System Value of Offshore Wind in Washington

Prepared for Trident Winds Inc.

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Energy+Environmental Economics

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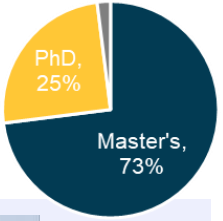
Study Background

Who is E3?

Thought Leadership, Fact Based, Trusted.

100+ full-time consultants | 30 years of deep expertise | Engineering, Economics, Mathematics, Public Policy…




San Francisco

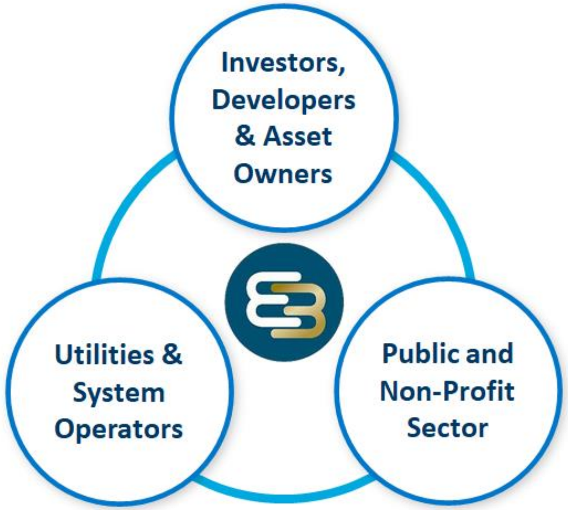

New York


Boston


Calgary

E3 Clients

300+ projects per year across our diverse client base



Recent Examples of E3 Projects

Buy-side diligence support on several successful investments in electric utilities (~$10B in total)

Acquisition support for investment in a residential demand response company (~$100M)

Supporting investment in several stand-alone storage platforms and individual assets across North America (10+ GW | ~$1B)

Acquisition support for several portfolios and individual gas-fired and renewable generation assets (20+ GW | ~$2B)

United Nations Deep Decarbonization Pathways Project

California: 100% clean energy planning and carbon market design for California agencies

Net Zero New England study with Energy Futures Initiative

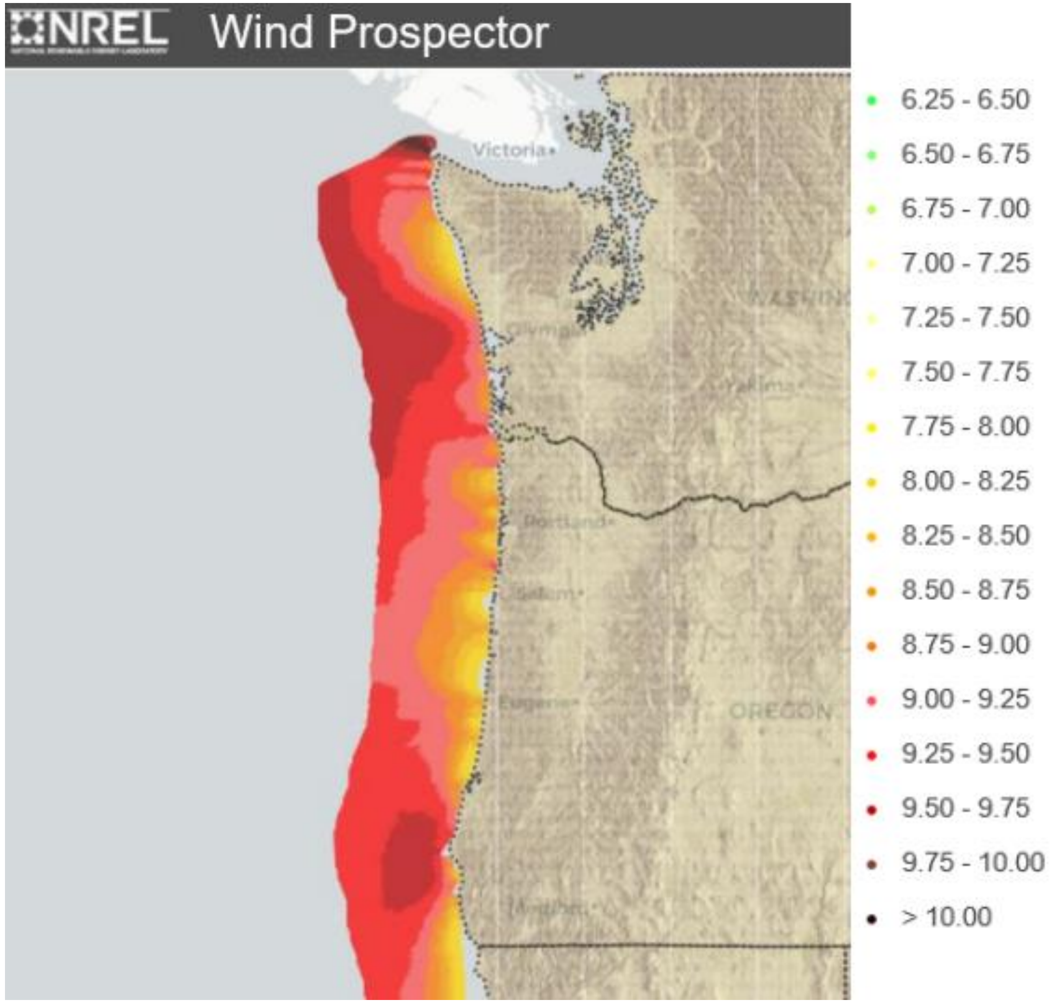
New York: NYSERDA 100% clean energy planning

Pacific Northwest: 100% renewables and resource adequacy studies for multiple utilities

Study Background

- **Trident Winds retained E3 to evaluate the potential role of Washington offshore wind energy in meeting Washington's long-run energy needs and climate goals using the most recent E3 energy system planning tools**
- **E3 utilized RESOLVE, an optimal capacity expansion model, to identify least-cost portfolios of electricity resources that maintain system reliability and achieve climate and energy policy goals**
- **E3 relied on the best available public data for both resource cost and quality as model inputs, and aligned on relevant sensitivities with Trident Winds to determine offshore wind value across multiple scenarios**
- **Key Study Questions:**
  - What is optimal amount of offshore wind chosen in each year?
  - What are the system cost savings for a system with offshore wind compared to a system without offshore wind?
  - What are the potential ratepayer impacts of offshore wind as a resource selection in Washington?

NREL Average January Offshore Wind Speed

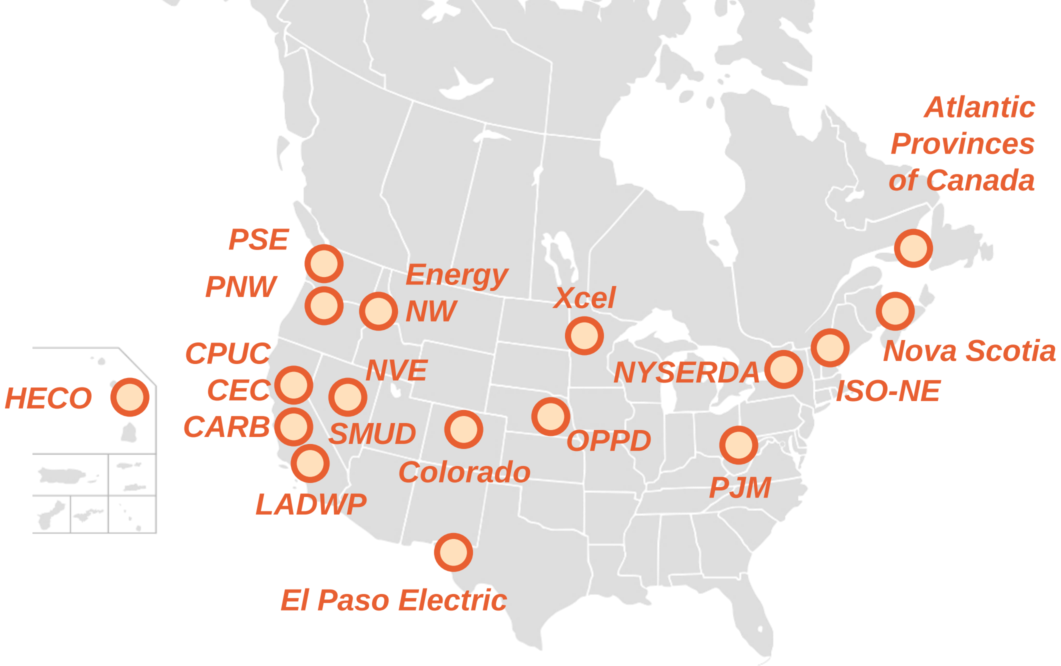


E3's Northwest RESOLVE Model

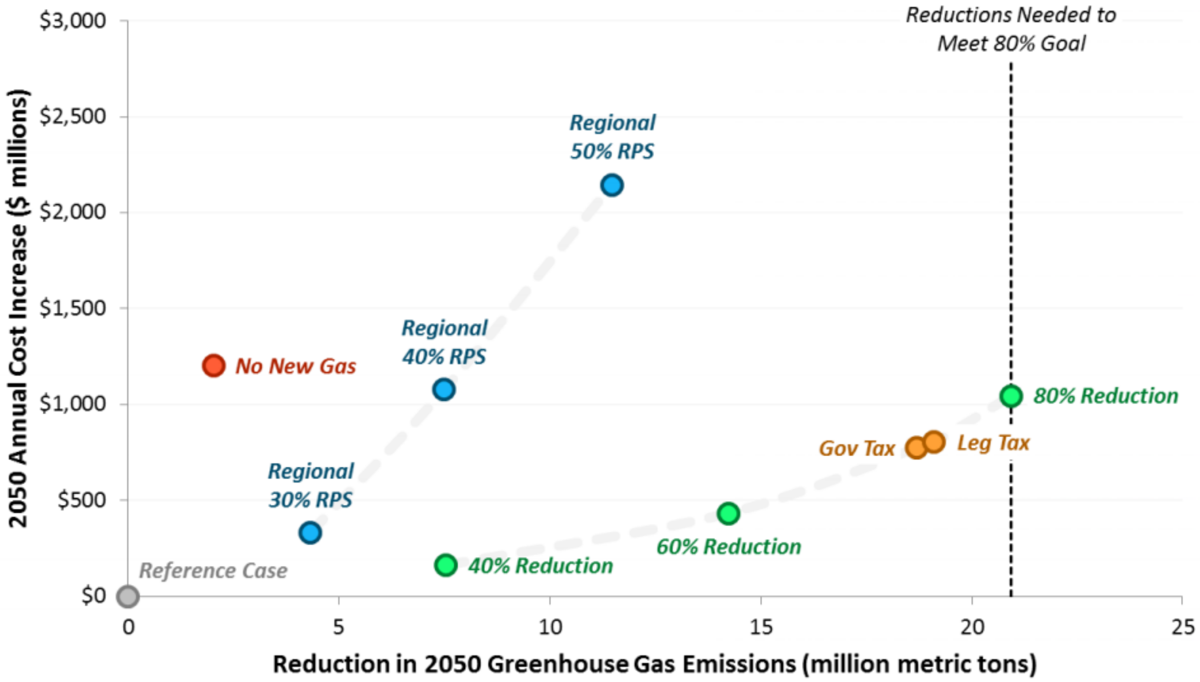
+ **E3 has used RESOLVE across North America to tackle complex policy and planning questions**
  - RESOLVE identifies optimal portfolios of resources to meet policy and reliability goals

+ **E3 has used RESOLVE in several prior Northwest studies**
  - PNW Low-Carbon Scenario Analysis (2017)
  - PNW Zero-Emitting Resources Study (2020)
  - Lower Snake River Dams Power Replacement Study (2022)

RESOLVE Case Studies



Pacific Northwest Low-Carbon Scenarios



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Challenges and Opportunities Under Washington Energy Policy

Washington Key Policy Drivers

Policy	Law	Year	Description
Clean Energy Transformation Act (CETA)	SB 5116	2019	• Eliminates coal in utility generation mix by 2025 • Carbon-neutral electric utility supply by 2030 • Eliminates CO2 emissions from electric utility generation by 2045
Greenhouse Gas Emission Reduction Goals	HB 2311	2020	• Sets new GHG emission reduction goals for the state: ○ 2030 - 45% below 1990 levels ○ 2040 - 70% below 1990 levels ○ 2050 - 95% below 1990 levels and achieve net zero emissions
Zero Emission Vehicles	SB 5811	2020	• Adopts California’s Zero Emissions Vehicle and Advanced Clean Truck Rule programs
Climate Commitment Act	SB 5126	2021	• Imposes a declining emissions cap on state’s largest emitters and industries • Allows businesses to find the most efficient path to lower carbon emissions • Is a complementary GHG emissions reduction tool HB 2311 targets
Clean Fuel Standard	HB 1091	2021	• Requires fuel suppliers to gradually reduce the carbon intensity of transportation fuels to 20% below 2017 levels by 2038.

Northwest Capacity Needs and Resource Options

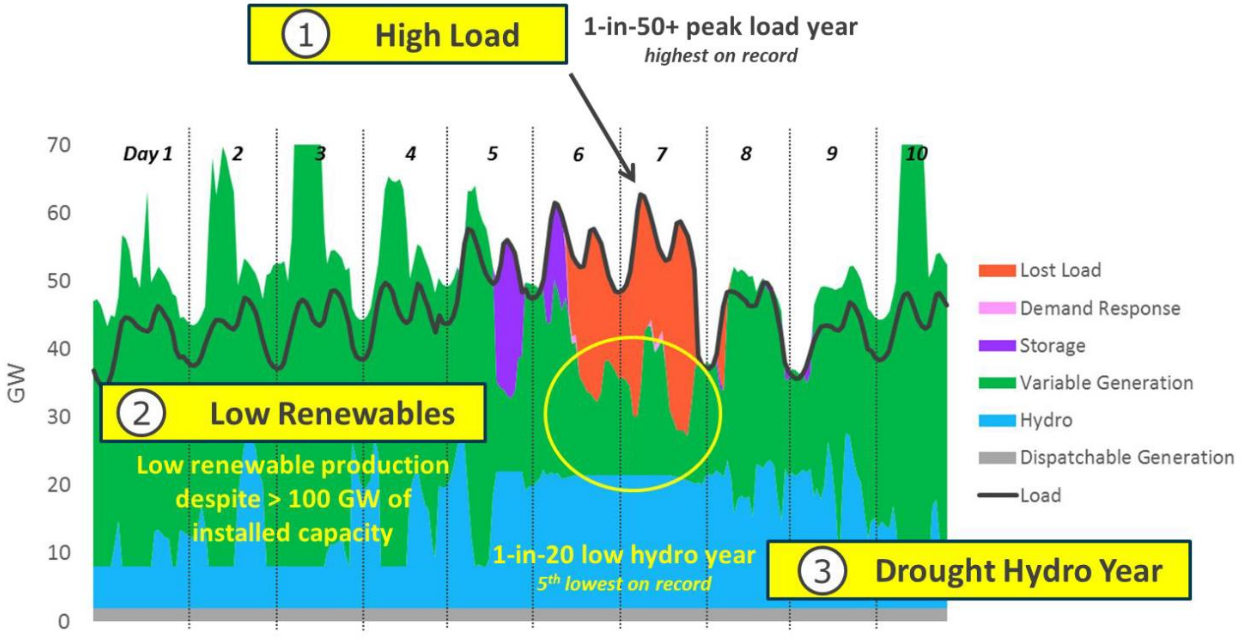
Northwest Capacity Need and Drivers	Near- to Mid-Term (today-2030)	Long-Term (2030-2050)
Capacity Need	Immediate capacity shortfall of ~3 GW (before capacity additions), rising to >8 GW by 2030	Capacity shortfall grows to > 14 GW by 2040
Key Drivers	• Increasing winter and summer peak demand • Coal retirements with few firm replacements • Renewable and storage additions with diminishing capacity benefit • Implementation of regional RA program	• Energy sufficiency-based reliability planning challenge • Decarbonization policies drive renewables; do not avoid need for firm capacity • Electrification loads could drive even higher peaks

- **Northwest faces an immediate capacity shortfall and a long-term need to replace its dispatchable capacity (largely thermal and hydro) with carbon-neutral alternatives to meet climate goals**
- **Additional Hydro is difficult to site and permit due to environmental concerns and existing hydro may see declining production due to changing climate and precipitation patterns**
- **Solar at Northwest latitudes is a poor match for the Northwest's winter peaking system and batteries have a low capacity contribution compared to the flexibility that hydro provides**
- **Local onshore wind has lower capacity factors than out-of-state wind and connecting out-of-state resources with western Washington would require significant investment in transmission**
- **Clean firm generation, like hydrogen turbines, will be necessary for the Northwest to meet peak load hours but existing technologies are nascent at commercial scale and building the infrastructure may take significant time and investment**
- **Washington offshore wind is strongest in winter, corresponding to hours of greatest system need and is near western Washington load centers**

Northwest Resource Adequacy Options

- **Meeting peak demand + a 15% planning reserve margin in the NW will be a challenge and could require a large resource buildout**
  - Capacity accreditation is installed capacity for firm resources, peaking capacity for hydro, and Effective Load Carrying Capability (ELCC) for non-firm resources
- **Northwest reliability risk limits the ability of battery storage to provide reliable capacity contributions**
  - Storage and hydro show “antagonistic” interactions, which limit energy storage reliability value in “energy-limited” conditions where energy storage resources are unable to charge (with low hydro and renewable output) and run out of discharge (during extended energy shortfall events)

Key Drivers of Future Northwest Reliability Events



Sample week in 2050 in a 100% GHG reduction scenario, from E3, *Resource Adequacy in the Pacific Northwest,* 2019.

