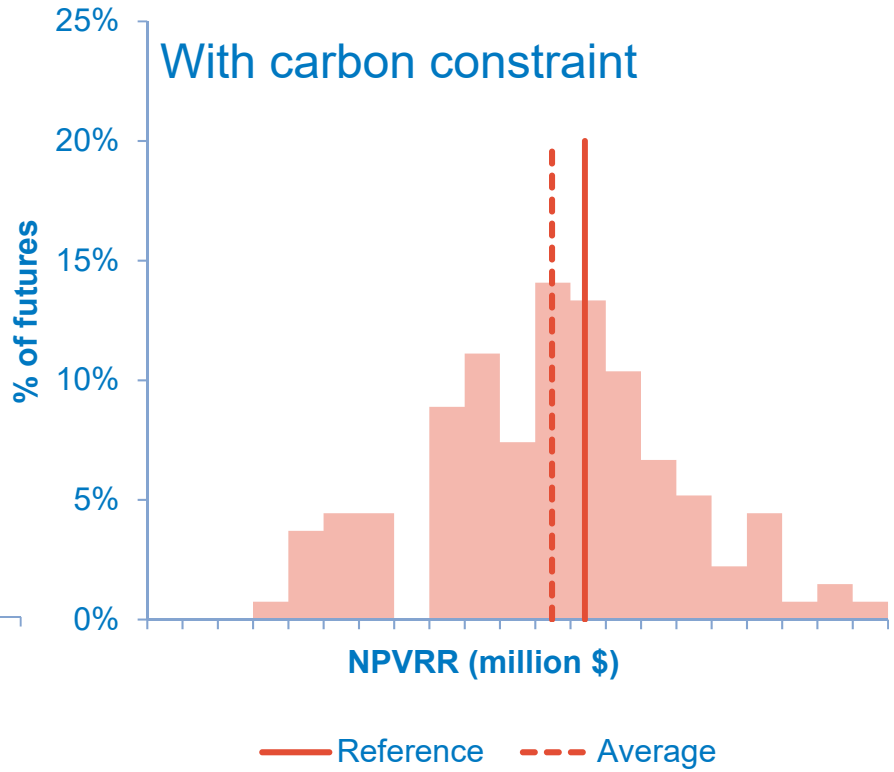


Illustrative – not indicative of PGE resource needs, carbon target, or portfolio performance

Strawman for 2019 IRP

Example: NPVRR distribution with 2025 wind addition





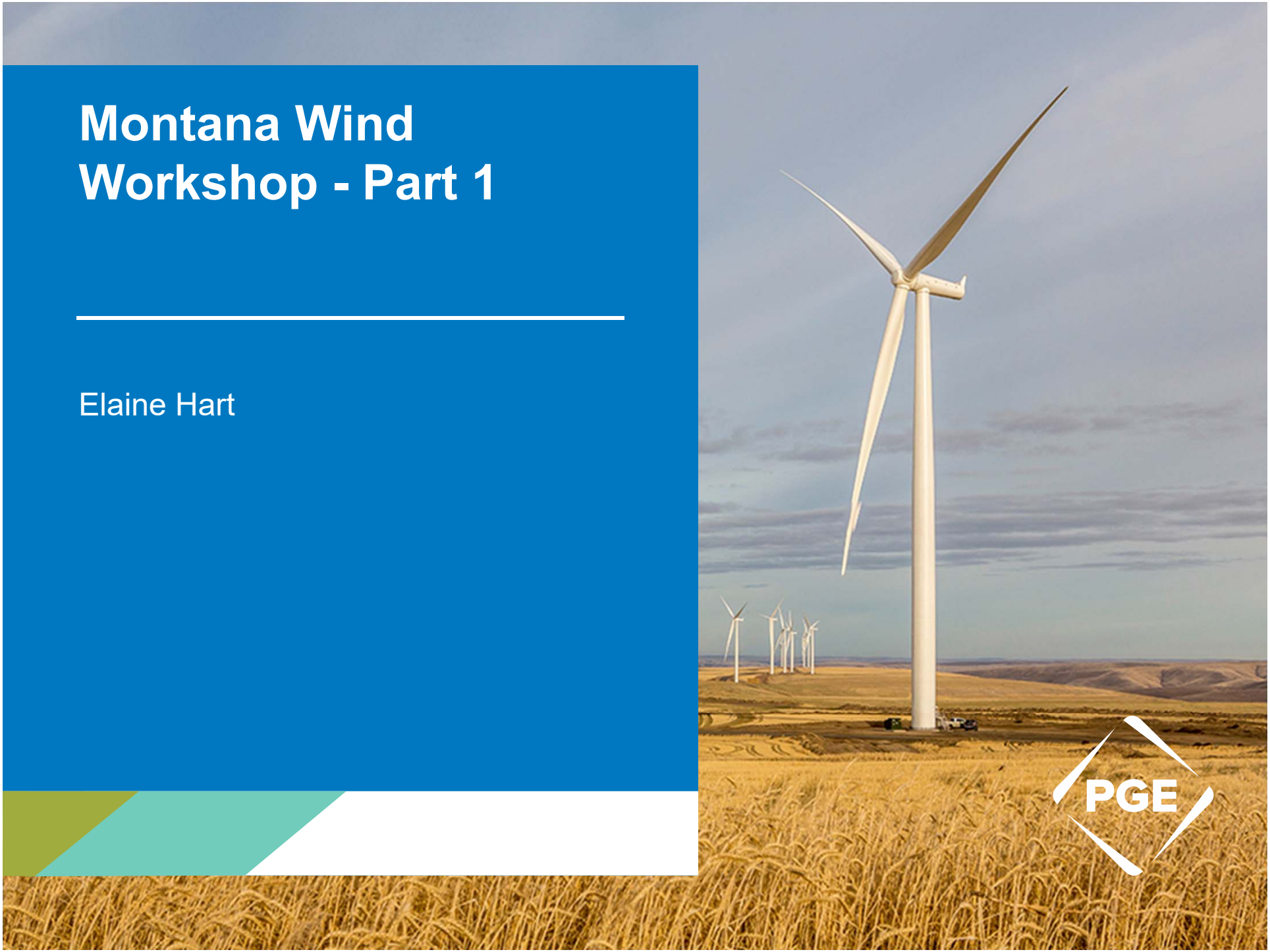
Illustrative – not indicative of PGE resource needs, carbon target, or portfolio performance

Stakeholder Feedback?

