Northwest **Power** and **Conservation** Council

December 5, 2017

MEMORANDUM

TO: **Council Members**

FROM: **Ben Kujala**

SUBJECT: **Briefing on Public Generating Pool Decarbonization Study**

BACKGROUND:

Presenter: Therese Hampton, Public Generating Pool, Arne Olsen, E3

Summary: The Public Generating Pool commissioned E3 to study what policies best support a least-cost approach to reducing carbon emissions and to examine what the implications were for the Northwest utility portfolios. This study was referenced by Randy Hardy at the November meeting. Links to the study were sent out after that meeting.

PGP and E3 will present and discuss the results of the study to the Council at this meeting and be available to answer questions from the Council Members.

More Info: http://www.publicgeneratingpool.com/e3-carbon-study/

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Energy+Environmental Economics

Pacific Northwest Low Carbon Scenario Analysis

Achieving Least-Cost Carbon Emissions Reductions in the Electricity Sector

November 8, 2017

Arne Olson, Partner

Nick Schlag, Sr. Managing Consultant

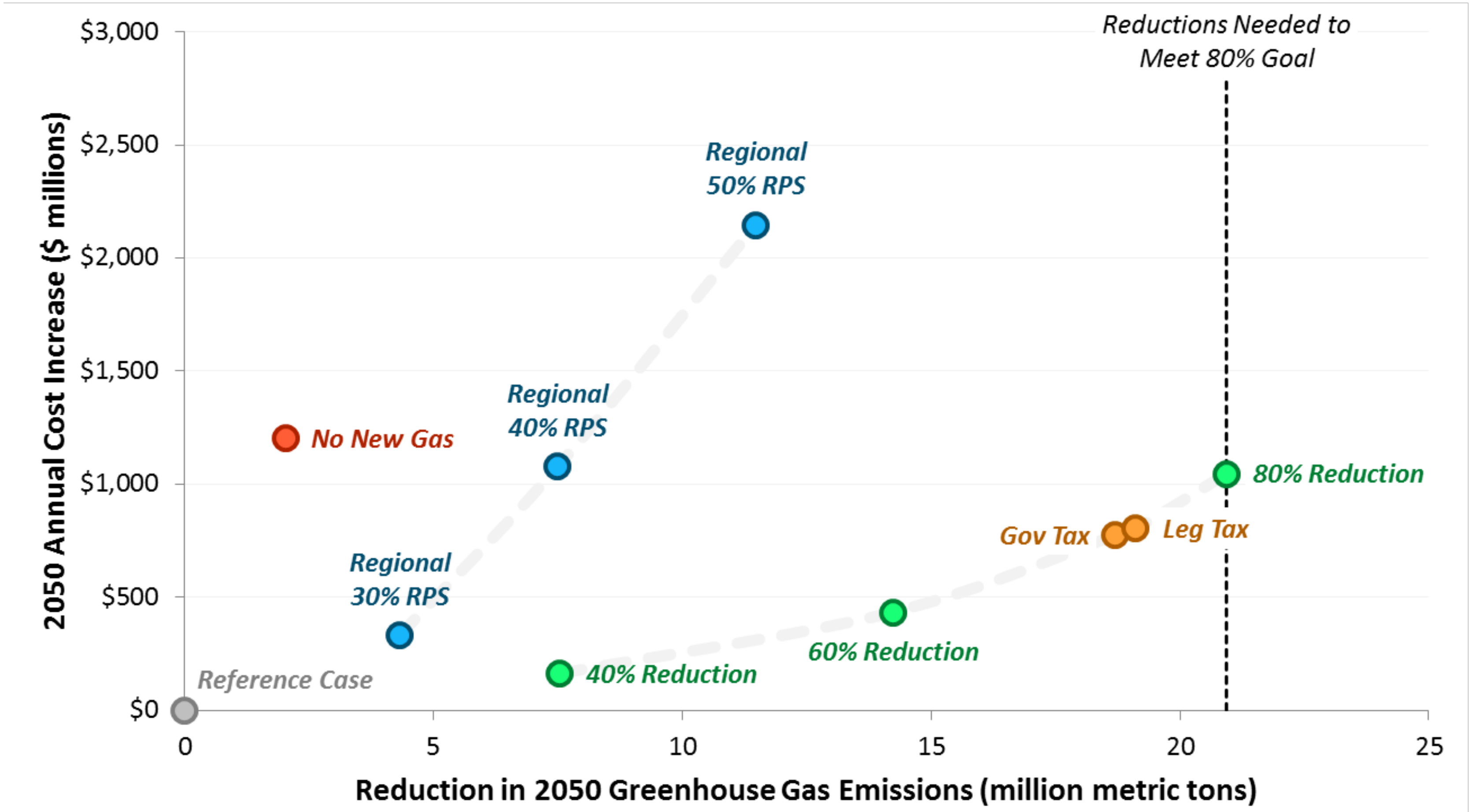
Jasmine Ouyang, Consultant

Kiran Chawla, Consultant

Outline

- Study Background & Context
- Methodology & Scenarios
- Results
- Conclusions

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

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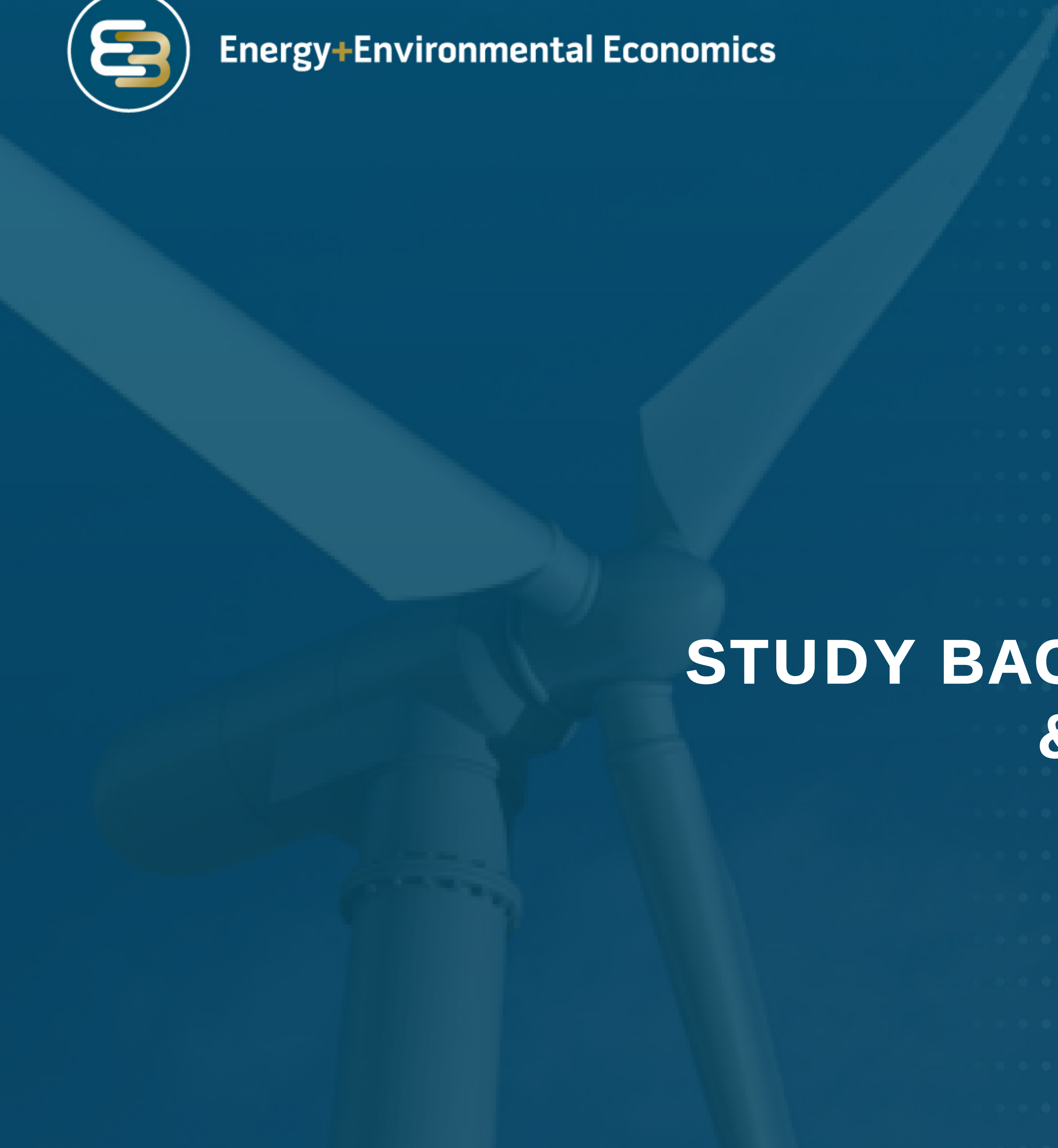
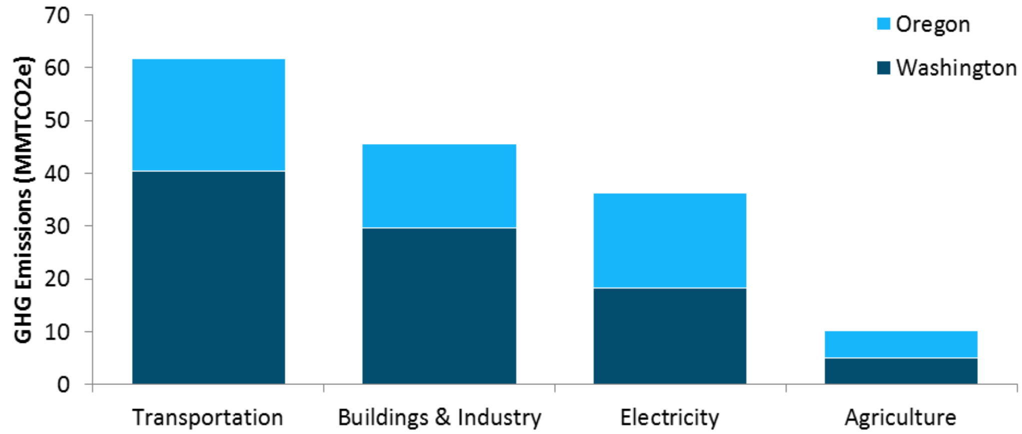


STUDY BACKGROUND & CONTEXT

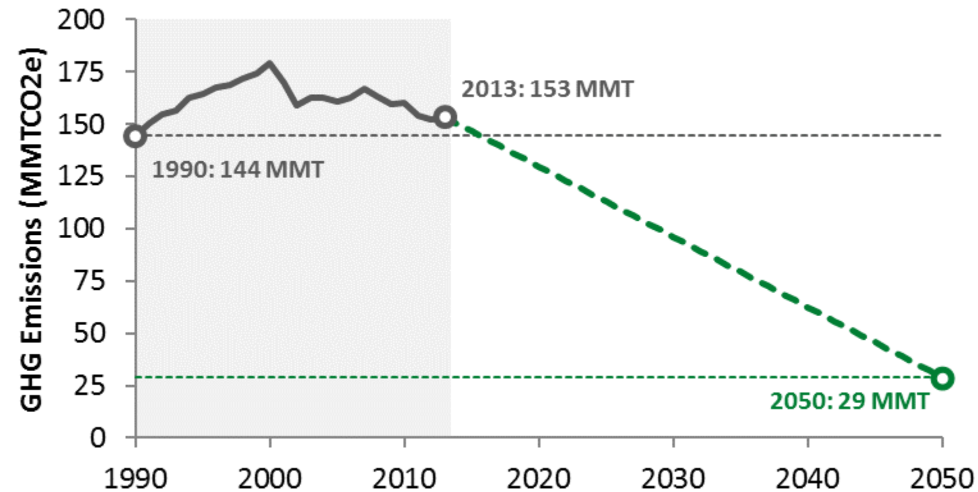
About This Study

- **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 inform policymakers on the effectiveness of various potential policies to reduce GHG emissions in the Northwest:**
  - What are the most cost-effective ways to reduce electricity sector emissions?
  - What is the value of existing carbon-free resources?

