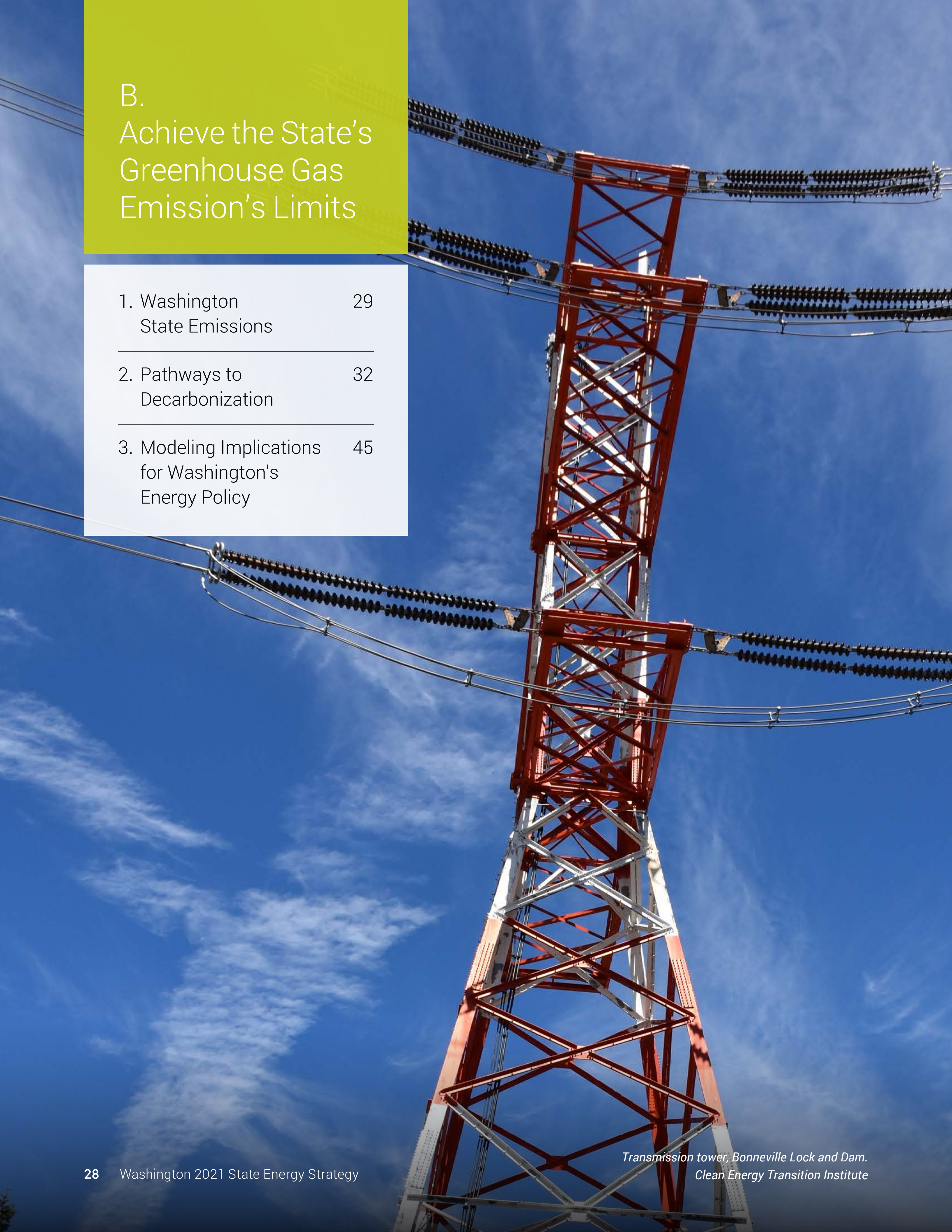
# B.
# Achieve the State's Greenhouse Gas Emission's Limits





*Transmission tower, Bonneville Lock and Dam.*
*Clean Energy Transition Institute*

