Northwest **Power** and
Conservation Council

February 5, 2019

MEMORANDUM

TO: **Council Members**

FROM: **Ben Kujala**

SUBJECT: **Presentation on serving load reliably under a changing resource mix**:

BACKGROUND:

Presenter: Therese Hampton, Public Generating Pool (PGP); and Arne Olson, Energy and Environmental Economics, Inc (E3)

Summary: The ability to maintain Resource Adequacy under some scenarios was flagged during the 2017 – 2018 E3 studies done for PGP. Scenarios that limit the building of new natural gas or decarbonization beyond 80% below 1990 levels were identified as needing a different model to evaluate the adequacy of the system.

As a result, the Public Generating Pool, in collaboration with Puget Sound Energy, Avista, and Northwestern, sponsored a study that examines the adequacy of the power system in 2018, 2030 and 2050 under different decarbonization levels.

This presentation will cover the results of that study and related findings.

Background: See attached FAQ

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

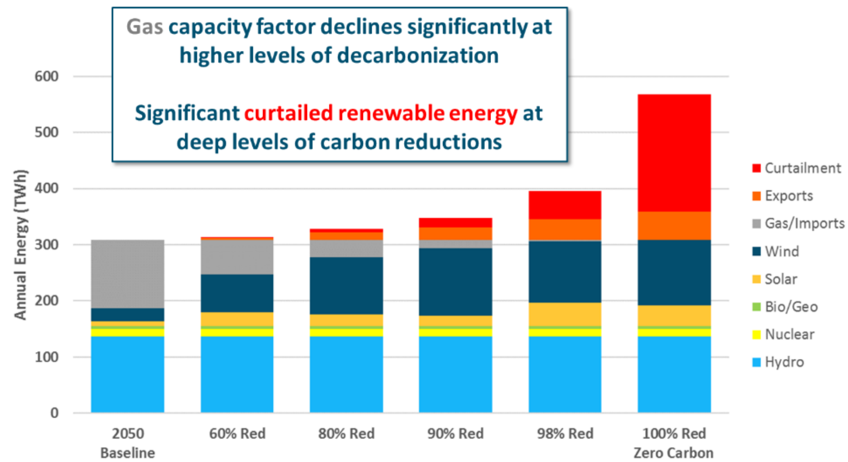
851 S.W. Sixth Avenue, Suite 1100
Portland, Oregon 97204-1348
www.nwcouncil.org

Steve Crow
Executive Director

503-222-5161
800-452-5161
Fax: 503-820-2370

Resource Adequacy in the Pacific Northwest:
Serving Load Reliably under a Changing Resource Mix

- **Significant greenhouse gas emission reductions leading to a deeply decarbonized grid can be achieved as long as sufficient <u>firm capacity</u> is available during periods of low wind, solar and hydro production to maintain adequate Resource Adequacy**
  - Natural gas generation is the most economic source of firm capacity and adding new gas *<u>capacity</u>* is not inconsistent with long-term carbon reduction
  - Wind, solar, demand response and short-duration energy storage can contribute to maintaining Resource Adequacy but have important limitations and diminishing returns in their ability to meet Northwest winter peak loads



- **It would be extremely costly and impractical to replace all firm generation capacity with solar, wind and storage, due to the significant renewable overbuild and required transmission construction needed to maintain adequacy**

100% Zero Carbon Results	
Forecasted 2050 Demand	54,000 MW
Required Renewable Build	143,000 MW of wind/solar + 29,000 MW of 6-hr Storage
Renewable Curtailment	47% of available renewable energy
Additional Cost ($/kWh)	$52/MWh - $89/MWh*

**2017 average retail rate in the Greater Northwest region = $80/MWh (Source: EIA)*

- **Renewable oversupply becomes pervasive and costly as the region moves beyond a 90% reduction in electric sector greenhouse gas emissions below 1990 levels**
  - It is necessary to "overbuild" renewable generation to assure enough zero-carbon energy is produced during low generation hours and maintain Resource Adequacy requirements

- **The Northwest anticipates the need for new firm generation capacity in the near-term_ to maintain an acceptable level of Resource Adequacy after planned coal retirements**
  - 8,000 MW of new firm capacity is needed by 2030 to meet load growth and replace retiring coal generation (3,000 MW of retirements are planned by 2030)
  - If all coal is retired in the region, then 16,000 MW of new firm capacity would be required
  - Investment in fuel delivery infrastructure may be needed to ensure generation capacity is truly firm

January 2019

Resource Adequacy in the Pacific Northwest: Serving Load Reliably under a Changing Resource Mix
Frequently Asked Questions

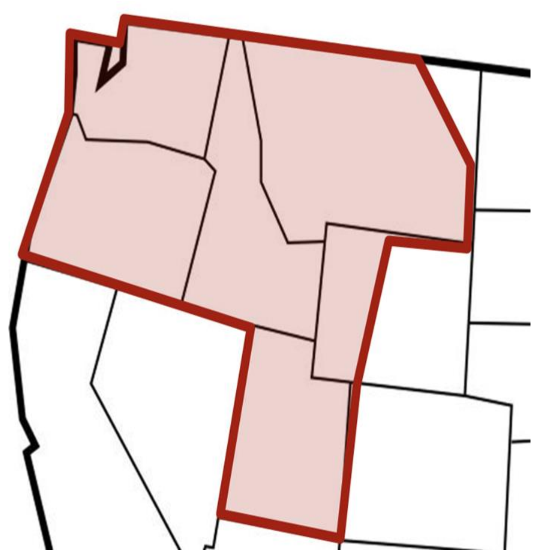
What is the purpose of the Energy + Environmental Economics study on resource adequacy in the Northwest?
The E3 Reliability study uses computer modeling to determine how the Northwest (Washington, Oregon, Idaho and portions of Montana, Wyoming and Utah) can serve electric load reliably in 2030 and 2050 under carbon reduction scenarios. In this study, an electric generation system is considered to be reliable, or "resource adequate," when metrics indicate power shortages will occur for less than one day in 10 years, or 2.4 hours per year. The scenarios illustrate how much effective generating capacity is needed to achieve these metrics.

How does this study differ from the studies E3 completed for Public Generating Pool and Climate Solutions in 2017-2018?
The previous studies focused on the cost of decarbonizing the Northwest grid but did not closely examine the issue of power system reliability. The previous studies utilized E3's RESOLVE model – an optimal dispatch and capacity expansion model – to develop least-cost portfolios of resources to meet specified policy goals over time. The current study conducts a detailed examination of long-term reliability requirements under deep decarbonization using E3's RECAP model, which was designed expressly for this purpose. RECAP calculates generating resource availability over thousands of simulated years in order to ensure a statistically representative set of results.

What are the key findings of the E3 reliability study?
The key findings are:

1. 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;
2. It would be extremely costly and impractical to replace all carbon-emitting firm generation capacity with solar, wind and storage, due to the very large quantities of these resources and the associated transmission construction that would be required;
3. 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; and
4. Current planning practices risk underinvestment in new capacity required to ensure Resource Adequacy at acceptable levels.

What are the limitations to E3's analysis relative to state policy?
The focus of E3's analysis is to understand how energy policies will affect resource adequacy for the entire Greater NW region. Resource adequacy is, to an extent, a regional issue as all Northwest utilities are interconnected and trade surplus energy and capacity with each other. However, individual utilities are ultimately responsible for ensuring resource adequacy for their own systems, and conclusions valid for the broad region may not hold true for individual utilities or states. In particular, the larger region will likely require a lower Planning Reserve Margin than individual utilities, due to diversity of both electric loads and resources across a broad geography. In addition, the effective capacity contribution of wind, solar and energy storage calculated by a model like RECAP will be different for each utility system.



Finally, it is important to recognize the cost of clean energy policy will not be borne equally across the region. Utilities currently relying on more carbon-intensive portfolios will require more investment and incur higher costs than utilities with relatively clean portfolios today.

Is it possible to meet all of the region's future electric power needs with renewables?
It would be extremely costly and impractical to replace all firm generation capacity with solar, wind and storage, due to the very large quantities of these resources that would be required. With current technology, the region would need to build so much extra renewable generation that only half of the available energy could be utilized. Without thermal firm generation capacity on the system, this overbuild of renewables is needed ensure that enough energy is stored to protect against multi-day events with high demand and low wind, solar, and hydro production. Extreme levels of overbuild are required at the highest levels of decarbonization (95 – 100%).

- Regional incremental costs become potentially significant in the 80 to 90% reduction scenarios. Annual renewable curtailment of between 4 and 10 percent for these scenarios tend to lower the value of incremental renewable generation.
- In a 98% reduction scenario, a significant oversupply results in 21% of available renewable generation being curtailed. Incremental resource costs also double compared to the 90% reduction scenario.
- Removing the final 2% of carbon under a 100% reduction scenario requires an *additional* $100 billion to $170 billion of investment, relative to the 98% reduction scenario. Under this scenario, nearly half of wind and solar generation is wasted because it is not needed to serve load during most hours.

What other challenges does the 100% clean energy scenario present?
The land use impacts of a 100% clean energy portfolio are significant. To maintain resource adequacy, 97,000 MW of new wind and 46,000 MW of new solar are needed. This translates into about 3 – 14 million acres of land – or 100 times the land mass of Portland and Seattle combined. It is unclear whether there are enough sites that are suitable for that level of renewable energy development. Another major challenge is transmission construction and siting. Most of the best wind and solar sites are located either in Montana or Wyoming (for wind) or Southern Idaho and Utah (for solar). Delivering energy from 140,000 MW of wind and solar into load centers would require dozens of new high voltage transmission lines.

Can clean resources such as wind and solar contribute to system resource adequacy?
Wind and solar energy can contribute to resource adequacy but have limitations which must be taken into consideration. Wind and solar power plants can produce energy only when the wind is blowing or the sun is shining. However, high electricity demand events in the Northwest tend to occur during the wintertime when historically there is little sun or wind. The study estimates for the combined northwest and mountain region today, 100 MW of wind would contribute only 7 MW of effective capacity, while 100 MW of solar would contribute 12 MW of effective capacity. The study does find using a more diverse portfolio of resources, including wind resources in Montana and Wyoming, would contribute more capacity value than today's wind resources that are largely located in the Columbia Gorge area. Under a more diverse portfolio in 2050, 100 MW of wind and solar would each contribute approximately 20 MW of effective capacity.

