Deep Decarbonization Pathways Analysis for Washington State: Executive Summary

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Context

In 2008, the Washington State Legislature established limits on greenhouse gas emissions in the state, requiring a reduction in GHG emissions to: (1) 1990 levels by 2020; (2) 25 percent below 1990 levels by 2035; and (3) 50 percent below 1990 levels by 2050. The Legislature also required the executive branch to continually recommend adjustments to the limits based on the most recent scientific consensus. Since then, climate science has continued to advance, and the state joined an agreement with other jurisdictions to reduce GHG emissions by 80 to 95 percent below 1990 levels by 2050.[1] In December 2016, the Washington State Department of Ecology recommended to the Legislature that GHG limits now in statute be updated to comparable levels.[2]

Having identified the need to achieve deeper reductions in GHG emissions, the Office of Financial Management and Office of the Governor retained Evolved Energy Research and the Deep Decarbonization Pathways Project (collectively the "study team"), a consortium of energy researchers who have helped jurisdictions around the globe identify practical pathways to reduce GHG emissions, to design and evaluate scenarios that reduce GHG emissions in Washington by 80 percent below 1990 levels by 2050.[3] These scenarios, which we refer to as deep decarbonization pathways, or DDPs, are strategies outlining the size, scope and timing of required changes to the state's energy system from today to 2050. This study is intended to:

(a) support recommended changes in statutory GHG limits
(b) identify policies and investments consistent with adjusted emission limits
(c) facilitate a broader stakeholder discussion

Approach

The study team produced each DDP using EnergyPATHWAYS, a bottom-up energy systems model, to estimate the energy, emissions and cost outcomes that could be realized through 2050. This model is the basis for similar analyses completed at the national level.[4] It was modified to include a detailed representation of the state's energy system, including infrastructure stocks and energy demands for buildings, industry, transportation and the electric power sector. This is supplemented by a representation of energy infrastructure across other states in the western United States to capture petroleum, natural gas, biofuels and electricity imports and exports. EnergyPATHWAYS balances energy supply and demand in each year, and includes an hourly

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1 This agreement is known as the "Under2 MOU."
2 Available at: https://fortress.wa.gov/ecy/publications/documents/1601010.pdf
3 A GHG target of 80 percent below 1990 levels by 2050 results in an emissions budget of 17.7 million metric tons CO_2e ($MMTCO_2e$). In our analysis, we assume that energy-related CO_2 emissions decrease by 86 percent, while nonenergy CO_2 and non-CO_2 GHGs decrease by 50 percent, resulting in an overall 80 percent reduction.
4 For example, see Risky Business Project, *From Risk to Return: Investing in a Clean Energy Economy*, 2016, available at: http://riskybusiness.org/fromrisktoreturn/

electricity dispatch at the regional level (i.e., the Northwest). Although the scenarios are characterized by key differences, they all share several key design principles, including:

(a) the same level of economic activity and demand for energy services
(b) energy infrastructure is replaced at the end of its life (i.e., there are no early retirements or stranded assets)
(c) power system reliability, including resource adequacy and flexibility
(d) limits on the supply of biomass for energy use
(e) constraints on renewable energy and pumped hydro storage resource potential
(f) the use of commercially demonstrated or near-commercial technologies[5]

Key findings

The three scenarios included in the analysis demonstrate that Washington can achieve an 80 percent reduction in GHG emissions below 1990 levels by 2050 using a variety of achievable technologies and approaches. Key findings include:

- Energy efficiency, decarbonization of electricity and switching to electric sources are common strategies. These "three pillars" are present in all pathways for Washington. The energy system transformation from today to 2050 includes: (1) a decline in the energy intensity of gross state product by approximately 70 percent; (2) a decrease in the carbon intensity of electricity generation to near zero; and (3) an increase in the share of energy directly coming from electricity or fuels produced from low-carbon electricity (e.g., hydrogen) from approximately 24 percent today to 50–60 percent in 2050.
- Energy expenditures shift from spending on fossil fuels to up-front capital investments. The physical changes to Washington's energy system entail more spending on energy technologies such as electric vehicles, heat pumps and wind power plants and less on gasoline, natural gas and diesel.
- Passenger transportation is electric in all pathways. Passenger transportation, which is a disproportionate share of the state's current GHG emissions, must shift from internal combustion engine (gasoline) vehicles to a fleet almost entirely composed of electric vehicles by 2050. Achieving the level of consumer adoption to realize this change is critical; innovations such as autonomous vehicle technology may facilitate the transition.
- Despite the current low-carbon electricity system, electricity generation must continue to decarbonize. The Pacific Northwest is endowed with hydroelectric resources that result in a carbon intensity of electricity that is much lower than the U.S. average. However, meeting these GHG targets leaves almost no room for unabated natural gas and coal generation, and necessitates additional wind, solar and other zero-carbon power plants. The hydroelectric fleet is supplemented with additional balancing resources, such as flexible loads and energy storage, to balance this level of inflexible generation.
- Bioenergy resources are valuable and their use depends on electrification policy. Biomass is a key component of deep decarbonization due to its versatility, which allows it to directly replace fossil fuels. However, the supply of biomass with net carbon emissions of zero is limited, and where it's allocated depends on whether buildings in the state are electrified. Electrifying buildings reduces the use of biogas for space heating, which allows scarce biomass resources to be used to decarbonize transportation fuels, such as renewable jet fuel for aviation.

