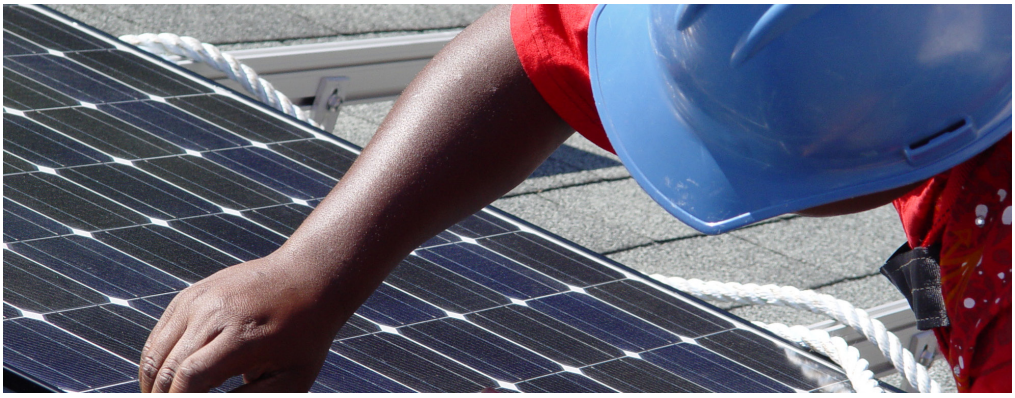
Within Reach

The Path to 100% Fossil-Free Electricity in the Pacific Northwest



September 2018

climate solutions
accelerating the transition to our clean energy future

Climate Solutions

For more than 20 years, Climate Solutions has advocated for a thriving, equitable Northwest, powered by clean energy, inspiring the transition to sustainable prosperity across the nation and beyond.

As a Northwest-based clean energy economy nonprofit, we accelerate solutions to the climate crisis by:

- championing transformational policies and market-based innovations to address the climate crisis;
- catalyzing powerful partnerships and helping grow a diverse movement for action and accountability; and
- communicating a bold vision for solutions at the scale required by climate science.

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Executive Summary

For over a century, the economy and energy systems in the United States have largely been reliant on polluting fossil fuels. Now, the public has shown a strong desire to shift towards cleaner sources of energy, the economy is leveling the playing field for renewable energy, and jurisdictions all across the United States are making climate commitments to transition away from fossil fuels. With a large renewable power base, abundant resource potential, and a tradition of clean energy and technology leadership, the Pacific Northwest is well-positioned to be at the forefront of this transition. This study takes a deeper look at Washington State as a jurisdiction poised to consider policy options to make that transition within reach.

The University of Washington's Climate Impacts Group recommends that Washington revise its greenhouse gas limits in statute to 80% reductions below 1990 levels by 2050,[1] reflecting the global emissions reductions necessary to prevent catastrophic climate change. Without policy interventions, current business-as-usual trajectories suggest that Washington is on track to exceed these greenhouse gas emissions targets by nearly 50 million metric tons in 2050.

Deep pollution reduction across the economy will rely on replacing a wide range of fossil fuel uses with fossil-free electricity. Because electricity plays such a critical role in a low-carbon future, even if all other sectors significantly reduce greenhouse gas emissions, Washington's business-as-usual utility planning could result in the state exceeding its energy emissions target by approximately 50% without continued efforts to decarbonize the electricity sector. With its abundant base of hydroelectric power, the Northwest can move to 100% fossil-free electricity rapidly, creating a clean grid to expedite zero-emissions electrification.

Climate Solutions commissioned new research identifying pathways to phase out fossil fuels from the power sector in the Pacific Northwest. The analysis, conducted by Energy and Environmental Economics (E3), modeled several scenarios that each provide a different strategy for achieving 100% fossil-free electricity in the Pacific Northwest by 2050. The analysis finds that building on the Northwest's foundation of hydropower, transitioning away from fossil fuels, and investing in renewable energy, energy storage, and energy efficiency can be affordable and reliable. Of the scenarios modeled, renewable electricity generation using wind, solar, and renewable natural gas appears to provide the most cost-effective pathway to a fossil-free grid. This scenario results in an incremental cost of approximately a half cent per kilowatt-hour levelized across the region, prior to accounting for any other costs and risks of fossil fuels.

The new research confirms that phasing out fossil fuels while phasing in non-fossil sources of energy can provide clean, reliable, affordable power. Washington utilities are planning to

1 Washington Department of Ecology. "Washington Greenhouse Gas Emission Reduction Limits." *https://fortress.wa.gov/ecy/publications/documents/1601010.pdf*

invest in over 2300 megawatts[1] in new gas plant capacity over the next two decades, which could put their customers at risk if these investments foreclose the opportunity for increased investment in fossil-free sources of energy. Significant new investments in infrastructure expected to rely on fossil fuels could result in stranded assets and leave customers on the hook for the costs of early retirements. A transition to 100% fossil-free electricity will take this into consideration up front and avoid risky investments in infrastructure that will cause us to exceed our carbon goals.

The analysis described here maps one path for deep pollution reduction in the Pacific Northwest's electricity sector. Follow-on research should evaluate additional strategies and market dynamics, such as higher levels of energy efficiency and demand response, improved accounting for out-of-region renewable resources, improved evaluation of storage use across days, additional zero-carbon resources like power-to-gas, and other factors that would likely reduce any challenges or costs associated with achieving a fossil-free grid.

1 Puget Sound Energy. "2017 PSE Integrated Resource Plan." *https://pse.com/aboutpse/EnergySupply/Documents/02_IRP17_Ch2_102017b.pdf* see also: Avista. "2017 Integrated Resource Plan." *www.myavista.com/-/media/myavista/content-documents/about-us/our-company/irp-documents/2017-electric-irp-final.pdf?la=en*

PART I

The Role of Electricity in a Low-Carbon Future

Decarbonization Pathways Across the United States

The United States has shifted aggressively towards cleaner sources of energy for economic, public health, and environmental reasons. Several states have begun to deploy strategies to cut emissions by millions of tons per year. As we move away from coal, we see more reliance on renewable energy and energy efficiency, but we also see large increases in the use of natural gas, which, like coal and oil, is a fossil fuel.