What role can energy storage play toward meeting resource adequacy needs?
Energy storage can help meet resource adequacy needs by charging with excess wind, solar, hydro or gas generation and storing the energy for future use. However, energy storage also has important limitations in the Northwest. First, it is challenging to maintain reliability during cold weather events since cold snaps tend to correlate with low wind and solar production that last for several days and current battery technology's energy durations are in the 4-10 hour range. Second, the Northwest already has a significant quantity of energy storage within the existing hydropower systems that can be deployed during these multi-day events. This means that new energy storage systems with 4-10 hour duration are not as helpful in the Northwest as they are in other regions that are less dependent on hydropower. The study does find that the first 2,000 MW of 6-hour energy storage would contribute a significant amount of capacity value, approximately 1,400 MW. Beyond 2,000 MW, storage technology contributes very little to resource adequacy; the second 2,000 MW of 6-hour energy storage would contribute only 200 MW of effective capacity.

How soon will the Northwest need additional firm generating capacity to meet electric load reliably?
The electric system will undergo significant changes to its generation mix due to increased penetration of wind and solar and coal retirements. Today's system relies on 24,000 megawatts (MW) of thermal generation, including 11,000 MW of coal generation. Currently, 3,000 MW of coal are slated for retirement. By 2030, the system would need 8,000 MW of new capacity to replace retiring coal and meet the forecasted increase in demand. If all coal is retired by 2030, the system would need 16,000 MW of new capacity. While additional wind, solar and energy storage could contribute during this time horizon, much of this new capacity will need to be natural gas or dual-fuel generation.

Is building new natural gas generation capacity consistent with long-term deep decarbonization?
Yes, large increases in wind and solar generation provide for electric system decarbonization, however, this study shows resource adequacy is maintained by utilizing natural gas generation capacity during multi-day reliability events. In fact, even the 98% carbon reduction scenario has more natural gas generating capacity than exists today in the region (14,000 MW of gas generation capacity under the 98% carbon reduction scenario vs. 12,000 MW today).

What level of energy efficiency was assumed?
The study's load forecast reflects all cost-effective conservation identified by the Northwest Power and Conservation Council's 7th Power Plan. The model does not assume additional energy efficiency that may become cost-effective in a more decarbonized electric sector. Consistent with the 2017 results, it will be important to identify the next generation of energy efficiency measures.

Did the demand forecast account for increased demand from electrification of other sectors?
Electrification of homes and vehicles is only included to the extent that it is reflected in current load growth forecasts. Heavy electrification of buildings, vehicles, or industry would increase resource adequacy requirements beyond what this study shows, resulting in additional required resources.

Why are nuclear power and new hydro not considered as a firm capacity option in the analysis?
The main purpose of the study was to evaluate the potential ability and contribution of traditional renewables to meet the adequacy requirements of the system. Alternative solutions such as nuclear generation, fossil generation with carbon capture and sequestration, ultra-long duration storage, and biogas may become available during this time frame, however each faces significant technical challenges before they can be deemed reliably available at scale. The study does include sensitivities on the role of these alternative technologies and finds that carbon-free baseload, such as small modular reactors, and biogas may have a useful role to play in the future under a deeply decarbonized electricity system.

Does this Reliability Analysis include all the within-hour flexibility, inertia and resiliency needed to assure reliable operation of the electric system?
This analysis focused on Resource Adequacy to ensure enough resources are built to meet the forecasted needs of the electric system. Other analysis is needed to confirm the flexibility and resiliency needs of the system.

How was the need for new transmission to support resources handled in this analysis?
A $/MW transmission cost was added to new resources for which existing transmission is not available. The study does not estimate the amount of new transmission that would be needed, however it is likely that the energy portfolio selected for 100% Zero Carbon scenario would require dozens of new high-voltage transmission lines stretching across multiple states.

How was the need for new gas pipeline capacity handled in this analysis?
This study assumes that all firm natural gas generating capacity has access to a firm, reliable fuel supply. Investment in fuel delivery capability may be required to ensure resource adequacy with potential options being new gas pipeline infrastructure or on-site fuel storage, including potential dual-fuel capability.

Does the study differentiate between types of future required firm natural gas generating capacity?
The two primary options for firm natural gas capacity are combined cycle units and combustion turbines. Combined cycle plants have slightly higher capital costs along with slightly lower operating costs and emissions. Because the firm natural gas generation in a deeply decarbonized world would be utilized very infrequently, traditional utility planning may preference combustion turbines for their low capital cost. However, a region that is heavily focused on carbon reductions may be willing to incur the higher cost for combined cycle units in order to realize the associated emissions benefits.

Who sponsored this study?
This study was funded by Puget Sound Energy, Avista, NorthWestern Energy and the Public Generating Pool (PGP). PGP is a trade association representing 10 consumer-owned utilities in Washington and Oregon.

Energy+Environmental Economics

Resource Adequacy in the Pacific Northwest

Serving Load Reliably under a Changing Resource Mix

Northwest Power and Conservation Council

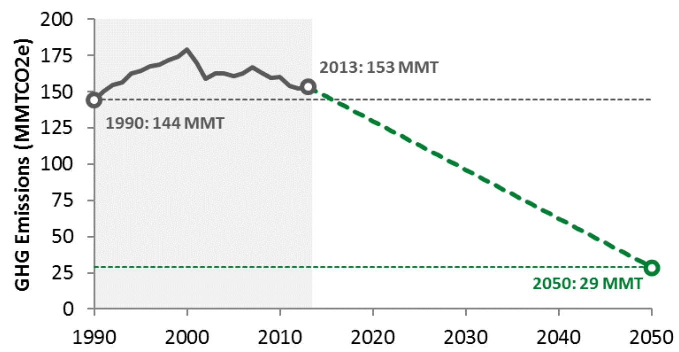
February 12, 2019
Portland, Oregon

Arne Olson, Sr. Partner

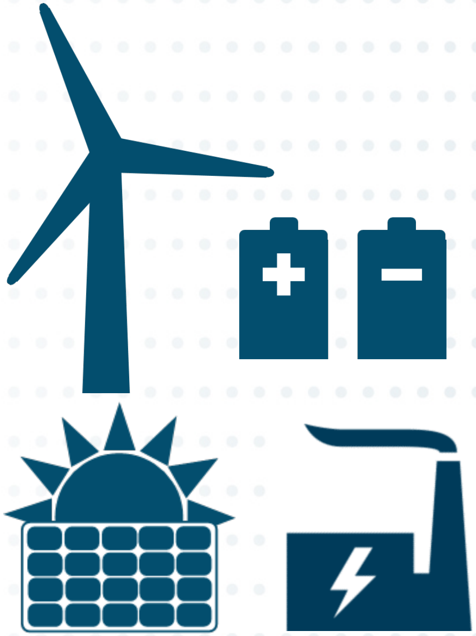
About This Study

- The Pacific Northwest is expected to undergo significant changes to its generation resource mix over the next 20 years due to changing economics and more stringent policy goals
  - Increased penetration of wind and solar generation
  - Retirements of coal generation
  - Questions about the role of new natural gas generation

Historical and Projected GHG Emissions for OR and WA



- This raises questions about the region's ability to serve load reliably as firm generation is replaced with variable resources
- This study was sponsored by 13 Pacific Northwest utilities to examine Resource Adequacy under a changing resource mix
  - How to maintain Resource Adequacy in the 2040-2050 time frame under stringent carbon abatement goals
  - How to maintain Resource Adequacy in the 2020-2030 time frame under growing loads and increasing coal retirements



Study Sponsors

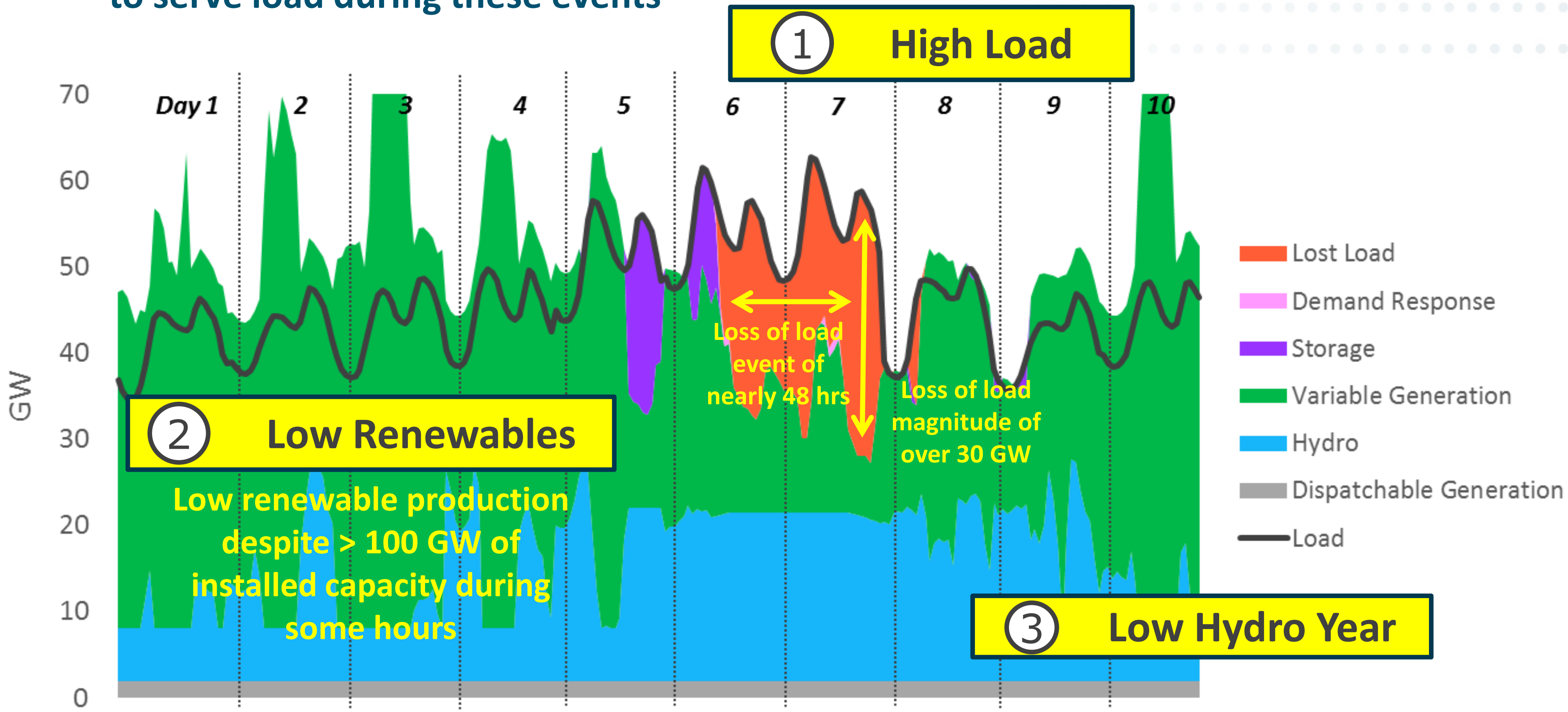
+ **This study was sponsored by Puget Sound Energy, Avista, NorthWestern Energy and the Public Generating Pool (PGP)**