[5] We included technologies that are outside this definition only in our innovation scenario, as described in detail below.

Scenarios

The study team worked in close coordination with state agencies to design three DDP scenarios that include alternative emission reduction strategies and technologies, as well as a reference case reflecting current policy, as summarized in Table 1 below. The electrification pathway requires substantial levels of electrification of vehicles and heating, while the renewable pipeline pathway meets GHG targets by substituting fossil natural gas for decarbonized pipeline gas fuels. The innovation pathway outlines how nascent technologies might facilitate decarbonization. These three DDP cases were purposely designed as "bookend" scenarios to demonstrate multiple, distinctive ways of reducing the state's GHG emissions by 80 percent below 1990 levels by 2050. The robustness of results was prioritized over the design of a single "optimal" scenario.[6]

Table 1 Overview of Scenarios

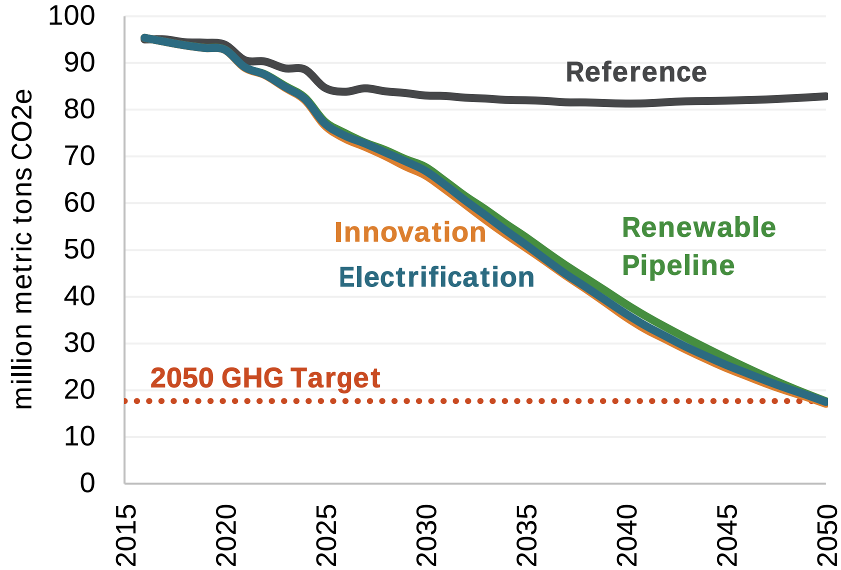
Scenario	Description
Reference	A continuation of current and planned regulations, policies and infrastructure, such as the Clean Air Rule, Renewable Portfolio Standard and Sound Transit 3.
Electrification	A world where emission reductions are realized by electrifying end-uses to the extent possible and significantly reducing pipeline gas consumption in buildings.
Renewable Pipeline	A world where buildings and industry continue to use a large share of pipeline gas, but the pipeline gas supply is decarbonized with a mix of biogas, synthetic natural gas and hydrogen.
Innovation	A world where policies of electrification are pursued and aided by technology breakthroughs in vehicle electrification and hydrogen fuel cells. Shared autonomous electric vehicles compose a large share of light-duty vehicles.

Conclusions

Greenhouse gas emissions – Each of the DDP scenarios achieves an 80 percent reduction in GHG emissions below 1990 levels by 2050, with overall GHG emissions no greater than 17.7 $MMTCO_2e$, as shown in Figure 1 below. This analysis demonstrates that Washington could deeply decarbonize its energy system and achieve the more stringent GHG limits using various mitigation strategies. As reflected in the reference case, GHG emissions are expected to decrease under current policy, with energy-related CO_2 emissions reductions partially offset by growth in nonenergy/non-CO_2 emissions. However, these emissions reductions fall substantially short of both current GHG limits and the deeper reductions considered in this study.

[6] These three DDP scenarios are neither prescriptive nor exhaustive. There are many additional pathways that were not evaluated in our study.

Figure 1. Washington State Greenhouse Gas Emissions (million metric tons CO_2e)



Energy demand – Final energy demand in the pathway cases ranges from 700 trillion to 800 trillion Btu in 2050, which is 35 to 40 percent below today's consumption, as summarized in Table 2.[7] This net decrease is primarily attributable to transitioning to zero emission vehicles and to efficiency improvements in aviation, which results in lower gasoline, diesel and jet fuel demand. A common theme in all pathways is that electricity consumption increases, which is primarily due to electrification of passenger transportation.

