Integrated Resource Planning

Roundtable 18-2

May 16, 2018

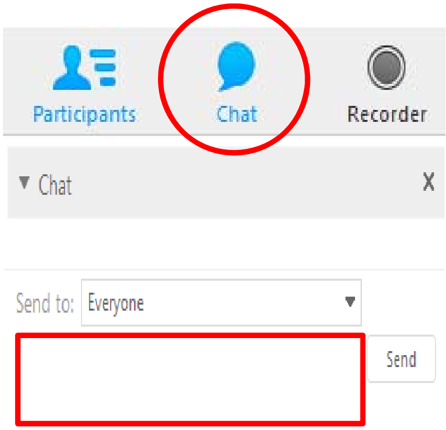
Meeting Logistics

Local Participants:

- 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 Presentation:

- https://www.portlandgeneral.com/irp
- Click on *Integrated Resource Planning*

Today's Roundtable Topics

- ❑ **Welcome / Safety moment**
- ❑ **2019 IRP Overview & Updates**
- ❑ **Load Forecast Workshop**
- ❑ **Futures**
- ❑ **Wholesale Electricity Market**
- ❑ **Portfolio Construction**
- ❑ **Scoring Metrics Workshop**
- ❑ **Decarbonization Study – Role in 2019 IRP**

Incremental steps to improve health and safety

Safety Moment

Did you know?

According to the London Health Institute…

1. Cancer is the world's leading cause of death – by avoiding 1 cigarette a day, cancer risk is reduced by 5% for an average smoker.
2. 20 minute walk twice a week, reduces heart disease risk by 30%.
3. By cutting 2 teaspoons of sugar every week, Risk of Diabetes, the 3rd leading cause of death in the world, can be reduced by 20%.
4. Half hour of extra family time every day increases life expectancy by 36 months

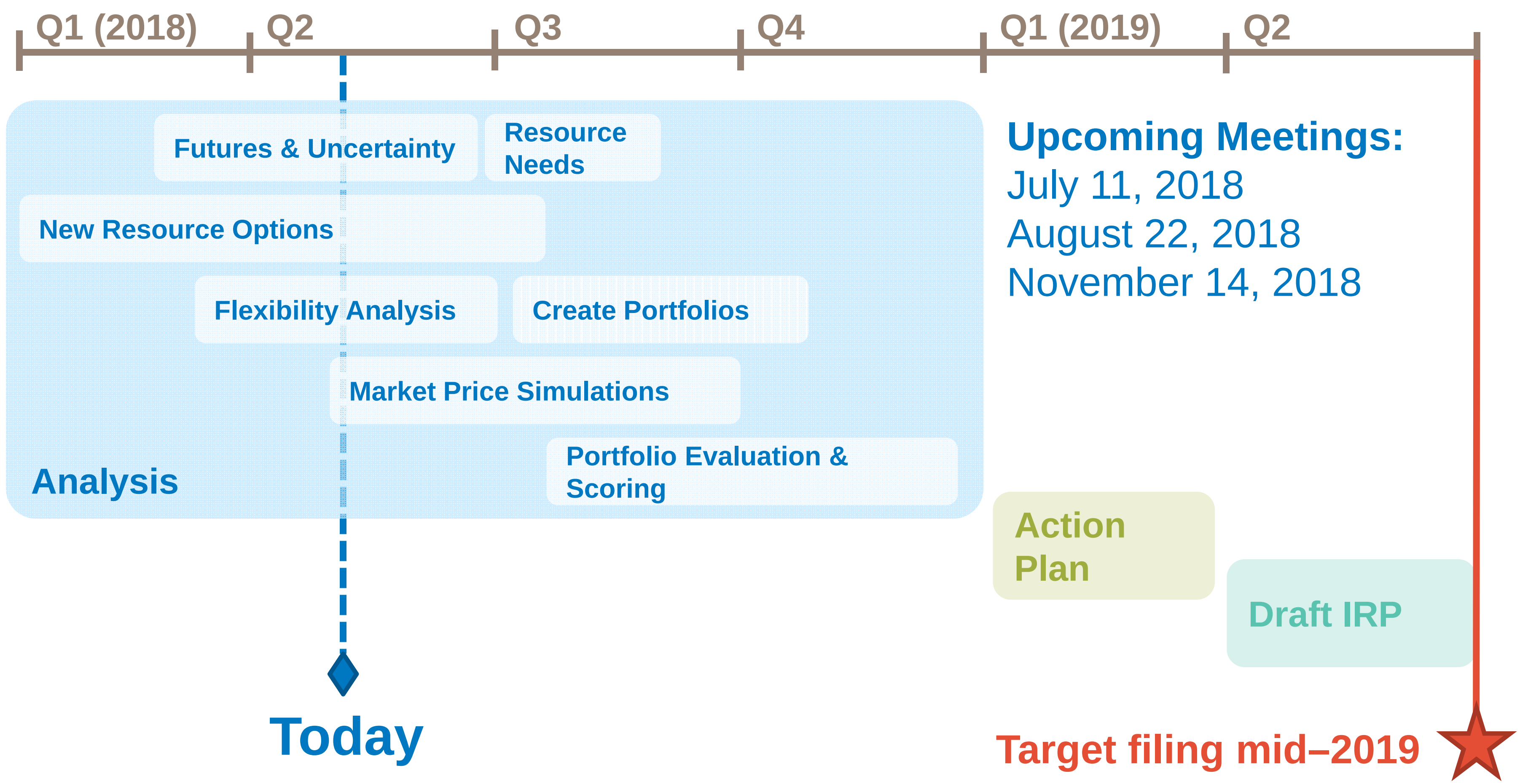
Summary: Incremental changes lead to a healthier life

1. Smoke less
2. Exercise more
3. Eat less sugar
4. Maintain work/life balance

Power of Incrementalism: 0.5% improvement every day more than doubles productivity in less than 3 months

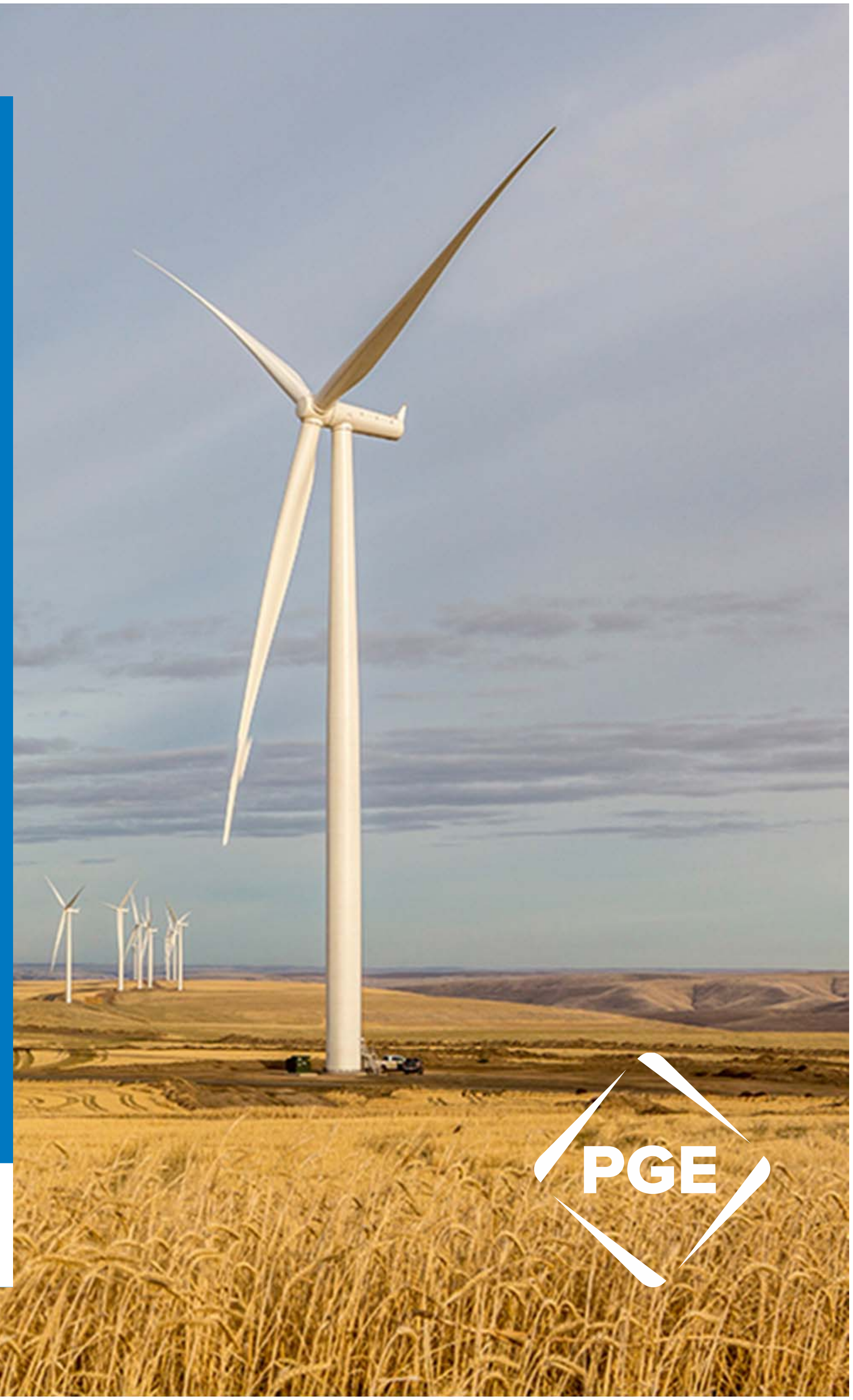
2019 IRP Overview

Progress continues on analysis to support the 2019 IRP



Load Forecast Methodology

Amber Riter / Alison Lucas



Review of February's Technical Workshop

Topics from last workshop:

1. PGE's Energy Deliveries Trends and Drivers
2. Conceptual Overview of Load Forecast Model Structure
3. LC 66 Order Action Items

Stakeholder input received during last workshop:

1. Request to see how PGE's forecasts have performed
2. Request for quantified confidence intervals around central load forecast
3. Suggested ideas for scenario analysis

Agenda for Today's Workshop

1. Load Forecast Trends and Performance
2. Load Forecast Model Study and Updates
3. Load Forecast Preliminary Results
4. Audience Questions and Feedback

Electric Deliveries Trends and Forecast Performance

Electric Deliveries Forecasts

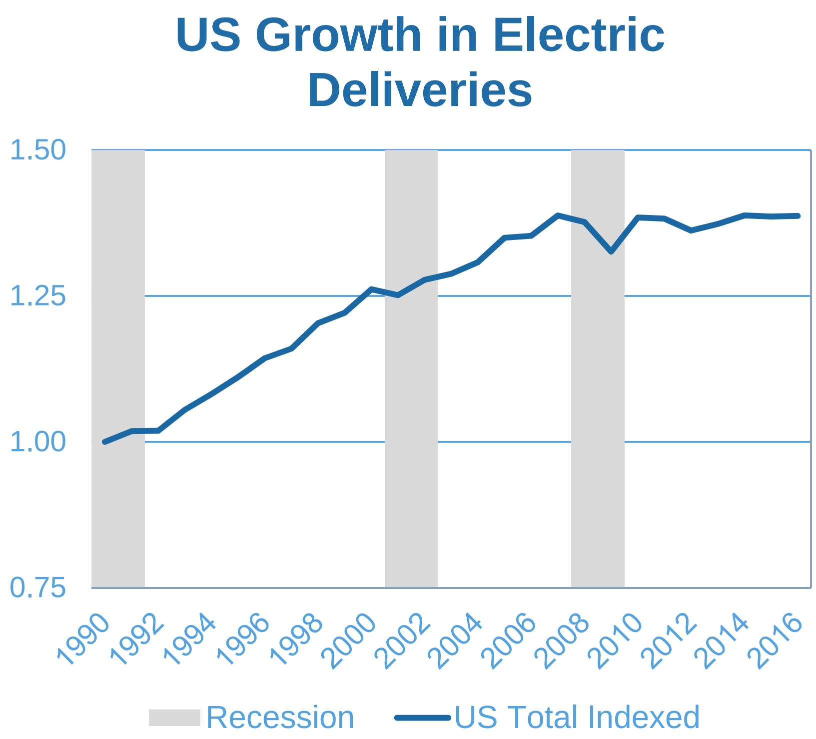
In the last IRP Roundtable we were asked:
"How has PGE's load forecast performed?"

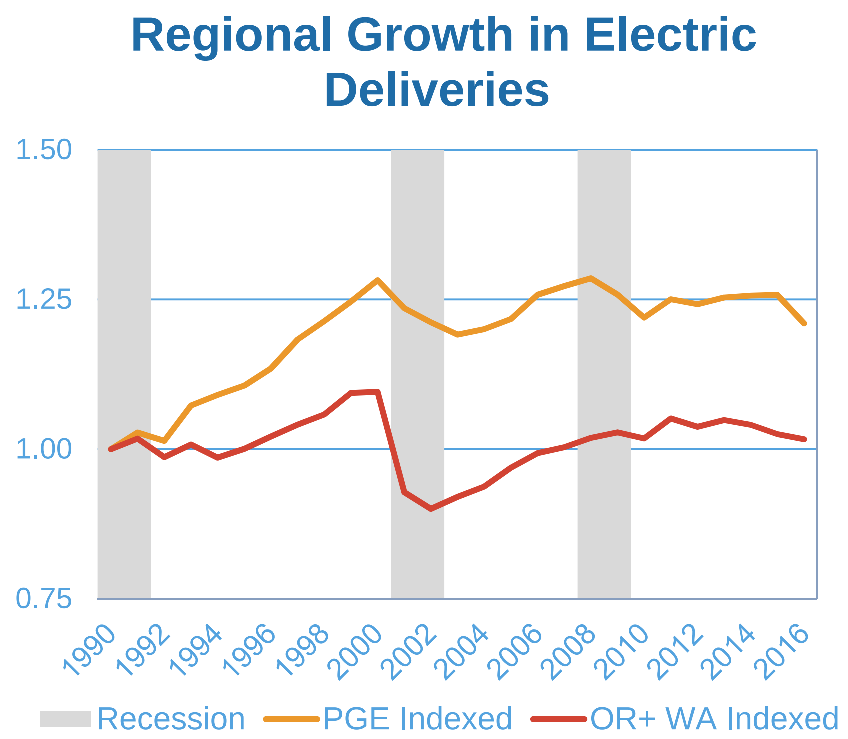
In response, in this section we'll cover:

1. Trends in energy deliveries
2. Recent industry research
3. How we evaluate performance
4. PGE's forecast performance
5. Recent and ongoing model refinements

Electric Deliveries Trends

Growth has slowed both nationally and regionally





Buzzy Topics in Electric Load Forecasting

Recent Load Forecast Research

Two recent studies reviewed load forecasting methods and performance across the industry, with an emphasis on long-term forecasting

Hong, Tao, "Load Forecasting Case Study." Prepared for Eastern Interconnection States' Planning Council and National Association of Regulatory Utility Commissioners, 2015.

- *Surveys the industry's forecasting tools and methodologies*
- *Presents case studies from 3 companies*
- *Makes general recommendations for forecasting processes and uses*

Carvallo, Juan, et al., "Load Forecasting in Electric Utility Integrated Resource Planning." Lawrence Berkley National Laboratory, 2016

- *Research was part of larger study on integrated resource planning*
- *Compares long term forecast methodologies and performance from 12 utilities in the WECC*
- *Shows 11 of 12 utilities over-forecasted over the 2005-2013 time period*

Recent Load Forecast Research

Conclusions and recommendations

*'All forecasts are wrong. While the ability to predict the future with as much accuracy as possible would be ideal, a more realistic expectation, especially for long-term forecasts, is the **insights on the various risks** that may confront a utility.'*

*'Long term load forecasts should be **probabilistic rather than point estimates**.'*

Tao Hong "Load Forecasting Case Study." Prepared for EISPC and NARUC, 2015.

*'…comprehensively addressing **load uncertainty should be prioritized** over developing more complex forecasting techniques'*

Carvallo et al "Load Forecasting in Electric Utility Integrated Resource Planning." LBNL, 2016

Recent Load Forecast Research

PGE's takeaways from the recent research

LBNL's comparison of forecasts across utilities is difficult to interpret without going to the source forecasts from each utility

- For example, PGE's forecast is shown before accounting for energy efficiency savings but is compared to actuals, which reflect energy efficiency savings.
- **Response**: PGE is developing an IRP Load Forecast Appendix to improve documentation and access to the data needed for better comparisons.

Limited conclusions can be drawn over specific time horizons and vintages of forecasts

- The 2008 recession was not accounted for in the utility forecast comparison
- Weather variations were also not considered in the comparison
  - *Both reports recommend additional analysis of uncertainty*
- **Response:** PGE is developing confidence intervals and approaches to address various sources of uncertainty.

Forecast Performance

PGE evaluates forecast performance several ways

Within the Model Development Phase

- Model statistics
- Out-of-sample testing

Variance Analysis

- Actual and normalized variance

Benchmarking

- Comparison to industry standard

Forecast Performance

PGE's year-ahead forecasts have performed well

PGE's Year-Ahead Forecast Variance Compared to Itron's Annual Utility Benchmark Survey:

	2011		2012		2013		2014		2015		2016	
	Survey	**PGE**	**Survey**	**PGE**	**Survey**	**PGE**	**Survey**	**PGE**	**Survey**	**PGE**	**Survey**	**PGE**
Residential	1.7%	0.5%	1.5%	0.0%	1.7%	0.3%	1.5%	1.2%	1.9%	1.5%	1.7%	0.1%
Commercial	1.7%	0.4%	2.0%	1.4%	2.1%	1.9%	1.3%	0.6%	1.6%	0.8%	1.8%	2.0%
Industrial	3.2%	0.7%	3.2%	4.5%	4.4%	8.8%	3.4%	0.5%	3.0%	2.8%	3.3%	2.7%
System	NA	0.5%	1.6%	1.5%	1.5%	2.5%	1.3%	0.6%	1.9%	1.5%	1.6%	1.4%

* Table shows mean absolute percentage error (MAPE)

PGE has <u>outperformed industry peers</u> in 4 of the last 5 years of this survey.

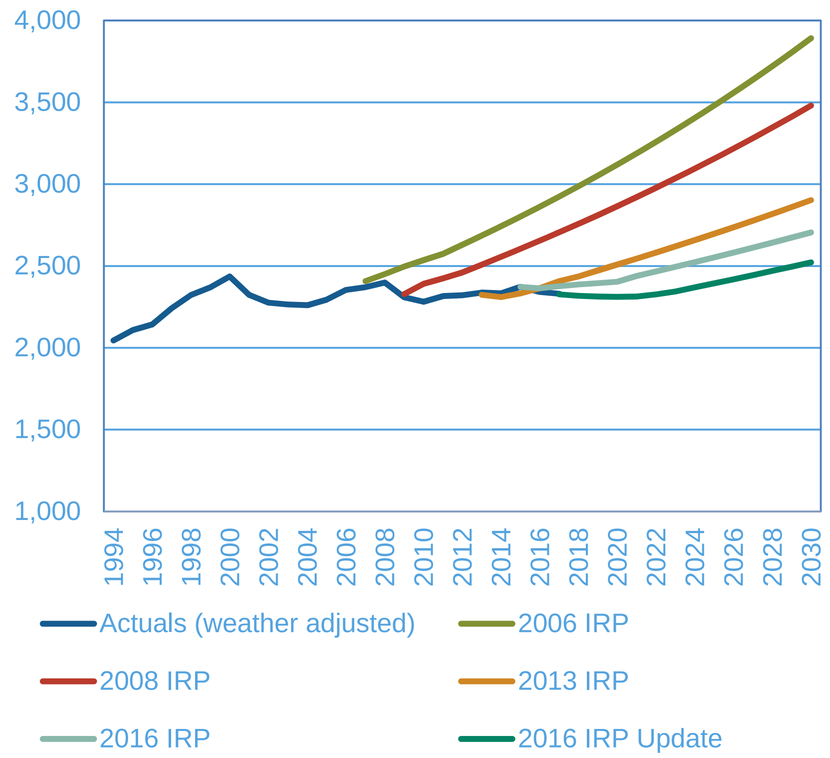
PGE's load forecast variance falls positive some years, negative in others (although the table above is in absolute values). This is a sign that PGE's models are not exhibiting continuous underlying bias in one direction. The goal is for variances to average to 0 over time.

Forecast Performance

Long-term forecasting brings particular challenges. For example, since the early 2000s, major impacts to load have included: energy crisis of 2000-2001, Great Recession and slow recovery, availability and penetration of energy efficient technologies, closures of large customers and emerging end uses and technology.

PGE continues to refine its models and we'll discuss some of these updates in following slides.

PGE Actual Energy Deliveries and IRP Forecasts

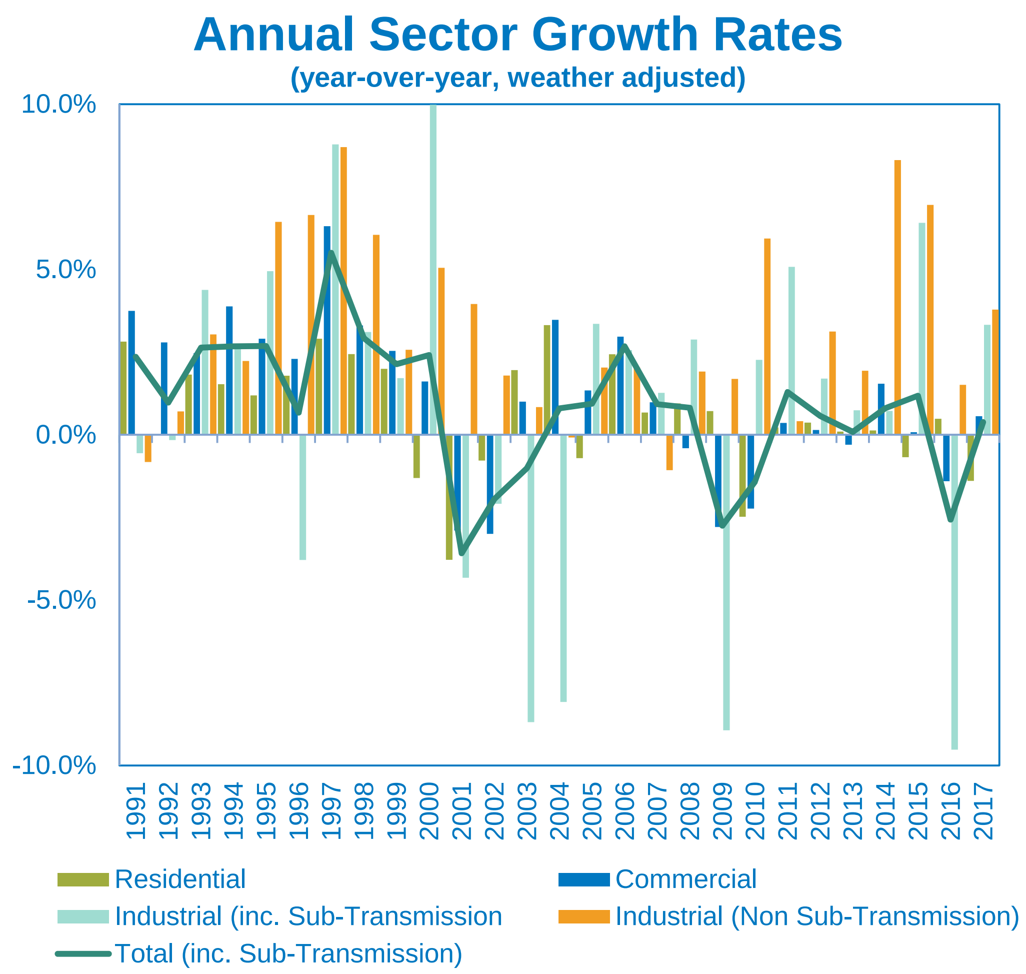


Sector Growth Rates

Voltage Class Deliveries Trends

Residential and commercial energy deliveries growth rates have slowed.

The industrial sector has always been volatile, yet changes in the mix of industries in PGE service area have increased (traditional manufacturing including metals and paper decline and high tech manufacturing and data centers have grown).



