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
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

Upcoming Meetings:
July 11, 2018
August 22, 2018
November 14, 2018

Target filing mid–2019

Q1 (2018)  Q2     Q3     Q4     Q1 (2019)  Q2

Analysis

- Futures & Uncertainty
- Resource Needs
- New Resource Options
- Flexibility Analysis
- Create Portfolios
- Market Price Simulations
- Portfolio Evaluation & Scoring

Action Plan
Draft IRP
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

- Changing Commercial Landscape
- Efficiency Gains
- Economic Recession
- Changing End Uses
- Consumer Preferences
- Increased Availability of Data
- Rooftop Solar PV
- Emerging Uses (Data Center, Block Chain)
- Response to Warming
- Increased Availability of Data
- Portland General Electric
Recent Load Forecast Research

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

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

- 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’

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:

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<thead>
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</thead>
<tbody>
<tr>
<td>Residential</td>
<td>1.7%</td>
<td>0.5%</td>
<td>1.5%</td>
<td>0.0%</td>
<td>1.7%</td>
<td>0.3%</td>
<td>1.5%</td>
<td>1.2%</td>
<td>1.9%</td>
<td>1.5%</td>
<td>1.7%</td>
<td>0.1%</td>
</tr>
<tr>
<td>Commercial</td>
<td>1.7%</td>
<td>0.4%</td>
<td>2.0%</td>
<td>1.4%</td>
<td>2.1%</td>
<td>1.9%</td>
<td>1.3%</td>
<td>0.6%</td>
<td>1.6%</td>
<td>0.8%</td>
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<td>2.0%</td>
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<td>Industrial</td>
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<td>0.7%</td>
<td>3.2%</td>
<td>4.5%</td>
<td>4.4%</td>
<td>8.8%</td>
<td>3.4%</td>
<td>0.5%</td>
<td>3.0%</td>
<td>2.8%</td>
<td>3.3%</td>
<td>2.7%</td>
</tr>
<tr>
<td>System</td>
<td>NA</td>
<td>0.5%</td>
<td>1.6%</td>
<td>1.5%</td>
<td>1.5%</td>
<td>2.5%</td>
<td>1.3%</td>
<td>0.6%</td>
<td>1.9%</td>
<td>1.5%</td>
<td>1.6%</td>
<td>1.4%</td>
</tr>
</tbody>
</table>

* Table shows mean absolute percentage error (MAPE)

PGE has **outperformed industry peers** 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.
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.
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.
# Probabilistic forecasts

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

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

<table>
<thead>
<tr>
<th>Forecast sector</th>
<th>Partial list of drivers considered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>• Employment&lt;br&gt;• Population (Oregon, county)&lt;br&gt;• Personal income&lt;br&gt;• Weather&lt;br&gt;• Energy Trust energy efficiency measures</td>
</tr>
<tr>
<td>Commercial</td>
<td>• Employment&lt;br&gt;• Population (Oregon, county)&lt;br&gt;• Weather&lt;br&gt;• Energy Trust energy efficiency measures</td>
</tr>
<tr>
<td>Industrial</td>
<td>• US GDP&lt;br&gt;• US Industrial Production Index&lt;br&gt;• Oregon GDP&lt;br&gt;• Employment&lt;br&gt;• Energy Trust energy efficiency measures</td>
</tr>
</tbody>
</table>
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).
Weather Dependence

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

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

Oregon population average annual growth, 2023-2030 : 1.1%
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

<table>
<thead>
<tr>
<th>Average annual growth rates, 2023 – 2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
</tr>
<tr>
<td>Base case</td>
</tr>
<tr>
<td>High growth</td>
</tr>
<tr>
<td>Low growth</td>
</tr>
</tbody>
</table>

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%

Average annual growth rates, 2023-2030
2016 IRP: 1.0%
Prelim. 2019 IRP: 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

<table>
<thead>
<tr>
<th></th>
<th>Employment</th>
<th>Commercial deliveries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base case</td>
<td>0.6%</td>
<td>0.6%</td>
</tr>
<tr>
<td>High growth</td>
<td>1.2%</td>
<td>1.1%</td>
</tr>
<tr>
<td>Low growth</td>
<td>0.0%</td>
<td>0.1%</td>
</tr>
</tbody>
</table>

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%.
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 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

Average annual growth rates, 2023-2030

- 2016 IRP: 0.6%
- Prelim. 2019 IRP: 0.2%
Industrial model

Forecast and high/low economic scenarios

Average annual growth rates, 2023 – 2030

<table>
<thead>
<tr>
<th></th>
<th>GDP</th>
<th>Industrial deliveries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base case</td>
<td>1.8%</td>
<td>1.9%</td>
</tr>
<tr>
<td>High growth</td>
<td>2.2%</td>
<td>2.1%</td>
</tr>
<tr>
<td>Low growth</td>
<td>1.4%</td>
<td>1.7%</td>
</tr>
</tbody>
</table>

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%.
Weather Dependence

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

Winter Peak

Summer Peak

MW

2019 IRP Base Case  2016 IRP Update  Actual
Preliminary Seasonal Peak Demand Model

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

**Winter Peak**

**Summer Peak**

<table>
<thead>
<tr>
<th>Year</th>
<th>2019 IRP Base Case</th>
<th>2016 IRP Update</th>
<th>Actual</th>
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<tbody>
<tr>
<td>2019</td>
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<tr>
<td>2020</td>
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<td>2030</td>
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</table>
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.