Resource	RA Capacity Contributions
Hydro	65%, based on sustained winter peaking capacity in critical water year conditions (per BPA/PNUCC)… WRAP method is still evolving
Battery storage	Sharply declining ELCCs
Pumped storage	Sharply declining ELCCs
Solar	Declining ELCCs
Onshore Wind	Declining ELCCs
Offshore Wind	Declining ELCCs but high starting ELCC
Demand Response	Declining ELCCs
Energy Efficiency	Limited potential vs. cost
Small Hydro	Limited potential
Geothermal	Limited potential
Natural gas to H2 retrofits	Clean firm, but not fully commercialized
New dual fuel natural gas + H2 plants	Clean firm, but not fully commercialized
New H2 only plants	Clean firm, but not fully commercialized
Gas w/ 90-100% carbon capture + storage	Clean firm, but not fully commercialized
Nuclear Small Modular Reactors	Clean firm, but not fully commercialized

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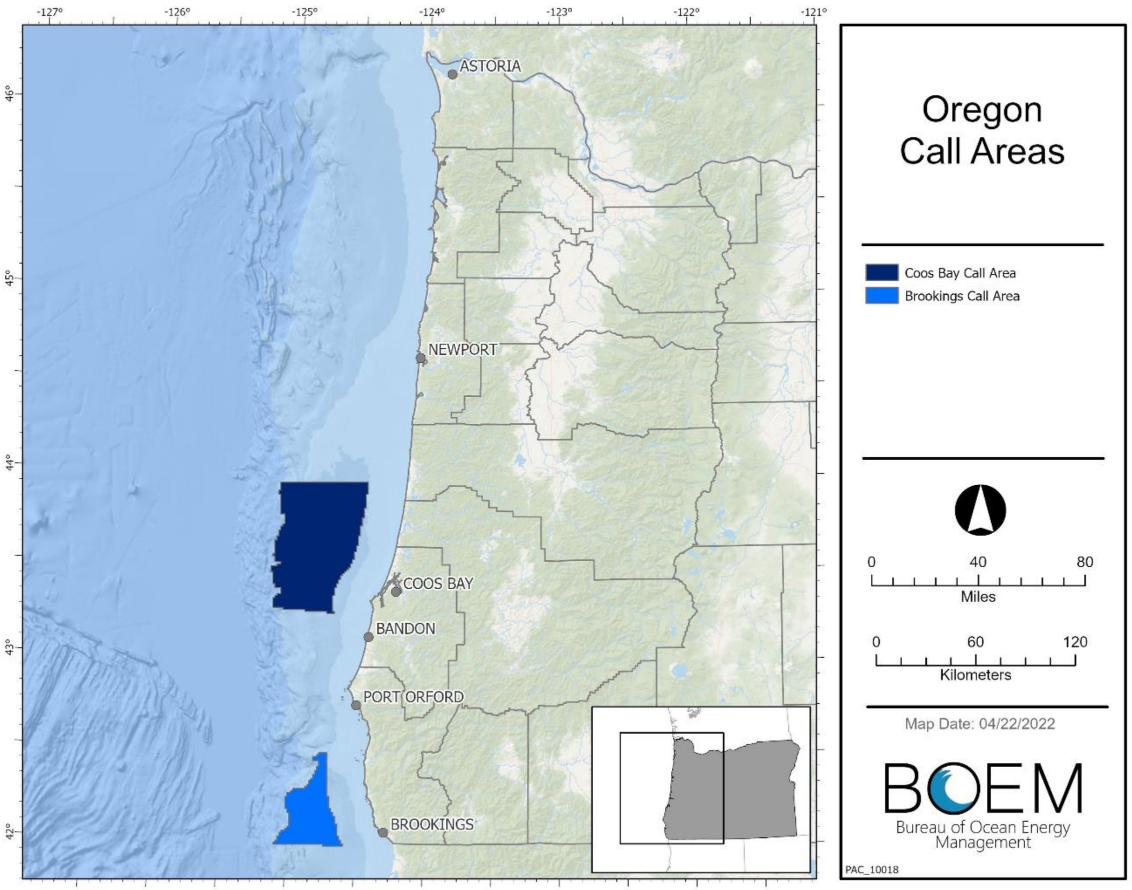
Value of Offshore Wind

Status of Offshore Wind in the Northwest

- **In concert with the Biden administration's goal to deploy 30 GW of offshore wind by 2030, BOEM created two Oregon offshore wind call areas 14 miles off the coast**
  - Coos Bay Call Area (1,364 square miles)
  - Brookings Call Area (448 square miles)
- **Oregon's Department of Energy developed a 2022 report outlining the benefits and challenges of integrating up to 3 GW of floating offshore wind by 2030**
- **Washington does not have existing BOEM call areas. However, Trident Winds submitted an unsolicited lease request to BOEM for a ~2 GW Olympic Wind project, for a site over 40 miles off the coast of Grays Harbor**

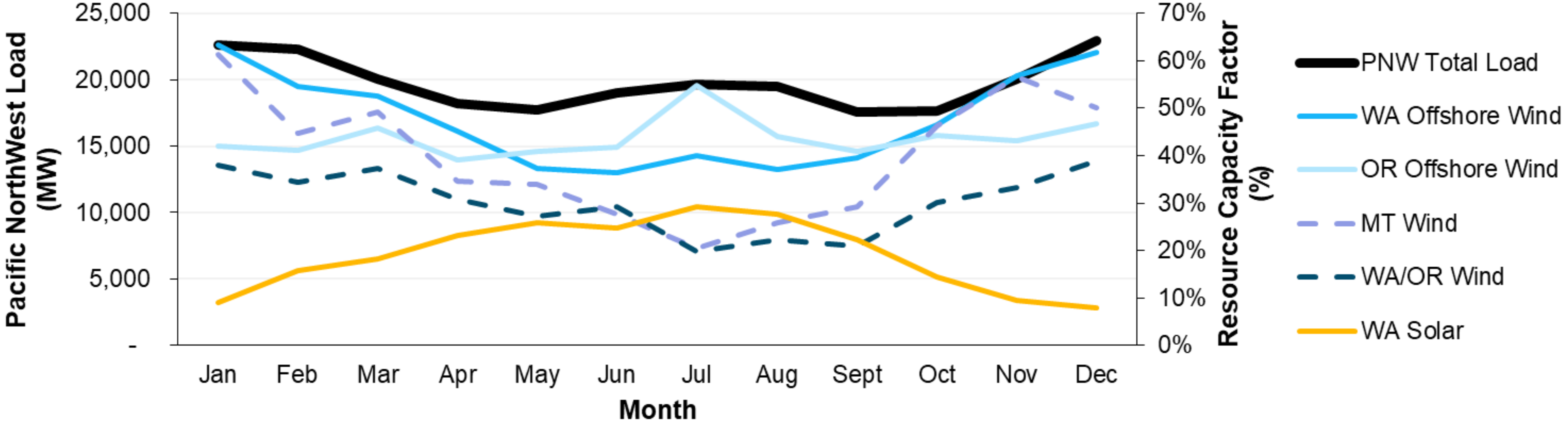
Oregon BOEM Call Areas



Washington Offshore Wind Production is Highest in Winter Months

- **Primary value of Washington offshore wind is its ability to serve load in winter months when coincident demand in the Northwest is at its peak**
- **Solar seasonal production is inversely related to Northwest seasonal load patterns**
- **Oregon offshore wind has a relatively flat seasonal production pattern with a summer spike**
- **Onshore wind resources exhibit a similar pattern to Washington offshore wind but at lower average capacity factors**

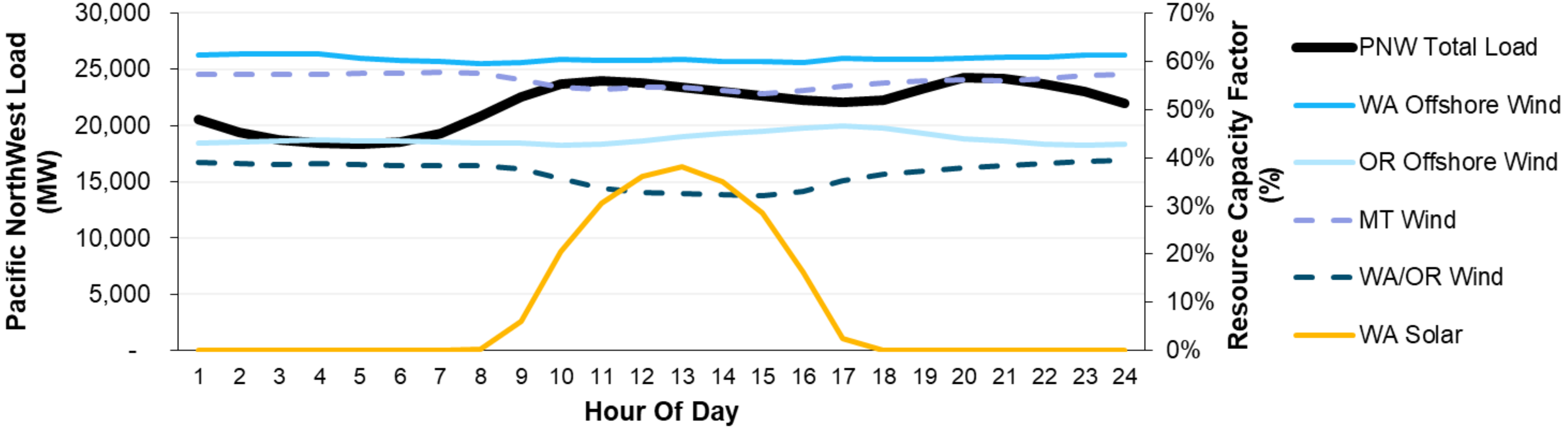
Average Monthly Northwest Load and Capacity Factor by Resource Type



Washington Offshore Wind Production is Higher Across All Hours in Winter Months

- + Washington offshore wind has the highest modeled average generation among solar, onshore wind, and Oregon offshore wind resources examined in this study across all hours in winter months, often generating at full capacity
- + Solar produces during winter hours of moderate system need but would require storage to shift production to highest value hours later in the day

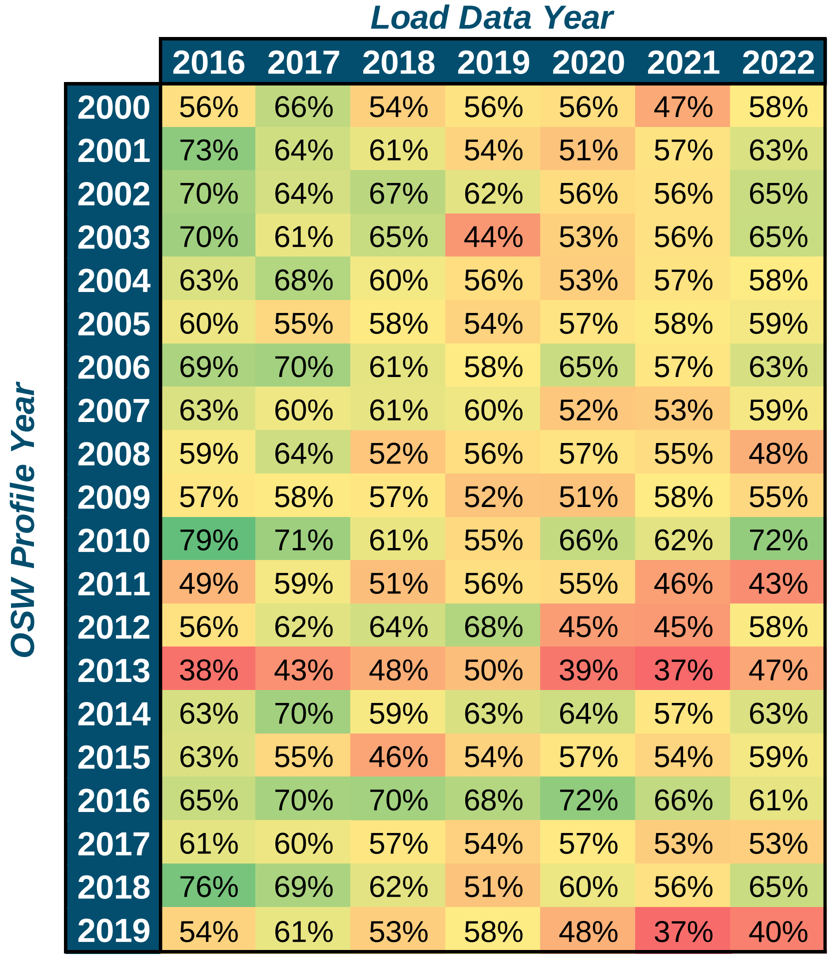
Average Northwest Hourly Load and Capacity Factor by Resource Type During Winter Months



Washington Offshore Wind Reliability Contribution

- **Washington offshore wind generation is expected to produce strongly in hours of greatest system need**
- **Existing reliability studies in the Northwest have not thoroughly examined offshore wind**
- **E3 estimated a range of capacity contribution for offshore wind by calculating the average capacity factor in top load hours using:**
  - Modeled hourly production across a 20-year dataset from NREL
  - Observed load in the Northwest during the top 500 annual load hours over the last 7 years from the EIA
- **Washington offshore wind has an average capacity factor of 58% across hours of greatest system need**
  - Oregon offshore wind and Montana wind have 48% and 50% capacity factors in same hours, respectively

Average Capacity Factor During Top 500 Load Hours



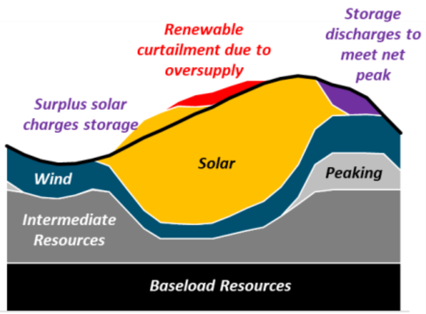
	Load Data Year						
OSW Profile Year	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
2000	56%	66%	54%	56%	56%	47%	58%
2001	73%	64%	61%	54%	51%	57%	63%
2002	70%	64%	67%	62%	56%	56%	65%
2003	70%	61%	65%	44%	53%	56%	65%
2004	63%	68%	60%	56%	53%	57%	58%
2005	60%	55%	58%	54%	57%	58%	59%
2006	69%	70%	61%	58%	65%	57%	63%
2007	63%	60%	61%	60%	52%	53%	59%
2008	59%	64%	52%	56%	57%	55%	48%
2009	57%	58%	57%	52%	51%	58%	55%
2010	79%	71%	61%	55%	66%	62%	72%
2011	49%	59%	51%	56%	55%	46%	43%
2012	56%	62%	64%	68%	45%	45%	58%
2013	38%	43%	48%	50%	39%	37%	47%
2014	63%	70%	59%	63%	64%	57%	63%
2015	63%	55%	46%	54%	57%	54%	59%
2016	65%	70%	70%	68%	72%	66%	61%
2017	61%	60%	57%	54%	57%	53%	53%
2018	76%	69%	62%	51%	60%	56%	65%
2019	54%	61%	53%	58%	48%	37%	40%

Study Approach

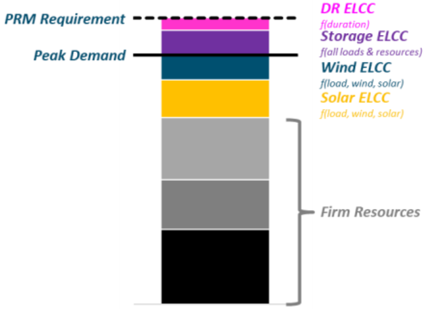
RESOLVE Optimizes Investments to Reliably Meet Clean Energy Targets

- **RESOLVE is an optimal capacity expansion model designed to 1) identify least-cost resource options to meet reliability needs and 2) achieve compliance with regulatory and policy requirements**
- **Linear optimization model explicitly tailored to study challenges to arise at high penetrations of variable renewables and energy storage**
- **Optimization balances fixed costs of new investments with variable costs of system operations, identifying a least-cost portfolio of resources to meet needs across a long time horizon**

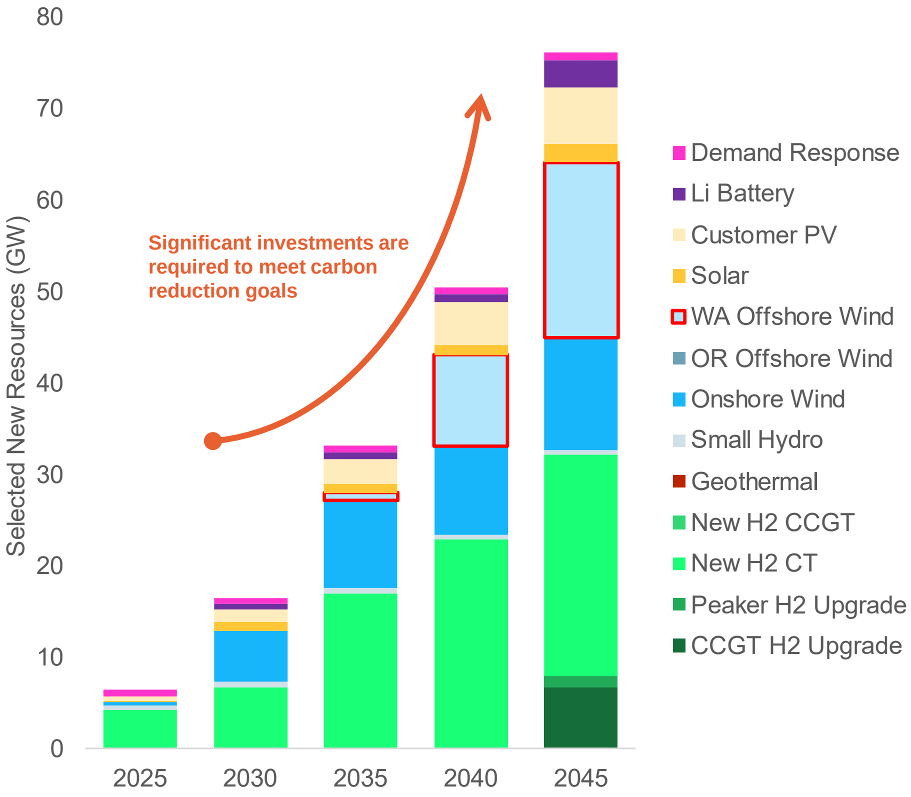
Operational module simulates hourly system operations for a sample of representative days