Model refinements

PGE is continually assessing its models and forecast performance. Actions in response to trends and modeling challenges include:

For 2019 IRP

- Probabilistic forecasts which emphasize approaches to address uncertainty
- Reassess long term models

Within the Last 3 Years

(Included in 2016 IRP and 2016 IRP Update)

Short Term Model:

- Reassess approach to large customer forecast with respect to risk
- Sample selection
- Drivers review

Long Term Model:

- Develop econometric model instead of using averaged growth rates to tie to macro forecast

Load Forecast Study and Updates

Load forecast scenarios & uncertainty

The IRP considers load scenarios and uncertainty in different stages of the IRP process. Load Forecasting analysis considers those specifically related to the regression models and macroeconomic driver variables.

Weather Volatility

RECAP

Future Uses of Electricity

DER Study (including EV's)

ETO Savings Scenarios

Macro Economic

Model Statistics

Load Forecasting Analysis

Probabilistic forecasts

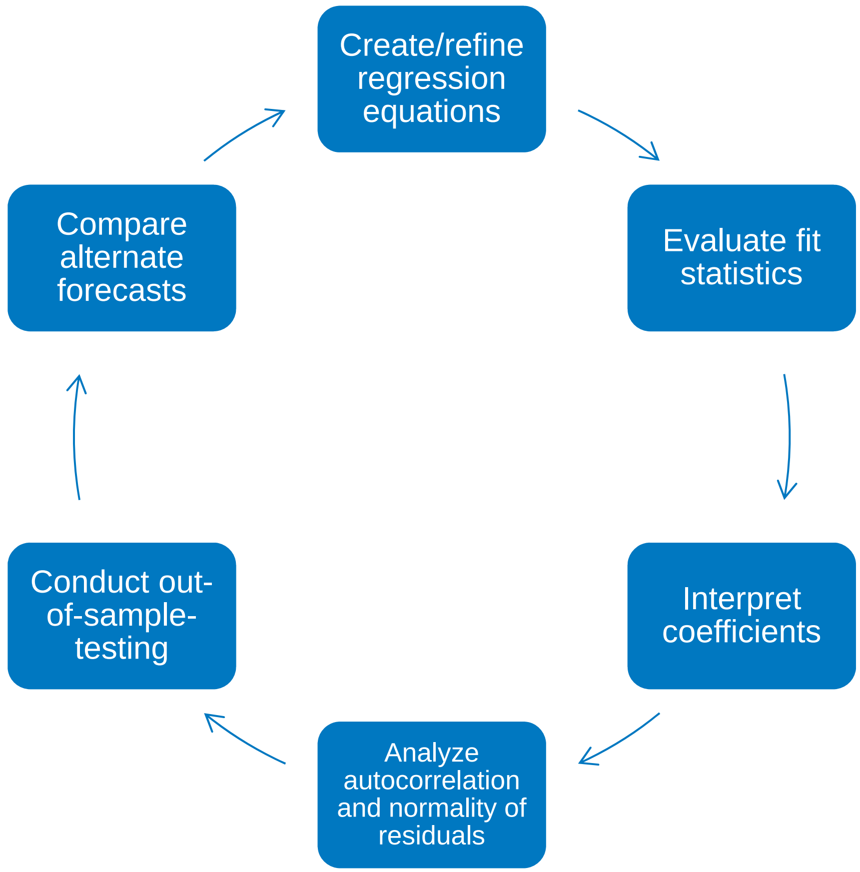
PGE will run Monte Carlo simulations, combining sources of uncertainty to create confidence bands around the Base Case forecast

Uncertainty category	Definition
Model uncertainty	The standard error of the regression. By bootstrapping the residuals, the model may show skewed confidence bands, rather than a normal distribution.
Coefficient uncertainty	The standard error associated with the inclusion of the driver in the regression. During simulation runs, coefficients are randomly varied along with residuals.
Forecast uncertainty of the endogenous (driver) variable	Uncertainty in the forecast of the driver. Applied in the model as a constant value or time series.
Optional pragmatic uncertainty	Broad adjustment to uncertainty level.

Forecast process

Development of the models' regression equations

1. Conduct analysis of time series data and determine if any transformations are warranted
2. Plot data against possible drivers, looking for obvious correlations, patterns, and trends
3. Then →



Forecast Drivers

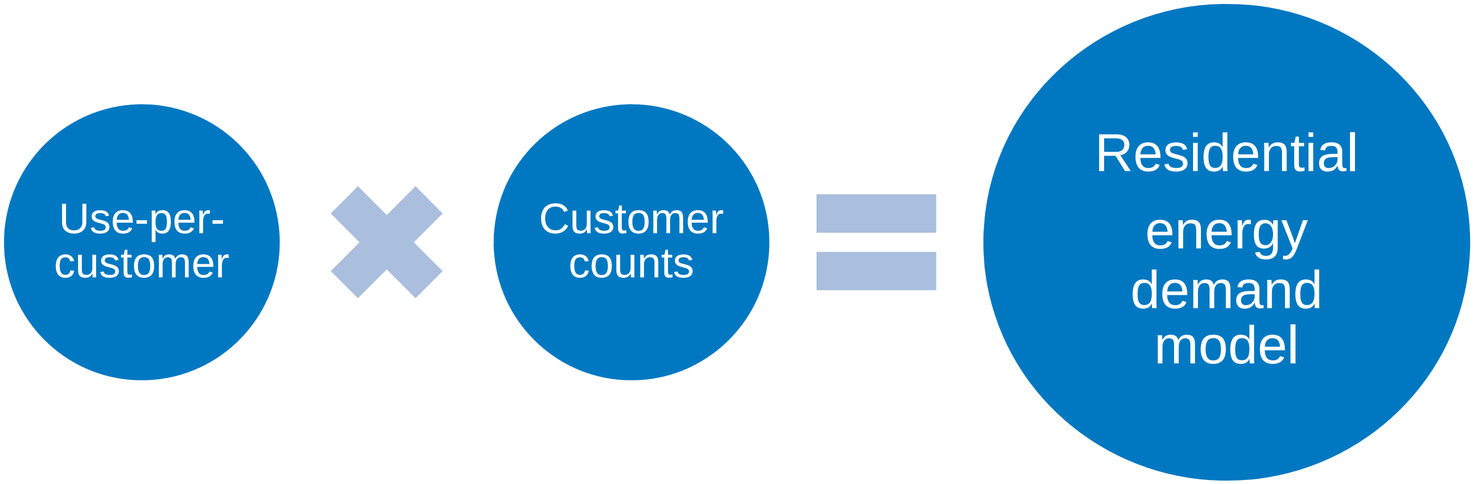
Partial list of drivers considered for the long-term forecast

Forecast sector	Partial list of drivers considered
Residential	• Employment • Population (Oregon, county) • Personal income • Weather • Energy Trust energy efficiency measures
Commercial	• Employment • Population (Oregon, county) • Weather • Energy Trust energy efficiency measures
Industrial	• US GDP • US Industrial Production Index • Oregon GDP • Employment • Energy Trust energy efficiency measures

Residential forecast structure

NEW: Adoption of a use-per-customer (UPC) model in the long term model

The separation of use-per-customer and customer counts allows us to isolate competing trends: decreasing average usage and an increasing customer base



Load Forecast Preliminary Results

Preliminary Results

A few items will change between now and the final June 2018 load forecast. Updates include:

1. Recent months of historical demand data
2. Update trended normal weather assumption with most recent weather data
3. Update economic forecasts from Oregon Office of Economic Analysis
4. Incorporate feedback received today from IRP Roundtable

The forecast will be finalized at the end of May.

June forecast results will be presented at the next workshop (date TBD).

Base Case Assumptions

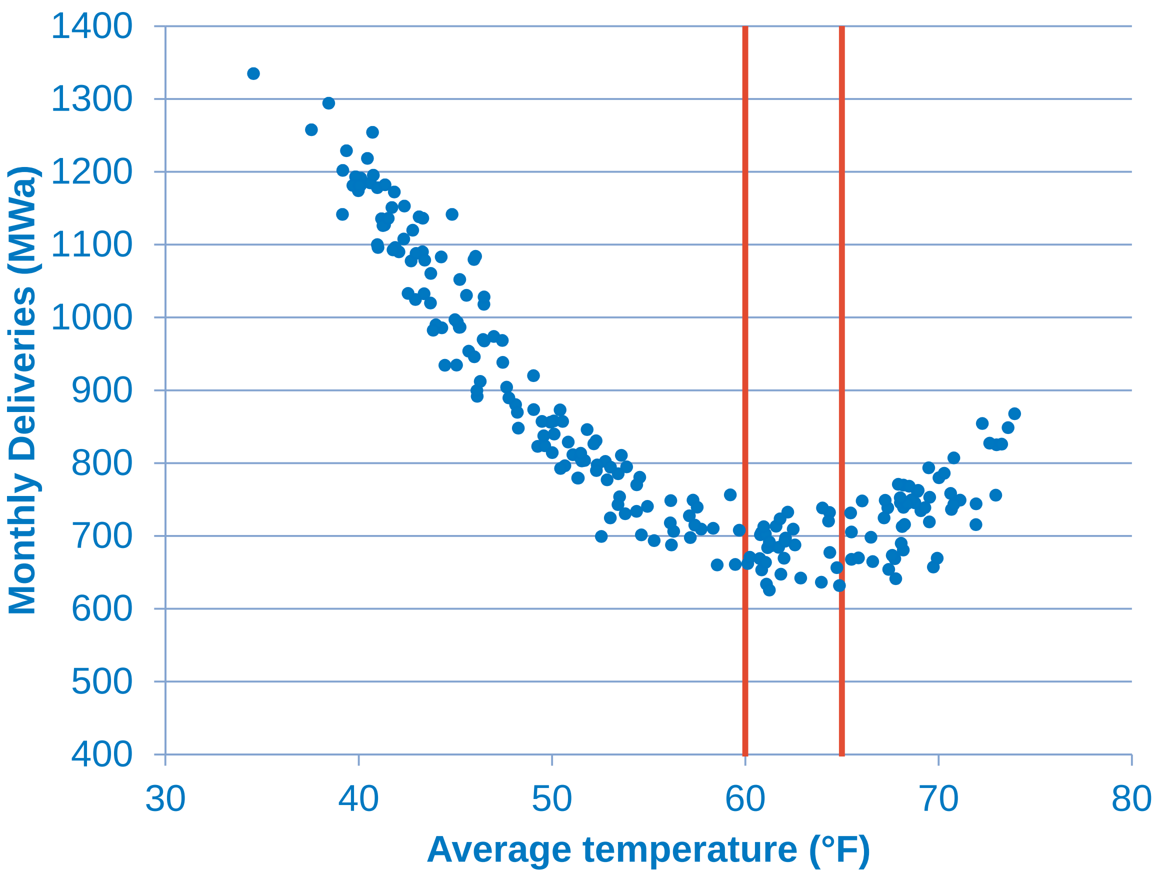
Inherent assumptions in PGE's Base Case models

- PGE's Base Case forecast models capture trends observed over a historical period in order to make inferences for the future.
- The models assume no dramatic departure from the trends in historical customer behavior. For example, no new government policies to influence demand, notable change to nominal electricity pricing, or increase in technological innovation or funding that would affect currently observed rates of efficiency gains and appliance saturation are assumed.
- Scenario analysis conducted in other stages of the IRP are used to represent the sensitivity of the Base Case forecast to specific changes (e.g., higher levels of programmatic energy efficiency, EV penetration, rooftop PV adoption).

Residential model

<u>Weather Dependence</u>

Residential energy usage increases as average temperature fall below 60˚F and when average temperature is above 65˚F

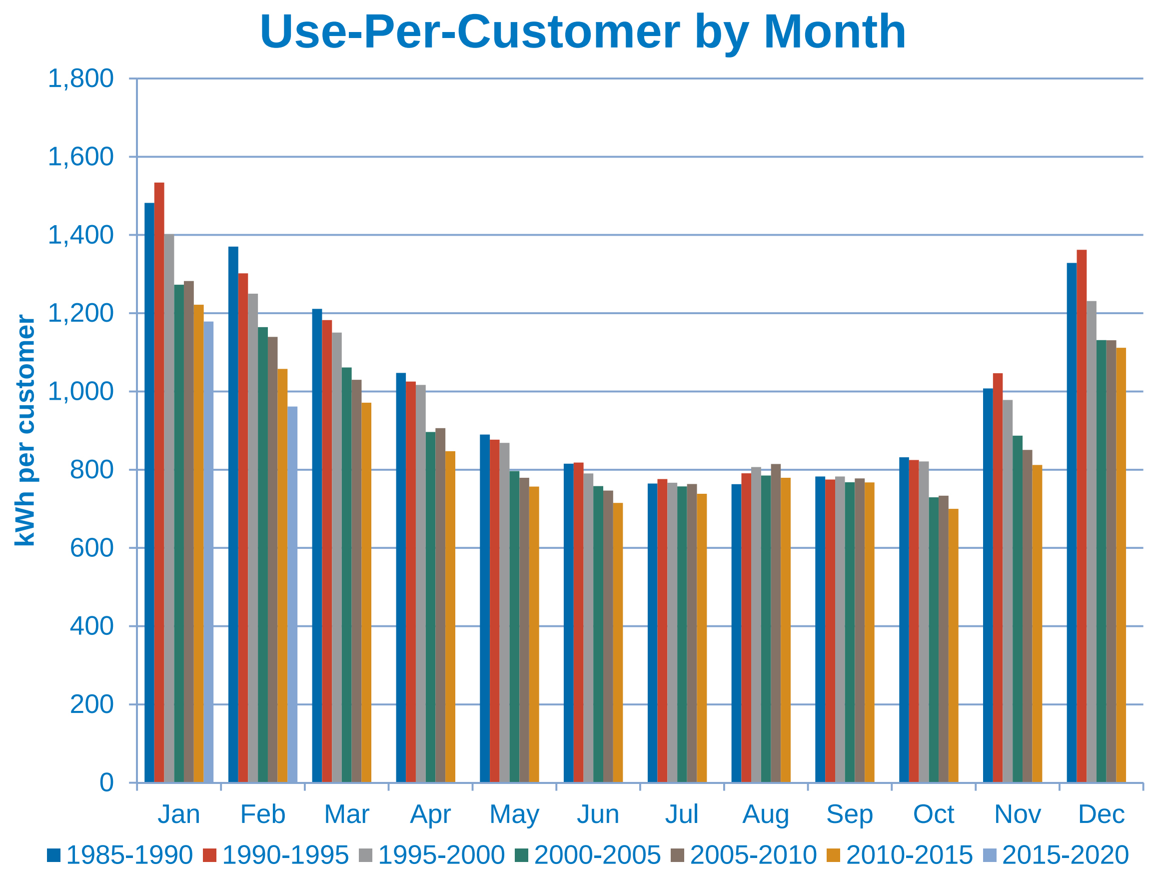


Residential model

Use-per-customer has been declining in winter months but stable or increasing in summer months.

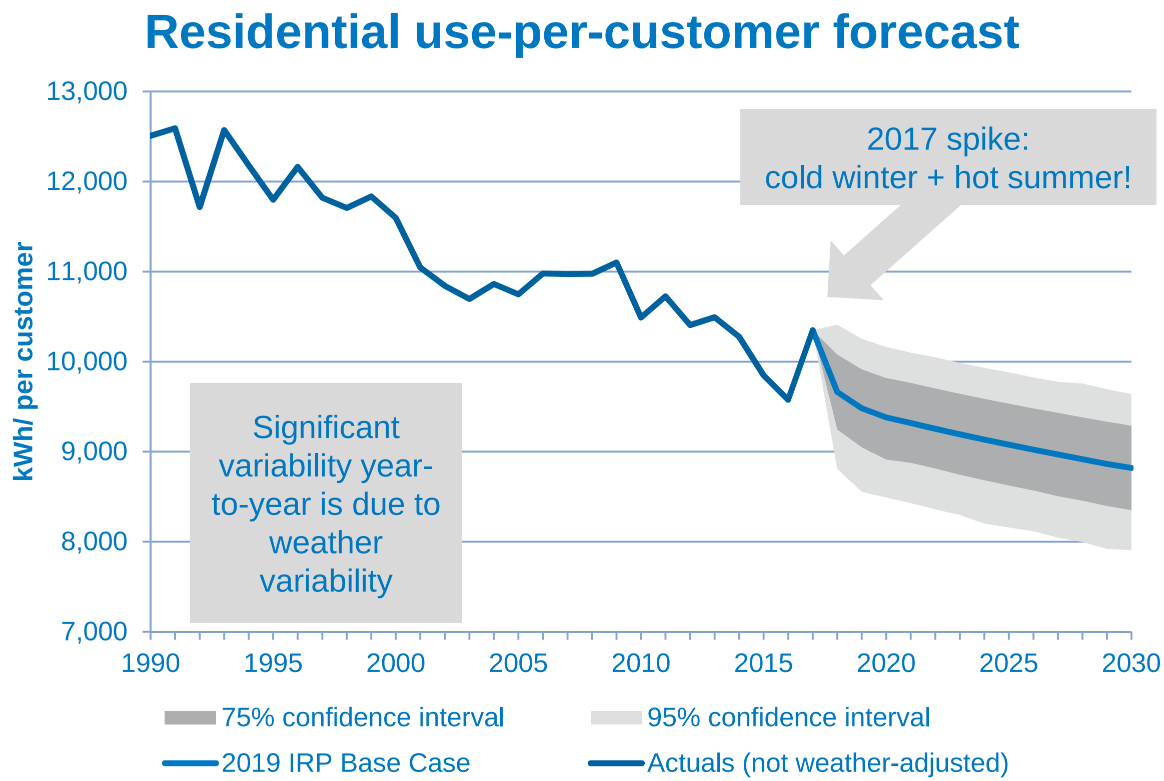
Some factors causing these trends:

- gas conversion
- energy efficiency
- codes and standards
- increased A/C saturation



Residential model

- Model drivers: HDD60, CDD65, monthly trend variables, monthly dummies
- Estimation period: 1990 – 2018
- Data frequency: monthly
- ARIMA (1, 0, 0)
- Average annual growth rate, 2023 – 2030 = -0.6%

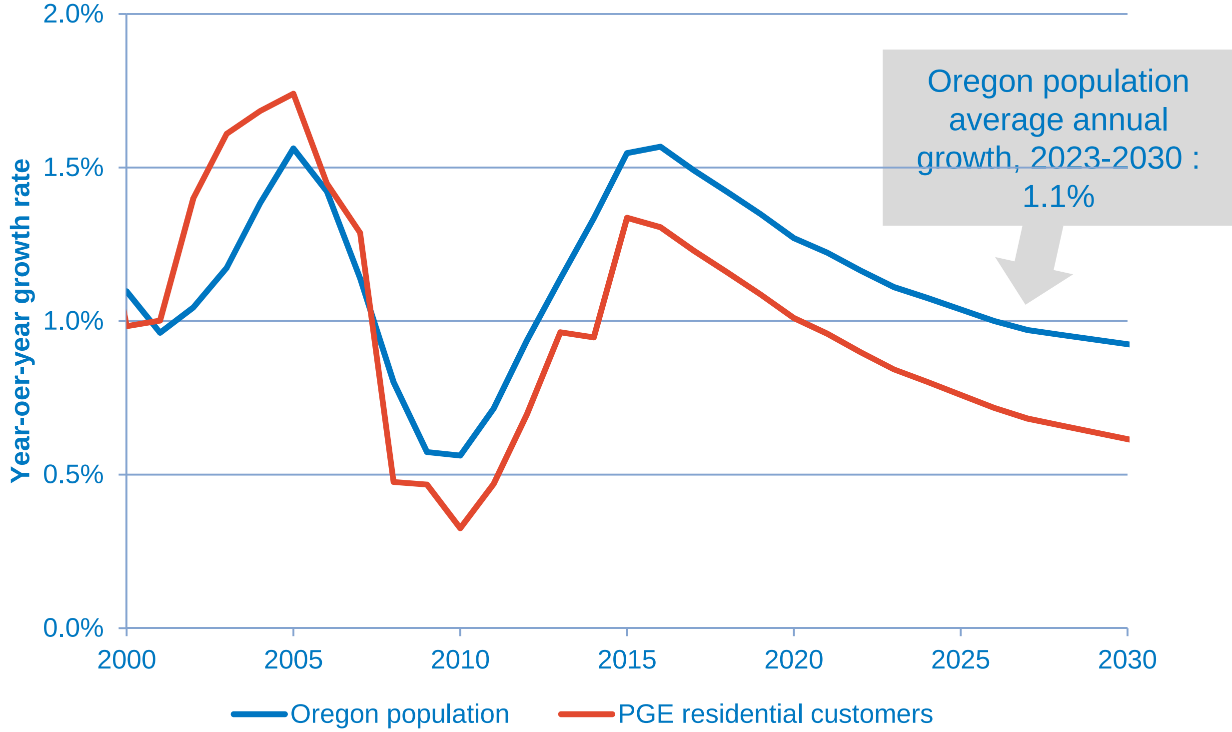


With the Base Case's "status quo" assumption, PGE anticipates the downward trend in use-per-customer will begin to level off in the next decade as the market reaches a saturation point for the current drivers of the decline.

Residential model

- Model driver: Oregon population
- Estimation period: 1990 – 2018
- Data frequency: annual
- ARIMA (0, 2, 0)
- Average annual growth rate, 2023 – 2030 = 0.8%

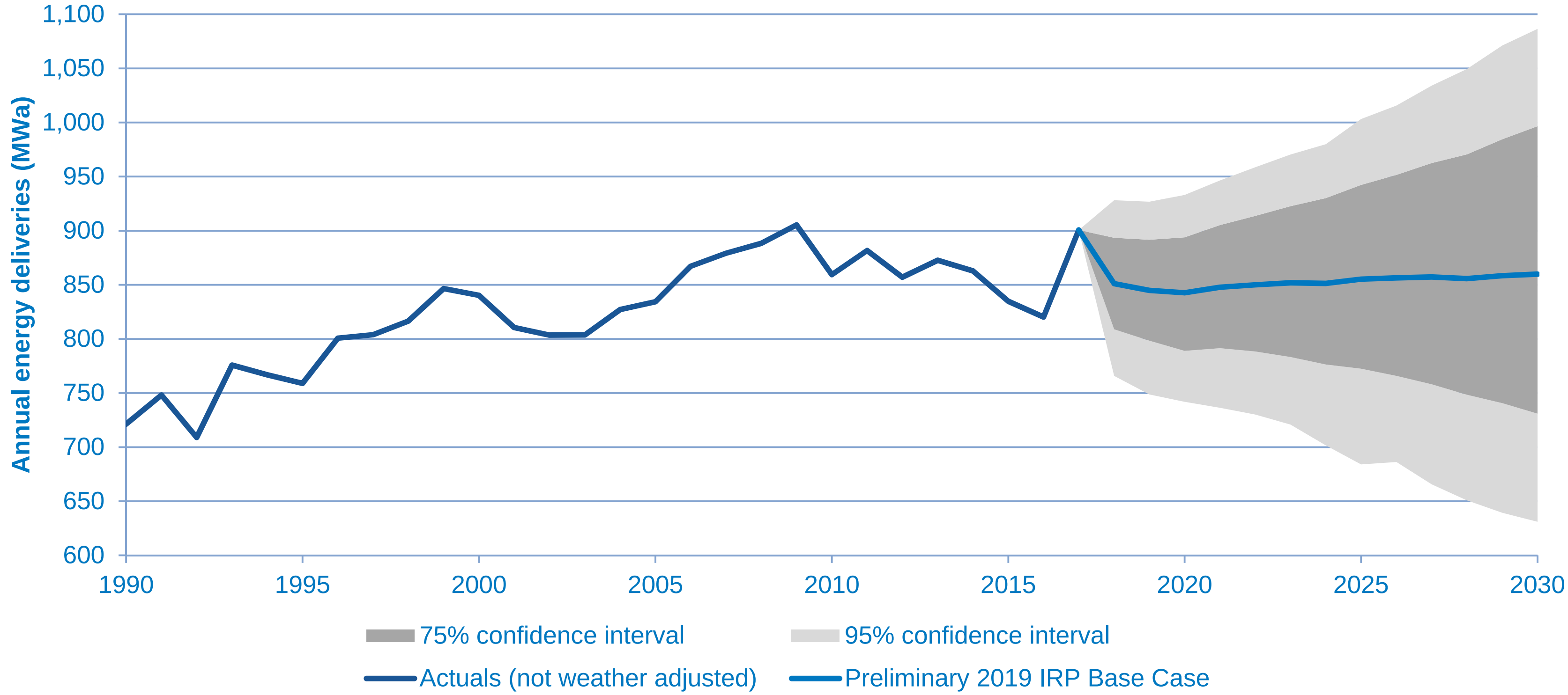
Population, residential customer growth



PGE's residential customer growth roughly follows Oregon population growth.

