Pacific Northwest Low Carbon Scenario Analysis
Achieving Least-Cost Carbon Emissions Reductions in the Electricity Sector

Eugene Water and Electric Board
Customer Carbon Forum
Eugene, Oregon
January 24, 2018
About E3

+ E3 is a San Francisco-based consultancy specializing in clean energy economics

+ E3 consults extensively for utilities, developers, government agencies and environmental groups on clean energy issues

- United Nations Deep Decarbonization Pathways Project
- Planning for California’s climate and renewable energy goals
- 100% renewables studies for California, Hawaii and New York
This study was funded by the Public Generating Pool (PGP), Benton County PUD, and Energy Northwest.

PGP is a trade association representing 10 consumer-owned utilities in Oregon and Washington.

- PGP members own more than 6,000 MW of generation and purchase approximately 34% of BPA’s preference power.

E3 thanks the staff of the Northwest Power and Conservation Council and the Bonneville Power Administration for providing data and technical review.
Agenda

- Introduction and background
- Portfolio summary
- Cost and emissions impacts
- Sensitivity results: retirement of existing zero-carbon resources
- Conclusions and key findings
INTRODUCTION AND BACKGROUND
Oregon and Washington are currently exploring potential commitments to deep decarbonization in line with international goals:

- 80-91% below 1990 levels by 2050 (proposed)

This study was conceived to provide information to policymakers:

- How can we reduce carbon in the electricity sector at the lowest cost in Oregon and Washington?
- What is the role of wind, solar, energy storage and natural gas generation?
- What is the importance of existing carbon-free generation?

Sources: Report to the Legislature on Washington Greenhouse Gas Emissions Inventory: 2010 – 2013 (link); Oregon Greenhouse Gas In-boundary Inventory (link)
Four “Pillars” of Decarbonization to Meet Long-Term Goals

Energy efficiency & conservation

Electrification

Low carbon electricity

Low carbon fuels

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

Across most decarbonization studies, electricity plays a key role in meeting goals:

- Through direct carbon reductions
- Through electrification of loads to reduce emissions in other sectors
Low-carbon electricity generation becomes the main source of energy for the entire economy

1. **Renewable**
   - **Hydroelectric**: *flexible low-carbon resource in the Northwest that can help to balance wind and solar power*
   - **Wind**: *high quality resources in West, particularly East of the Rockies, intermittent availability*
   - **Solar**: *high quality resources across the West, intermittent availability*
   - **Geothermal**: *resource limited*
   - **Biomass**: *resource limited*

2. **Nuclear**
   - **Conventional**: *baseload low-carbon resource*
   - **Small modular reactors**: *potentially flexible low-carbon resource (not considered)*

3. **Gas or coal generation with carbon capture and storage (CCS)**
Northwest electricity sector carbon emissions are already relatively low

Pacific Northwest carbon emissions are lower than other regions due to our existing base of hydro, wind and nuclear generation

2013 Regional Carbon Intensity of Electricity Supply (tons/MWh)

2013 emissions intensity:
0.26 tons/MWh
(includes out-of-state coal resources)

Northwest Electricity Mix

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydro</td>
<td>59%</td>
</tr>
<tr>
<td>Coal</td>
<td>15%</td>
</tr>
<tr>
<td>Gas</td>
<td>12%</td>
</tr>
<tr>
<td>Nuclear</td>
<td>5%</td>
</tr>
<tr>
<td>Wind</td>
<td>8%</td>
</tr>
<tr>
<td>Biomass</td>
<td>1%</td>
</tr>
</tbody>
</table>

Figure developed using data gathered from state 2013 GHG inventories for Washington, Oregon, and California; supplemented with data from EIA Annual Energy Outlook 2016
A handful of plants are responsible for most of the electric sector GHG emissions in the Northwest

- Nine coal-fired power plants are responsible for 80% of carbon emissions attributed to Washington & Oregon
  - Includes contracted generation in Montana, Utah, and Wyoming
  - 33 million metric tons in 2014

- Sixteen gas-fired power plants account for 20% of carbon emissions
  - 9 million metric tons in 2014
Overview of the Analysis