Reliability module ensures portfolio can meet load during extreme conditions using an ELCC approach

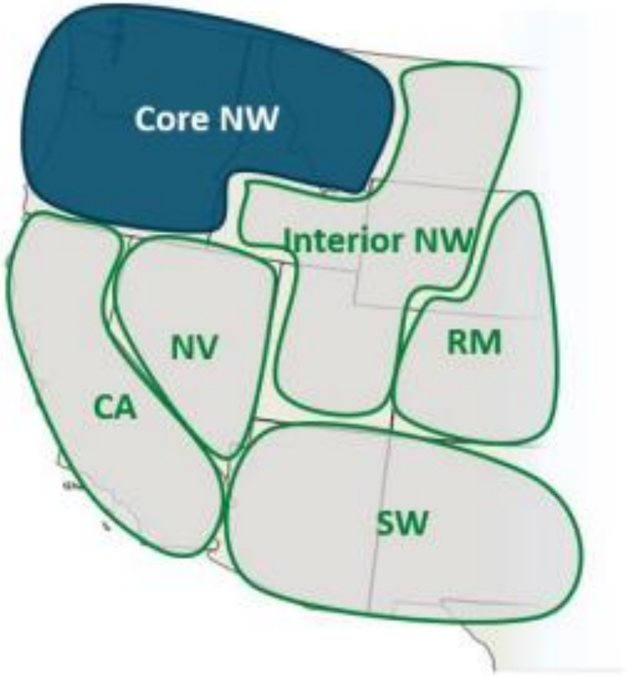


Least-cost plan co-optimizes investments and operations to meet clean energy policy targets, selecting from a diverse set of potential resources including wind, solar, storage, demand side management, and natural gas

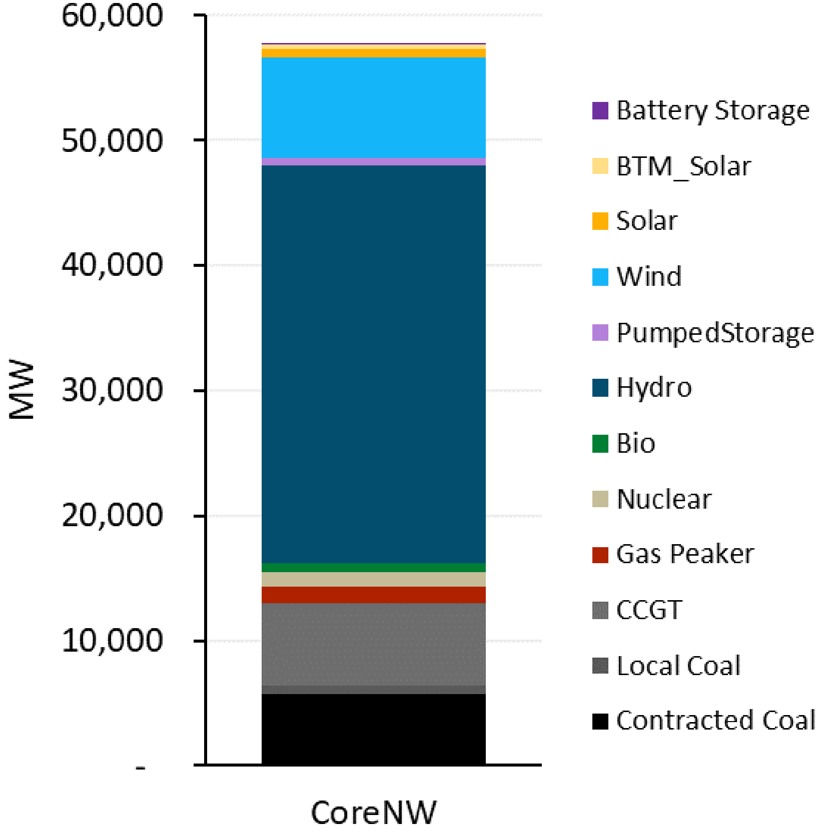


Northwest RESOLVE Footprint

- **RESOLVE optimizes a portfolio of resources to serve load in the "Core NW" region**
  - Core NW includes WA, OR, and the BPA and Avista regions of ID and MT to reflect procurement occurring on a regional scale rather than under strict state boundaries
- **In this study, regional system benefits of Washington offshore wind procurement are allocated to Washington state based on the proportion of load**
  - WA accounts for ~50% of NW load
- **New builds in non-Core NW zones are based on capacity needs to meet the Planning Reserve Margin and comply with existing policies**
- **Existing and expected builds come from the WECC 2030 Anchor dataset and the NWPCC 2021 Power Plan**



Core NW 2022 Capacity



Key Modeling Assumptions

Element	Study Approach
Study Years	• 2025 through 2045, including fuel price forecasts and declining renewable + storage costs
Clean Energy Policy	• Aggressive OR+WA legislation reflected, including coal retirements and zero-emissions (100% carbon reduction) • One scenario uses a 95% GHG reduction target to test the effects of non-policy attainment on resource buildout
Load Growth Scenarios	• Load forecast is developed in two phases: 1. **Baseline** (based on NWPCC 2021 Plan adjusted to E3's boundary of Core NW Zone) 2. **High electrification** (based Washington's State Energy Strategy high electrification load) • High electrification load forecast was used in all scenarios reflecting aggressive decarbonization
Cost Scenarios	• Cost trajectories for candidate resources were developed using E3's ProForma model which incorporates technology inputs from NREL's Annual Technology Baseline and Lazard's Levelized Cost of Energy/Storage • Additional sensitivities on faster offshore wind cost declines were incorporated to reflect ongoing research efforts
Reliability Needs	• Modeling ensures reliability needs during extreme conditions (e.g. high loads + low hydro) • Captures ability (and limits) of renewables, battery storage, and demand response to support system reliability
Technologies Modeled	• Broad range of variable and dispatchable clean technology options considered: • **Baseline technologies**: solar, onshore wind, offshore wind, battery, pumped storage, energy efficiency, demand response, dual fuel natural gas + hydrogen combustion plants • Capacity factors and operations for technologies are based on public NREL resource quality data • Offshore wind is modeled as unlimited to measure demand for resource without build potential constraints • New transmission is available to be built for candidate offshore wind resources, model includes transmission availability for Boardman to Hemingway and Montana to Washington transmission lines
Distributed Energy Resource Options	• Energy efficiency, demand response, and customer solar embedded into modeling inputs

Study Scenarios

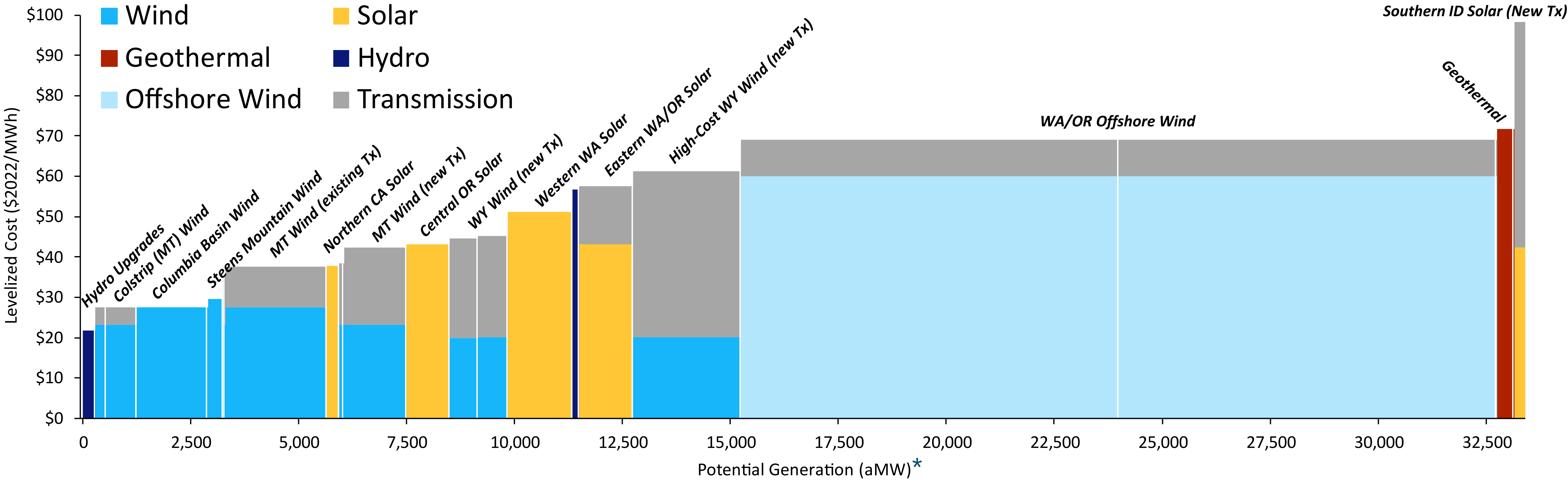
- **All scenarios use an offshore wind cost trajectory that reaches $60/MWh LCOE in 2035, a cost that is higher than the $45/MWh by 2035 target set by the Department of Energy**
- **All scenarios use a 100% clean energy standard by 2045 and all except the 95% GHG target scenario use a 100% GHG reduction below 1990 levels by 2045**
- **All scenarios use a high electrification load growth scenario reflecting deep decarbonization in line with Washington state policies on buildings and electric transportation**

Scenario	Description	Resource Availability
Base	Base assumptions in NW RESOLVE updated for IRA cost impacts	NW RESOLVE Base Case
95% GHG Target	Base assumptions with relaxed GHG reduction target	NW RESOLVE Base Case
Limited Out-of-State Wind	Resource availability for out-of-state resources limited to a single WY dual 500 kV system and no new transmission upgrades for system connections to Montana	• Limited Wyoming wind to 3 GW which could be delivered on a double circuit 500kV line • Limited Montana wind to Colstrip Tx, existing Tx, and 200 MW of new Tx outlined in the NWPCC Seventh Power Plan but removed Tx upgrade potential that is included in the Base Case
Slow Hydrogen Build	Hydrogen build is slightly limited recognizing potential practical limits on the hydrogen build, despite the RESOLVE model's preference for available clean firm resources	• Hydrogen build limited to 2, 5, 10, 15, and 20 GW in 2025, 2030, 2035, 2040, and 2045, respectively

Renewable Resource Supply Curve

- **Transmission costs are included within cost curves that RESOLVE sees for resource selection**
  - Some resources, particularly out-of-state wind, have large transmission costs relative to the base resource cost
- **WA and OR offshore wind are given the same cost curve but have different generation profiles and capacity accreditation based on coincidence of generation and historic peak load hours**

Renewable Resource Supply Curve in 2035 ($2022/MWh)



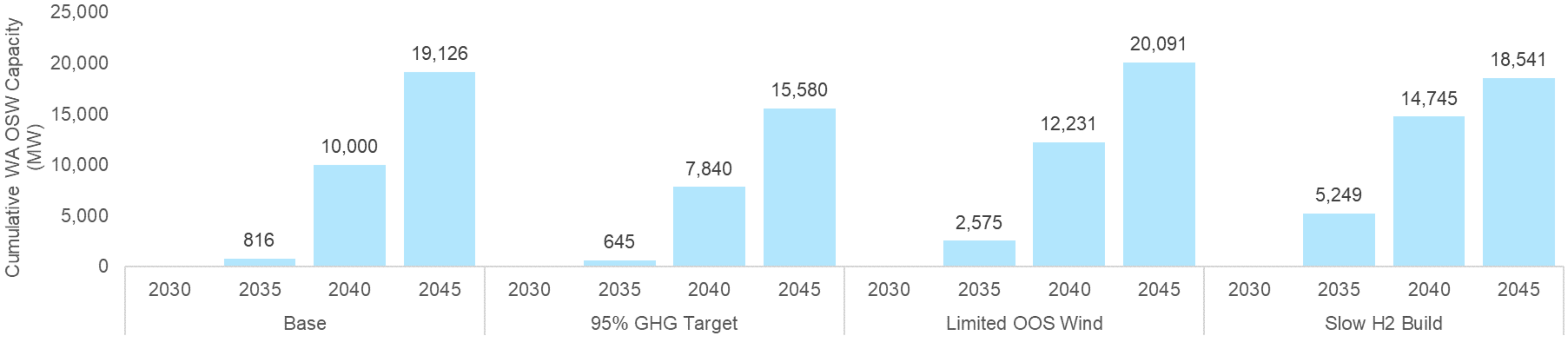
*aMW represents the resource capacity adjusted for level of production

Study Results

Washington Offshore Wind is Selected in Large Quantities in All Scenarios

- **Washington offshore wind is selected in all scenarios at quantities that exceed the expected buildout in possible offshore wind areas reflecting high demand for the resource**
- **Washington offshore wind is selected above Oregon offshore wind in all scenarios due to a more favorable generation pattern and reliability contribution**
  - Limits on available Washington offshore wind would cause some of the selection to be allocated to Oregon
- **There is additional upside for Washington offshore wind if resources like out-of-state wind on new transmission or green hydrogen are limited or require long development timelines**

Cumulative Washington Offshore Wind Capacity Additions Selected by RESOLVE by Scenario

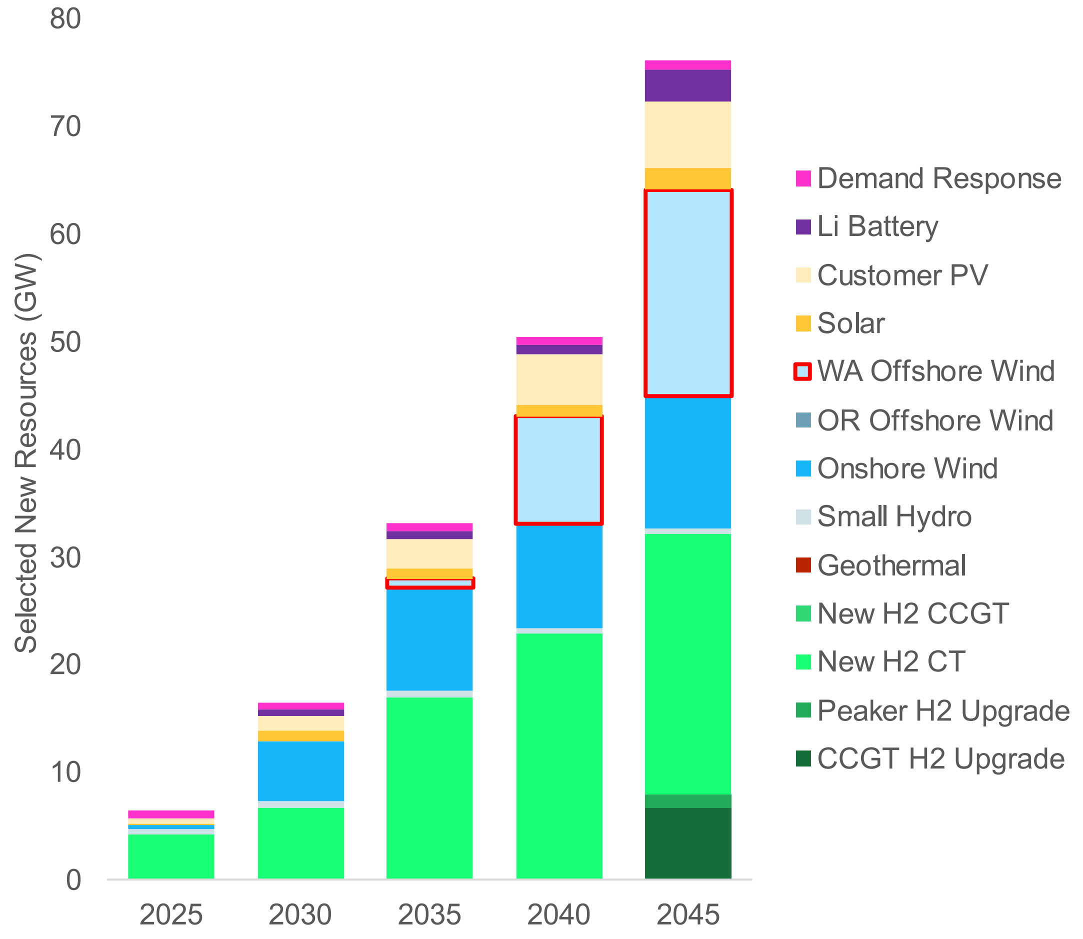


	2030	2035	2040	2045
Base		816	10,000	19,126
95% GHG Target		645	7,840	15,580
Limited OOS Wind		2,575	12,231	20,091
Slow H2 Build		5,249	14,745	18,541