Residential model

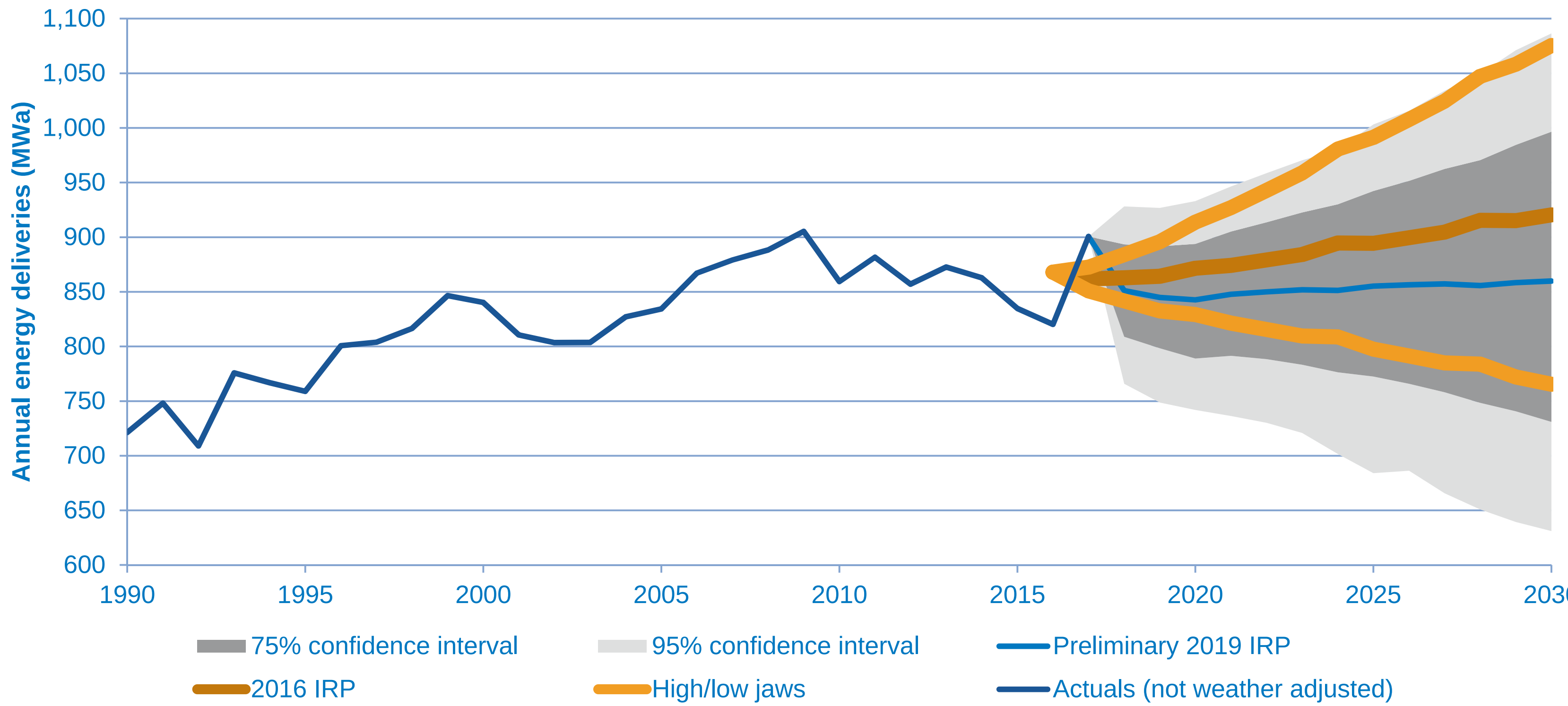
Base Case forecast and confidence intervals



Residential model

Comparison with 2016 IRP forecast and jaws

Average annual growth rates, 2023-2030
2016 IRP: 0.6%
Prelim. 2019 IRP: 0.2%



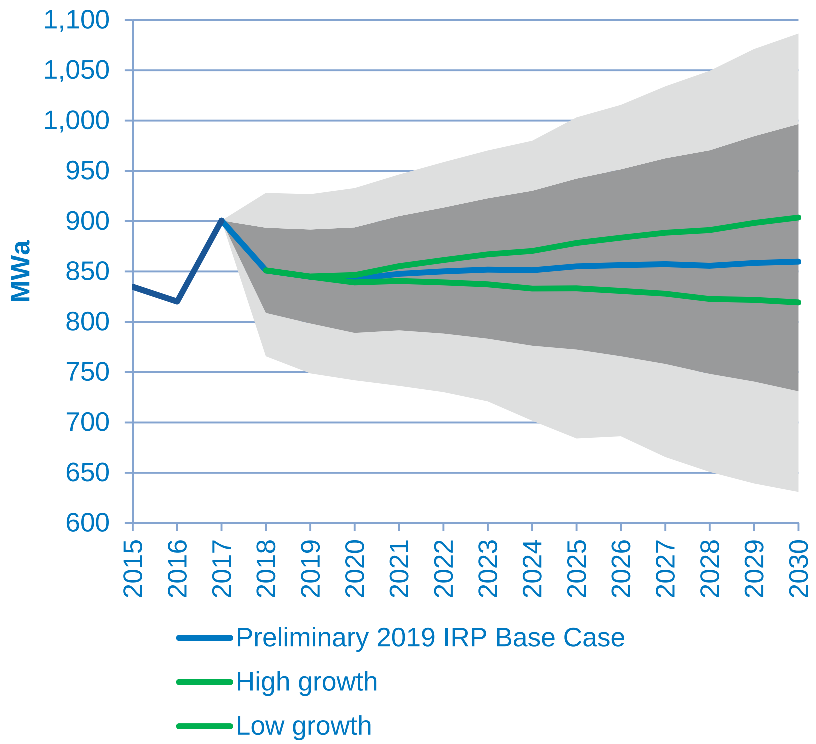
Residential model

Forecast and high/low economic growth scenarios

Average annual growth rates, 2023 – 2030		
	Population	**Residential deliveries**
Base case	1.0%	0.2%
High growth	1.5%	0.6%
Low growth	0.5%	-0.3%

PGE used the Oregon Office of Economic Analysis's population forecast to create high and low scenarios, which are 0.5% above and below that base forecast.

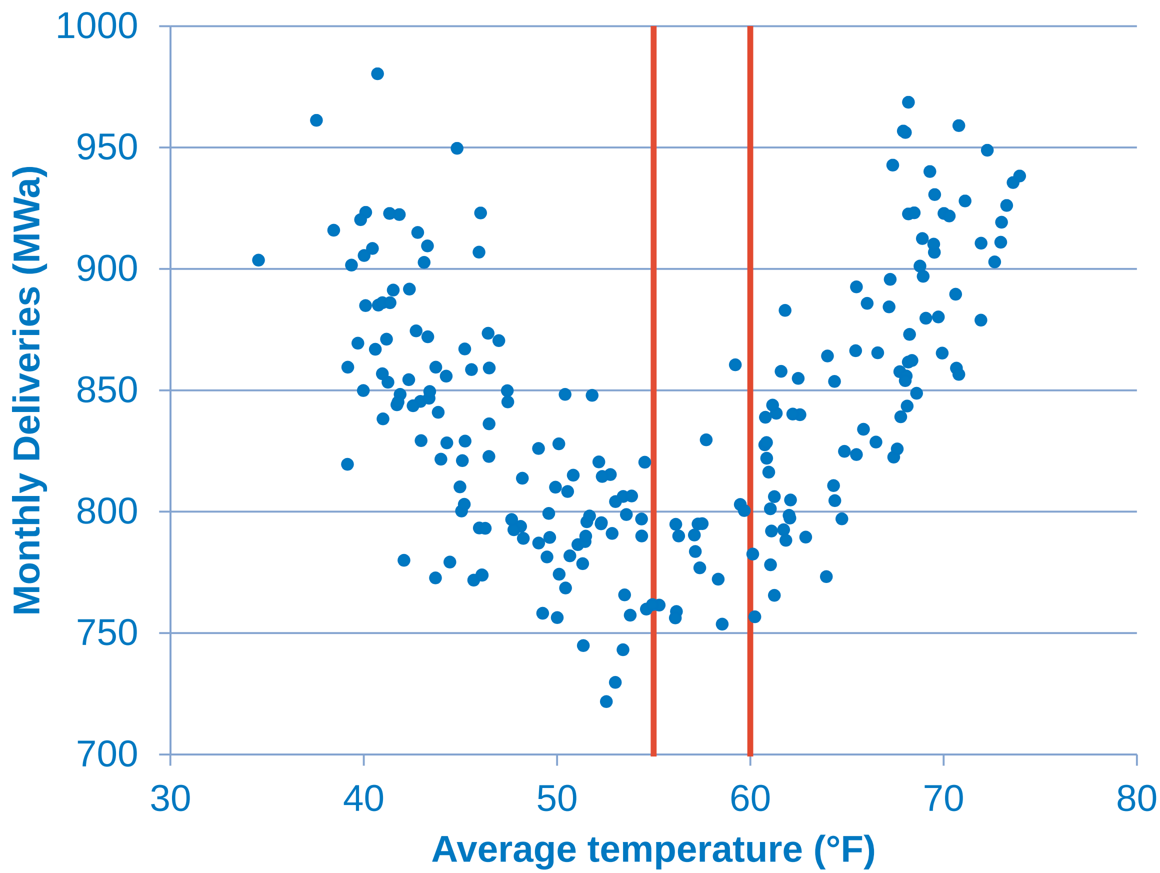
Between 1990 and 2016, Oregon's annual population growth has ranged from 0.6% to 2.3% and averaged 1.4%.



Commercial model

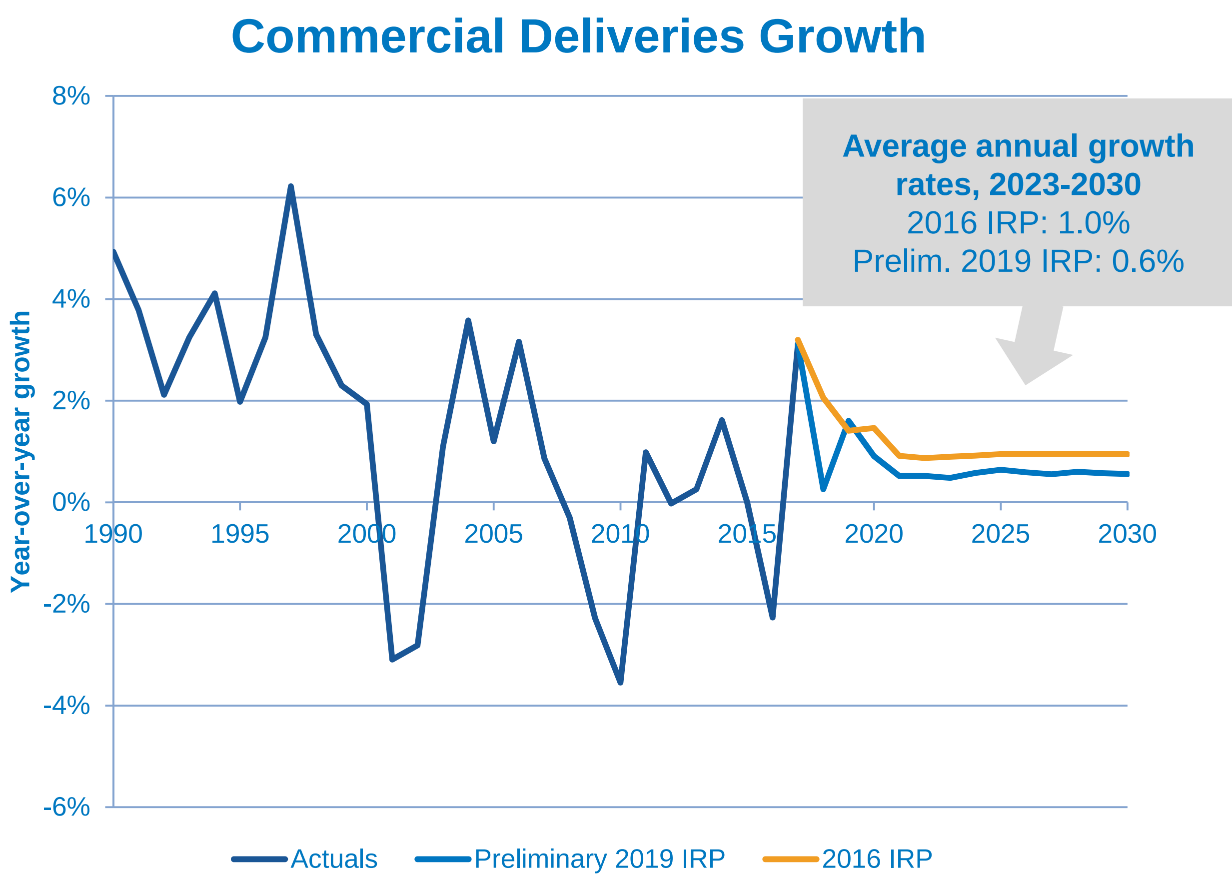
Weather Dependence

Commercial energy usage increases as average temperature fall below 55˚F and when average temperature is above 65˚F



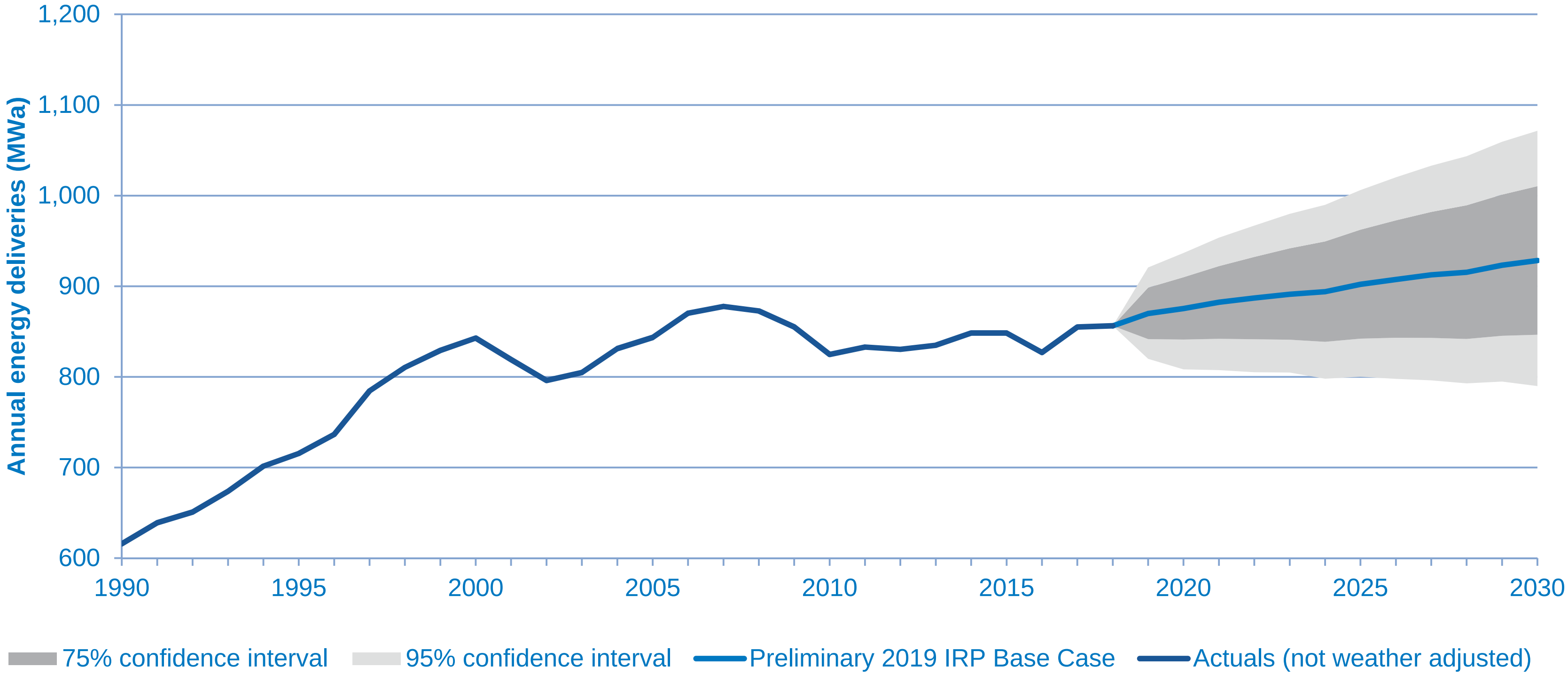
Commercial model

- **Model drivers: Weather, Oregon non-farm employment, monthly dummies**
- **Estimation period: 1990 – 2018**
- **Data frequency: monthly**
- **ARIMA(0,1,1)(0,0,1)$_{12}$**
- **Average annual growth rate, 2023 – 2030 =0.6%**



Commercial model

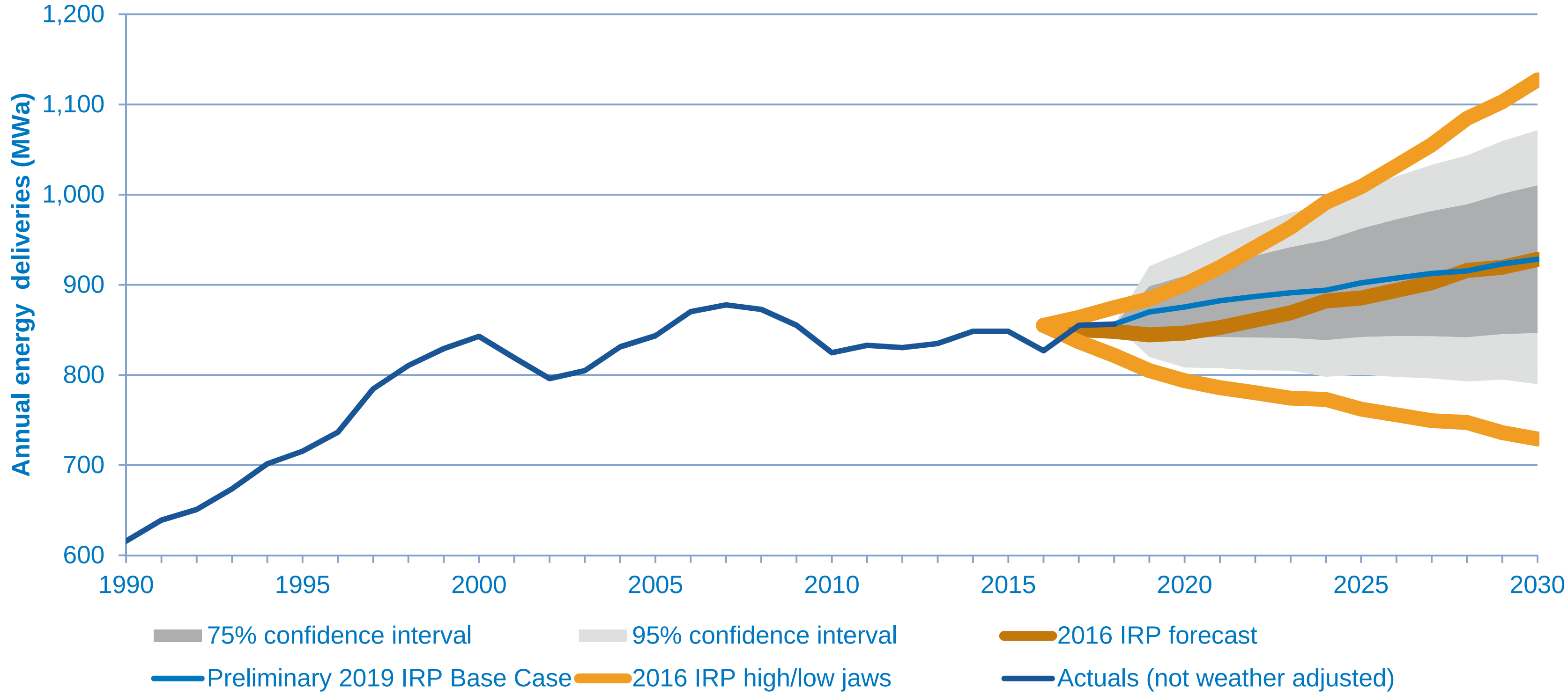
Base Case forecast and confidence intervals



Commercial forecast

Comparison with 2016 IRP forecast and jaws

Average annual growth rates, 2023-2030
2016 IRP: 0.6%
Prelim. 2019 IRP: 0.2%



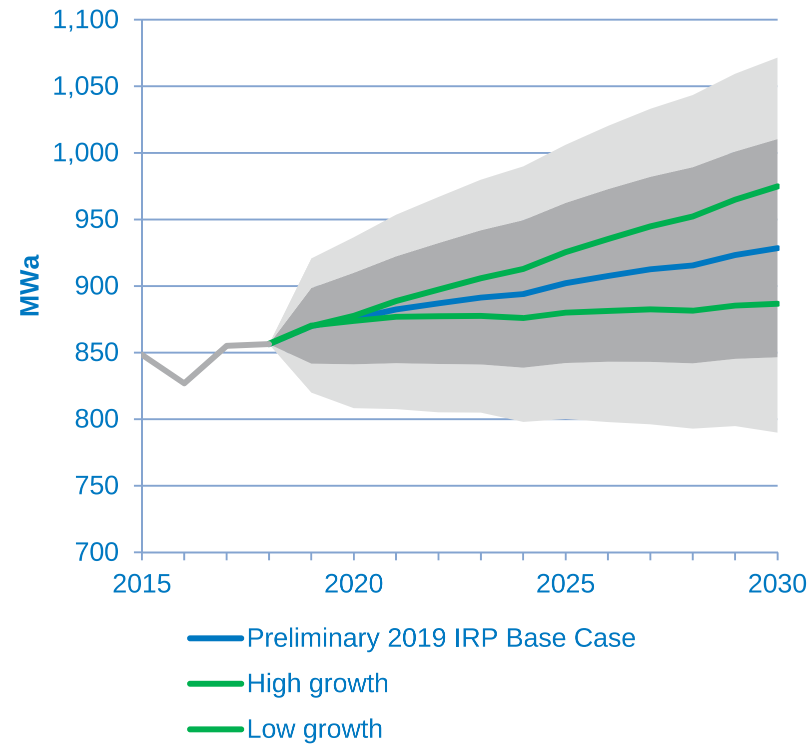
Commercial model

Forecast and high/low economic growth scenarios

Average annual growth rates, 2023 – 2030		
	Employment	**Commercial deliveries**
Base case	0.6%	0.6%
High growth	1.2%	1.1%
Low growth	0.0%	0.1%

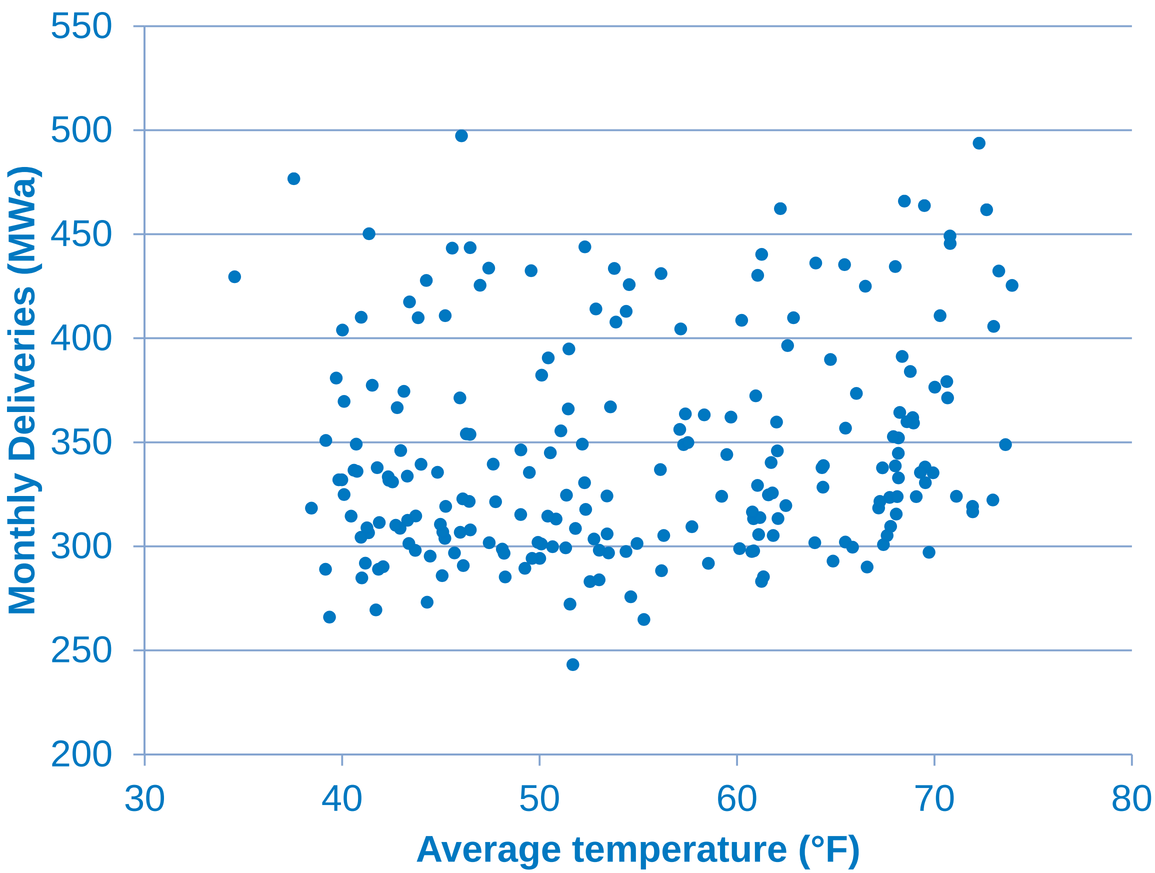
PGE used the Oregon Office of Economic Analysis's state total non-farm employment forecast to create high and low scenarios which are 0.6% above and below that base forecast.