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

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

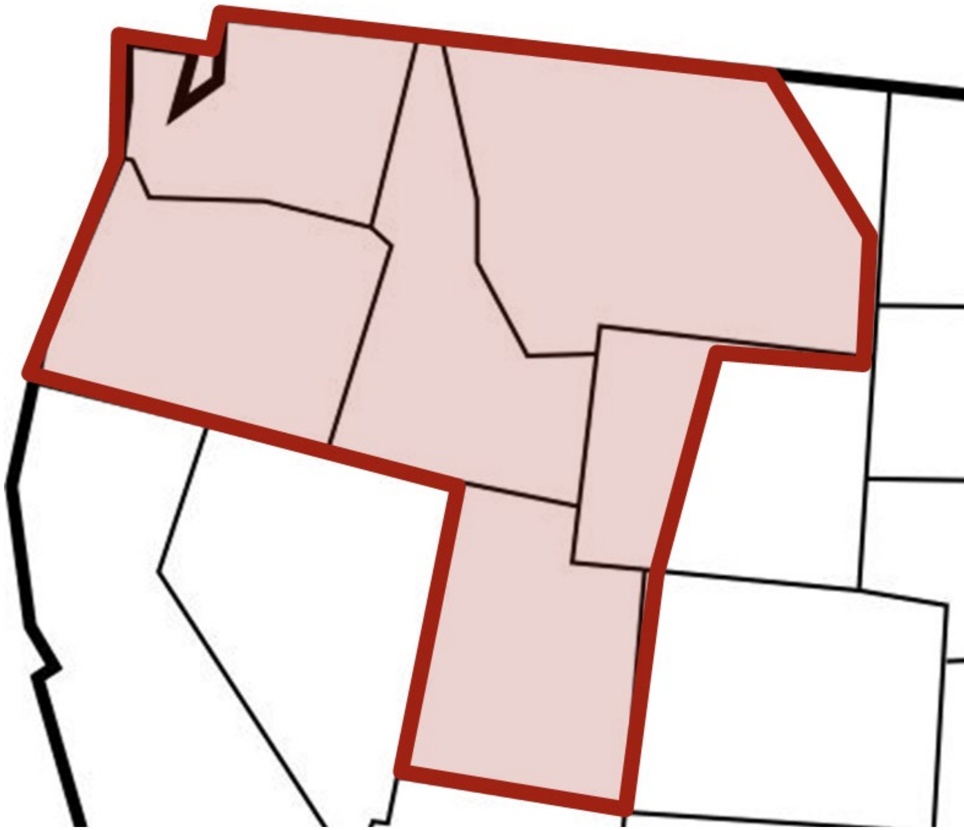
The most difficult conditions for reliable electric service are multi-day high load, low renewable production events

- Power systems that depend on wind and solar to provide a significant proportion of 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



Study Region – The Greater NW

- **The study region consists of the U.S. portion of the Northwest Power Pool (excluding Nevada)**
- **It is assumed that any resource in any area can serve any need throughout the Greater NW region**
  - Model assumes no transmission constraints, no transactional friction (i.e. full coordination), and full benefits from regional load and resource diversity
  - Costs and Resource Adequacy requirements may be **higher** due to transmission or transactional constraints
- **Results for any individual utility may be different than for the GNW region**
  - Individual systems are likely to need a higher PRM, ELCC values will differ due to load shapes, and transmission constraints will differ



Balancing Authority Areas include: Avista, Bonneville Power Administration, Chelan County PUD, Douglas County PUD, Grant County PUD, Idaho Power, NorthWestern Energy, PacifiCorp (East & West), Portland General Electric, Puget Sound Energy, Seattle City Light, Tacoma Power, Western Area Power Administration

2018 system is in very tight load-resource balance

- A planning reserve margin of 12% is required to meet 1-in-10 reliability standard
- The 2018 system does not meet 1-in-10 reliability standard (2.4 hrs./yr.)
- The 2018 system does meet Northwest Power and Conservation Council standard for Annual LOLP (5%)

	Reliability Metrics
Annual LOLP	3.7%
LOLE (hrs./year)	**6.5**
EUE (MWh/year)	5,777
EUE norm (EUE/Load)	0.003%
1-in-2 Peak Load (GW)	43
Required PRM to meet 2.4 LOLE	12%
Required Firm Capacity (GW)	48

2018 Load and Resource Balance

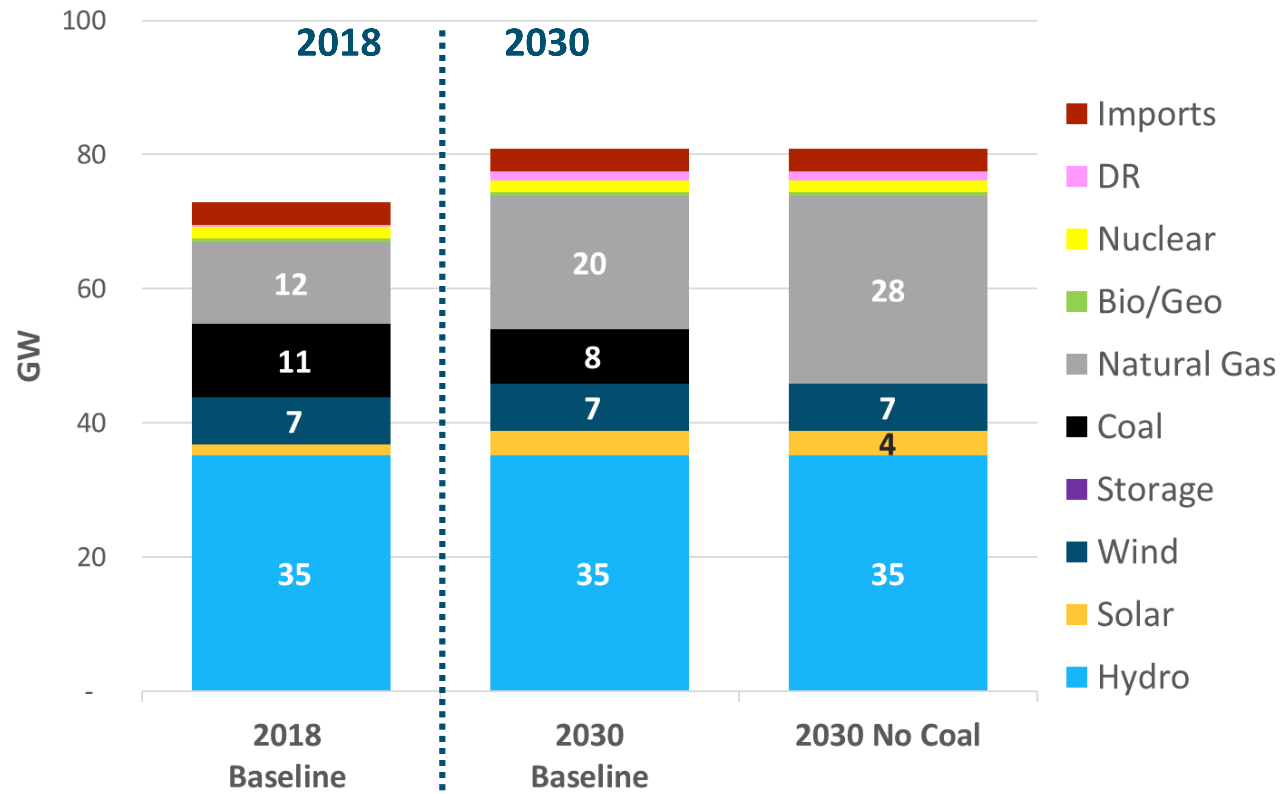
	2018
Load (GW)	
Peak Load	43.2
PRM (%)	*12%*
PRM	5.2
Total Load Requirement	48.3

Resources / Effective Capacity (GW)	2018	Nameplate Capacity (GW)	ELCC* (%)	Capacity Factor (%)
Coal	10.9			
Gas	12.2			
Bio/Geo	0.6			
Imports	2.5			
Nuclear	1.2			
DR	0.3			
Hydro	18.7	*35.2*	*53%*	*44%*
Wind	0.5	*7.1*	*7%*	*26%*
Solar	0.2	*1.6*	*12%*	*27%*
Storage	0.0			
Total Supply	47.1			

Wind and solar contribute little effective capacity with ELCC* of 7% and 12%

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

2030 Portfolios



GHG Free Generation (%)	61%	61%
Carbon (MMT CO2)	67	42
% GHG Reduction from 1990 Level	-12%*	31%

**Assumes 60% coal capacity factor*

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)