2013 GHG Emissions for Oregon and Washington



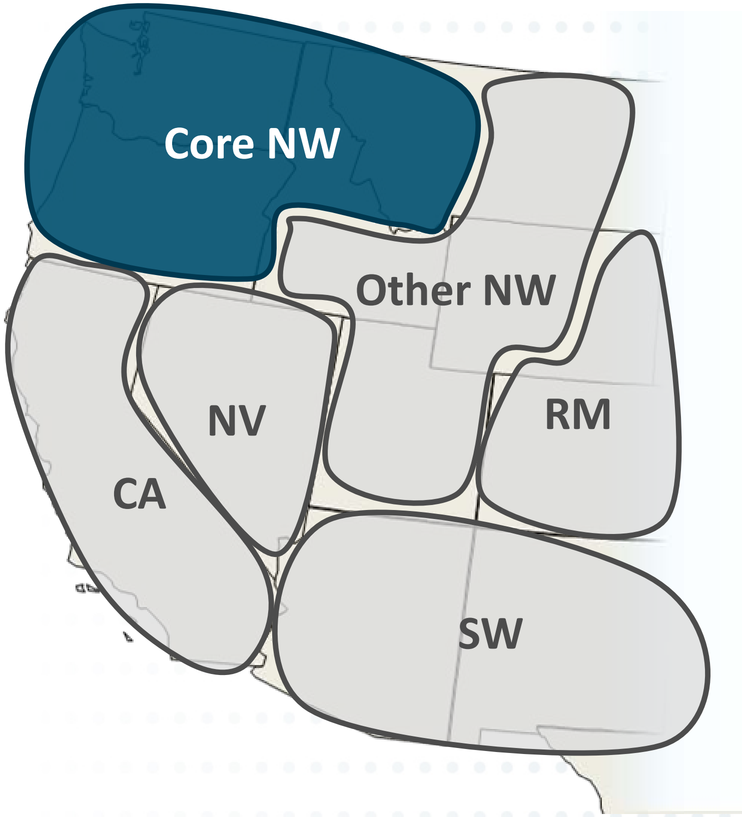
Historical and Projected GHG Emissions



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

Study Footprint

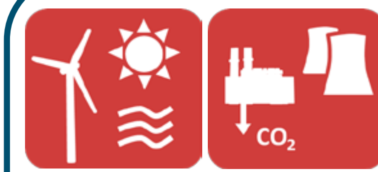
- E3's RESOLVE Model is used to optimize a resource portfolio for electric loads in "Core NW" region
  - Washington, Oregon, North Idaho and Western Montana
- Study considers the Northwest's unique, hydro-dominated system
- Remaining BAs of the WECC are grouped into five zones
  - RESOLVE optimizes operations—but not investments—in external zones to reflect market opportunities for energy trading between regions in investment decisions
- British Columbia and Alberta are not modeled



Four "Pillars" of Decarbonization to Meet Long-Term Goals

Energy efficiency & conservation

Electrification



Low carbon electricity

Low carbon fuels

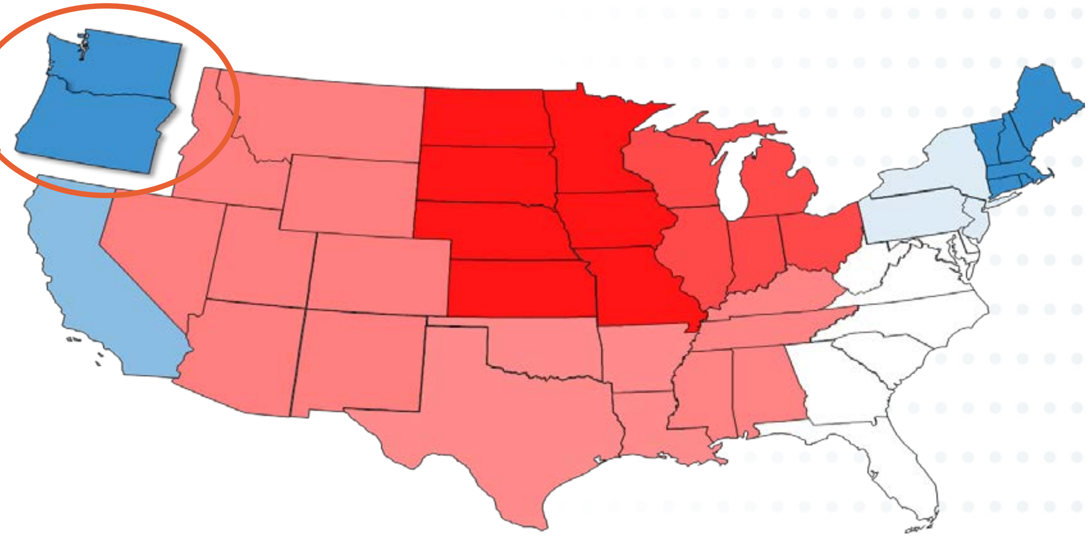
- **Four foundational elements are consistently identified in studies of strategies to meet deep decarbonization goals**
- **Across most decarbonization studies, electric sector plays a central role in meeting goals**
  - Through direct carbon reductions
  - Through electrification of loads to reduce emissions in other sectors

Carbon Intensity of the Northwest's Electricity Sector is Relatively Low

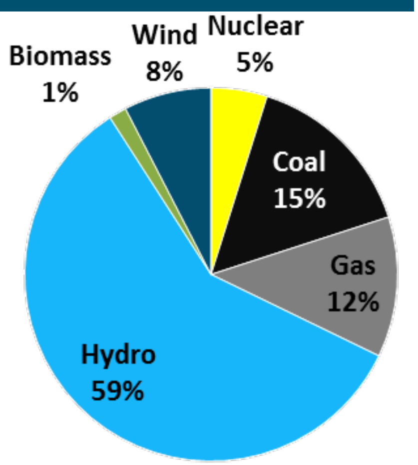
- **Due to large fleet of existing zero-carbon resources, electric emissions intensity in the Pacific Northwest is already below other regions in the United States**

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

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



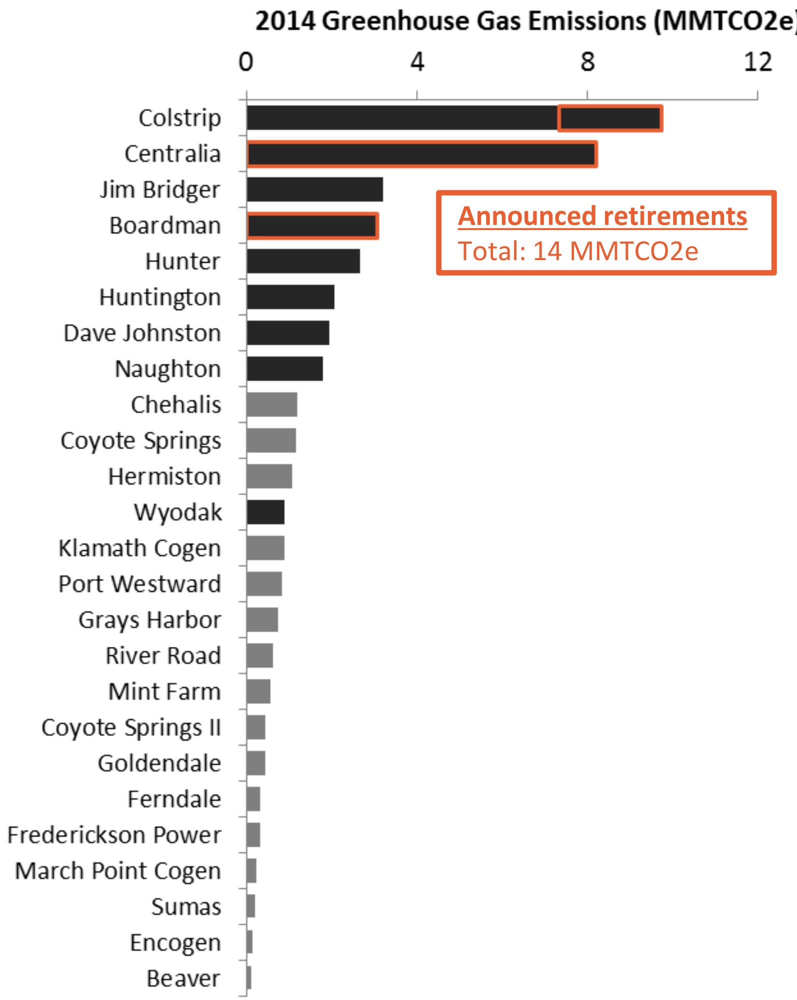
WA/OR Generation Mix



2013 Emissions Intensity (tons/MWh)												
0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80

Figure developed using data gathered from state 2013 GHG inventories for Washington, Oregon, and California; supplemented with data from EIA Annual Energy Outlook 2016

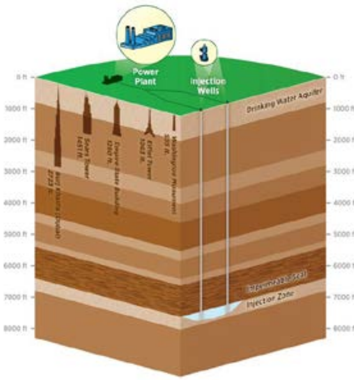
A Handful of Plants are Responsible for Most of the Electric Sector GHG Emissions in the Northwest



- **Existing coal plants (9 units) are responsible for 33 million metric tons of emissions—roughly 80% of all emissions attributed to Washington & Oregon**
  - Includes contracted generation in Montana, Wyoming
- **Existing gas generation accounts for roughly 9 million metric tons**