# B. Achieve the State's Greenhouse Gas Emission's Limits

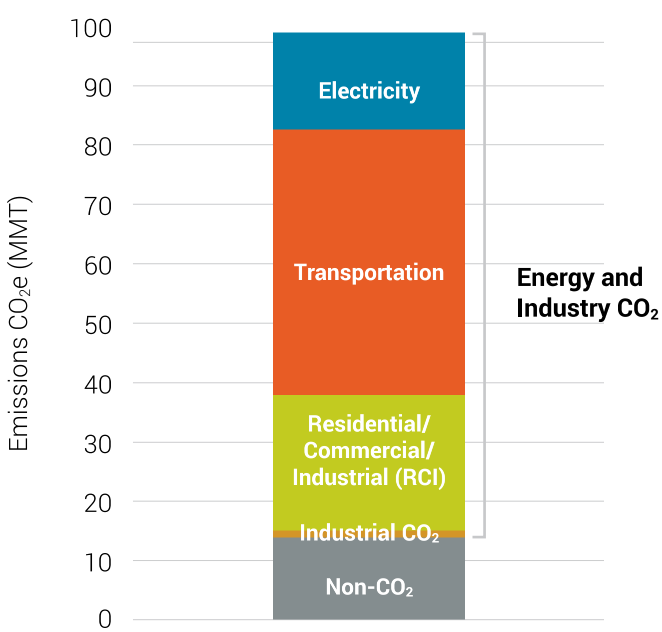
### 1. Washington State Emissions

Washington's residents and businesses were responsible for 98.9 million metric tons of greenhouse gas emissions in 2018, the year of the most recent state emissions inventory. Nearly half (45%) of the emissions were from transportation. The state's transportation emissions approximate the U.S. average per capita: compared to other states, Washingtonians drive slightly less per capita[26] but consume more fuel for freight, air and ship travel.

The reason transportation is dominant in Washington's greenhouse gas emissions profile is due to the state's relatively clean electricity supply. Only 16% of Washington's greenhouse gas emissions in 2018 were from the electricity sector. Buildings and industry comprised nearly a quarter of emissions, and non-energy/non-$CO_2$ emissions were approximately 15%. (See Figure 6.)

Washington's greenhouse gas emissions have grown by roughly 10% since 1990, the baseline year from which to calculate the state's emissions limits. Consequently, the 2030 emissions target of a 45% reduction relative to 1990 translates to a 53% reduction relative to emissions in 2018. (See Figure 8.)