2030 Load and Resource Balance

	2030
Load (GW)	
Peak Load (Pre-EE)	50.4
Peak Load (Post-EE)	46.9
PRM	*12%*
PRM	5.6
Total Load Requirement	52.6

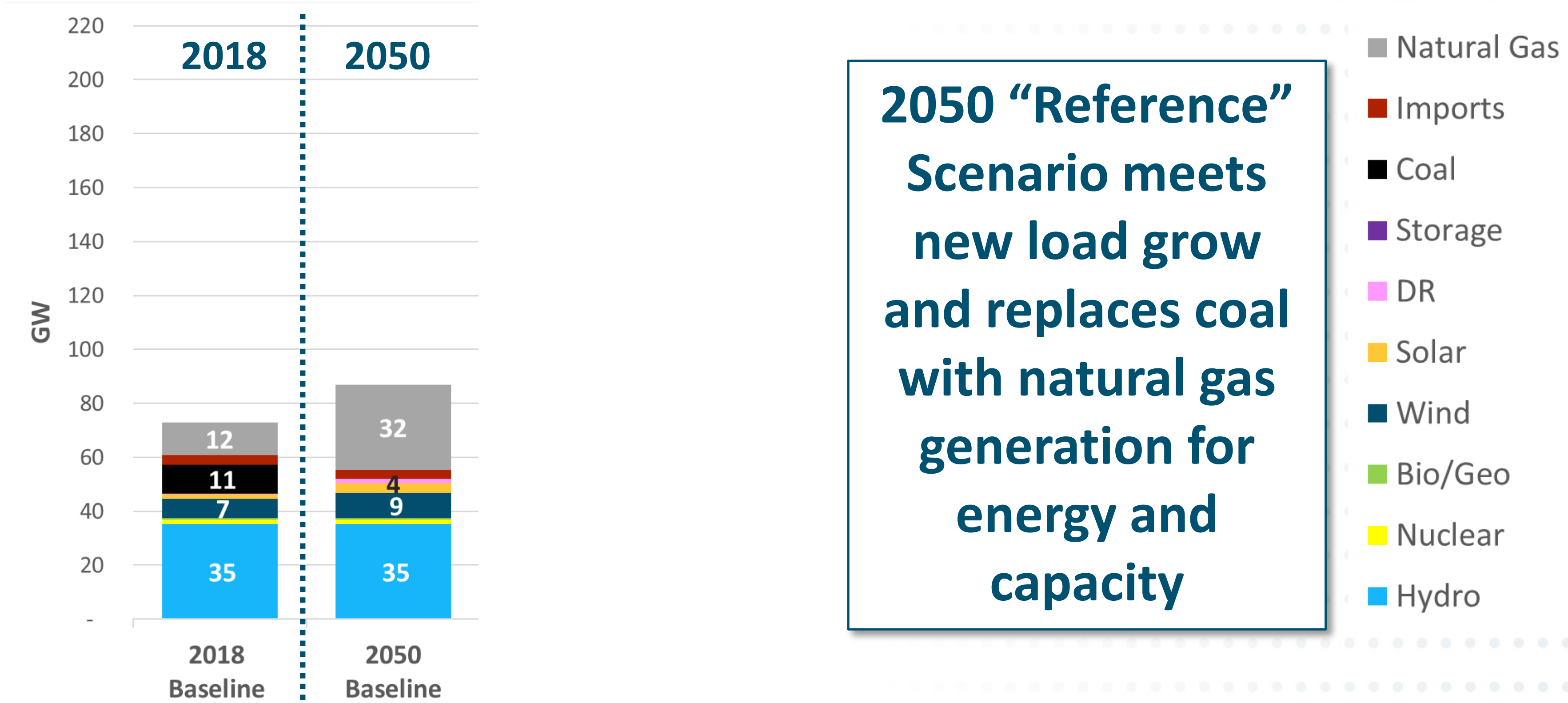
Resources / Effective Capacity (GW)		Nameplate Capacity (GW)	ELCC (%)	Capacity Factor (%)
Coal	8.2			
Gas	19.9			
Bio/Geo	0.6			
Imports	2.5			
Nuclear	1.1			
DR	1.0			
Hydro	19.7	*35.2*	*56%*	*44%*
Wind	0.6	*7.1*	*9%*	*26%*
Solar	0.2	*1.6*	*14%*	*27%*
Storage	0.0			
Total Supply	53.8			

7.7 GW new effective capacity needed by 2030

Wind and solar contribute little effective capacity with ELCC* of 9% and 14%

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

2050 Scenario Summary



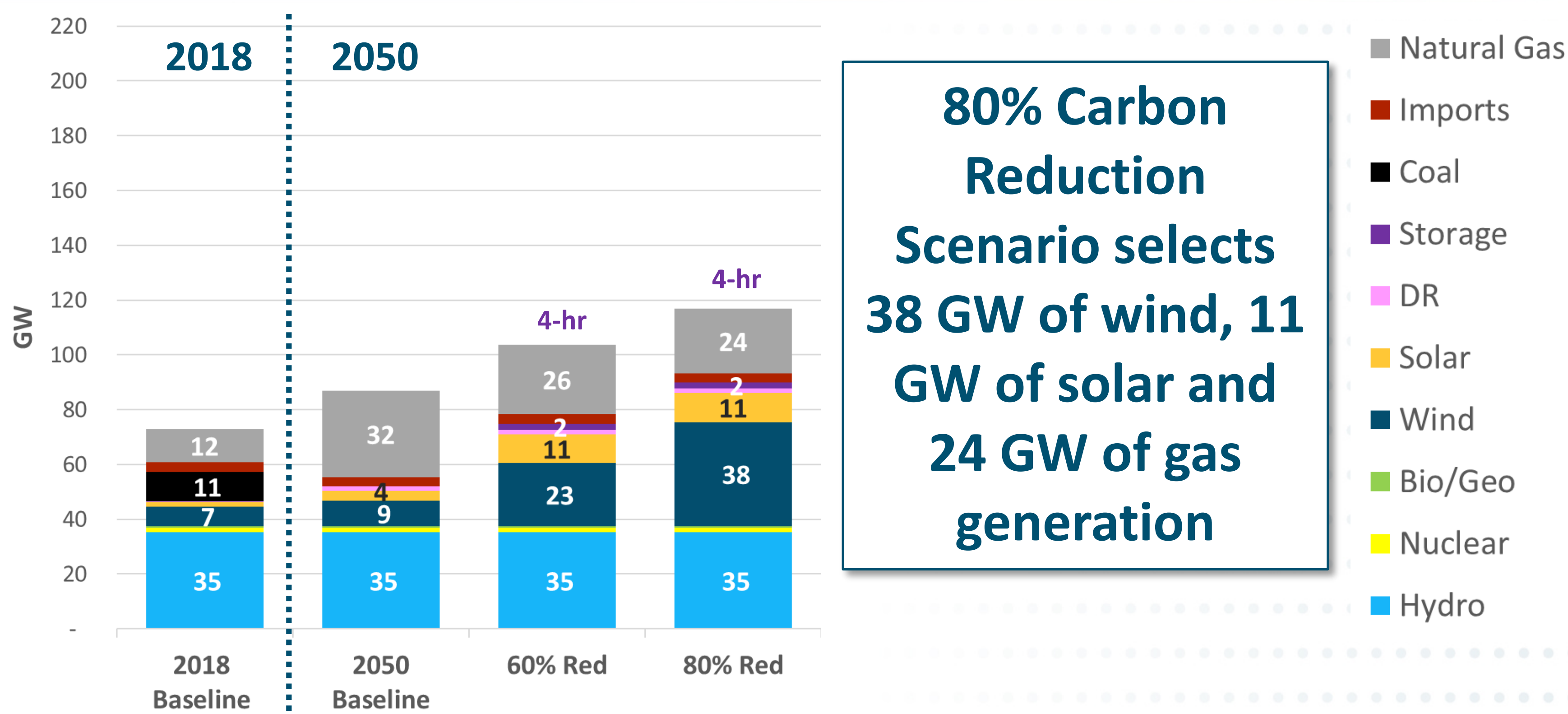
Carbon (MMT CO2)	50
CPS (%)[1]	63%
GHG Free Generation (%)[2]	60%
Annual Renewable Curtailment (%)	Low
Annual Cost Delta ($B)	Base
Additional Cost ($/MWh)	Base
% GHG Reduction from 1990 level	16%
Gas Capacity Factor (%)	46%

2050 "Reference" Scenario meets new load grow and replaces coal with natural gas generation for energy and capacity

[1]CPS+ % = renewable/hydro/nuclear generation divided by retail electricity sales

[2]GHG-Free Generation % = renewable/hydro/nuclear generation, minus exports, divided by total wholesale load

2050 Scenario Summary



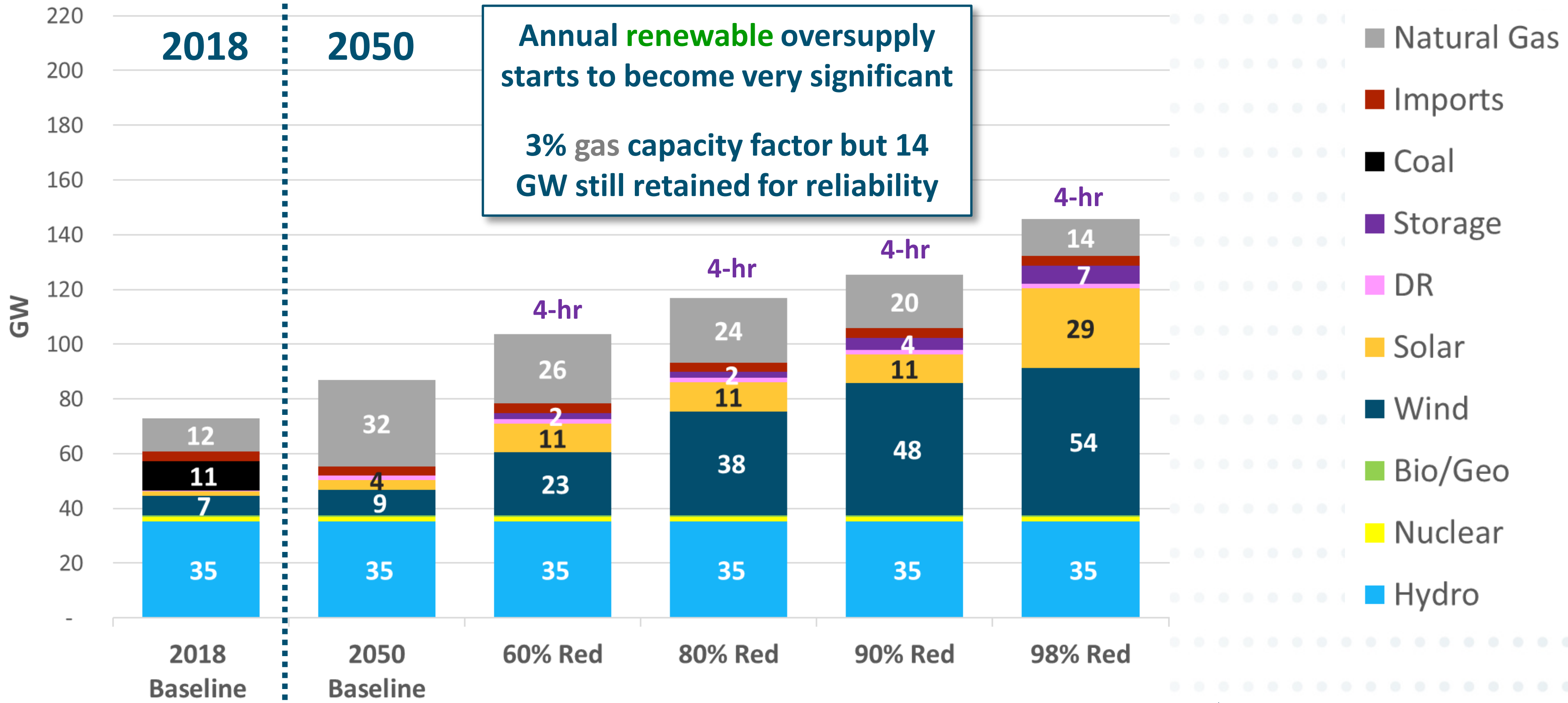
80% Carbon Reduction Scenario selects 38 GW of wind, 11 GW of solar and 24 GW of gas generation