Low-Carbon Electricity Generation Becomes the Predominant Source of Primary 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. **Fossil generation with carbon capture and storage (CCS)**



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METHODOLOGY & SCENARIOS

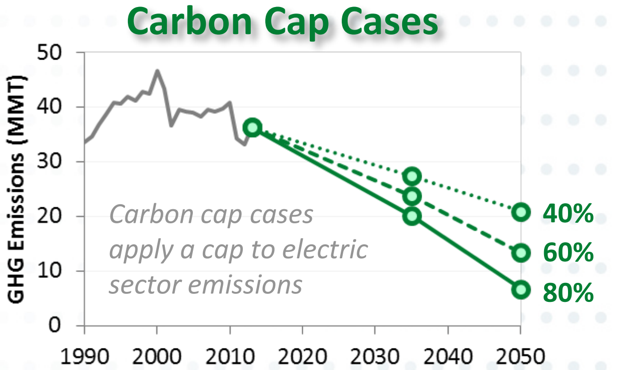
Overview of the Analysis

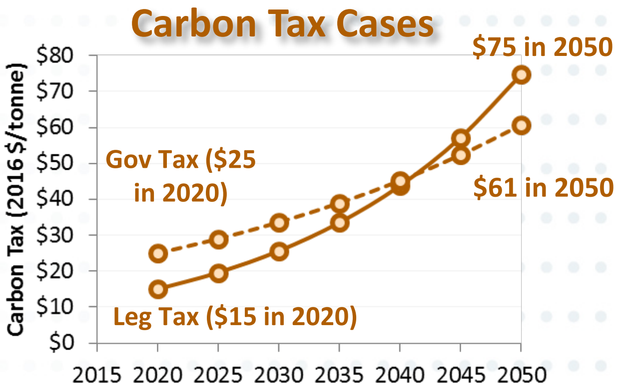
+ **This study uses E3's Renewable Energy Solutions (RESOLVE) Model**
  - Designed for modeling operations and investments for high-renewable power systems
  - Utilized in several jurisdictions including California, Hawaii and New York
+ **Selects optimal portfolio of renewable and conventional resources over time**
  - Optimal dispatch over a representative set of operating days in each year
  - Meets energy, capacity and balancing needs
  - Complies with RPS or GHG target ("overbuilding" portfolio if necessary)

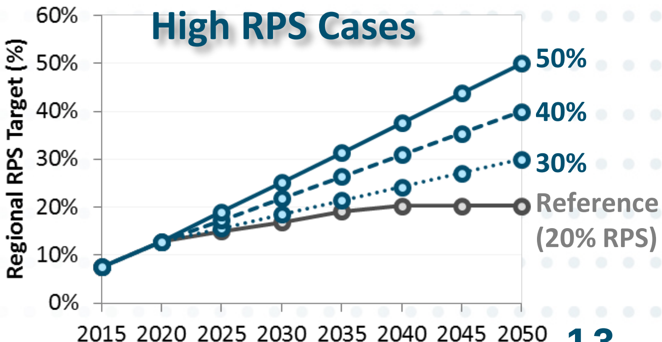
Resource Option	Examples of Available Options
Natural Gas Generation	• Simple cycle gas turbines • Reciprocating engines • Combined cycle gas turbines • Repowered CCGTs
Renewable Generation	• Geothermal • Hydro upgrades • Solar PV • Wind
Energy Storage	• Batteries (>1 hr) • Pumped Storage (>12 hr)
Energy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

Overview of Core Policy Scenarios

1. **Reference Case:** reflects current state 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





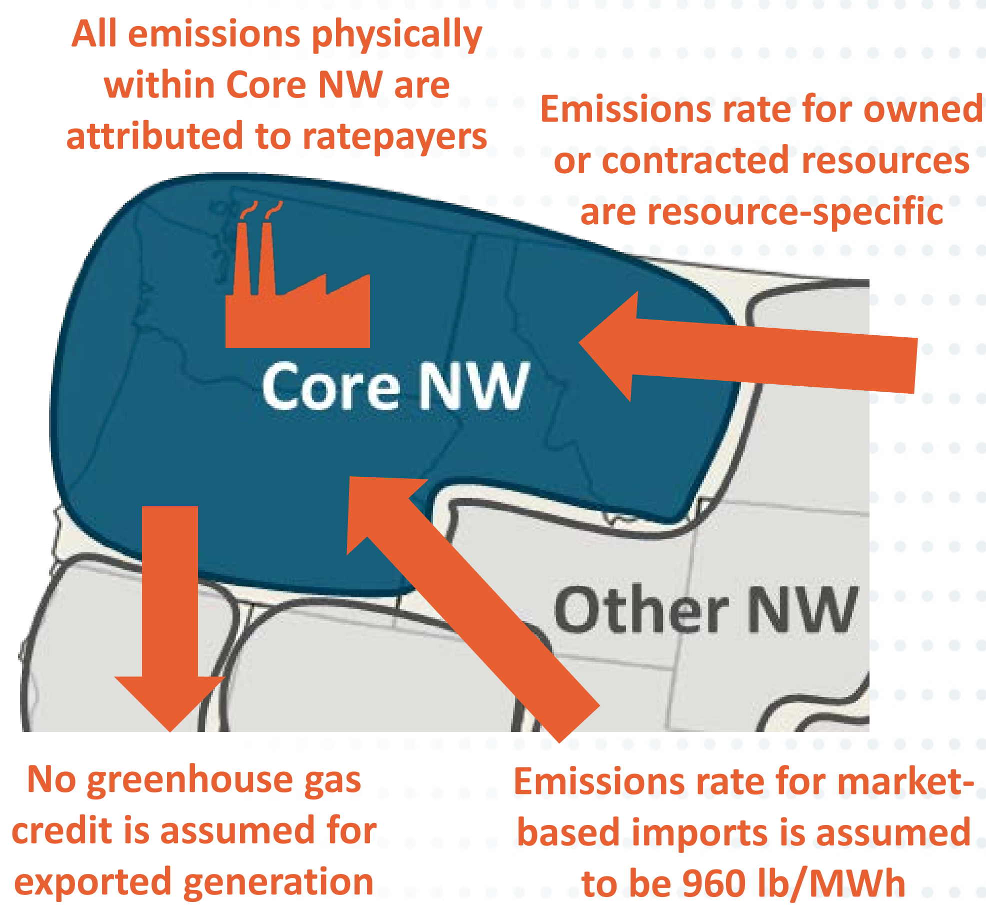


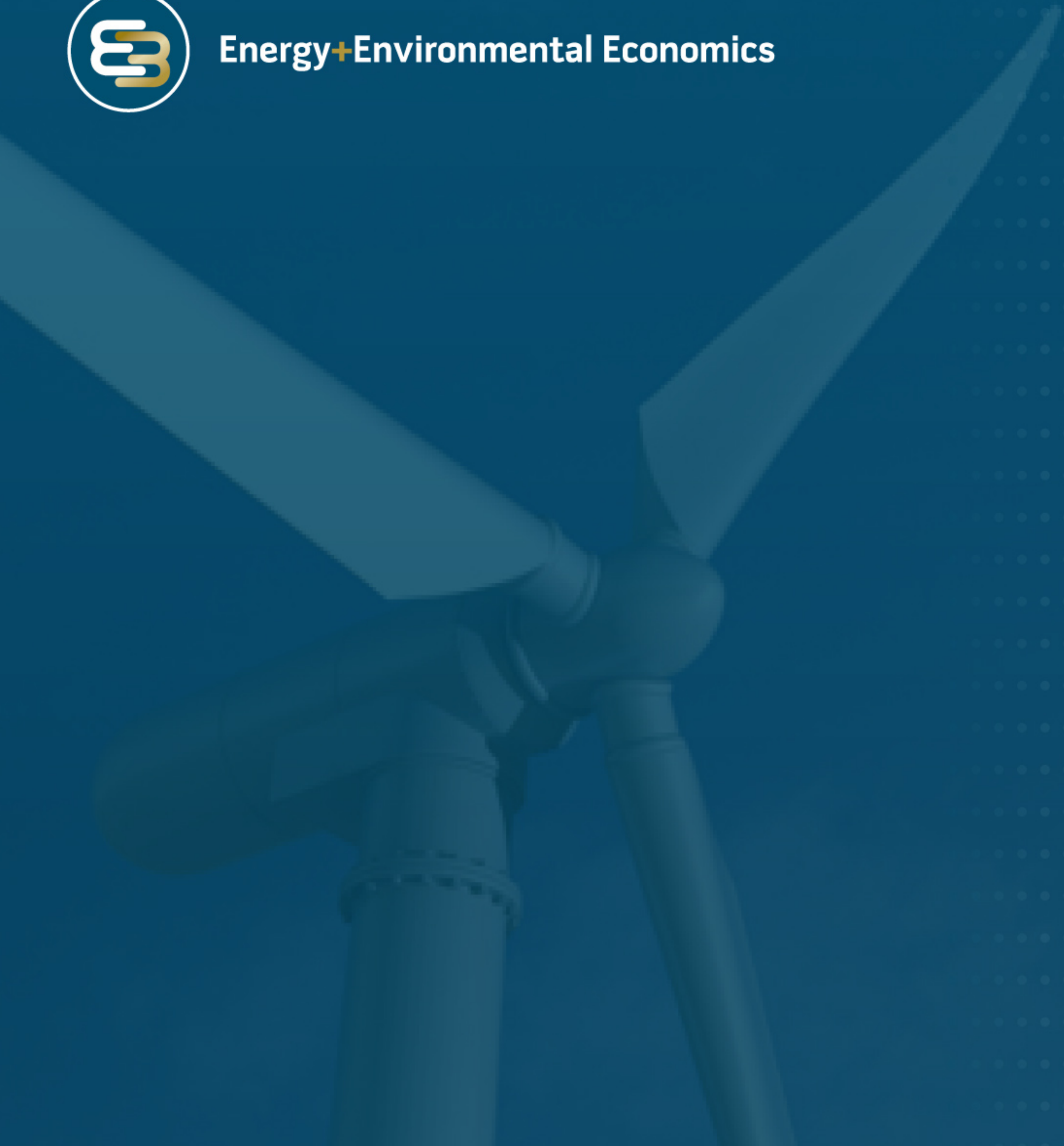
Sensitivity Analysis Used to Explore Additional Questions

Sensitivity	Purpose
A. No Revenue Recycling	Examine impact to ratepayers if revenue collected under carbon pricing mechanism is not returned to the electricity sector
B. Loss of Existing Carbon-Free Resources	Examine the cost and GHG implications of decommissioning existing hydro and nuclear generation
C. High Energy Efficiency	Examine the potential role of higher-cost energy efficiency measures in a GHG-constrained future
D. High Electric Vehicles	Explore the role of vehicle as a potential strategy for reducing GHG emissions in the transportation sector
E. High & Low Gas Prices	Examine sensitivity of key learnings to assumptions on future natural gas prices
F. Low Technology Costs	Explore changes in cost and portfolio composition under assumptions of lower costs for solar, wind and energy storage
G. California 100% RPS	Explore implications of California clean energy policy on decarbonization in the Northwest