**FIGURE 6. WASHINGTON STATE 2018 GREENHOUSE GAS EMISSIONS INVENTORY BY SECTOR**



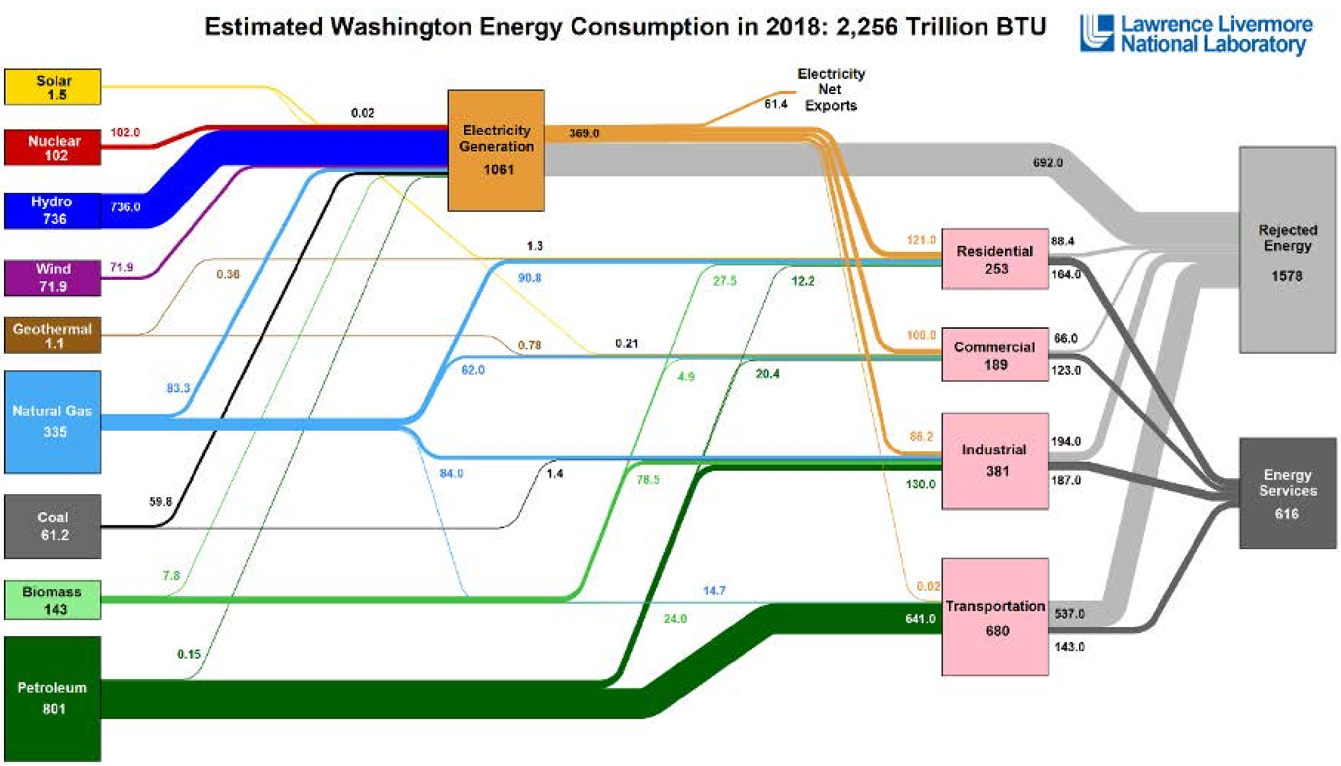

Source: Washington State Department of Ecology Greenhouse Gas Inventory.

[26] U.S. VMT Per Capita By State, 1981-2017," 2019, https://www.enotrans.org/eno-resources/u-s-vmt-per-capita-by-state-1981-2017/.

The state's 2018 emissions result from energy consumption as depicted in Figure 7 below, which shows an estimate of Washington's energy consumption in 2018 using Energy Information Agency data.[27]

> Washington's emissions have grown roughly 10% since 1990, the baseline year from which reductions are calculated.

## FIGURE 7. ESTIMATED WASHINGTON ENERGY CONSUMPTION IN 2018




Source: LLNL June, 2020. Data is based on DOE/EIA SEDS (2019). Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports consumption of renewable resources i.e., hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant heat rate. The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is the estimated as 65% for the residential sector, 65% for the commercial sector, 49% for the industrial sector, and 21% for the transportation sector. Totals may not equal sum of components due to independent Rounding. LLNL-MI-410527.
https://flowcharts.llnl.gov/commodities/energy

[27] "Estimated Washington Energy Consumption in 2018," Lawrence Livermore National Laboratory, accessed December 1, 2020, https://flowcharts.llnl.gov/content/assets/images/charts/Energy/Energy_2018_United-States_WA.png.

## 1.1. Pathway to Zero Net Emissions in 2050

The objectives of the 2021 State Energy Strategy are directly linked to the revised greenhouse gas emissions reductions limits established by the Legislature in 2020. Updating limits set in 2008, the Legislature established ambitious economy-wide goals: a 95% reduction below 1990 levels by 2050, with interim economy-wide emissions limits of 45% below 1990 levels by 2030 and 70% below 1990 levels by 2040.

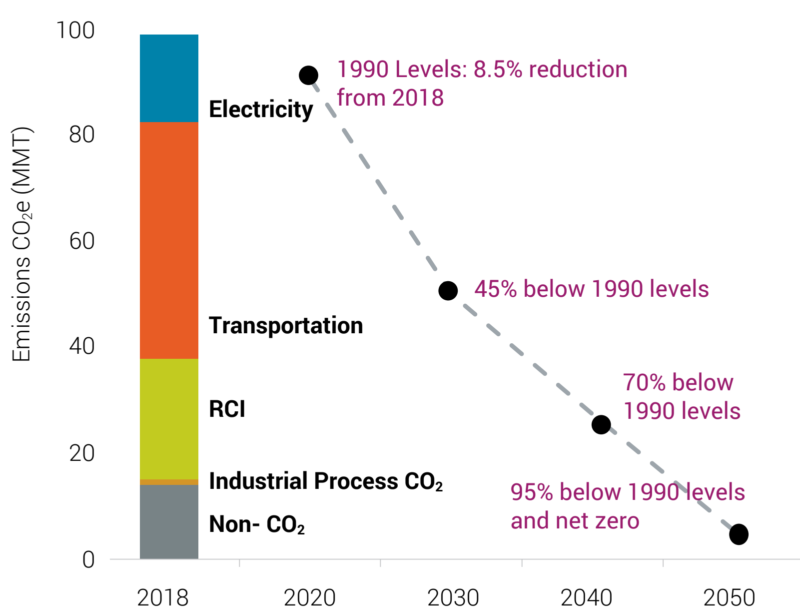
In addition, the state committed to net zero emissions by 2050, which means that the residual 5% (or 5 $MMTCO_2e$) of emissions in 2050 will need to be balanced by an equivalent amount of biological or geological emissions removal from the atmosphere. These limits are established in statute[28] and are based on scientific assessment of the pace of emissions decline needed globally to keep warming to within 1.5 degrees Celsius above pre-industrial levels.