Though gas plants fueled by fossil fuels emit between 40% and 60% fewer greenhouse gases than coal per megawatt-hour produced at the smokestack, this reduction still falls short to achieve the greenhouse emissions reductions necessary. Furthermore, leakage of gas from extraction and delivery causes methane emissions that may offset the lower emission rate at the smokestack. Over a twenty year period, a leakage rate of just 3.9% would render fossil natural gas as damaging as coal.[1] Even before accounting for this leakage, fossil gas plants account for 506 million metric tons of carbon emission annually in the United States, and a comprehensive number is likely significantly higher.[2] Though emissions gradually decline, the United States is not yet pursuing the level of emission reductions needed to prevent further climate instability and irreversible impacts from climate change.

Numerous studies covering different geographies have all reached a similar conclusion: in order to achieve meaningful economy-wide greenhouse gas emissions reductions, the electricity sector must approach zero emissions. While some studies consider employing a variety of strategies to achieve decarbonization in the electricity sector, including carbon capture and storage, conclusions remain consistent that the use fossil fuels must largely cease. An electrical system that continues to rely on uncontrolled fossil natural gas will not result in the necessary greenhouse gas reductions, and new research demonstrates that a transition to a fossil-free grid can be affordable and feasible with existing technologies.

The United States Mid-Century Strategy for Deep Decarbonization, a federal effort to chart a path to meeting national climate goals released in November 2016,[3] found that achieving national carbon reduction goals would require electricity to be generated almost entirely from low-carbon

1 Nicolas Sanchez, David C. Mays. "Effect of methane leakage on the greenhouse gas footprint of electricity generation." *Climatic Change*. 2015.

2 U.S. Energy Information Administration. "Frequently Asked Questions: How much of U.S. carbon dioxide emissions are associated with electricity generation?" 8 June 2018. *www.eia.gov/tools/faqs/faq.php?id=77&t=11*

3 The White House. *United States Mid-Century Strategy For Deep Decarbonization.* November 2016. *https://unfccc.int/files/focus/long-term_strategies/application/pdf/us_mid_century_strategy.pdf*

sources by 2050. The report evaluated a mix of renewables, fossil fuels paired with carbon capture, utilization, and storage (CCUS), and nuclear power to achieve deep reductions in the electricity sector. Their prescription, which sought to optimize economy-wide pollution reduction, left little room for fossil fuels not employing CCUS, and called for the electricity sector to achieve much deeper reductions than the economy-wide target of 80% compared to 1990 levels. Their blend of low-carbon generation sources exceeds 90% of the resource mix in their 80% reduction benchmark scenario. The study concludes that electricity must lead the transition into a low-carbon economy, in part due to the cost-competitiveness of available technologies, centralized decision-making and generation assets, and the ability of customers to choose low-carbon distributed energy.

Another study, *Northeast 80x50 Pathway,*[1] was published by National Grid, a major gas and electric utility serving parts of New York, Massachusetts, and Rhode Island whose electricity generation is made up of over 50% fossil fuels.[2] The report analyzes how New York and New England can achieve economy-wide 40% reductions below 1990 levels by 2030 and 80% reductions below 1990 levels by 2050, concluding that the electricity sector will need to be a zero-carbon system by 2050. The study acknowledges that the exact sources of energy supply and storage are not yet known, but that the role of energy storage and renewables will grow as we decarbonize the sector.

On the other hand, National Renewable Energy Laboratory's (NREL) report, *Electrification & Decarbonization: Exploring U.S. Energy Use and Greenhouse Gas Emissions in Scenarios with Widespread Electrification and Power Sector Decarbonization*,[3] demonstrates the risks of failing to reach zero-carbon or near-zero-carbon electricity by 2050. NREL studied the impacts of deep electrification of residential, industrial, commercial, and transportation uses of energy. They modeled a scenario with no electric sector carbon reduction policy that allowed U.S. utilities to make business-as-usual decisions about future resource procurements, and a second scenario that required 80% greenhouse gas reductions in electric sector emissions. While the second scenario requiring some electric sector reductions resulted in deeper overall reductions, both scenarios failed to achieve economy-wide decarbonization consistent with 80% reductions by 2050. In the absence of power sector decarbonization, electrification will lead to 41% economy-wide reductions below 2005 levels, which falls sig nificantly short of the reductions necessary.[4]

Even with deep electrification and decarbonization in other sectors, these studies demonstrate that it is critical the electricity sector go further in order to achieve economy-wide emissions reductions targets. These findings and others align with Washington's decarbonization analysis, discussed below.

A Pathway for the State of Washington

In 2017, Washington published the first economy-wide pathway analysis for the state, the *Deep Decarbonization Pathways Study*.[5] The results showed that a transition to clean energy that reduces greenhouse gas emissions by 80% below 1990 levels is possible and affordable, but requires ambitious and aggressive action at a scale not yet undertaken.

The study's emissions reduction target tracks current requirements in peer West Coast jurisdictions such as California and Oregon. The Western Climate Initiative jurisdictions, which include western U.S. states and Canadian provinces, previously agreed to an 80% reduction target as a region, and many states in the U.S.