Base Scenario Resource Selection

- **Washington offshore wind is selected starting in 2035 in the base scenario with 19.1 GW selected by 2045**
  - High overall capacity factor and consistent production during hours of greatest system need cause offshore wind to be selected despite elevated costs compared to other renewables
- **Lowest cost onshore wind and solar options are the candidate renewable resources selected early in the modeling timeframe**
  - Small amount of battery storage is added late in the forecast but has limited reliability contribution due to hydro dispatch flexibility
- **Green hydrogen production, or another clean firm technology, is necessary to meet reliability standards in the Northwest**

New Resource Selection in Base Scenario at $60/MWh 2035 Offshore Wind LCOE

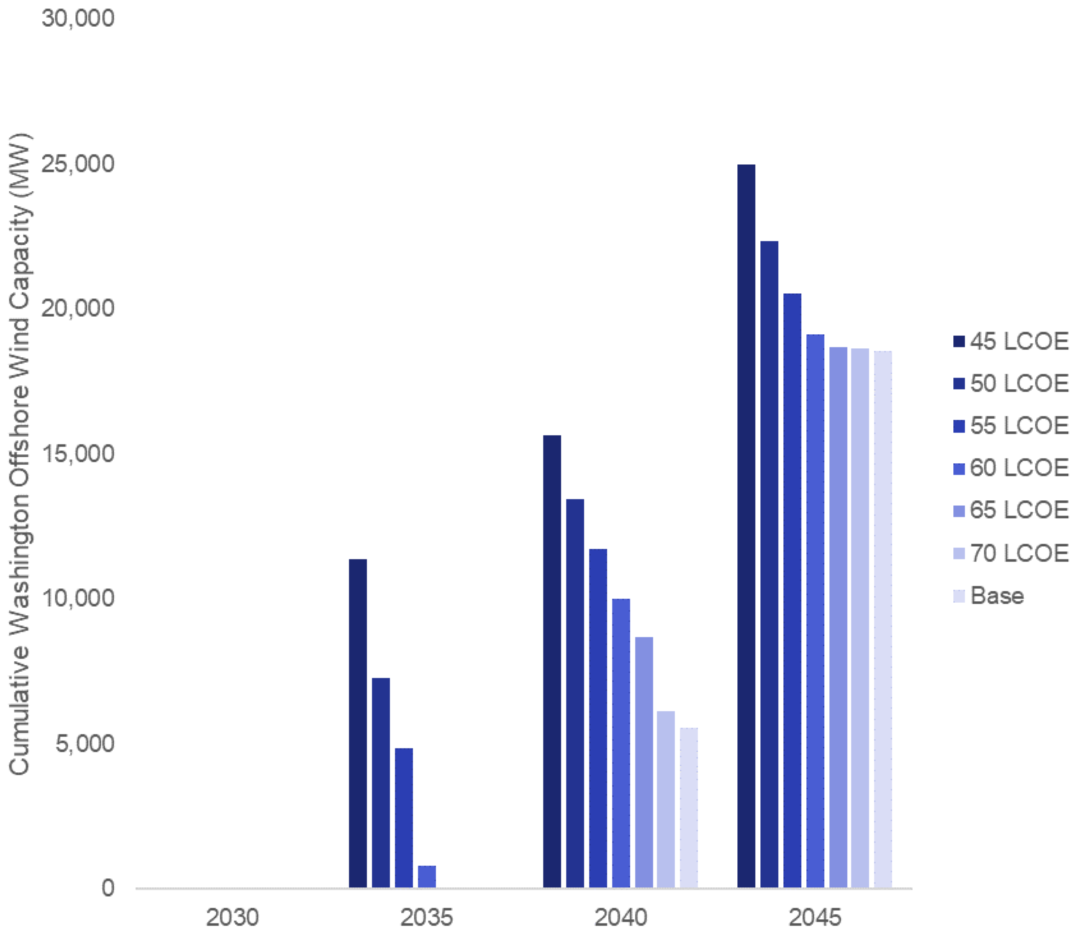


Washington Offshore Wind Cost Sensitivities

- **Washington offshore wind is selected in large quantities across all LCOE sensitivities in the Base Scenario**
  - All cost sensitivities select more than 5.5 GW of Washington offshore wind by 2040 and 18.5 GW by 2045
- **Offshore wind is first selected in 2035 at a ~$60/MWh LCOE in limited quantities and selected in large quantities in 2035 at lower a LCOE**

Cumulative Washington Offshore Wind Additions (MW)					
Cost Scenario	**2025**	**2030**	**2035**	**2040**	**2045**
45 LCOE	0	0	11,394	15,665	25,000
50 LCOE	0	0	7,299	13,468	22,361
55 LCOE	0	0	4,884	11,737	20,545
60 LCOE	0	0	816	10,000	19,126
65 LCOE	0	0	0	8,688	18,681
70 LCOE	0	0	0	6,131	18,630
Base	0	0	0	5,564	18,571

Cumulative Washington Offshore Wind Selected in Base Scenario by Year and 2035 LCOE Trajectory



System Benefits of Washington Offshore Wind

- **Offshore wind has the potential to reduce system costs to Washington ratepayers by as much as $6.2 billion on a Net Present Value (NPV) basis in the Base Scenario**
  - System Cost Savings = Costs in Case without Offshore Wind in WA/OR – Costs with Offshore Wind Allowed
- **Offshore wind could provide levelized rate savings of 0.6 cts/kWh in the Base Scenario**
  - Savings = Avg. Rates in Case without Offshore Wind in WA/OR – Avg. Rates with Offshore Wind Allowed
- **Most system benefits of offshore wind are concentrated in 2045 due to large additions to reach policy goals**
- **Savings are calculated under an unlimited potential Washington offshore wind buildout assumption and do not reflect projected sea space constraints**

Annual System Cost Savings Over Time ($ Millions)

Scenario	2025	2030	2035	2040	2045	NPV
Base	$0	$0	-$14	$134	$1,674	**$6,242**
95% GHG Target	$0	$0	$2	$85	$1,292	**$4,818**
Limited OOS Wind	$0	-$1	$26	$726	$3,992	**$15,595**
Slow H2 Build	$0	$2	-$50	$1,281	$4,463	**$17,990**

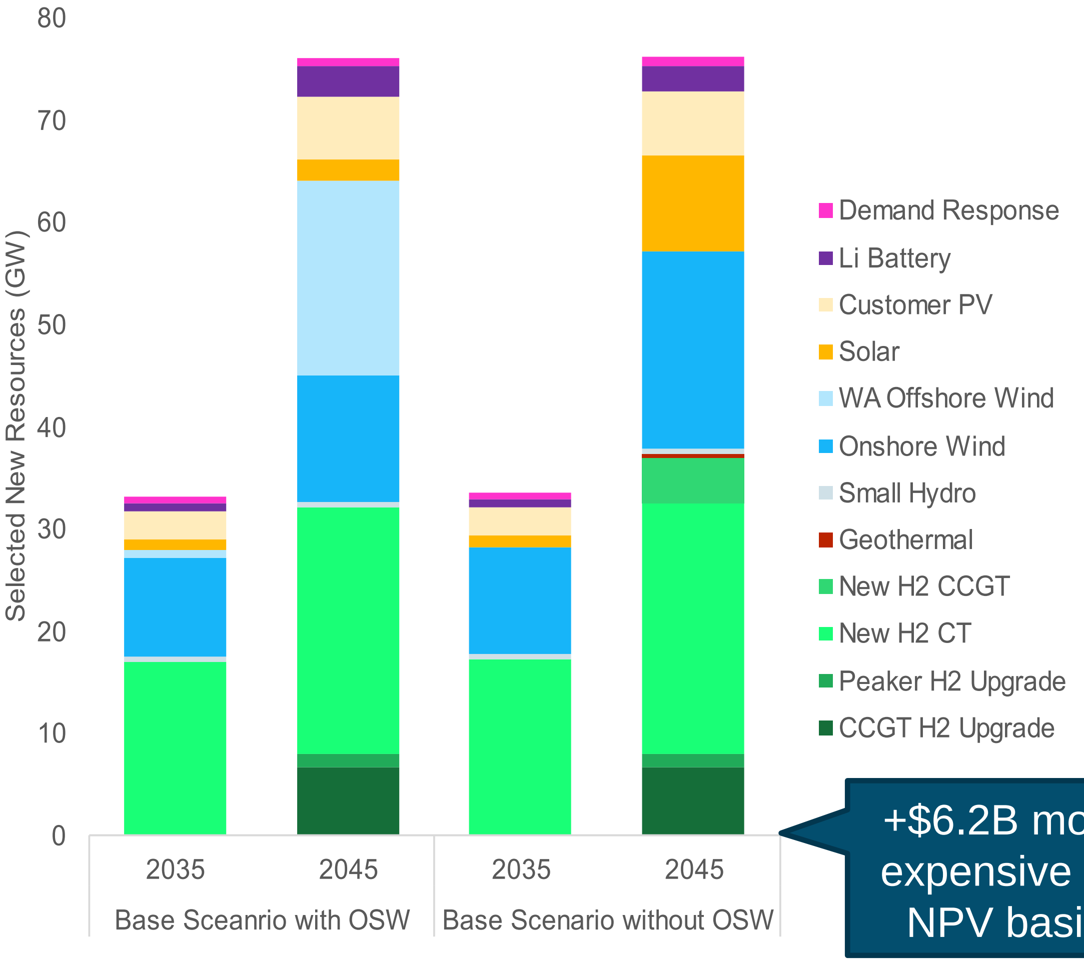
Average Rate Savings (cts/kWh)

Scenario	2025	2030	2035	2040	2045	Levelized
Base	0.0	0.0	0.0	0.3	1.8	**0.6**
95% GHG Target	0.0	0.0	0.0	0.3	1.4	**0.4**
Limited OOS Wind	0.0	0.0	0.0	1.0	3.8	**1.2**
Slow H2 Build	0.0	0.0	0.1	1.5	4.2	**1.5**

Offshore Wind Offers Washington Long-Term Value

- **An economic buildout of offshore wind in Washington could save ratepayers up to $6.2B (NPV) versus scenarios that rely completely on onshore resources**
  - Estimated savings is generated because the RESOLVE model selected nearly 20 GW of Washington offshore wind instead of a more expensive combination of alternatives
  - Washington offshore wind is selected due to a production profile that closely matches the winter-peaking load pattern of the Washington energy system and can provide reliability benefits above solar and onshore wind
- **RESOLVE results do not reflect likely constraints on available sea space for Washington offshore wind (e.g. DOD and other conflicting uses of ocean space)**
  - Sea space constraints do not change the overall conclusions. If Washington offshore wind is limited to 7 GW, the model shows system cost savings of $5.1B compared to $6.2B when Washington offshore wind was unlimited.

Long-Term Resource Additions with and without Offshore Wind



+$6.2B more expensive on NPV basis

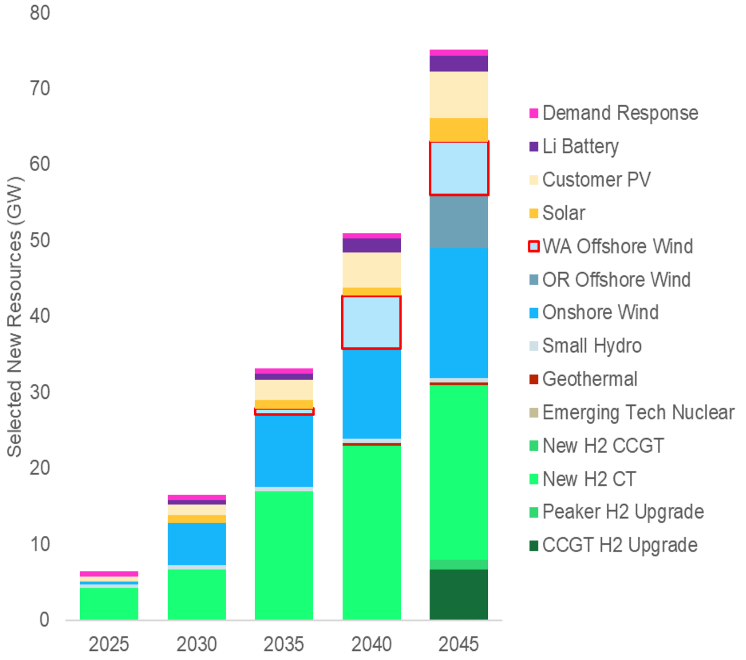
Impact of Limited Offshore Wind

- **Offshore wind has the potential to reduce system costs to Washington ratepayers by as much as $5.1 billion on a Net Present Value (NPV) basis in the Base Scenario WHEN OR and WA are limited to 7 GW each of OSW**
  - System Cost Savings = Costs in Case without Offshore Wind in WA/OR – Costs with Offshore Wind Allowed
- **Offshore wind could provide levelized rate savings of 0.4 cts/kWh in this scenario**
  - Savings = Avg. Rates in Case without Offshore Wind in WA/OR – Avg. Rates with Offshore Wind Allowed
- **Most system benefits of offshore wind are concentrated in 2045 due to large additions to reach policy goals**

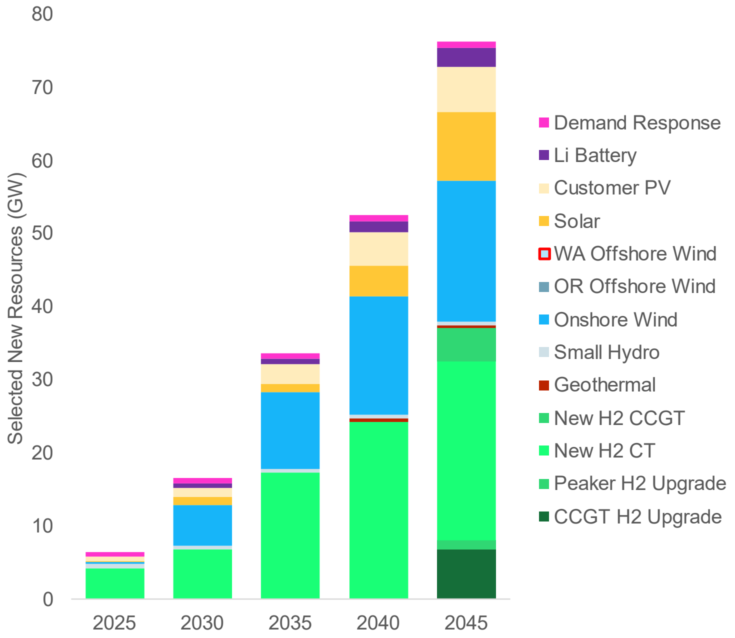
Limited OSW Savings

Savings	2025	2030	2035	2040	2045	NPV
Annual System Cost Savings ($M)	$0	$0	$7	$200	$1,261	**$5,142**
Average Rate Savings (cts/kWh)	$0	$0	$0	$0.2	$1.2	**$0.4**

Selected Resources with Limited OSW



Selected Resources without OSW



Key Conclusions

Washington Offshore Wind is Part of the Least-Cost System to Achieve Clean Energy and Climate Policies

- **Washington will need a large increase of clean generation to meet policy goals and system planners must consider all resource options that could contribute to an overall least-cost solution**
- **Washington offshore wind has an expected production profile that matches the winter-peaking load pattern of the Washington energy system and can provide reliability benefits superior to solar and onshore wind**
  - Alternatives to meet the same level of system reliability and clean energy production rely on out-of-state wind that would require a large transmission buildout or technologies like green hydrogen combustion plants that have not yet reached commercial scale
- **Latest cost estimates for floating offshore wind and federal ambition to drive costs lower suggest that it could play a major role as a cost-effective clean resource under Washington's clean energy and GHG reduction policies**
- **Washington offshore wind is selected in all scenarios in this study and is preferrable to Oregon offshore wind due to a superior generation profile compared to Northwest load patterns**
- **An economic buildout of offshore wind in Washington could save ratepayers up to $6.2 billion (NPV) versus scenarios that rely completely on onshore resources**
  - Savings are concentrated in 2040s and are calculated under the assumption of an unlimited potential Washington offshore wind buildout

Thank you

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Appendix

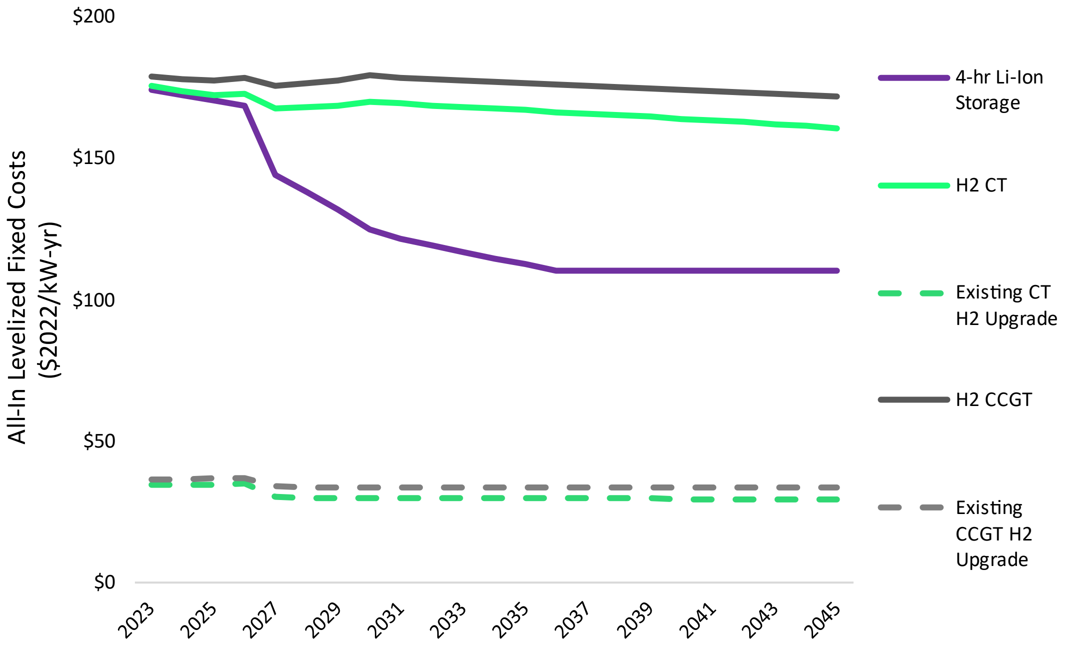
Abbreviations

Abbreviation	Definition	Abbreviation	Definition
BOEM	Bureau of Ocean Energy Management	MW / MWh	Megawatt / Megawatt-Hour
BPA	Bonneville Power Authority	NREL	National Renewable Energy Laboratory
CCGT	Combined Cycle Combustion Turbine	NPV	Net Present
CT	Combustion Turbine	NWPCC	Northwest Power and Conservation Council
EIA	Energy Information Administration	PNW	Pacific Northwest
ELCC	Effective Load Carrying Capability	RA	Resource Adequacy
GHG	Greenhouse Gas	Tx	Transmission
GW	Gigawatt	WECC	Western Electricity Coordinating Council
LCOE	Levelized Cost of Energy		