- Does PGE's proposed approach provide adequate information to show how near term actions position PGE to meet long term carbon goals?
- How might portfolio performance under carbon-constrained conditions be accounted for in portfolio evaluation?

Montana Wind Workshop - Part 1

Elaine Hart



Agenda

- Review of 2016 IRP Montana Wind analysis
- Review of relevant findings from Montana Renewable Development Action Plan
- Strawman for considering Montana Wind in 2019 IRP

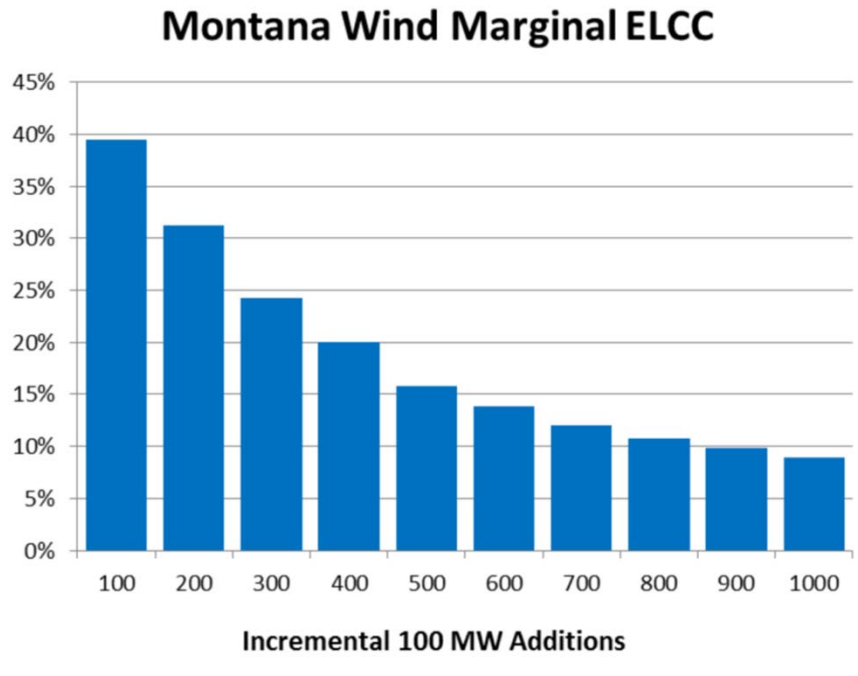
Montana Wind in the 2016 IRP

Montana Wind was considered in three components of the 2016 IRP:

