Energy+Environmental Economics

Achieving Deep Carbon Reductions in the Pacific Northwest

Cost and Reliability Implications

Chelan County Public Utility District
Board of Directors

February 19, 2019
Wenatchee, Washington

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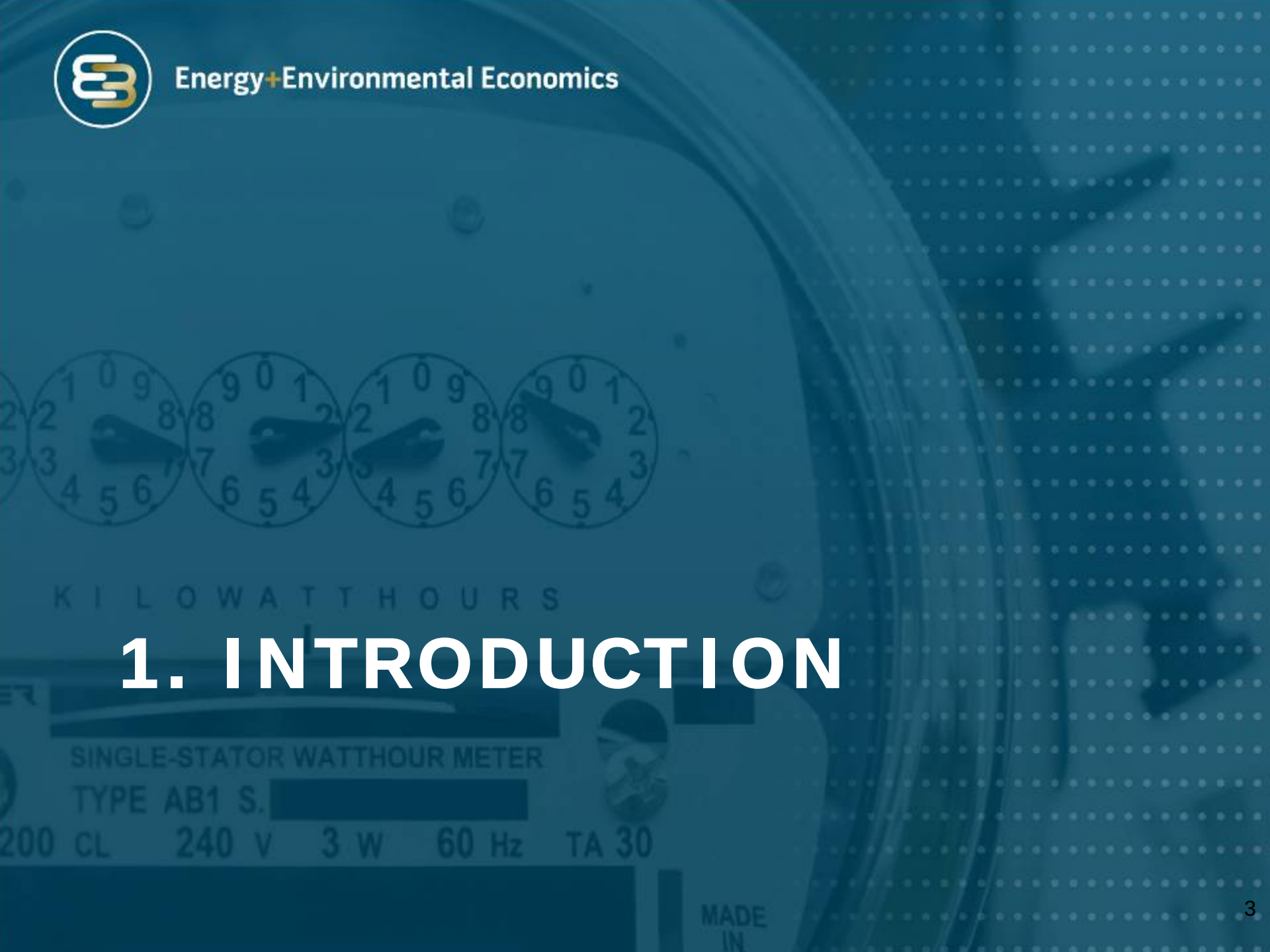
Overview

- **This presentation summarizes recent studies prepared by E3 of the cost and reliability implications of achieving a deeply decarbonized electricity grid in the Pacific Northwest**
  - Pacific Northwest Low Carbon Scenario Analysis, sponsored by Public Generating Pool (https://www.ethree.com/projects/study-policies-decarbonize-electric-sector-northwest-public-generating-pool-2017-present/)
  - Resource Adequacy in the Pacific Northwest, sponsored by Puget Sound Energy, Public Generating Pool, Avista, and NorthWestern (http://www.publicgeneratingpool.com/e3-carbon-study/)
- **Presentation Outline:**
  1. Introduction
  2. Reliability challenges under deep decarbonization
  3. Optimal portfolios for achieving clean energy goals
  4. Cost and emissions impacts
  5. Conclusions and lessons learned



1. INTRODUCTION

Study Sponsors

- **These studies were sponsored by Puget Sound Energy, Avista, NorthWestern Energy and the Public Generating Pool (PGP)**

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

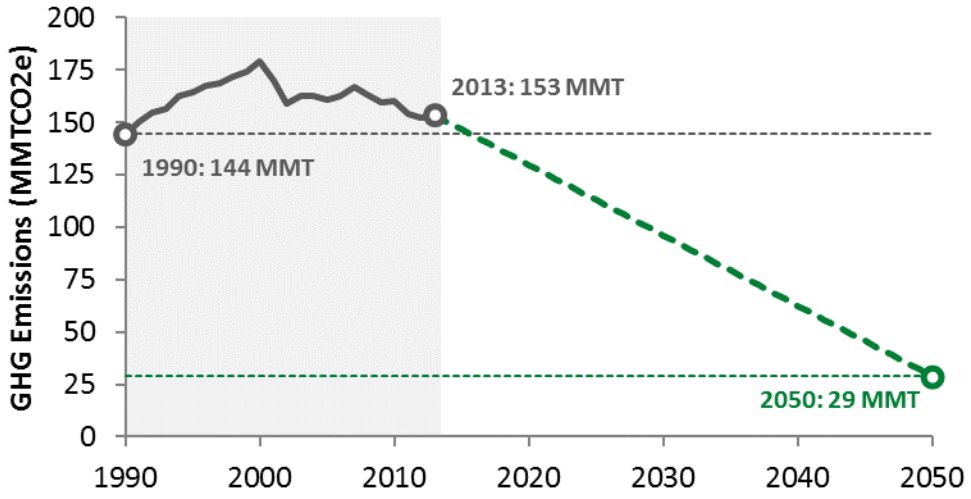
- **The studies build off of decarbonization work originally funded by Chelan PUD**

E3 thanks the staff of the Northwest Power and Conservation Council for providing data and technical review

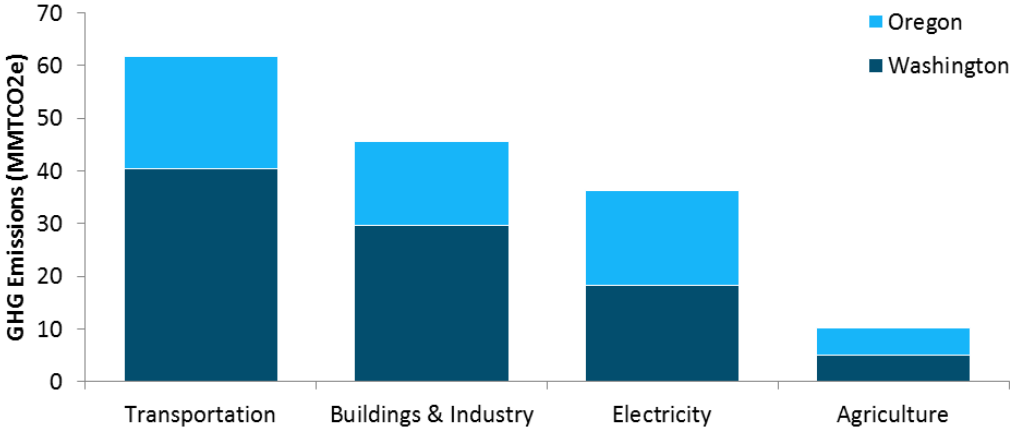
About the studies

- **Oregon and Washington are currently exploring potential commitments to deep decarbonization in line with international goals:**
  - 80-91% below 1990 levels by 2050 (proposed)
- **The studies were conceived to provide information to policymakers**
  - How can we reduce carbon in the electricity sector at the lowest cost in Oregon and Washington?
  - How can we maintain reliable electric service under high penetrations of wind and solar?
  - What is the importance of the region's existing base of carbon-free hydro generation?