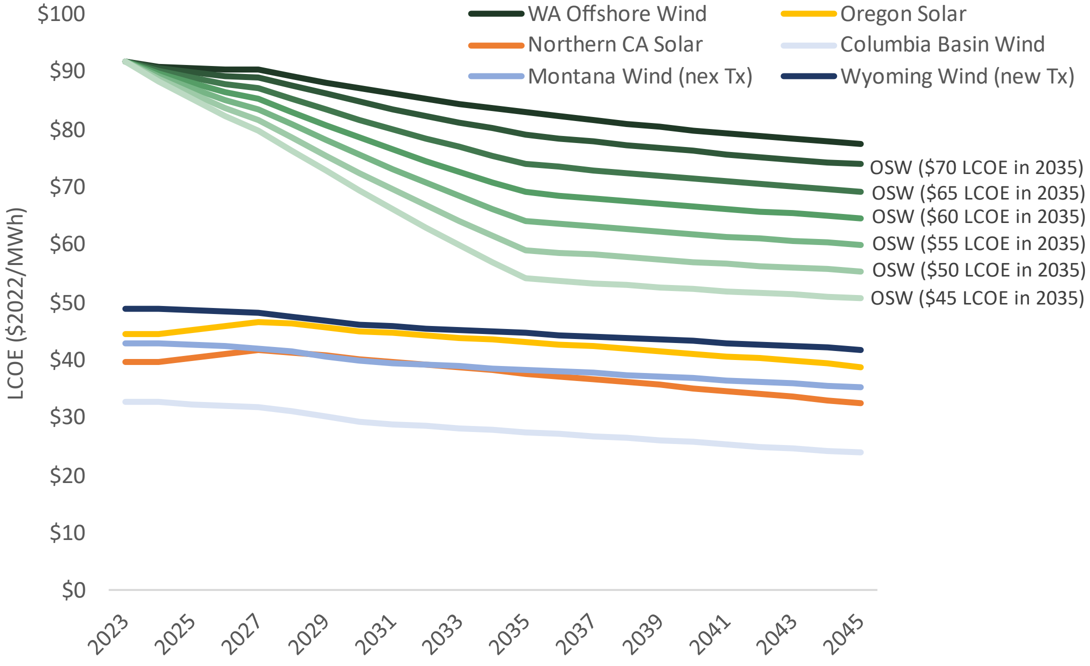
Resource Cost Inputs

- **Resource costs are derived from E3’s in house view and adjusted by location to account for resource quality**
  - Battery costs integrate Lazard’s Levelized Cost of Storage 8.0
  - Renewable, CCGT, and CT costs integrate NREL’s Annual Technology Baseline 2022
  - New hydrogen or hydrogen upgrades include a ~10% additional cost that converges with gas CT and CCGT by 2050
- **Cost sensitivities for offshore wind were developed trending from a business-as-usual case to $45/MWh in 2035 aligning with Department of Energy’s Floating Offshore Wind Energy Shot which aspires to reduce the cost of floating offshore wind energy by 2035 for deep water sites**

Dispatchable Resource Cost Inputs ($/kW-yr)



Renewable Resource Cost Inputs* ($/MWh)



* Inclusive of transmission costs

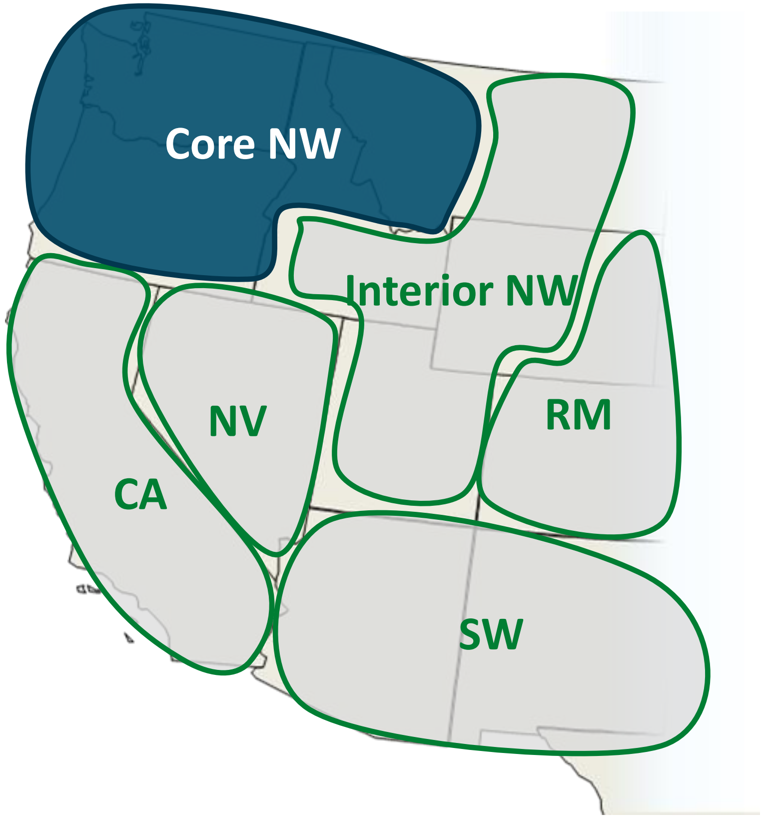
Resource Cost Inputs

LCOE ($2022/MWh)

Resource	2025	2030	2035	2040	2045	Transmission Adder
Hydro Upgrade	$22.68	$21.73	$21.73	$21.73	$21.73	$0.00
Colstrip (MT) Wind	$27.37	$24.64	$23.11	$21.58	$20.05	$4.36
Columbia Basin Wind	$32.38	$29.23	$27.48	$25.70	$23.95	$0.00
Steens Mountain Wind	$34.80	$31.42	$29.51	$27.60	$25.72	$0.00
MT Wind (existing Tx)	$27.37	$24.64	$23.11	$21.58	$20.05	$12.23
Northern CA Solar	$40.33	$40.17	$37.71	$35.12	$32.54	$0.00
MT Wind (new Tx)	$27.37	$24.64	$23.11	$21.58	$20.05	$19.28
Central OR Solar	$45.28	$45.00	$43.09	$41.17	$38.84	$0.00
WY Wind (new Tx)	$23.81	$21.26	$19.83	$18.41	$16.98	$24.84
Western WA Solar	$54.03	$53.56	$51.13	$48.77	$46.34	$0.00
Eastern WA/OR Solar	$45.28	$45.00	$43.09	$41.17	$38.84	$14.54
High-Cost WY Wind	$24.04	$21.47	$20.03	$18.59	$17.15	$41.21
WA/OR Offshore Wind	$78.88	$69.50	$60.00	$57.50	$55.52	$9.16
Geothermal	$75.74	$73.20	$71.75	$70.33	$68.96	$0.00
Southern ID Solar (New Tx)	$44.52	$44.24	$42.35	$39.89	$37.10	$55.84

External Zone - Approach

- RESOLVE makes investment decisions for the Core NW zone while simulating the dispatch decisions for all zones modeled including the main Core NW zone and external zones.
- The investment decisions for external zones are pre-determined based on the results of another WECC-wide capacity expansion model developed by E3. Policy targets assumed for each state is listed below



Policy Targets for the Pre-determined External Zones Builds

State	Requirement	Policy	2050 Renewable Target
AZ	40% by 2030; 60% by 2045	Transitions to CES	70%
CA	60% by 2030; 100% by 2045	Transitions to CES	100%
CO	30% by 2020; 50% by 2030, 76% by 2050 (Xcel reaches 100% while other utilities stay at 50%)	Transitions to CES	75%
ID	90% by 2045 (ID Power's announced utility goals)	RPS	90%
MT	87% by 2045 (state carbon reduction goal)	RPS	87%
NM	40% by 2025; 100% by 2045	Transitions to CES	100%
NV	50% by 2030; 100% by 2050	Transitions to CES	95%
UT	50% by 2030; 55% by 2045 (PacifiCorp's IRP)	RPS	55%
WY	50% by 2030, 55% by 2045 (PacifiCorp's IRP)	RPS	55%

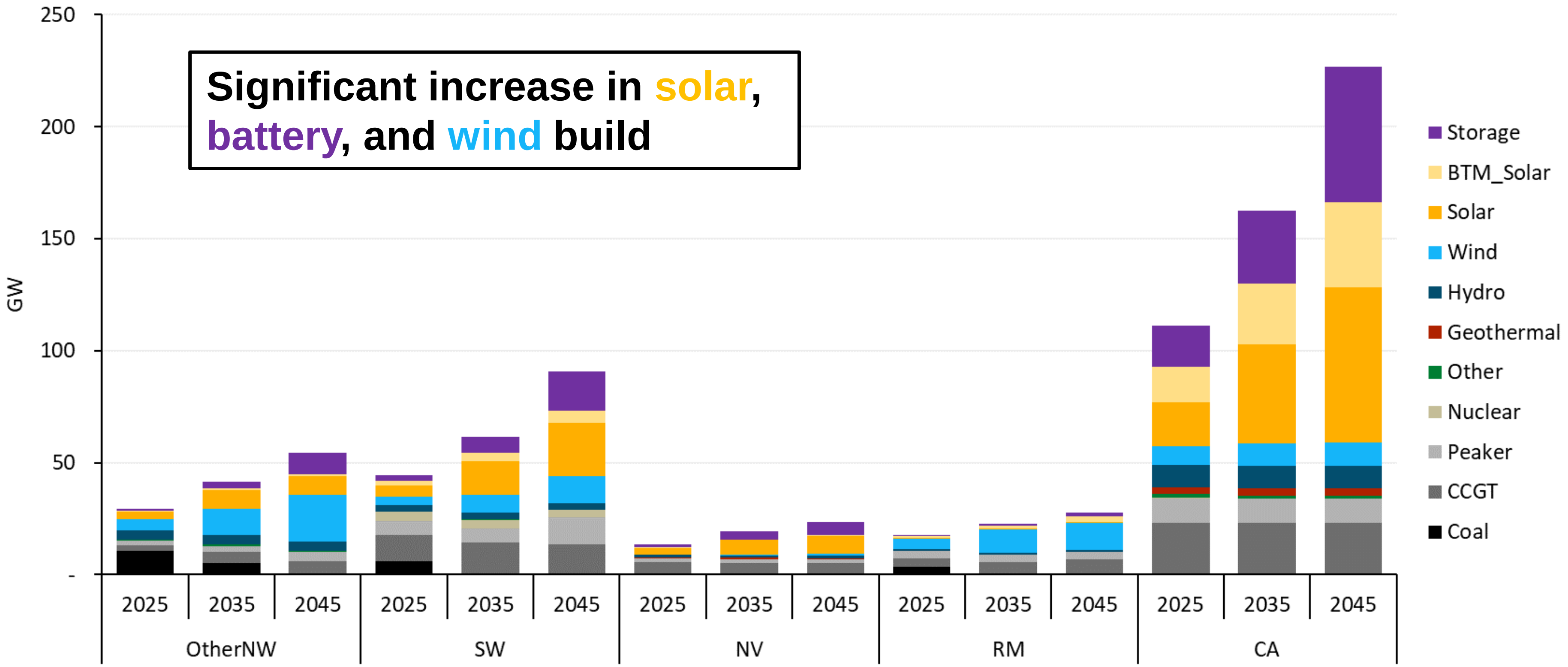
Notes:

- **Individual LSE targets implemented for Public Service Co of Colorado, LADWP, Nevada Power Co, and APS**
- **Post-2030 targets include hydro and nuclear carbon-free generation**
- **Some regions reflect targets that are strongly expected to come to fruition**

External Zone Installed Capacity Portfolio

- **There is a significant increase in solar and battery capacity installed capacity due to the more aggressive RPS targets, assumed electrification, and the decline of technology cost forecasts**
  - Load is based on 2018 Electrification Futures Study and E3 internal incremental electrification impact assumptions

Total Installed Capacity for External Zones

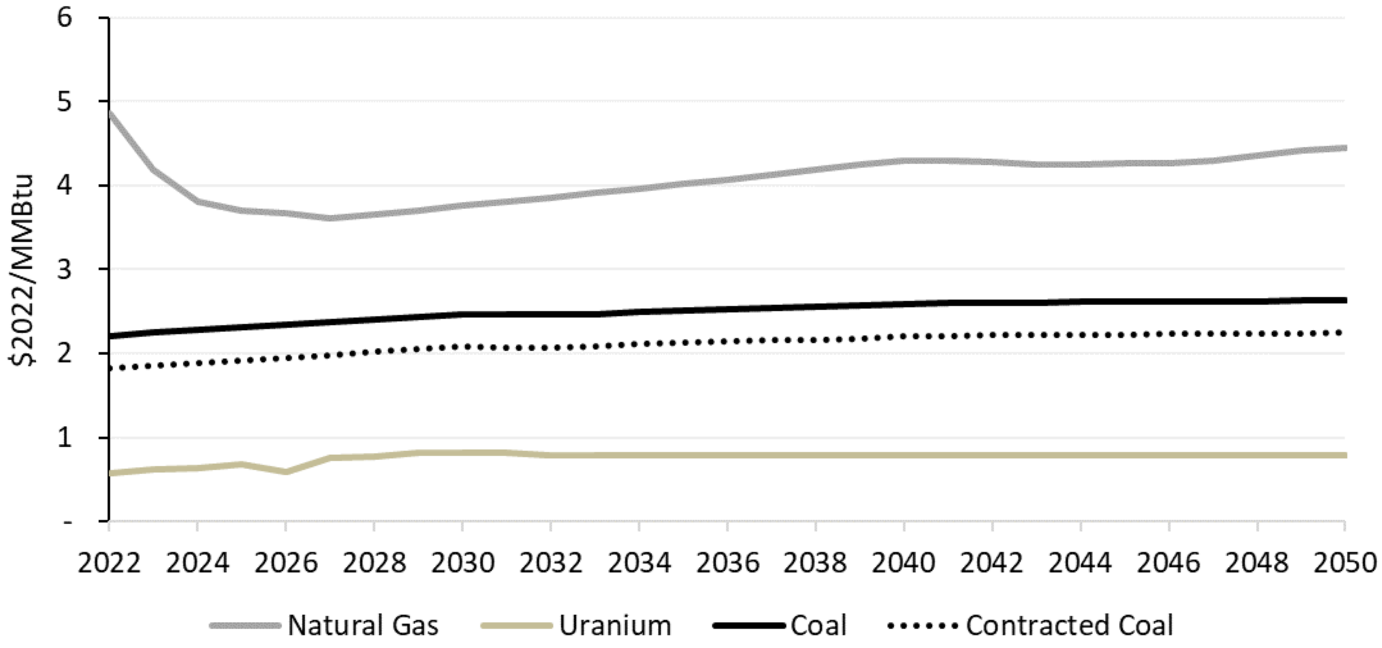


Significant increase in solar, battery, and wind build

Fuel Prices

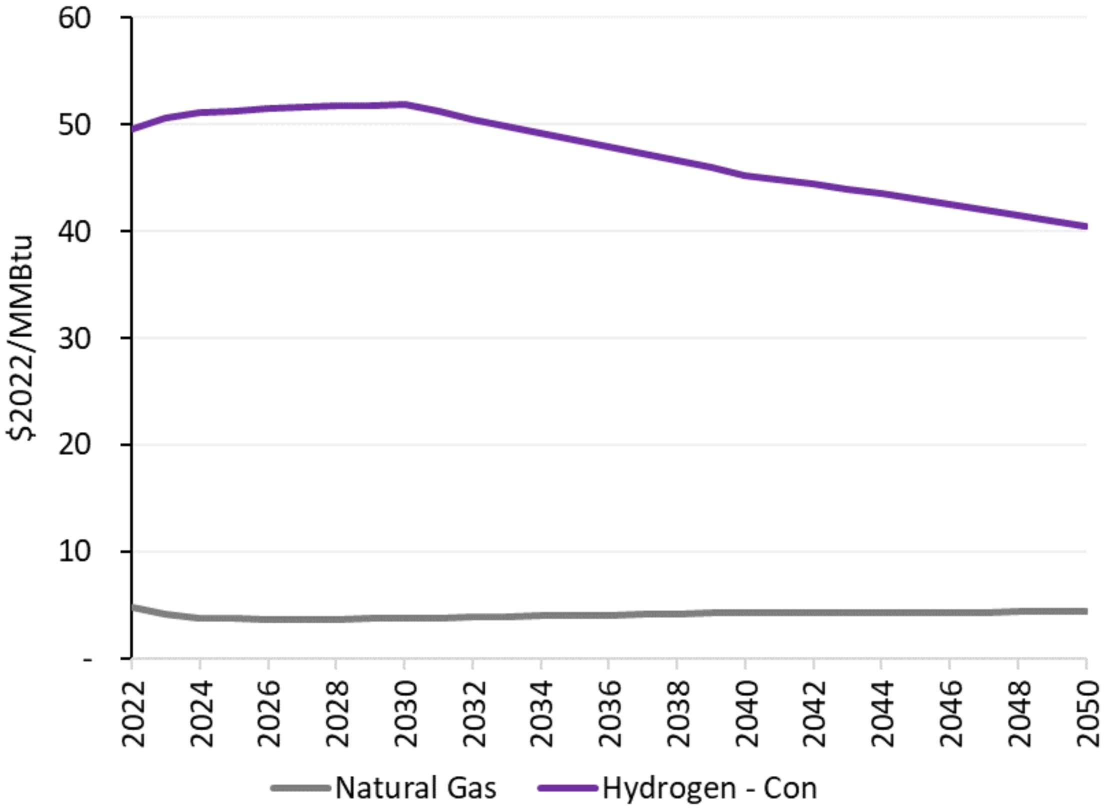
- E3 base gas prices are derived using a combination of SNL forwards in the near term (2022-2026) and then trending it to the EIA's AEO fundamentals-based 2040 forecast for the longer term
- Coal prices are from EIA's AEO forecast
- Uranium prices are from E3's in-house work with regional players

