IGP Forecast Assumptions Working Group
Forecast Methodologies

◆ Welcome and Overview 9:00 – 9:10
◆ Forecast Methods (Underlying & DER) 9:10 – 10:05
Break 10:05 – 10:20
◆ Forecast Methods (EE, EoT & Summary) 10:20 – 10:55
◆ Forecast Methods from Other Utilities 10:55 – 11:55
  – ERCOT
  – NV Energy
  – Portland General
  – SMUD
◆ Wrap-up 11:55 – 12:00
It takes a village to raise a forecast.
Our forecast is developed in layers.

Forecast will be further modified by demand response (DR) and controllable DER.
Hawaiian Electric
Maui Electric
Hawai‘i Electric Light

Sales Forecast with Layers

- Recorded Sales % YoY
- Forecast % YoY
- Recorded Sales
- Underlying Forecast
- Forecast with DER
- Forecast with DER & EE
- Forecast with DER & EE & EoT

GWh Sales

YOY % Change


Actual
Forecast
Forecasting Methods

Underlying Forecast
Sales Forecast with Layers

- Recorded Sales % YoY
- Forecast % YoY
- Recorded Sales
- Underlying Forecast
- Forecast with DER
- Forecast with DER & EE
- Forecast with DER & EE & EoT

Hawaiian Electric
Maui Electric
Hawai‘i Electric Light
Underlying Forecast – Energy Sales

◆ Data
  – Historical periods
    – Structural changes
    – Historical disruptions
  – Adjustments and reasons for adjustments
    – Large customer loads
    – Embedded layers
    – Estimated impacts
Forecast Inputs

- Grid Technologies
- Analytical Planning
- Fuels
- Project Mgt
- Renewable Acquisitions
- Customer Billing
- DER
- EoT
- Corporate Energy Planning
- Customer Solutions
- Commercial Account Mgt / Key Account Mgt
- Customer Research
- Financial Analysis
- Annual Business Forums
Underlying Forecast – Energy Sales

Overview of Methods

- Market Analysis, Individual projects
- Customer Service
- Trending
- Econometric
  - External variables, to be discussed in future meeting on assumptions
    - Weather
    - Economic forecast
    - Electricity prices
  - e.g. Sales = f(electricity price, jobs, weather)
Evaluating Relationship Between Sales and External Drivers

- Non-ag Jobs
- GWh
- Cooling Degree Days
- GWh

Hawaiian Electric
Maui Electric
Hawai‘i Electric Light
Multiple Underlying Sales Models

- Historical Underlying
- Econ Option 1
- Econ Option 2
- Econ Option 3
- Econ Option 4
- Econ Option 5

GWh Sales

Underlying Forecast – Load Shapes

- **Hourly Load Shapes**
  - **Shapes**
    - Class Load Studies
    - Total System
  - **Method**
    - Hourly regression models
  - **Hourly Shape Drivers**
    - Seasonality / Calendar (Month)
    - Day of Week / Holiday
    - Weather
Hourly Profile By Class

- Residential
- Small Commercial
- Large Commercial
- St Lighting
- Total
Underlying Forecast – Load Shapes

- **Hourly Load Shapes**
  - Adjustments to underlying
    - Individual large project profiles / energy
    - Layers

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**Hawaiian Electric**
**Maui Electric**
**Hawai‘i Electric Light**
Distributed Energy Resources
Forecast Methods
Sales Forecast with Layers

- Recorded Sales % YoY
- Forecast % YoY
- Recorded Sales
- Underlying Forecast
- Forecast with DER
- Forecast with DER & EE
- Forecast with DER, EE, EE & EoT

GWh Sales

YOY % Change


DER Impact

Hawaiian Electric
Maui Electric
Hawai‘i Electric Light
DER Forecast

- Primary focus is behind the meter PV and battery storage
- Other technologies included on ad hoc basis for known projects
- New additions of capacity in each month by island, rate class and program
- Monthly sales impact
- Hourly load impact
- Future capacity on distribution circuits
Different Methods Used by Utilities

- New Capacity Additions
  - Judgmental
  - Fixed program targets or mandates
  - Trending
  - Bass technology diffusion model
  - Econometric regression
  - Probabilistic regression
  - Economic choice

- Sales and Hourly Load Impact
  - Metered customer-sited PV data
  - NREL estimates
  - Historical bill reductions
Future Capacity Forecast Methods

- **Near to mid-term**
  - Current pace of incoming applications and executed agreements
  - Existing program subscription level and caps
  - Feedback from program administrators and installers
  - Customer input
  - Short-term hurdles (e.g. circuit study, equipment upgrades)