Historical and Projected GHG Emissions for OR and WA

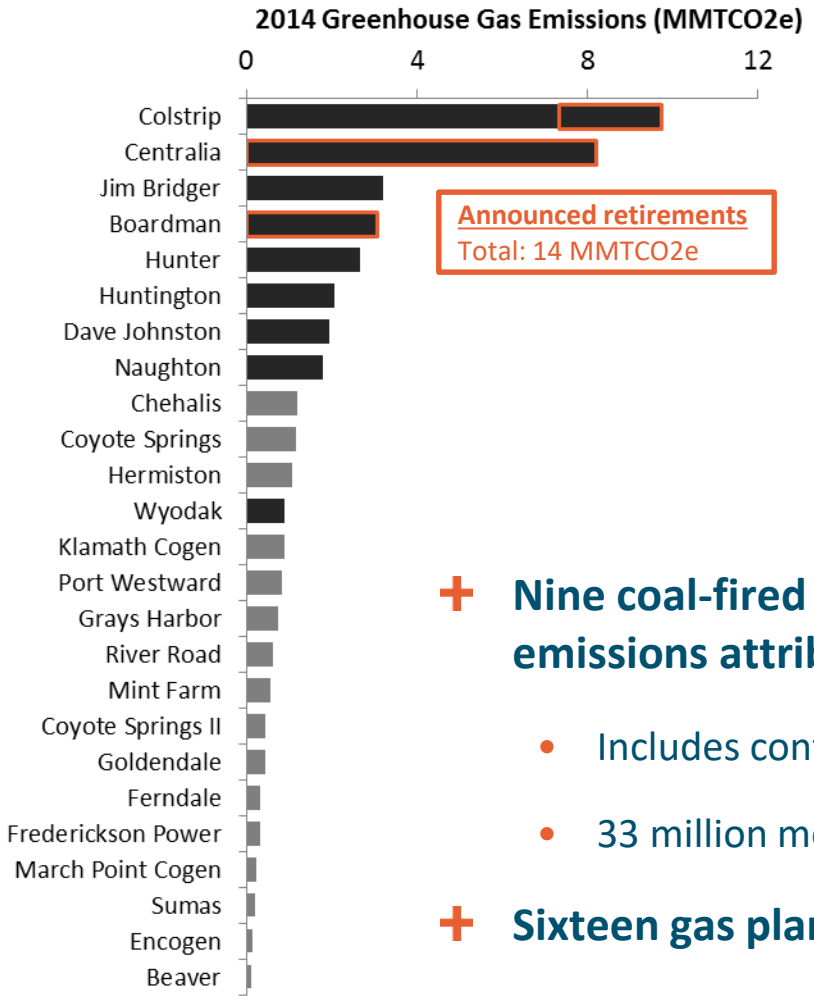


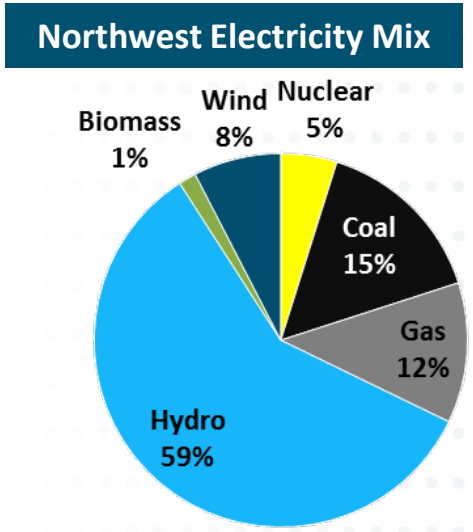
2013 CO2 Emissions for Oregon and Washington



Sources: Report to the Legislature on Washington Greenhouse Gas Emissions Inventory: 2010 – 2013 (link); Oregon Greenhouse Gas In-boundary Inventory (link)

A handful of plants are responsible for most of the electric sector GHG emissions in the Northwest

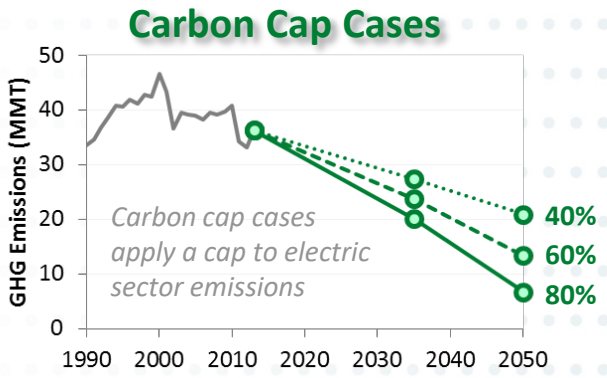


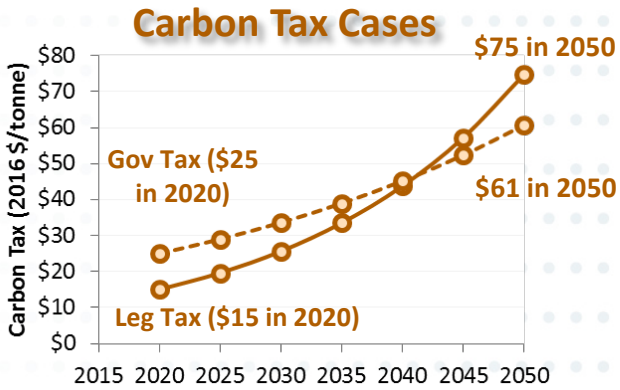


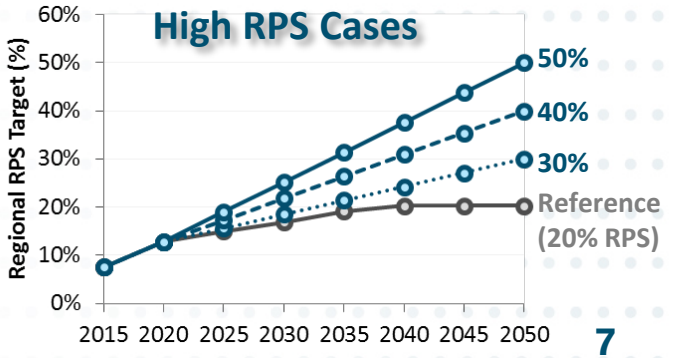
+ **Nine coal-fired power plants are responsible for 80% of carbon emissions attributed to Washington & Oregon**
  - Includes contracted generation in Montana, Utah, and Wyoming
  - 33 million metric tons in 2014
+ **Sixteen gas plants account for 20% of carbon emissions**
  - 9 million metric tons in 2014

Several core policy scenarios were considered

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





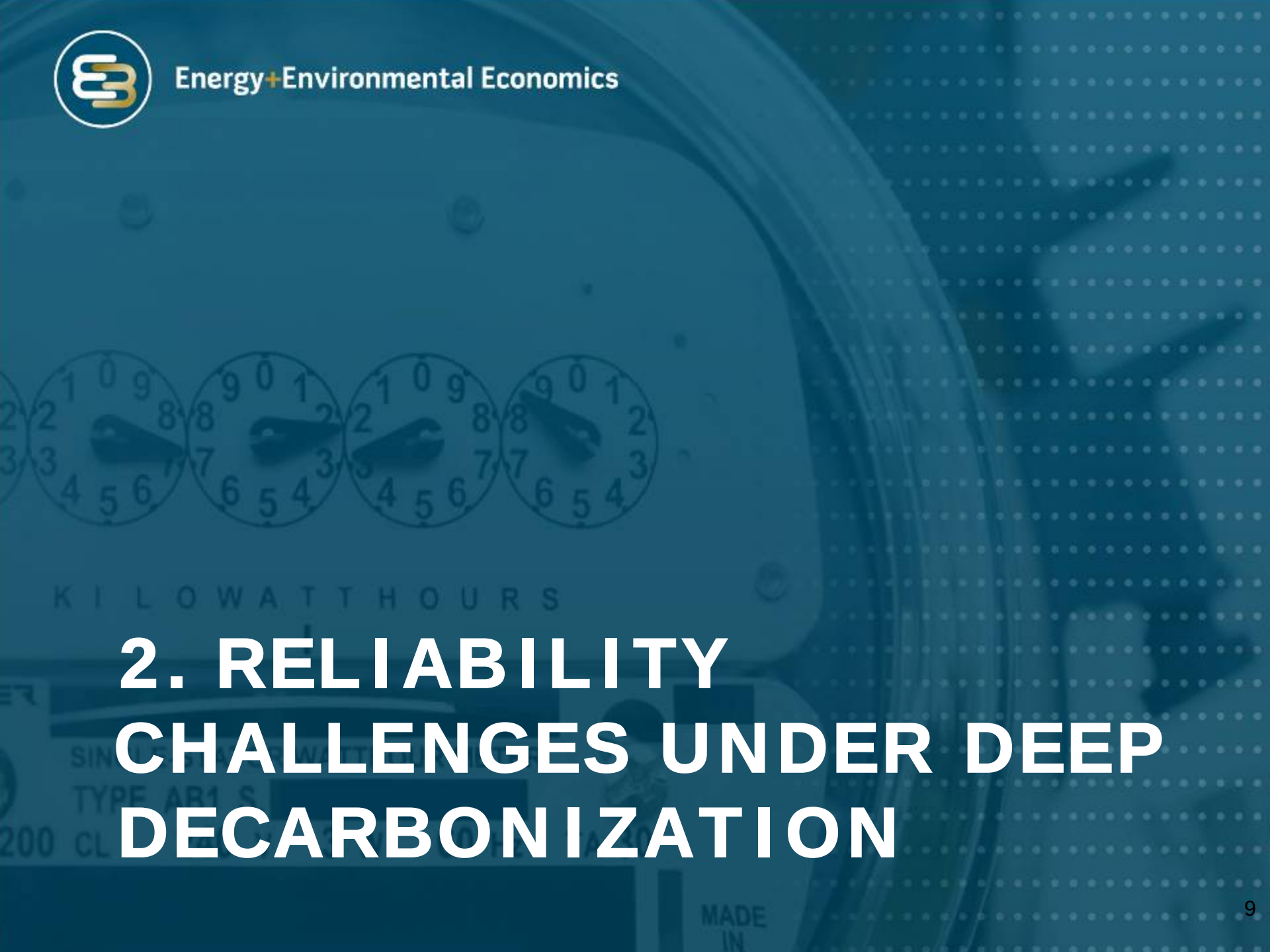


Study used E3's RESOLVE model to develop optimal resource portfolios for the Northwest