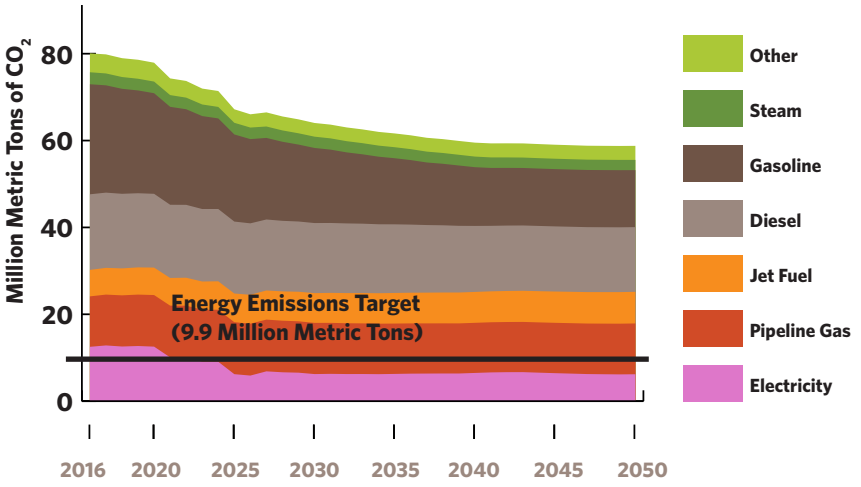
1 National Grid. *Northeast 80X50 Pathway*. 2018. *http://news.nationalgridus.com/wp-content/uploads/2018/06/80x50-White-Paper-FINAL.pdf*

2 National Grid. "RI Disclosure Label." November 2017. *www.nationalgridus.com/media/pdfs/billing-payments/bill-inserts/ri/cm4391_ri-edisclosure.pdf*

3 National Renewable Energy Laboratory. *Electrification & Decarbonization: Exploring U.S. Energy Use and Greenhouse Gas Emissions in Scenarios with Widespread Electrification and Power Sector Decarbonization.* July 2017. *www.nrel.gov/docs/fy17osti/68214.pdf*

4 Ibid.

5 Evolved Energy Research. *Deep Decarbonization Pathways Analysis for Washington State.* December 2016. *www.governor.wa.gov/sites/default/files/Deep_Decarbonization_Pathways_Analysis_for_Washington_State.pdf*

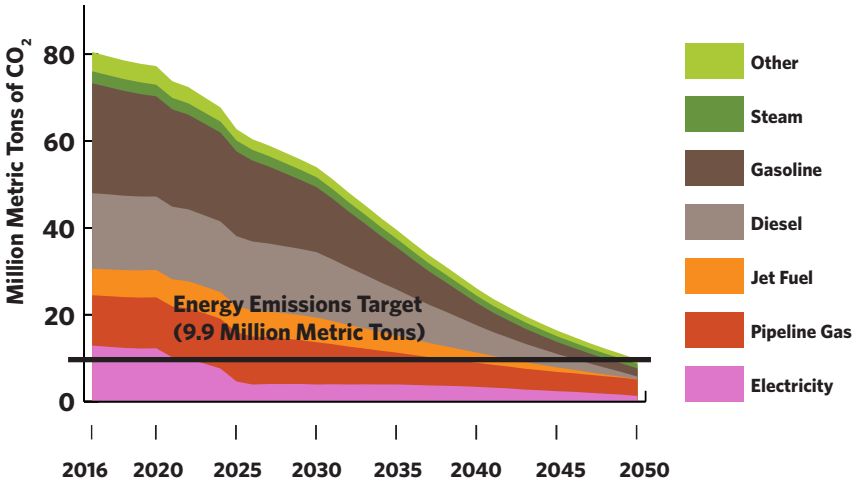


Energy emissions under current policy

Figure 1: Washington's business-as-usual energy emissions trajectory falls nearly 50 million metric tons short of target.

Energy vs. Non-Energy Global Warming Emissions

Energy emissions include greenhouse gas emissions from the electric sector, the transportation sector, buildings, and other sources that generally result from the combustion of fuels. Non-energy emissions are those that originate from industrial processes, the agriculture sector and waste management, and generally do not rely on the combustion of a fuel.



A low-carbon pathway

Figure 2: Deep emissions reductions in the electricity sector and widespread electrification create a pathway for Washington to achieve greenhouse gas emissions targets.

have enacted or are considering aggressive carbon reduction policies to achieve greenhouse gas reduction goals, shown in figure 2. For example, California recently passed a 100% clean bill (SB100) which requires a mix of renewable and zero carbon electricity to match the state's retail electricity sales by 2045, and the state has already exceeded its 50% clean energy goals with gross state product up over 80%.[1]

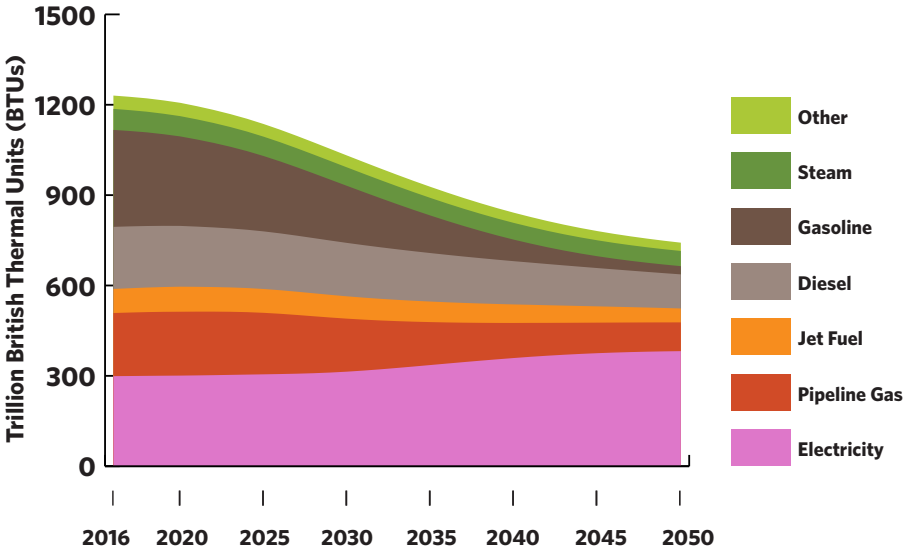
As can be seen in figure 1, Washington is not on track to achieve emission reductions consistent with 80% reduction targets. Under existing policies, Washington's energy emissions will gradually decline over the next two decades before leveling off. Electricity sector emissions are projected to decline as coal facilities are replaced with a mix of new fossil natural gas generation and renewable sources of energy. Gasoline and diesel emissions are also projected to fall as combustion engines become more efficient and an increasing share of electric vehicles are sold. Greenhouse gas emissions associated with fossil natural gas used in industrial settings and for space and water heating are the only major emissions sources projected to increase.