- **Mid to long-term blended method**
  - Bass technology diffusion model
  - Customer economic choice model
  - Judgmental analysis
  - Assumption-driven high adoption
Example Near-Term Capacity Forecast

Monthly DG PV Incremental Capacity Additions

Hawaiian Electric
Maui Electric
Hawai‘i Electric Light
Bass Technology Diffusion Model

- Popular diffusion model to forecast uptake
- Usually used for new technology uptake
  - Historic data either not present or very little of it present
- Uses coefficients that relate to “market”
  - Adoption
  - Innovators & Imitators
  - Market size
- Several methods were explored
  - Diffusion models are limited given where we are with PV adoption
  - Perform poorly when trying to reflect impact of policy and economic changes
  - May be useful to inform allocation of forecast to more granular geographic areas
Introduction of new programs are not captured well, even though the Bass model “sees” this data in the fitting step.
Generalized BASS Model (GBM)

- Wang, et al. attempted to model the PV adoption using GBM.
- Bass function (PDF) transforms from the smoothed fitted curve to something that suggests responds to decision drivers.
Generalized Bass Model - NEM

- GBM appeared to be “promising”
- Still resulted in similar forecasts as Bass.
  - Early historical adoption has surpassed the point of inflection

After including payback decision variable, we can see how the curve appears to fit along the historical executed applications.
Blended ARIMA + Bass: ‘Take-off’

- Based on Christodolous et. Al.
- A ‘take-off’ is the forecast from the GLM + AR/MA and exogenous terms
  - ‘simple payback’
- Designed to lift curve after ITC ended as we did not think adoption would hover close to 0.
**Blended ARIMA + Bass**

- After ‘take-off’ period the model iterates through two-step process
  - Generalized Regression with ARIMA errors used to fit the model initially
  - The last two points are appended for the Bass model
  - The Bass is used to re-calibrate the forecast from ARIMA

The Bass model “pushes” down the forecast from the generalized ARIMA so that we get back to the adoption curve.
Economic choice model

- Analyze historical relationship between adoption rate and economics
  - Dependent variable: Percent of potential PV customers that installed a system each month
  - Primarily driven by economics (savings, costs, payback time)
- Input future projections for economic drivers to get future percent adoption in each year
- New capacity additions derived by incorporating 2 additional key assumptions:
  \[(\% \text{ adoption}) \times (\text{number of potential adopters}) \times (\text{average system size})\]
Economic Choice Model

Percent Adoption

- Post-NEM closure
- Tax credit reductions
- Declining costs over long term

History Fitted Forecast
Number of Adopters and Associated Installed Capacity

- Capacity History
- Capacity Future
- Adopters History
- Adopters Future
# Economic Choice Model

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Challenges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incorporates local historical economics and behavior</td>
<td>Defining proper segmentation and populations of potential participants</td>
</tr>
<tr>
<td>Future payback on investment and remaining pool of customers directly affect forecast</td>
<td>Incorporating demographics</td>
</tr>
<tr>
<td>Responsive to varying assumptions for future economics</td>
<td>Modeling multiple program choices</td>
</tr>
<tr>
<td>Accommodates PV paired with storage</td>
<td>Predicting future disruptions (program closures or launches, technology breakthrough)</td>
</tr>
</tbody>
</table>
Fixed Endpoint Method

◆ Assume certain conditions at end of forecast horizon

◆ An example:
  – Single-family homes achieve net-zero
  – Participating commercial sectors mirror historical participation, but at a much higher penetration
  – Not driven or limited by cost-effectiveness of projects
  – Straight-line growth from the end of near-term forecast to end of forecast horizon
Sales Impact & Hourly Shape Method

- Method to estimate solar resource
- Historical island-wide satellite imagery provides gridded hourly irradiance
  - Weighted based on where PV is installed
  - Weighted hourly irradiance converted to unitized PV generation and monthly capacity factors
- Historical data used to create future capacity factors and hourly shapes
- Battery storage load shifting derived from hourly energy balancing of customer load, PV generation and storage
Full Forecast Period PV Shape
Time for a break
IGP Forecast Assumptions Working Group
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- Wrap-up 11:55 – 12:00
Energy Efficiency Forecast

- Hawaii Energy’s plans for the near term forecast (1–3 years)
- Longer term forecast will be based on Applied Energy Group’s (“AEG”) EEPS potential study and will consider:
  - Customer segmentation
  - Technologies and measures
  - Appliance standards and building codes
  - Hourly analysis
  - Study available in September

- Sensitivity analysis will be performed following discussions with the FAWG and AEG
Example of end-use mapped to facility type and rate