This strategy focuses on the $CO_2$ emissions that result from energy use, but the statewide emissions limits cover all types of greenhouse gas emissions, including non-$CO_2$ emissions, such as methane from agriculture, waste, and natural gas leakage, and perfluorocarbons in aluminum production. While reductions in non-$CO_2$ emissions are possible, the solutions are highly uncertain.

For the purpose of modeling for this strategy, we assume that all of the non-$CO_2$ greenhouse gas emissions in 2050 will be offset by biological or geological sequestration, thereby achieving the net zero limit of state law. This means that, in 2050, energy and industrial $CO_2$ emissions (referred to as energy emissions in the rest of this section) must be zero. This allows for the use of carbon-neutral fuels, including zero net emissions biofuels and synthetic fuels that capture carbon from the atmosphere and release it again. Figure 8 shows the trajectory of limits to be achieved by 2050 based on Washington State's 2018 greenhouse gas emissions.

**FIGURE 8. WASHINGTON STATE 2030-2050 GREENHOUSE GAS EMISSION LIMITS**

(Assumes residual 5% of 1990 emissions remaining in 2050 will be offset by biological or geological sequestration)

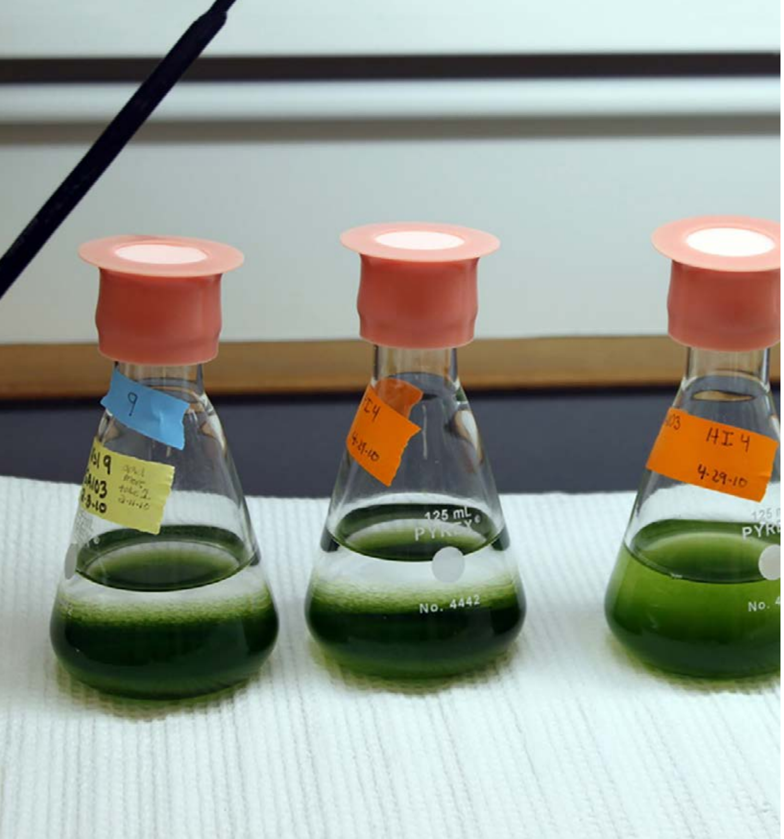



Source: Washington State Department of Ecology and Washington State.[29]

Appendix A –Deep Decarbonization Pathways Modeling Technical Report, December 11, 2020 (p. 15).

[28] Chapter 70A.45.020 RCW.

[29] Chapter 70A.45.020 RCW.



*Beakers with algae used to create biofuels. liloh*

### 1.2. Washington's 2030 Emissions Challenge: Cutting Energy Emissions in Half

Meeting the state's emission reduction limit for 2030 is at least as challenging as reaching the deeper 2050 limit and will require all sectors of the economy to reduce emissions at a rapid pace.

