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# Pacific Northwest Low Carbon Scenario Analysis

## 2018 Scenarios and Sensitivities

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# Introduction

- **This is a joint report to share the results of independently sponsored studies**
- **Each of the entities in the report independently requested and sponsored additional scenarios and sensitivities to the 2017 PGP Study**
- **Some entities requested the same studies**
  - Those studies were run consistently for each entity

# Presentation Structure

- Background
- National Grid Sponsored Scenarios and Results

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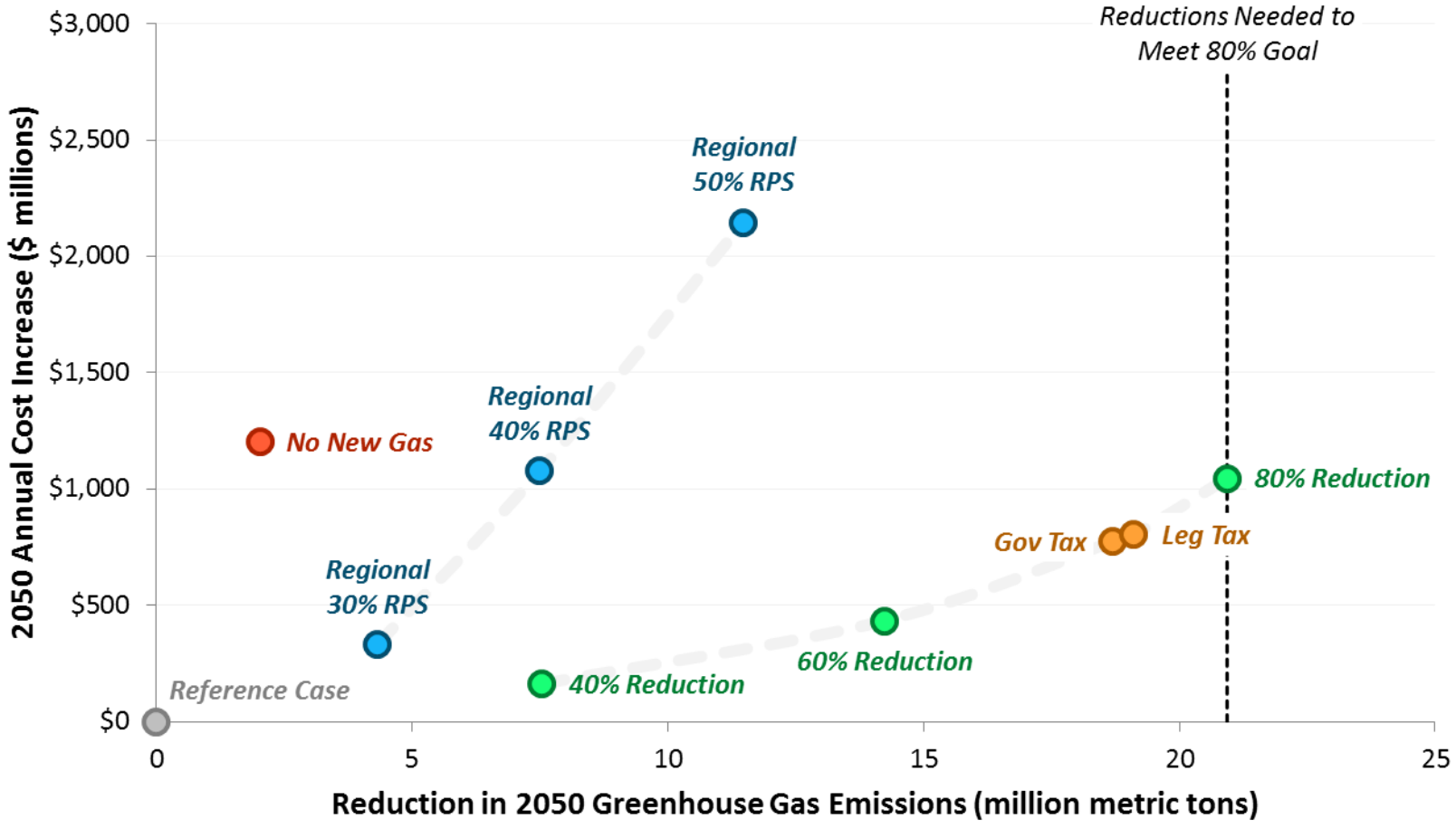
# Background and Context