- **RESOLVE is an optimal capacity expansion model used in resource planning**
  - Designed for high renewable systems
  - Utilized in several jurisdictions including California, Hawaii and New York
- **Selects combination of renewable and conventional resources to minimize operational and investment costs 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

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

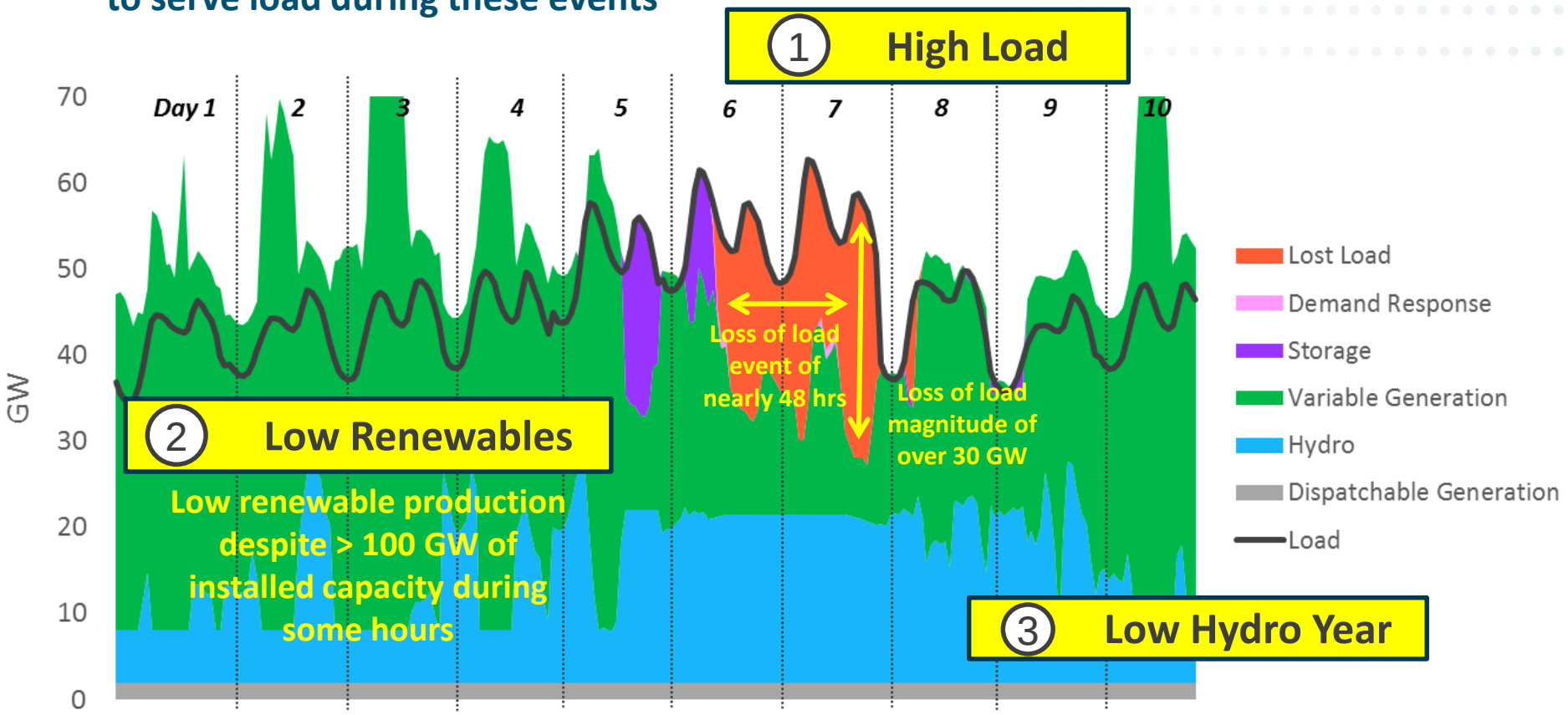
Information about E3's RESOLVE model can be found here:
https://www.ethree.com/tools/resolve-renewable-energy-solutions-model/



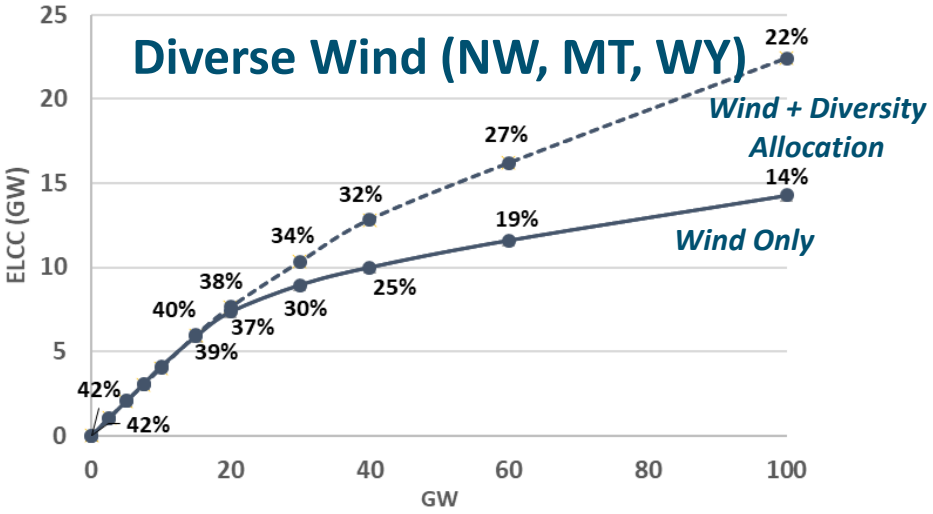
2. RELIABILITY CHALLENGES UNDER DEEP DECARBONIZATION

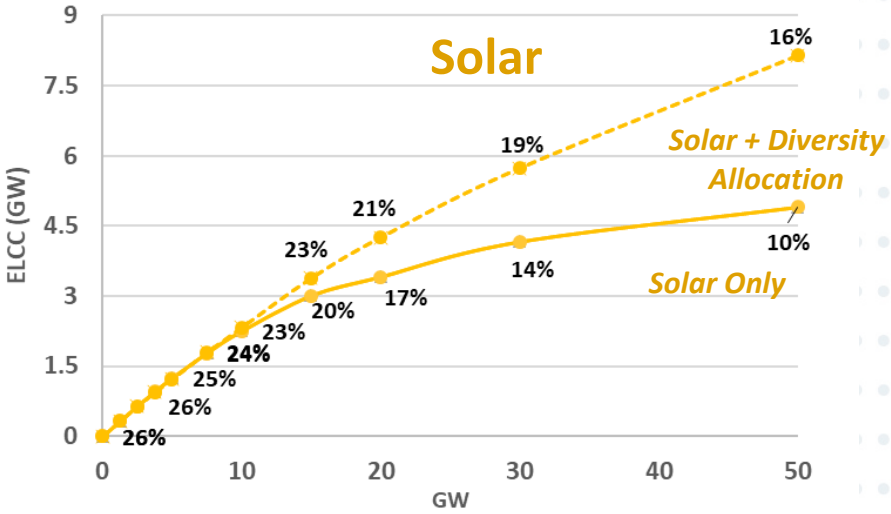
The most difficult conditions for reliable electric service are multi-day high load, low renewable production events