- Capacity contribution
- Flexibility analysis
- Portfolio analysis

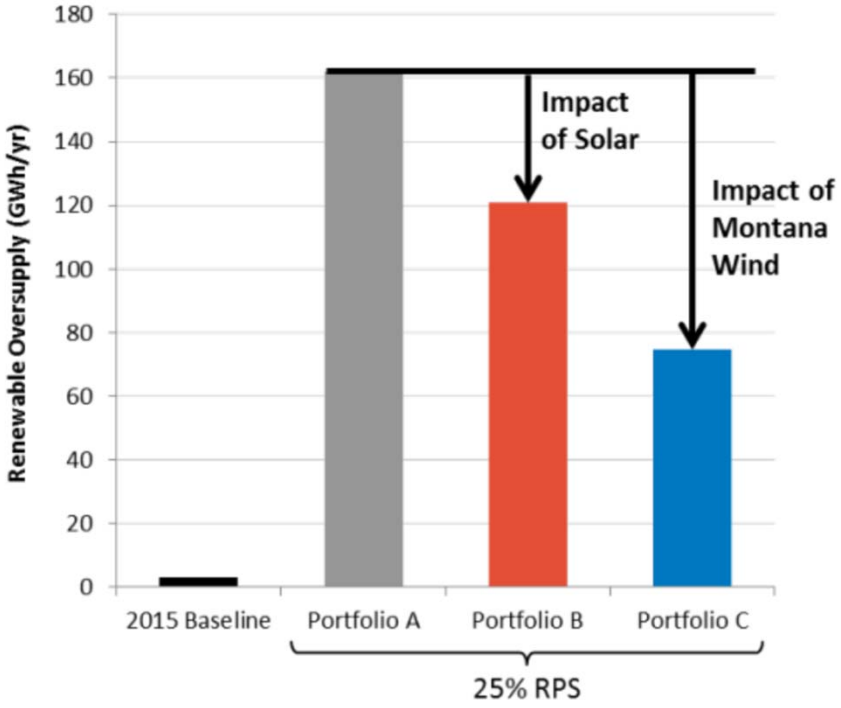
Montana Wind in the 2016 IRP

Capacity contribution



Montana Wind in the 2016 IRP

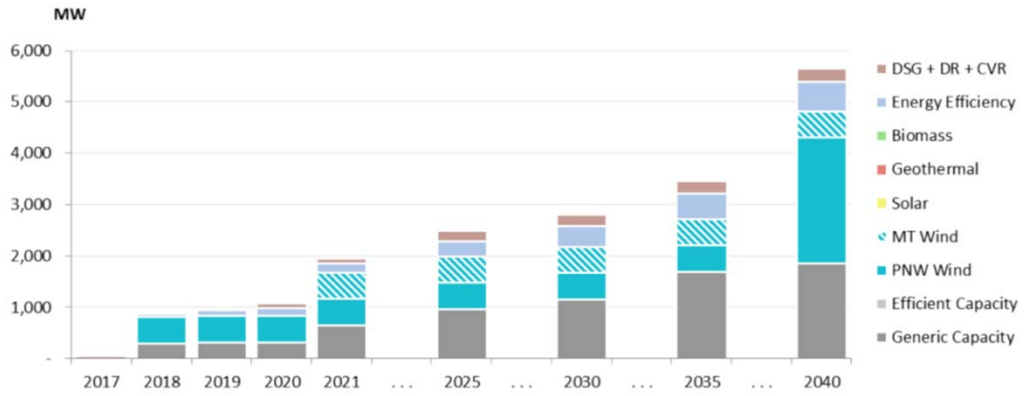
Flexibility analysis



Montana Wind in the 2016 IRP

Portfolio analysis

FIGURE O-11: Portfolio 6 cumulative resource additions, capacity (MW)