# Context of 2018 Analysis

- **In 2017, the Public Generating Pool (PGP) sponsored the Pacific Northwest Low Carbon Scenario Analysis, a study of alternative policies for achieving reductions in electric sector carbon emissions in the Northwest**
  - The original study can be found here: https://www.ethree.com/e3-completes-study-of-policy-mechanisms-to-decarbonize-the-electric-sector-in-the-northwest/
- **In 2018, follow-up studies were individually sponsored by three organizations to explore specific questions left unanswered by the original study**
  - Public Generating Pool
  - Climate Solutions
  - National Grid
- **This document reports on the assumptions and results from these additional studies**

# Original Study Results:
## Cost & Emissions Impacts in 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

# 2050 Scenario Summary From the Original Study

| 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*

# About the Additional Studies

- **PGP sponsored additional studies exploring the means for and cost of achieving additional CO2 emissions reductions beyond the 80% goal assumed in the original study:**
  - 90%, 95% and 100% GHG emissions reductions with varying quantity and price of carbon-free biogas as a substitute for fossil natural gas
- **Climate Solutions sponsored additional studies exploring 100% GHG emissions reductions:**
  - With and without biogas and small modular nuclear reactors (SMR), under alternative technology costs, and with a ceiling or "off-ramp" on compliance costs
- **National Grid sponsored additional studies exploring the potential role for pumped hydro storage:**
  - Alternative assumptions about the cost of new pumped hydro facilities and new gas-fired generation, and accelerated coal retirement
- **All scenarios assume revenue recycling**

# Scenario Matrix
## – All Sponsored Scenarios and Sensitivities

| Scenario | INPUT ASSUMPTIONS: Original Study Assumptions | Biogas P&Q Sensitivities | Alternative Technology Costs | Pumped Storage Cost Update | High Gas Capital Costs | Limited New Gas Build |
|---|---|---|---|---|---|---|
| Reference | ● | | ● | ● | ● | ● |
| 40% Reduction | ● | | | | | |
| 60% Reduction | ● | | | | | |
| 80% Reduction | ● | | | ● | ● | ● |
| 30% RPS | ● | | | | | |
| 40% RPS | ● | | | | | |
| 50% RPS | ● | | | | | |
| Leg Tax ($15-75) | ● | | | | | |
| Gov Tax ($25-61) | ● | | | | | |
| No New Gas | ● | | | | | |
| 90% Reduction | ● | | | | | |
| 95% Reduction | ● | | | | | |
| 100% Reduction with Hydro, Wind Geothermal, and Solar (HWGS) | ● ● | | | | | |
| 100% Reduction + Biogas | ● ● | ● | ● | | | |
| 100% Reduction + SMR | ● | | | | | |
| 100% Reduction + Off Ramp | ● | | | | | |
| 30% RPS + No Coal | ● | | | ● | ● | ● |

● Original PGP Study; ● PGP; ● Climate Solutions; ● National Grid

# Base Cost Assumptions for Candidate Technologies

| Technology | Resource | Unit | 2018 | 2022 | 2026 | 2030 |
|---|---|---|---|---|---|---|
| **Gas** | Annual Core NW Fuel Costs | *$/MMBtu* | **$3.24** | **$2.95** | **$3.32** | **$3.82** |
| | CT-Frame | *$/kW-ac* | **$950** | **$950** | **$950** | **$950** |
| | CCGT | *$/kW-ac* | **$1,300** | **$1,300** | **$1,300** | **$1,300** |
| **Hydro Upgrades** | Non Powered Dam | *$/kW-ac* | **$4,500** | **$4,500** | **$4,500** | **$4,500** |
| | Upgrades | *$/kW-ac* | **$1,277** | **$1,254** | **$1,206** | **$1,158** |
| **Geothermal** | Central Oregon | *$/kW-ac* | **$4,557** | **$4,557** | **$4,557** | **$4,557** |
| **Wind** | Columbia River Basin | *$/kW-ac* | **$1,925** | **$1,910** | **$1,896** | **$1,882** |
| | Montana | *$/kW-ac* | **$1,823** | **$1,810** | **$1,796** | **$1,783** |
| | Wyoming | *$/kW-ac* | **$1,722** | **$1,709** | **$1,697** | **$1,684** |
| **Solar** | WA/OR | *$/kW-ac* | **$1,617** | **$1,558** | **$1,513** | **$1,438** |
| | WA/OR | *$/kW-dc* | $1,244 | $1,199 | $1,164 | $1,106 |
| **Battery Storage (4-hr Storage)** | - | *$/kWh* | **$587** | **$455** | **$372** | **$352** |
| **Pumped Storage (10-hr Storage)** | - | *$/kWh* | **$261** | **$261** | **$261** | **$261** |