Greenhouse Gas Accounting Conventions for Study Footprint

- **Study focuses on quantifying greenhouse gases associated with Core NW resource mix**
- **Accounting conventions mirror current cap & trade rules in California**
- **Emissions attributed to Core NW include:**
  - All fossil generation physically located in the Core NW
  - Ownership shares of remotely-owned coal plants
  - Economic imports, at an assumed rate of 960 lb/MWh
  - No GHG credit for exported generation



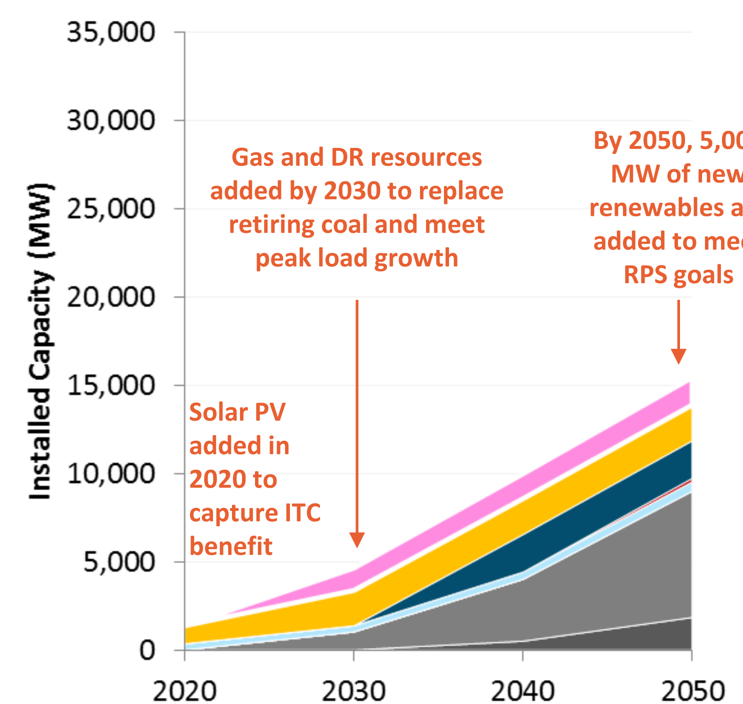


RESULTS

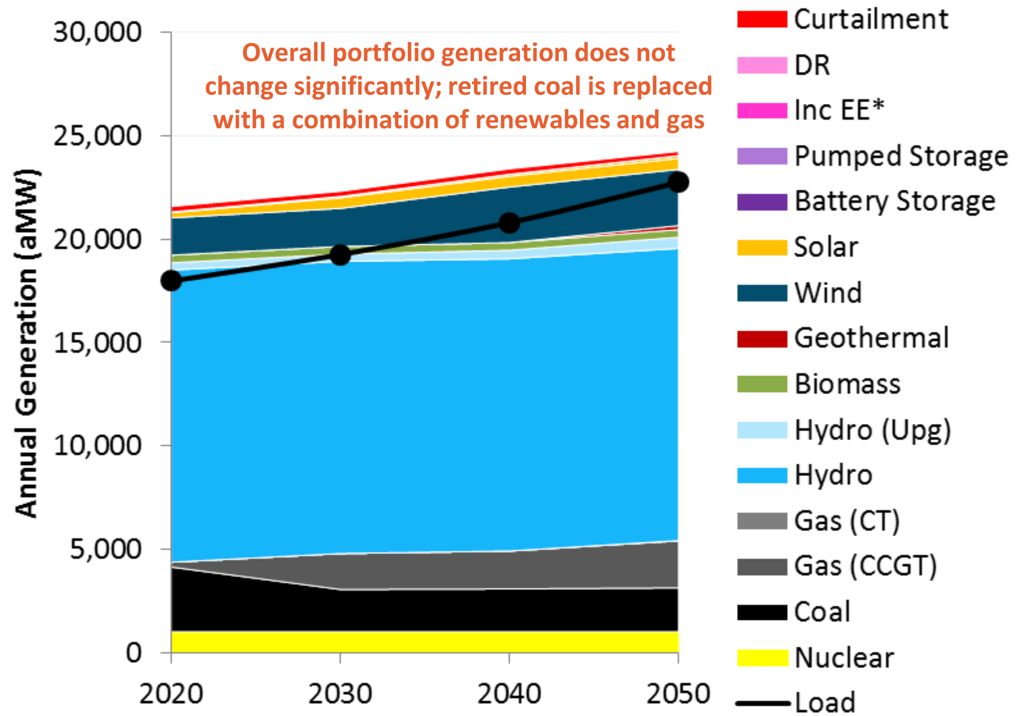
Portfolio Summary
Reference Case

+ New gas gen. and DR added after 2020 to meet capacity needs
+ Planned coal retirements result in increased reliance on gas generation
+ By 2050, 5 GW of renewable resources are needed to meet RPS goals

Resources Added (MW)



Energy Balance (aMW)



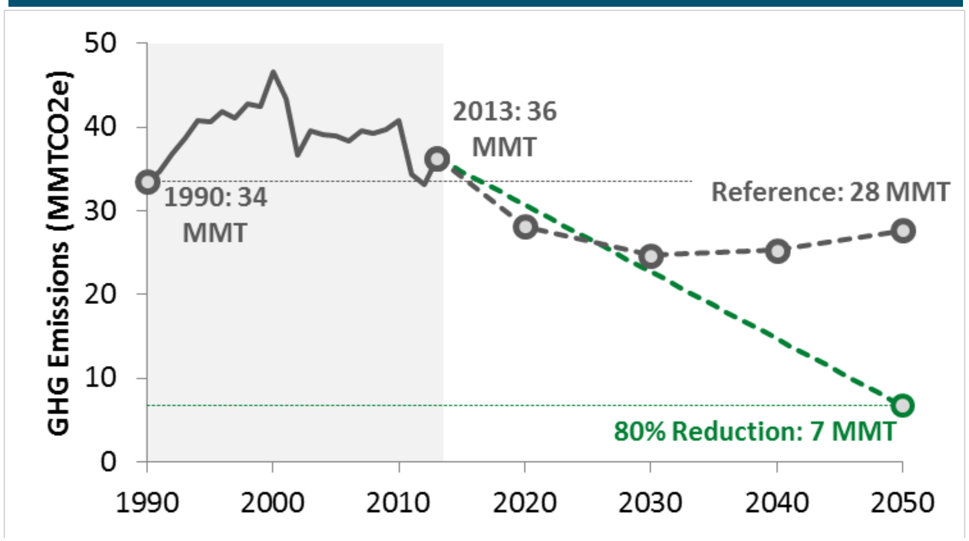
* EE shown here is incremental to efficiency included in load forecast (based on NWPCC 7th Plan)

Emissions Trajectory
Reference Case

+ **Through 2030, current policies and trends result in emissions reductions that are generally consistent with long-term goals**
  - Load growth limited by cost-effective energy efficiency
  - 2,500 MW of renewable generation added to meet RPS policy goals by 2030
  - 2,300 MW of coal capacity retired

+ **Additional measures are needed to meet long-term goals beyond 2030**
  - Coal generation remains the largest source of emissions beyond 2030
  - Additional gas generation & imports are needed to meet load growth
  - Emissions start to trend back up after 2030 without new policy

Electricity Sector Emissions Trajectory (MMTCO2e)



2050 Portfolio Summary

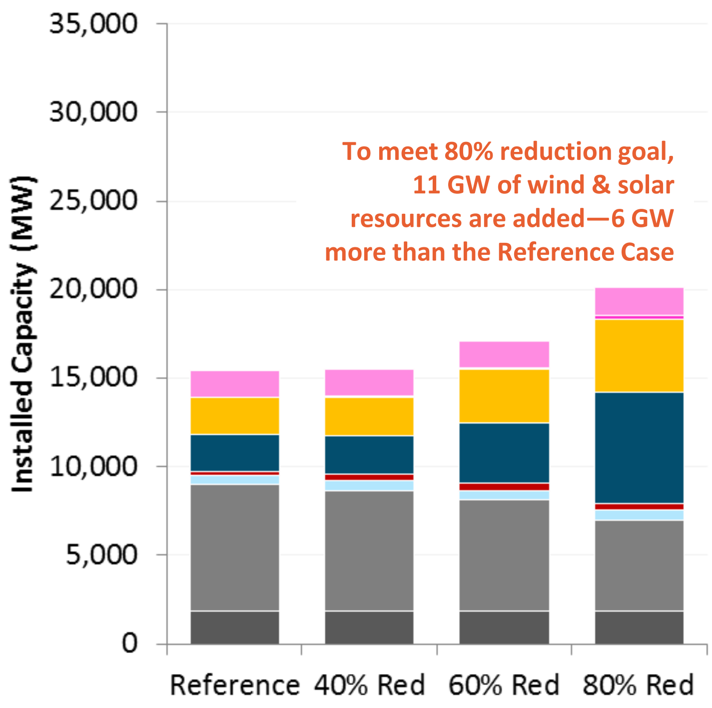
Carbon Cap Scenarios

Highlights

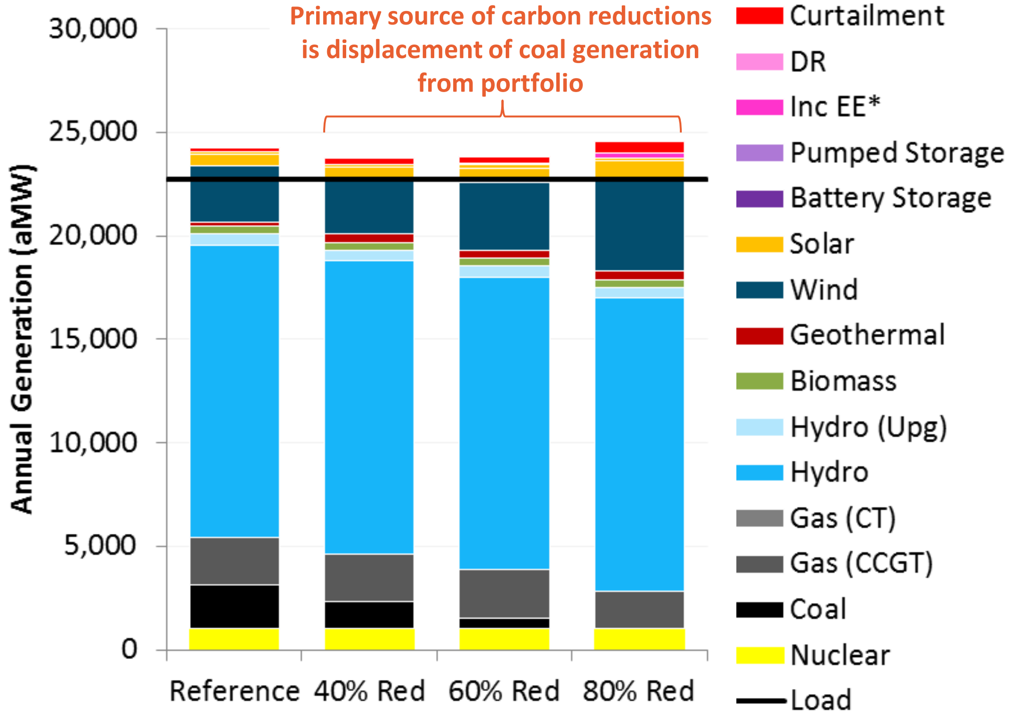
- Coal retired under 80% Case, replaced with renewables & gas
- 11 GW of new renewables by 2050
- 7 GW of new gas capacity added
- Gas capacity factor is 30% in 2050