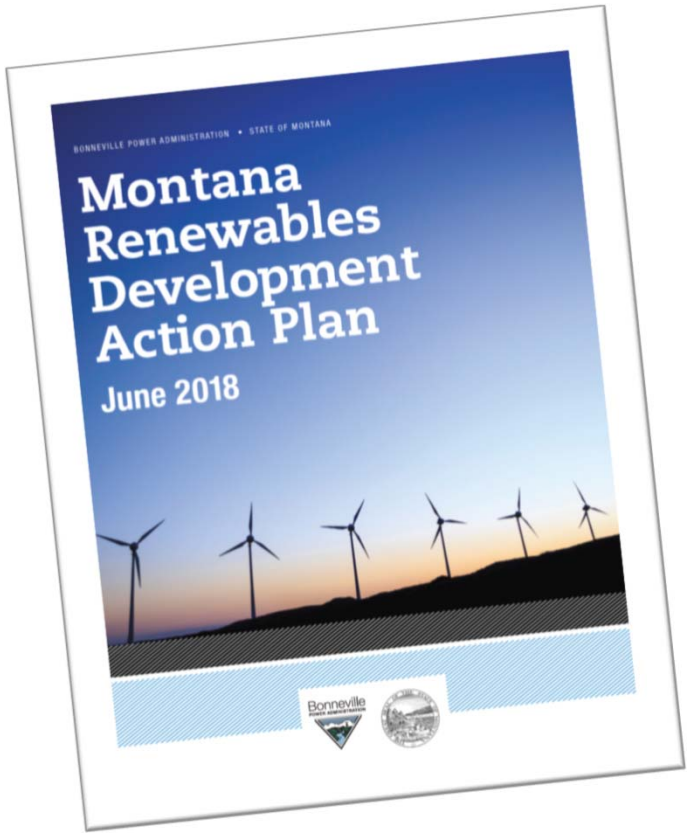


- Due to transmission cost uncertainty, PGE investigated the net portfolio benefits of Montana Wind relative to PNW Wind
- This analysis identified a $65/kW-yr transmission budget for Montana Wind to compete with PNW Wind

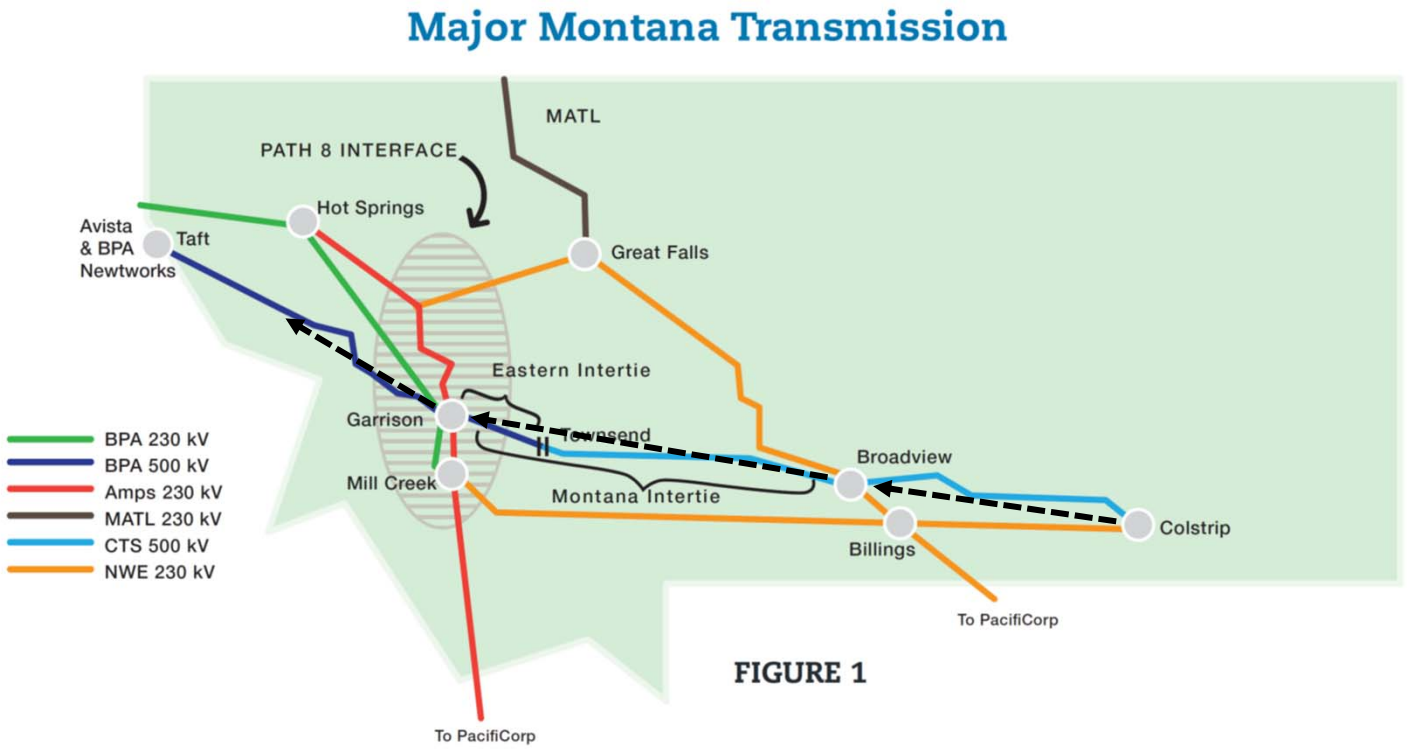
Montana Renewables Development Action Plan