Base capital cost assumptions are the same as in the original PGP study
Capital costs are kept flat beyond 2030

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# National Grid Sponsored Scenarios

# Summary of Sponsored Scenarios – National Grid

| Scenario Name | Question Answered | Updates to Model |
|---|---|---|
| **30% RPS with Coal Retirement** | Effect of a 30% RPS combined with a forced retirement of coal generators | Retires all coal generators in 2030 |

| Sensitivity Name | Question Answered | Updates to Model |
|---|---|---|
| **Low Pumped Storage Capital Costs (Low PS Capex)** | What capacity of pumped storage resources are selected when costs are updated using Swan Lake facility capital costs | Updated pumped storage capital cost |
| **Low Pumped Storage Capital Costs & High Gas Capital Costs (Low PS Capex & High Gas Capex)** | What capacity of pumped storage resources are selected when, building on the Low PS Capex sensitivity, the capital cost of a gas facility is increased | Updated pumped storage capital cost. Updated natural gas resource capital cost using the final capital cost value for the Carty Generating Station |
| **Low Pumped Storage Capital Costs & Limited New Gas Build (Low PS Capex & Limited New Gas)** | What capacity of pumped storage resources are selected when, building on the Low PS Capex sensitivity, you constrain the build of new gas units | Updated pumped storage capital cost. Constrain build of new gas units to repowering of CCGT units and 1000 MW of CT every decade |

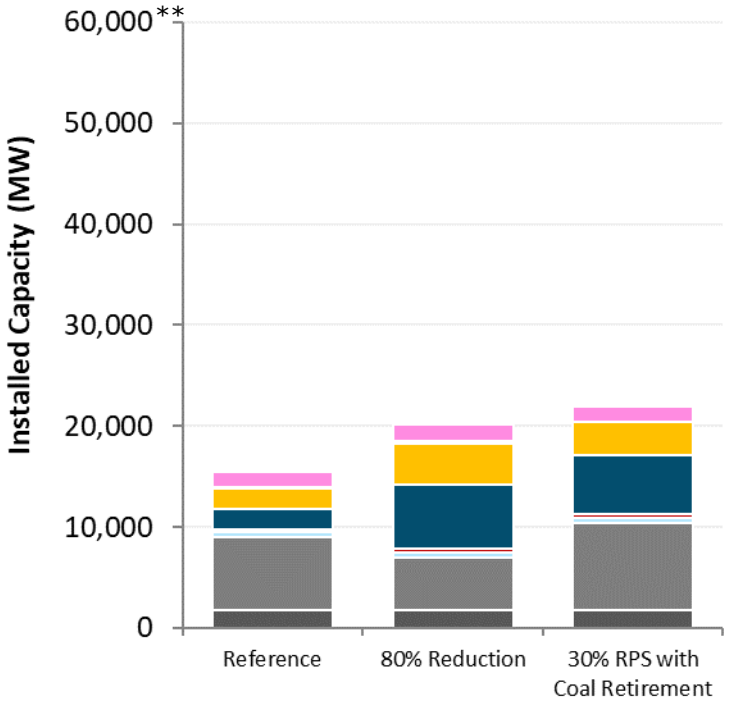
# 2050 Portfolio Summary – National Grid
## Low Pumped Storage Capital Costs

