The pivotal role of reliable electricity to achieve decarbonization in the NW
About Us: Energy & Environmental Economics (E3)

- **DERs & Rates**: Analyzes distributed energy resources, emphasizing their costs and benefits now and in the future. Supports rate design and distribution system planning.

- **Asset Valuation**: Determines asset values from multiple perspectives. Uses proprietary in-house models and in-depth knowledge of public policy, regulation, and market institutions.

- **Clean Energy**: Provides market and policy analysis on clean energy technologies and climate change issues. Includes comprehensive and long-term GHG analysis.

- **Planning**: Develops and deploys proprietary tools to aid resource planners. Informs longer-term system planning and forecasting.

- **Market Analysis**: Models wholesale energy markets both in isolation and as part of broader, more regional markets. Key insights to inform system operators and market participants.

E3 is a 60+ person energy & environmental economics consulting firm based in SF with five practice areas.
Over the past three years, E3 has completed a trio of studies* that examine the NW’s transition to a low-GHG energy system, these studies identify:

1. The pivotal role of electricity in achieving deep decarbonization in the region
2. Strategies to decarbonize electricity at least-cost

The Pacific Northwest is expected to undergo significant changes to its generation resource mix over the next 20 years due to changing economics and policy goals. These changes include:

- Increased penetration of wind and solar generation
- Retirements of coal generation
- A shift in the role of natural gas generation

This transition raises questions about the region’s ability to serve load reliably as firm generation is replaced with variable resources

*Note that the geographic scope of these studies varies. More detail is available in the appendix
Agenda

+ The electric sector in the context of economy-wide decarbonization

+ Ensuring reliability of a very-low emissions electricity system
  - What is resource adequacy?
  - How resource adequate is the region today?
  - Resource adequacy over the coming decade
  - Resource adequacy in a deeply decarbonized 2050 electricity system
The Electric Sector in the Context of Economy-wide Decarbonization
Four “Pillars” of Decarbonization to Meet Long-Term Goals

1. Energy efficiency & conservation
2. Electrification
3. Low carbon electricity
4. Low carbon fuels

+ Four foundational elements are consistently identified in studies of strategies to meet deep decarbonization goals.

+ Across most decarbonization studies, electric sector plays a central role in meeting goals:
  - Through direct carbon reductions
  - Through electrification of loads to reduce emissions in other sectors

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Deep decarbonization scenarios mean both annual and peak load growth

- A low carbon electricity system enables emissions reductions elsewhere in the economy via measures like transportation and building electrification.
- However, those measures will increase both the annual and peak loads in the Northwest, even in scenarios that include deep energy efficiency savings.

![Annual Load Growth](chart)

![1-in-10 year space-heating peak](chart)
Fossil generation emissions decline in the near-term as coal generation is replaced by gas and renewables. The largest source of incremental generation is wind energy.

This example is consistent with a 90% reduction in electric sector GHG emissions relative to 1990.
Some approaches to decarbonize electricity are more effective than others.

Note: Reference Case reflects current industry trends and state policies, including Oregon’s 50% RPS goal for IOUs and Washington’s 15% RPS for large utilities.
Ensuring Reliability in a Low-Carbon Electricity System
What is “capacity” and why is it important?

+ Capacity is the ability to generate electric energy at any given point in time

+ Utilities need adequate generation capacity to meet continuously-varying electric loads reliably over a broad range of conditions

+ The consequence of inadequate capacity is loss of load
  - Loss of load is inconvenient, expensive, and potentially life-threatening

+ Utilities plan their systems to ensure that loss of load occurs very rarely

Source: http://www.energy.siemens.com
1. **High Load**
   - **1-in-50+ peak load year**
   - Highest on record
   - Low renewable production despite > 100 GW of installed capacity during some hours
   - Loss of load event of nearly 48 hrs
   - Loss of load magnitude of over 30 GW

2. **Low Renewables**
   - Low renewable production despite > 100 GW of installed capacity during some hours
   - 1-in-20 low hydro year
   - 5th lowest on record