Scenario	Inc Cost ($MM/yr.)	GHG Reductions (MMT)	Effective RPS %	Zero CO2 %
Reference	—	—	20%	91%
40% Reduction	+$163	7.5	21%	92%
60% Reduction	+$434	14.2	25%	95%
80% Reduction	+$1,046	20.9	31%	102%

Resources Added (MW)



Energy Balance (aMW)



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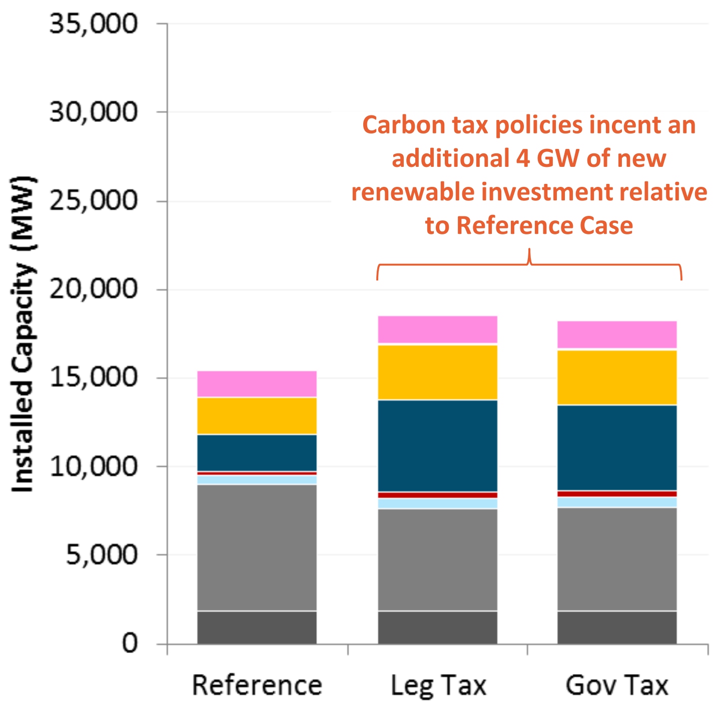
2050 Portfolio Summary
Carbon Tax Scenarios

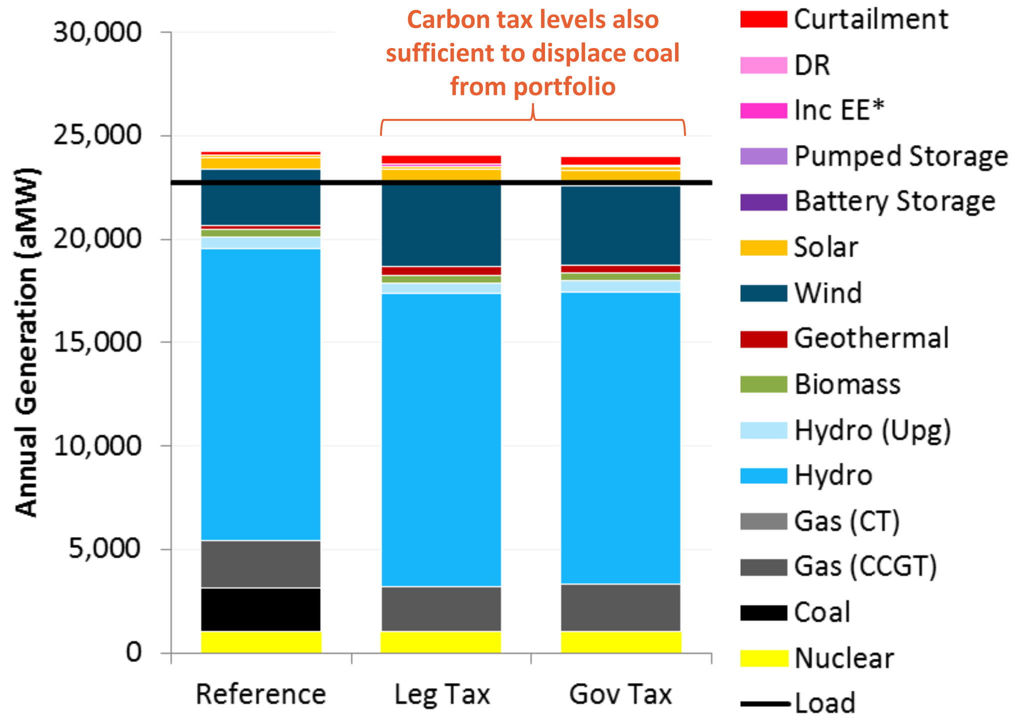
Highlights
- Coal retired under both cases and replaced with renewables & gas
- 9 GW of new renewables needed
- Carbon tax and cap lead to similar outcomes with these resource costs

Scenario	Inc Cost ($MM/yr.)	GHG Reductions (MMT)	Effective RPS %	Zero CO2 %
Reference	—	—	20%	91%
Leg Tax ($15-75)	+$804	19.1	28%	99%
Gov Tax ($25-61)	+$775	18.7	28%	99%

Resources Added (MW)



Energy Balance (aMW)



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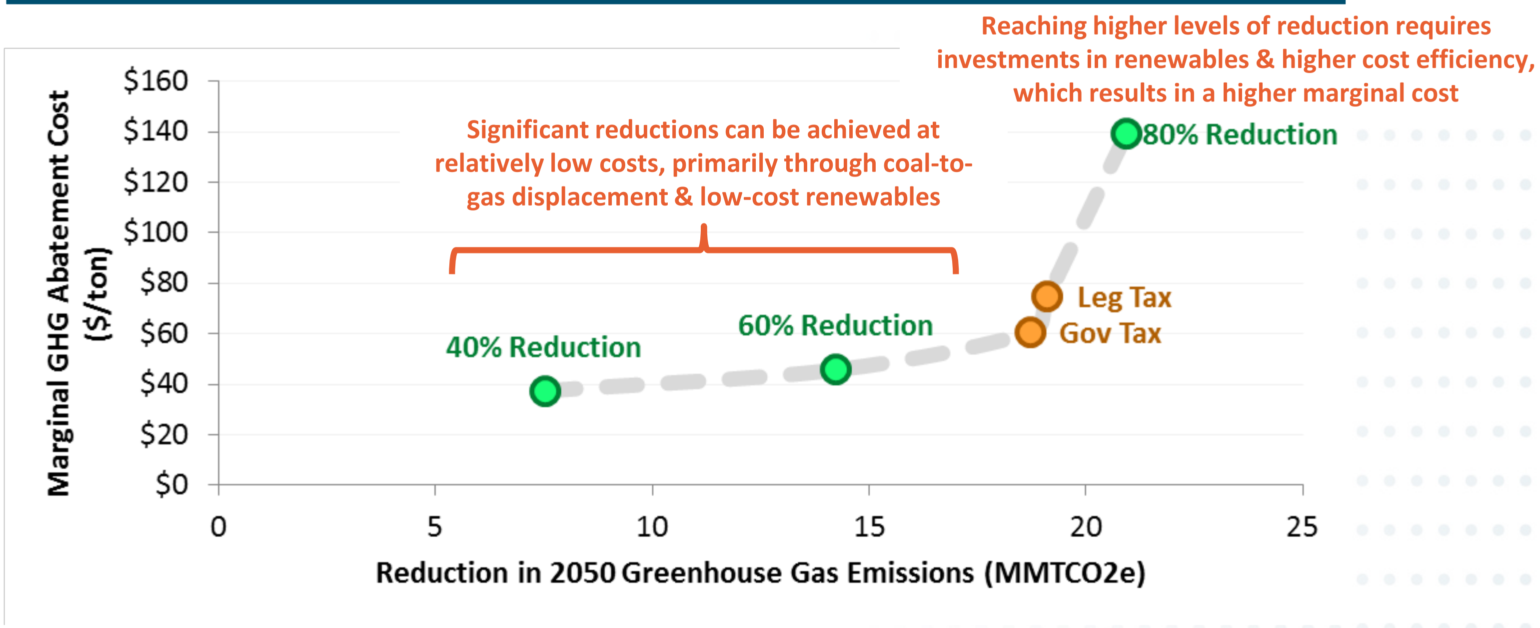
Marginal Greenhouse Gas Abatement Costs

- Shape of GHG marginal cost curve highlights (1) low-hanging fruit; and (2) high cost of final mitigation measures needed to meet 2050 targets
- GHG abatement results of carbon tax scenarios are consistent with scenarios based on targets

Marginal Greenhouse Gas Abatement Cost Curve ($/metric ton)



Note: marginal GHG abatement cost based on shadow price of GHG constraint for GHG policy scenarios; based on assumed 2050 carbon tax for tax scenarios

Carbon Tax vs. Cap-and-Trade: Qualitative Factors

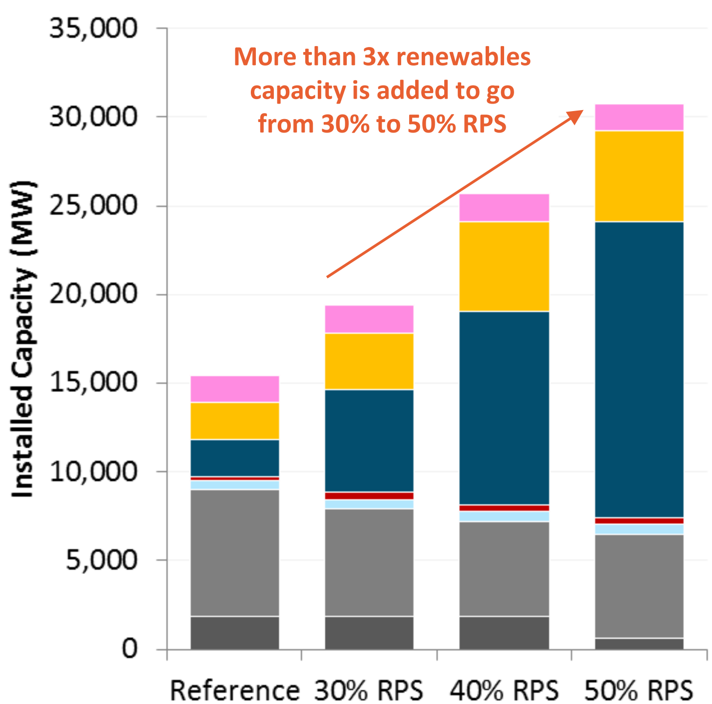
Resource Option	Carbon Tax	Carbon Cap-and-Trade
Compliance mechanism	Pay tax on each ton of CO2 emissions	Surrender carbon allowance for each ton of CO2 emissions
Disposition of funds collected	Tax revenue appropriated through legislative process	Allowances can be auctioned or allocated to affected companies; auction revenues administered by state agency (e.g., DEQ)
Breadth of carbon abatement options	In-state abatement options only	Ability to link with regional carbon markets to expand liquidity
Effect on electric markets	Potential for multiple prices on carbon within Western Interconnection creates challenges for market liquidity and interconnected operations	Single regional price on carbon would preserve wholesale power market liquidity and avoid operational wrinkles
Emissions reductions	Carbon price is fixed but actual emissions levels would vary	Emissions levels are specified, but carbon price would vary over time as abatement costs change