Thermal Fuel Prices



Fuel Prices - Hydrogen

Hydrogen price forecast (2020$/MMBtu)*

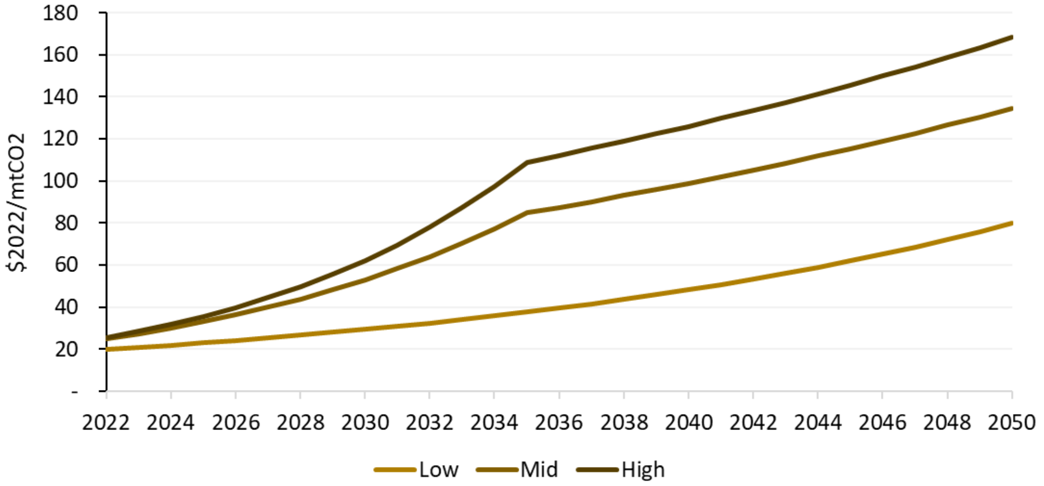


*Note the optimistic fuel price in the near term is not currently viable. It is shown for illustrative purposes under the assumption underground storage and dedicated pipelines are actively in use today.

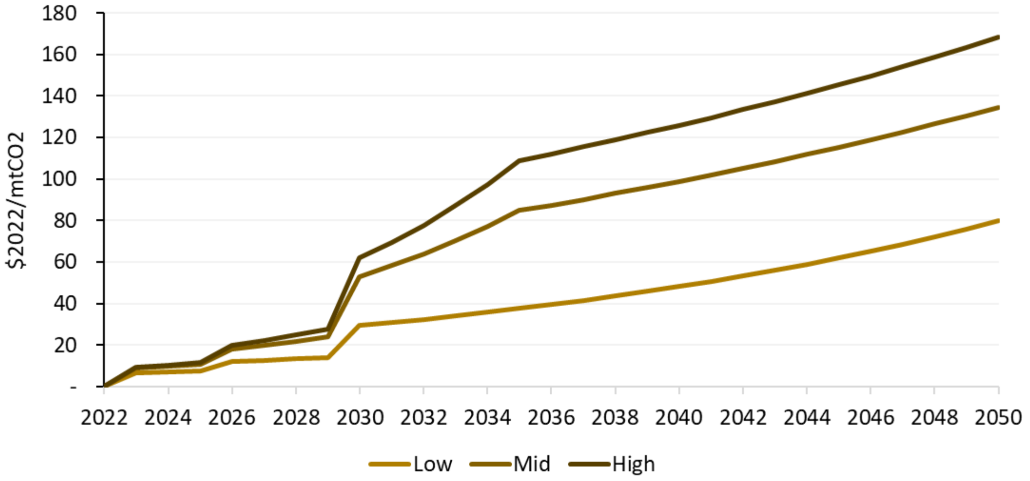
- **The conservative hydrogen price is used as the basis for all scenarios. It assumes**
  - There is not a massive H_2 economy and thus electrolyzer capital costs and efficiencies have only slightly decreased
  - H_2 is stored in above ground tanks and delivered via trucks.
- **Conservative assumes dedicated off-grid Core NW wind power are used to produce H_2 while optimistic assumes off-grid northern CA solar provides the needed electricity**
  - Renewable levelized fixed costs are derived from NREL’s ATB.
  - Capacity factors from E3 analysis
- **Fuel price trajectories assume ~225 mile trip to deliver hydrogen.**
- **RESOLVE modeling assumes an unconstrained amount of off-grid supply of H_2**

Carbon Price

California carbon price forecast (2022$/mton CO_2)



CoreNW carbon price forecast (2022$/mton CO_2)

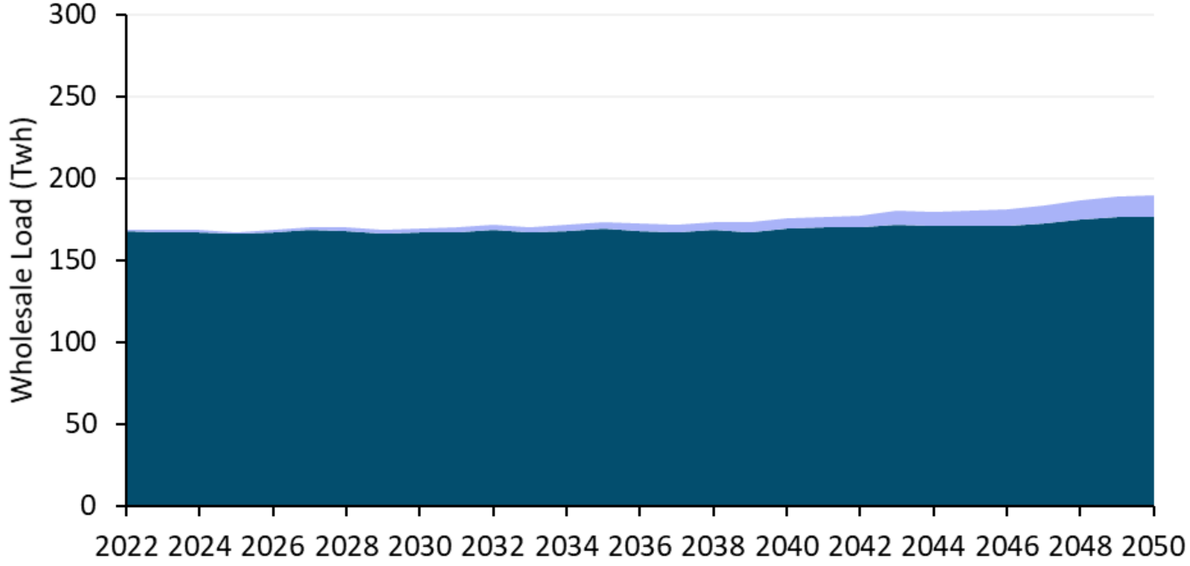


- **California's caron price is from the Final 2021 IEPR GHG Allowance Price Projections (12/21)**
- **CoreNW assumes**
  - Washington's cap-and-trade program set to implement in 2023 will sell at roughly 50% of California
  - That Oregon will follow close behind with and a carbon price will be implemented by 2026
  - Until 2026 the resulting carbon price is a load weighted share
  - Both states will converge to California's floor price by 2030
- **"Mid" forecast will be the default assumption for both regions**

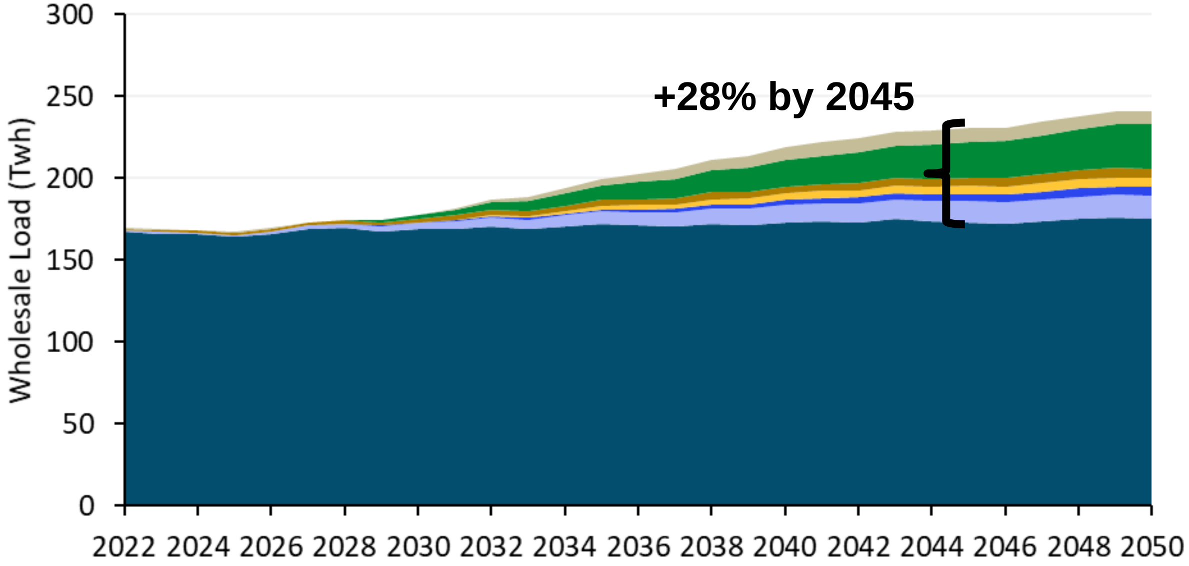
Load Forecast

- **Base load forecast is from NWPCC 2021 Plan benchmarked to E3's boundary of Core NW**
- **High Electrification scenario takes Washington's State Energy Strategy high electrification load and then scales up and benchmarked to the Core NW**
  - Electrification grows across all sectors, most noticeably in commercial and transportation to meet state's net-zero emissions by 2050.
  - Commercial and residential SH electrification indicates a switch to high electric resistance & heat pump adoption which will significantly impact load profiles and ultimately peak load

Base Forecast for Core NW

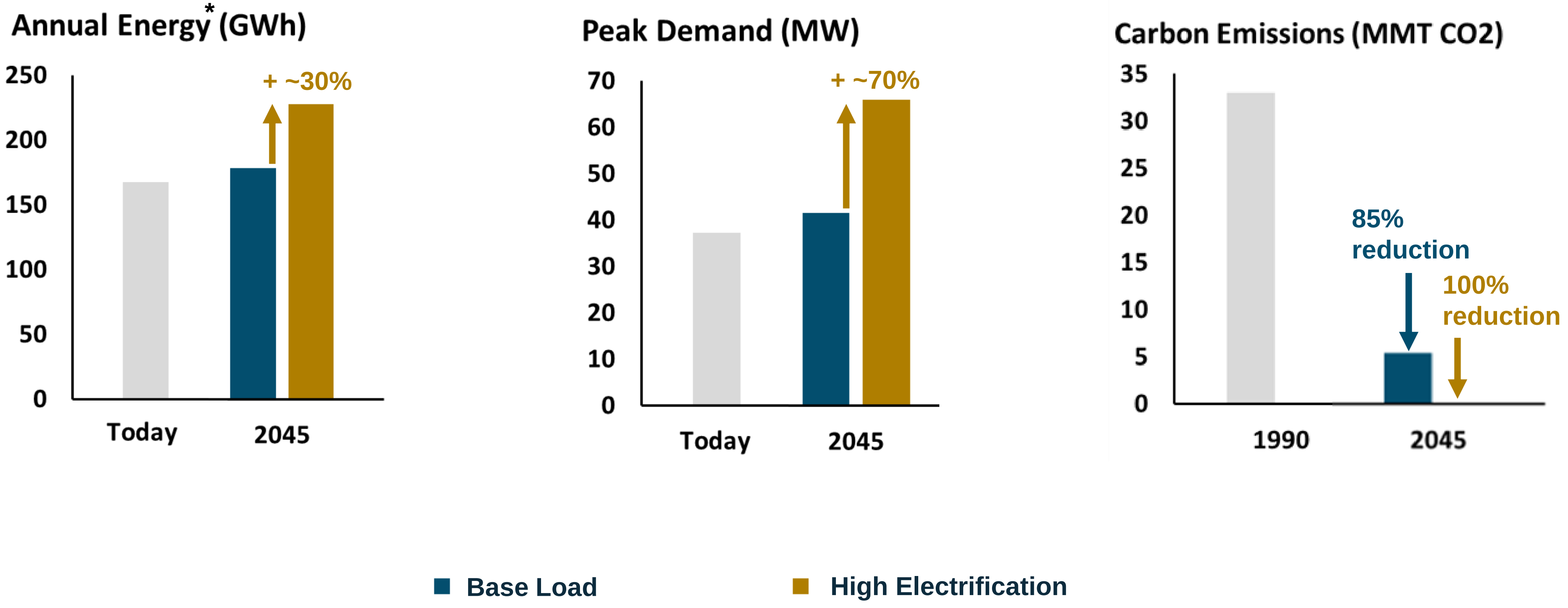


High Electrification Load Forecast for Core NW



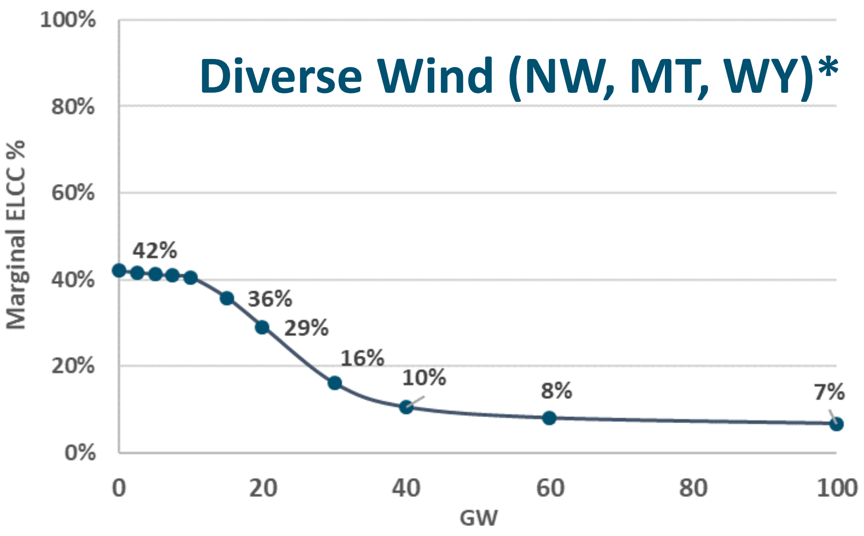
Load growth and carbon emissions in two clean energy scenarios modeled

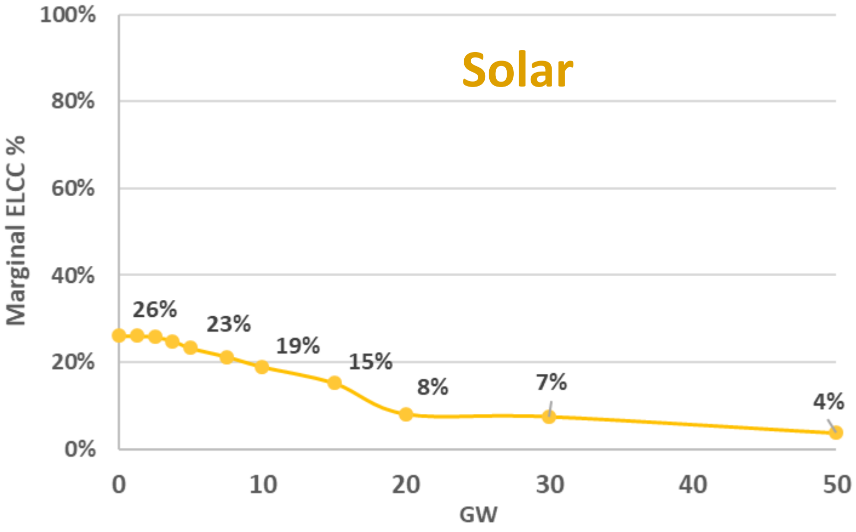
Increases in Electricity Use and Declines in Carbon Emissions