<table>
<thead>
<tr>
<th>EE End-Use Type</th>
<th>EE End-Use Facility</th>
<th>Rate Class</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Residential (Individual Meter)</td>
<td>R</td>
</tr>
<tr>
<td>Lighting</td>
<td>Office/Misc. Commercial</td>
<td>G</td>
</tr>
<tr>
<td></td>
<td>Retail and Food Services</td>
<td>J</td>
</tr>
<tr>
<td>HVAC</td>
<td>Hotel</td>
<td>P</td>
</tr>
<tr>
<td>Water Heating</td>
<td>Education</td>
<td></td>
</tr>
<tr>
<td>Refrigeration</td>
<td>Others</td>
<td></td>
</tr>
<tr>
<td>Appliances</td>
<td>Others - essential (Individual Meter)</td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>Others - essential (Individual Meter)</td>
<td></td>
</tr>
</tbody>
</table>

Percentage distribution:
- Lighting: 81%
- HVAC: 11%
- Water Heating: 3%
- Refrigeration: 2%
- Appliances: 1%
- Others: 1%
Load profiles for each facility type are used to identify operating hours.

Typical energy efficiency load profile for large office buildings:
Forecast Methods
Electric Vehicle Forecasting
1. Forecasting Number of Electric LDV on the Road

2. Sales & Demand Impacts from EV Charging
1. Electric Vehicle Forecast

**Bass Model** (Top-Down Model --- *Macro*)
1. Vehicle Cost (EV and ICEV)
2. Vehicle Fuel Economy (EV and ICEV)
3. Number of Charging Ports
4. Discount (Tax Credit/Rebate)
5. Electricity Price
6. Gasoline Price
7. Income
8. Number of PV Installations

**Agent-Based Model (ABM)** (Bottom-Up Model --- *Spatial*)
1. Innovation Parameter
2. Imitation Parameter
3. Housing Characteristics
4. Commuting Patterns
5. Road Accessibility
6. Energy Consumption

% EV Saturation of Total LDVs to 2035
- Historic: 0%
- Forecast: 18%

Historic by-product

Total LDV Forecast
- 2018: 0
- 2020: 100,000
- 2022: 200,000
- 2024: 300,000
- 2026: 400,000
- 2028: 500,000

EV Count Forecast
- 2018: 0
- 2020: 50,000
- 2022: 100,000
- 2024: 150,000
- 2026: 200,000
- 2028: 250,000

Spatially Distributed Customer Adoption
- 2018: 500,000
- 2020: 600,000
- 2022: 700,000
- 2024: 800,000
- 2026: 900,000

Historic Forecast
- % EV Saturation of Total LDVs to 2045
- 2018: 0%
- 2020: 3%
- 2022: 6%
- 2024: 9%
- 2026: 12%
- 2028: 15%
- 2030: 18%

**By-product**
2. EV Charging Profiles

Inputs & Assumptions

I. Vehicle Miles Traveled ("VMT") & Energy Used per Vehicle
II. Charging Segmentation
III. Shapes of Charging Profiles
I. Vehicle Miles Traveled & Energy Used per Vehicle

**VMT**
- **Annual VMT By County** (DBEDT)
- **Historical** = Annual VMT by County
- **Forecast** = Apply 1.01% CAGR from 2015-2035 and 0.71% from 2015-2045 (FHWA)

**kWh/mile**
- **County’s EV Sales by Vehicle Models** (Polk/EPRI)
- **Historical** = Weighted average kWh/mile of most popular types of EVs
- **Forecast** = Apply growth rate from EIA reference case fuel economy forecast of 100 mile EV

**Annual kWh per Vehicle** = \[rac{\text{Annual VMT} \times (\text{kWh/m}) \times 10^6}{\text{Total Vehicle Forecast}}\]
II. Charging Segmentation

- Residential
  - Home Chargers
  - Public Charging Stations
  - Workplace Charging Stations

- Commercial
  - Place of Business
  - Public Charging
  - Workplace Charging
  - Fleet Day Operation
  - Fleet Night Operation
  - Fleet 24hr Operation

Vehicle Ownership (Own/Lease/Rent)
Place of Charging/Charging Options
Types of Charging Profiles
Types of Meters
Rate Schedules
III. Average Charging Profiles

TOU 10pm
- Weekday
- Weekend

Non TOU
- Weekday
- Weekend

Workplace
- Weekday
- Weekend

R-Public
- Weekday
- Weekend

C-Public
- Weekday
- Weekend

C-Day
- Weekday
- Weekend

C-Night & 24hr
- Weekday
- Weekend

TOU-Day
- Weekday
- Weekend

TOU_12am
- Weekday
- Weekend
Electric Bus Forecasting
Method

Collaborative discussions to gather preliminary assumptions on future state of EV Bus fleets.