2050 Portfolio Summary
High RPS Scenarios

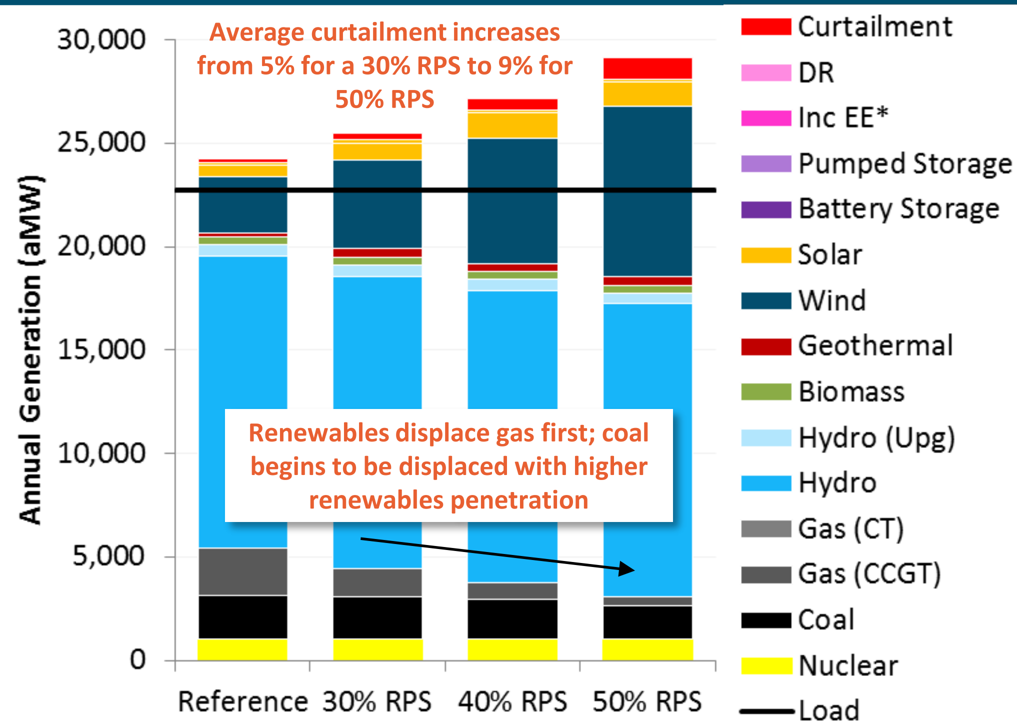
Highlights
- 23 GW of new renewables needed to meet a 50% RPS by 2050
- Curtailment increases to 9% of available renewable energy
- Coal provides most thermal energy

Scenario	Inc Cost ($MM/yr.)	GHG Reductions (MMT)	Effective RPS %	Zero CO2 %
Reference	—	—	20%	91%
30% RPS	+$330	4.3	30%	101%
40% RPS	+$1,077	7.5	40%	111%
50% RPS	+$2,146	11.5	50%	121%

Resources Added (MW)



Energy Balance (aMW)



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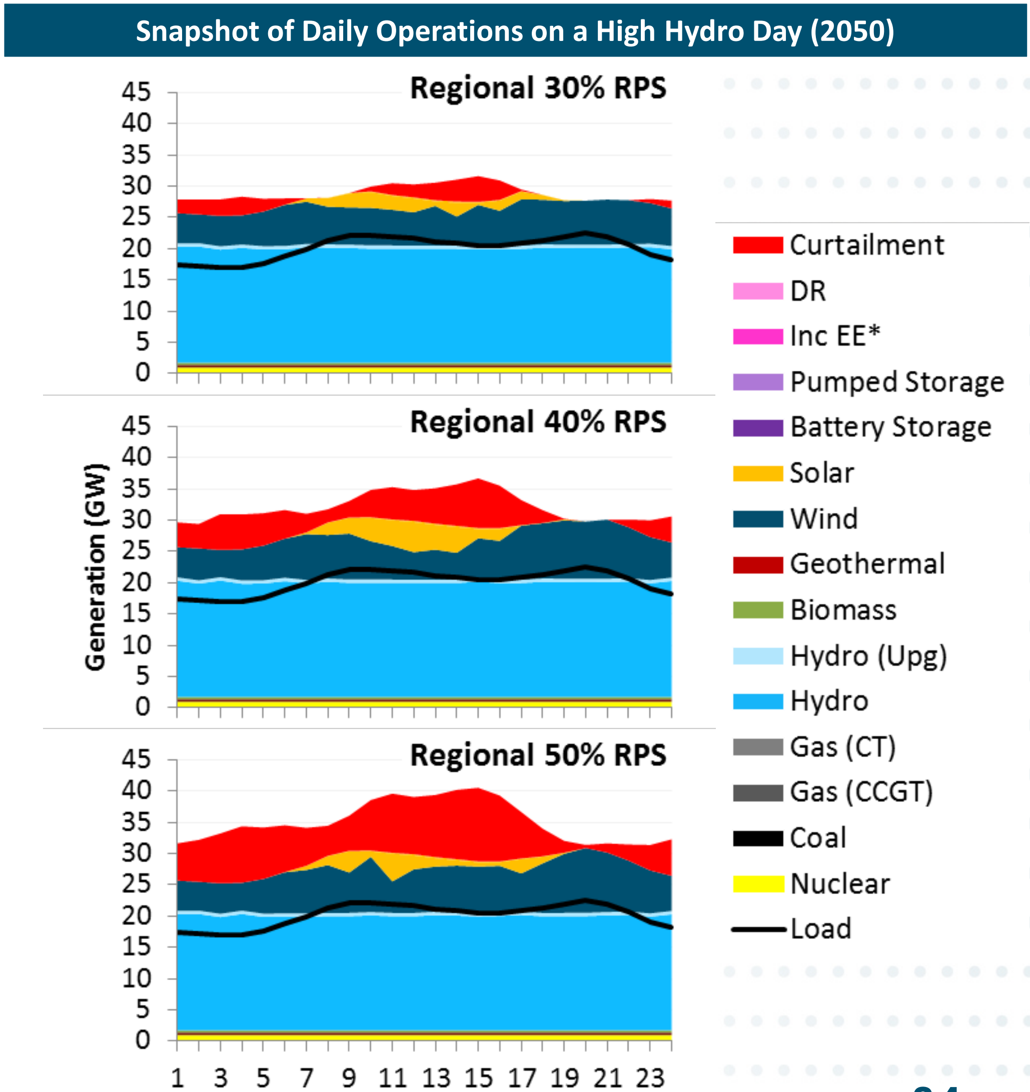
Renewable Curtailment Becomes the Primary Integration Challenge

- Higher renewable generation results in increased frequency and magnitude of renewable curtailment
- A significant proportion of incremental renewable generation above 30% RPS is either exported or curtailed
- Predominance of hydropower contributes to renewable curtailment but already serves as a zero-carbon baseload power source in the region



2050 Portfolio Summary

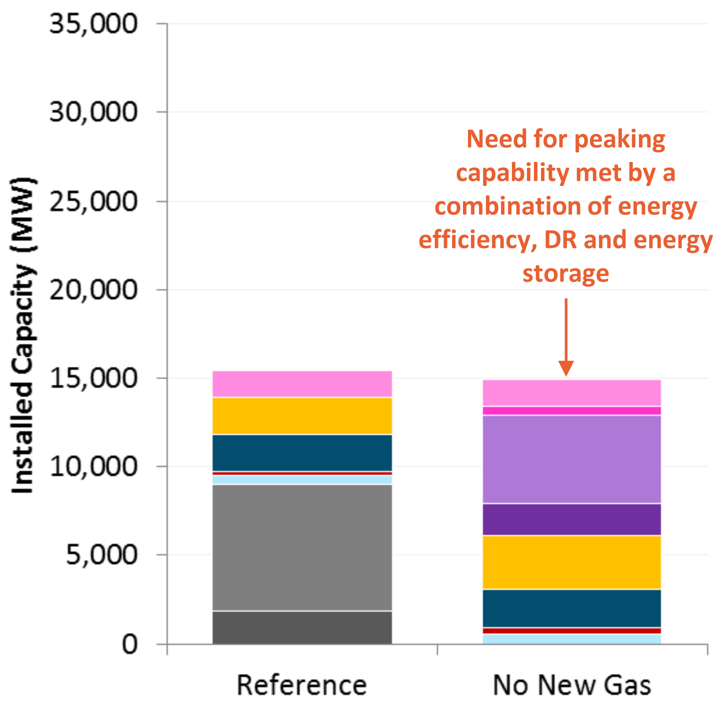
No New Gas Scenario

Highlights

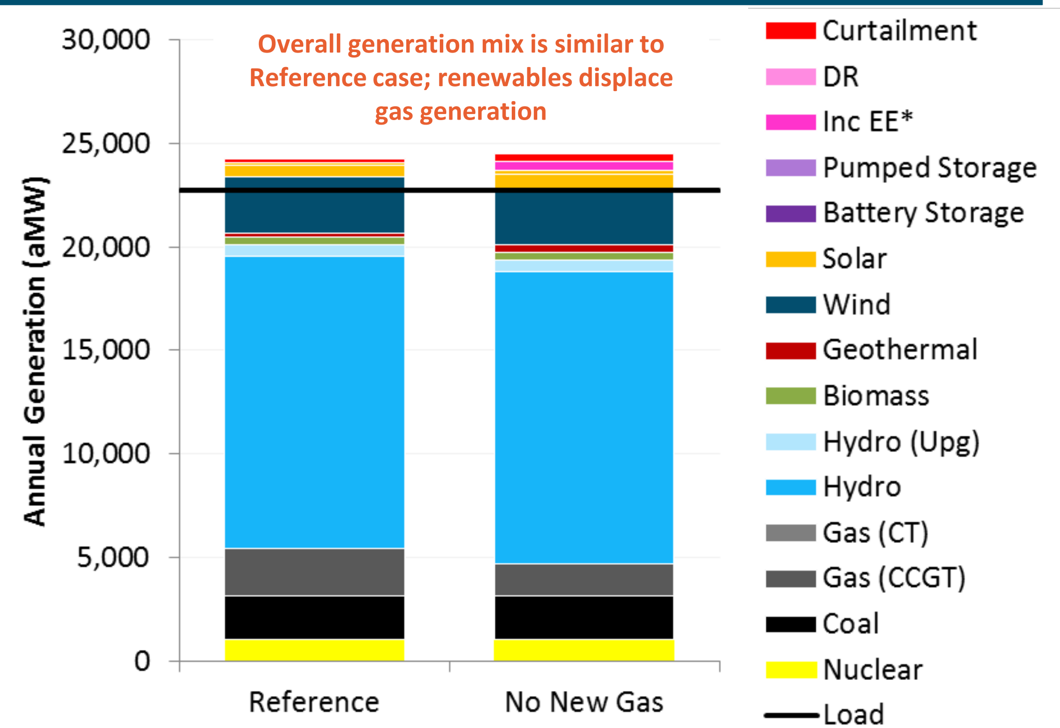
- 7 GW of new energy storage added to meet capacity needs
- Very little change in coal & gas generation or GHG emissions