The business-as-usual path leads to reductions of about a quarter of Washington's 2016 energy emissions, but falls short of the 2050 target by nearly 50 million tons. Without further action to reduce emissions, Washington is projected to exceed emissions targets in 2050 by nearly 500%.

A low-carbon economy that prioritizes decarbonization of the electricity sector and electrification of end uses leads to a significant reduction of total energy usage and deep emissions reductions. Total energy usage would decline significantly over the 34 years covered by the study, due to electrification and a more efficient use of energy. While this scenario projects an overall reduction in energy usage of 40% by 2050, Washington would be expected to see a 27% increase in energy use from the electricity sector due to the electrification of other sources of energy, making up 52% of Washington's total energy use in 2050, compared to just 24% in 2016.

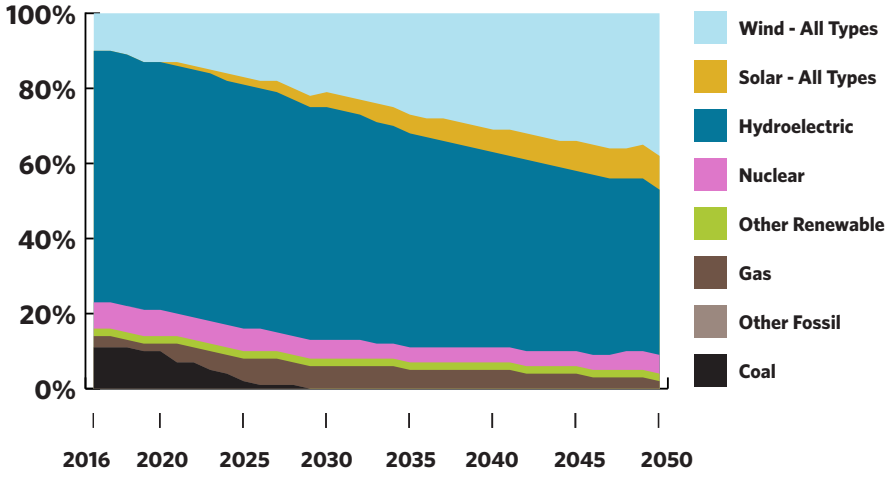
In this scenario, diesel and jet fuels would be de-

1 California Energy Commission. "Greenhouse Gas Emissions Reductions." December 2017. *www.energy.ca.gov/renewables/tracking_progress/documents/Greenhouse_Gas_Emissions_Reductions.pdf*



Energy sources in a low-carbon pathway

Figure 3. As Washington electrifies the economy, the share of energy coming from electricity more than doubles.



Electricity sources in a low-carbon pathway

Figure 4: Electricity generation in a low-carbon future is over 98% fossil-free.

rived from renewable sources, and industrial uses would continue to use a combination of fossil natural gas and renewable natural gas. Much of the rest of the economy would be electrified by 2050, including all single occupancy vehicles and significant increases in electric heat pumps.

This projected increased share of electricity use in Washington, shown in figure 3, underscores the central role a clean power policy has in achieving deep carbon reduction goals. Research consistently shows the importance of decarbonizing electricity to achieve long-term carbon reduction goals. Without electricity sector decarbonization, Washington's business-as-usual utility planning will result in the state exceeding its energy sector greenhouse gas emissions target by approximately 50%.

As can be seen in figure 4, the electricity sector must gradually phase out fossil fuels by 2050, leaving less than 2% of electricity coming from fossil fuels. In a low-carbon 2050, Washington would continue to rely on a robust hydropower base, with new energy sources principally from wind and solar. By 2050, Washington would generate over 98% of its electricity from non-fossil fuel sources.

It is worth noting that the *Deep Decarbonization Pathways Study* made a number of assumptions that may impact Washington's path to decarbonization. First, the study assumed that all bioenergy is carbon neutral; and second, the study did not attribute emissions from natural gas leakage to Washington, which may not be accounted for where the leakage occurs. These two assumptions indicate that the state may need to pursue deeper penetrations of fossil-free electricity to achieve emissions reductions goals, likely between 98-100%, after accounting for leakage emissions and emissions from more carbon-intensive forms of bioenergy.

PART II

Modeling the Pathways to a 100% Fossil-Free Grid

Research Background

In 2017, the Public Generating Pool ("PGP"), a group of ten publicly owned utilities in the Pacific Northwest, sponsored a study conducted by E3, called the *Pacific Northwest Low-Carbon Scenario Analysis*, that examined policies and potential pathways for achieving 80% carbon reductions in the electricity sector.[1] Based on the findings that the electricity sector must exceed 80% reductions in order to achieve 80% economy-wide emissions reductions, Climate Solutions sponsored a follow-up study, also conducted by E3, that examined pathways to full decarbonization of the grid in the Pacific Northwest. This follow-up study held constant the assumptions in the original PGP study to achieve a true comparative analysis of the impact of additional scenarios. Both studies used the RESOLVE model, an optimal capacity expansion model that allows for user-selected constraints and optimizes the most cost-effective portfolio of resources within those constraints.

100% Fossil-Free Electricity Scenarios

Climate Solutions modeled three main scenarios examining different pathways to 100% fossil-free electricity in the Pacific Northwest[2] in comparison with a "reference" case reflecting current policies and industry trends. Each scenario permits varying levels of flexibility and resource options for procurement:

- *The first scenario* limits fossil-free generating resource options to the same options as the original 2017 study, which includes hydroelectric, wind, solar, and geothermal resources.
- *The second scenario* adds to the first scenario the availability of renewable natural gas. With the same resource availability assumptions, we then modify the scenario by reducing the renewable energy cost assumptions to better reflect recent market projections.
- *The third scenario* most closely resembles policies that the Washington State Legislature considered in the 2018 legislative session. This scenario provides a cost containment mechanism that allowed for the use of fossil fuels if the marginal abatement cost exceeds $200 per metric ton of carbon.