Recommendations relevant to PGE's IRP:

4) Pacific Northwest utilities that may have an interest in acquiring Montana renewables should include scenarios with Montana renewables when studying their flexible capacity needs.



Montana Renewables Development Action Plan



Transmission System	Transmission Rate	Losses
PSE CTS → MT Int → BPA	$4.95/kW-mo	4.6%

Montana Wind in the 2019 IRP

Resource Adequacy

- RECAP modeling will incorporate analysis of Montana Wind

Flexibility Analysis

- Flexibility analysis will incorporate analysis of Montana Wind

Portfolio Analysis

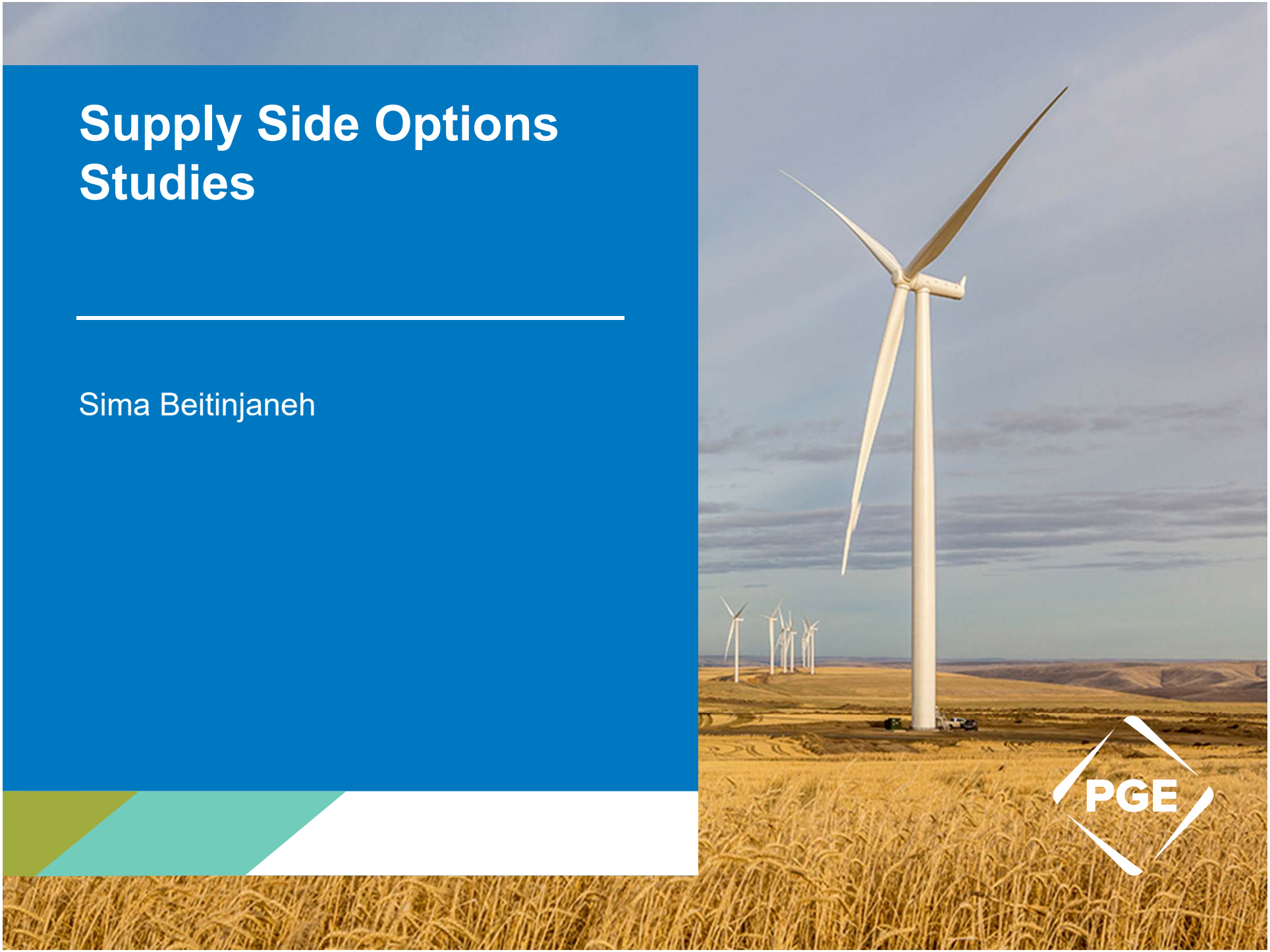
- Assume available transmission to Mid-C and incorporate wheeling cost findings from MRDAP into a portfolio with Montana Wind in the near-term
- Evaluate Montana Wind resource that makes use of PGE transmission rights from Colstrip after Colstrip exits PGE portfolio