**Summary**

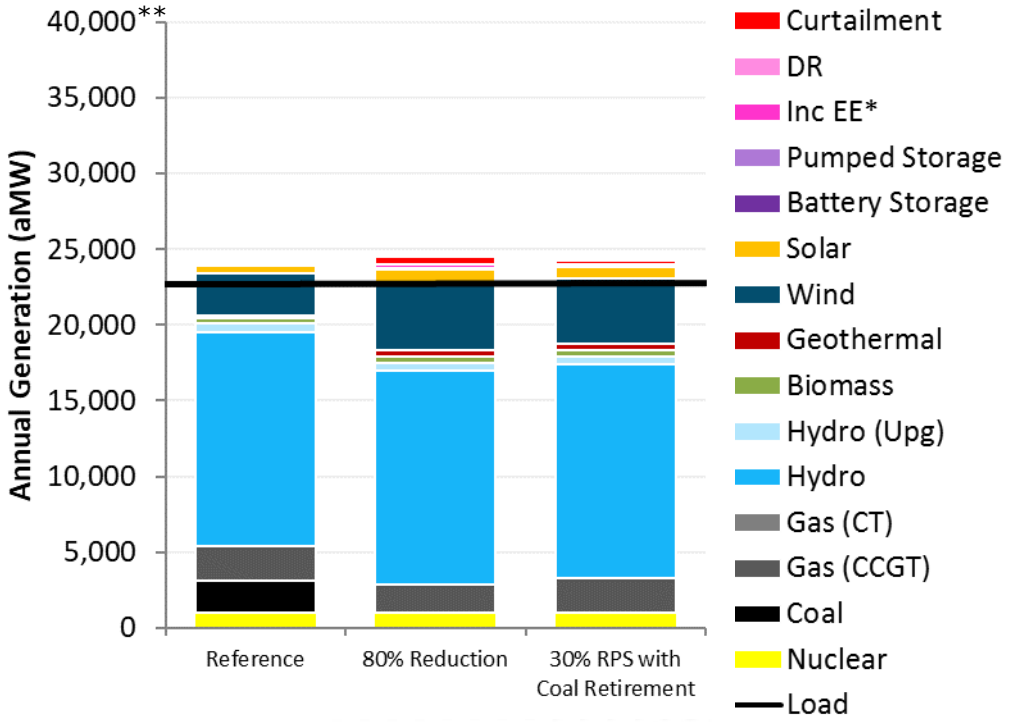
- 8 MW of pumped storage capacity is added by 2050 in the Reference Scenario
- 22 MW of pumped storage capacity is added by 2050 in the 80% Reduction Scenario
- 52 MW of pumped storage capacity is added by 2050 in the 30% RPS with Coal Retirement Scenario

| Scenario | Inc Cost ($MM/yr.) | GHG Reductions (MMT) | Effective RPS % | Zero CO2 % |
|---|---|---|---|---|
| **Reference** *(Low PS Capex)* | - | - | 20% | 91% |
| **80% Reduction** *(Low PS Capex)* | +$1,047 | 20.9 | 31% | 102% |
| **30% RPS with Coal Retirement** *(Low PS Capex)* | +$1,139 | 18.3 | 30% | 101% |

**Resources Added (MW)**




**Energy Balance (aMW)**






**Note the change in the Y-axis scale change

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

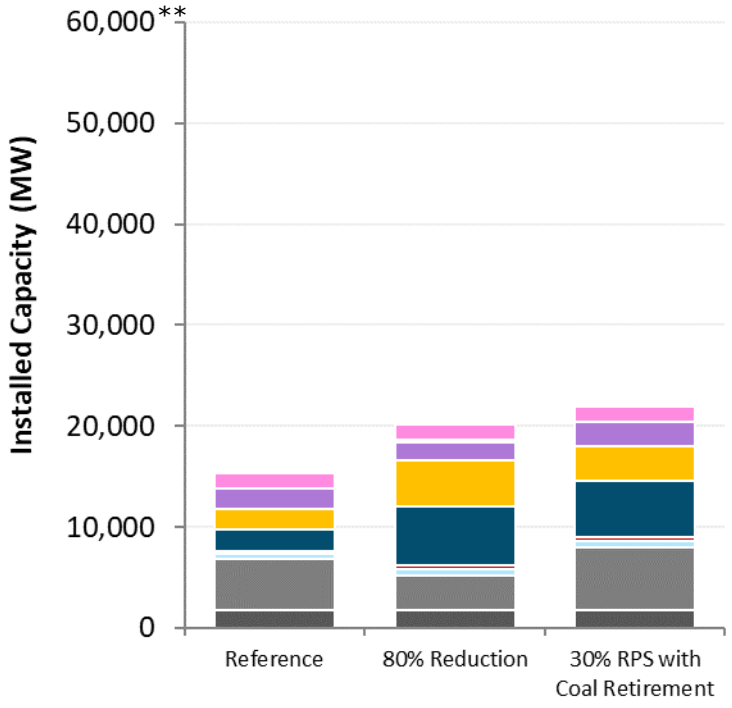
# 2050 Portfolio Summary – National Grid
## Low Pumped Storage Capital Costs & High Gas Capital Costs