Data analysis and forecasting to determine potential impact to sales and hourly load demands.

Generate ideas between partners to develop charging rates to align impact to customers’ bills with grid needs.
Representative blend of major types of buses evaluated in Hawaii.

- Shuttle services; tourism market
- Oahu mass transit system
- Public school bus transportation
- Airport terminal and Consolidated Rental Car Facility (CONRAC) shuttle system
Assumptions were developed by considering multiple factors.

- Route Information
  Miles traveled

- Location of chargers
  (bulk/opportunity)

- Operating Hours

- Technical Specifications
  (Battery size, charging rate, kWh/mi.)
Charging shapes were then developed

- Utilizing unitized charging profiles from light duty vehicle forecast.
- Raw profiles blended to create a starting point for e-bus charging.
- Energy used for charging is placed under the charging curve.
- Long-term forecasts were developed by weekday, weekend and holidays for each bus operator to assess load and impact to peaks by circuit.
Buses pull-out for morning express and regular routes. (start-of-day)

Day charge opportunity mainly express buses pulling in from morning shift.

Buses start to pull-out for evening express routes.

Buses pulling in to depot. (end-of-day)

Buses on non-express routes will also do interval charging.

Buses start regular routes. (start-of-day)

Buses mainly on road with some interval charging.

Buses pulling in to depot and will charge in early morning hours. (end-of-day)

Electric Bus Charging Profile Example

24 hour EV charging profile; weekend vs. weekday

Hawaiian Electric
Maui Electric
Hawai‘i Electric Light
Forecasting Methods
Hourly Forecast
Hourly Shape Method

- **Determine Class Shapes**
  - Class load study hourly shapes by rate class, no impact of PV
  - Hourly regression models using independent variables: weather, month, day of the week, holidays
  - Simulate future shapes for each rate class with independent variable assumptions

- **Layers**
  - Layer shapes: DER (PV), Battery load shift, EE, EoT, future layers?
  - Possible to have multiple shapes by layer

- **Future Hourly System Load**
  - Input: monthly energy, future load shapes, loss factor
  - Result: hourly net system load for entire forecast period
Hourly Profile By Layer
Hourly Profile By Layer

Week Of September 22, 2024

Hawaiian Electric
Maui Electric
Hawai’i Electric Light
Hourly System Load Over Forecast Horizon
IGP Forecast Assumptions Working Group
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• Assemble Panel Discussion on Preliminary Economic Outlook Meetings Assumptions, Sensitivities & Scenarios Review Tentative: August 27

Update Forecast as Needed

Economic Outlook Meetings

Assemble Working Group

Kick-Off Meeting March 13

Panel Discussion on DER, EE, EoT May 22 and 23

Forecast Methods

Preliminary Forecast

Finalize Forecast
Scenario Based Long-Term Load Forecasting

Calvin Opheim

July 17, 2019
Forecasting Assumptions Working Group
Agenda

• History
• Scenario based forecasting
• 2018 Long-Term System Assessment (LTSA)
• Questions
Past

- Load forecasting was generally straightforward.
- Could forecast pretty much with a linear regression.
GDP VS. ELECTRIC RELATIONSHIP

Index Comparison
GDP vs Electric Consumption

- Slow breakdown of GDP/Electric relationship
- Divergent since 2010
Past

• The breakdown or divergence between energy forecasts and economic variables was initially branded as the “job less” economic recovery
Today

• Other forces are impacting load forecasting
  – Roof top PV
  – Electric Vehicles
  – Batteries
  – Smart devices

• How do we account for all of these?
Scenario Based Forecasting

• A DOE project was funded for the ERCOT region in 2010
  – To improve its capability to conduct long-range transmission planning
  – Develop more rigorous long-term plans that reflect the diverse views of the stakeholder community
Scenario Based Forecasting

• ERCOT expanded the study period from 10 to 20 years
  – Because longer-term forecasts are more uncertain, ERCOT examined numerous scenarios to capture a broad range of possible futures
  – Develop more rigorous long-term plans that reflect the diverse views of the stakeholder community
Long-Term System Assessment (LTSA)

• Scenarios
  – Created in a collaborative manner through meetings with Market Participants
  – Include load impacts such as high growth industries and areas, rooftop PV, energy storage, electric vehicles, demand response, energy efficiency, extreme weather, recession, etc.
  – Fuel/technology prices, environmental regulations, capital costs, DC Tie additions, etc.
Long-Term System Assessment (LTSA)

- The results were not definitive statements of what ERCOT expected to happen but rather what might happen in the future
The Long-Term System Assessment (LTSA) is a planning study conducted by ERCOT System Planning per its obligation under PURA Section 39.904[1] and the ERCOT Planning Guide. The LTSA analyzes system conditions 10 to 15 years in the future and uses a scenario-based approach to transmission planning, in which ERCOT Planners study the economic and reliability needs of the system across a wide range of scenarios.
Long-Term System Assessment (LTSA)

• Planners may use the bases cases developed in this study to evaluate large transmission additions to the ERCOT System. Additionally, the study will help facilitate communication and understanding of long-term transmission needs among stakeholders.