Uncertainty Inputs in Portfolio Construction

- Multiple uncertainties
- Grouping
- Prioritize
- Boundaries

Portfolio Construction
- Upper/lower bounds
- Key cases

Roundtable 18-1, 2018.02.14, Slide 8
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\textsubscript{2}, and reference assumptions for all other variables)
Portfolio Analysis and Evaluation

Aurora
- Wholesale Market Prices
- Variable Cost and Revenue

ROSE-E
- Portfolio Construction (Optimized or Hand Designed)

Evaluation
- Score, Screen, Compare

Other
## CO₂ Prices

<table>
<thead>
<tr>
<th>Variable</th>
<th>Aurora</th>
<th>ROSE-E</th>
<th>Evaluation</th>
<th>Other</th>
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</thead>
<tbody>
<tr>
<td>CO₂ Prices</td>
<td>Low Ref High</td>
<td>Low Ref High</td>
<td>Low Ref High</td>
<td>Sensitivities of no new CO₂ pricing and emission cap</td>
</tr>
</tbody>
</table>

- 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 CO₂ 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 CO₂ legislation (other price variables in reference condition).

- Examine the impact of PGE portfolio CO₂ constraints as a sensitivity in portfolio development (ROSE-E). [Not a pricing variable.]
Natural Gas Prices

<table>
<thead>
<tr>
<th>Variable</th>
<th>Aurora</th>
<th>ROSE-E</th>
<th>Evaluation</th>
<th>Other</th>
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<td>Low Ref High</td>
<td>Low Ref High</td>
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</tr>
</tbody>
</table>

- 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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Aurora</th>
<th>ROSE-E</th>
<th>Evaluation</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>PNW Hydro Generation</td>
<td>Low Ref</td>
<td>Low Ref</td>
<td>Low Ref</td>
<td></td>
</tr>
</tbody>
</table>

- 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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Aurora</th>
<th>ROSE-E</th>
<th>Evaluation</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>WECC-wide Renewables</td>
<td>Ref High</td>
<td>Ref High</td>
<td>Ref High</td>
<td></td>
</tr>
</tbody>
</table>

- 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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Aurora</th>
<th>ROSE-E</th>
<th>Evaluation</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>PGE Need</td>
<td>Low Ref High</td>
<td>Low Ref High</td>
<td></td>
<td>Sensitivities for need assessments</td>
</tr>
</tbody>
</table>

- 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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Aurora</th>
<th>ROSE-E</th>
<th>Evaluation</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar &amp; Storage Cap Cost</td>
<td>Low Ref High</td>
<td>Low Ref High</td>
<td>Low Ref High</td>
<td></td>
</tr>
<tr>
<td>Wind Cap Cost</td>
<td>Low Ref High</td>
<td>Low Ref High</td>
<td>Low Ref High</td>
<td></td>
</tr>
</tbody>
</table>

- 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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Aurora</th>
<th>ROSE-E</th>
<th>Evaluation</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Financial</td>
<td></td>
<td></td>
<td></td>
<td>Sensitivities for top portfolios</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Aurora</th>
<th>ROSE-E</th>
<th>Evaluation</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO(_2) Prices</td>
<td>Low Ref High</td>
<td>Low Ref High</td>
<td>Low Ref High</td>
<td>Sensitivities of no new CO(_2) pricing and emission cap</td>
</tr>
<tr>
<td>Natural Gas Prices</td>
<td>Low Ref High</td>
<td>Low Ref High</td>
<td>Low Ref High</td>
<td></td>
</tr>
<tr>
<td>Hydro Output</td>
<td>Low Ref High</td>
<td>Low Ref High</td>
<td>Low Ref High</td>
<td></td>
</tr>
<tr>
<td>WECC- Wide Renewables</td>
<td>Ref High</td>
<td>Ref High</td>
<td>Ref High</td>
<td></td>
</tr>
<tr>
<td>PGE Need</td>
<td></td>
<td>Low Ref High</td>
<td>Low Ref High</td>
<td>Sensitivities for need assessments</td>
</tr>
<tr>
<td>Solar &amp; Storage Capital Costs</td>
<td>Low Ref High</td>
<td>Low Ref High</td>
<td>Low Ref High</td>
<td></td>
</tr>
<tr>
<td>Wind Cap. Costs</td>
<td></td>
<td>Low Ref High</td>
<td>Low Ref High</td>
<td></td>
</tr>
<tr>
<td>Financial</td>
<td></td>
<td></td>
<td></td>
<td>Sensitivities for top portfolios</td>
</tr>
</tbody>
</table>
Examining many conditions . . .