**Summary**

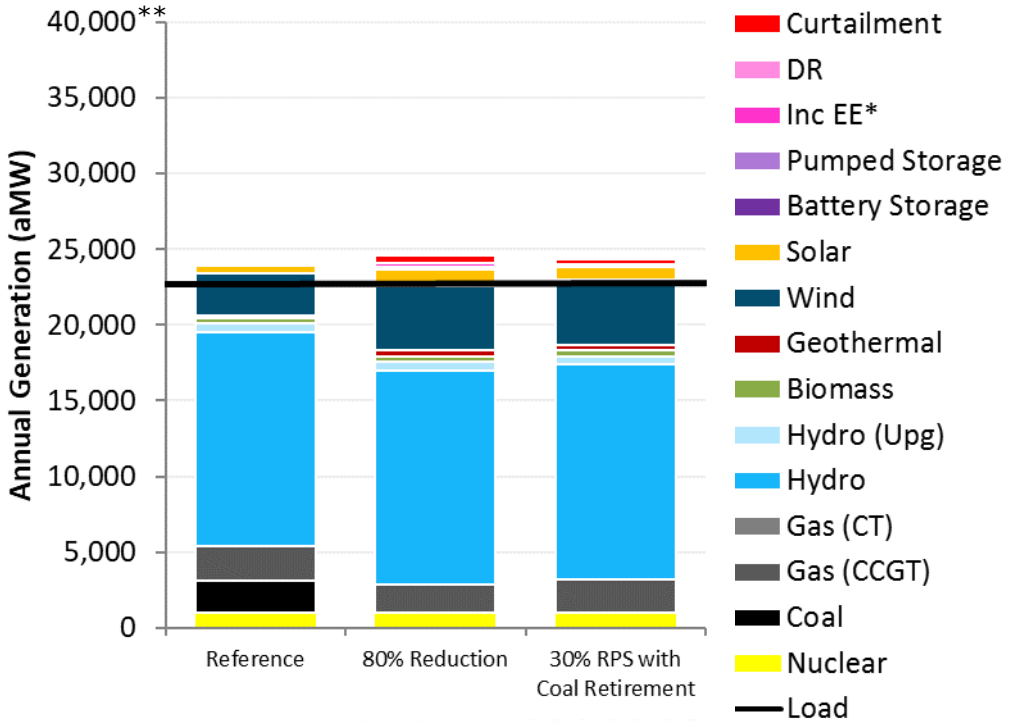
- 2 GW of pumped storage capacity is added by 2050 in the Reference Scenario
- 1.6 GW of pumped storage capacity is added by 2050 in the 80% Reduction Scenario
- 2.3 GW of pumped storage capacity is added by 2050 in the 30% RPS with Coal Retirement Scenario

| Scenario | Inc Cost ($MM/yr.) | GHG Reductions (MMT) | Effective RPS % | Zero CO2 % |
|---|---|---|---|---|
| **Reference** *(Low PS & High Gas Capex)* | - | - | 20% | 91% |
| **80% Reduction** *(Low PS & High Gas Capex)* | +$1,028 | 21.1 | 31% | 102% |
| **30% RPS with Coal Retirement** *(Low PS & High Gas Capex)* | +$1,170 | 18.4 | 30% | 101% |