• Primary focus is on the 345 kV system
Long-Term System Assessment (LTSA)

- Section 39.904(k) of the Public Utility Regulatory Act states that the commission and the independent organization certified for ERCOT shall study the need for increased transmission and generation capacity throughout this state and report to the legislature the results of the study and any recommendations for legislation. The report must be filed with the legislature not later than December 31 of each even-numbered year.
2018 LTSA Scenarios

- Current Trends
- High Renewable and Distributed PV Growth
- High Economic Growth
- High Renewable Costs
- Emerging Technology
1. Scenario: Current Trends

Economic Growth
• 1.3% annual net of all factors affecting the system
• Industrial growth in Houston area
• Oil and gas and mid-stream development in west Texas area continues at moderate pace
• Average GDP growth in line with long-term average
• LNG growth based on permits existing
• Average weather assumptions used

Technology
• No breakthroughs – steady modest cost improvements
• Only known potential DC tie (Southern Cross) added in the East

Environmental Regulation
• Ozone, SO2 (NAAQs)- Implementing Current Regulations through 2025, SO2 non-attainment area
• Low emission cost on SO2, NOx, CO2
• 10$/ton Carbon throughout study horizon

Government policy/mandate
• No reserve margin set for ERCOT
• Maintain energy-only market
• Economic retirements continues based on economics

End-Use
• Energy efficiency spending rises slowly to a rate of 0.25%/year
• Distributed generation increases to 2.5 GW by 2033
• Moderate increase in Demand Response

Alternative Generation
• Renewable incentives expire as scheduled (2022)
• Increase in investment then slow to declining in rate of increase after 2022
• Limit capacity addition to 3000 MW wind and 1500 MW of solar annually
• Use Lazard assumptions for Storage

Natural Gas Price
• 2017 High Oil & Gas Production case from the 2017 EIA AEO
2. Scenario: High Renewable and Distributed PV Penetration

**Economic Growth**
- 1.3% annual net of all factors affecting the system
- Industrial growth in Houston area
- Oil and gas and mid-stream development in west Texas area continues at moderate pace
- Average GDP growth in line with long-term average
- LNG growth based on permits existing
- Average weather assumptions used

**Environmental Regulation**
- Ozone, SO2 (NAAQs) - Implementing Current Regulations through 2025, SO2 non-attainment area
- Low emission cost on SO2, NOx, CO2
- 20$-40$/ton Carbon throughout study horizon

**Technology**
- No breakthroughs – steady modest cost improvements
- Only known potential DC tie (Southern Cross) added in the East

**Government policy/mandate**
- No reserve margin set for ERCOT
- Maintain energy-only market
- Economic retirements continues based on economics

**End-Use**
- Energy efficiency spending rises to a rate of 1%/year due to more aggressive building codes
- Distributed generation increases to 18 GW by 2033
- Moderate increase in Demand Response

**Alternative Generation**
- Renewable incentives continue through the study horizon
- Increase in investment then slow to declining in rate of increase after 2022
- Increase capacity addition to value greater than Current Trends

**Natural Gas Price**
- 2017 High Oil Production case from the 2017 EIA AEO
3. Scenario: High Economic Growth

**Economic Growth**
- 1.8% annual net of all factors affecting the system
- Higher Industrial growth in Houston area (Gulf coast block load additions of 200 MW every 5 years)
- Oil and gas and mid-stream development in west Texas area picks up steam (at 1000 MW by 2018)
- Average GDP growth in line with long-term average
- LNG growth continues (4th train at Freeport, New terminal in Corpus Christi (500 MW) and Brownsville area (800 MW)

**Environmental Regulation**
- Ozone, SO2 (NAAQs)- Implementing Current Regulations through 2025, SO2 non-attainment area
- Low emission cost on SO2, NOx, CO2
- 10$/ton Carbon throughout study horizon

**Technology**
- No breakthroughs – steady modest cost improvements
- Only known potential DC tie (Southern Cross) added in the East