This study uses specialized software that analyzes electricity systems with high levels of wind and solar power

- Utilized in several jurisdictions including California, Hawaii and New York

Selects the least-cost combination of renewable and conventional resources over time

- Simulates operations of the Northwest electricity system including existing hydro and thermal generators
- Adds new resources as needed
- Complies with renewable energy and carbon policy targets
- Meets electricity system reliability needs

<table>
<thead>
<tr>
<th>Resource Type</th>
<th>Examples of New Resource Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas Generation</td>
<td>• Simple cycle gas turbines</td>
</tr>
<tr>
<td></td>
<td>• Reciprocating engines</td>
</tr>
<tr>
<td></td>
<td>• Combined cycle gas turbines</td>
</tr>
<tr>
<td></td>
<td>• Repowered CCGTs</td>
</tr>
<tr>
<td>Renewable Generation</td>
<td>• Geothermal</td>
</tr>
<tr>
<td></td>
<td>• Hydro upgrades</td>
</tr>
<tr>
<td></td>
<td>• Solar PV</td>
</tr>
<tr>
<td></td>
<td>• Wind</td>
</tr>
<tr>
<td>Energy Storage</td>
<td>• Batteries (&gt;1 hr)</td>
</tr>
<tr>
<td></td>
<td>• Pumped Storage (&gt;12 hr)</td>
</tr>
<tr>
<td>Energy Efficiency</td>
<td>• HVAC &amp; appliances</td>
</tr>
<tr>
<td></td>
<td>• Lighting</td>
</tr>
<tr>
<td>Demand Response</td>
<td>• Interruptible tariff (ag)</td>
</tr>
<tr>
<td></td>
<td>• DLC: space &amp; water heating (res)</td>
</tr>
</tbody>
</table>

Information about E3’s RESOLVE model can be found here: [https://www.ethree.com/tools/resolve-renewable-energy-solutions-model/](https://www.ethree.com/tools/resolve-renewable-energy-solutions-model/)
Overview of Core Policy Scenarios

1. **Reference Case:** reflects current policy and industry trends
   - Achieves regionwide average 20% RPS by 2040
   - Reflects announced coal retirements: Boardman, Colstrip 1 & 2, Centralia

2. **Carbon Cap Cases:** 40%, 60%, and 80% reduction below 1990 levels by 2050

3. **Carbon Tax Cases:** Two specific Washington proposals
   - **Gov.:** $25/ton in 2020, 3.0% real escalation
   - **Leg.:** $15/ton in 2020, 5.5% real escalation

4. **High RPS Cases:** 30%, 40%, and 50% regionwide average RPS by 2050

5. **‘No New Gas’ Case:** prohibits construction of new gas generation
Cap-and-trade drives the clean energy transition through a price on carbon

New Resources Added by 2050 (MW)

- 11,000 MW of new wind and solar power are added by 2050
- 7,000 MW of new natural gas generation needed for reliability

Annual Energy Production in 2050 (aMW)

- Primary source of carbon reductions is displacement of coal generation from portfolio
- Hydro generation still dominates
- Wind and solar generation replace coal
- Meets carbon goal at relatively low cost
Carbon tax has a similar effect as a cap-and-trade, depending on tax rate

New Resources Added by 2050 (MW)

- 9,000 MW of new wind and solar power are added by 2050
- 7,000 MW of new natural gas generation needed for reliability

Annual Energy Production in 2050 (aMW)

- Hydro generation still dominates
- Wind and solar generation replace coal
- Does not quite meet carbon goal
High RPS policy results in “overbuild” of renewables but does not reduce coal

### New Resources Added by 2050 (MW)

<table>
<thead>
<tr>
<th>Installed Capacity (MW)</th>
<th>Reference</th>
<th>30% RPS</th>
<th>40% RPS</th>
<th>50% RPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>23,000 MW of new wind and solar power are added by 2050</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7,000 MW of new natural gas generation needed for reliability</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Annual Energy Production in 2050 (aMW)

- Very large surpluses of wind and solar energy
- Coal generation continues to operate
- Much higher cost and does not meet goal

More than 3x renewables capacity is added to go from 30% to 50% RPS

Average curtailment increases from 5% for a 30% RPS to 9% for 50% RPS

Renewables displace gas first; coal begins to be displaced with higher renewables penetration
Battery storage is less effective in the Northwest than in solar-dominated systems like California. California can store surplus solar power with 4-6 hour grid batteries. Northwest has surplus of wind and hydro generation that occurs day after day during high hydro years.