Between 1990 and 2016, Oregon's annual employment growth has ranged from -6.2% to 4.2% and averaged 1.5%.



Industrial model

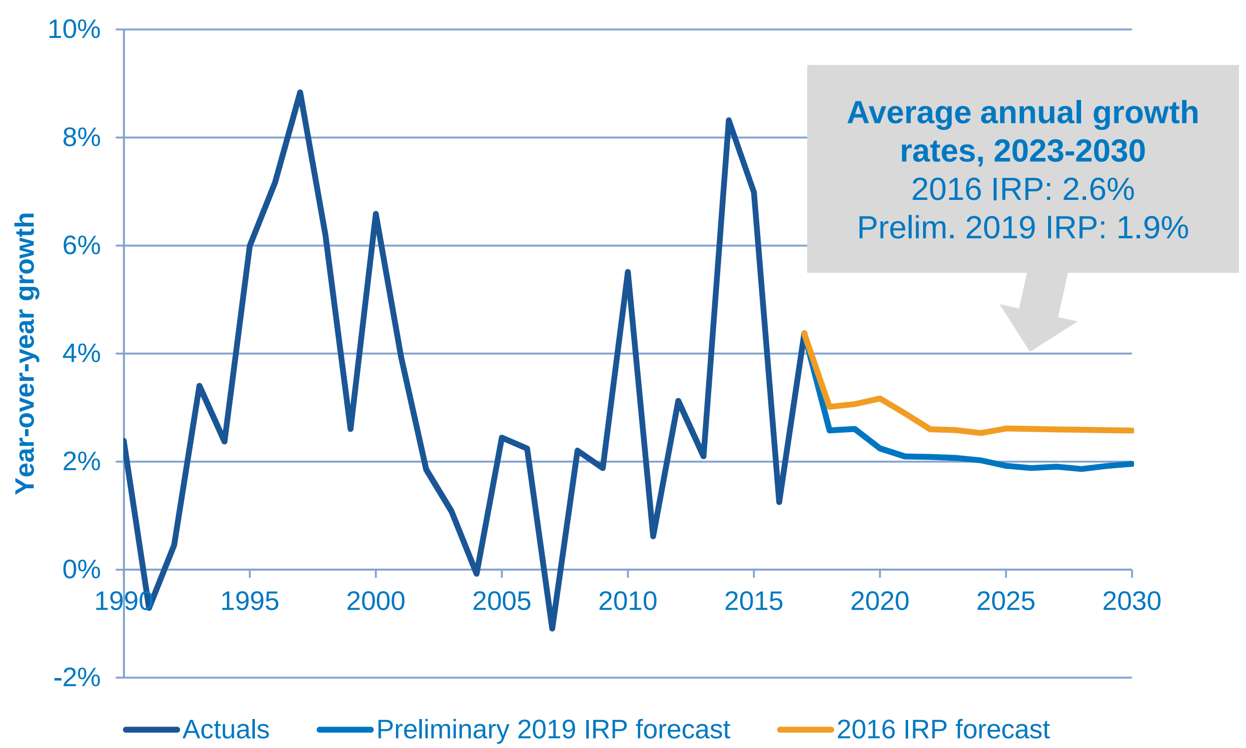
Energy deliveries to the industrial class have no meaningful weather dependence



Industrial model

- Model drivers: US GDP, monthly dummies
- Estimation period: 1990 – 2018
- Data frequency: monthly
- ARIMA (1, 1, 1)
- Average annual growth rate, 2023 – 2030 = 1.9%

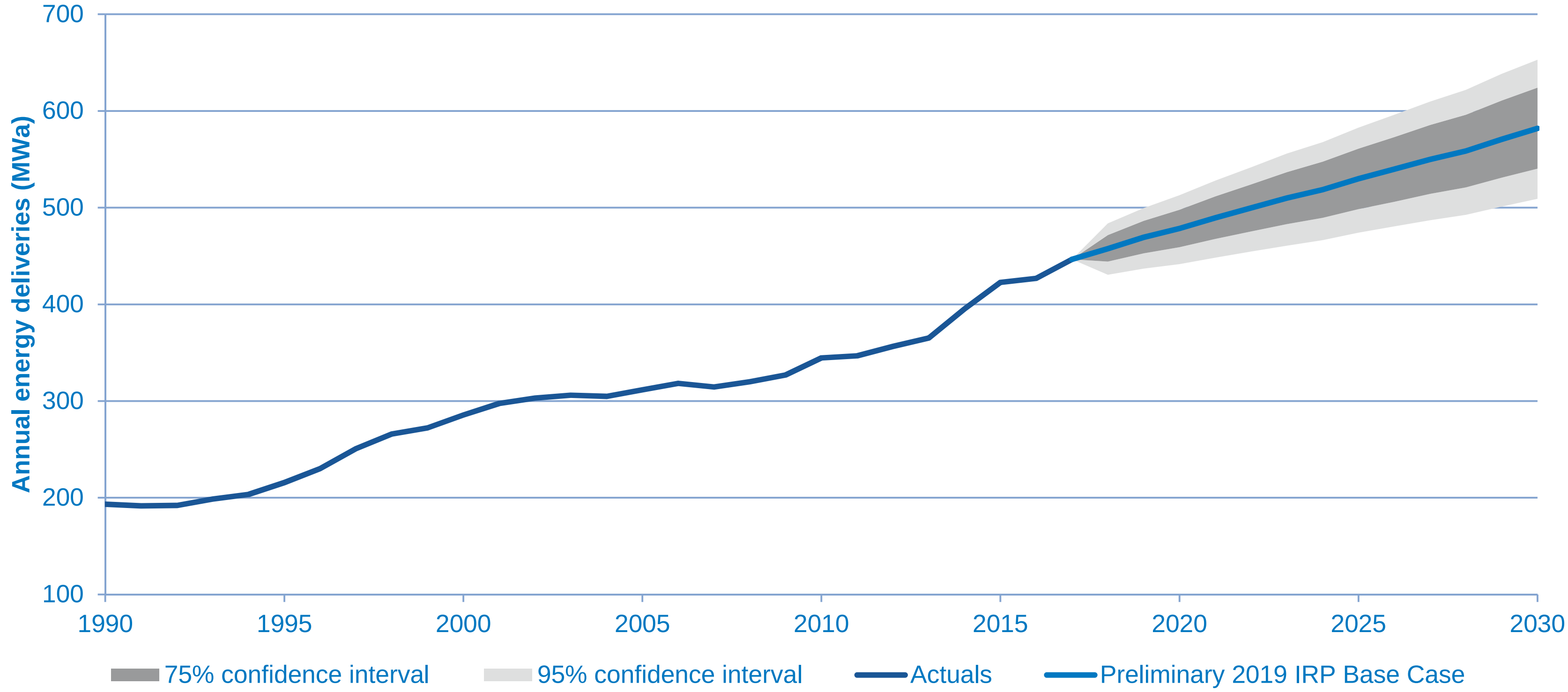
Industrial* Deliveries Growth



*Industrial here is defined as Primary Voltage customers (Revenue Class 5) and does not include Sub-Transmission Voltage customers, for which PGE assumes no long-term growth.

Industrial model

Forecast and confidence intervals



Industrial model

Comparison with 2016 IRP forecast and jaws

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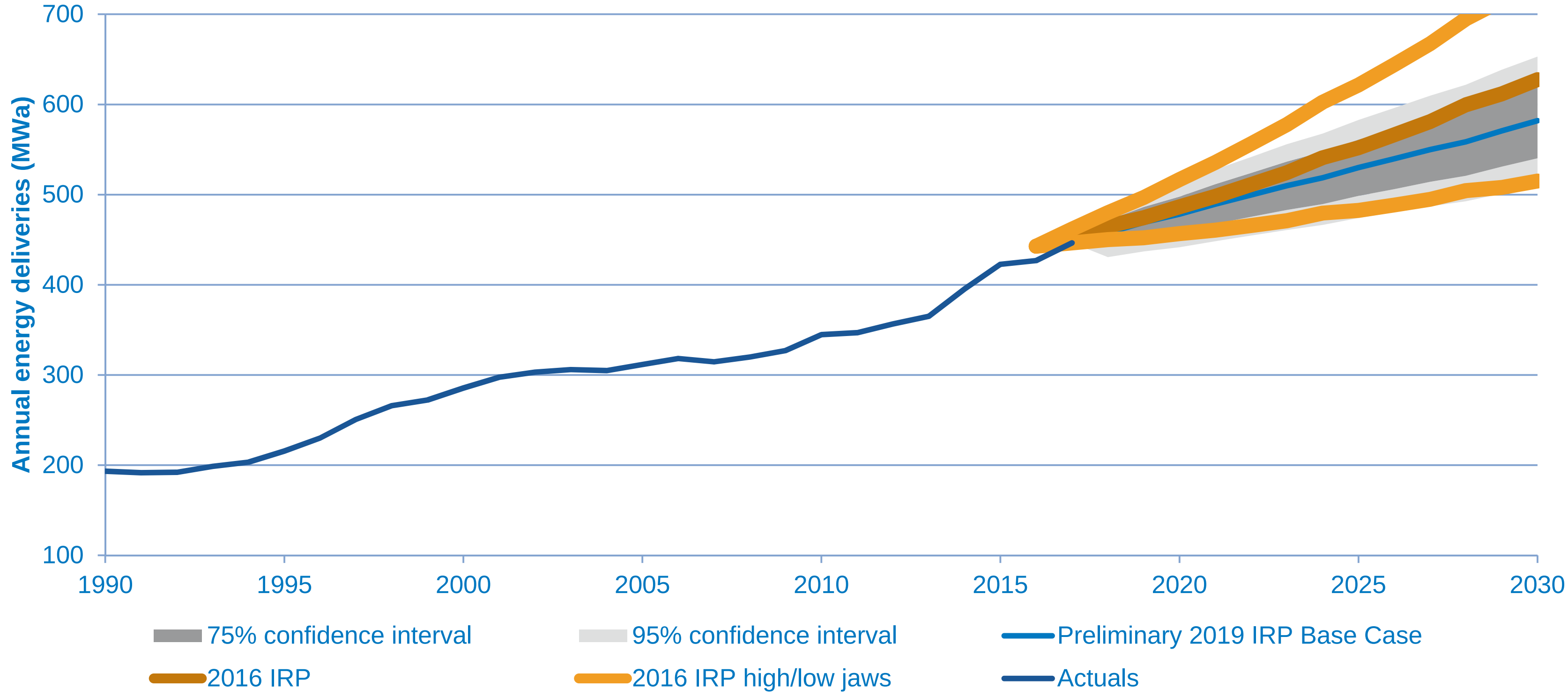


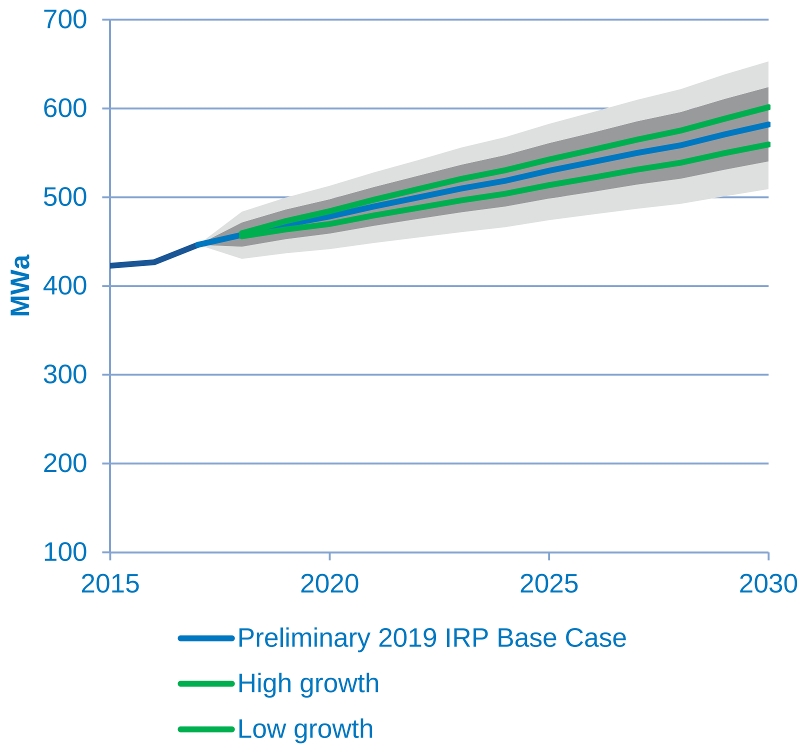
Industrial model

Forecast and high/low economic scenarios

Average annual growth rates, 2023 – 2030		
	GDP	**Industrial deliveries**
Base case	1.8%	1.9%
High growth	2.2%	2.1%
Low growth	1.4%	1.7%

PGE used IHS Markit's Gross Domestic Product base, optimistic, and pessimistic forecasts to create these scenarios.

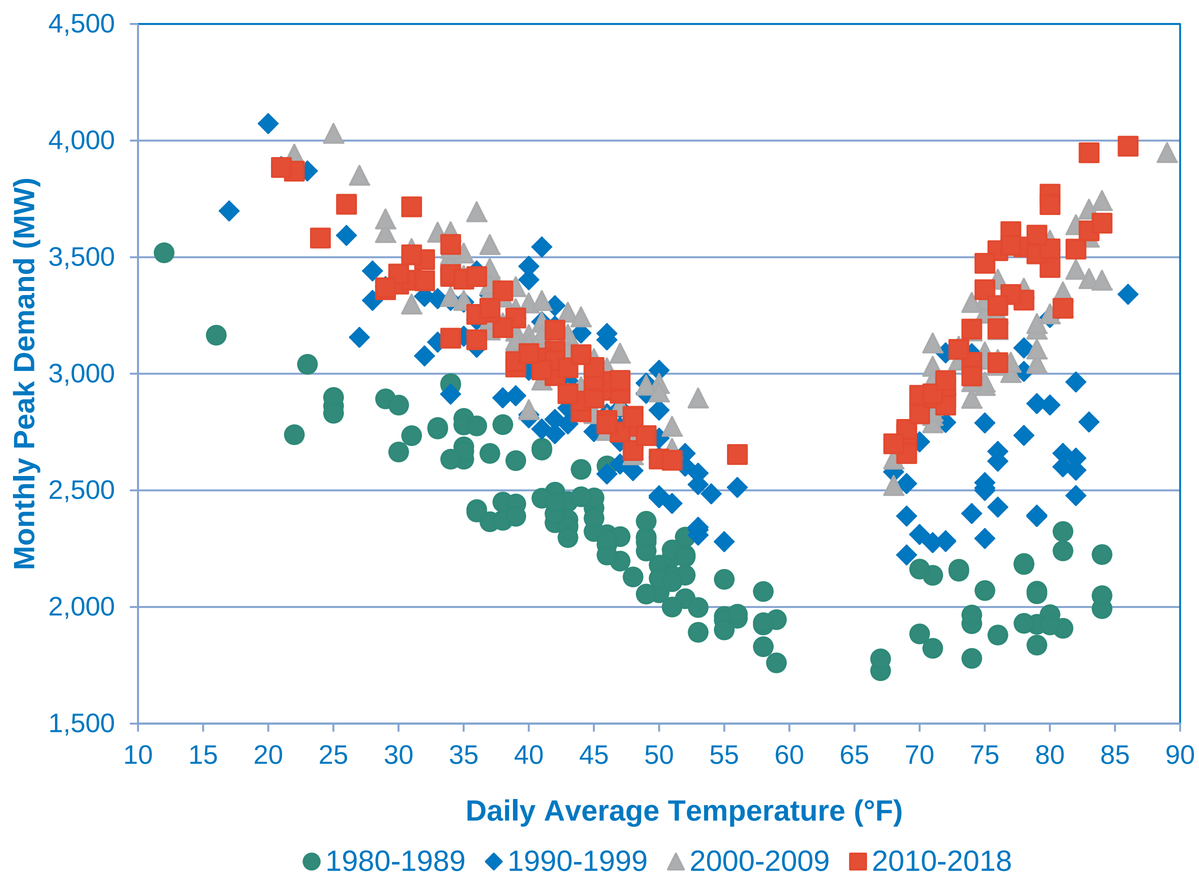
Between 1990 and 2016, US GDP growth has ranged from -2.8% to 4.7%, averaging 2.4%.



Peak Demand Trends

Weather Dependence

Peak demands are dependent upon underlying magnitude of average energy (shift) and responsiveness to weather events (slope)

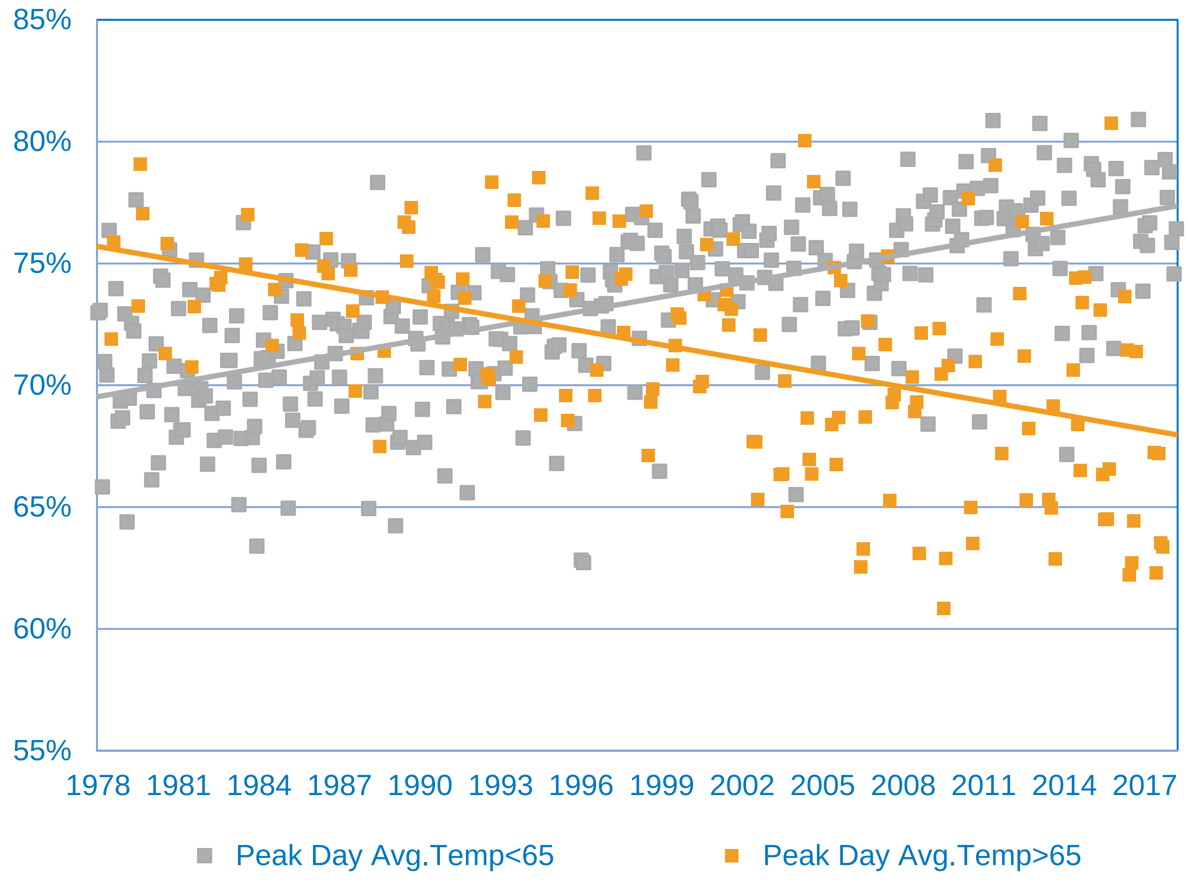


Peak Demand Trends

Load Factor

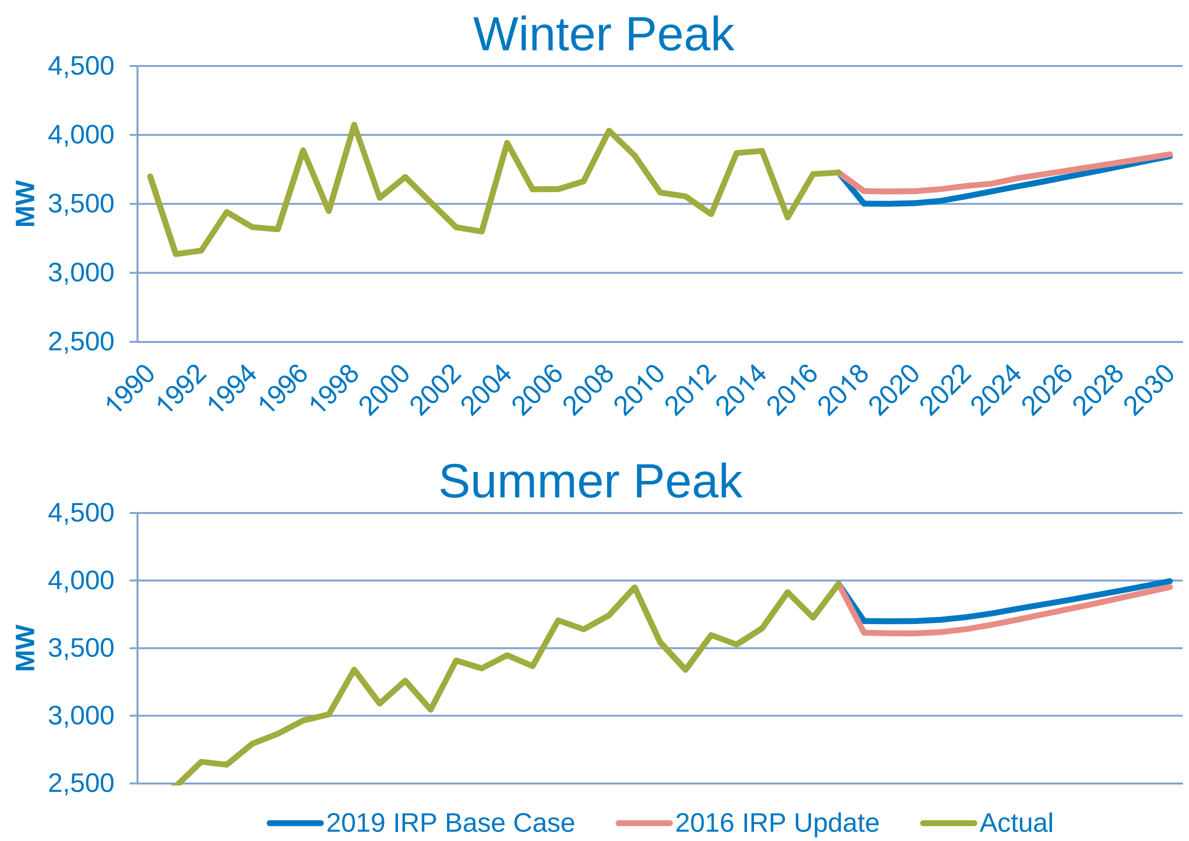
Load Factor =

Monthly Average Hourly Demand (MWa) ÷ Monthly Max Hourly Demand (MW)