1 Energy + Environmental Economics. *Pacific Northwest Low Carbon Scenario Analysis: Achieving Least-Cost Carbon Emissions Reductions in the Electricity Sector*. 8 November 2017. *www.publicgeneratingpool.com/wp-content/uploads/2017/11/E3_NW_LowCarbonStudy_Full-Slide-Deck_2017-11-08.pdf*

2 Energy + Environmental Economics. *Pacific Northwest Low Carbon Scenario Analysis: 2018 Scenarios and Sensitivities.* June 2018. *www.ethree.com/wp-content/uploads/2018/06/Climate-Solutions_2018-Pacific-NW-Scenarios-and-Sensitivities_Final-Report.pdf*

Research Assumptions

This model makes a number of assumptions which are detailed in the technical support documents from the *Pacific Northwest Low Carbon Scenario Analysis* (see note 1 above). Here are the key assumptions that impact our present analysis:

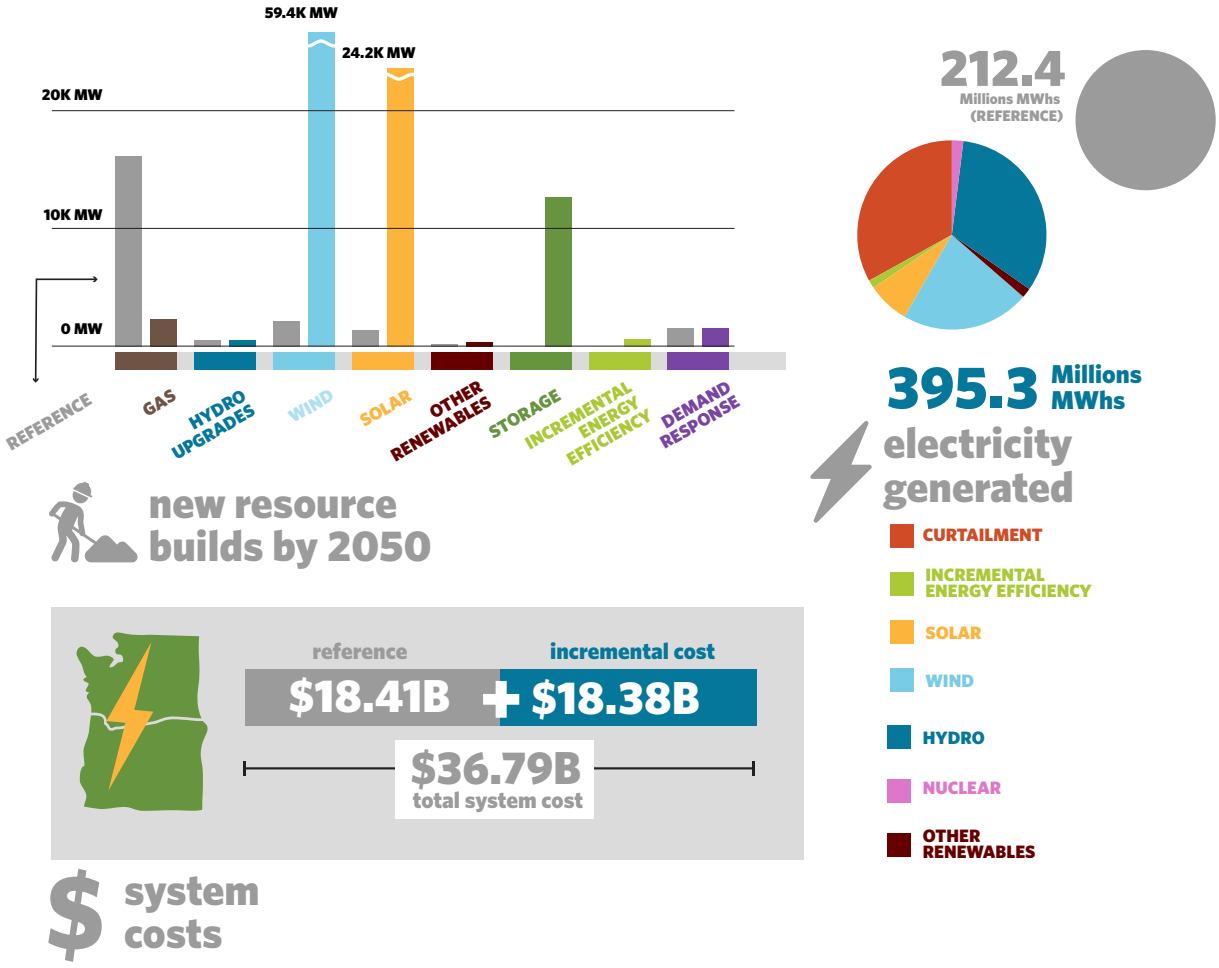
- This study focuses on a suite of 100% clean energy scenarios in the electricity sector in Washington and Oregon, referred to in this study as the "Core Northwest" region.
- The "reference case" reflects current policies and industry trends, intended to serve as a point of comparison for alternative scenarios.
- Load growth is partially offset by the acquisition of cost-effective energy efficiency, identified by the Northwest Power and Conservation Council, which reduces regional load growth from 1.3% per year to 0.7% per year.
- Total load growth from transportation electrification in this scenario is based on Northwest Power and Conservation Council's medium electric vehicle trajectory, of which 60% is managed smart charging.
- Existing coal plants, including plants that are geographically located outside of the region but serve utility loads within the region, remain in service through 2030 with the exception of announced retirements: Boardman, Centralia 1 & 2, and Colstrip 1 & 2. The Columbia Generating Station and the Lower Snake River Dams are assumed to be in operation beyond 2050.
- Existing gas plants within the region remain in service through 2050, except gas plants that are expected to reach the end of their economic lives or have known retirement dates, and in the first scenario which does not allow for fossil or renewable natural gas generation.
- Unless otherwise indicated, resource cost assumptions are consistent with PGP's original study and based on E3's 2016 analysis and recommended resource cost assumptions to Western Electricity Coordinating Council, which are higher than the cost of some current projects.*