**Resources Added (MW)**




**Energy Balance (aMW)**

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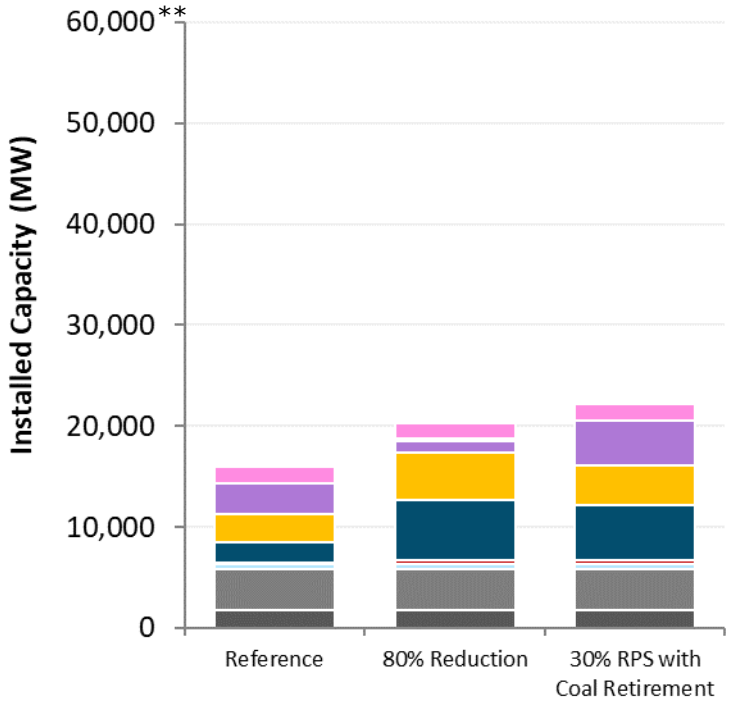
# 2050 Portfolio Summary – National Grid
## Low Pumped Storage Capital Costs & Limited New Gas Build

**Summary**

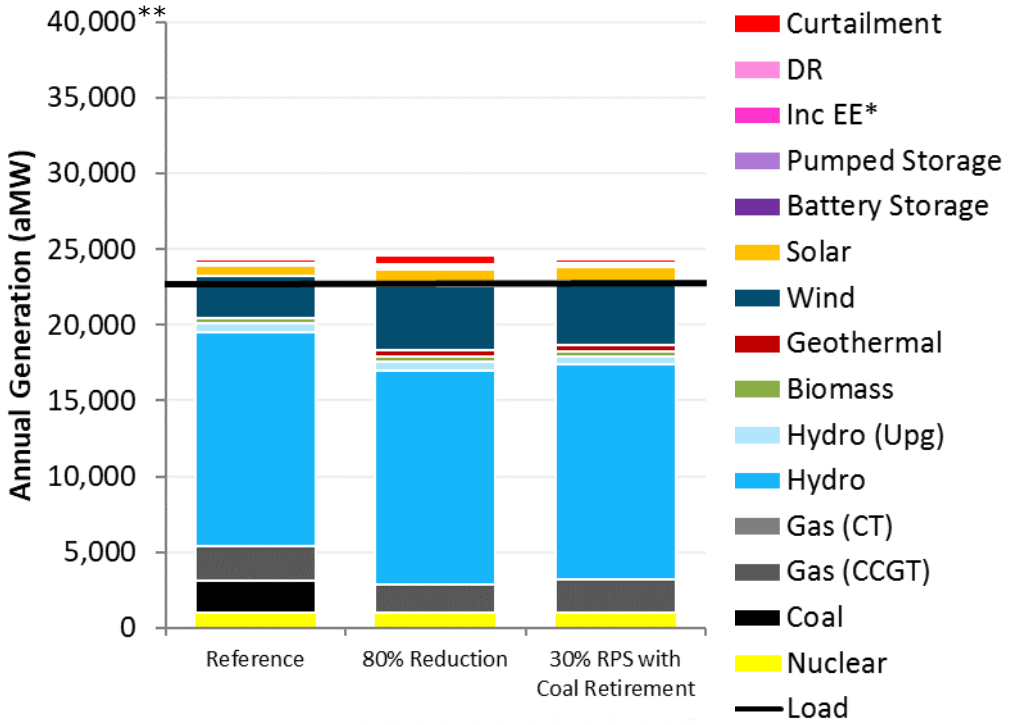
- 3 GW of pumped storage capacity is added by 2050 in the Reference Scenario
- 1 GW of pumped storage capacity is added by 2050 in the 80% Reduction Scenario
- 4.4 GW of pumped storage capacity is added by 2050 in the 30% RPS with Coal Retirement Scenario

| Scenario | Inc Cost ($MM/yr.) | GHG Reductions (MMT) | Effective RPS % | Zero CO2 % |
|---|---|---|---|---|
| **Reference** *(Low PS & Limited New Gas)* | - | - | 20% | 91% |
| **80% Reduction** *(Low PS & Limited New Gas)* | +$1,030 | 21.1 | 31% | 102% |
| **30% RPS with Coal Retirement** *(Low PS & Limited New Gas)* | +$1,181 | 18.4 | 30% | 101% |