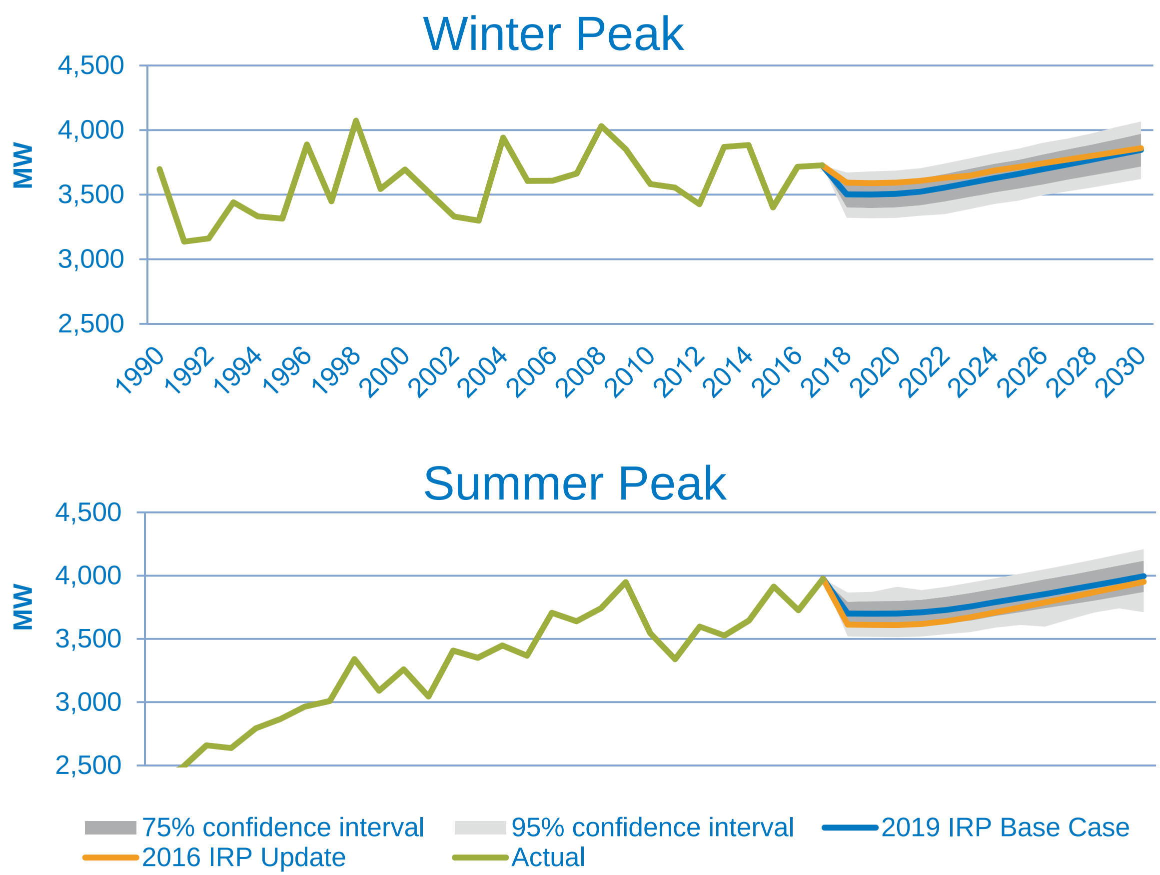
Preliminary Seasonal Peak Demand Model

- Model drivers: Daily CDD, AC Saturation, Prior Day CDD, Daily HDD, Average Wind Speed, Average Energy, Monthly dummies
- Est period: 1990 – 2018
- Data frequency: monthly
- ARIMA(2,0,1)(0,1,0)$_{12}$
- Average Growth Rate: 1.0%



Preliminary Seasonal Peak Demand Model

- Confidence intervals reflect model and coefficient uncertainties
- Incorporate uncertainty from energy models to widen intervals



Next Time…

Present Results of 2019 IRP Long Term Load Forecast

Questions? Feedback?

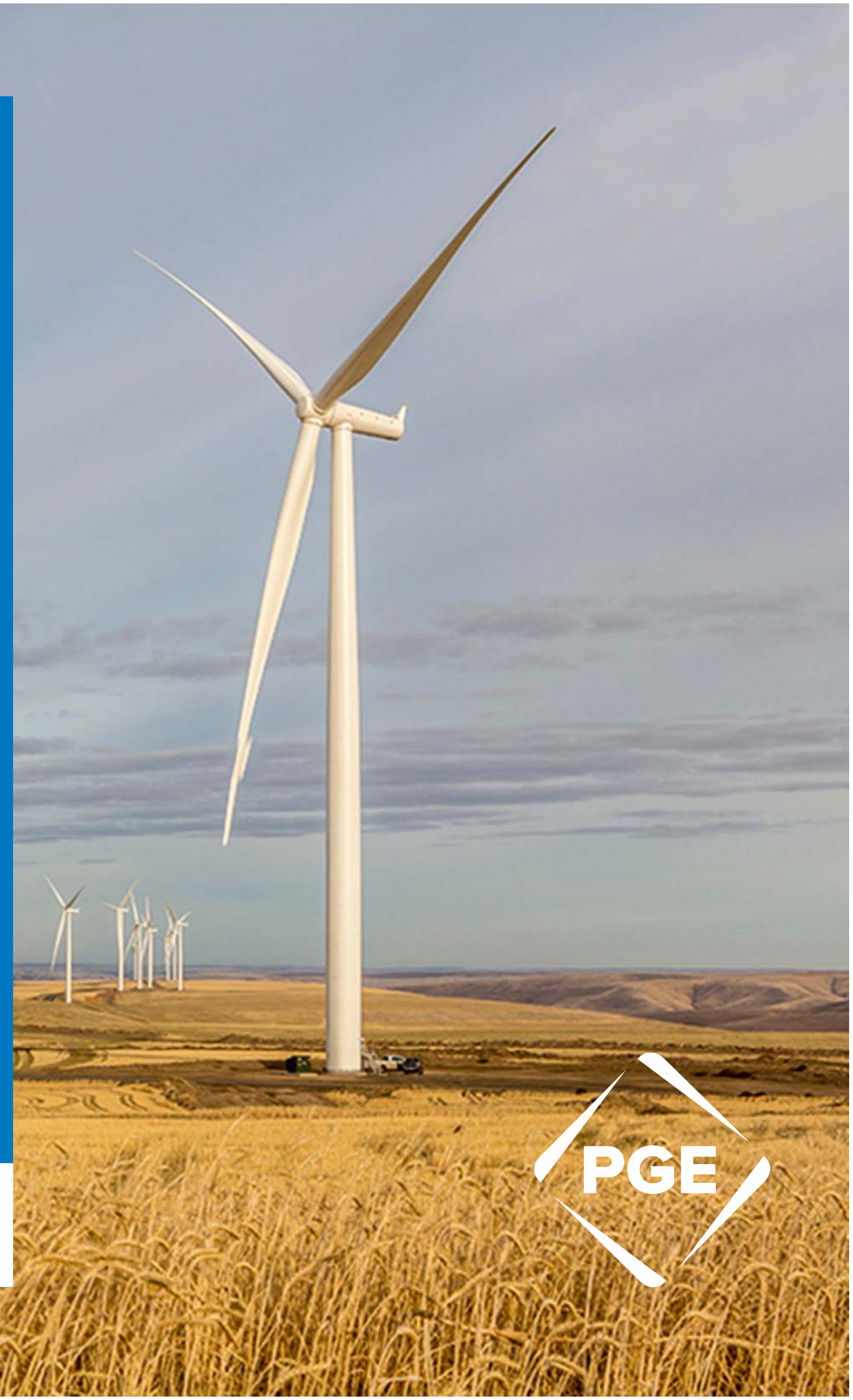
Forecast will be finalized at the end of May.

Suggestions for future Load Forecast Workshop Topics?

Email: irp@pgn.com and direct your comment to load forecasting

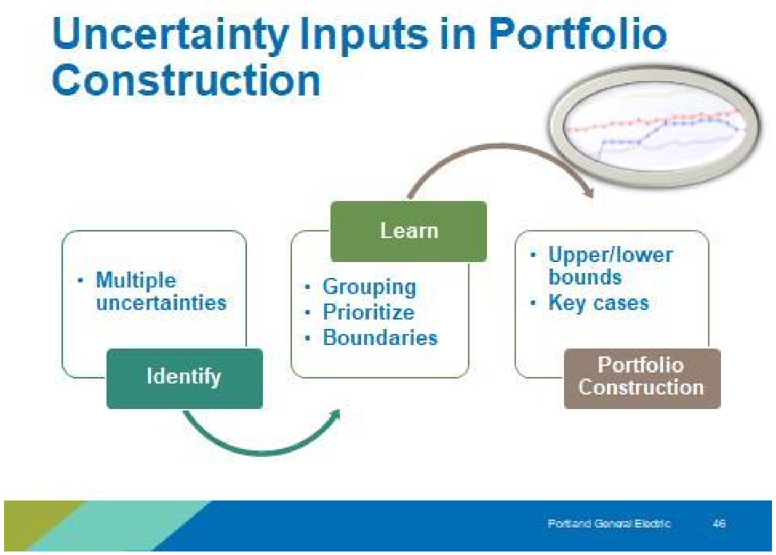
Futures

Kate von Reis Baron



Uncertainties – Roundtable 18-1

- In Roundtable 18-1, we discussed a long list of uncertainties including: load, energy efficiency adoption of distributed technologies, qualifying facilities, overnight capital costs, financial parameters, fixed O&M, commodity costs, environmental costs, and environmental requirements.
- Uncertainties will be examined through futures and sensitivities.
  - Some items will be bundled/grouped/simplified to keep the number of futures examined to a manageable volume.

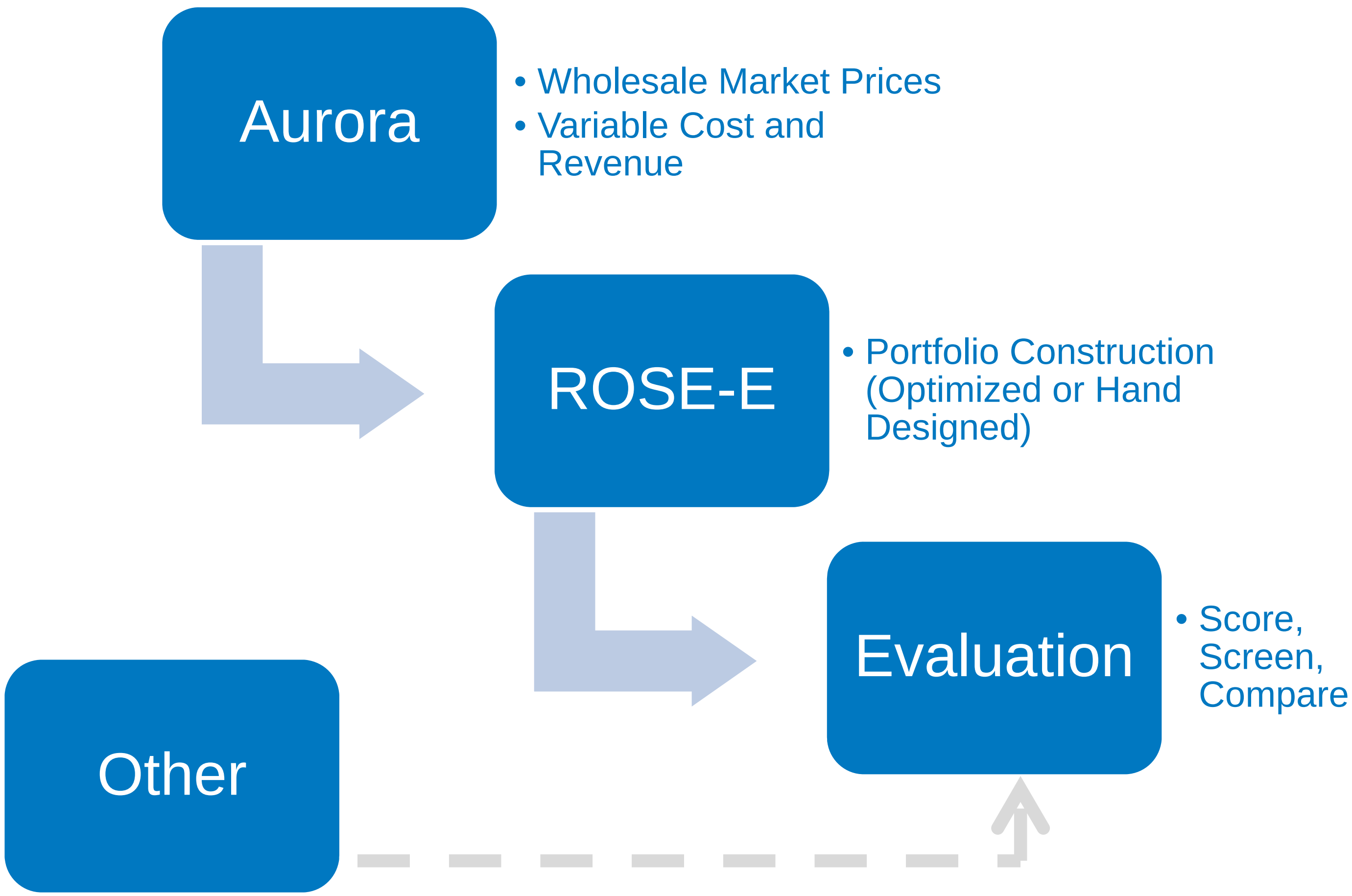


Roundtable 18-1, 2018.02.14, Slide 8

Variable Condition Futures

Variable	• A single uncertainty (e.g., gas prices)
Condition	• a particular treatment of a variable (e.g., high gas prices)
Futures	• A set of condition assumptions that describe a potential circumstance that impacts portfolio performance (e.g., a future with high gas, high CO_2, and reference assumptions for all other variables)

Portfolio Analysis and Evaluation



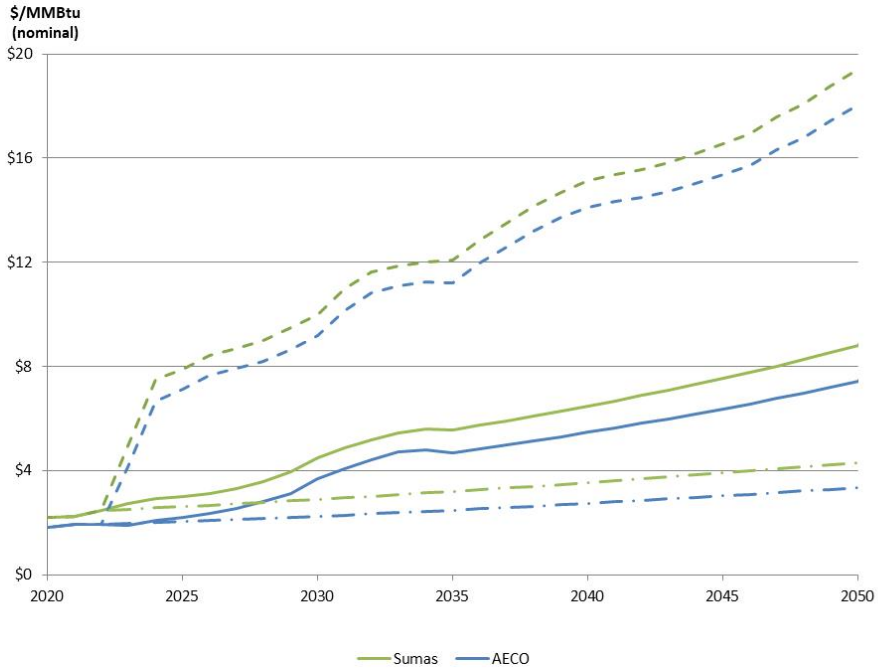
CO_2 Prices

Variable	Aurora	ROSE-E	Evaluation	Other
CO_2 Prices	Low Ref High	Low Ref High	Low Ref High	Sensitivities of no new CO_2 pricing and emission cap

- Examine the impacts of potential future Oregon Green House Gas legislation and other GHG costs/legislation in the region on wholesale market prices and resource costs through three CO_2 pricing conditions. These will be examined across the combinations of the other pricing variables and will be discussed more in the Wholesale Market discussion (next).
- Price Sensitivity: A condition of no new CO_2 legislation (other price variables in reference condition).
- Examine the impact of PGE portfolio CO_2 constraints as a sensitivity in portfolio development (ROSE-E). [Not a pricing variable.]

Natural Gas Prices

Variable	Aurora	ROSE-E	Evaluation	Other
Natural Gas Prices	Low Ref High	Low Ref High	Low Ref High	



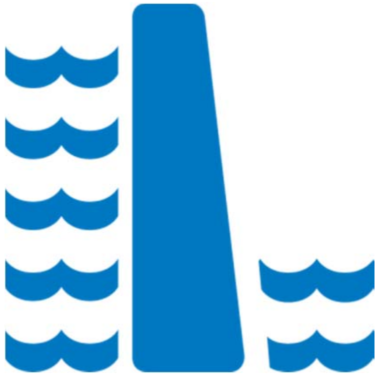
2016 IRP Update Gas Price Forecasts

- Model three gas price conditions using the same forecast methodology as the 2016 IRP Update, but with the 2018.H1 long-term forecast.

Hydro Generation

Variable	Aurora	ROSE-E	Evaluation	Other
PNW Hydro Generation	Low Ref High		Low Ref High	

- Model reference hydro and approximately one standard deviation of annual PNW generation for pricing futures across all other pricing variables.
- A simplified methodology that provides a reasonable sense of the range of potential market price risk associated with a range of hydro conditions.
- Plan to include price impact in portfolio evaluation but not as a condition in portfolio construction (ROSE-E).



WECC-wide Renewables

Variable	Aurora	ROSE-E	Evaluation	Other
WECC-wide Renewables	Ref High	Ref High	Ref High	

- Model an alternative build-out of resources across the WECC that reflects a substantially larger deployment of renewables and storage.
- Model across combination of other Aurora pricing variables (gas, carbon, hydro).
- Simplified/high level modeling.
- This is discussed in more detail in the next presentation.

PGE Need - Capacity, RPS, Energy

Variable	Aurora	ROSE-E	Evaluation	Other
PGE Need		Low Ref High	Low Ref High	Sensitivities for need assessments

- Develop need assessment sensitivities that examine impacts of varying assumptions for many factors, such as: economic factors, customer choice, QF completion and execution rates, distributed solar adoption, energy efficiency.
- Evaluate sensitivities to develop low and high cases for input to portfolio construction (ROSE-E) and portfolio evaluation.

Capital Cost

Variable	Aurora	ROSE-E	Evaluation	Other
Solar & Storage Cap Cost		Low Ref High	Low Ref High	
Wind Cap Cost		Low Ref High	Low Ref High	

- Examine impact of different capital cost conditions through input of Low, Reference, High cases in ROSE-E.
- In ROSE-E, these variations in fixed costs can be examined across the different variable cost outcomes from Aurora.
- Solar and storage costs vary together, but independent of wind.

Financial Sensitivities

Variable	Aurora	ROSE-E	Evaluation	Other
Financial				Sensitivities for top portfolios

- Sensitivities may be used to examine the impact on top portfolios of alternative conditions (e.g., economic life).

Variables to Examine

Variable	Aurora	ROSE-E	Evaluation	Other
CO_2 Prices	Low Ref High	Low Ref High	Low Ref High	Sensitivities of no new CO_2 pricing and emission cap
Natural Gas Prices	Low Ref High	Low Ref High	Low Ref High	
Hydro Output	Low Ref High		Low Ref High	
WECC- Wide Renewables	Ref High	Ref High	Ref High	
PGE Need		Low Ref High	Low Ref High	Sensitivities for need assessments
Solar & Storage Capital Costs		Low Ref High	Low Ref High	
Wind Cap. Costs		Low Ref High	Low Ref High	
Financial				Sensitivities for top portfolios

Examining many conditions . . .

IRP	Aurora	ROSE-E	Evaluation	Other
2016 IRP	27 price futures	NA	21 price futures 5 sensitivities	Sensitivities of hydro, capital cost, capacity factor
2019 IRP	**54 price futures**	**486?**	**1458?**	**Sensitivities for CO_2, Need, Financial**

. . . leads to many futures and long processing time.

Stakeholder Feedback

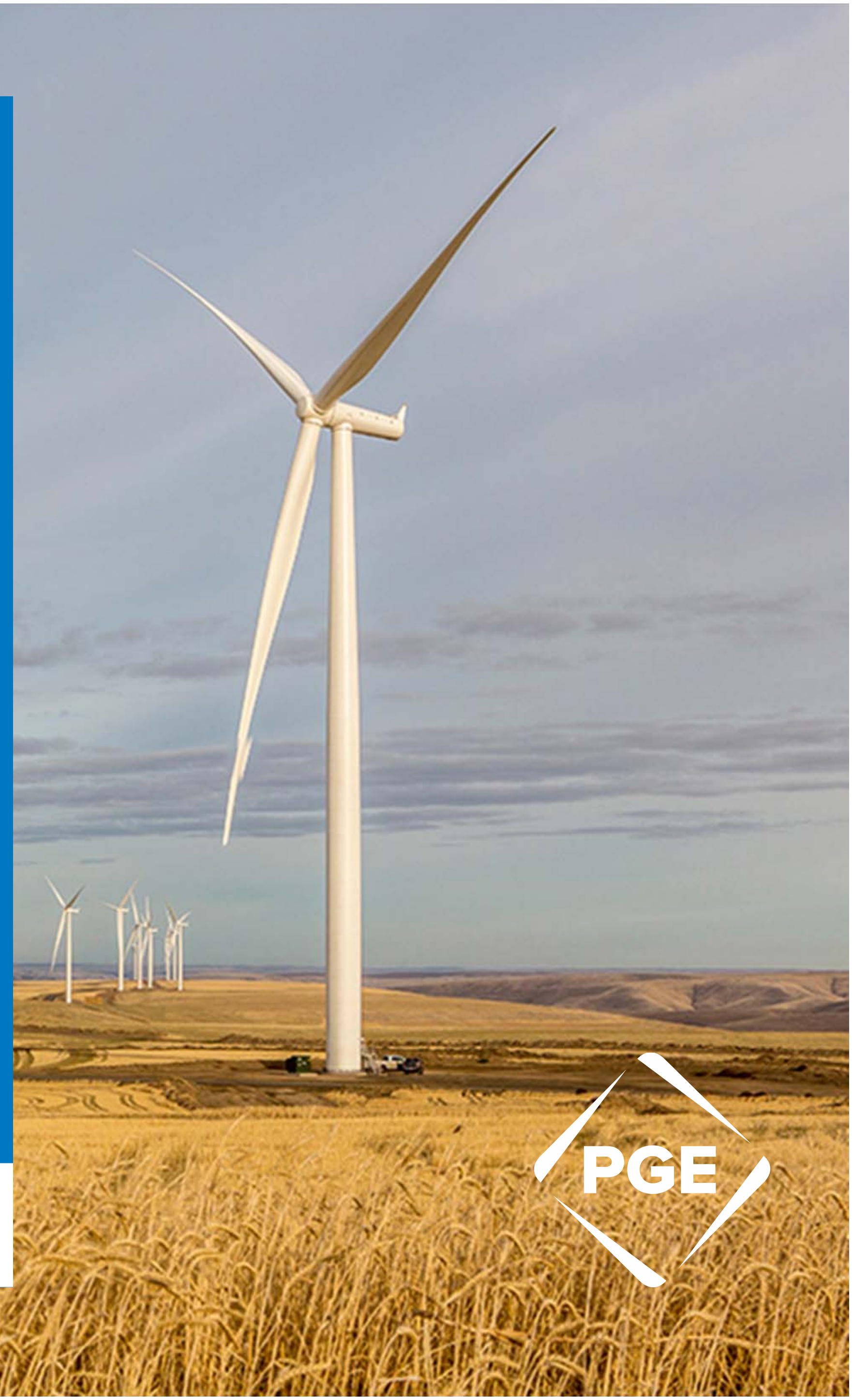
- Additional thoughts about variables/conditions to examine?
- Futures/sensitivities that are of particular interest?
- Thoughts on combinations that may be illogical?