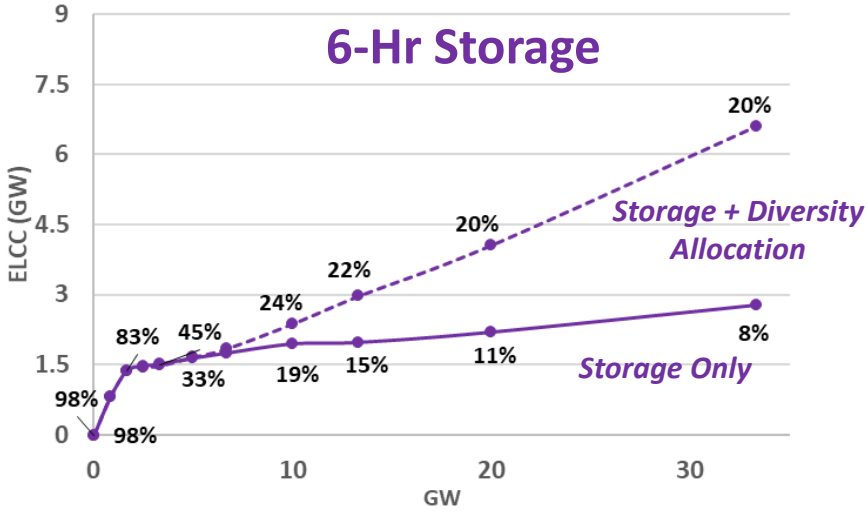
- Power systems that depend on wind and solar to provide a significant proportion of its energy are extremely vulnerable to low production events
- A massive "overbuild" of the portfolio would be needed to provide enough energy to serve load during these events



Wind, solar and energy storage provide limited effective capacity because they are not always available when needed







- A combined portfolio of diverse wind, solar and diurnal energy storage provides effective capacity of approximately 20% of nameplate
- Replacing 25 GW of firm capacity while maintaining equivalent reliability would require 125 GW of wind, solar and storage

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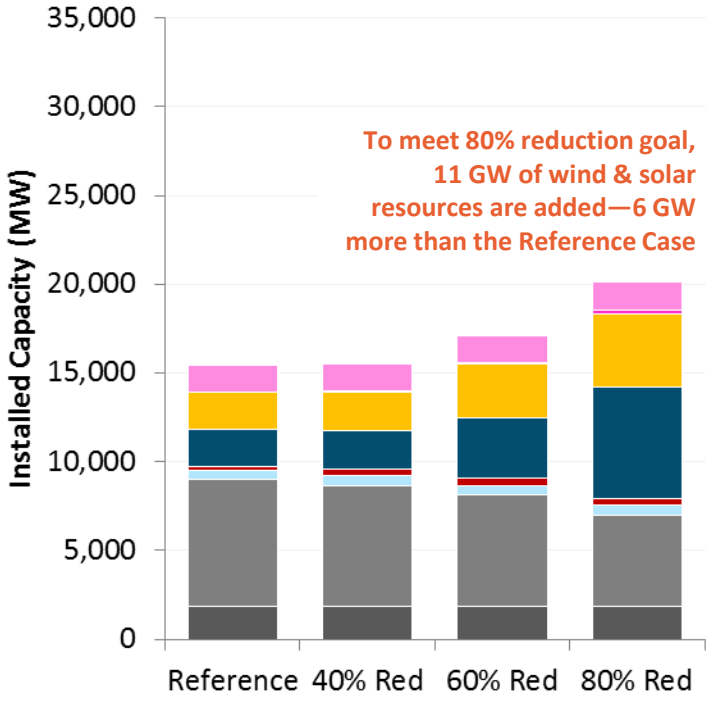
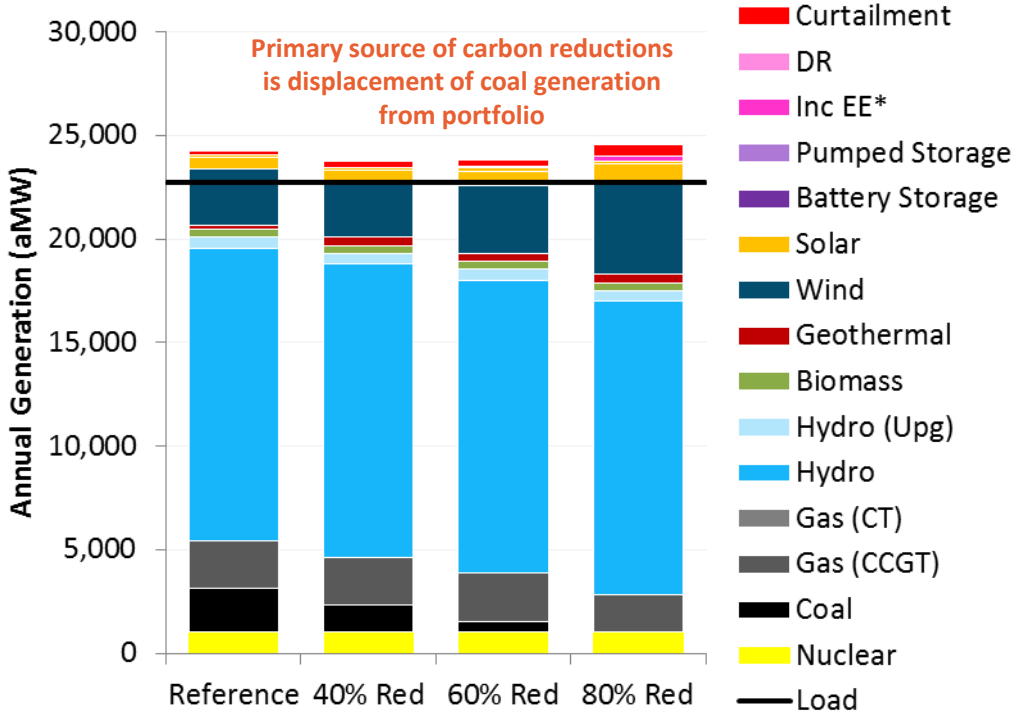
3. PORTFOLIO RESULTS

Cap-and-trade drives the clean energy transition through a price on carbon

New Resources Added by 2050 (MW)



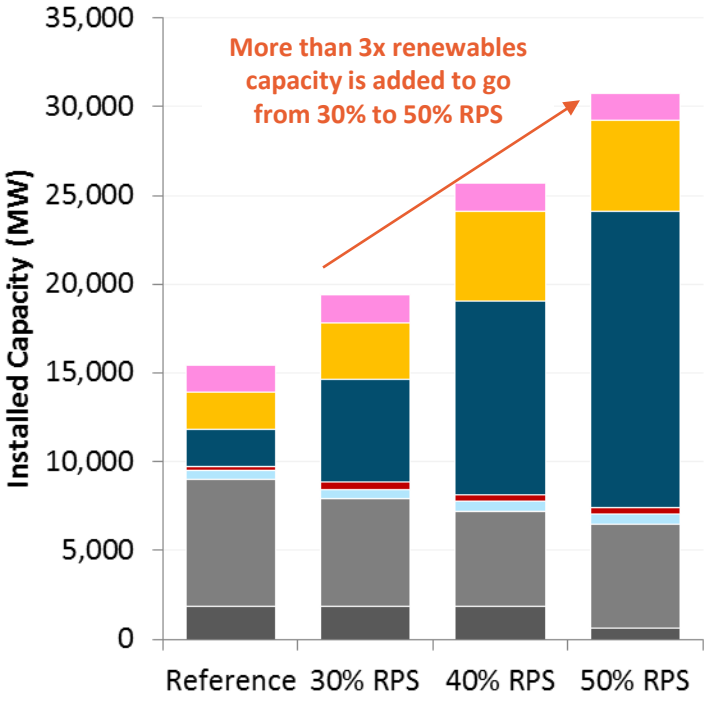
Annual Energy Production in 2050 (aMW)



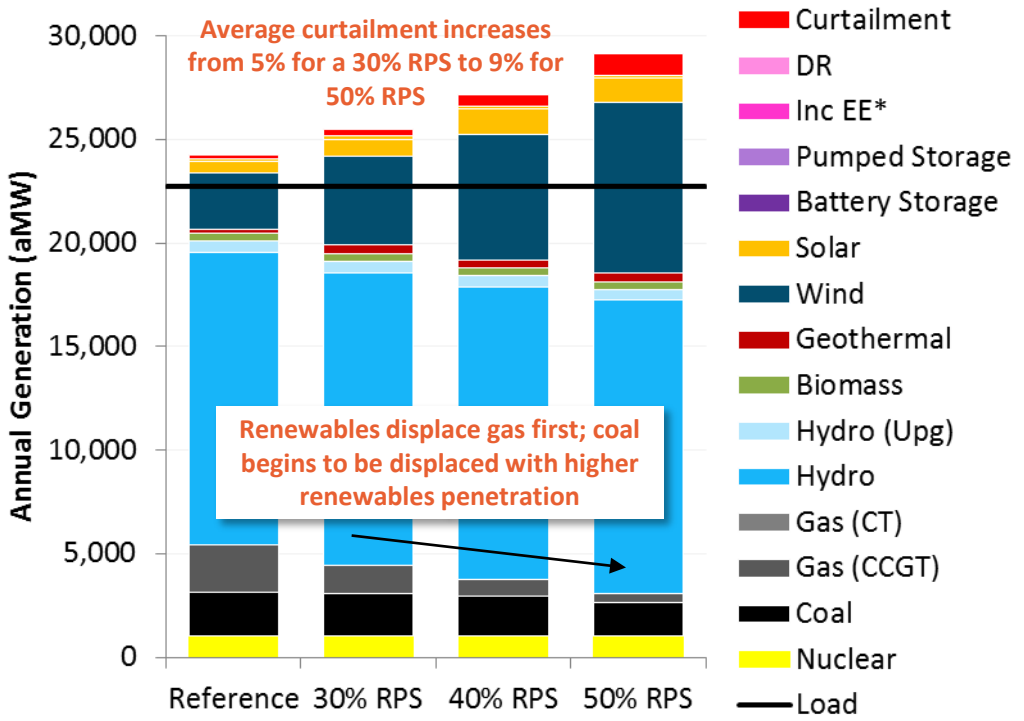
- 11,000 MW of new wind and solar power are added by 2050
- 7,000 MW of new natural gas generation needed for reliability
- Hydro generation still dominates
- Wind and solar generation replace coal
- Meets carbon goal at relatively low cost