Draft Market Prices

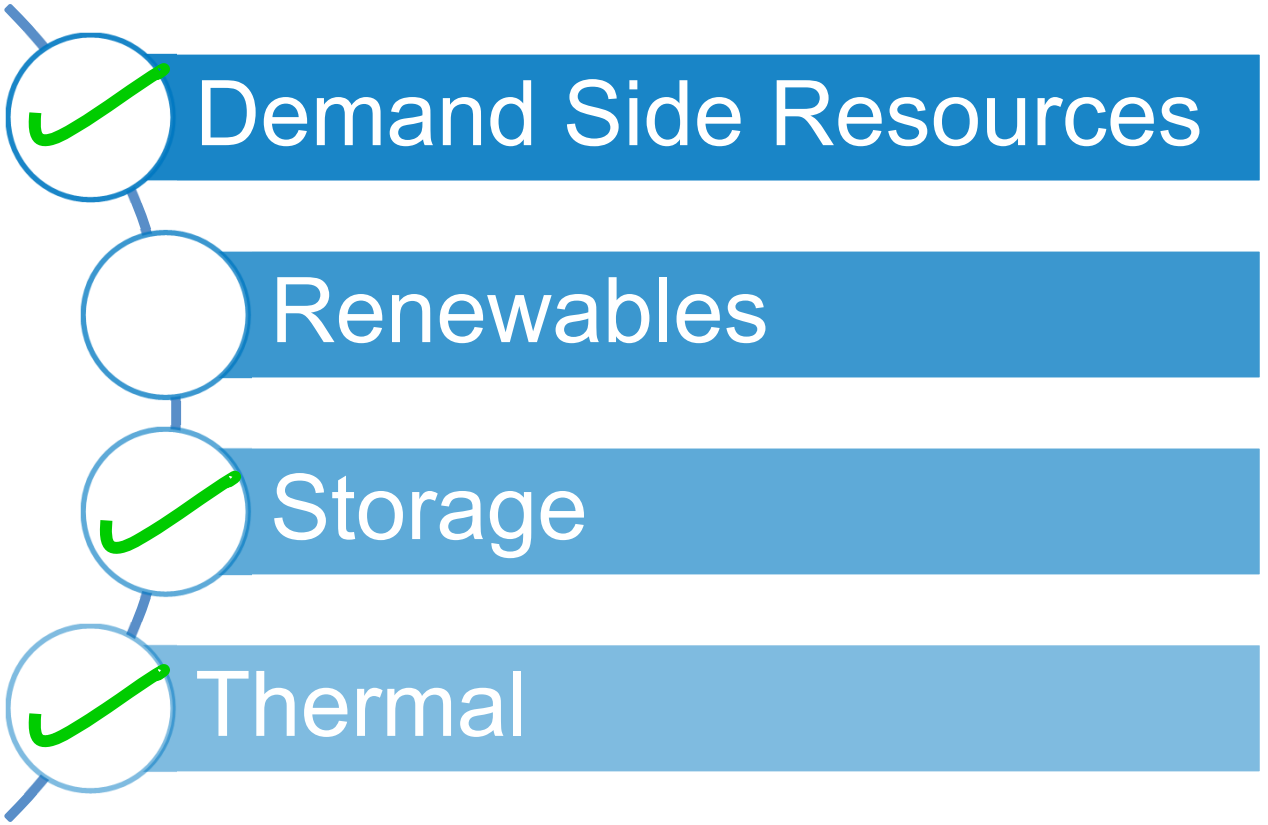
Shauna Jensen

Supply Side Options Studies

Sima Beitinjaneh

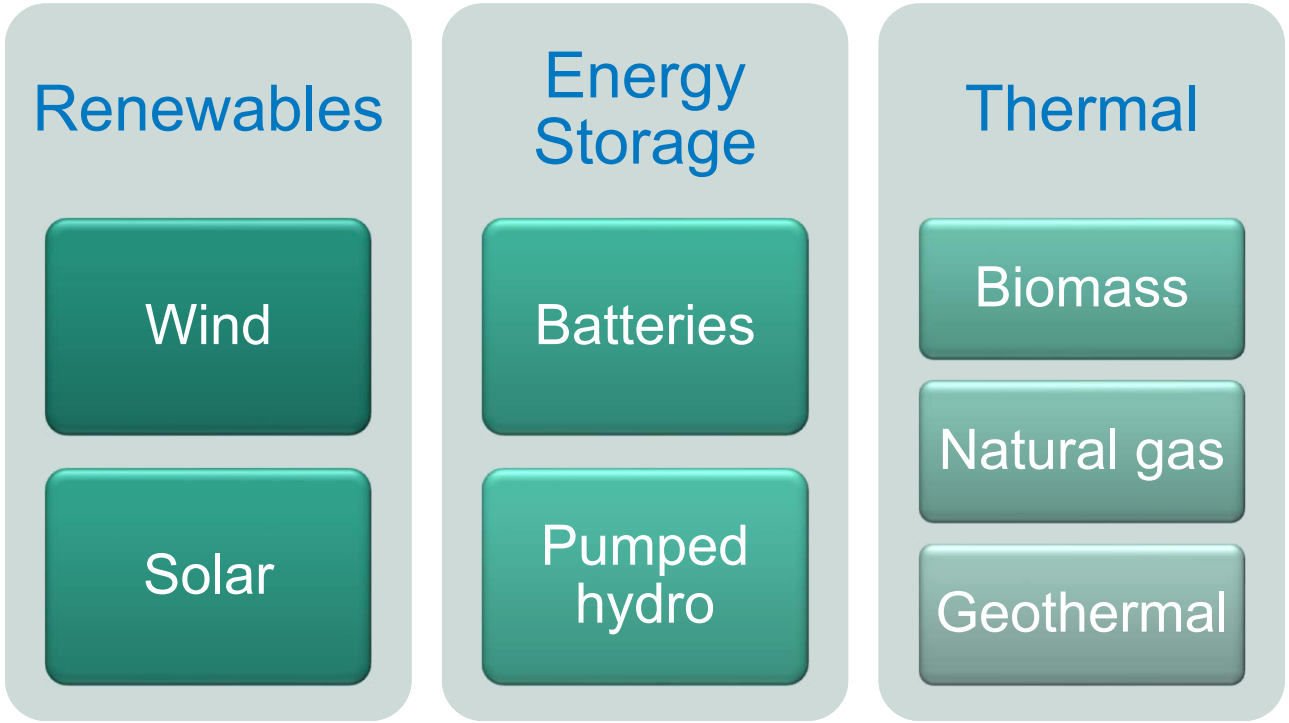


What types of resources will be evaluated in the 2019 IRP?



Supply Side Resources

For generic new resource options in the 2019 IRP, PGE contracted HDR Engineering Inc. to develop cost and technical assumptions for generic supply side resources located in the PNW.



Energy Storage

Batteries

In the 2019 IRP, PGE is evaluating a 100 MW Li-ion Battery Energy Storage System (BESS) with 2, 4, and 6-hour durations.

100 MW Lithium Ion BESS			
Discharge duration	2 hour	4 hour	6 hour
Max storage limit	200 MWh	400 MWh	600 MWh
Round trip efficiency	82%	87%	89%
Overnight Capital Cost*	$916/kW $458/kWh	$1,554/kW $388/kWh	$1,902/kW $317/kWh
Fixed O&M*	$12/kWh-yr	$8/kWh-yr	$7/kWh-yr

** Cost in 2018$, notice to proceed in 2018, $/kWh values are per storage limit (capacity x duration).*

Energy Storage

Pumped Hydro Storage

Energy Storage

Pumped Hydro Storage

PGE is evaluating a 1200 MW generic pumped hydro energy storage plant located in the NW. The general characteristics of the plant are: 3x400 MW nominal, variable speed, closed loop system with an 8-hour duration.

Generation	Pumping	Average turnaround efficiency	Ramp Rate	Overnight Capital cost*	Fixed O&M cost*
Average min ~147MW Average max ~383MW	Average min ~377MW Average max ~517MW	80%	255 MW/min	$2,252/kW	$14/kWh-yr

** Cost in 2018$, notice to proceed in 2018, $/kWh values are per storage limit (capacity x duration).*

Thermal Resources

In the 2019 IRP, PGE will evaluate one biomass, one geothermal, three generic natural gas peaking resources and one generic natural gas combined resource. HDR has provided generic operating and financial characteristics for the resources to be used as input assumptions in our analysis.

Thermal Resources

General Operating Characteristics

Resource type	Capacity, New & Clean (MW)	Heat Rate, New & Clean (Btu/kWh)
Biomass -wood	30	13460
Geothermal	30	NA
6x0 Wartsila Recips	18/unit	8453
1x0 GE LMS 100	96	8931
1x0 GE 7HA Frame Single Cycle	356	9135
1x1 GE 7HA Frame Combined Cycle	517	6233