Translated proportionately to the energy emissions, the 2030 limit is equivalent to removing 45 million tons of the 85 million tons of $CO_2$ emitted from energy in 2018. The state starts from a 69% clean electricity grid that contributed 16 million tons of $CO_2$ in 2018. If all electricity emissions were removed, Washington's 2018 emissions would have to drop a further 29 million tons to meet the 2030 state limit.

Additional emission reductions will need to come from measures other than decarbonizing electricity. These measures include electrification and efficiency improvements to energy-using technologies in buildings, transportation and industry and displacing fossil fuel use, primarily in transportation, with clean fuels.

The challenge for Washington will be implementing a decarbonization strategy integrated across all sectors of the economy that reduces energy-related greenhouse gas emissions in half by 10 years.

## 2. Pathways to Decarbonization

To examine potential paths to meet the 2030 and 2050 emissions limits, the Department of Commerce commissioned deep decarbonization pathways modeling. This effort analyzed alternative decarbonization scenarios within a modeling framework to inform the selection of policies and actions to decarbonize the state's energy sector over the coming decades.

Evolved Energy Research conducted this analysis using the EnergyPATHWAYS and RIO modeling suite. Earlier versions of these models supported decarbonization modeling for the region and the state.[30, 31] The modeling for the state energy strategy incorporates current technology and economic data; the state's clean electricity and emissions limits; state and regional assumptions developed in consultation with stakeholders; and a set of scenarios that capture the effect of potential strategies. The full technical report for the 2021 State Energy Strategy deep decarbonization modeling can be found in Appendix A. In this section, we address the modeling's key conclusions.

### 2.1. Decarbonization Scenarios

The deep decarbonization modeling explores one Reference Scenario and five decarbonization scenarios described in Table 2. The results tease out the key opportunities and challenges in decarbonizing all sectors of the energy economy at the pace indicated by the state's emissions limits. All five decarbonization scenarios modeled meet those limits.

[30] "Deep Decarbonization," accessed November 2, 2020, https://www.governor.wa.gov/issues/issues/energy-environment/deep-decarbonization.

[31] Northwest Deep Decarbonization Pathways Study", 2019, accessed December 1, 2020, https://tinyurl.com/y42w3a6v.

## TABLE 2. REFERENCE AND FIVE DECARBONIZATION SCENARIOS ANALYZED

| Scenario | Summary | Key Questions | Policy Mandates |
|---|---|---|---|
| **Reference** | Business as usual | Assumes no emissions target and that current policy is implemented | No constraints on emissions |
| **Electrification** | Investigates a rapid shift to electrified end uses | What if energy systems achieve aggressive electrification and aggressive efficiency, and relatively unconstrained in-state and out-of-state technology were available? | Meets 2050 net zero emissions target |
| **Transport Fuels** | Investigates reaching decarbonization targets with reduced transportation electrification | What alternative investments are needed when larger quantities of primary fuels remain in the economy? | |
| **Gas in Buildings** | Investigates reaching decarbonization targets by retaining gas use in buildings | What is the difference in the cost of decarbonization if gas appliances are retained in buildings? | |
| **Constrained Resources** | Investigates a future that limits potential for transmission expansion into Washington | What alternative investments in in-state resources would Washington make if transmission expansion is limited due to siting/permitting challenges? | |
| **Behavior Changes** | Investigates how lower service demands could impact decarbonization | What if policy-driven or natural behavior changes (i.e., more telecommuting post COVID-19) lower service demands? | |

Source: Appendix A – Deep Decarbonization Pathways Modeling Report, December 11, 2020 (p. 21).

In each decarbonization scenario, the model finds the lowest cost way of supplying energy to meet the 2030 and 2050 emissions limits. Technology costs are based on the best publicly available projections. Actions to reduce emissions cross the sectors of the economy. Comparing the scenarios provides useful information about the best strategies for decarbonization, targeting the lowest cost actions first. Projected Reference Scenario emissions from energy use and the energy emissions limits for the decarbonization scenarios are shown in Figure 9.

The Reference Scenario reflects future developments consistent with the U.S. Department of Energy's Annual Energy Outlook's Reference Scenario, as well as current policy in the region. For example, the state's 100% clean electricity law (CETA) is reflected in the Reference Scenario. Even with the elimination of emissions from electricity under CETA, Washington's overall emissions do not decrease in the Reference Case because without new policies fossil fuel consumption will increase as fast as the electricity sector phases out fossil fuels.