High RPS policy results in "overbuild" of renewables but does not reduce coal

New Resources Added by 2050 (MW)



Annual Energy Production in 2050 (aMW)

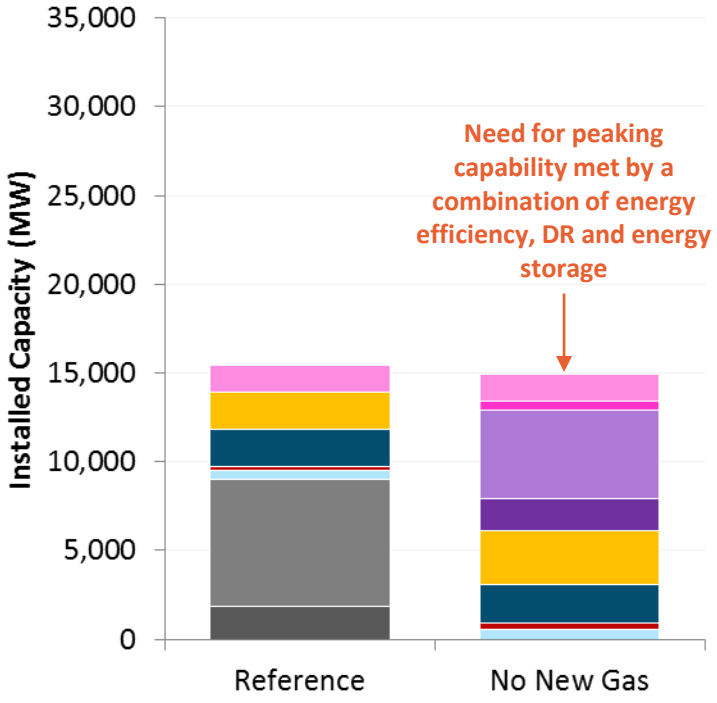


- + 23,000 MW of new wind and solar power are added by 2050
- + 7,000 MW of new natural gas generation needed for reliability

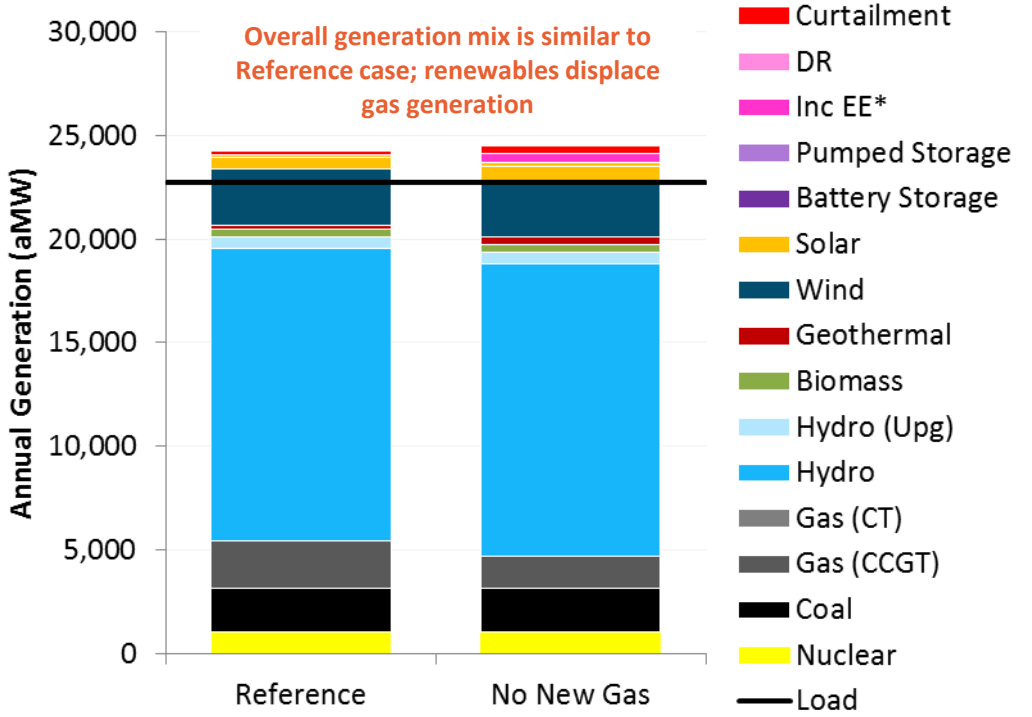
- + Very large surpluses of wind and solar energy
- + Coal generation continues to operate
- + Much higher cost and does not meet goal

Prohibition on new gas generation does little to reduce carbon

New Resources Added by 2050 (MW)



Annual Energy Production in 2050 (aMW)

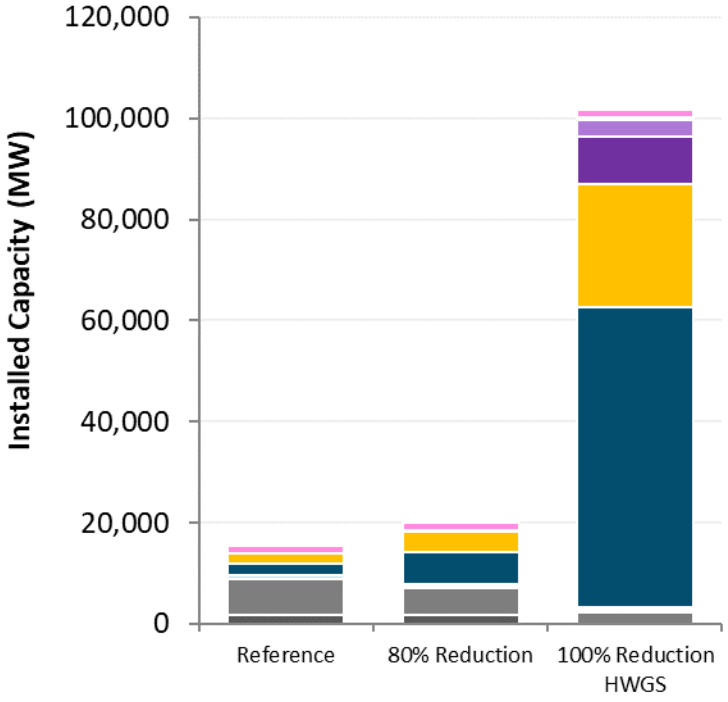


- Very little change in wind and solar from the Reference Case
- 7,000 MW of pumped hydro and battery storage replaces gas

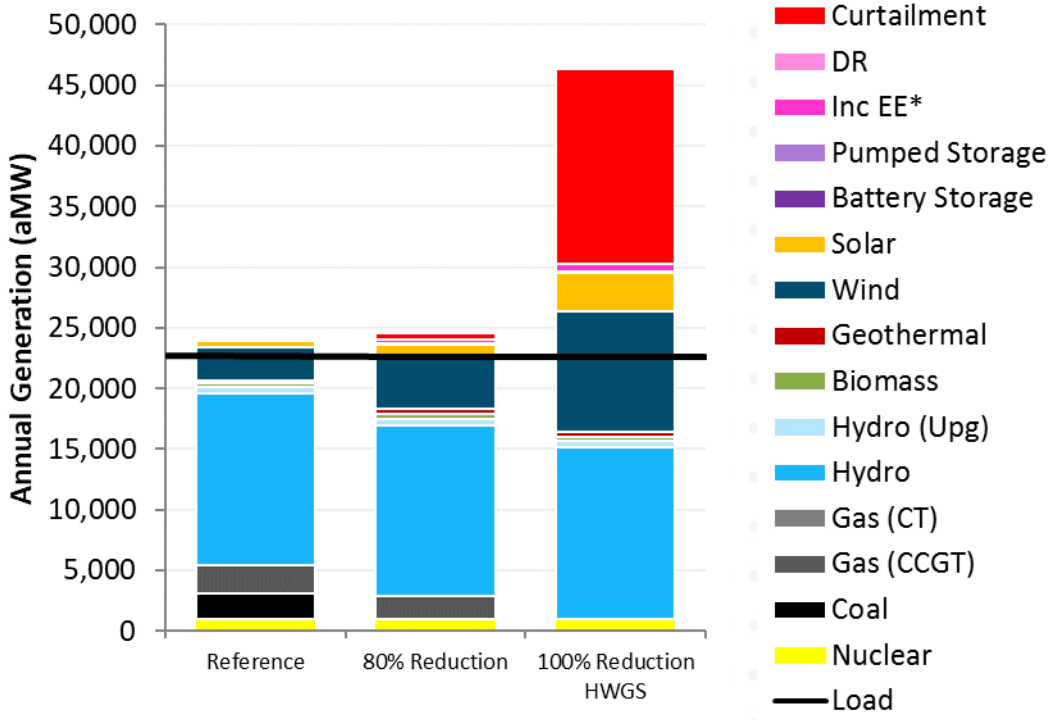
- Little change in wind and solar generation
- Coal generation continues to operate
- Electric system does not meet industry standards for reliability