	2050 Baseline	60% Red	80% Red
Carbon (MMT CO2)	50	25	12
CPS (%)[1]	63%	86%	100%
GHG Free Generation (%)[2]	60%	80%	90%
Annual Renewable Curtailment (%)	Low	Low	4%
Annual Cost Delta ($B)	Base	$0 - $2	$1 - $4
Additional Cost ($/MWh)	Base	$0 - $7	$3 - $14
% GHG Reduction from 1990 level	16%	60%	80%
Gas Capacity Factor (%)	46%	27%	16%

[1]CPS+ % = renewable/hydro/nuclear generation divided by retail electricity sales

[2]GHG-Free Generation % = renewable/hydro/nuclear generation, minus exports, divided by total wholesale load

2050 Scenario Summary

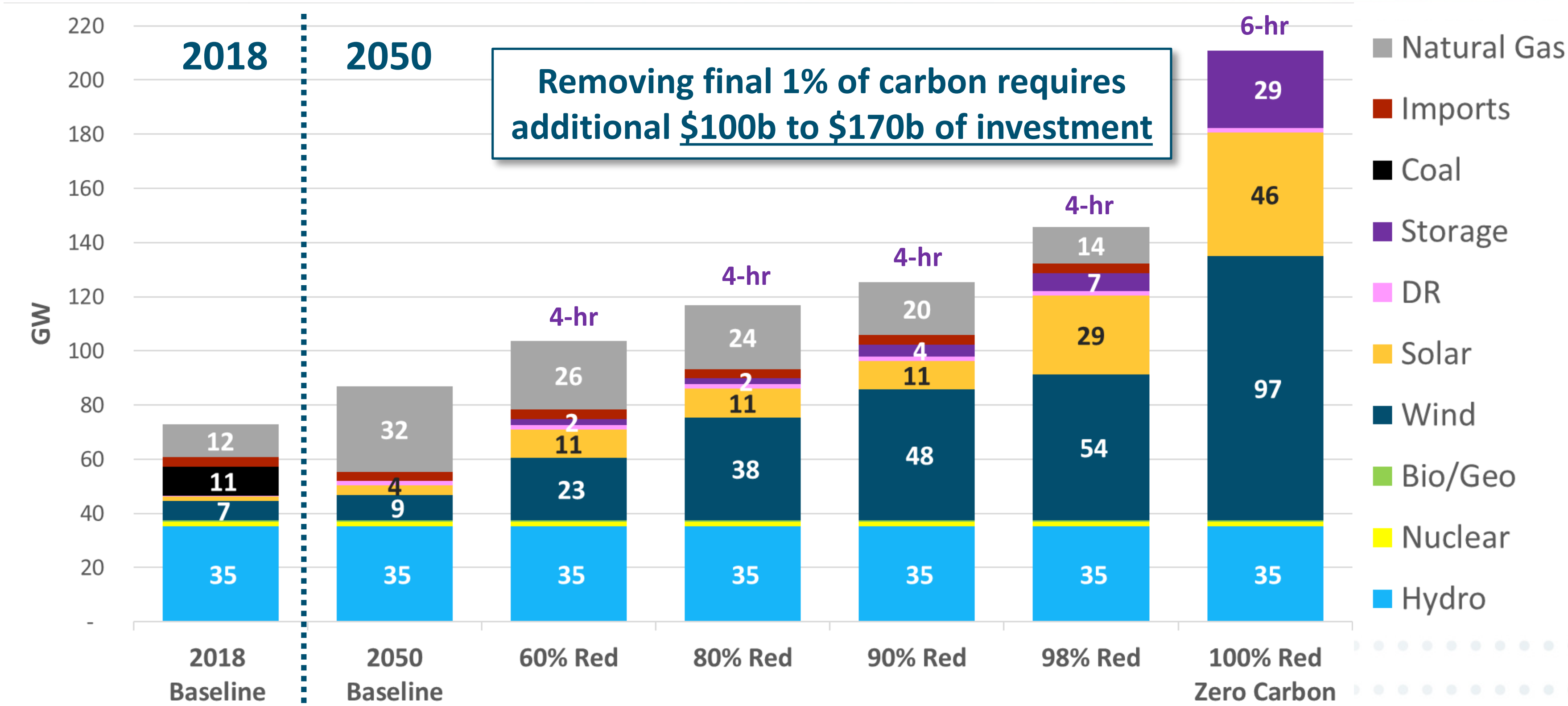


Carbon (MMT CO2)	50	25	12	6	1
CPS (%)[1]	63%	86%	100%	108%	117%
GHG Free Generation (%)[2]	60%	80%	90%	95%	99%
Annual Renewable Curtailment (%)	Low	Low	4%	10%	21%
Annual Cost Delta ($B)	Base	$0 - $2	$1 - $4	$2 - $5	$3 - $9
Additional Cost ($/MWh)	Base	$0 - $7	$3 - $14	$5 - $18	$10 - $28
% GHG Reduction from 1990 level	16%	60%	80%	90%	98%
Gas Capacity Factor (%)	46%	27%	16%	9%	3%

[1]CPS+ % = renewable/hydro/nuclear generation divided by retail electricity sales

[2]GHG-Free Generation % = renewable/hydro/nuclear generation, minus exports, divided by total wholesale load

2050 Scenario Summary

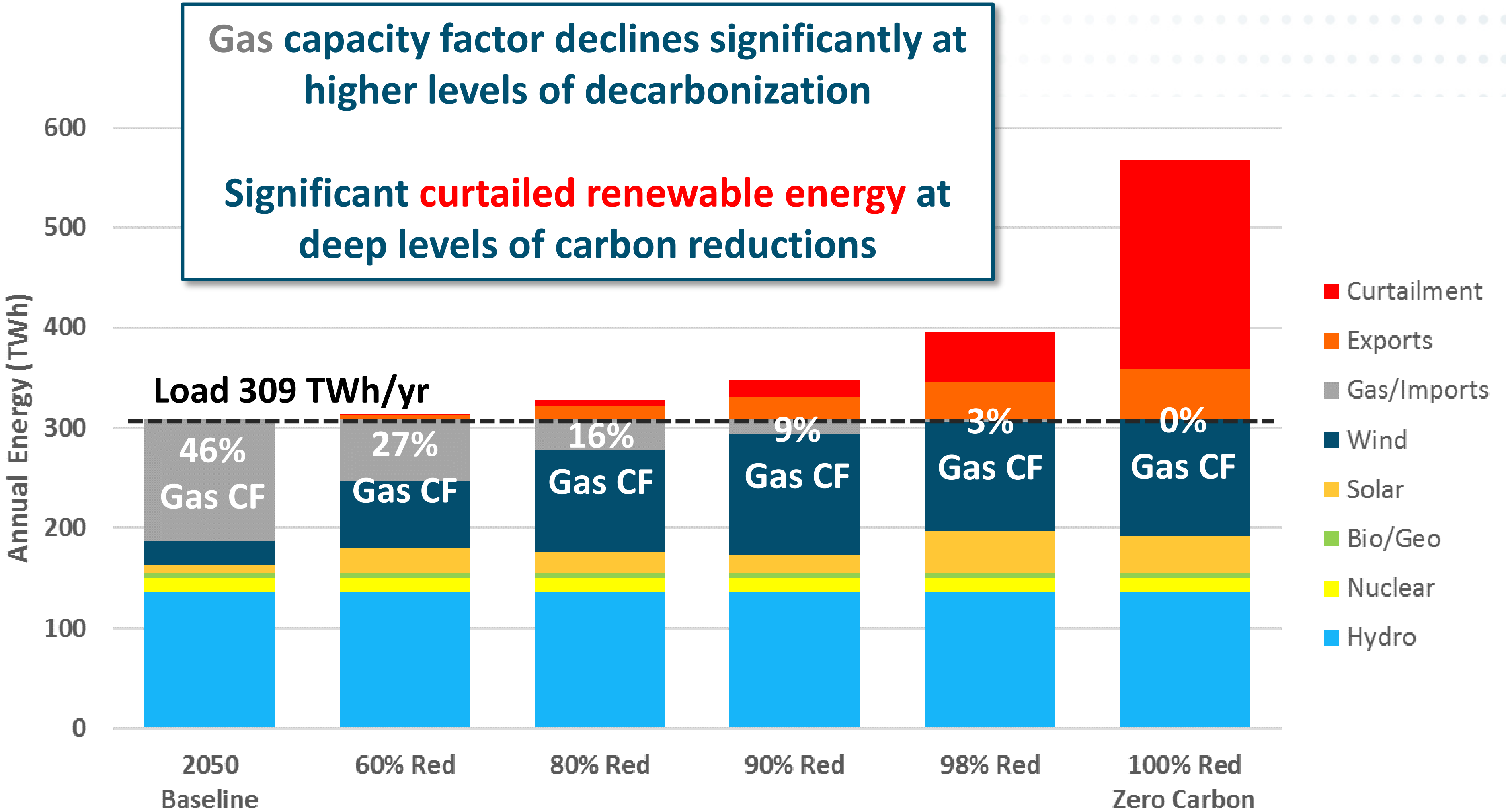


	2050 Baseline	60% Red	80% Red	90% Red	98% Red	100% Red Zero Carbon
Carbon (MMT CO2)	50	25	12	6	1	-
CPS (%)[1]	63%	86%	100%	108%	117%	123%
GHG Free Generation (%)[2]	60%	80%	90%	95%	99%	100%
Annual Renewable Curtailment (%)	Low	Low	4%	10%	21%	47%
Annual Cost Delta ($B)	Base	$0 - $2	$1 - $4	$2 - $5	$3 - $9	$16 - $28
Additional Cost ($/MWh)	Base	$0 - $7	$3 - $14	$5 - $18	$10 - $28	$52 - $89
% GHG Reduction from 1990 level	16%	60%	80%	90%	98%	100%
Gas Capacity Factor (%)	46%	27%	16%	9%	3%	0%