Next Steps

- Finalize inputs to pricing futures.
- Finalize inputs for non-pricing variables and treatment in ROSE-E and evaluation.
- Share information in August Roundtable.

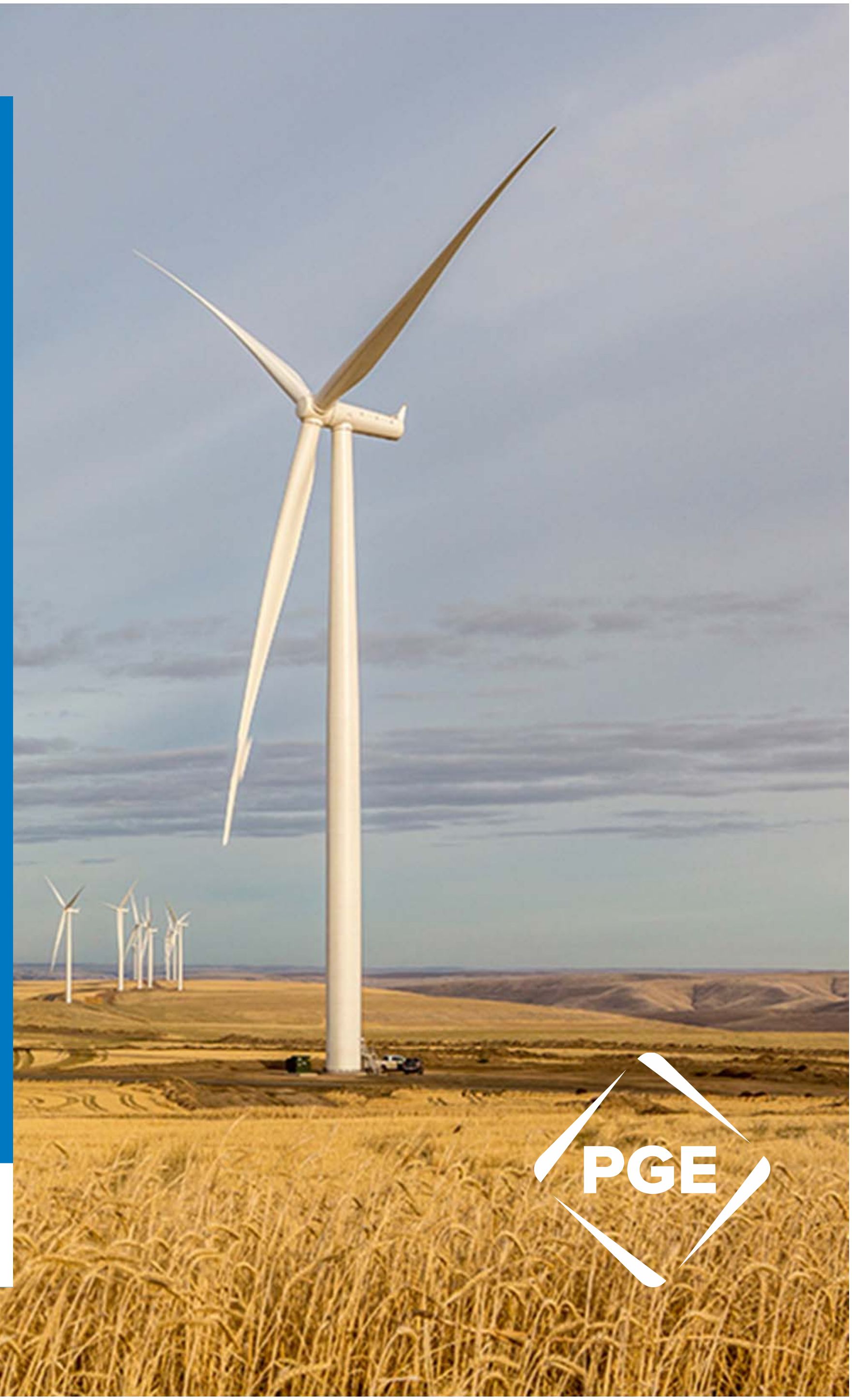
Wholesale Electricity Market

Shauna Jensen



Portfolio Construction

Elaine Hart



Portfolio Construction

- Update on ROSE-E, PGE's portfolio optimization model
- Proposed portfolio construction framework with mock portfolios
- Stakeholder feedback
  - What questions are you interested in exploring with portfolio construction

ROSE-E Update

- PGE is continuing to develop ROSE-E functionality
  - ✓ RPS & REC constraints
  - ✓ Resource adequacy constraints
  - ✓ Energy need constraints
  - ❑ Alternative objectives
  - ❑ Carbon constraints
  - ❑ Energy storage constraints
- Testing underway with data from 2016 IRP
  - Mock portfolio construction being used to test proposed framework
- PGE presented ROSE-E formulation and functionality at April 26th Technical Meeting

Proposed Portfolio Construction Framework

- **Optimized portfolios**
  - Develop multiple "optimized" portfolios with ROSE-E by adjusting settings or objective function

    Examples:
    - Minimize within a future
      - Reference Case, High Tech Progress, Low Tech Progress, etc.
    - Minimize Expected NPVRR across futures
    - Minimize Cost & Risk to build efficient frontier
- **Hand designed portfolios**
  - Create portfolios to answer specific questions or test resources that don't arise from "optimized" portfolios

Mock Portfolio Construction Exercise

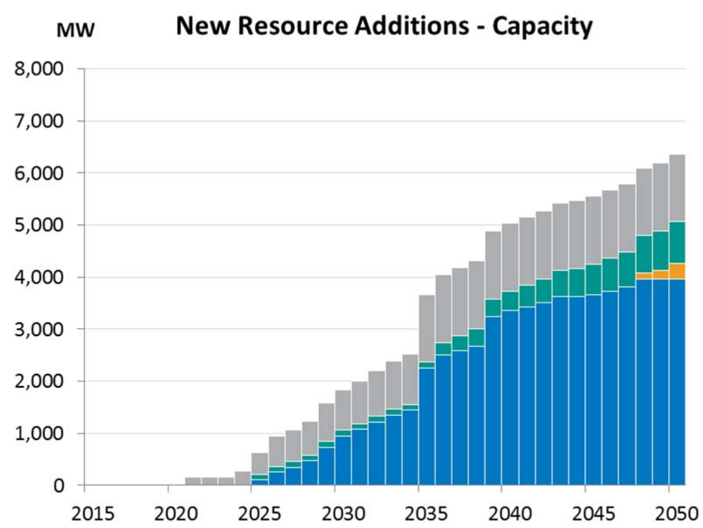
The following slides walk through an example of how ROSE-E could be used to complement hand-designed portfolios

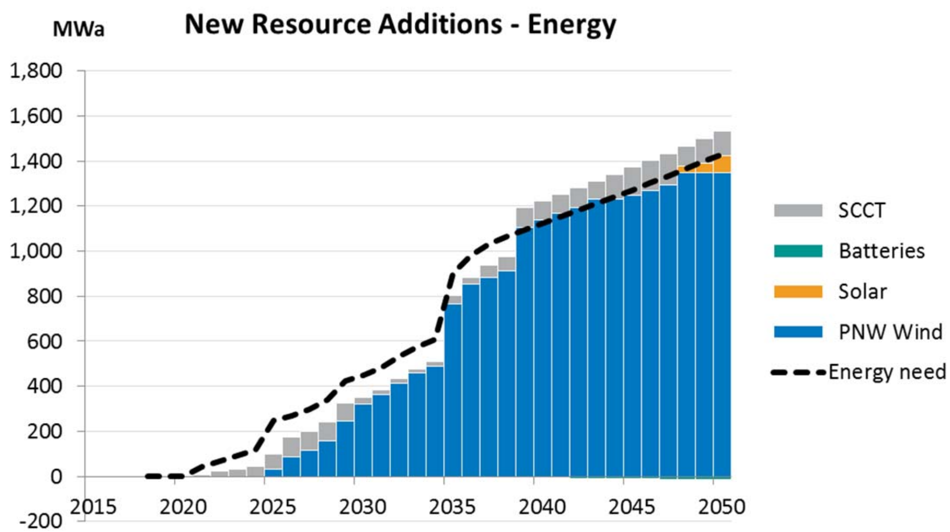
Portfolios and results in this mock exercise are based on outdated and/or fabricated data and are not indicative of PGE’s needs, resource performance, or expected outcomes in the 2019 IRP.

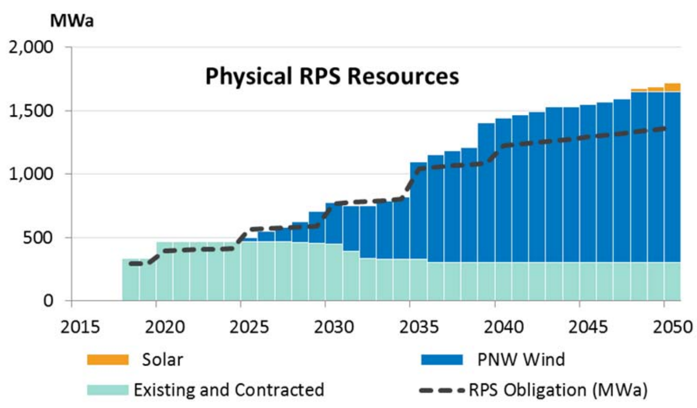
Optimized Portfolios

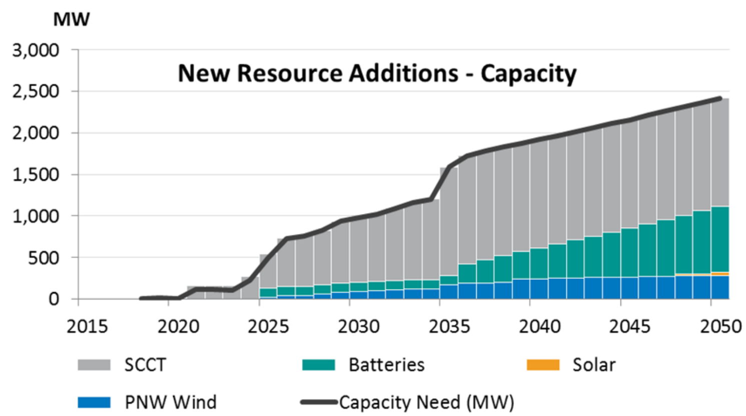
1. Minimize NPVRR in Reference Case

Reference Need Future
Ref CO2 Prices, **Ref** Gas Prices
Ref Tech Costs







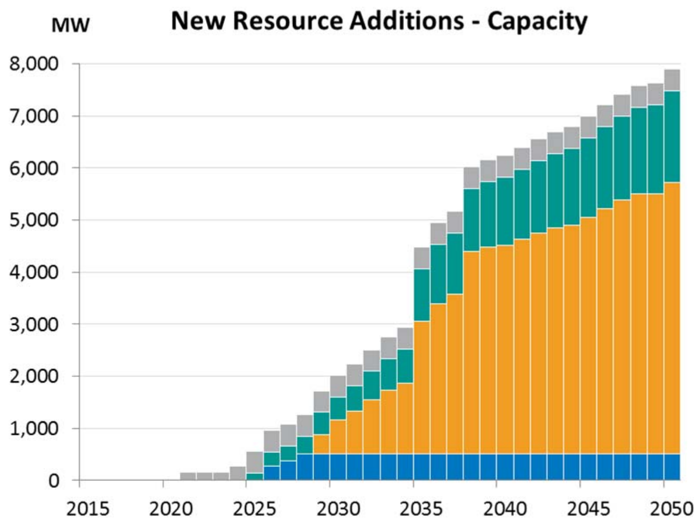


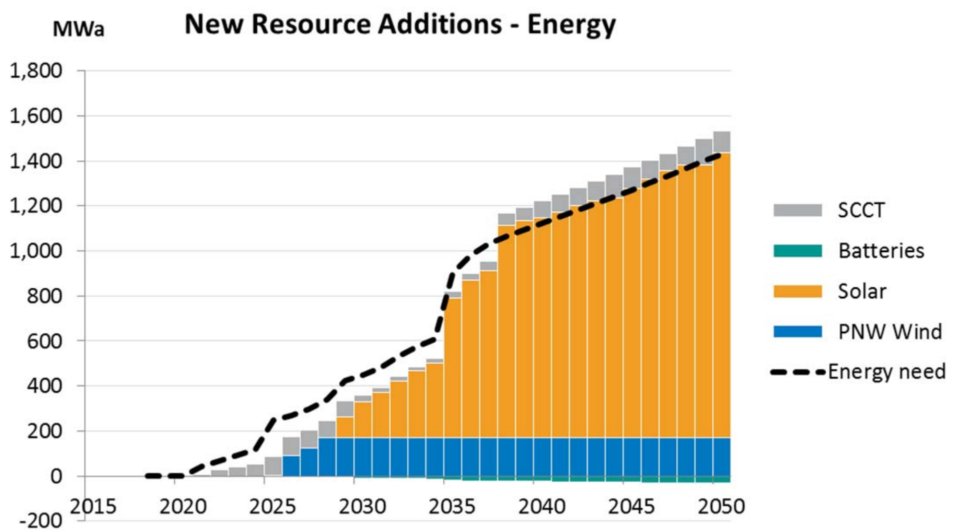
Illustrative results, not indicative of PGE's resource needs or actual resource performance

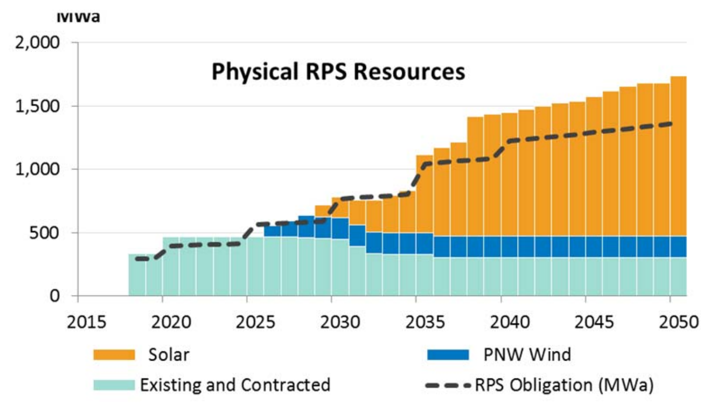
Optimized Portfolios

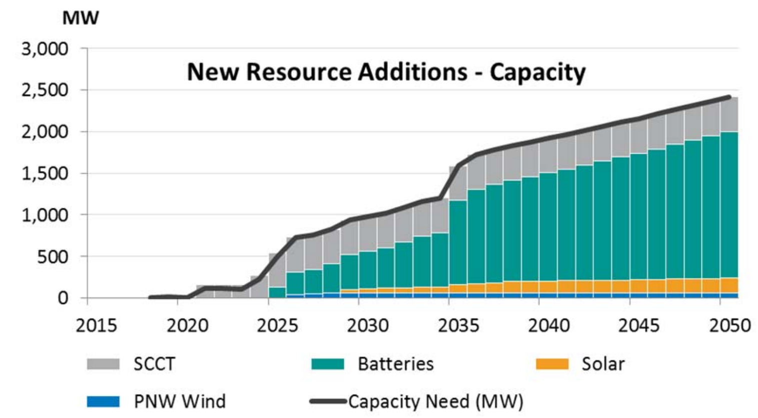
2. Minimize NPVRR in High Tech Case

Reference Need Future
High CO_2 Prices, **Ref** Gas Prices
Low Solar & Storage Costs







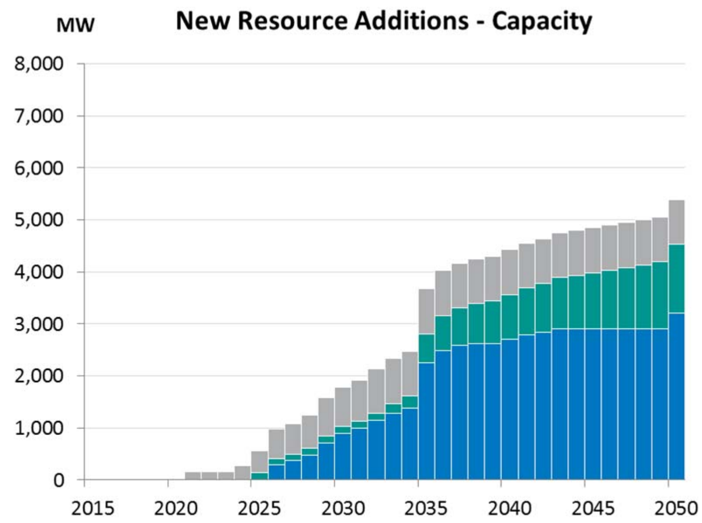


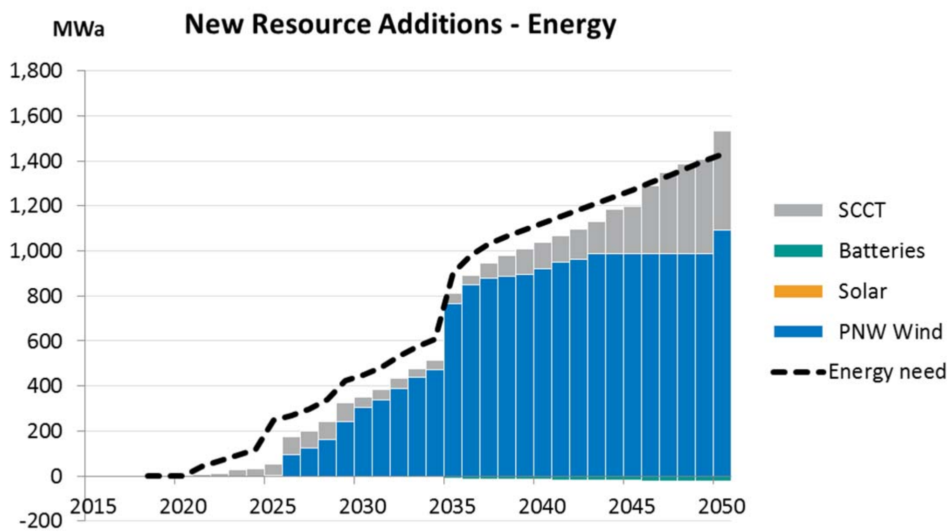
Illustrative results, not indicative of PGE's resource needs or actual resource performance

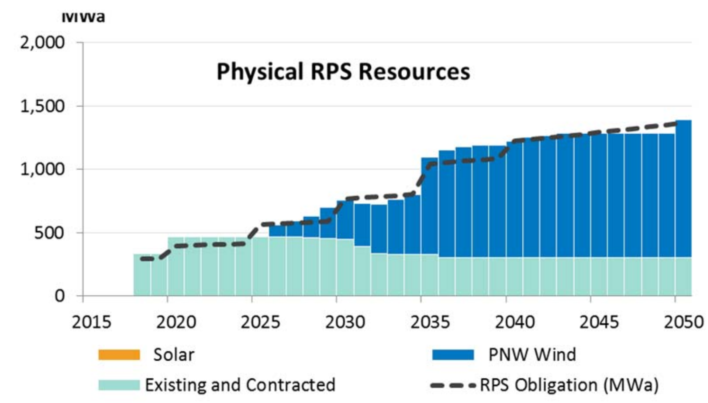
Optimized Portfolios

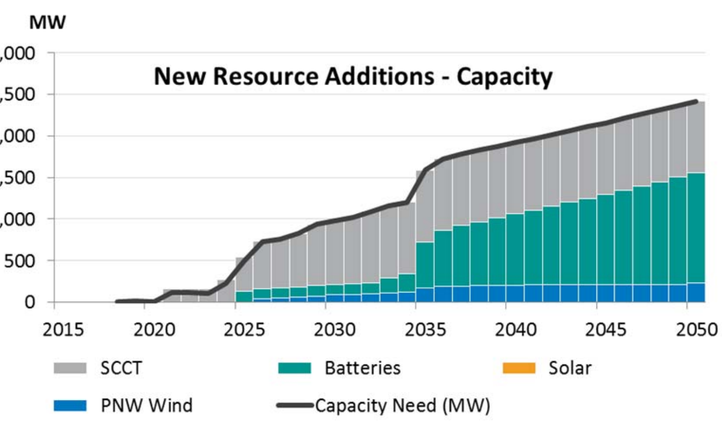
3. Minimize NPVRR in Low Tech Case

Reference Need Future
No CO2 Prices, **Ref** Gas Prices
High Solar & Storage Costs







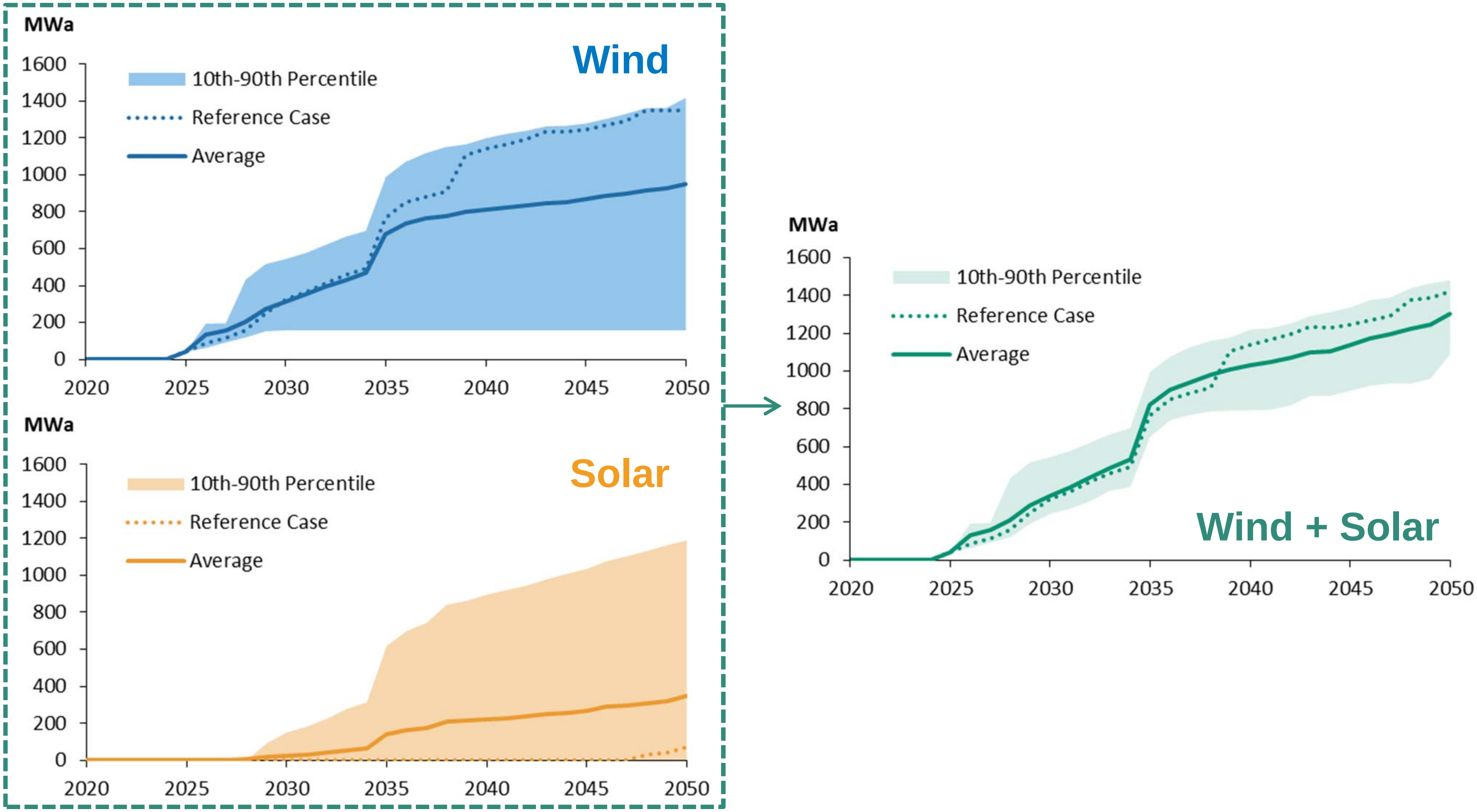


Illustrative results, not indicative of PGE's resource needs or actual resource performance

Optimized Portfolios

Equal weighting across all need, price, and technology cost futures
Portfolios vary by future after 2025

