Western Electricity Markets

Skamania Lodge

Annual Energy Conference
June 7th, 2018
Geography & Climate Challenges

Weather Related Records

- The four states with the highest maximum temperature records
- Five of the 10 states with the lowest minimum temperature records
- The 10 driest and five of the 10 snowiest locations
- The 10 sunniest and six of the 10 cloudiest locations
- Both the most and least humid locations

Source: WECC 2016 State of the Interconnection
The Bulk-Power System

Four major system networks serve the U.S. & Canada

- Interconnections
- Regional Entities
- Reliability Coordinators
- Balancing Authorities
- ISOs & RTOs
- ESPs

Source: WECC
Generation Resource:

- Wind
- Solar
- Coal
- Nuclear
- Water
- Natural Gas
- Petroleum Products
- Geothermal
- Biomass-Based Renewables
- Biogas
- Other

Source: Oregon.gov/energy
The Western Interconnection is made up of approximately 136,000 miles of transmission lines.

Long high-voltage lines connect remotely located generating resources with distant population centers.

Other lines carry power from hydroelectric resources in the Pacific Northwest to California and other states.
Peak Demand relatively flat over last 5 years

Western Interconnection
Peak Demand by Year (MW)

<table>
<thead>
<tr>
<th>Year</th>
<th>Demand (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>152K</td>
</tr>
<tr>
<td>2014</td>
<td>148K</td>
</tr>
<tr>
<td>2015</td>
<td>151K</td>
</tr>
<tr>
<td>2016</td>
<td>157K</td>
</tr>
<tr>
<td>2017</td>
<td>156K</td>
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</table>

California ISO
Peak Demand by Year (MW)

<table>
<thead>
<tr>
<th>Year</th>
<th>Demand (MW)</th>
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<tbody>
<tr>
<td>2013</td>
<td>45K</td>
</tr>
<tr>
<td>2014</td>
<td>45K</td>
</tr>
<tr>
<td>2015</td>
<td>47K</td>
</tr>
<tr>
<td>2016</td>
<td>46K</td>
</tr>
<tr>
<td>2017</td>
<td>49K</td>
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</table>

Portland General Electric
Peak Demand by Year (MW)

<table>
<thead>
<tr>
<th>Year</th>
<th>Demand (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>3.9K</td>
</tr>
<tr>
<td>2014</td>
<td>3.9K</td>
</tr>
<tr>
<td>2015</td>
<td>4.0K</td>
</tr>
<tr>
<td>2016</td>
<td>3.7K</td>
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<tr>
<td>2017</td>
<td>4.0K</td>
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</tbody>
</table>

Source: WECC
Evolving Generation Mix
RPS Procurement Percentages
Renewable Portfolio Standards

Oregon Renewable Portfolio Standard (SB 1517)

Source: Oregon.gov
Electricity Consumed in Oregon
Based on 3 year average (2014-2016)

Fuels Used to Generate Electricity Consumed in Oregon

- **Hydro**
  - 40.47% of total
  - 19,488,884 MWh

- **Coal**
  - 31.89% of total
  - 15,358,984 MWh

- **Natural Gas**
  - 16.58% of total
  - 7,983,566 MWh

- **Wind**
  - 6.49% of total
  - 3,124,236 MWh

Other fuels like nuclear, biomass, solar, geothermal, biogas, waste, petroleum, other biogenic, other non-biogenic, landfill gases, and others are also used but in smaller percentages.
Comparison by Zone
Based on 3 year average (2014-2016)

Portland General Electric
- 18,843,380 MWh

Pacific Power
- 14,847,916 MWh

Average MWh

Fuel
- Other Non-Biogenic
- Petroleum
- Waste
- Biomass
- Other Biogenic
- Solar
- Biogas
- Wind
- Market Purchases*

Individual Fuel Contributions for Portland General Electric and Pacific Power/PacifiCorp.
CAISO Generation Capacity
Generation Capacity by Fuel Type

Total installed capacity
71,417 MW
as of 06/19/2017

- 53.5% natural gas
- 0.34% oil
- 0.76% coal
- 1.1% other
- 12% large hydro
- 3.2% nuclear
- 48% renewables
- 29% renewables
- 30.2% wind
- 9% geothermal
- 6.2% small hydro
- 6.2% biofuels
- 0.6% storage battery

Source: EIA
Massive amounts of solar come online in the middle of the day.
The grid operator then manages around load and renewable generation, so called “Net Demand”.

Ramp rate
~9809MW in 3 hours
CAISO Evolution of Generation Mix
Generation Capacity by Fuel Type

Source: EIA
CAISO Generation Supply Curve
Cumulative Operating Capacity & Variable Cost

Variable Cost (\$/MWh)

Cumulative Operating Capacity (MW)

- Solar
- Geothermal
- Wind
- Combined Cycle
- Nuclear
- Steam Turbine
- Hydro
- Combustion Turbine
- Internal Combustion
- Pumped Storage

Source: EIA
WECC Retirements Versus Builds

Retirements (MW)

Build (MW)

Source: U.S. Power Plant Stack: Interactive Dashboard (BNEF)
Supply Curve Dynamics
New Renewable supply has shifted the entire generation supply curve.
Marginal Generator Remains Natural Gas

Demand

Generation Supply Curve

Natural Gas remains the Marginal Generator

Renewables & Hydro

Natural Gas
Less natural gas generation shifts the supply curve left and makes it steeper.
Impact on Hourly Prices

Annual Average **Profile** of Hourly Prices since 2013
Rolling Fixed Price Forward ATC Strip (12, 36, 60 Months)

<table>
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## Rolling Fixed Price Forward ATC Strip (12, 36, 60 Months)

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### Graph

- **X-axis**: Year (2012 to 2018)
- **Y-axis**: Price ($)

The graph shows the rolling fixed price for the Oregon Forward Market Mid Columbia for the years 2012 to 2018. The prices range from $18 to $48, with peaks and troughs indicating market variability. The chart also includes a legend indicating the trend lines, each with a different color for clarity.
Calpine Energy Solutions

- Licensed to sell gas and power in 64 utility territories across 20 states
- Serves more than 1,300 exclusively commercial and industrial customers through ~100,000 meters representing a peak load ~7,500 megawatts
- Delivers more than 85,000 MMBTU of gas per day in Western markets
- Provides supply service to ESCO’s and billing & data management services to all active Community Choice Aggregators ("CCA’s") in California
- Owned by America’s largest natural gas and geothermal electricity producer with nearly 26,000 MW of capacity