*Energy + Environmental Economics. *Review of Capital Costs for Generation Technologies.* January 2017. *www.wecc.biz/Administrative/2017-01-31%20E3%20WECC%20Capital%20Costs%20v1.pdf*

Research Model Limitations

The model has a number of limiting assumptions, listed below. As with many models, these limitations likely provide for more conservative results than expected when actually implemented, meaning that costs are likely conservative. We highlight key limitations that impact the scenarios, making the result more conservative:

- The energy efficiency supply curve is limited to the Northwest Power and Conservation Council's supply curve, which has consistently underestimated energy efficiency acquisition by more than 10%.
- Demand response is limited to approximately 1,600 MW, restricted to an agricultural/industrial interruptible rate and space/water heating in residential settings based on available data.
- The model balances over individual days, precluding the option for multi-day storage and not fully capturing the value of the hydro system.
- The model does not model deeper market coordination across the West and does not allow for any non-claimed imports into the Core Northwest in 2050 due to how carbon is attributed to unspecified resources.
- The model does not capture new technologies not yet on the market that may arise between now and 2050.



SCENARIO 1

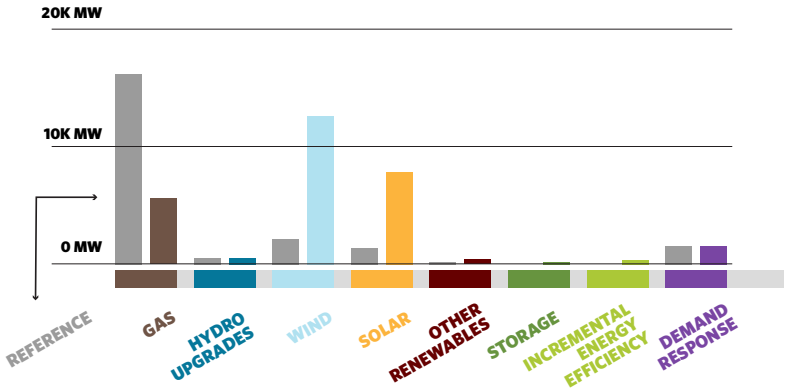
100% reduction with hydro, wind, geothermal, solar (HWGS)

Limiting new fossil-free generating resources to hydro, wind, solar, and geothermal to achieve 100% fossil-free electricity results in high levels of costs and curtailment.

The first scenario assumes a path to 100% clean electricity utilizing only hydro, wind, solar, and geothermal as the available new fossil-free generating resource options. The model places limits on demand response and self-curtailment capabilities, and restricts new dispatchable sources of generation that can be turned on and off to meet demand. Without dispatchable generation, this scenario significantly overbuilds resources to ensure there is sufficient capacity to meet peak demand. As shown in the figure, this scenario would add 84 GW of renewable energy and 10 GW of storage to the grid, compared to a business-as-usual reference case that adds 15 GW of new resources. The primary source of new energy would be wind, along with solar, battery storage, pumped hydro, and other resources.

In this scenario, over one-third of the energy would be wasted (approximately 131 million MWhs) referred to in the chart as "curtailment."[1] The total system costs of this scenario are estimated to be $36.8 billion, compared to a reference case total system cost of $18.4 billion. While the costs are likely a high estimate due to the model limitations, this scenario as modeled would nearly double the total system cost in 2050. Limiting the resources to hydro, wind, solar, and geothermal does not currently represent the most cost-effective pathway for achieving a 100% fossil-free grid.

1 Note that this scenario does not assume high electrification, power-to-gas, or other technologies that may make use of the excess energy available in this scenario.

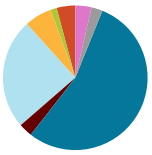


new resource builds by 2050

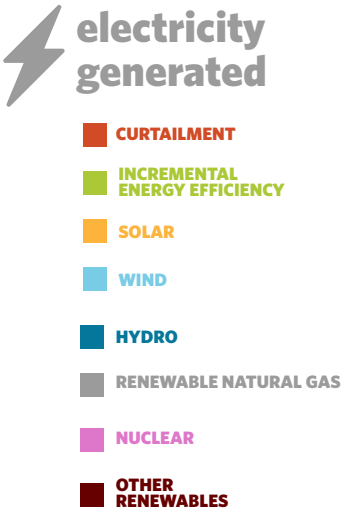
reference $18.41B + incremental cost $3.26B