**Government policy/mandate**
- No reserve margin set for ERCOT
- Maintain energy-only market
- Economic retirements continues based on economics

**End-Use**
- Energy efficiency spending rises slowly to a rate of 0.25%/year
- Distributed generation increases to 3 GW by 2033 (slightly higher than Current Trends)
- Moderate increase in Demand Response

**Alternative Generation**
- Renewable incentives expire as scheduled (2022)
- Lower capital cost than Current Trends
- Limit capacity addition to lower than Current Trends
- Use Lazard assumptions for Storage

**Natural Gas Price**
- Higher than Current Trends
- Average of 2017 Ref and HOG case from the 2017 EIA AEO
4. Scenario: High Renewable Costs

**Economic Growth**
- 1.3% annual net of all factors affecting the system
- Industrial growth in Houston area
- Oil and gas and mid-stream development in west Texas area continues at moderate pace
- Average GDP growth in line with long-term average
- LNG growth based on permits existing
- Average weather assumptions used

**Technology**
- No breakthroughs – steady modest cost improvements
- Only known potential DC tie (Southern Cross) added in the East

**Environmental Regulation**
- Ozone, SO2 (NAAQs)- Implementing Current Regulations through 2025, SO2 non-attainment area
- Low emission cost on SO2, NOx, CO2
- 10$/ton Carbon throughout study horizon

**Government policy/mandate**
- No reserve margin set for ERCOT
- Maintain energy-only market
- Economic retirements continues based on economics

**End-Use**
- Energy efficiency spending rises slowly to a rate of 0.25%/year
- Distributed generation lower than Current Trends
- Moderate increase in Demand Response

**Alternative Generation**
- Renewable incentives expire sooner than Current Trends
- Capital costs higher than Current Trends; especially for Solar based on a potential import tariff
- Limit capacity addition to 3000 MW wind and 1500 MW of solar annually

**Natural Gas Price**
- 2017 High Oil Production case from the 2017 EIA AEO
5. Scenario: Emerging Technology

**Economic Growth**
- 1.3% annual net of all factors affecting the system
- Industrial growth in Houston area
- Oil and gas and mid-stream development in west Texas area continues at moderate pace
- Average GDP growth in line with long-term average
- LNG growth based on permits existing
- Average weather assumptions used

**Environmental Regulation**
- Ozone, SO2 (NAAQs): Implementing Current Regulations through 2025, SO2 non-attainment area
- Low emission cost on SO2, NOx, CO2
- 10$/ton Carbon throughout study horizon

**Alternative Generation**
- Renewable incentives expire as scheduled (2022)
- Increase in storage, some co-located with renewable generation
- Increase in investment then slow to declining in rate of increase after 2022
- Limit capacity addition to 3000 MW wind and 1500 MW of solar annually
- Use Lazard assumptions for Storage

**Technology**
- EV penetration of 3 million vehicles on Texas roads by 2033. Some with vehicle to grid enabled
- Second-life EV batteries installed in residential locations
- Only known potential DC tie (Southern Cross) added in the East

**Government policy/mandate**
- No reserve margin set for ERCOT
- Maintain energy-only market
- Economic retirements continues based on economics

**End-Use**
- Energy efficiency spending rises slowly to a rate of 0.25%/year
- Distributed generation increases greater than Current Trends by 2033
- Moderate increase in Demand Response