3. **Drought Hydro Year**
   - 1-in-50+ peak load year
   - Highest on record
   - Loss of load event of nearly 48 hrs
   - Loss of load magnitude of over 30 GW
HOW RESOURCE ADEQUATE IS THE NW TODAY?
### 2018 System in the Northwest

<table>
<thead>
<tr>
<th>Resource</th>
<th>2018 Nameplate MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydro</td>
<td>35,221</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>12,181</td>
</tr>
<tr>
<td>Coal</td>
<td>10,895</td>
</tr>
<tr>
<td>Wind</td>
<td>7,079</td>
</tr>
<tr>
<td>Nuclear</td>
<td>1,150</td>
</tr>
<tr>
<td>Solar</td>
<td>1,557</td>
</tr>
<tr>
<td>Other Hydro</td>
<td>524</td>
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<tr>
<td>Biomass</td>
<td>489</td>
</tr>
<tr>
<td>Geothermal</td>
<td>80</td>
</tr>
<tr>
<td>Demand Response</td>
<td>299</td>
</tr>
<tr>
<td>Imports</td>
<td>2,500</td>
</tr>
</tbody>
</table>

### Capacity Mix %

- **Hydro**: 35,221 MW
- **Natural Gas**: 12,181 MW
- **Coal**: 10,895 MW
- **Wind**: 7,079 MW
- **Nuclear**: 1,150 MW
- **Solar**: 1,557 MW
- **Biomass**: 489 MW
- **Geothermal**: 80 MW
- **Demand Response**: 299 MW
- **Imports**: 2,500 MW
The Northwest system is in very tight load-resource balance

Over the past year, studies from multiple organizations have been released that show an electric sector capacity deficit in the Northwest

These deficits appear due to a combination of thermal power plant retirements and renewed load growth in the region
WHAT COULD THE RESOURCE ADEQUACY SITUATION BE IN 2030?
Northwest Electricity Capacity in 2030

5 GW net new capacity by 2030 is needed for reliability (450 MW/yr)

With planned coal retirements of 3 GW, 8 GW of new capacity by 2030 is needed (730 MW/yr)

If all coal is retired, then 16 GW new capacity is needed (1450 MW/yr)

GHG Free Generation (%)

<table>
<thead>
<tr>
<th></th>
<th>2018 Baseline</th>
<th>2030 Baseline</th>
<th>2030 No Coal</th>
</tr>
</thead>
<tbody>
<tr>
<td>2018 Baseline</td>
<td>12</td>
<td>20</td>
<td>28</td>
</tr>
<tr>
<td>2030 Baseline</td>
<td>11</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>2030 No Coal</td>
<td>7</td>
<td>7</td>
<td>4</td>
</tr>
</tbody>
</table>

Carbon (MMT CO2)

<table>
<thead>
<tr>
<th></th>
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<th>2030 Baseline</th>
<th>2030 No Coal</th>
</tr>
</thead>
<tbody>
<tr>
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<td>35</td>
<td>35</td>
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</tr>
<tr>
<td>2030 Baseline</td>
<td>7</td>
<td>7</td>
<td>4</td>
</tr>
</tbody>
</table>

% GHG Reduction from 1990 Level

<table>
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<tr>
<th></th>
<th>2018 Baseline</th>
<th>2030 Baseline</th>
<th>2030 No Coal</th>
</tr>
</thead>
<tbody>
<tr>
<td>2018 Baseline</td>
<td>-12%*</td>
<td>61%</td>
<td>61%</td>
</tr>
<tr>
<td>2030 Baseline</td>
<td>67</td>
<td>42</td>
<td></td>
</tr>
<tr>
<td>2030 No Coal</td>
<td>31%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Assumes 60% coal capacity factor
A resource’s contribution to system reliability

What portion of a generator’s nameplate capacity can you count on during times of system stress?