$21.67B total system cost

$ system costs



235.5 Millions MWhs electricity generated



SCENARIO 2
100% reduction with HWGS + biogas

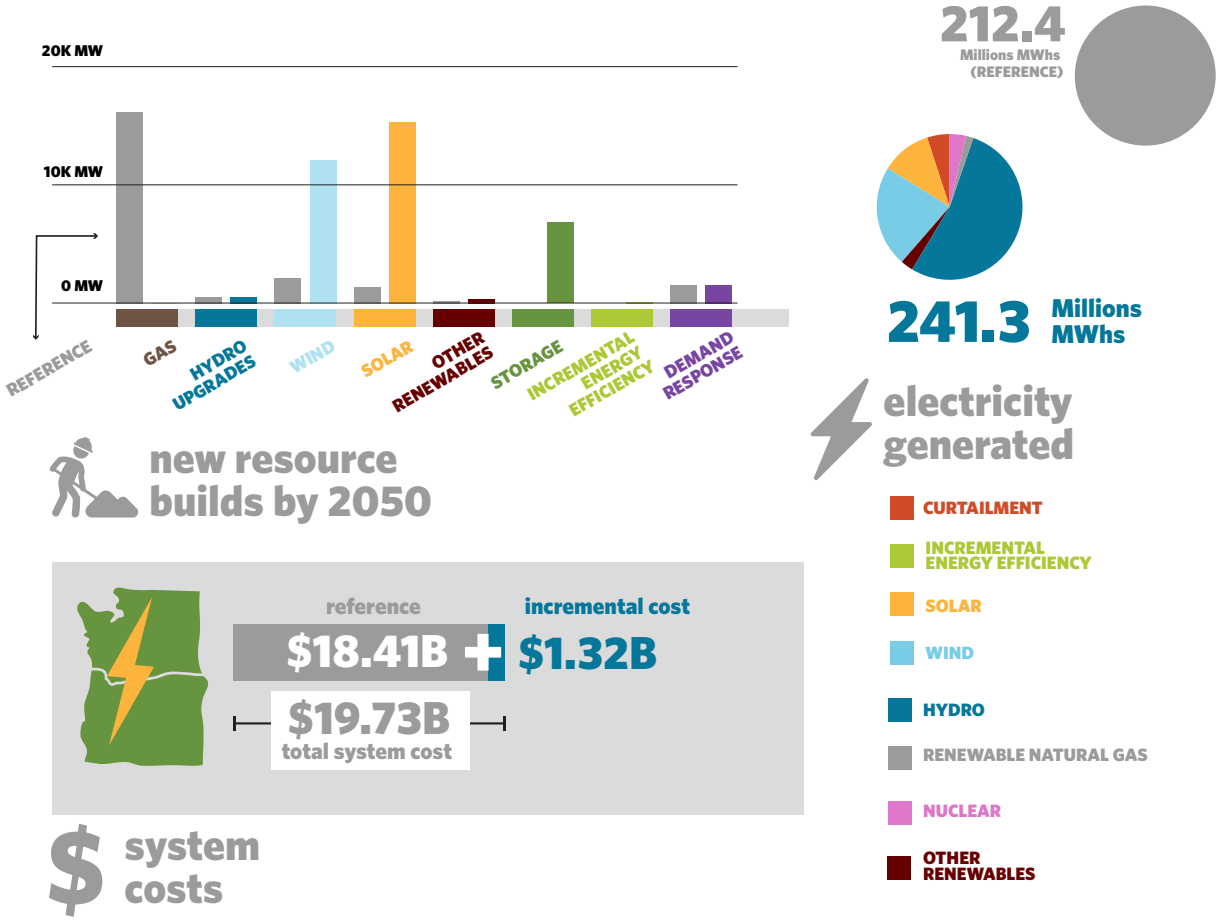
The addition of renewable natural gas as a resource option for achieving 100% fossil-free electricity significantly reduces curtailment and cuts costs by over 80%.

The second scenario makes one change from the first scenario: it adds renewable natural gas as an available fossil-free generating resource, along with hydro, wind, geothermal, and solar. Renewable natural gas is modeled at $31 per MMbtu, based on U.S. Department of Energy's *2016 Billion-Ton Report* identifying market potential supply curves under scenarios with and without purpose-grown crops.[1] This scenario results in using approximately 41.3 Tbtu of renewable natural gas, which is about one third of Washington and Oregon's projected in-state market supply without relying on purpose-grown crops.

The addition of renewable natural gas as a resource option significantly reduces the need to overbuild resources in order to meet peak demand, resulting in 21 GW of new renewable resource builds, compared to 84 GW in the first scenario. The amount of wasted energy would be reduced by 90%, and the total energy that is produced in order to balance the grid would fall from approximately 394 million MWhs to approximately 236 million MWhs. While this scenario projects new investments in gas infrastructure, gas plants would burn renewable natural gas in 2050. The incremental cost of this scenario falls by 83%, to a total system cost of $21.6 billion compared to a reference of $18.4 billion. Spread across all generation in Washington and Oregon, this incremental cost correlates to approximately $0.016/kWh.

Fossil Natural Gas vs. Renewable Natural Gas

Natural gas consists mainly of methane, primarily used in the United States for electricity generation, heating, and industrial uses. While the majority of natural gas is derived from fossil fuels often fracked from deep underground, natural gas can also come from renewable sources. Renewable natural gas is methane sourced from organic raw materials instead of fossil fuels, and often involves capturing methane that would otherwise have been released into the atmosphere. Common sources of renewable natural gas include wastewater treatment facilities, local landfills, manure, and decomposing plant material. Renewable natural gas can be used in existing gas plants to provide a source of fossil-free generation that can be turned on and off as needed.



SCENARIO 2B

100% reduction with HWGS, biogas + updated renewable costs

Reductions in renewable energy costs make achieving 100% fossil-free electricity even more affordable and avoids new gas infrastructure.

In this modified scenario, renewable resource cost assumptions are reduced to better reflect today's market and recent trends in renewable energy technology costs. Solar costs are updated using the NREL's *2017 Annual Technology Baseline*;[1] wind capital costs are reduced by 20%, consistent with integrated resource plans in the Pacific Northwest;[2] battery storage costs are updated using Lazard's *Levelized Cost of Storage 3.0*;[3] and the cost of renewable natural gas is reduced by 20% to reflect a lower cost projection.

By reducing renewable energy costs, the model no longer projects new investments in gas plants in the Northwest, and instead relies on 28 GW of new investments in renewable energy resources and 7 GW of new storage resources to provide energy, capacity, and balancing services. The use of renewable natural gas would decline to 32.5 Tbtu, which is just over a quarter of the projected in-state capacity without purpose-grown crops.