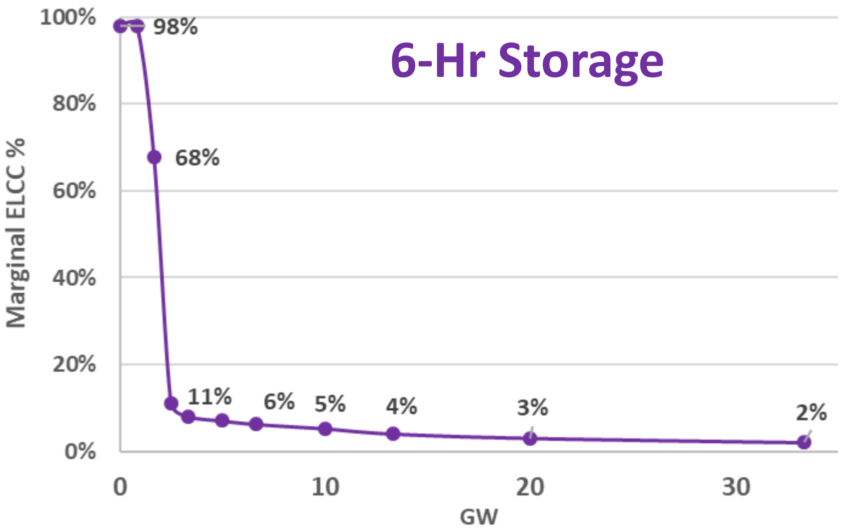


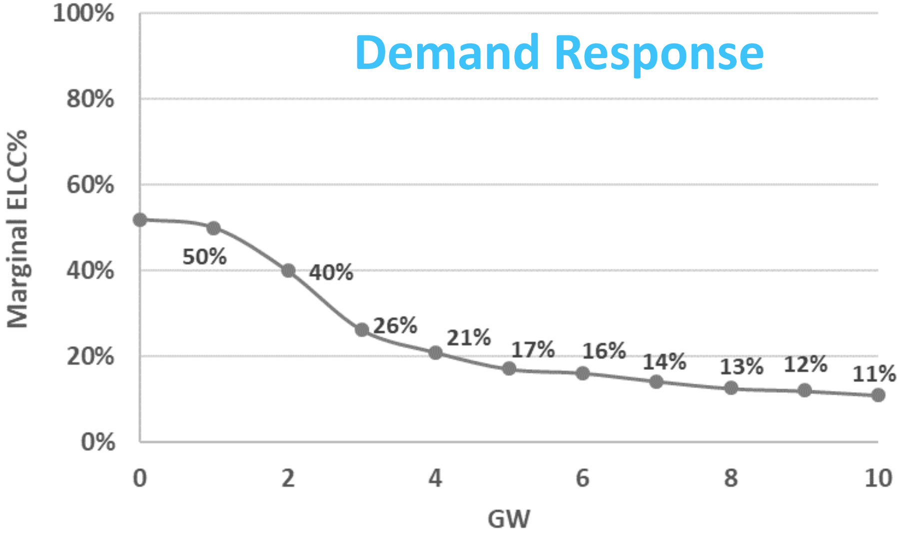
* Load based on 2021 NWPCC Power Plan, shown as retail sales (after assumed growth in customer PV and energy efficiency)

This study incorporates information on the capacity contribution of renewables, storage and DR









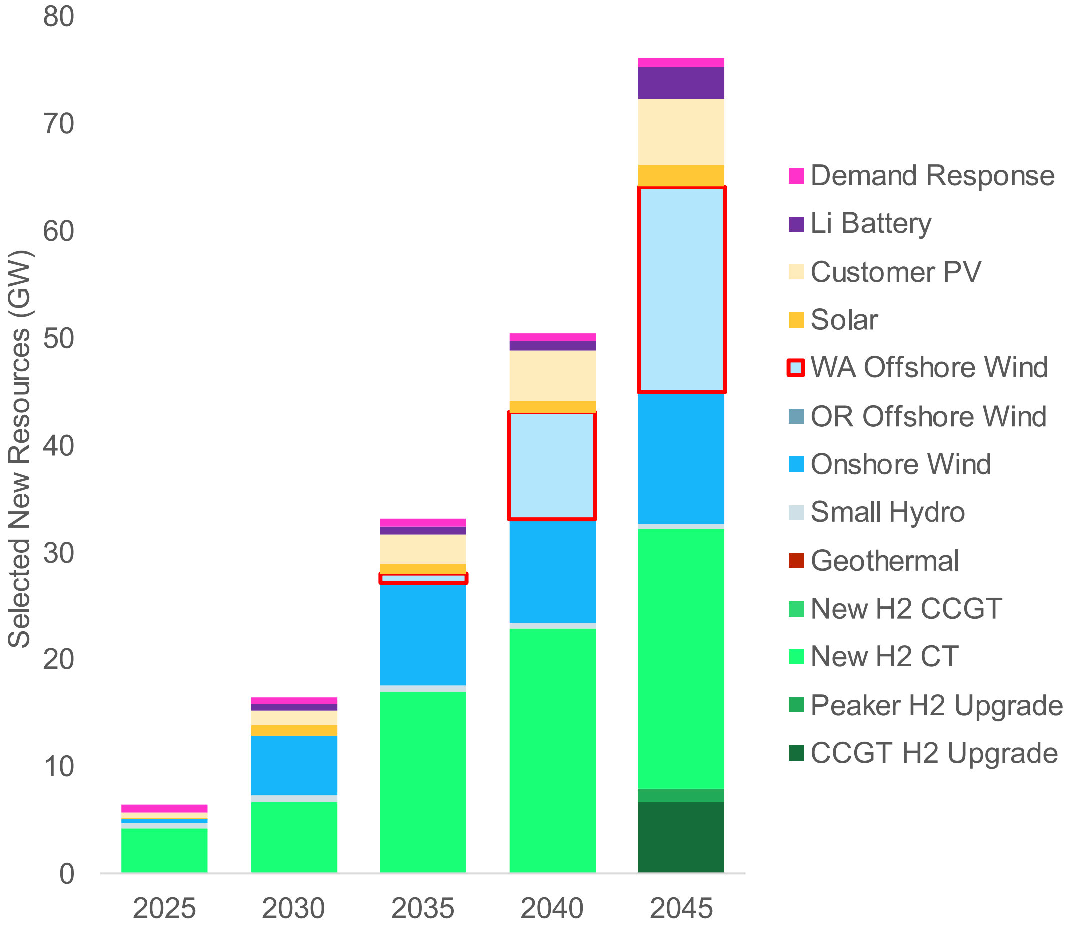
- A reliable electric system requires enough capacity to meet peak loads and contingencies
- This study incorporates information from E3's 2019 report *Resource Adequacy in the Northwest* about the effective capacity contribution of renewables, storage and DR at various penetration levels

* The offshore wind sensitivity in this study assumed the same ELCC curve as modeled for diverse on-shore wind resources in the Resource Adequacy in the Northwest report.

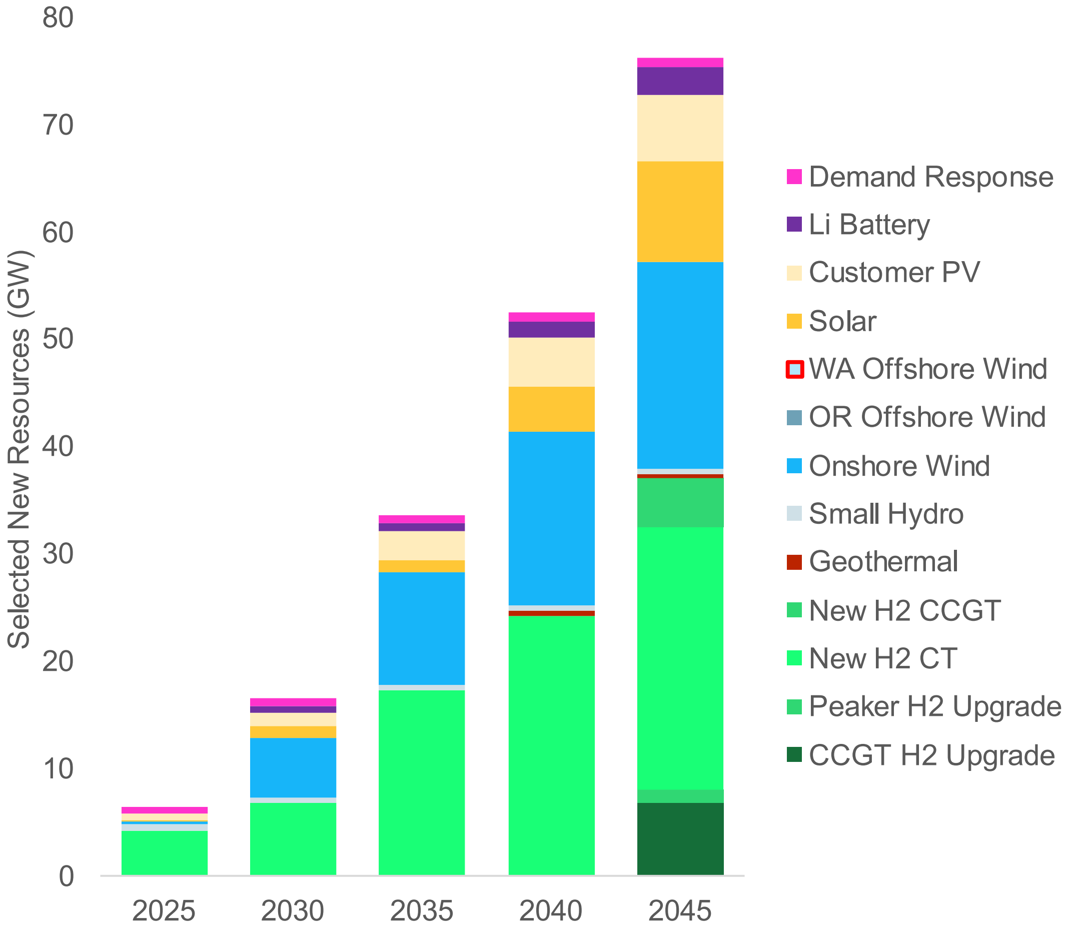
ELCC = Effective Load Carrying Capability = firm contribution to system peak load