Table 2. Washington State Final Energy Demand, Today and 2050 (trillion Btu)

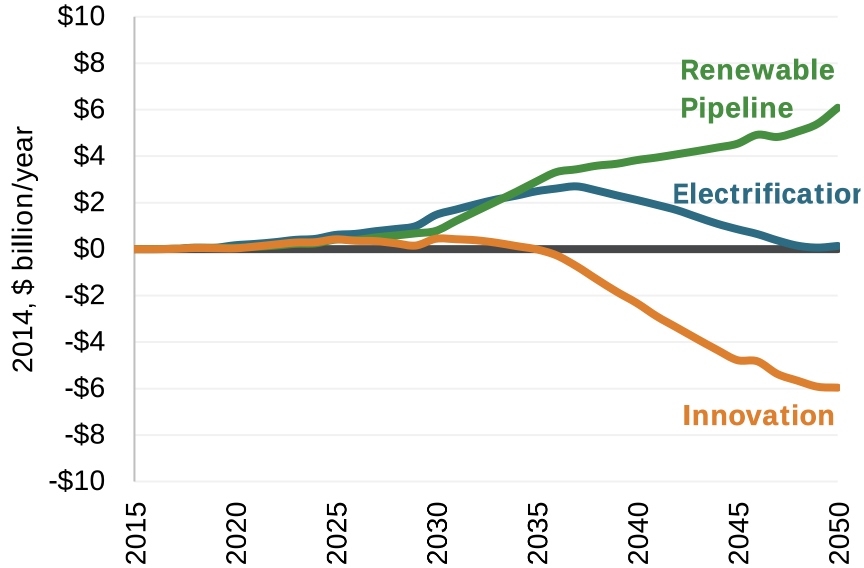
	Today	Electrification	Renewable Pipeline	Innovation
Electricity	300	382	344	384
Pipeline gas	210	95	220	95
Petroleum fuels	608	187	157	152
Liquid hydrogen	0	0	0	14
Other	114	78	79	78
Total	1,232	742	800	723

Costs – The cost of decarbonizing the state's energy system is estimated by comparing the incremental cost of investment in low-carbon and efficient equipment and infrastructure against the savings from avoiding fossil fuel purchases.[8] This net energy system cost metric, which excludes costs outside of the energy system and benefits from avoiding climate change and air pollution, is

[7] Final energy is energy used in the delivery of services such as heating or transportation, which is different from energy consumed in converting to other forms of energy (i.e., natural gas in power plants converted to electricity).
[8] EnergyPATHWAYS estimates the annual cost of producing, distributing and consuming energy ("energy system costs"), which includes components such as power plants, vehicles, water heaters and fossil fuel expenditures. Net energy system cost is the difference between a DDP case and reference case energy system costs.

shown for each pathway in Figure 2. The net cost of achieving reductions is likely to be quite reasonable, ranging from $6 billion of costs to $6 billion of savings in 2050. When compared against the state's projected gross state product, these incremental costs are small (-0.6 percent to 0.6 percent).

Figure 2. Washington State Net Energy System Cost (2014, $ billion/year)



Energy infrastructure and equipment transition – Achieving an 80 percent reduction below 1990 levels by 2050 will require Washington's current energy infrastructure and equipment to be replaced with low-carbon and efficient alternatives over the coming decades. The timing, scale and type of replacements depend on the pathway taken, with some common transitions across pathways, as well as noticeable differences. Figure 3 illustrates this concept by showing when scenarios reach key milestones during the 2025–50 time frame and their maximum potential by 2050. For example, Washington requires 1 million electric vehicles on the road during the 2030–35 time frame under any pathway, but the year when retail electricity sales surpass 100,000 GWh varies by a decade. These study results are intended to inform the policy, investment and planning required to ensure emission reduction objectives are achieved.

Figure 3. Pathways Timing and Scale Comparison

REF Reference | ELE Electrification | RPL Renewable Pipeline | INV Innovation

Sector	Milestone	2025	2030	2035	2040	2045	Maximum potential by 2050
Residential Heating	0.5 million heat pumps	ELE, INV				REF, RPL	ELE, INV 2.1 million
Transportation	1.0 million electric vehicles on the road		ELE, RPL	INV			ELE 3.2 million
Electricity Sector	100,000 GWh of retail electricity sales			INV, ELE		RPL, REF	ELE, INV 112,00 GWh
	15,000 MW of wind and solar installed		ELE, RPL, INV				RPL 33,600 MW
	3,500 MW of new bulk elec. storage			ELE			ELE 4,850 MW
Synthetic Electric Fuels	10,000 GWh consumed			RPL	INV		RPL 35,000 GWh
Pipeline Gas	10 percent decrease in emissions intensity		RPL	ELE	INV		RPL 100 percent
Biofuels Production	5 million barrels of renewable jet fuel				ELE, INV		ELE, INV 8.1 million

Notes: Synthetic electric fuels include hydrogen produced from electrolysis of water and synthetic natural gas produced from hydrogen.