[1]CPS+ % = renewable/hydro/nuclear generation divided by retail electricity sales

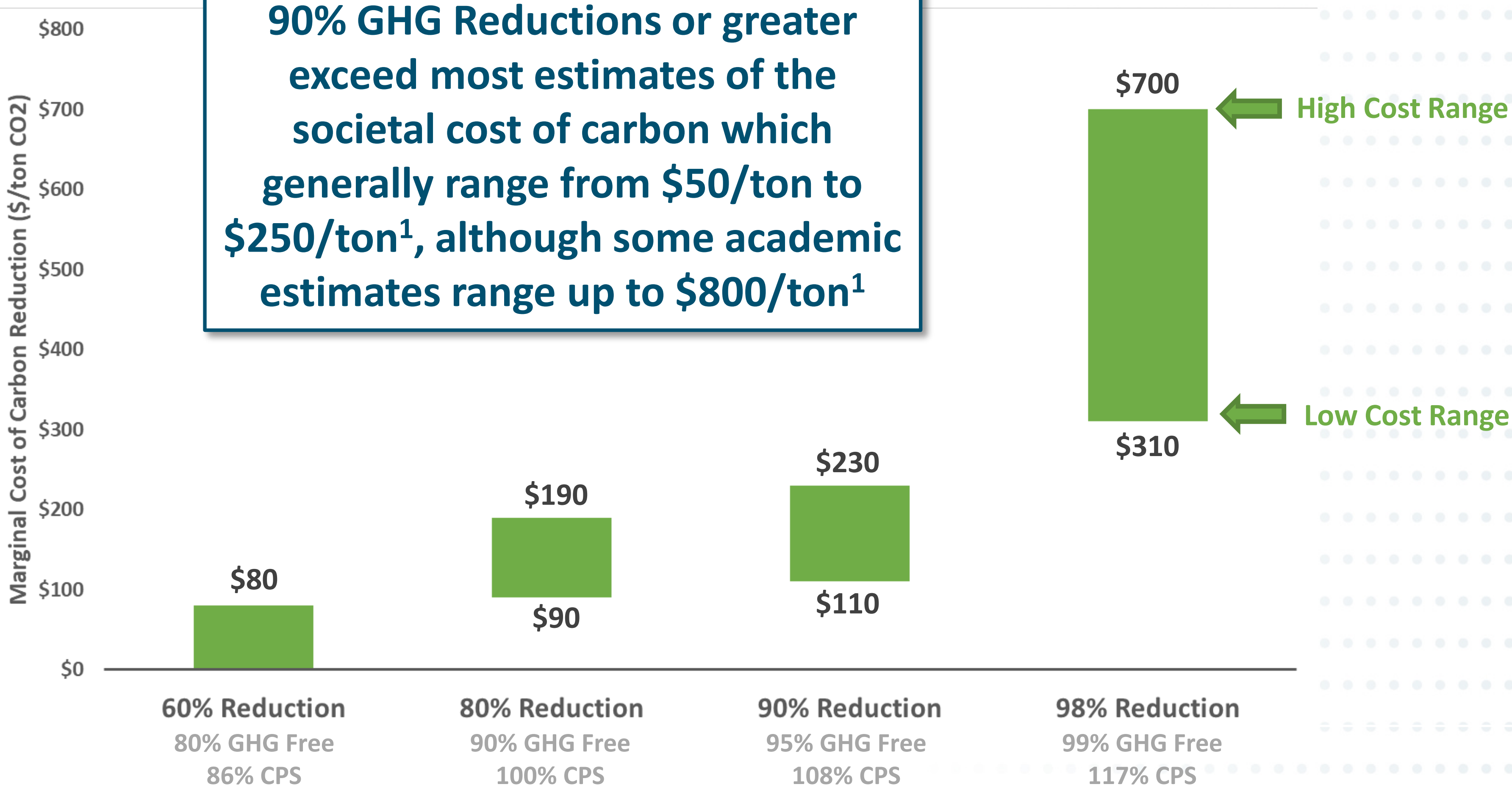
[2]GHG-Free Generation % = renewable/hydro/nuclear generation, minus exports, divided by total wholesale load

2050 Annual Energy Balance



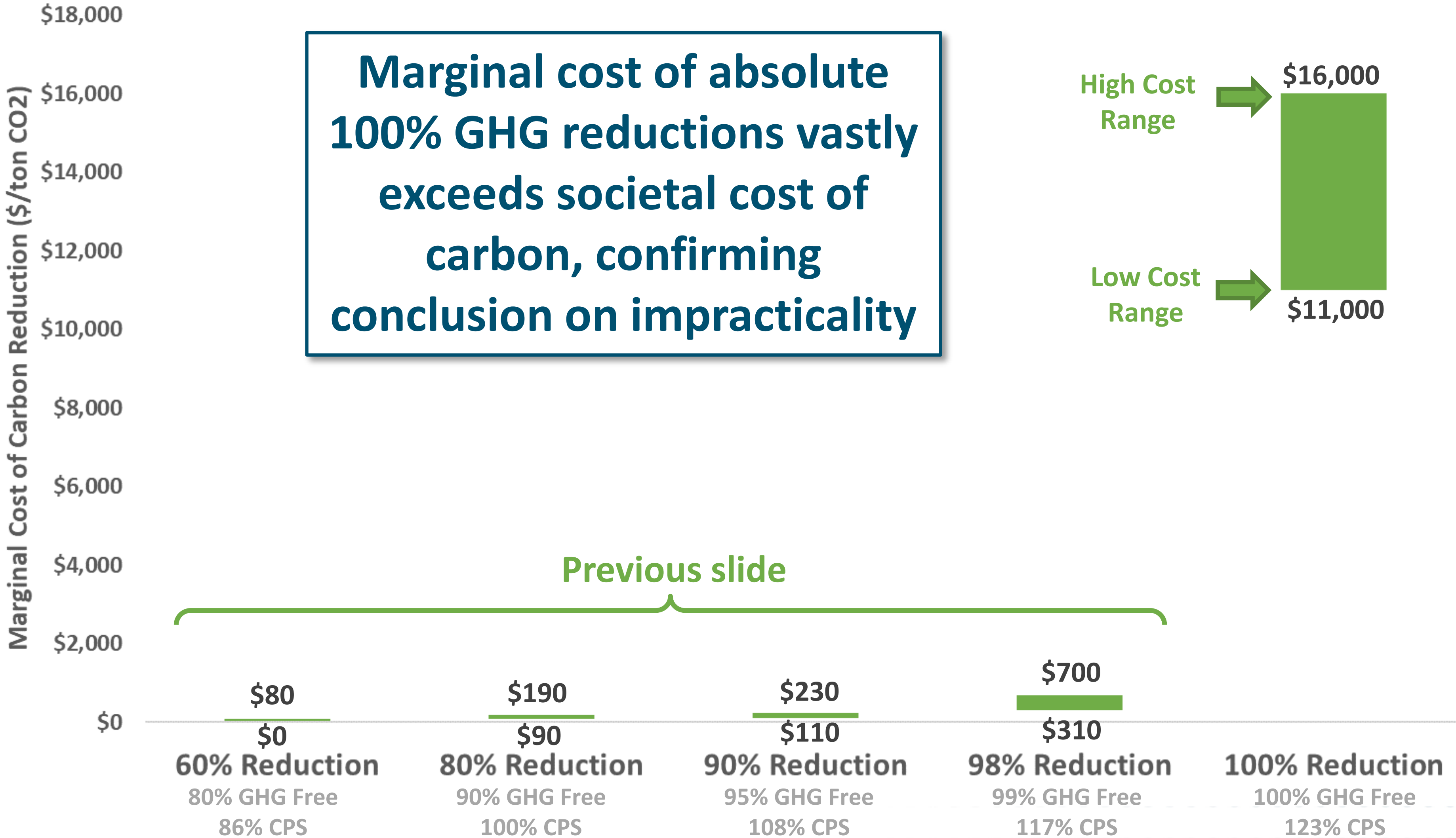
Marginal Cost of GHG Reduction

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]