Achieving a zero-carbon grid with only renewables and storage is prohibitively expensive

New Resources Added by 2050 (MW)



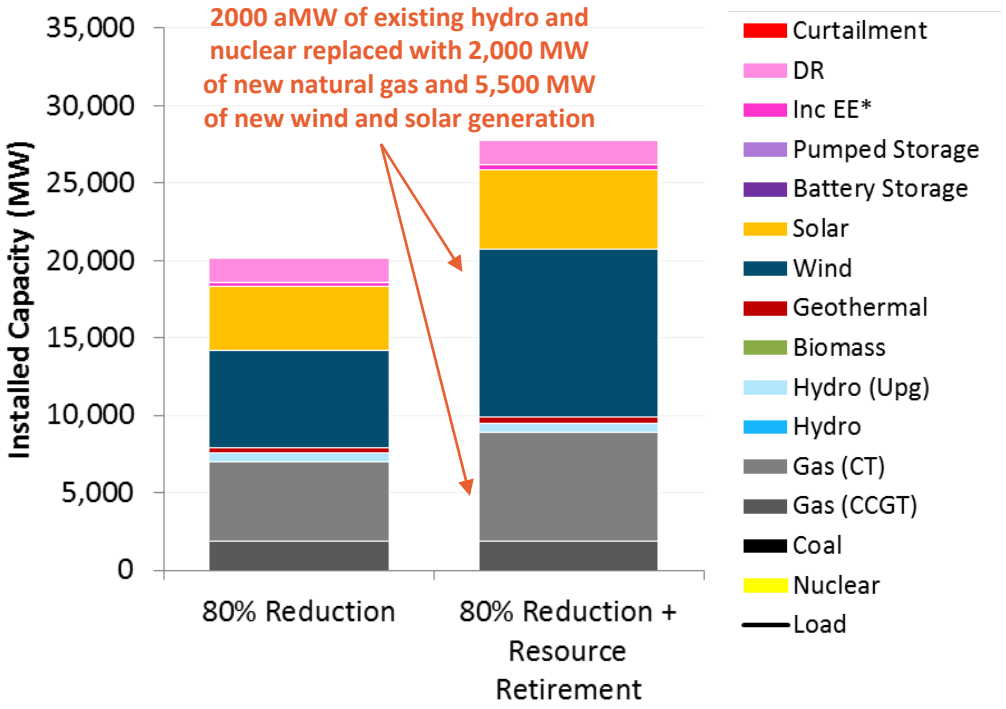
Annual Energy Production in 2050 (aMW)



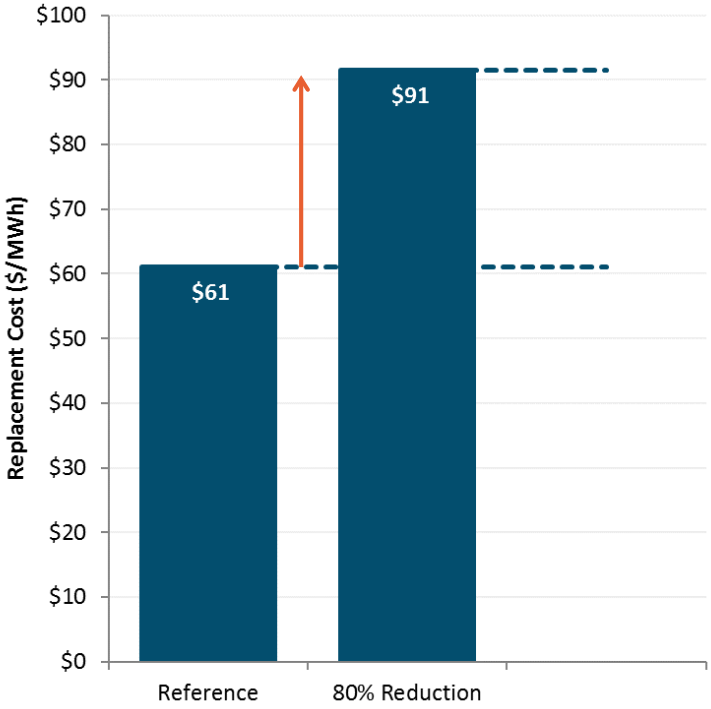
- 84,000 MW of new wind and solar added by 2050
- 10,000 MW of new energy storage
- Massive overbuild of wind and solar resources causes curtailment of nearly half of available renewable energy

Existing zero-carbon resources are valuable under a deep GHG reduction scenario

80% Carbon Reduction Case with Retirement



Cost of Replacement Power



- 2,000 aMW of existing resources replaced with 7,500 MW of new wind, solar and gas
- Total cost of meeting carbon goal increases from $1B to $2.6B per year by 2050
- Cost of replacement power is over $90/MWh in 80% Reduction case
- Hydro is valued for capacity, flexibility and zero-carbon energy

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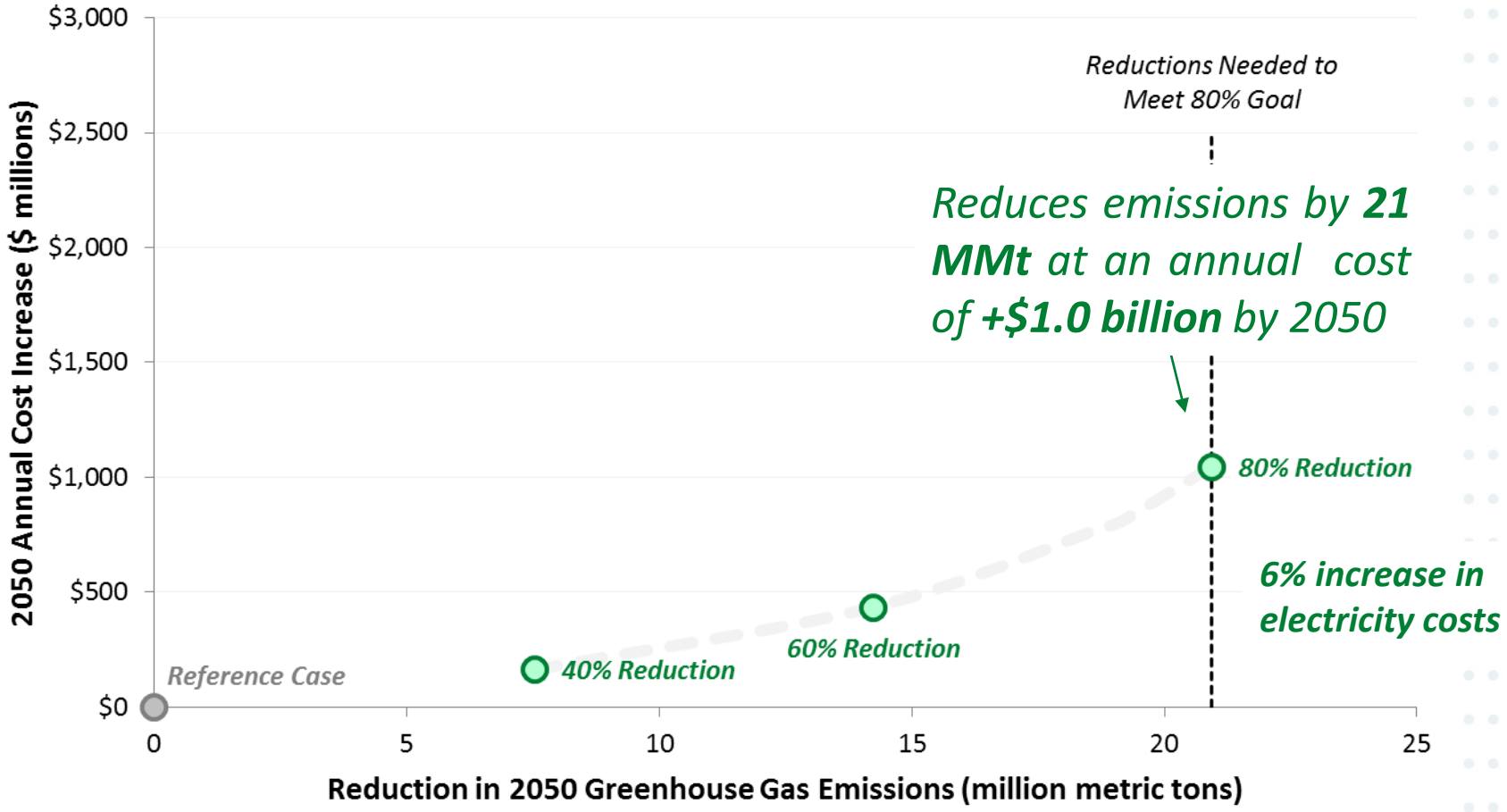
4. COST AND EMISSIONS IMPACTS