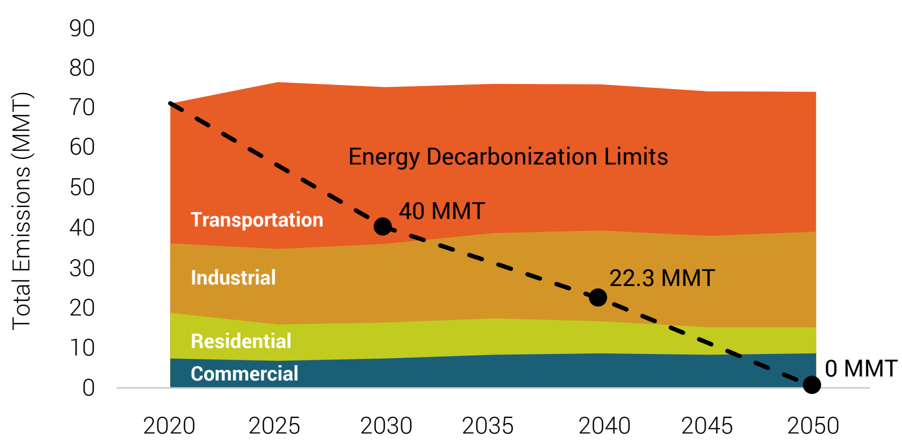
The decarbonization scenarios investigate different pathways toward reaching the state's greenhouse gas emission limits, with each scenario reflecting different policy priorities and/or uncertainties in future outcomes. Comparisons between and among the different investments and overall costs of decarbonizing the economy in each scenario inform the policy choices in the 2021 State Energy Strategy.

The Electrification Scenario explores the impacts of a rapid shift to electrified end uses. The Transport Fuels Scenario models a slower transition to electrification in transportation, either due to policy driving a more gradual shift, or because of slower than expected electric vehicle adoption.

The Gas in Buildings Scenario models a future where demand for gas in the built environment, such as for heating and cooking, remains through 2050. Gas supplied through the pipeline can include a blend of different types of gas. This blend is referred to as "pipeline gas" throughout the remainder of the strategy. Pipeline gas can be partially or even fully decarbonized by replacing fossil gas with cleaner alternatives such as biogas, synthetic gas or hydrogen.

The Constrained Resources Scenario models the impact if Washington were unable to expand transmission interties to other states. Finally, the Behavior Change Scenario evaluates the impact of consumer choices to decrease their energy consumption by driving less and reducing their demand for energy services in buildings.[32]

## FIGURE 9. WASHINGTON STATE TRAJECTORY TO 2050, BY ENERGY CONSUMPTION IN EACH SECTOR




Source: Appendix A – Washington State Energy Decarbonization Modeling 2020, Evolved Energy Research (p.17).

[32] For the assumptions behind all six scenarios, please see Appendix A – Deep Decarbonization Modeling Technical Report, December 11, 2020. Appendix B – Data accompanying Deep Decarbonization Modeling Technical Report, December 11, 2020.