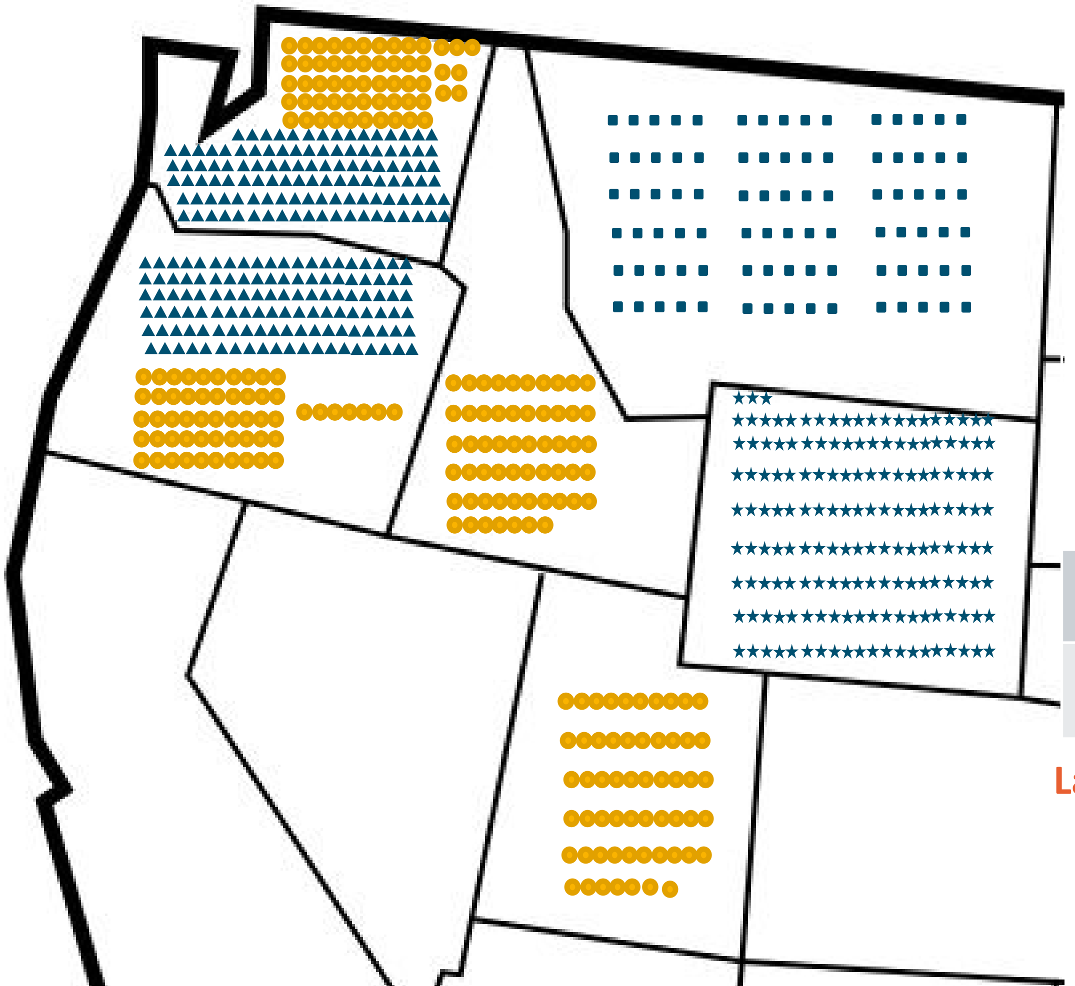
[1] https://19january2017snapshot.epa.gov/climatechange/social-cost-carbon_.html; https://www.nature.com/articles/s41558-018-0282-y

Marginal Cost of GHG Reduction



Renewable Land Use

100% Reduction in 2050



Technology	Nameplate GW
● Solar	46
▲ NW Wind	47
■ MT Wind	18
★ WY Wind	33

	Solar Total Land Use (thousand acres)	Wind - Direct Land Use (thousand acres)	Wind - Total Land Use (thousand acres)
80% Clean	84	94	1,135 – 5,337
100% Red	361	241	2,913 – 13,701

Land use in 100% Reduction case ranges from

20 to 100x

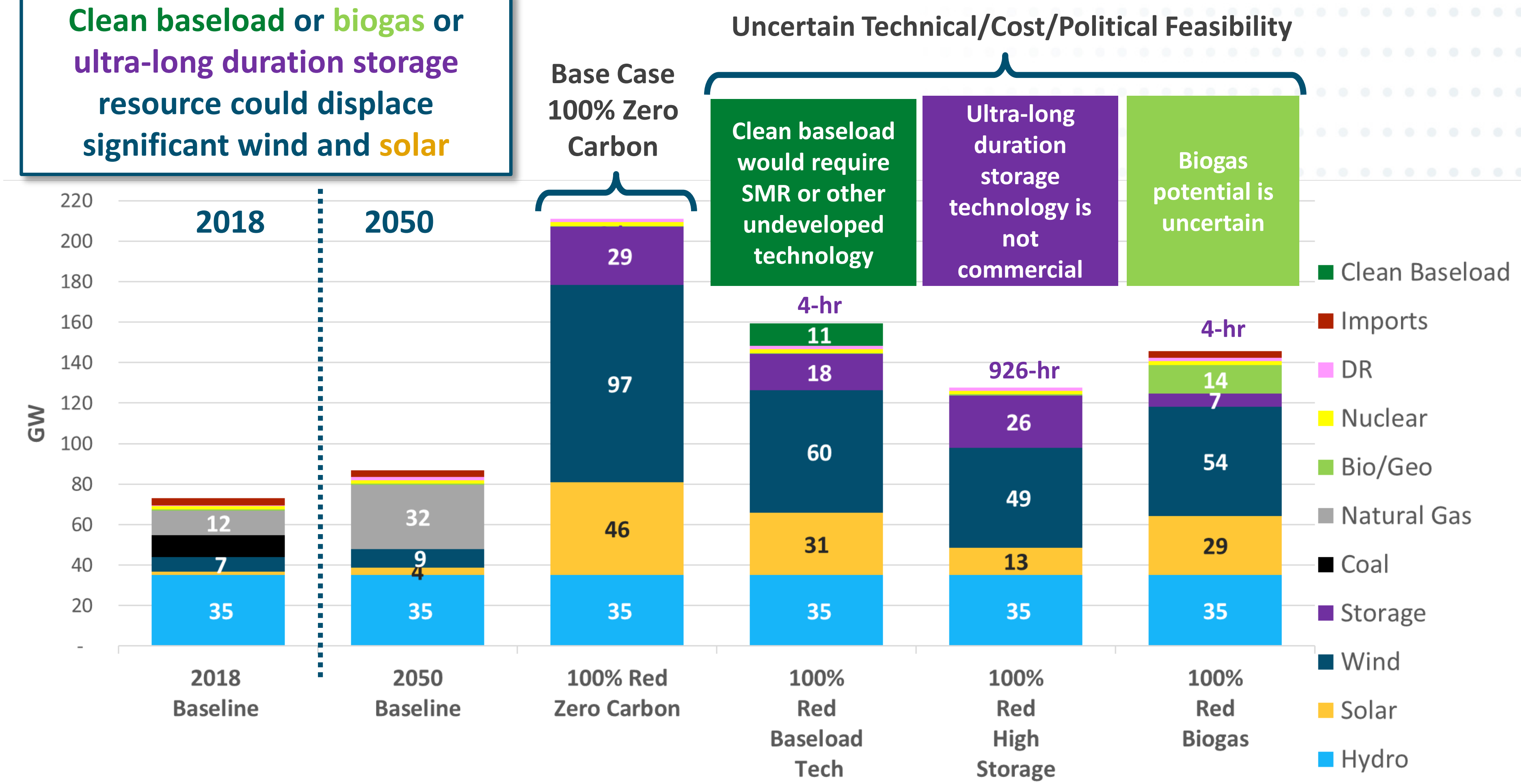
the area of Portland and Seattle combined

Each point on the map indicates 200 MW.
Sites not to scale or indicative of site location.

Portland land area is 85k acres
Seattle land area is 56k acres
Oregon land area is 61,704k acres

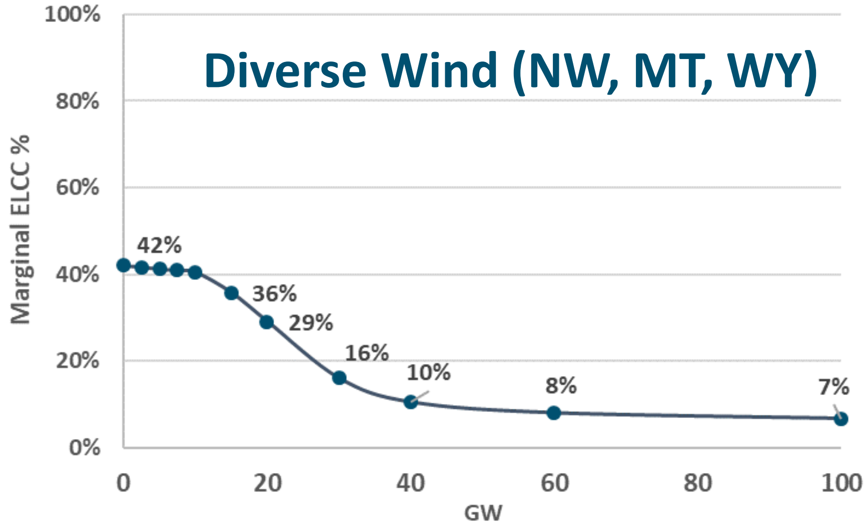
100% Reduction Portfolio Alternatives in 2050

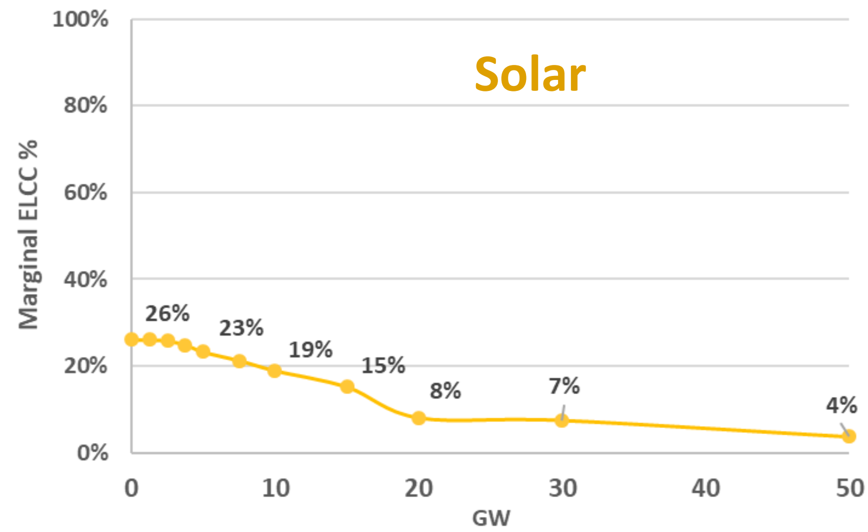
Clean baseload or biogas or ultra-long duration storage resource could displace significant wind and solar