**Resources Added (MW)**




**Energy Balance (aMW)**



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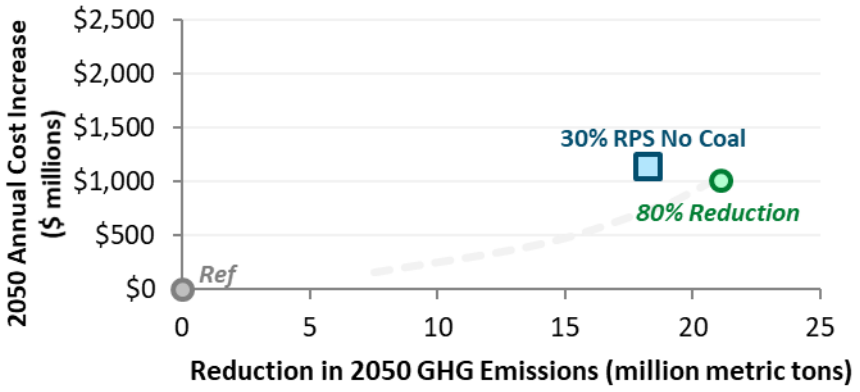
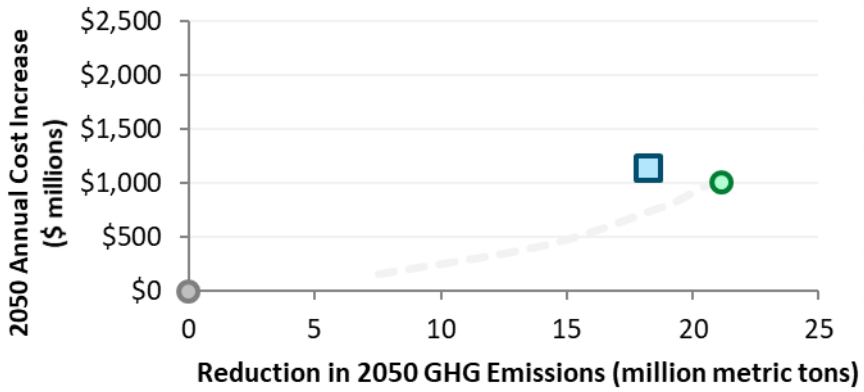
# Cost & Emissions Impact – National Grid All Sensitivities