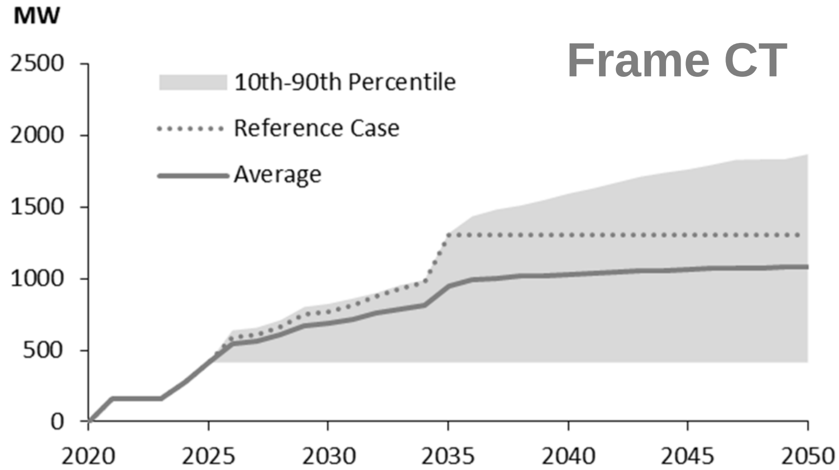
4. Minimize Expected NPVRR

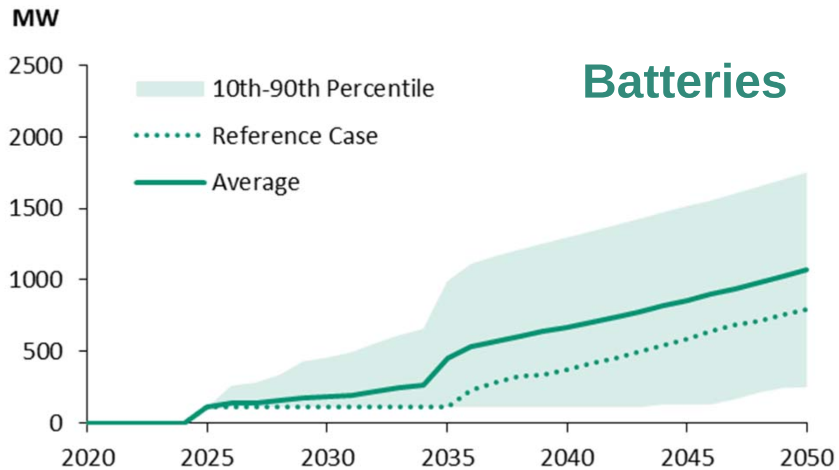


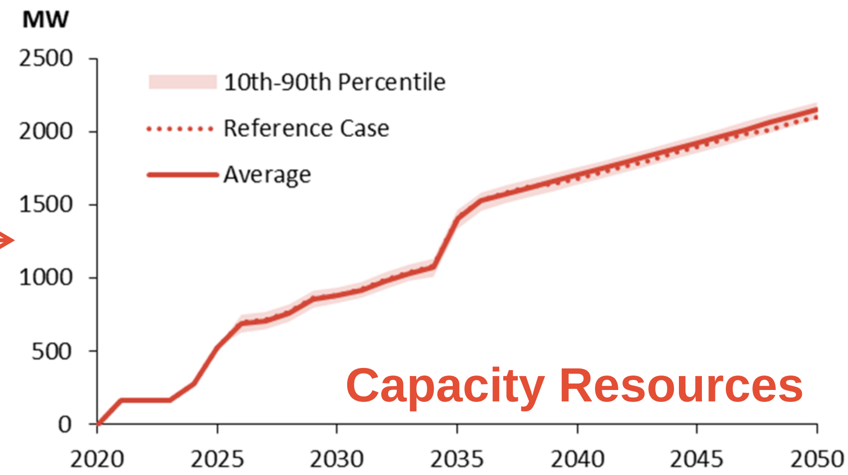
Optimized Portfolios

Equal weighting across all need, price, and technology cost futures
Portfolios vary by future after 2025

4. Minimize Expected NPVRR





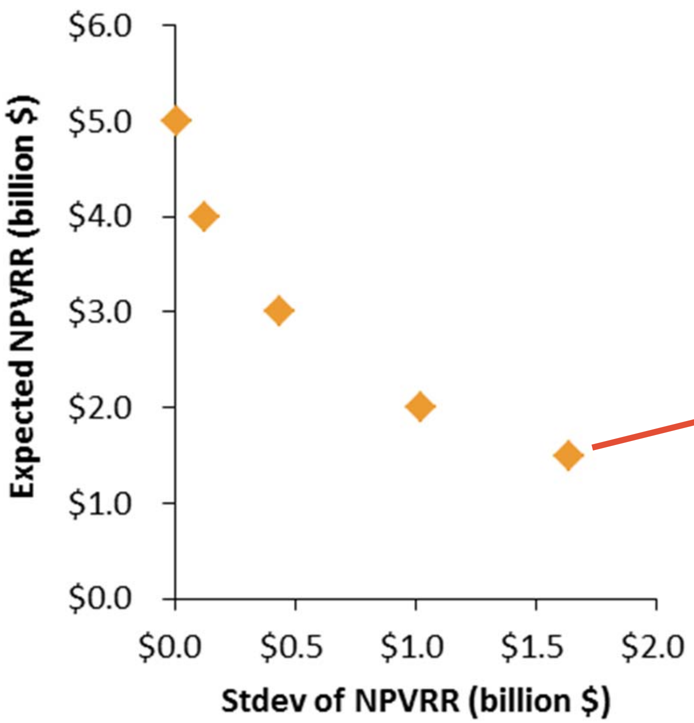


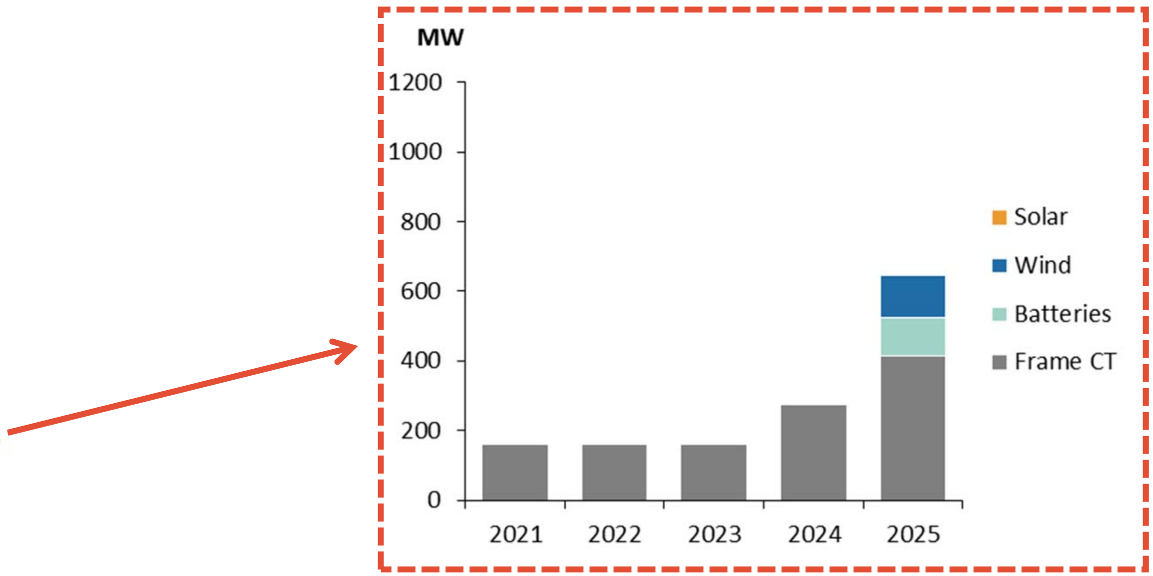
Illustrative results, not indicative of PGE's resource needs or actual resource performance

Optimized Portfolios

Cost/Risk Portfolios

Minimize variance subject to cost constraint to find efficient frontier
Portfolios vary by future after 2025



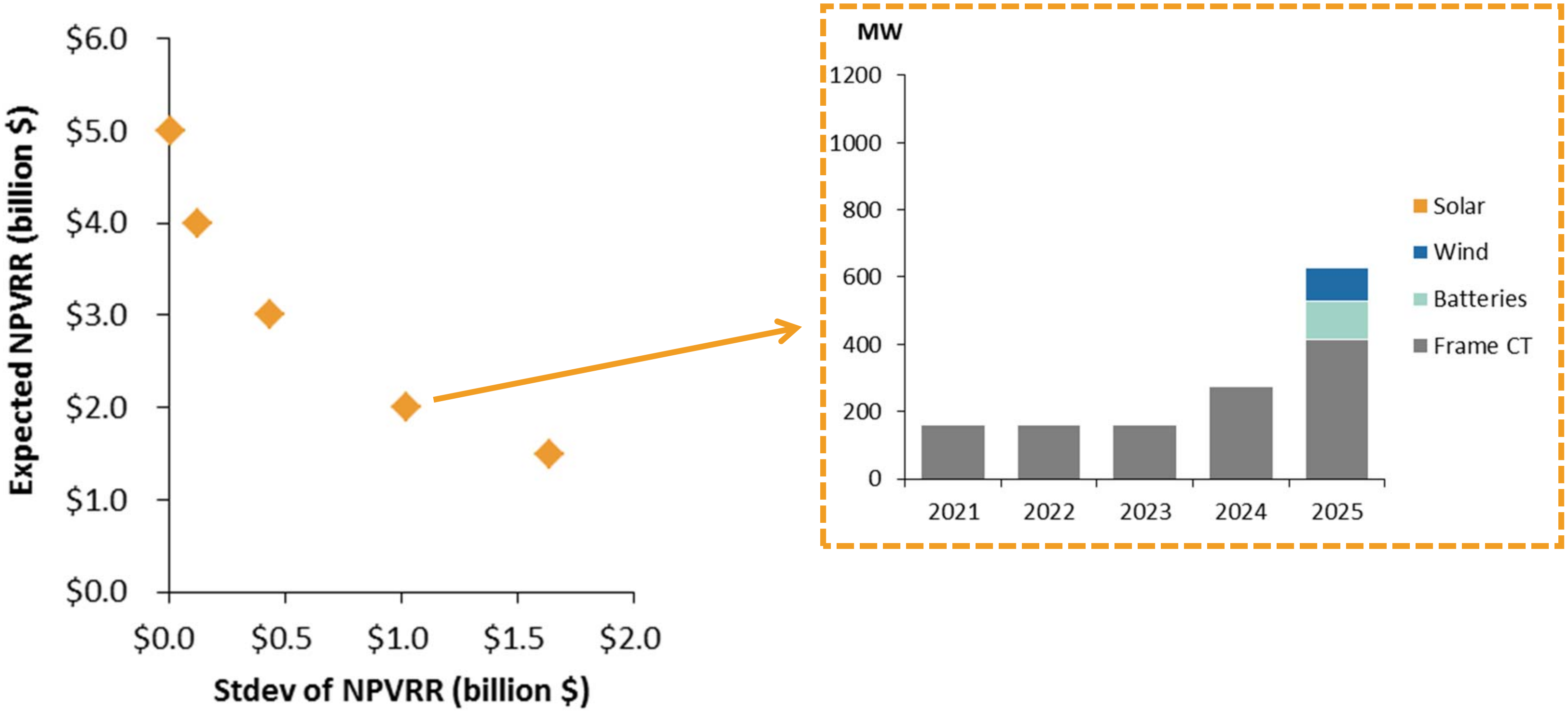


Illustrative results, not indicative of PGE's resource needs or actual resource performance

Optimized Portfolios

5. Cost/Risk Portfolios

Minimize variance subject to cost constraint to find efficient frontier
Portfolios vary by future after 2025

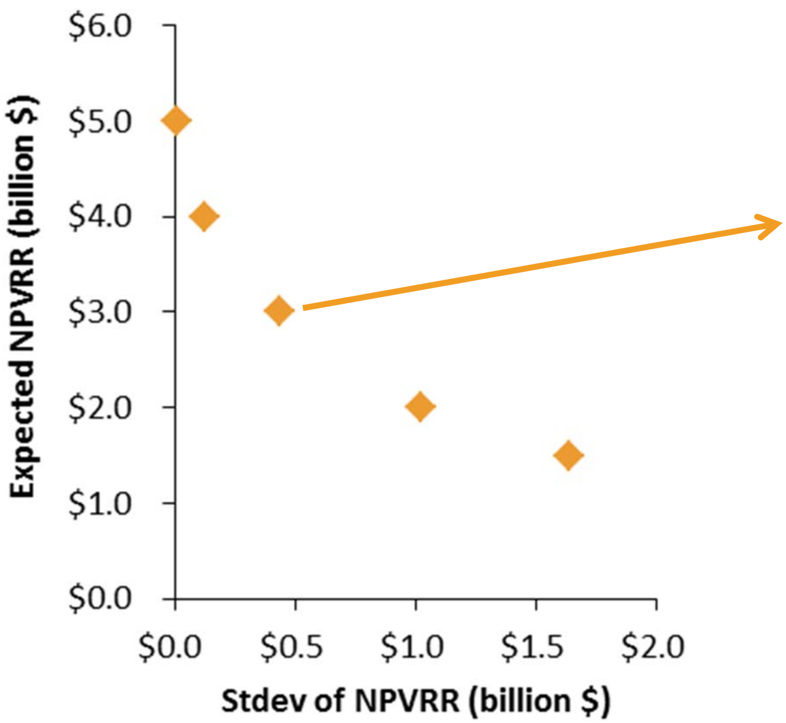


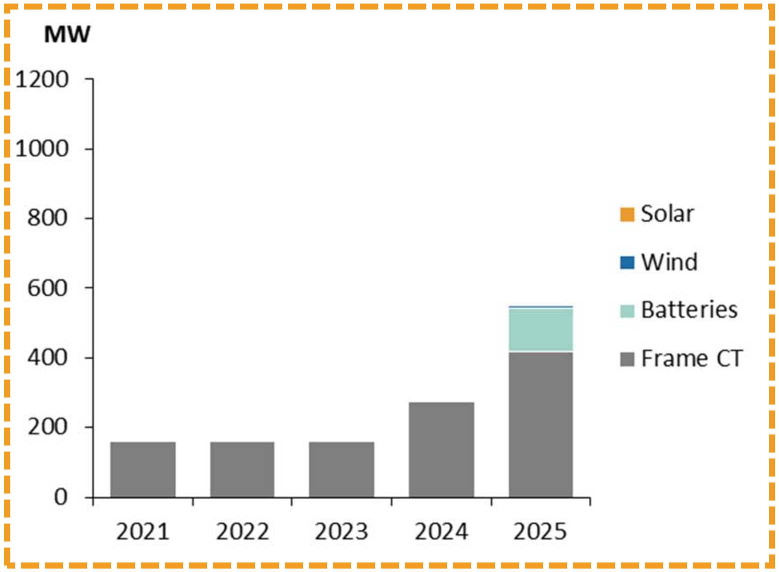
Illustrative results, not indicative of PGE's resource needs or actual resource performance

Optimized Portfolios

6. Cost/Risk Portfolios

Minimize variance subject to cost constraint to find efficient frontier
Portfolios vary by future after 2025



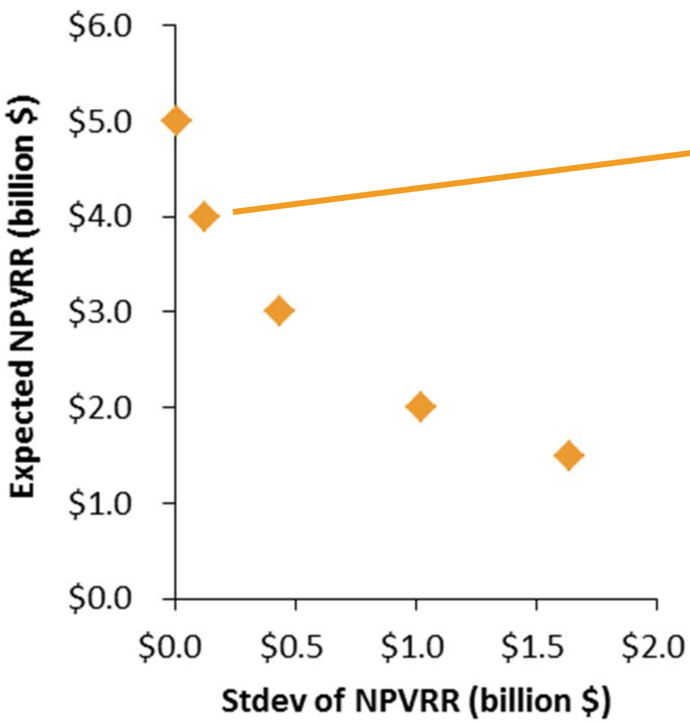


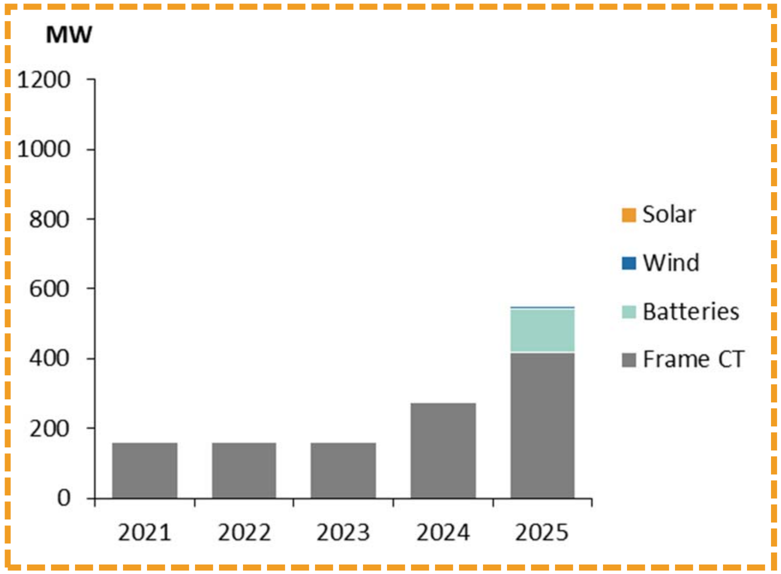
Illustrative results, not indicative of PGE's resource needs or actual resource performance

Optimized Portfolios

7. Cost/Risk Portfolios

Minimize variance subject to cost constraint to find efficient frontier
Portfolios vary by future after 2025



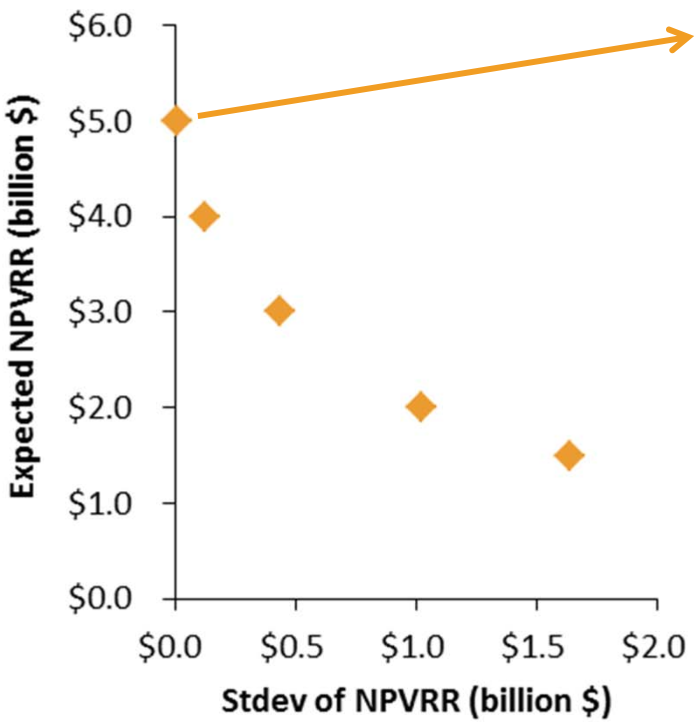


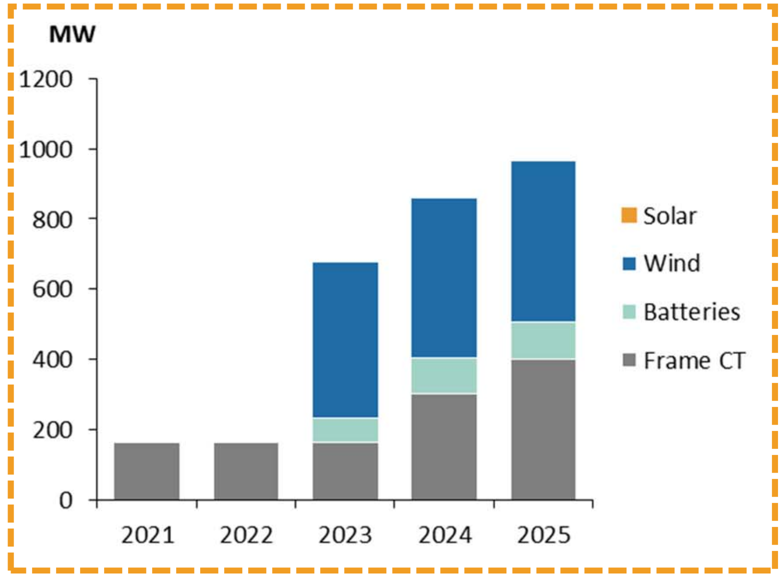
Illustrative results, not indicative of PGE's resource needs or actual resource performance

Optimized Portfolios

8. Cost/Risk Portfolios

Minimize variance subject to cost constraint to find efficient frontier
Portfolios vary by future after 2025

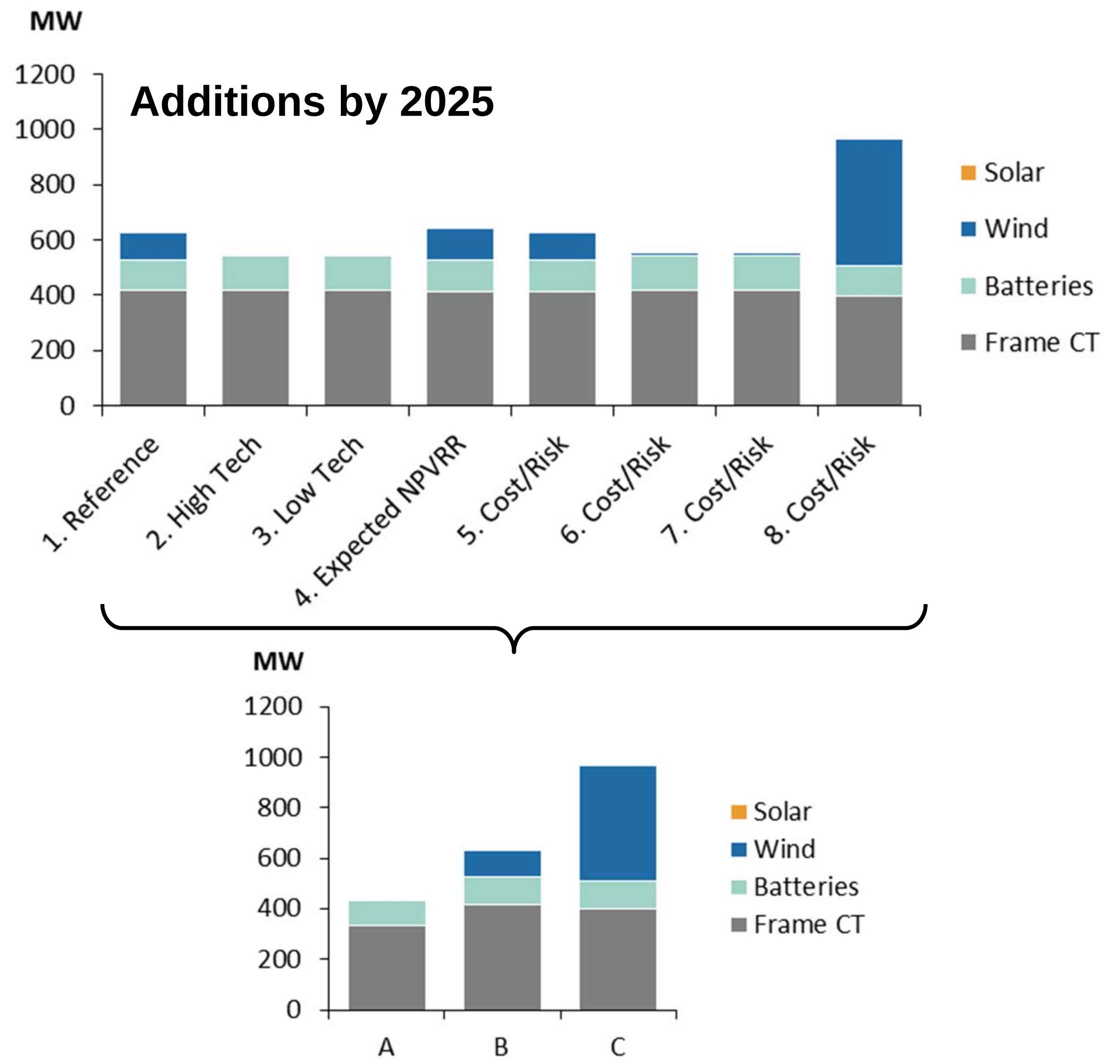




Illustrative results, not indicative of PGE's resource needs or actual resource performance