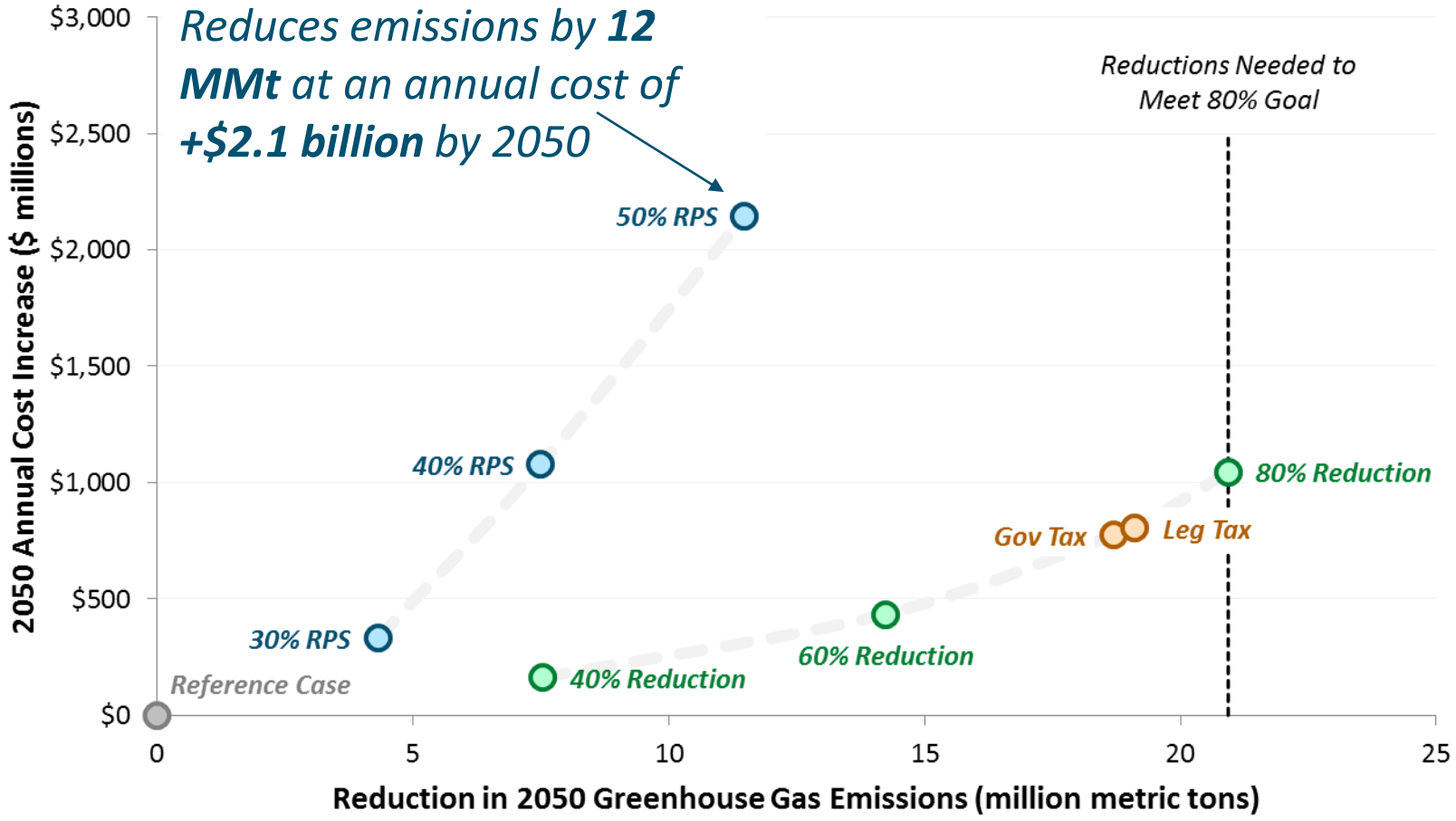
Cost & Emissions Impacts
Carbon Cap Cases



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

RPS Cases



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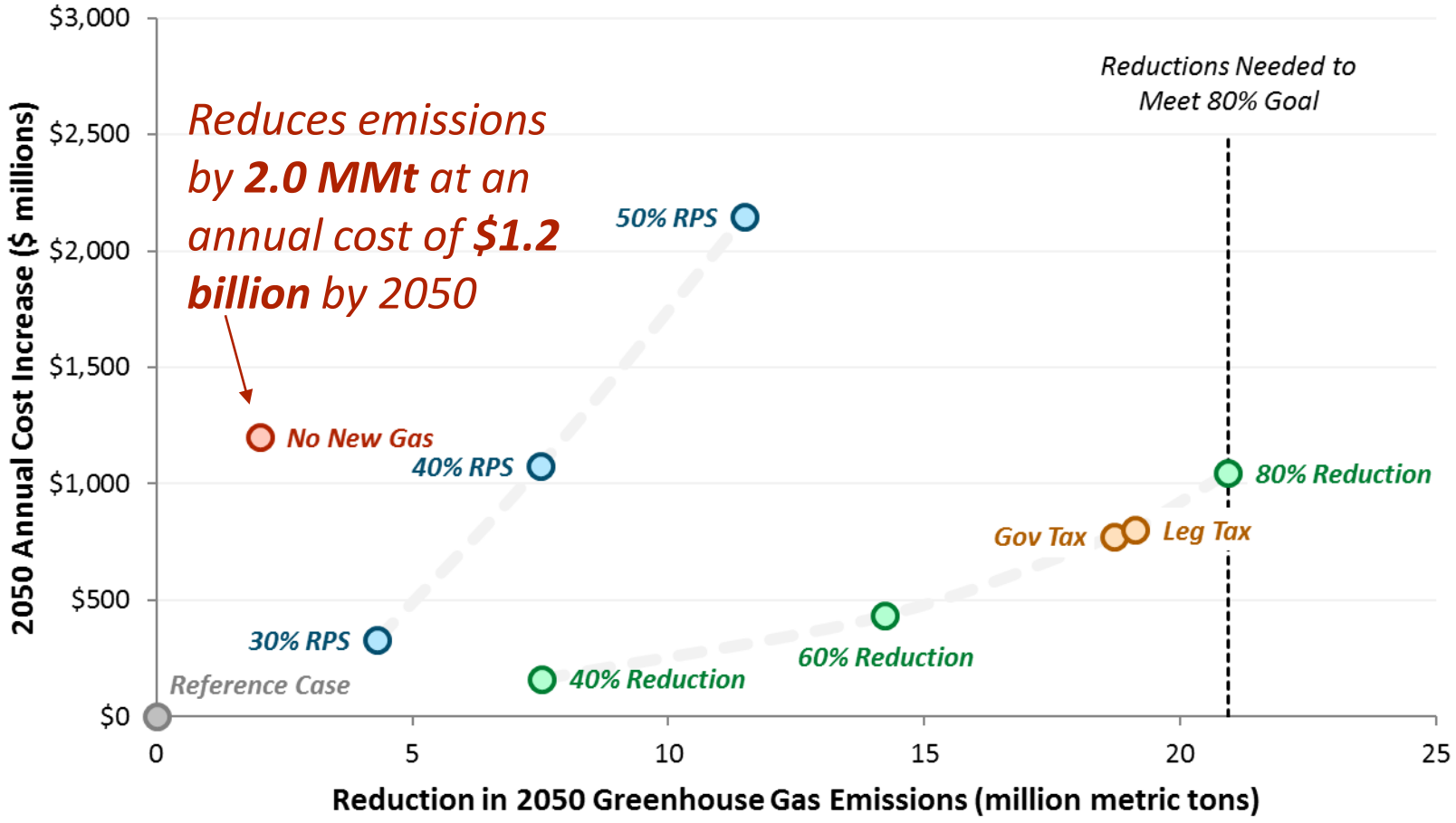
Cost & Emissions Impacts