**Natural Gas Price**
- 2017 High Oil Production case from the 2017 EIA AEO
## 2018 LTSA Scenario Summary

<table>
<thead>
<tr>
<th>Category</th>
<th>Assumption</th>
<th>Scenario 1</th>
<th>Scenario 2</th>
<th>Scenario 3</th>
<th>Scenario 4</th>
<th>Scenario 5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>General</strong></td>
<td></td>
<td></td>
<td>High Renewable and Distributed PV Penetration</td>
<td>High Economic Growth</td>
<td>High Renewable Costs</td>
<td>Emerging Technology</td>
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<tr>
<td>Load</td>
<td>System Load Growth</td>
<td>Average</td>
<td>Same as Current Trends</td>
<td>High</td>
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<td>LNG export additions</td>
<td>Known</td>
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<td>High</td>
<td>Same as Current Trends</td>
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<td><strong>Policy</strong></td>
<td>Environmental Regs</td>
<td>Ozone, SO2 (NAAQs)</td>
<td>Same as Current Trends</td>
<td>Same as Current Trends</td>
<td>Same as Current Trends</td>
<td>Same as Current Trends</td>
</tr>
<tr>
<td>Emission Cost</td>
<td></td>
<td>Low</td>
<td>Same as Current Trends</td>
<td>Medium</td>
<td>Same as Current Trends</td>
<td>Same as Current Trends</td>
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<tr>
<td>Renewable incentives</td>
<td>Medium</td>
<td></td>
<td>High</td>
<td>Same as Current Trends</td>
<td>Low</td>
<td>Same as Current Trends</td>
</tr>
<tr>
<td>DC Tie additions</td>
<td>Add known DC tie</td>
<td></td>
<td>Same as Current Trends</td>
<td>Same as Current Trends</td>
<td>Same as Current Trends</td>
<td>Same as Current Trends</td>
</tr>
<tr>
<td><strong>End Use</strong></td>
<td>Distributed PV</td>
<td>Low</td>
<td>High</td>
<td>Medium</td>
<td>Lower than Current Trends</td>
<td>High - EV with Storage</td>
</tr>
<tr>
<td></td>
<td>EE Growth</td>
<td>Low</td>
<td>High</td>
<td>Same as Current Trends</td>
<td>Same as Current Trends</td>
<td>Same as Current Trends</td>
</tr>
<tr>
<td></td>
<td>DR Growth</td>
<td>Medium</td>
<td>Same as Current Trends</td>
<td>Same as Current Trends</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td><strong>Renewables</strong></td>
<td>Capital cost</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td>Low cost storage</td>
</tr>
<tr>
<td></td>
<td>Annual Cap. Limitation</td>
<td>Medium</td>
<td>High</td>
<td>Same as Current Trends</td>
<td>Low</td>
<td>Same as Current Trends</td>
</tr>
<tr>
<td><strong>Fuel Prices</strong></td>
<td>NG price forecast</td>
<td>2017 HOG</td>
<td>Same as Current Trends</td>
<td>Medium</td>
<td>Same as Current Trends</td>
<td>Same as Current Trends</td>
</tr>
</tbody>
</table>
### Load Forecast Scenarios

Current forecast methodology includes:
- 200 MW of Load Management
- 150 MW of Energy Efficiency
- 200 MW of behind the meter DG

<table>
<thead>
<tr>
<th>Year</th>
<th>Current Forecast (MW)</th>
<th>Higher Overall Growth</th>
<th>Industrial Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>72,934</td>
<td>74,514</td>
<td>74,349</td>
</tr>
<tr>
<td>2018</td>
<td>74,149</td>
<td>76,333</td>
<td>75,988</td>
</tr>
<tr>
<td>2019</td>
<td>75,588</td>
<td>77,645</td>
<td>76,910</td>
</tr>
<tr>
<td>2020</td>
<td>76,510</td>
<td>78,954</td>
<td>77,817</td>
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<tr>
<td>2021</td>
<td>77,417</td>
<td>80,328</td>
<td>80,503</td>
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<tr>
<td>2022</td>
<td>78,377</td>
<td>81,724</td>
<td>81,470</td>
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<tr>
<td>2023</td>
<td>79,348</td>
<td>83,129</td>
<td>82,416</td>
</tr>
<tr>
<td>2024</td>
<td>80,315</td>
<td>84,523</td>
<td>83,441</td>
</tr>
<tr>
<td>2025</td>
<td>81,261</td>
<td>86,012</td>
<td></td>
</tr>
<tr>
<td>2026</td>
<td>82,286</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Average Annual Growth Rate | 1.3% | 1.8% | 1.5% |

Higher Overall Growth – increases current forecast growth rate by 0.5% per year.
Industrial Growth – increases current forecast for large industrial loads:
1) 200 MW in the Permian Basin in 2018 on
2) 200 MW in the Gulf Coast in 2019 on
3) 755 MW for LNG in 2023 on (500 in South, 255 in Coast)
2018 LTSA: The process

Scenario Development
- Review trends and forecasts
- Expert presentations with focus on key drivers for current LTSA
- Finalize scenario descriptions and assumptions for current LTSA

Load forecasting
- Develop 8760-hour load forecasts for each scenario with normal weather assumptions
- Develop 90th percentile summer peak forecast for each scenario

Generation Expansion
- Identify amount of generation added and retired by technology based on scenario description
- Identify potential sites for new generation

Transmission Analysis
- Build start cases based on the LTSA Scope and scenario descriptions
- Perform reliability analysis
- Perform economic analysis
- Identify transmission projects to address economic and reliability needs
YOUR FINANCIAL FORECAST TURNED OUT TO BE WRONG.

IS THAT A SURPRISE, GIVEN THAT FORECASTS ARE MOSTLY JUST GUESSING PLUS MATH?

THE MATH IS SUPPOSED TO FIX THE GUESSING.