Current storage technologies can be helpful but cannot solve all renewable integration challenges in the Northwest!
Prohibition on new gas generation does little to reduce carbon

<table>
<thead>
<tr>
<th>New Resources Added by 2050 (MW)</th>
<th>Annual Energy Production in 2050 (aMW)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><img src="https://via.placeholder.com/150" alt="Graph" /></td>
</tr>
</tbody>
</table>

- Very little change in wind and solar from the Reference Case
- 7,000 MW of pumped hydro and battery storage replaces gas
- Little change in wind and solar generation
- Coal generation continues to operate
- Storage does not produce energy!
A system without enough gas generation may not meet our expectations for reliable electric service.

Cold Winter Day under 80% Reduction

+ Gas generation is dispatched to help meet electric loads during cold weather events

Cold Winter Day Without Gas

+ Without thermal generation, there is not enough energy to serve load during all hours

Most challenging conditions for the Northwest power system are multi-day cold snaps that occur during drought years

Wind and solar production tends to be very low during these conditions

Absent a technology breakthrough, gas generation appears to be needed for reliability

Energy from Zero-Carbon Resources

- Wind
- Solar
- Hydro Upgrades/NPD
- Biomass
- Geothermal
- Coal
- Load
COST AND EMISSIONS IMPACTS
Cost & Emissions Impacts
Carbon Cap Cases

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.
Cost & Emissions Impacts
Carbon Tax Cases

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.

Reduces emissions by 19 MMt at an annual cost of +$800 million by 2050.

Reductions Needed to Meet 80% Goal

2050 Annual Cost Increase ($ millions)

$3,000

$2,500

$2,000

$1,500

$1,000

$500

$0

0

5

10

15

20

25

Reference Case

40% Reduction

60% Reduction

80% Reduction

Gov Tax

Leg Tax

Reduction in 2050 Greenhouse Gas Emissions (million metric tons)
Reduces emissions by 12 MMt at an annual cost of $2.1 billion by 2050.
Cost & Emissions Impacts
No New Gas Case

Reduces emissions by 2.0 MMt at an annual cost of $1.2 billion by 2050

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.
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# 2050 Scenario Summary

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Inc Cost ($MM/yr.)</th>
<th>GHG Reductions (MMT)</th>
<th>Avg GHG Abatement Cost ($/ton)</th>
<th>Effective RPS %</th>
<th>Zero Carbon %</th>
<th>Renewable Curtailment (aMW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>20%</td>
<td>91%</td>
<td>201</td>
</tr>
<tr>
<td>40% Reduction</td>
<td>+$163</td>
<td>7.5</td>
<td>$22</td>
<td>21%</td>
<td>92%</td>
<td>294</td>
</tr>
<tr>
<td>60% Reduction</td>
<td>+$434</td>
<td>14.2</td>
<td>$30</td>
<td>25%</td>
<td>95%</td>
<td>364</td>
</tr>
<tr>
<td>80% Reduction</td>
<td>+$1,046</td>
<td>20.9</td>
<td>$50</td>
<td>31%</td>
<td>102%</td>
<td>546</td>
</tr>
<tr>
<td>30% RPS</td>
<td>+$330</td>
<td>4.3</td>
<td>$77</td>
<td>30%</td>
<td>101%</td>
<td>313</td>
</tr>
<tr>
<td>40% RPS</td>
<td>+$1,077</td>
<td>7.5</td>
<td>$144</td>
<td>40%</td>
<td>111%</td>
<td>580</td>
</tr>
<tr>
<td>50% RPS</td>
<td>+$2,146</td>
<td>11.5</td>
<td>$187</td>
<td>50%</td>
<td>121%</td>
<td>1,033</td>
</tr>
<tr>
<td>Leg Tax ($15-75)</td>
<td>+$804</td>
<td>19.1</td>
<td>$42</td>
<td>28%</td>
<td>99%</td>
<td>437</td>
</tr>
<tr>
<td>Gov Tax ($25-61)</td>
<td>+$775</td>
<td>18.7</td>
<td>$41</td>
<td>28%</td>
<td>99%</td>
<td>424</td>
</tr>
<tr>
<td>No New Gas</td>
<td>+$1,202</td>
<td>2.0</td>
<td>$592</td>
<td>22%</td>
<td>93%</td>
<td>337</td>
</tr>
</tbody>
</table>