Cluster Like Portfolios

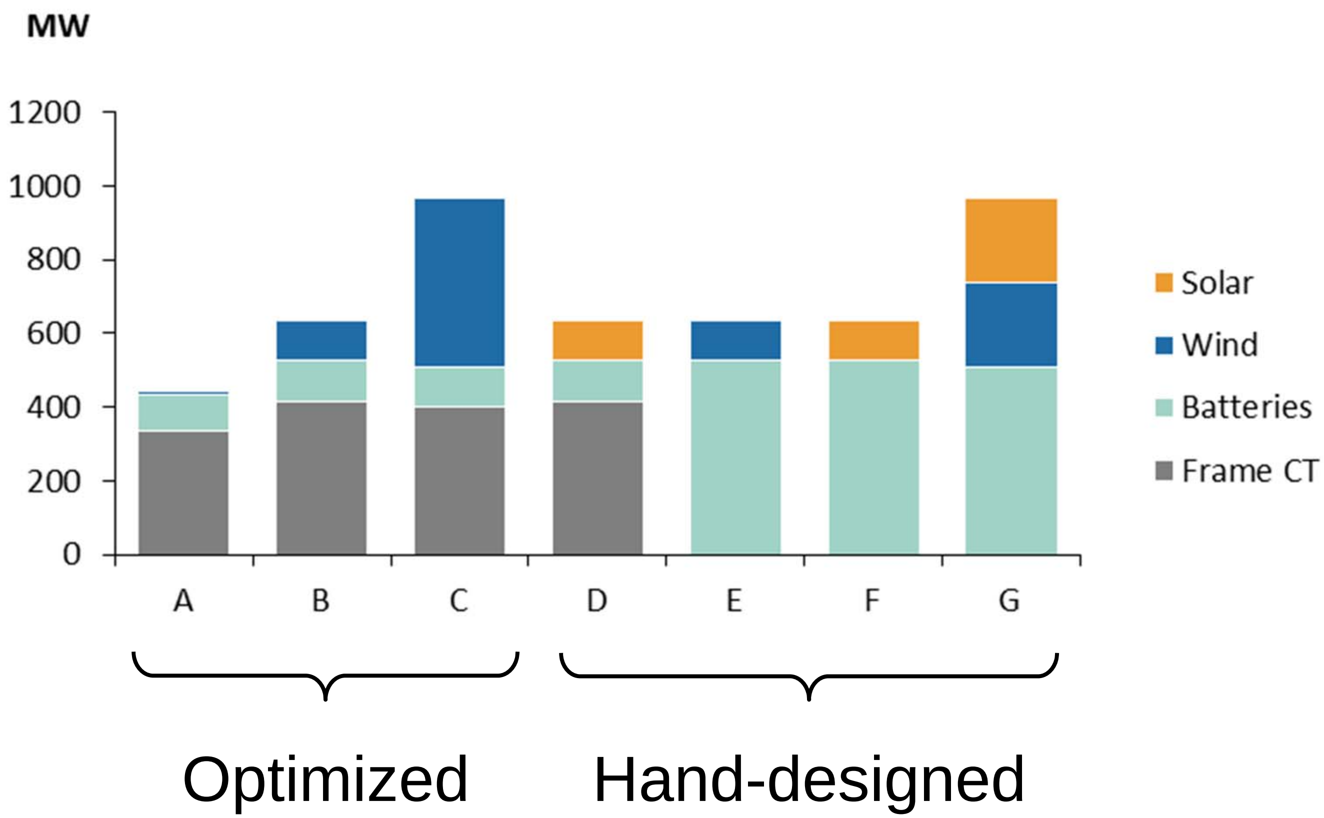
Optimized portfolios may have similar or identical near-term actions



Illustrative results, not indicative of PGE's resource needs or actual resource performance

Hand-designed portfolios

Design portfolios to answer questions and test resources not explored by optimized portfolios



Illustrative results, not indicative of PGE's resource needs or actual resource performance

Stakeholder feedback

What questions are you interested in exploring with portfolio construction?

- Relative economics of wind and solar over time
- Relative economics of batteries versus generic capacity
- Relative value of Montana versus Gorge wind
- Cost/risk tradeoff for portfolio diversity
- Cost/risk tradeoff for incrementalism
- Others?

Scoring Metrics

Sima Beitinjaneh

Portfolio scoring in the 2019 IRP

Goals for today's discussion

- Introduce a framework for portfolio scoring
- Introduce a list of cost/risk, values metrics
- Define the different metrics

Seek stakeholders feedback

What’s new since the last IRP?

ROSE-E

- ✓ Construction of optimized portfolios
- ✓ Different objective functions to answer variety of questions
- ✓ Calculations of different metrics to evaluate portfolios.

What’s new since the last IRP?

✓Stakeholders revealed what they value most in an IRP process

✓Stakeholders’ values will be embedded throughout the long term resource planning process

✓Values considered in the portfolio scoring

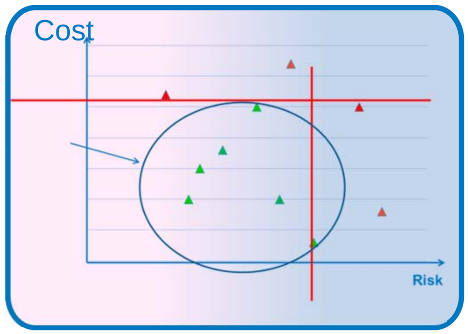
Proposed framework for portfolio scoring

Portfolios

ROSE-E

PHASE 1

Screen



PHASE 2

Screen

Values

- Environmental: $CO_2/SO_x/NO_x$ emissions, Water use
- Risk: Variability, severity
- Reliability: TailVar90,EUE
- Long/short term cost
- Technology: optionality, modularity, diversity
- Energy market exposure

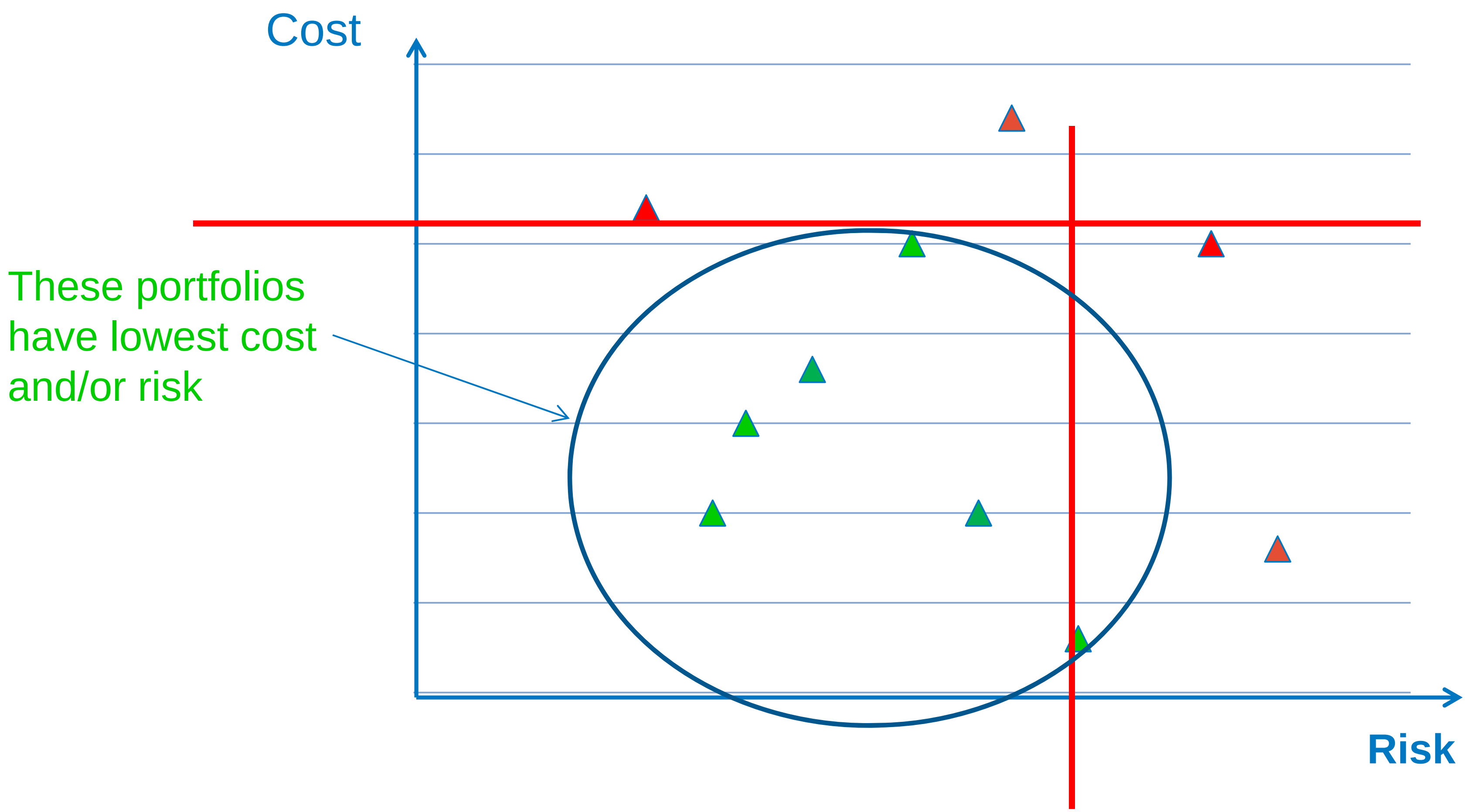
PHASE 3

Best Portfolios

Selection of preferred portfolio

Action Plan

Phase 1 screen



Phase 1

- Purpose: Compare relative performance of portfolios' cost and risk

Cost

NPVRR of reference case

Expected NPVRR

Risk

Semi variance of NPVRR> reference case

Standard deviation

Phase 2

In this screen, portfolios are evaluated based on their performance across a list of values-metrics identified as important by stakeholders and PGE.

These values are classified in the following categories:

- Environmental: CO_2/SO_x/NO_x emissions, Water use
- Risk: Variability, severity
- Reliability: TailVar90,EUE
- Long/short term cost
- Technology: optionality, modularity, diversity
- Energy market exposure

How do we translate these values into metrics?

Environmental

Value	Definition	Formula
Emissions	Emissions of CO_2,SO_x and NO_x of a portfolio across futures	Average annual emissions (tons/year)
Water consumption	Water consumption of a portfolio, mainly for cooling	Average annual water consumption (gallons/year)

Risk

Value	Definition	Formula
Severity	Highest potential cost futures of a portfolio	Average top 10% highest NPVRR across futures ($)
Variability	Change of a portfolio cost across futures	Standard deviation of NPVRR across futures / semi variance ($)

How do we translate these values into metrics?

Cost

Value	Definition	Formula
Short term cost	Cost of the portfolio in the first 5 years	NPVRR of reference case / or expected NPVRR [5 years]
Long term cost	Cost of the portfolio in the first 20 years	NPVRR of reference case / or expected NPVRR [20 years]
Long term cost	Cost of the portfolio in the study horizon of 33 years	NPVRR of reference case / or expected NPVRR [33 years]

Technology

Value	Definition	Formula
Diversity	Reflect the diversity of the resource types in the portfolio in 2025	Sum(Wi*SIGMAi)/SIGMAi
Optionality	*These 2 values were mentioned by stakeholders repeatedly. What do optionality and modularity mean for you? How would you translate these into metrics*	
Incrementalism		

How do we translate these values into metrics?

Reliability

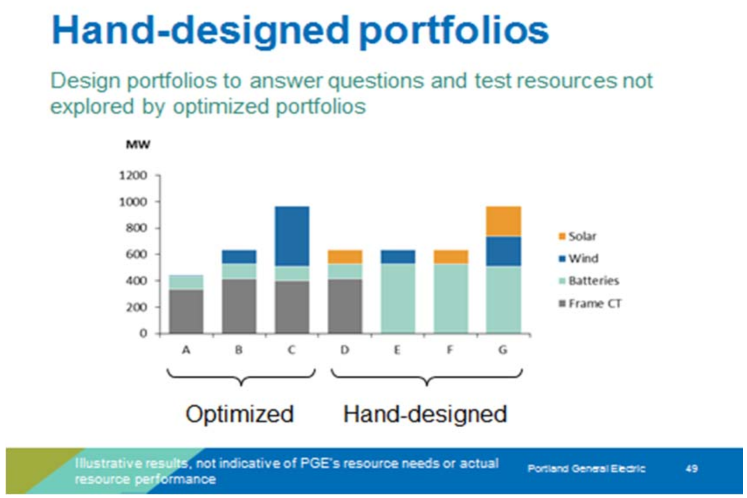
Value	Definition	Formula
TailVar 90	Worst 10th percentile Loss of Load events	TailVar 90 of loss of load events
EUE	Expected Unserved Energy	Average MW across all loss of load events

Energy Market exposure

Value	Definition	Formula
Energy market exposure	Portfolio reliance on market purchases	Market purchases minus market sales

Mock example

❖To show what Phase 2 of the scoring process looks like, we apply some of the defined metrics on the mock portfolios A though H which were described above in the Portfolio Construction section.



❖We use a heat map representation to show the relative performance of each portfolio in a specific metric.

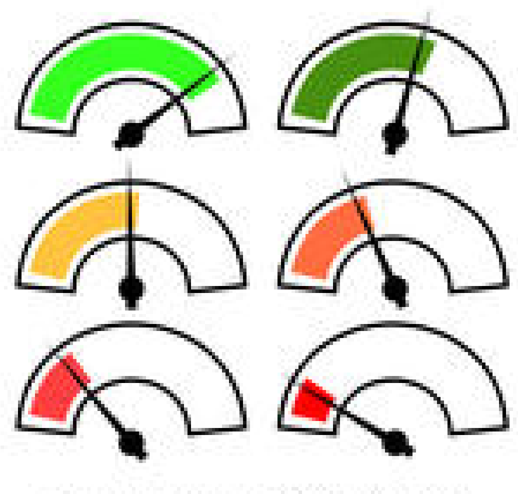
Mock example results

Ranking portfolios by category

Category	Metric	A	B	C	D	E	F	G	H
		Mock Portfolios Ranks							
Short/long-term cost	33 years	2	3	7	4	5	6	8	1
	20 years	2	3	7	4	5	6	8	1
	5 years	2	3	7	4	5	6	8	1
Risk	Variability/ standard deviation	5	6	2	4	8	7	3	1
	Severity	2	3	7	4	5	6	8	1
Environmental	CO2	5	7	2	6	4	3	1	8
	SOx	5	7	2	6	4	3	1	8
	NOx	5	7	2	6	4	3	1	8
	Water use	5	7	2	6	4	3	1	8
Technology	Diversity	7	3	1	5	4	8	2	6

Stakeholders feedback and next steps

- General feedback on scoring framework
- What metrics to use for cost and risk?
- Feedback on value metrics definition and formula



Next steps:

- Finalize scoring framework and list of metrics
- Technical meeting in July/August to discuss portfolio ranking results processing

Decarbonization Study

Role in 2019 IRP

Elaine Hart

PGE's Decarbonization Study

- PGE requested and received acknowledgement of a Decarbonization Study from the OPUC in the 2016 IRP and engaged Evolved Energy Research (EER) in 2017 to conduct the study
- Study developed economy-wide decarbonization pathways across PGE's service area (including transportation and non-electric end uses)
- PGE commissioned the study to address key questions**:**
  - How might energy services be met in PGE's service area in a decarbonized future?
  - What are the implications for PGE's electricity demand – both magnitude and shape?
  - How much renewable infrastructure will be needed to support economy-wide decarbonization?
  - What might energy (not just electricity) costs look like for our customers?

Study principles

- Study assumes natural rollover of energy infrastructure – appliances and vehicles replaced upon end of useful life
- Technology adoption rates are exogenous and selected to meet 2050 goal, do not represent market forecasts
- Study assumes no specific policies to affect technology adoption
- Study assumes no structural change to the demand for energy services
- Scenarios provide insights via comparison, are not forecasts

Deep Decarbonization Pathways Investigated

High Electrification

Fossil fuel consumption is reduced by electrifying end-uses to the extent possible and increasing renewable electricity generation

Low Electrification

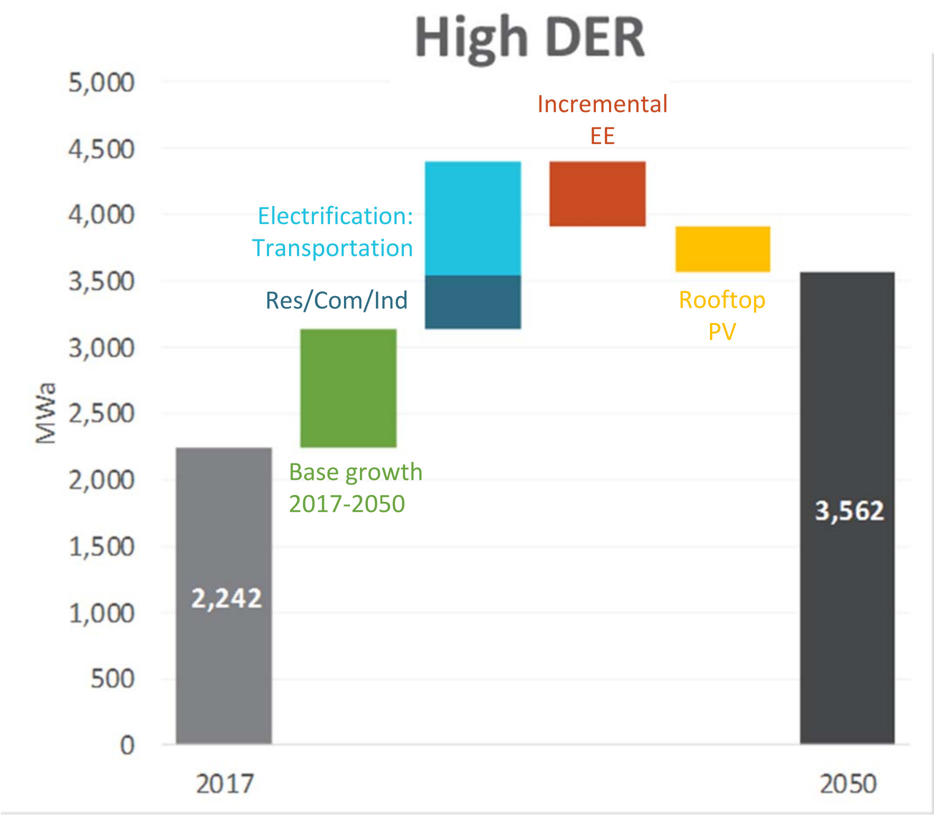
Greater use of renewable fuels, notably biofuels and synthetic electric fuels, to satisfy energy demand and reduce emissions

High DER

Distributed energy resources proliferate in homes and businesses, which also realize higher levels of electrification

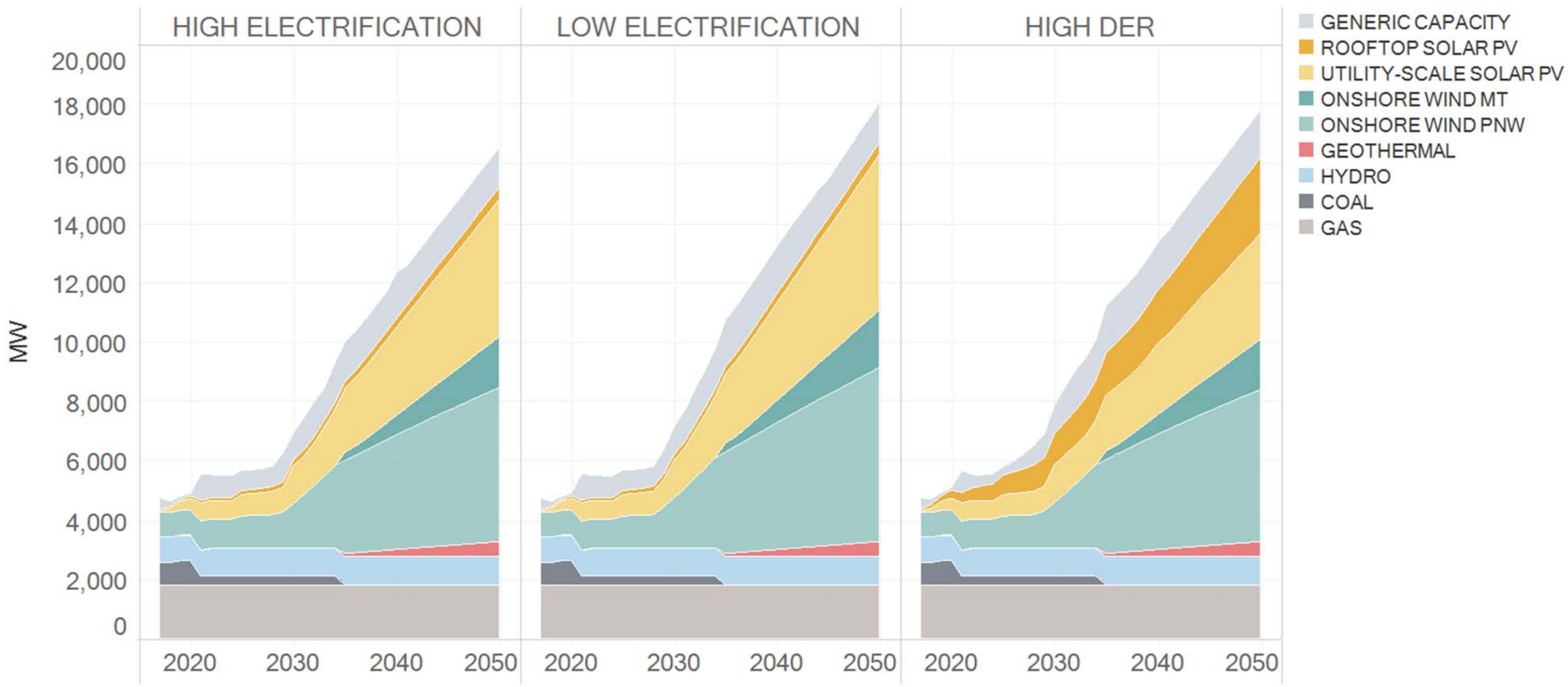
Load impacts of electrification

Electricity use grows to fuel new clean end uses, like electric vehicles, heat pumps, and/or synthetic fuel production



Renewable development

Average renewable capacity additions are approximately 600 MW per year between 2030 and 2050



Decarbonization Takeaways

- Meeting 2050 GHG goal across the economy in PGE's service area is possible, but will require transformative changes in how we use, produce, and deliver energy
- Transformation of the energy economy will rely on:
  - Both consumer and producer participation
  - New energy infrastructure, including massive investment in renewable resources
  - Timely planning and cross-jurisdictional coordination to reduce barriers to implementation
- New sources of flexibility (e.g., energy storage and flexible loads) can complement traditional sources of flexibility (hydro and thermal) to ensure renewables are efficiently integrated
  - Flexible EV charging and flexible water heaters show particular promise under the electrification pathways

Stakeholder Feedback

- How can PGE make best use of the insights in the Decarbonization Study in the IRP process?
  - Use as motivation for improved treatment of new technologies?
    - Explicitly account for non-linear electric vehicle adoption forecasts?
  - Use Decarbonization Scenarios as sensitivities?
    - Load levels
    - Renewable requirements
    - Test if near-term actions are consistent with long-term needs under Decarbonization Scenarios?
  - Other ideas?

Wrap up

Franco