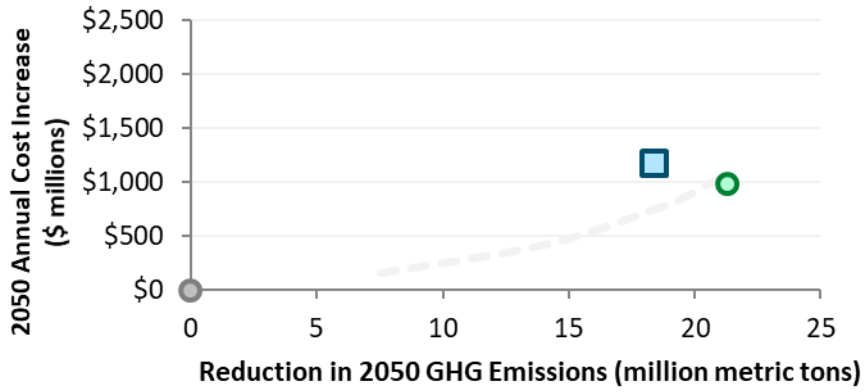
## Original PGP Study



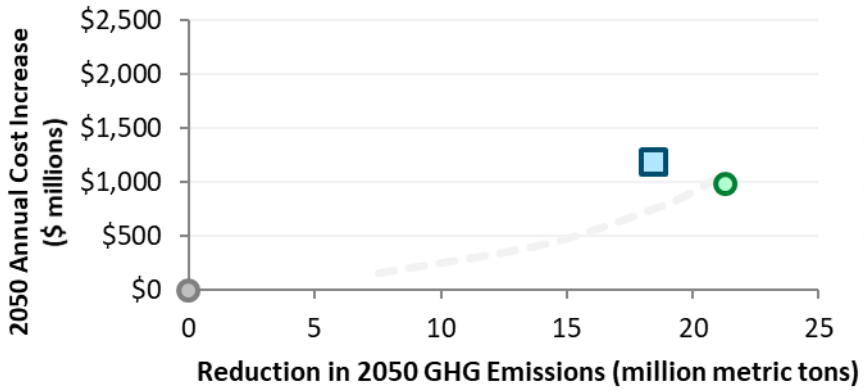

## Low PS Capex




## Low PS Capex & High Gas Capex




## Low PS Capex & Limited New Gas Build



# 2050 Summary of Results from National Grid Additional Scenarios

| Scenario | Inc Cost ($MM/yr.) | GHG Reductions (MMT) | Avg GHG Abatement Cost ($/ton) | Effective RPS % | Zero Carbon % | Renewable Curtailment (aMW) |
|---|---|---|---|---|---|---|
| ***Original Study Assumptions*** | | | | | | |
| **Reference** | — | — | — | 20% | 91% | 201 |
| **80% Reduction** | +$1,046 | 20.9 | $50 | 31% | 102% | 546 |
| **30% RPS No Coal** | +$1,139 | 18.3 | $62 | 30% | 101% | 313 |
| **Low Pumped Storage Capital Costs** | | | | | | |
| **Reference** | — | — | — | 20% | 91% | 192 |
| **80% Reduction** | +$1,047 | 20.9 | $50 | 31% | 102% | 504 |
| **30% RPS No Coal** | +$1,139 | 18.3 | $62 | 30% | 101% | 297 |
| **Low Pumped Storage Capital Costs & High Gas Capital Costs** | | | | | | |
| **Reference** | — | — | — | 20% | 91% | 205 |
| **80% Reduction** | +$1,028 | 21.1 | $49 | 31% | 102% | 487 |
| **30% RPS No Coal** | +$1,170 | 18.4 | $64 | 30% | 101% | 287 |
| **Low Pumped Storage Capital Costs & Limited New Gas Build** | | | | | | |
| **Reference** | — | — | — | 20% | 91% | 210 |
| **80% Reduction** | +$1,030 | 21.1 | $49 | 31% | 102% | 492 |
| **30% RPS No Coal** | +$1,181 | 18.4 | $64 | 30% | 101% | 292 |

*Incremental cost and GHG reductions are measured relative to the respective Reference cases*

# Summary of Selected Pumped Storage Capacity Results

| Scenario | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|
| ***Original Study Assumptions*** | | | | |
| **Reference** | — | — | — | — |
| **80% Reduction** | — | — | — | — |
| **30% RPS No Coal** | — | — | — | — |
| **Low Pumped Storage Capital Costs** | | | | |
| **Reference** | — | — | — | 8 |
| **80% Reduction** | — | — | — | 22 |
| **30% RPS No Coal** | — | — | — | 52 |
| **Low Pumped Storage Capital Costs & High Gas Capital Costs** | | | | |
| **Reference** | — | 655 | 1,051 | 2,010 |
| **80% Reduction** | — | 666 | 820 | 1,690 |
| **30% RPS No Coal** | — | 762 | 1,001 | 2,342 |
| **Low Pumped Storage Capital Costs & Limited New Gas Build** | | | | |
| **Reference** | — | — | 274 | 3,054 |
| **80% Reduction** | — | — | 21 | 1,184 |
| **30% RPS No Coal** | — | — | 2,067 | 4,456 |

*Incremental cost and GHG reductions are measured relative to the respective Reference cases*

# Reliability analysis is needed for energy limited systems with high levels of storage as a capacity resource

- **Thermal fleet retirements coupled with load growth create a need for replacement capacity to ensure resource adequacy**
  - In the limited gas scenario and when gas capital costs are assumed to be high, pumped storage is added as a capacity resource
- **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 systems with significant storage capacity as modeled meet reliability expectations**
  - 1 MW of 10-hr storage capacity is assumed equivalent to 1 MW of natural gas capacity
  - However, it is unclear how much energy storage can contribute to Resource Adequacy in the Pacific Northwest

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# Thank You!

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