Base Scenario Selected Resources

Selected Resources with Offshore Wind

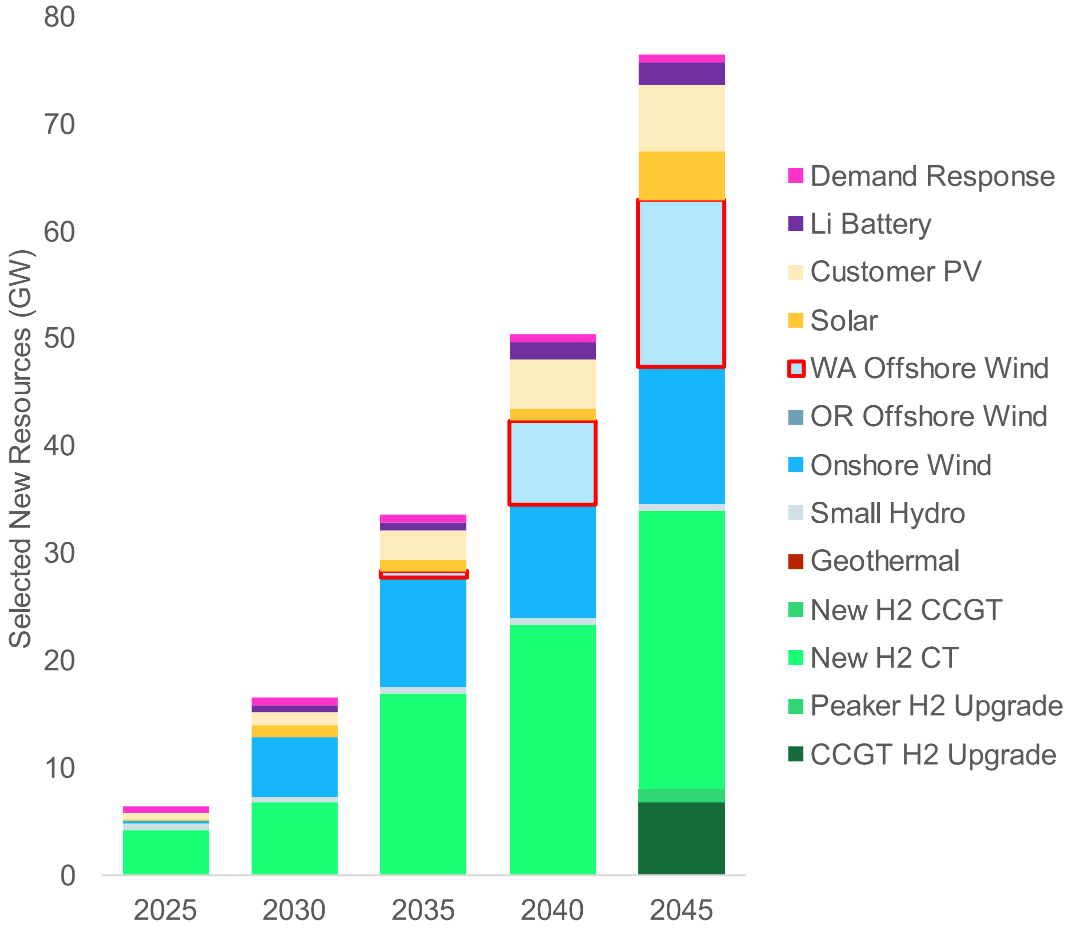


Selected Resources without Offshore Wind

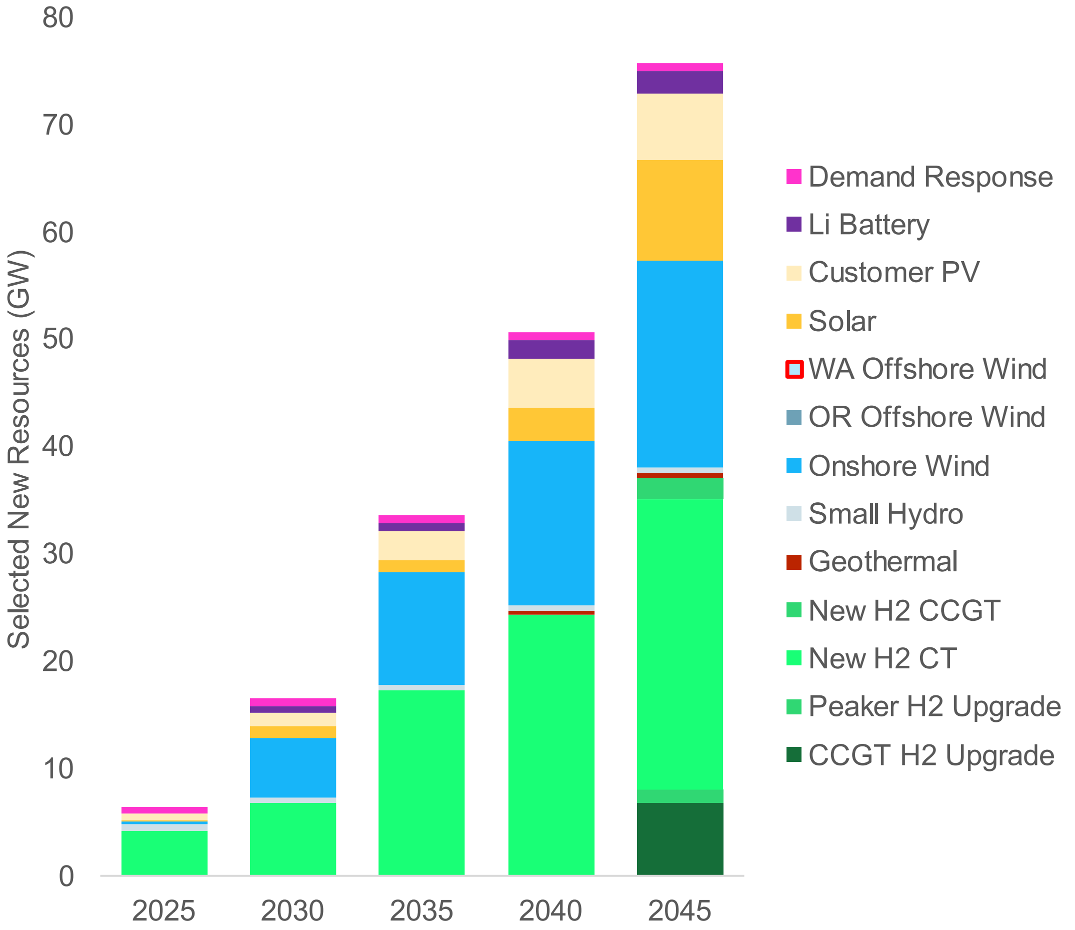


95% GHG Target Scenario Selected Resources

Selected Resources with Offshore Wind

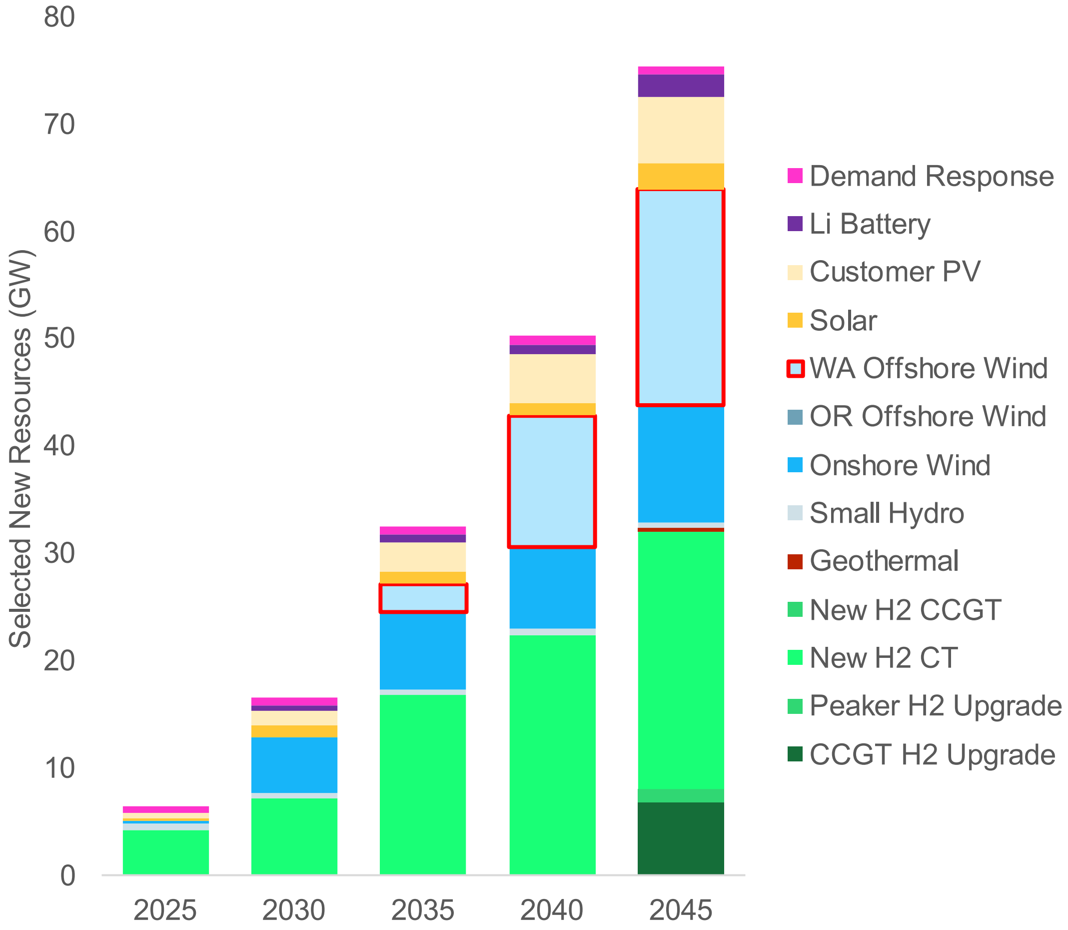


Selected Resources without Offshore Wind

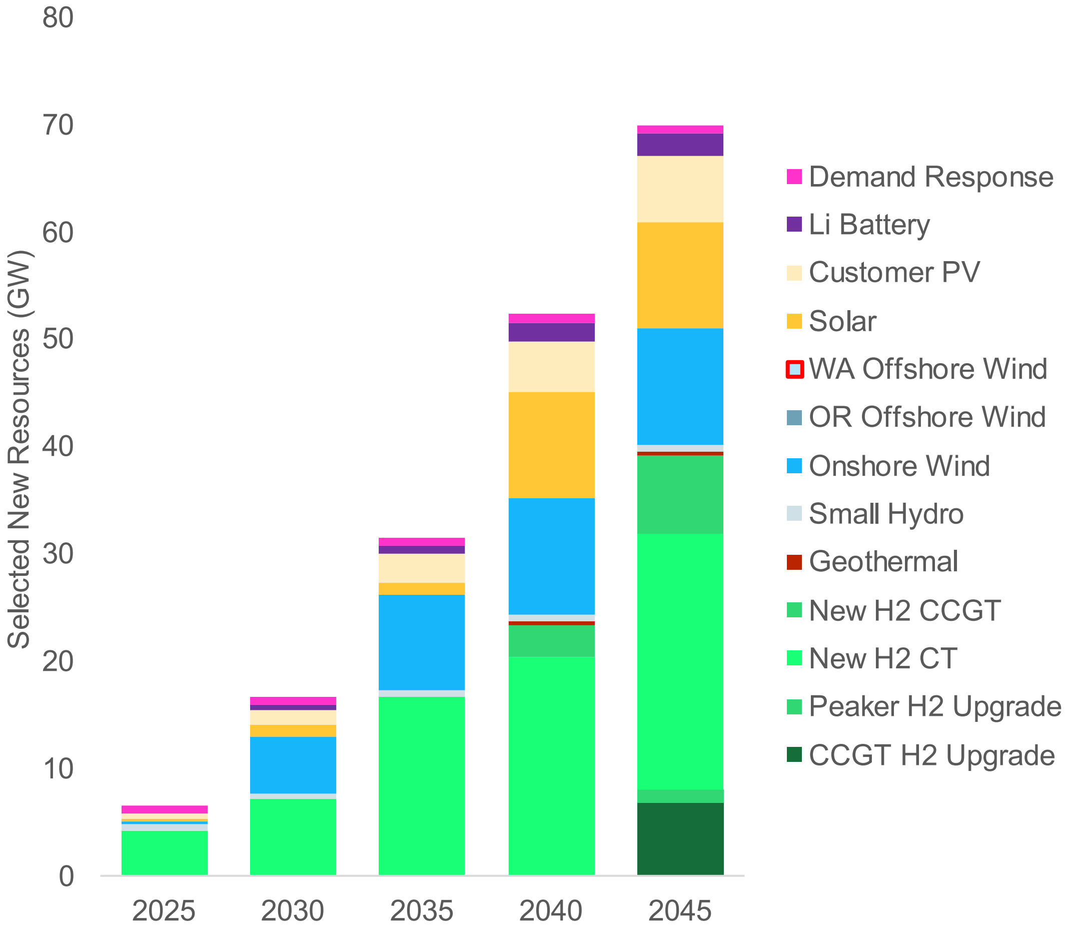


Limited Out of State Wind Scenario Selected Resources

Selected Resources with Offshore Wind

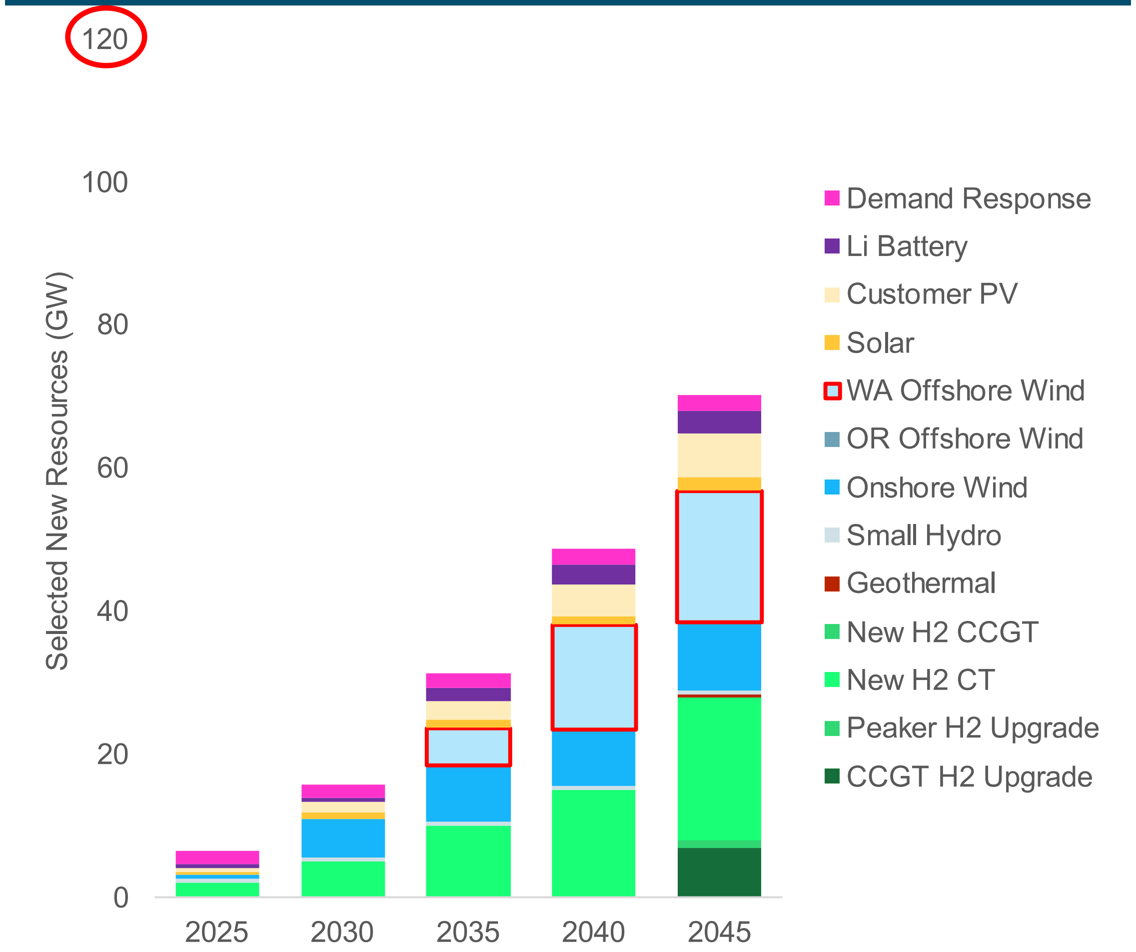


Selected Resources without Offshore Wind

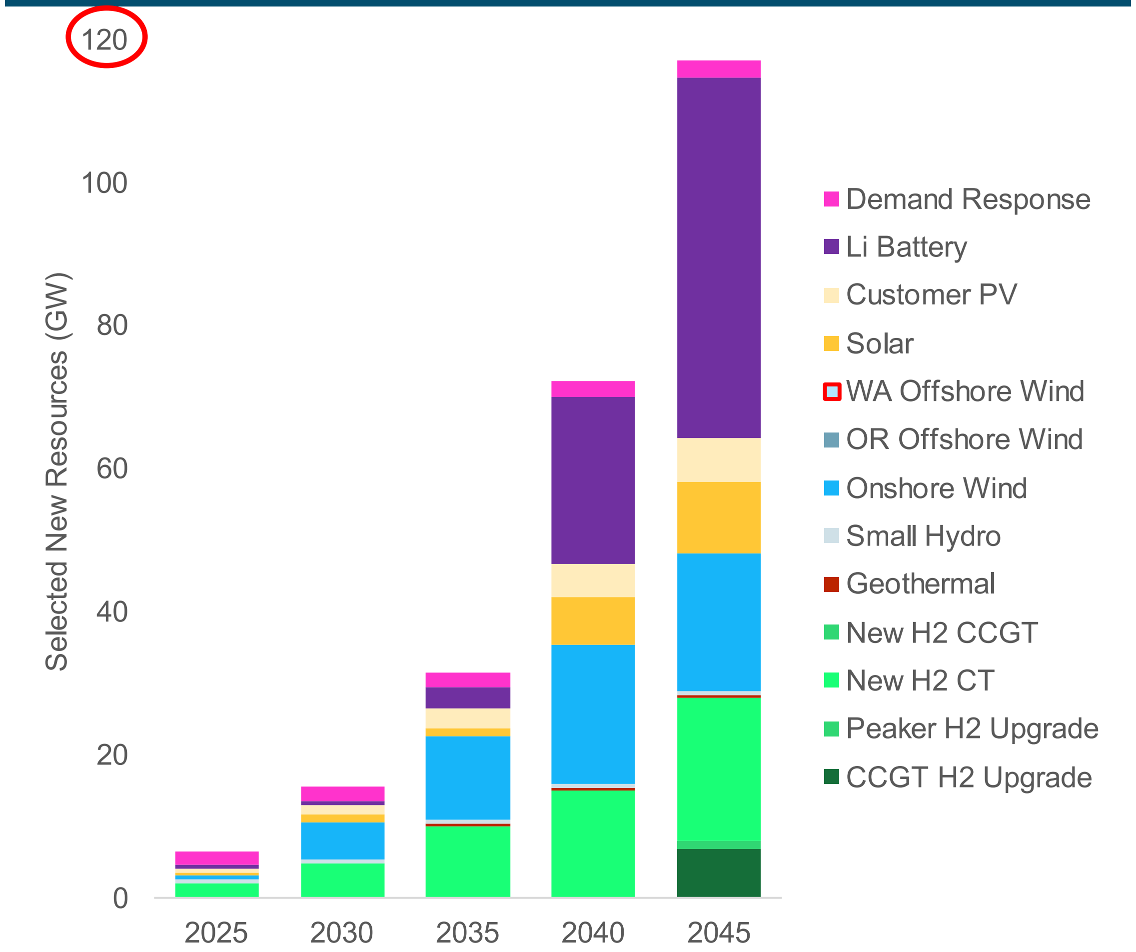


Slow Hydrogen Build Scenario Selected Resources

Selected Resources with Offshore Wind



Selected Resources without Offshore Wind

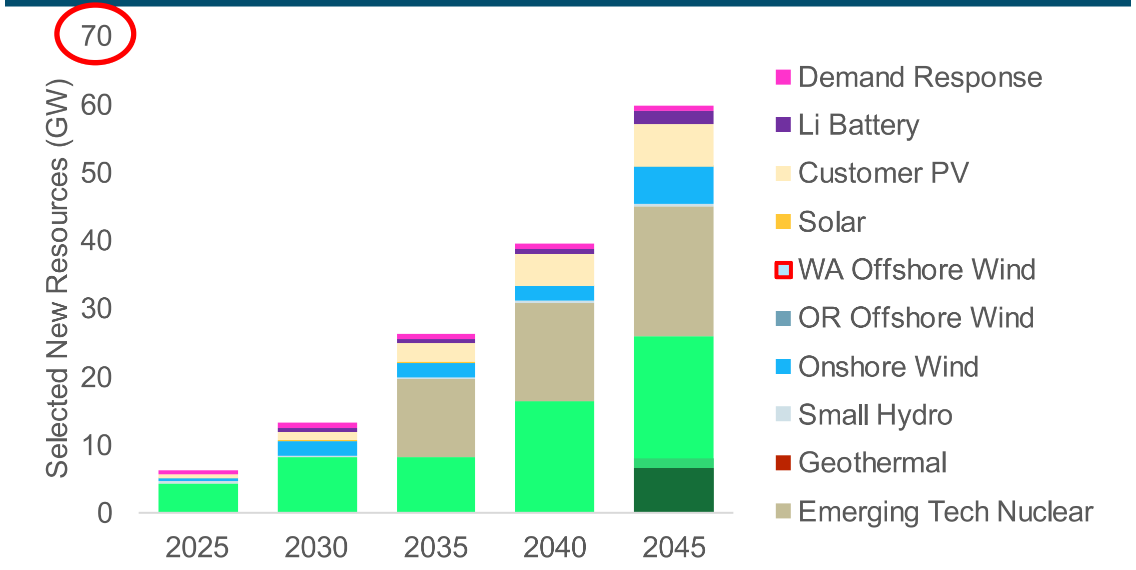


*Note change in vertical axis scale

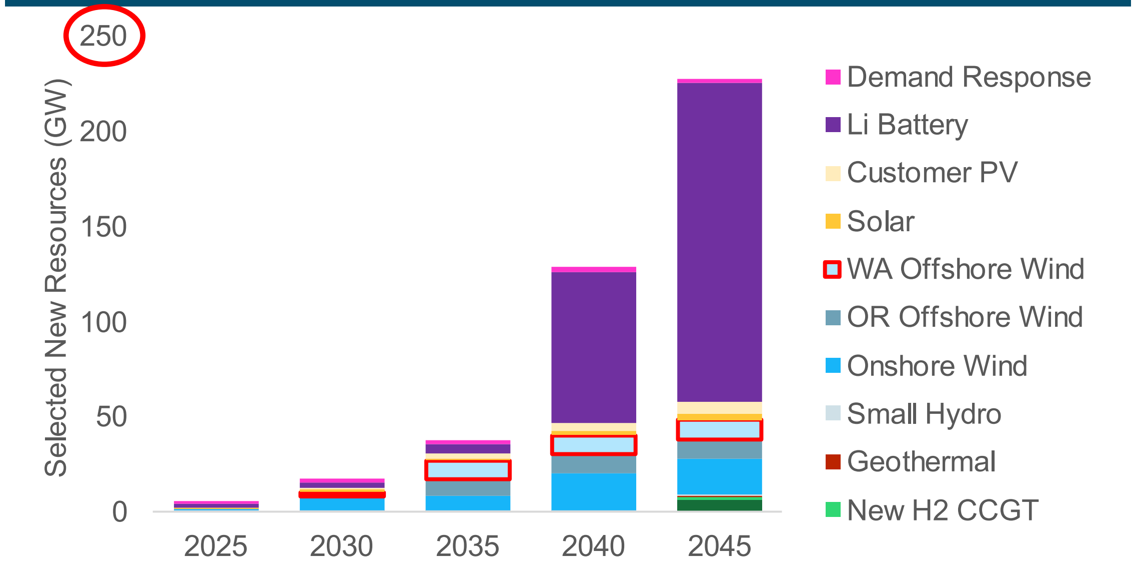
E3 Conducted Additional Scenarios on No New Hydrogen and the Proliferation of Emerging Nuclear Technologies

- **Emerging Nuclear Technology Scenario made small modular reactors available in 2035**
  - SMR costs are derived from NuScale, for an "nth of a kind" installation of the technology they are developing
- **No New Hydrogen Scenario removes new hydrogen availability and limits offshore wind build to 10 GW in Washington and 10 GW in Oregon resulting in unrealistic battery storage additions**

Emerging Tech Small Modular Reactor Scenario Yields Low Variable Renewable Selection



No Hydrogen Scenario with Limited Offshore Wind Build Yields Infeasible Battery Additions



*Note change in vertical axis scale