I THINK WE’VE ISOLATED THE PROBLEM TO YOU.
Portland General Electric Overview

Quick facts

• Vertically integrated electric company
• 887,000 customers in 51 Oregon incorporated cities
• 46 percent of Oregon’s population lives within PGE service area
• 75 percent of Oregon’s commercial and industrial activity occurs in PGE service area

Load Information

• 2018 peak demand of 3,816 MW
• Energy deliveries approximately 40% residential
• Installed customer sited rooftop PV capacity of approx. ~100 MW DC
Energy Deliveries Forecast: Approach

**Near Term (1-5 Years)**
- 25 regression-based monthly energy deliveries models
- Business cycle influences energy deliveries
- Adjusts for any known large customer changes and miscellaneous schedules
- Explicitly removes incremental energy efficiency
- Updated multiple times per year

**Long Term (5+ Years)**
- Convergence to long term growth rates, agnostic to business cycle and specific customer changes
- Three aggregated customer class models (by energy deliveries voltage, or revenue class) determine long term growth rates
- Assumes energy efficiency is embedded in growth rates
- Updated for IRP Cycle

**Forecast Time Horizon**
- 2018
- 2018, 2022, 2040
- 5-Year Models
- Long Term Growth Rates
Energy Deliveries Forecast: Integration of DER’s

Distributed Resource and Flexible Load Study
• Performed by Navigant
• Scope included Energy Efficiency*, Demand Response, Solar, Storage and Transportation Electrification

Integration into Load Forecast
• To combine this analysis with PGE’s econometric forecast, PGE took the following approach
  • Assume EVs and passive DER embedded in the top-down forecasts as equal to the 2018 estimated values
  • Layer the incremental impacts from the Navigant analysis to PGE’s forecast

* Navigant’s study provided additional analysis on energy efficiency scenarios, PGE’s base case EE forecast is provided by the Energy Trust of Oregon, a nonprofit organization that administers efficiency programs in Oregon.
Discussion Regarding SMUD DER Forecasting

Hawaii Utilities Integrated Grid Planning Forecast Assumptions Working Group

Patrick McCoy
Strategic Business Planner
July 17, 2019
DER Forecasting Discussion

- Forecasting method
  - Data
  - Forecasting horizon
  - Customer treatment
  -Granularity
  - Constraints
- Forecast modeling
  - Techniques
  - Market potential
- Forecasting impacts
  - Tariffs, programs, incentives
  - Degradation, replacement
  - Other constraints
Forecasting Method

• Data
  – Metered hourly interval
  – PV production
  – LiDAR
  – Distribution grid
    • Feeder
    • Substation
    • Service Transformer
  – Customer billing
  – Customer identifier
    • Account
    • Meter number
    • Premise
    • Device location number (DLN)
  – PRIZM (residential)

• Business systems, processes and competencies
Forecasting Method

• Forecasting horizon
  – Customer programs and services – 3 years
  – Distribution planning – 5 years
  – Load forecasting and resource planning – 20 years

• Customer treatment
  – Residential: PRIZM segmentation, propensities
  – Commercial: currently economics (financial payback)

• Granularity
  – Currently feeder level, moving towards customer segments and aggregating up

• Forecast constraints
Forecasting Method – Modeling Technique

- Currently: linear multi-variate regression model
  - Bass technology diffusion model utilized for first adoption forecast
- Migrating to: logistic regression model
- Developing DER adoption forecasting tool with Clean Power Research

\[
p_t^k = \beta^0 + \beta^1 x_t^{k,1} + \beta^2 x_t^{k,2} + \cdots + \beta^n x_t^{k,n}
\]

- Probability that remaining customer \( k \) will adopt in year \( t \)
- Weighting factor
- Predictive variable, evaluated for customer \( k \) in year \( t \)
Forecasting Method – Market Potential

- Technical potential
  - Capacity
  - PV energy production
- Economic potential
  - Financial assumptions
  - Payback analysis

- Market potential
  - Predictive analytics
  - Adoption curves

- Forecasting Method – Market Potential
  - Technical potential
    - Capacity
    - PV energy production
  - Economic potential
    - Financial assumptions
    - Payback analysis

- Probability Weighted Random Selection of Sites Up to Annual Adoption Level
Forecasting Impacts

• Tariffs, programs and incentives
  – Net energy metering
  – Tariff rate structure
  – Fees and surcharges
• PV degradation and replacement
  – Degradation algorithm
  – Replacement? Expansion of existing system?
• Other
  – Technology cost curves
• Currently built into tool (scenario builder)
Thank You!

Patrick McCoy
Strategic Business Planner
Energy Strategy Research and Development
Grid Strategy and Operations

Patrick.McCoy@smud.org