<table>
<thead>
<tr>
<th>IRP</th>
<th>Aurora</th>
<th>ROSE-E</th>
<th>Evaluation</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016 IRP</td>
<td>27 price futures</td>
<td>NA</td>
<td>21 price futures 5 sensitivities</td>
<td>Sensitivities of hydro, capital cost, capacity factor</td>
</tr>
<tr>
<td>2019 IRP</td>
<td>54 price futures</td>
<td>486?</td>
<td>1458?</td>
<td>Sensitivities for CO2, Need, Financial</td>
</tr>
</tbody>
</table>

. . . 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

Illustrative results, not indicative of PGE’s resource needs or actual resource performance
Optimized Portfolios

2. Minimize NPVRR in High Tech Case

Illustrative results, not indicative of PGE’s resource needs or actual resource performance
Optimized Portfolios

3. Minimize NPVRR in Low Tech Case

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

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

Portland General Electric
Optimized Portfolios

4. Minimize Expected NPVRR

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

Illustrative results, not indicative of PGE’s resource needs or actual resource performance
Optimized Portfolios

4. Minimize Expected NPVRR

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

Frame CT

Batteries

Capacity Resources

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?

- 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

PHASE 1
ROSE-E
Screen

PHASE 2
Cost
Risk
Screen

Values

• Environmental: CO₂/SOₓ/NOₓ emissions, Water use
• Risk: Variability, severity
• Reliability: TailVar90,EUE
• Long/short term cost
• Technology: optionality, modularity, diversity
• Energy market exposure

Selection of preferred portfolio

PHASE 3
Action Plan
Best Portfolios
Phase 1 screen

These portfolios have lowest cost and/or risk
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

<table>
<thead>
<tr>
<th>Value</th>
<th>Definition</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emissions</td>
<td>Emissions of CO₂, SOₓ and NOₓ of a portfolio across futures</td>
<td>Average annual emissions (tons/year)</td>
</tr>
<tr>
<td>Water consumption</td>
<td>Water consumption of a portfolio, mainly for cooling</td>
<td>Average annual water consumption (gallons/year)</td>
</tr>
</tbody>
</table>

### Risk

<table>
<thead>
<tr>
<th>Value</th>
<th>Definition</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Severity</td>
<td>Highest potential cost futures of a portfolio</td>
<td>Average top 10% highest NPVRR across futures ($)</td>
</tr>
<tr>
<td>Variability</td>
<td>Change of a portfolio cost across futures</td>
<td>Standard deviation of NPVRR across futures / semi variance ($)</td>
</tr>
</tbody>
</table>
How do we translate these values into metrics?

### Cost

<table>
<thead>
<tr>
<th>Value</th>
<th>Definition</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short term cost</td>
<td>Cost of the portfolio in the first 5 years</td>
<td>NPVRR of reference case / or expected NPVRR [5 years]</td>
</tr>
<tr>
<td>Long term cost</td>
<td>Cost of the portfolio in the first 20 years</td>
<td>NPVRR of reference case / or expected NPVRR [20 years]</td>
</tr>
<tr>
<td>Long term cost</td>
<td>Cost of the portfolio in the study horizon of 33 years</td>
<td>NPVRR of reference case / or expected NPVRR [33 years]</td>
</tr>
</tbody>
</table>

### Technology

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

## Reliability

<table>
<thead>
<tr>
<th>Value</th>
<th>Definition</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>TailVar 90</td>
<td>Worst 10(^{th}) percentile Loss of Load events</td>
<td>TailVar 90 of loss of load events</td>
</tr>
<tr>
<td>EUE</td>
<td>Expected Unserved Energy</td>
<td>Average MW across all loss of load events</td>
</tr>
</tbody>
</table>

## Energy Market exposure

<table>
<thead>
<tr>
<th>Value</th>
<th>Definition</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy market exposure</td>
<td>Portfolio reliance on market purchases</td>
<td>Market purchases minus market sales</td>
</tr>
</tbody>
</table>
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 through 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

<table>
<thead>
<tr>
<th>Category</th>
<th>Metric</th>
<th>Mock Portfolios Ranks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>A</td>
</tr>
<tr>
<td>Short/long-term cost</td>
<td>33 years</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>20 years</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>5 years</td>
<td>2</td>
</tr>
<tr>
<td>Risk</td>
<td>Variability/standard deviation</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Severity</td>
<td>2</td>
</tr>
<tr>
<td>Environmental</td>
<td>CO2</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>SOx</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>NOx</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Water use</td>
<td>5</td>
</tr>
<tr>
<td>Technology</td>
<td>Diversity</td>
<td>7</td>
</tr>
</tbody>
</table>
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