No New Gas Case



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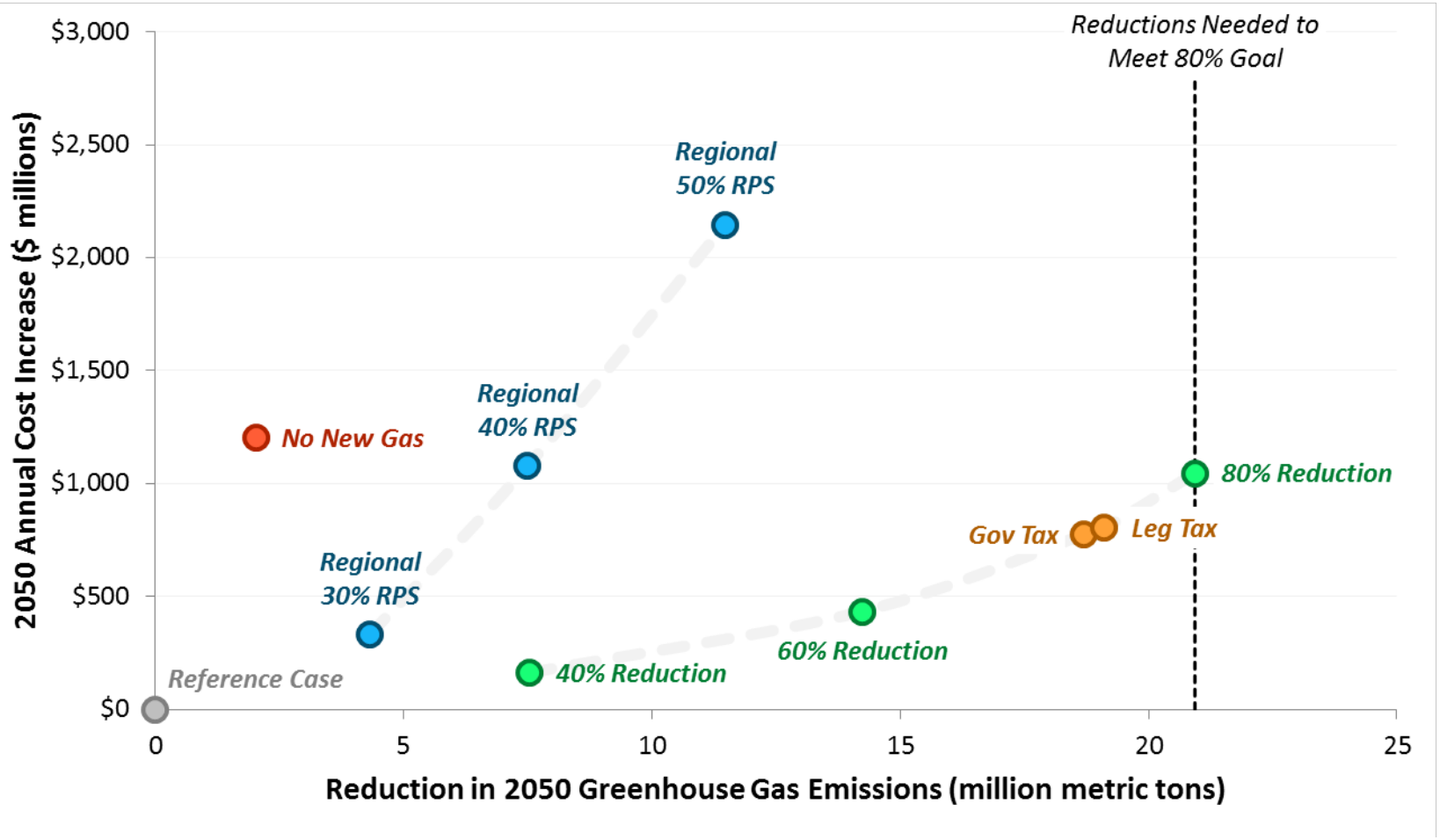
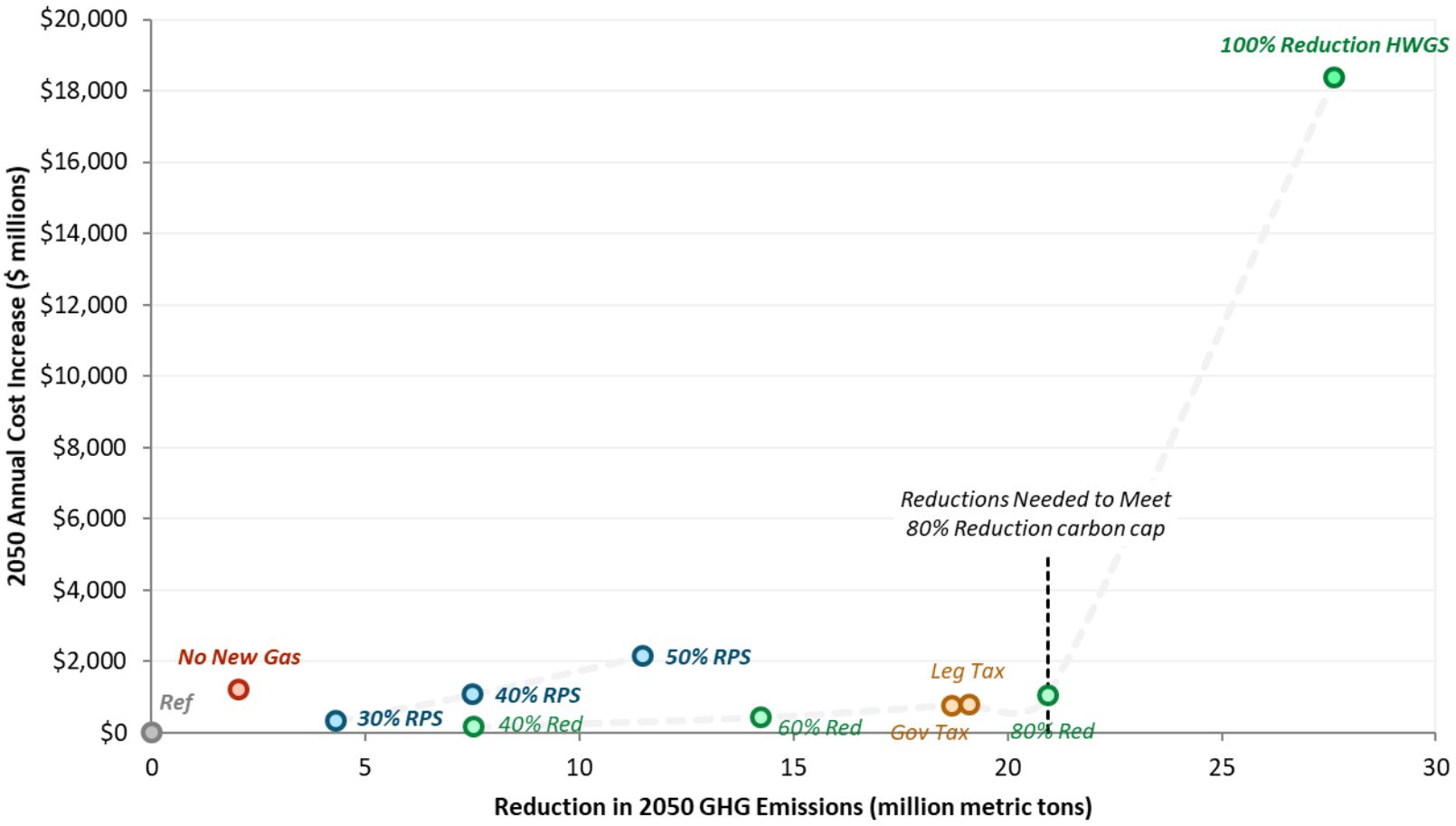
Cost & Emissions Impacts
All Cases



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

All Cases – Original PGP Study + 100% Reduction HWGS



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5. CONCLUSIONS AND LESSONS LEARNED

Key Findings (1 of 2)

1. **The lowest cost way to reduce carbon emission in the Northwest grid is to replace coal with a combination of energy efficiency, renewables and natural gas**
   - An economy-wide **price on carbon** is a technology-neutral policy that provides incentives for achieving emissions reductions at the lowest cost
2. **It is possible to maintain Resource Adequacy for a deeply decarbonized Northwest electricity grid, as long as sufficient firm capacity is available during periods of low wind, solar and hydro production**
   - Natural gas generation is the most economic source of firm capacity, and adding new gas *capacity* is not inconsistent with deep reductions in carbon emissions
   - Wind, solar, demand response and short-duration energy storage can contribute but have important limitations in their ability to meet Northwest Resource Adequacy needs
   - Other potential low-carbon firm capacity solutions include (1) new nuclear generation, (2) gas or coal generation with carbon capture and sequestration, (3) ultra-long duration electricity storage, and (4) replacing conventional natural gas with carbon-neutral gas
3. **It would be extremely costly and impractical to replace all carbon-emitting firm generation capacity with solar, wind and storage**

Key Findings (2 of 2)

4. **Renewables will play a critical role in a deeply decarbonized future, however a higher Renewables Portfolio Standard results in higher costs and higher carbon emissions than policies that focus directly on carbon**
   - RPS policy has **unintended consequences** such as oversupply and negative wholesale electricity prices that create challenges for reinvestment in existing zero-carbon resources
5. **Retiring existing hydro and nuclear generation makes it much more challenging and costly to meet carbon goals**
   - Policies that encourage the **retention of existing zero-carbon generation** resources will help contain costs of meeting carbon goals
6. **The Northwest is anticipated to need new capacity in the near-term in order to maintain an acceptable level of Resource Adequacy after planned coal retirements**
7. **Current practice of relying on "market purchases" instead of firm capacity risks underinvestment in new capacity required to ensure Resource Adequacy at acceptable levels**
   - The region should investigate a formal mechanism for sharing of planning reserves

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Thank You!

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