Thermal Resources

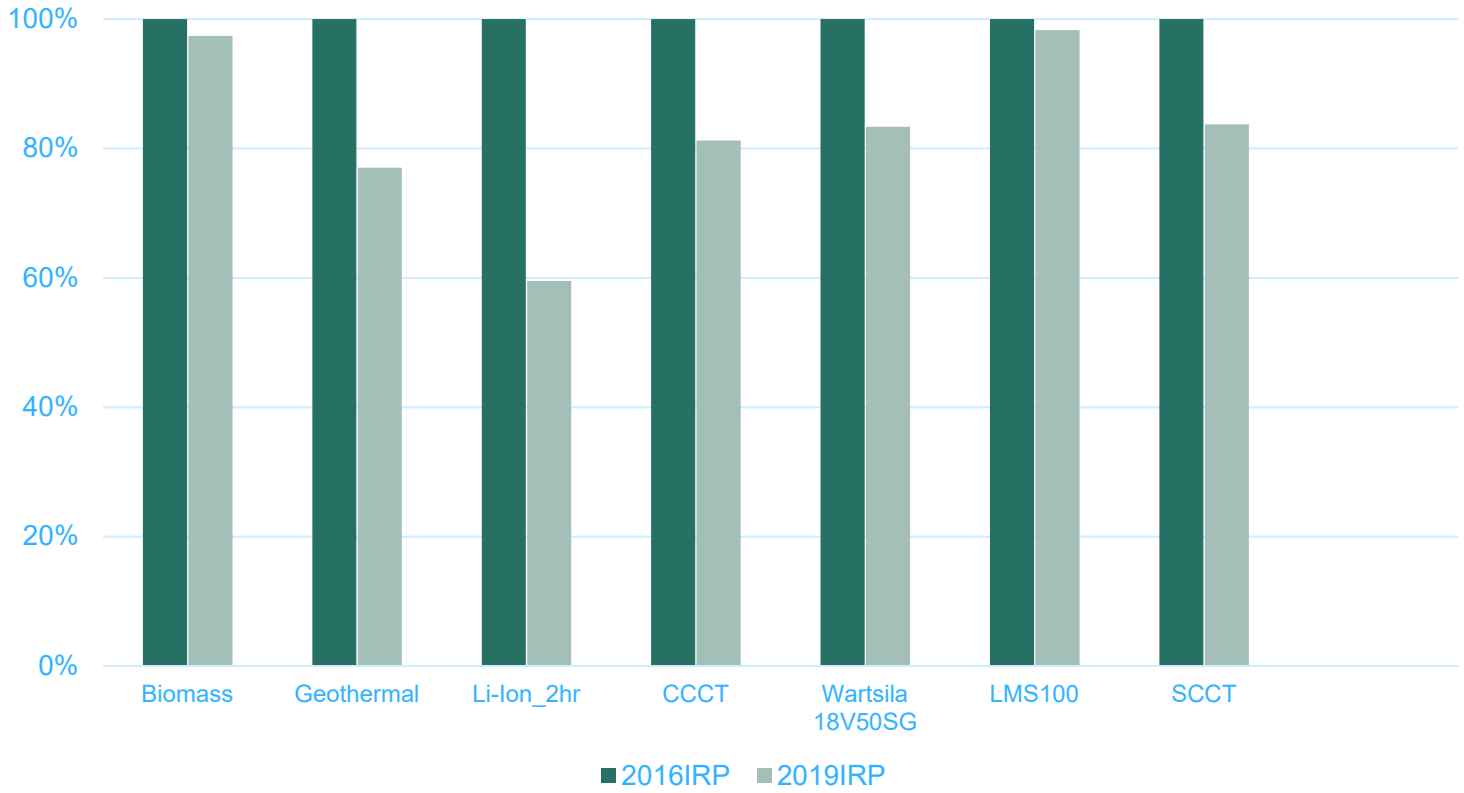
Financial Characteristics

Resource type	Overnight Capital Cost* $/kW	Fixed O&M $/kW-yr	Non-fuel Variable O&M $/MWh
Biomass -wood	$5,839	$110.84	$5.28
Geothermal	$6,216	$119.53	$2.39
6x0 Wartsila Recips	$1,265	$5.15	$5.42
1x0 GE LMS 100	$1,111	$5.61	$5.20
1x0 GE 7HA Frame Single Cycle	$518	$2.10	$9.69
1x1 GE 7HA Frame Combined Cycle	$888	$6.57	$3.57

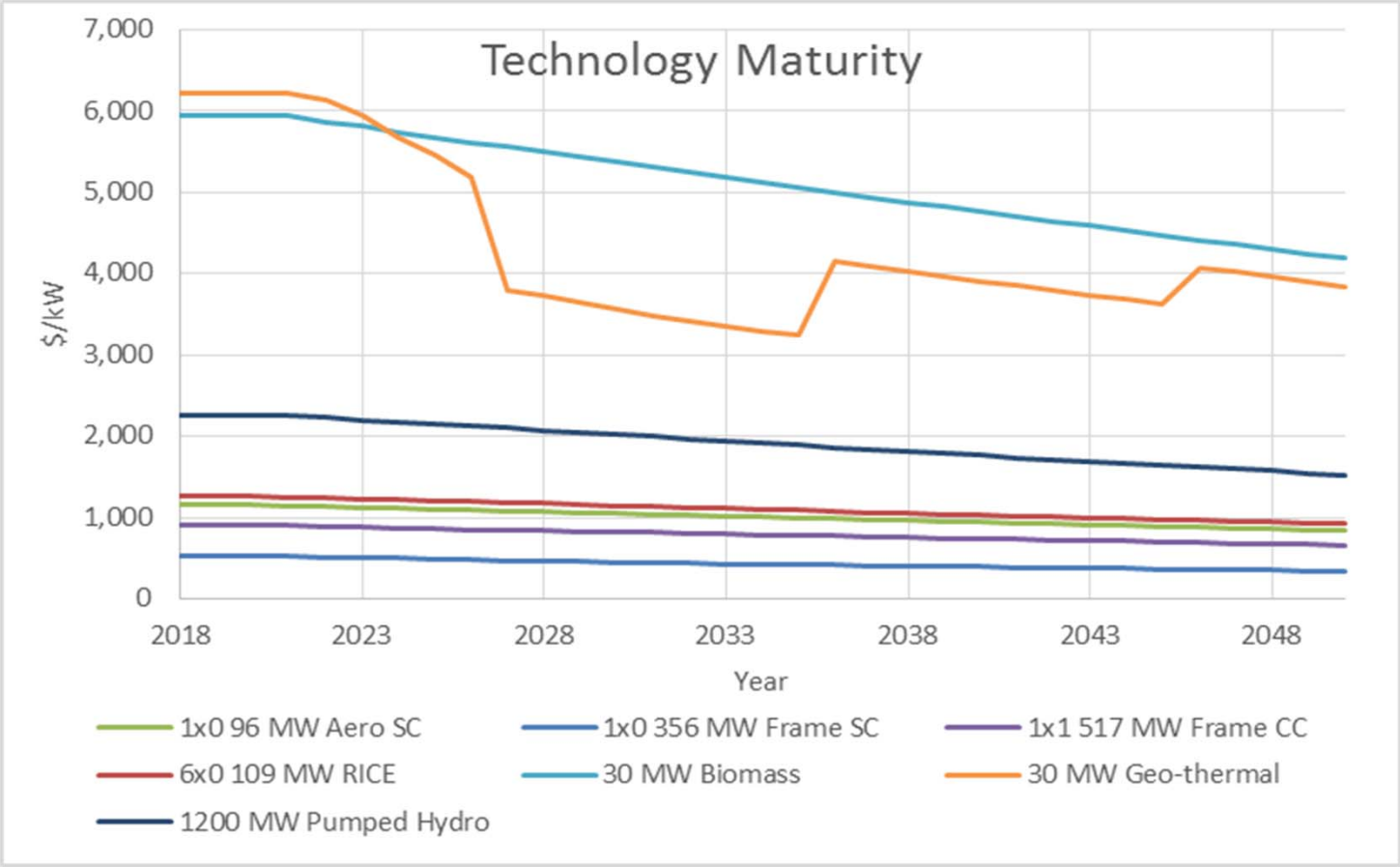
** Cost in 2018$ for a notice to proceed in 2018*