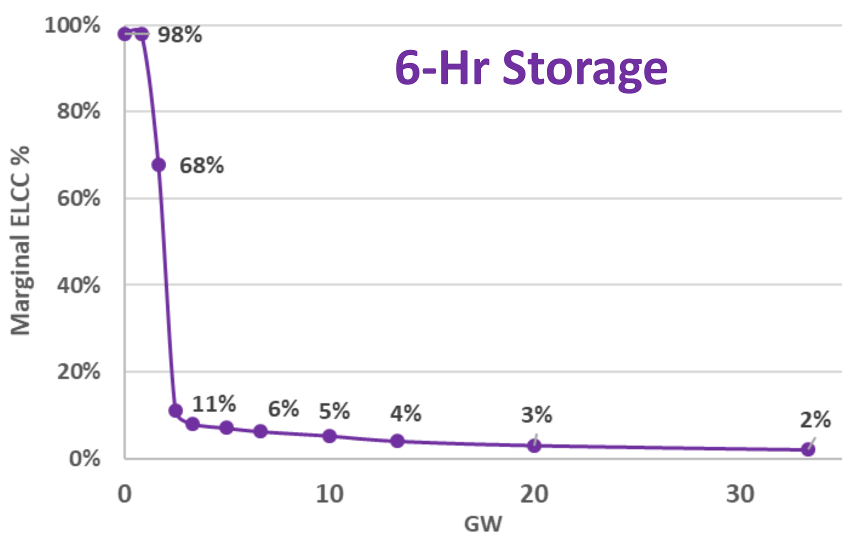


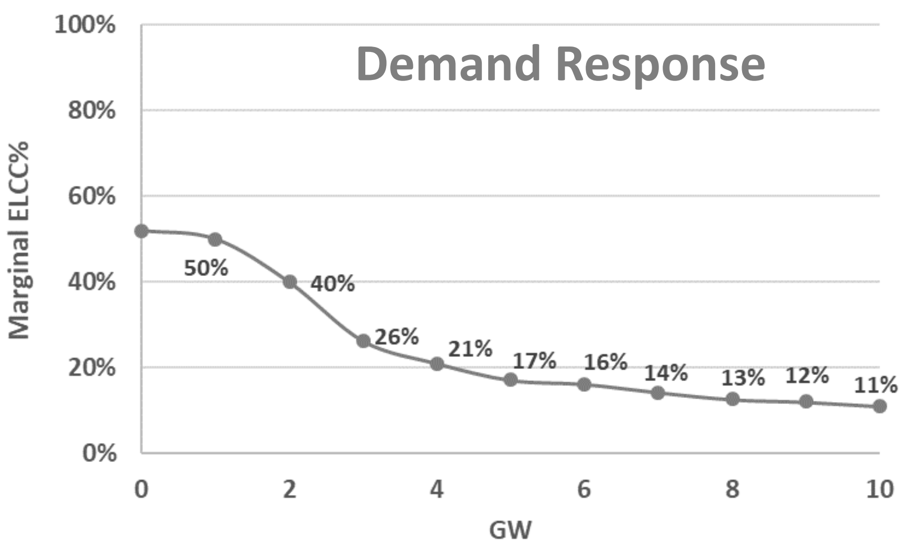
Carbon (MMT CO2)	50	0	0	0	0
Annual Cost Delta ($B)	Base	$16- $28	$14-$21	$550-$990	$4 - $9
Additional Cost ($/MWh)	Base	$52-$89	$46-$69	$1,800-$3,200	$14 - $30

Wind, solar, storage, and demand response all exhibit diminishing capacity values as more capacity is added

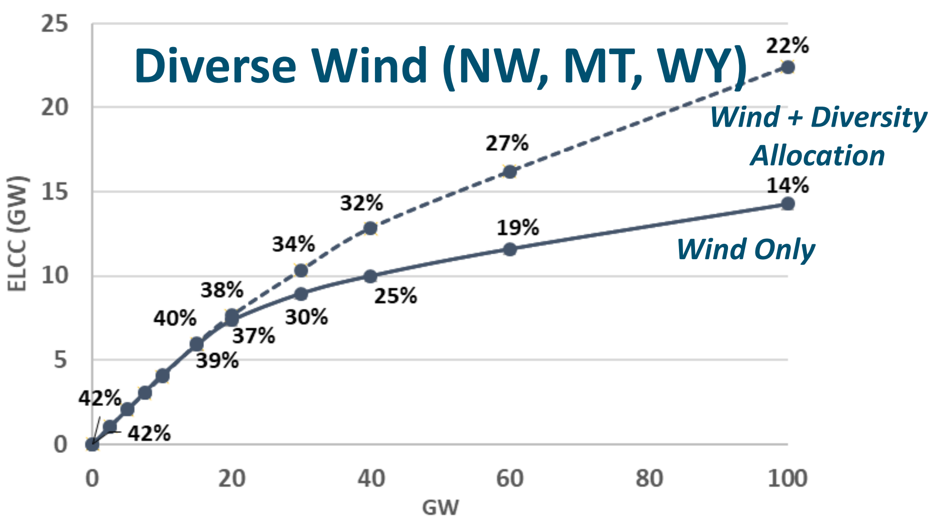


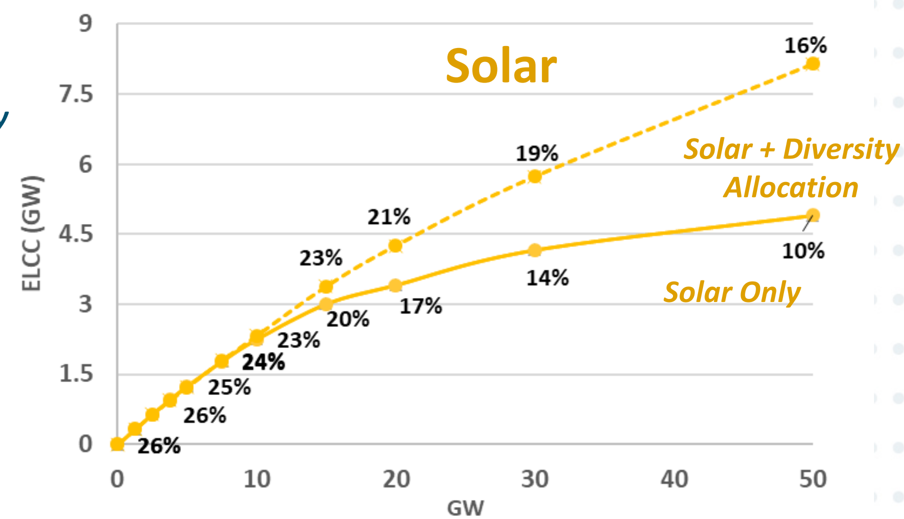


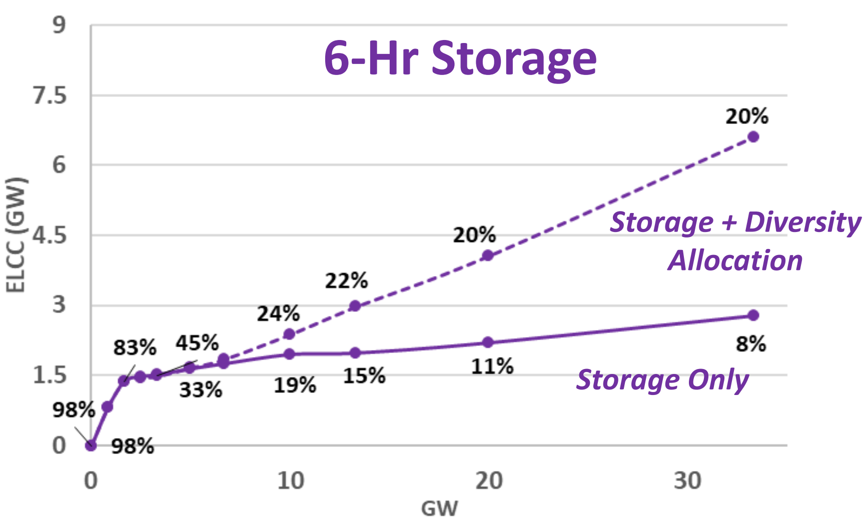




A combination of diverse wind, solar and diurnal energy storage provides durable capacity value







- 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 would require 125 GW of wind, solar and storage

Key Findings (1 of 2)

1. **It is possible to maintain Resource Adequacy for a deeply decarbonized Northwest electricity grid, as long as sufficient <u>firm capacity</u> 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
2. **It would be <u>extremely costly and impractical</u> to replace all carbon-emitting firm generation capacity with solar, wind and storage, due to the very large quantities of these resources that would be required**
3. **The Northwest is anticipated to need <u>new capacity in the near-term</u> in order to maintain an acceptable level of Resource Adequacy after planned coal retirements**

Key Findings (2 of 2)

4. **Current planning practices risk underinvestment in new capacity required to ensure Resource Adequacy at acceptable levels**

   - Reliance on “market purchases” or “front office transactions” reduces the cost of meeting Resource Adequacy needs on a regional basis by taking advantage of load and resource diversity among utilities in the region
   - However, because the region lacks a formal mechanism for counting physical firm capacity, there is a risk that reliance on market transactions may result in double-counting of available surplus generation capacity
   - Capacity resources are not firm without a firm fuel supply; investment in fuel delivery infrastructure may be required to ensure Resource Adequacy even under a deep decarbonization trajectory
   - The region might benefit from and should investigate a formal mechanism for sharing of planning reserves on a regional basis, which may help ensure sufficient physical firm capacity and reduce the quantity of capacity required to maintain Resource Adequacy

The results/findings in this analysis represent the Greater NW region in aggregate, but results may differ for individual utilities

Energy+Environmental Economics

Thank You!

Energy and Environmental Economics, Inc. (E3)
101 Montgomery Street, Suite 1600
San Francisco, CA 94104
Tel 415-391-5100
Web http://www.ethree.com

Arne Olson, Senior Partner (arne@ethree.com)
Zach Ming, Managing Consultant (zachary.ming@ethree.com)
Huai Jiang, Consultant II (huai@ethree.com)
Manohar Mogadali, Consultant II (manu@ethree.com)