## 2.2. Changes in Energy Demand

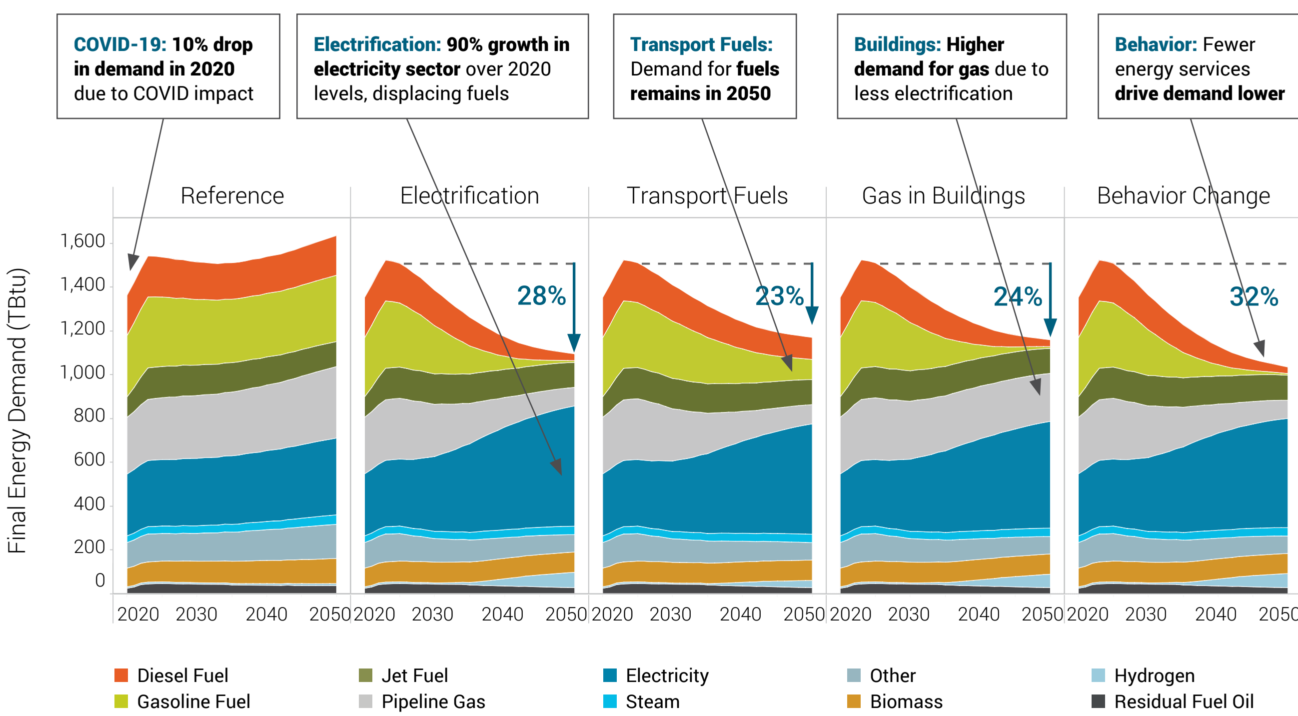
In all five decarbonization scenarios, electrification and efficiency drive lower total final energy demand than in the Reference Scenario, where energy demand in 2050 increases by 6% relative to 2023, the year we assume the economy has recovered from the COVID-19 pandemic (see Figure 10). In all scenarios other than Behavior Change, customers have the same demand for energy services. For example, they heat their homes to the same temperature and drive the same number of miles.

Final energy demand varies because of differences in the energy efficiency of the different types of equipment customers can use to provide these services. For example, a battery electric vehicle requires less energy per mile than an internal combustion engine fueled by gasoline.

However, improvements in efficiency cannot happen overnight. Retiring existing equipment — a late model gasoline vehicle for example — is expensive. Replacing equipment on that scale would be infeasible all at once. Therefore, we assume, conservatively, that customers invest in more efficient equipment only at the end of the useful life of their existing equipment, a time when they would have bought new equipment anyway. The total stocks of equipment in homes, businesses and on the road is of varying age at any given time. It takes time to roll over total stocks of equipment to more efficient and cleaner versions.

Using energy more efficiently through electrification and other measures reduces overall demand and the investment needed in energy supply infrastructure and fuels. The costs of the new equipment necessary to lower final

### FIGURE 10. FINAL ENERGY DEMAND 2020-2050




Source: Appendix A – Deep Decarbonization Pathways Modeling Report, December 11, 2020 (p. 28).

energy demand is likely greater than the cost of less efficient equipment. However, reducing supply infrastructure and fuel investments saves money. How a scenario compares in total cost to any other depends on its relative demand- and supply-side costs. Differences in the pace of electrifying transportation accounts for the largest differences in demand across all the scenarios.[33]

In the Electrification Scenario, total energy demand drops 28%. Electricity demand grows 90% over 2020 levels by 2050, displacing fossil fuels in buildings and transportation through assumptions that drive replacement of existing equipment with electrified appliances and vehicles at the end of their useful lives. The Constrained Resources Scenario shares the same final energy demand as the Electrification Scenario and is therefore not shown in Figure 10.

Total energy demand drops the least in the Transport Fuels Scenario (23%). Demand for fuels is still significant in 2050 because greater numbers of internal combustion engines will remain on the roads. These vehicles have lower energy efficiency than electric alternatives.

The Gas in Buildings Scenario sees a 24% drop in total energy demand by 2050. In contrast to the Electrification Scenario, customers replace gas-consuming appliances with more efficient modern gas appliances.

The Behavior Change Scenario achieves the greatest drop in demand for energy (32%) with less use of the services that energy provides in transport and buildings. This scenario illustrates the benefits if policy makers act to encourage driving cars less and using fewer energy services in buildings. As we will see, achieving the levels of electrification required to hit the 2030 emission reduction limit presents several technical and economic challenges.