Incremental cost and GHG reductions are measured relative to the Reference Case.
SENSITIVITY RESULTS

Retirement of Existing Zero-Carbon Resources
The sponsors wished to explore the impacts of retiring existing hydro and nuclear generation on the cost and ability to meet long-run carbon goals.

E3 evaluated a sensitivity in which 2,000 aMW of nuclear & hydro are assumed to retire:

- Columbia Generating Station (1,207 MW)
- 1,000 aMW of generic existing hydro

This scenario was tested under both the Reference Case (current policy) and 80% GHG Reduction Case.
Replacing existing resources is expensive and may increase carbon emissions

### Reference Case with Retirement

<table>
<thead>
<tr>
<th>Installed Capacity (MW)</th>
<th>Reference</th>
<th>Reference + Resource Retirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing hydro and nuclear replaced with 2,000 MW of new natural gas generation</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 80% Carbon Reduction Case with Retirement

<table>
<thead>
<tr>
<th>Installed Capacity (MW)</th>
<th>80% Reduction</th>
<th>80% Reduction + Resource Retirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing hydro and nuclear replaced with 2,000 MW of new natural gas and 5,500 MW of new wind and solar generation</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Existing resources replaced with gas**
- **Cost is $1.1 billion per year by 2050**
- **Carbon emissions increase by 5 million metric tons**
- **2,000 MW of existing resources replaced with 7,500 MW of new wind, solar and gas**
- **Total cost of meeting carbon goal increases by $1.6 billion per year by 2050**
1. **The lowest cost way to reduce carbon in the Northwest grid is to replace coal with a combination of energy efficiency, renewables and natural gas**
   - Coal generation produces approximately 80% of the Northwest’s electricity-sector GHG emissions today
   - An economy-wide *price on carbon* is a technology-neutral policy that provides incentives for achieving emissions reductions at the lowest cost

2. **Renewables will play a critical role, however a higher Renewables Portfolio Standard results in higher costs and higher carbon emissions**
   - RPS policy has been successful at driving investment in renewables but ignores other measures such as energy efficiency and coal displacement
   - **RPS policy has unintended consequences** such as oversupply and negative wholesale electricity prices that create challenges for reinvestment in existing zero-carbon resources
3. **Prohibiting the construction of new natural gas generation adds significant cost but does little to reduce carbon**
   - More study is needed to determine whether the system that was modeled would meet historical reliability standards
   - New gas resources can be part of a least-cost pathway to achieving deep carbon reductions

4. **Retiring existing hydro and nuclear generation makes it much more challenging and costly to meet carbon goals**
   - Replacing 2,000 aMW of existing hydro or nuclear generation would require 5,500 MW of new wind and solar generation and 2,000 MW of natural gas generation at an annual cost of $1.6 billion by 2050
   - Policies that encourages the retention of existing zero-carbon generation resources will help contain costs of meeting carbon goals
5. Returning revenues raised under a carbon pricing policy to the electricity sector is crucial to mitigate higher costs
   - This is a common feature of carbon pricing programs adopted in other jurisdictions
   - This helps ensure that electricity ratepayers are not required to pay twice: first for the cost of investments in GHG abatement measures, and second for the emissions that remain

6. Research and development is needed for the next generation of Energy Efficiency measures
   - Higher-cost measures that have not traditionally been considered may become cost-effective in a carbon-constrained world

7. Vehicle electrification is a low-cost measure for reducing carbon emissions in the transportation sector
   - Electrification has benefits for society as a whole, but may increase costs in the electric sector
Thank You!

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