Scenario	Inc Cost ($MM/yr.)	GHG Reductions (MMT)	Effective RPS %	Zero CO2 %
Reference	—	—	20%	91%
No New Gas	+$1,202	2.0	22%	93%

Resources Added (MW)



Energy Balance (aMW)



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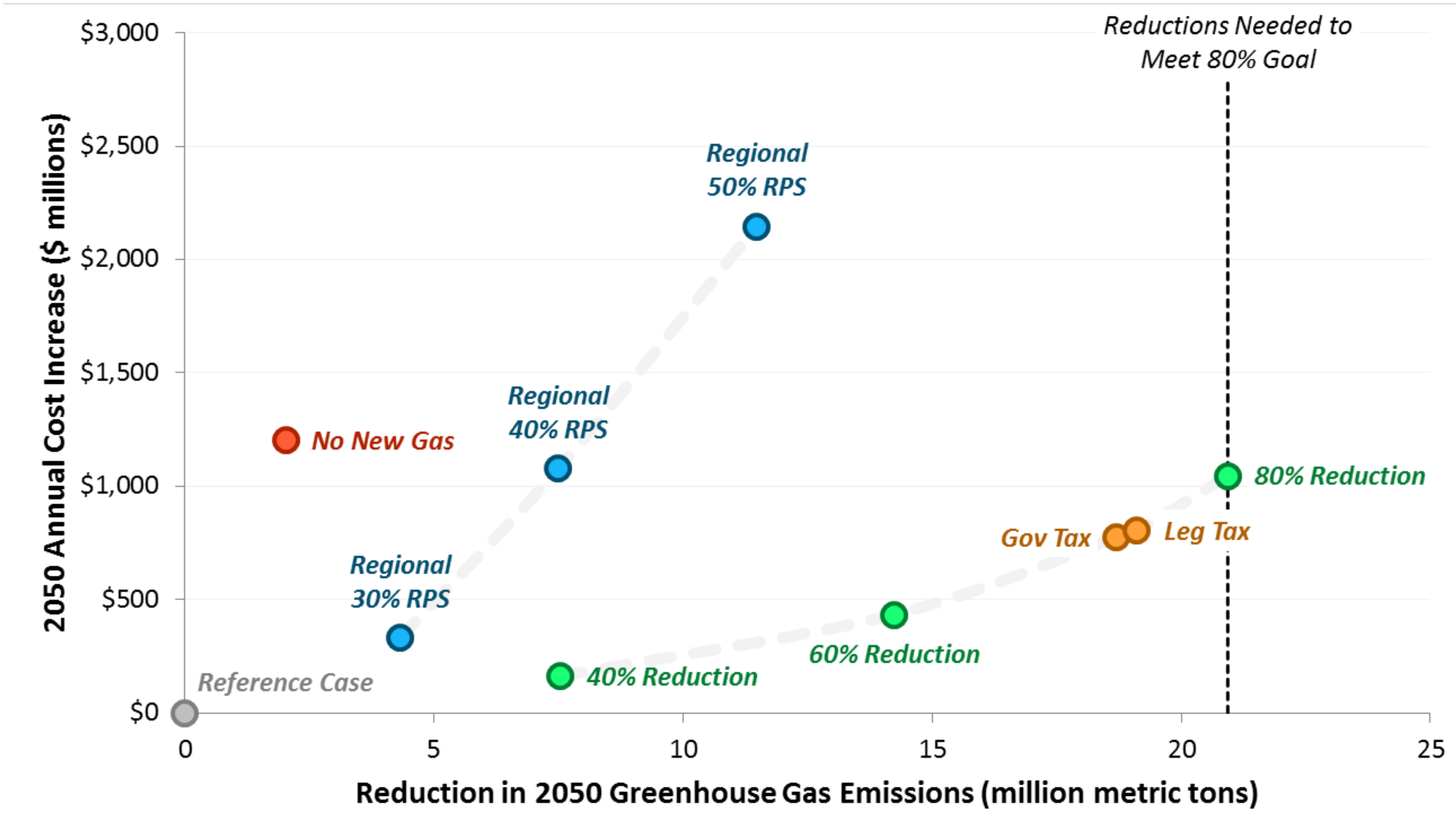
No New Gas Scenario Might Not Be Resource Adequate After 2025

+ **New resources are needed in 2025-2030 time frame to ensure resource adequacy due to coal plant retirements and load growth**
  - Primary source of capacity added under No New Gas Case is energy storage (pumped hydro & batteries)
+ **Storage provides capacity to help meet peak demands but does not generate energy that is needed during low hydro years or multi-day low generation events**
+ **More study is needed to analyze whether the system as modeled meets reliability expectations**
  - The 'No New Gas' portfolio meets the current reserve margin requirement with the addition of new energy storage
  - However, it is unclear how much energy storage can contribute to Resource Adequacy in the Pacific Northwest

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

2050 Scenario Summary

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

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

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SENSITIVITY RESULTS

Existing Resource Retirement

Retirement of Existing Zero-Carbon Generation

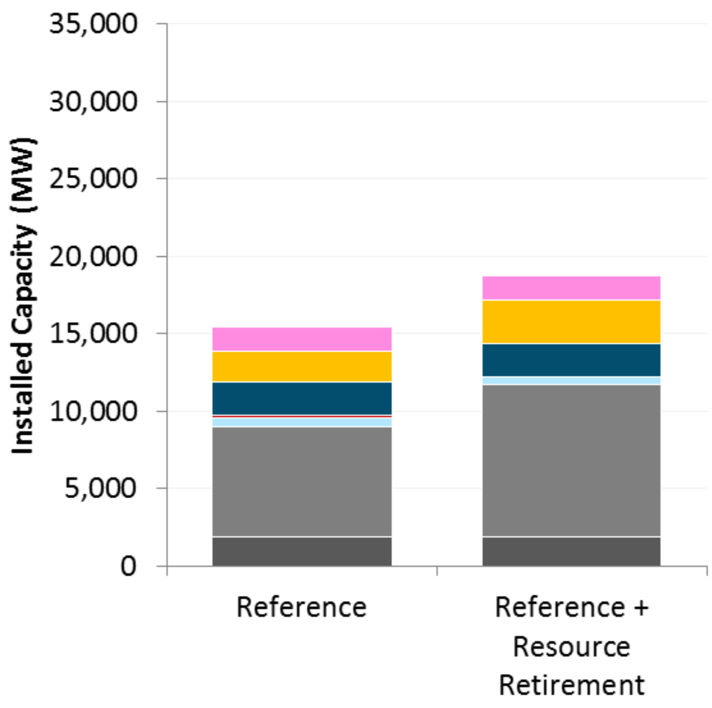
- **In order to highlight the value of existing zero carbon (non-RPS-qualifying) resources—and their key role in meeting GHG goals—E3 evaluated a sensitivity in which approximately 2,000 aMW of nuclear & hydro was assumed to retire:**
  - Columbia Generating Station (1,207 MW)
  - 1,000 aMW of generic existing hydro
- **Sensitivity analysis conducted on Reference Case (current policy), 80% GHG Reduction Case and 50% RPS Case**

2050 Portfolio Summary
Reference Case (Existing Resource Retirement)

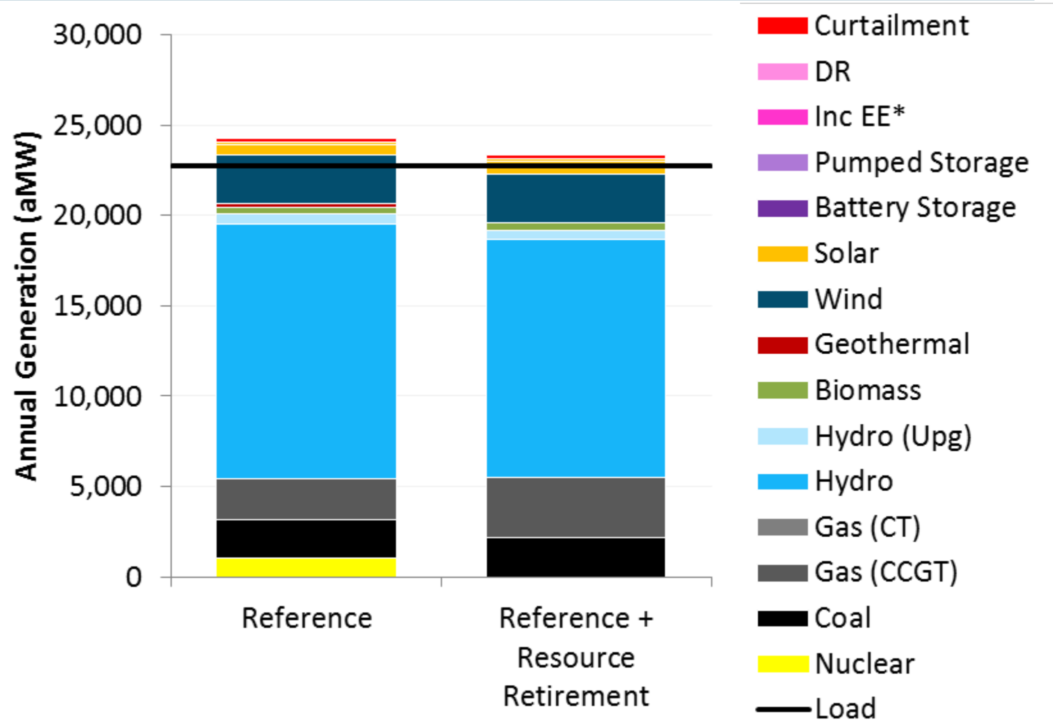
Highlights
- Under Reference Case, retiring resources are replaced with gas generation
- Results in both higher costs and GHG emissions