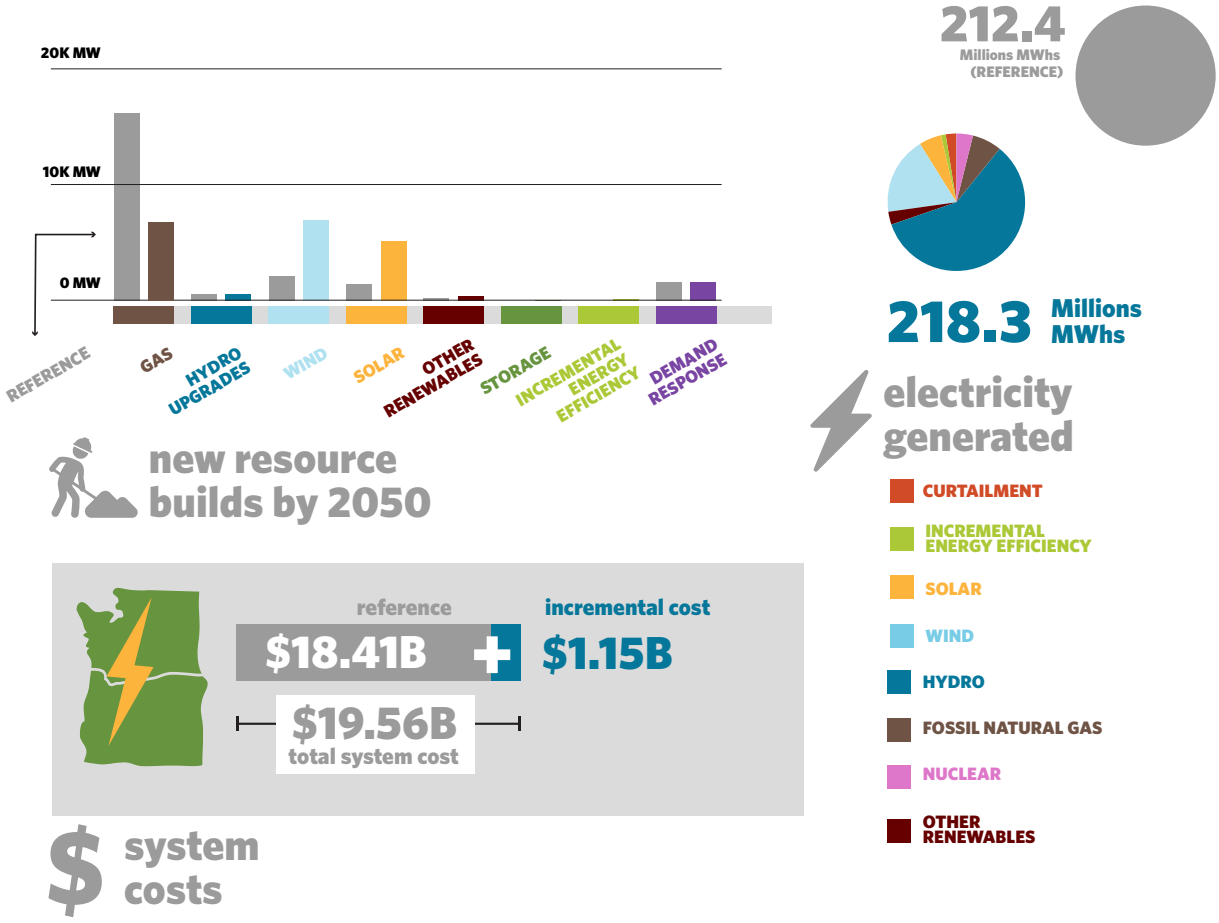
The costs of achieving a fossil-free grid would drop even further to a system cost of $19.7 billion, compared to the reference $18.4 billion. Spread across all the electricity consumed in Washington and Oregon, this translates into a cost of around a $0.006/kwh, making this scenario the most cost-effective pathway modeled in this study.[4]

1 National Renewable Energy Laboratory. *2017 Annual Technology Baseline.* *https://atb.nrel.gov/electricity/2017/*

2 Puget Sound Energy. "2017 PSE Integrated Resource Plan, Appendix M: Wind and Solar Costs." *https://pse.com/aboutpse/EnergySupply/Documents/IRP17_AppM.pdf*

3 *Lazard.* Lazard's *Levelized Cost of Storage Analysis* - Version 3.0. 2017. *https://www.lazard.com/media/450338/lazard-levelized-cost-of-storage-version-30.pdf*

4 With lower battery cost projections, the model relies more heavily on storage as a capacity resource and additional study may be needed to ensure reliability in this scenario.



SCENARIO 3
100% reduction + policy flexibility

Policy flexibility preserves a pathway to 100% fossil-free electricity, while containing costs and providing flexibility for technology advancement.

The final scenario in this study most closely resembles 100% fossil-free policies that the Washington State Legislature considered in the 2018 legislative session. This scenario puts utilities on the pathway to eliminating fossil fuels from the grid by 2050, but provides a cost-containment mechanism of $200 per ton of carbon. If the marginal abatement cost of reducing carbon exceeds $200/ton, the model dispatches fossil fuels instead of selecting a bundle of fossil-free resources with similar characteristics.

This mechanism ensures a minimum level of greenhouse gas reductions, but allows the flexibility for technological advancement that would further reduce emissions. Even using higher clean energy cost assumptions, the 100% scenario with policy flexibility would result in an 83% reduction below 1990 levels in the electric sector, at a cost of approximately a half cent per kWh ($0.005/kwh) if spread across the entire load of Washington and Oregon. Adding flexibility in this scenario preserves a path for achieving a full 100% reduction of carbon emissions by 2050, assuming costs continue to decline at rates similar to the past decade.

Summary and Conclusion

While the U.S. has made gains in transitioning away from coal, our economy is still heavily dependent on fossil fuels. Despite the public's strong desire to transition to fossil-free energy, Washington utilities are currently planning to invest heavily in new gas plants over the next two decades. New gas plants are likely to remain in service for an average life of over 30 years. If fueled by fossil gas, this level of investment could lock Washington in to a greater reliance on fossil fuels, preventing the state from doing its part to achieve the greenhouse gas emissions reductions needed to prevent irreversible damage from climate change.

Studies have consistently demonstrated that in order to achieve 80% greenhouse gas emissions reductions, the electric sector must be nearly 100% fossil-free. E3's new research demonstrates that by building on our base of hydropower, we can achieve a 100% fossil-free grid with minimal impact on electricity bills in the Pacific Northwest. Continuing to rely on fossil fuels poses risks for customers, but declining renewable energy costs, a range of options for new fossil-free generation, and policy flexibility will ensure that customers are protected from risky investments that rely on fossil fuels. We can, and should, put utilities on a pathway to 100% fossil-free electricity now, and avoid investments in resources that don't align with emissions reductions goals. That will allow us to create new demand for technological innovation in the Northwest, to invest in our local communities, and to protect our climate and clean air.