In practice, determining capacity values of variable resources is a complicated exercise

Illustrative Capacity Value by Resource Type

- Fossil
  - 95 MW Capacity Value
- Wind
  - 7 MW Capacity Value
- Solar
  - 12 MW Capacity Value
- Hydro
  - 55 MW Capacity Value

100 MW nameplate
Resource Adequacy Challenges in a High Renewables System

1. High Load
   - 1-in-50+ peak load year
     - Highest on record
   - Loss of load event of nearly 48 hrs
   - Loss of load magnitude of over 30 GW

2. Low Renewables
   - Low renewable production despite > 100 GW of installed capacity during some hours
   - 1-in-20 low hydro year
     - 5th lowest on record

3. Drought Hydro Year
   - Water levels critically low
   - 10th driest year on record

- Lost Load
- Demand Response
- Storage
- Variable Generation
- Hydro
- Dispatchable Generation
- Load

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RESOURCE ADEQUACY IN 2050
Electric Capacity in 2050

Removing final 1% of carbon requires additional $100b to $170b of investment

1\textsuperscript{CPS+ \% = renewable/hydro/nuclear generation divided by retail electricity sales}
2\textsuperscript{GHG-Free Generation \% = renewable/hydro/nuclear generation, minus exports, divided by total wholesale load}
Gas capacity factor declines significantly at higher levels of decarbonization.

Significant curtailed renewable energy at deep levels of carbon reductions.
Resource Adequacy Challenges in a High Renewables System

1. High Load
   - 1-in-50+ peak load year
   - Highest on record

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   - 5th lowest on record
   - Loss of load event of nearly 48 hrs
   - Loss of load magnitude of over 30 GW

3. Drought Hydro Year
   - 1

Days: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

GW

Lost Load
Demand Response
Storage
Variable Generation
Hydro
Dispatchable Generation
Load

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Marginal cost of CO₂ reductions at 90% GHG Reductions or greater exceed most estimates of the societal cost of carbon which generally range from $50/ton to $250/ton\(^1\), although some academic estimates range up to $800/ton\(^1\).
Marginal cost of absolute 100% GHG reductions vastly exceeds societal cost of carbon.
The electric sector is a key driver of economy-wide decarbonization. Low-GHG electricity enables decarbonization throughout the economy.

Given the pivotal role of electricity, reliability is key. However, the region faces both near- and long-term reliability issues without firm capacity.

Natural gas power plants have a key role to play in maintaining reliability, but those plants' usage decreases rapidly over time.

Potential resources that could supplant natural gas as a key reliability resource are not commercially available.
Thank You!

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Dan Aas, Senior Consultant (dan@ethree.com)
E3 studies cited in this presentation

+ **Pacific Northwest Low-Carbon Scenario Analysis (2017)**
  
  
  - Geography: WA, OR, ID, Western MT

+ **Pacific Northwest Pathways to 2050 (2018)**
  
  
  - Geography: WA, OR

+ **Resource Adequacy in the Pacific Northwest (2019)**
  
  
  - Geography: WA, OR, ID, Western MT, Western WY, UT
100% Reduction Portfolio Alternatives in 2050

Clean baseload or biogas or ultra-long duration storage resource could displace significant wind and solar.

<table>
<thead>
<tr>
<th>Carbon (MMT CO2)</th>
<th>50</th>
<th>0</th>
<th>0</th>
<th>0</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Cost Delta ($B)</td>
<td>Base</td>
<td>$16- $28</td>
<td>$14-$21</td>
<td>$550-$990</td>
<td>$4 - $9</td>
</tr>
<tr>
<td>Additional Cost ($/MWh)</td>
<td>Base</td>
<td>$52-$89</td>
<td>$46-$69</td>
<td>$1,800-$3,200</td>
<td>$14 - $30</td>
</tr>
</tbody>
</table>
Effective Capacity by Resource

Effective capacity from wind, solar, storage, and demand response is limited due to saturation effects.

- **Diverse Wind (NW, MT, WY)**
- **Solar**
- **6-Hr Storage**
- **Demand Response**

*ELCC = Effective Load Carrying Capability = firm contribution to system peak load*