2016 and 2019 IRP Comparison

Overnight capital costs change in 2018$/kW for a 2018 Notice to Proceed



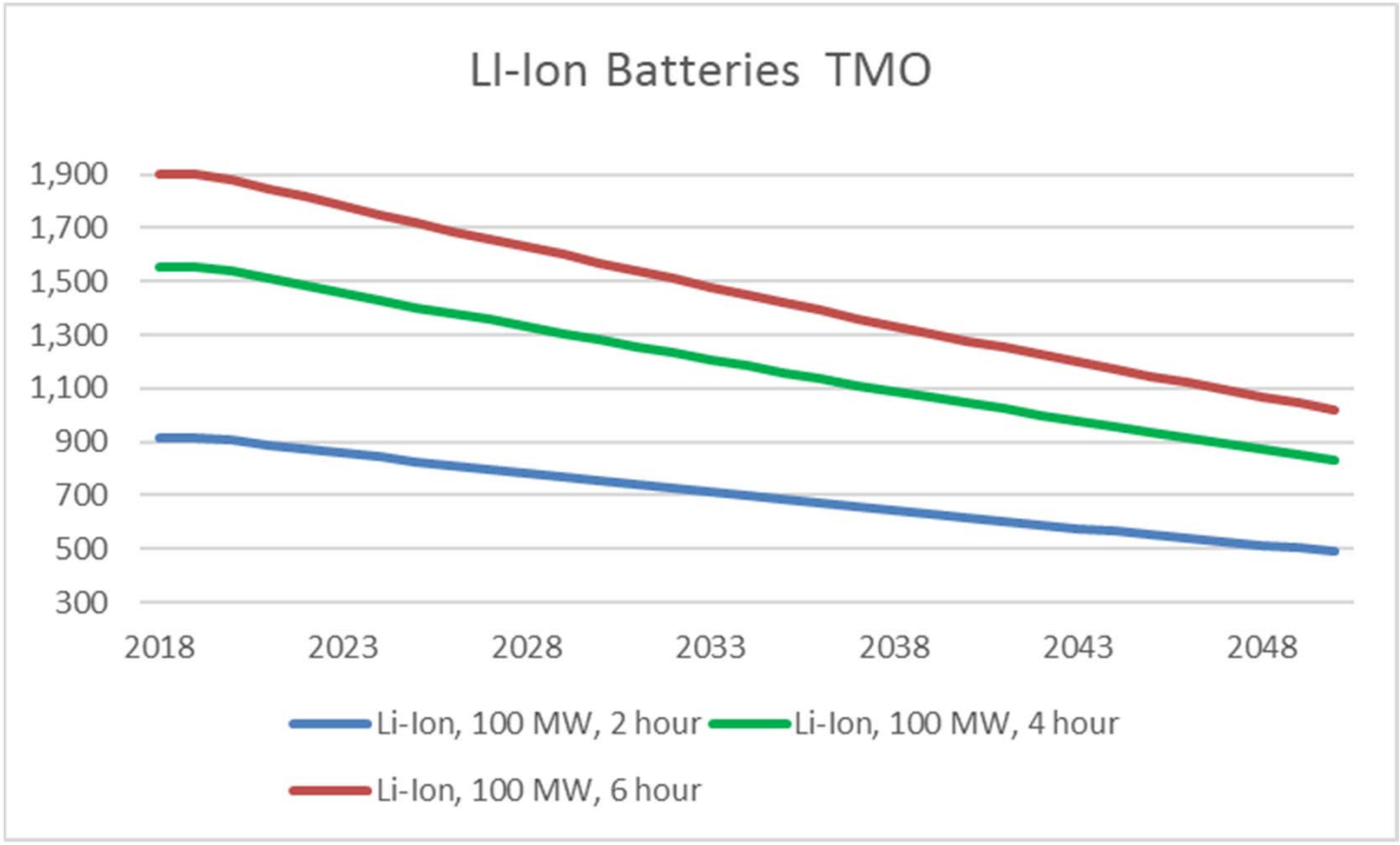
Technical Maturity Outlook



Source: HDR forecast based on the trends of Energy Information Administration's (EIA) 2017 Annual Energy Outlook (AEO)

Technical Maturity Outlook

Li-Ion Batteries TMO in 2018$/kW by Notice to Proceed year



Wrap up

Elaine Hart

Upcoming 2018 Roundtables

Roundtable 18-4
Wednesday, September 26, 2018
(8:00 am - 1:00 pm PST)

2 World Trade Center, Oregon Room
121 SW Salmon St., Portland, OR 97204

AGENDA

- **Draft Portfolios**
- **Draft Scoring Metrics**
- **Supply Side Studies Update**
- **Final Navigant Results**

Roundtable 18-5
Wednesday, October 31, 2018
(8:00 am - 1:00 pm PST)

2 World Trade Center, Skybridge A&B
121 SW Salmon St., Portland, OR 97204

AGENDA

- Load Forecast
- Flexibility Integration
- Need Snapshot
- Portfolio & Scoring Update

Roundtable 18-6
Wednesday, November 28, 2018
(8:00 am - 1:00 pm PST)

2 World Trade Center, Plaza Conference
121 SW Salmon St., Portland, OR 97204

AGENDA

- Flexibility Adequacy & Value
- Portfolio & Scoring Update
- Distribution Resource Planning
- Transmission