Scenario	Inc Cost ($MM/yr.)	GHG Reductions (MMT)	Effective RPS %	Zero CO2 %
Base	—	—	20%	91%
Retirement Case	+$1,071	-5.1	20%	82%
Delta	+$1,071	-5.1	—	-9%

Selected Resources (MW)



Energy Balance (aMW)



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2050 Portfolio Summary

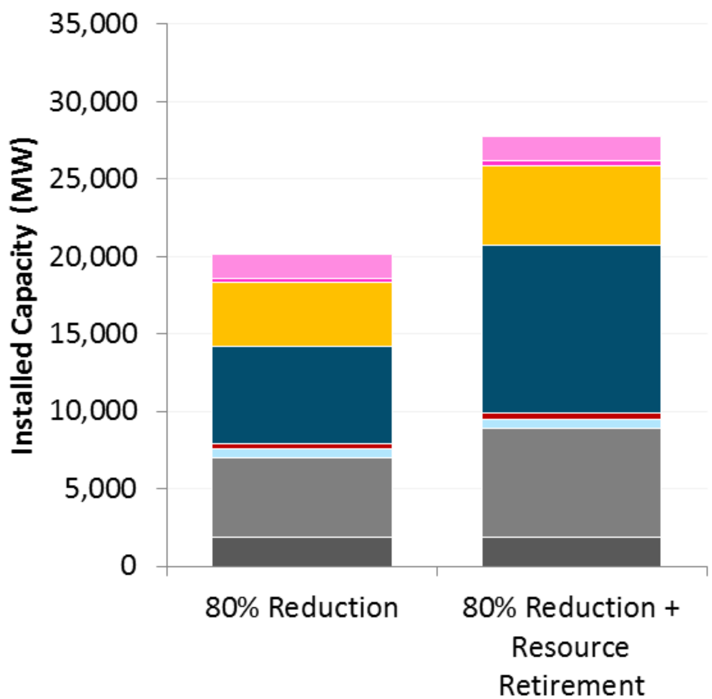
80% Reduction (Existing Resource Retirement)

Highlights

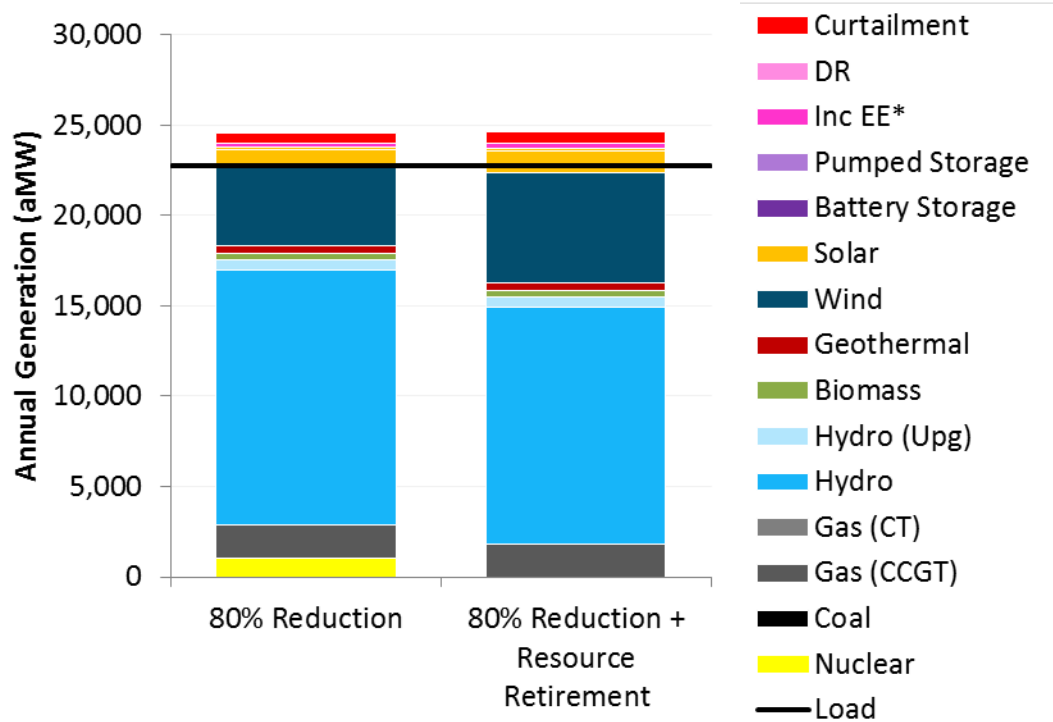
- Under 80% GHG reduction scenario, retiring carbon-free resources replaced with 5.5 GW of renewables and 2 GW of gas
- Cost to meet goal increases $1.6 B

Scenario	Inc Cost ($MM/yr.)	GHG Reductions (MMT)	Effective RPS %	Zero CO2 %
Base	+$1,046	20.9	31%	102%
Retirement Case	+$2,652	20.9	40%	102%
Delta	+$1,606	—	+9%	—

Selected Resources (MW)



Energy Balance (aMW)



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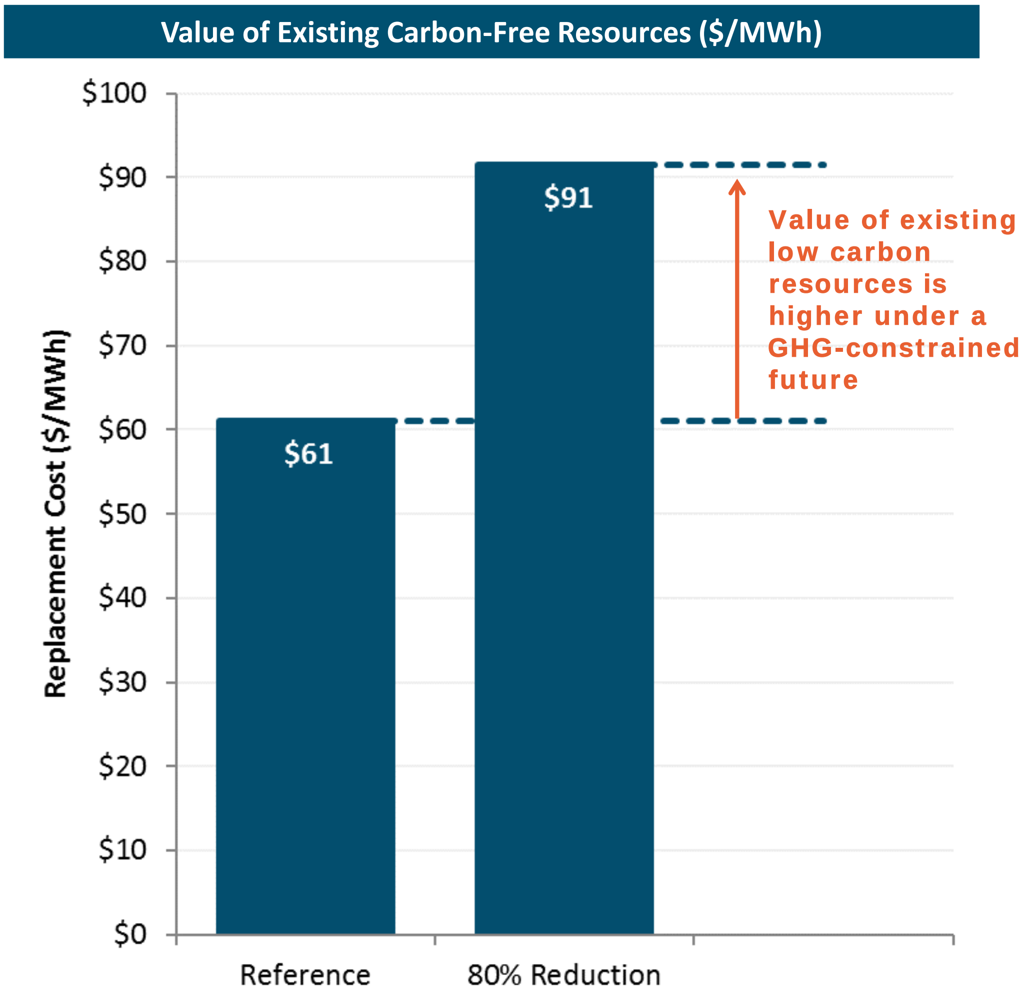
Value of Existing Zero Carbon Gen Increases Under GHG Constraints



- In the Reference Case, lost capacity and energy is replaced with natural gas generation
- In the 80% GHG Reduction Case, lost energy is replaced with 5500 MW of renewables and lost capacity is replaced with 2000 MW of gas generation
- Higher value in a carbon constrained world reflects the significant increase in cost to meet GHG policy goals should existing low carbon resources retire

CONCLUSIONS & KEY FINDINGS

Key Findings (1 of 3)

1. **The most cost-effective opportunity for reducing carbon in the Northwest is to displace coal generation with a combination of energy efficiency, renewables and natural gas**
   - Coal generation produces approximately 80% of the Northwest's electricity-sector GHG emissions today
   - A technology-neutral policy that focuses on carbon provides incentives for leveraging the lowest-cost GHG emissions reductions
2. **Renewable generation is an important component of a low-carbon future, however a Renewables Portfolio Standard results in higher costs and higher carbon emissions than a policy that focuses directly on carbon**
   - 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

Key Findings (2 of 3)

3. **Prohibiting the construction of new natural gas generation adds significant cost but does little to save GHG emissions**
   - Older gas plants run at a higher capacity factor and generate more carbon emissions
   - More study is needed to determine whether the system modeled has sufficient energy and capacity to meet resource adequacy requirements
   - Building new gas resources for capacity is part of a least-cost portfolio even under carbon-constrained scenarios
4. **Meeting decarbonization goals becomes significantly more challenging and costly should existing zero-carbon resources retire**
   - Replacing 2,000 aMW of existing hydro or nuclear generation would require nearly 6,000 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
   - A policy that encourages the retention of existing zero-carbon generation resources will help contain costs of meeting carbon goals

Key Findings (3 of 3)

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

Next Steps

- **This study considered many scenarios and sensitivities, however, additional research is indicated in the following areas:**

  1. Economy-wide analysis of deep decarbonization pathways for the Pacific Northwest that examines the role of electric vehicles, building electrification, biofuels, hydrogen, and other potential GHG abatement measures
  2. The role of natural gas in buildings and electric generation in meeting economy-wide GHG abatement goals
  3. The role of energy storage in meeting capacity needs in a hydro-dominated region such as the Pacific Northwest, particularly under cases with restrictions on gas generation
  4. The potential benefits of greater regional coordination in electricity system operations, renewable resource procurement, transmission planning and carbon allowance trading

Energy+Environmental Economics

Thank You!

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