> Greater interconnection among the 11 Western states is a key part of all scenarios and points to the importance of expanded regional coordination and transmission to lower overall decarbonization costs.

This puts an even finer point on the need to encourage less energy use wherever possible.

## 2.3. Modeling the Supply Side

The previous section presents the demands for energy in Washington with different assumptions about the types of equipment customers would adopt on the demand side. The next step of the modeling determined the least-cost way of providing that energy through investments in and operations of Washington's energy supply. This includes the infrastructure to produce, store and transport fuels and electricity.

Section 1.2 introduced the challenge of reducing emissions by 2030. The relatively small amount of emissions from electricity in Washington means that if we were to decarbonize all electricity production, additional emissions reductions in other forms of energy use would still be needed. By 2030, the system will look different, depending on the scenario, as described in the previous section.

Adopting electrified energy uses and more efficient equipment means electricity demand will increase as a share of the total demand, but overall total energy demand will be less. Due to the limits on how fast equipment can be replaced with these more efficient options, reaching the target also requires reducing emissions by using clean fuels. Clean fuels in this section refers to fuels produced from biogenic feedstocks (biofuels) and fuels derived from hydrogen production through electrolysis (synthetic fuels), including hydrogen itself.

This section explores these two top-line strategies in energy supply:

1. Building a clean electricity sector to supply expanding electric loads
2. Decarbonizing fuels to meet the short-term emission limits

### *2.3.1. Building a Clean Electricity Sector to Supply Expanding Electric Loads*

Total demand for electricity nearly doubles by 2050 in the Electrification Scenario and expands significantly in the other scenarios. Supplying this electricity from clean

[33] See Appendix A – Deep Decarbonization Modeling Technical Report, p. 29

electricity sources is cheaper than other alternatives, such as decarbonizing fuels. Washington's electricity supply is already 69% clean because of the state's significant hydro resource, however we assume there is no opportunity to expand hydroelectricity supply in the future, so wind and solar resources provide the additional energy needed.

In 2020, Washington is a net exporter of energy. As renewable generation fills the state's additional energy needs, Washington becomes a net importer, bringing in 43% of its electricity by 2050 in the Electrification Scenario, 36% of which comes from Montana and Wyoming wind. To understand where imports into Washington derive from throughout the West, please see page 39 of the technical report in Appendix A. The lower relative cost of these out-of-state resources versus in-state opportunities limits the growth of new renewable capacity in state until 2040 when Washington starts to build solar and offshore wind.[34]

Quantities of resources built in Washington are relatively similar across the decarbonization scenarios with the exception of the Constrained Resources Scenario. By constraining transmission expansion into Washington, more clean electricity must come from in-state resources. Prior to 2040, electricity needs are largely met with increased imports of renewable energy from other states as in the other decarbonization scenarios. However, in 2040 to 2050, significantly more in-state solar and offshore wind are built as the capacity to import more from elsewhere is exhausted. In-state solar capacity in 2050 is 18 GW versus 12 GW in the Electrification Scenario, and offshore wind capacity is 10 GW versus 4 GW in the Electrification Scenario.[35]

In all decarbonization scenarios, wind is the dominant form of energy in the Western U.S. by 2050, followed by solar. This drives expansion of transmission across the West to take advantage of both renewable and geographic resource diversity. Northwest wind and Southwest solar are relatively complementary resources, and energy flows across the West increase to take advantage of this diversity to lower total system costs. Greater interconnection among the 11 Western states is a key part of all scenarios and points to the importance of expanded regional coordination and transmission to lower overall decarbonization costs. Six GW of new transmission (the maximum permitted in the model) are added between Montana and Washington and 5 GW between Idaho and Washington by 2050.[36]

*Wind turbines seen from Steptoe Butte State Park, WA.*

Part of the increase in electric loads in all scenarios comes from new flexible loads, including from electrolysis and electric boilers. Synthetic fuels derived from hydrogen, such as clean diesel, gasoline and jet fuel, can be cheaply stored. This allows electrolysis loads to ramp up during periods of plentiful renewable energy production and reduce or go offline during times of lower renewable output. This novel, large flexible load helps balance the grid and shore up reliability.

[34] Ibid, p. 29.

[35] Ibid, p. 36.

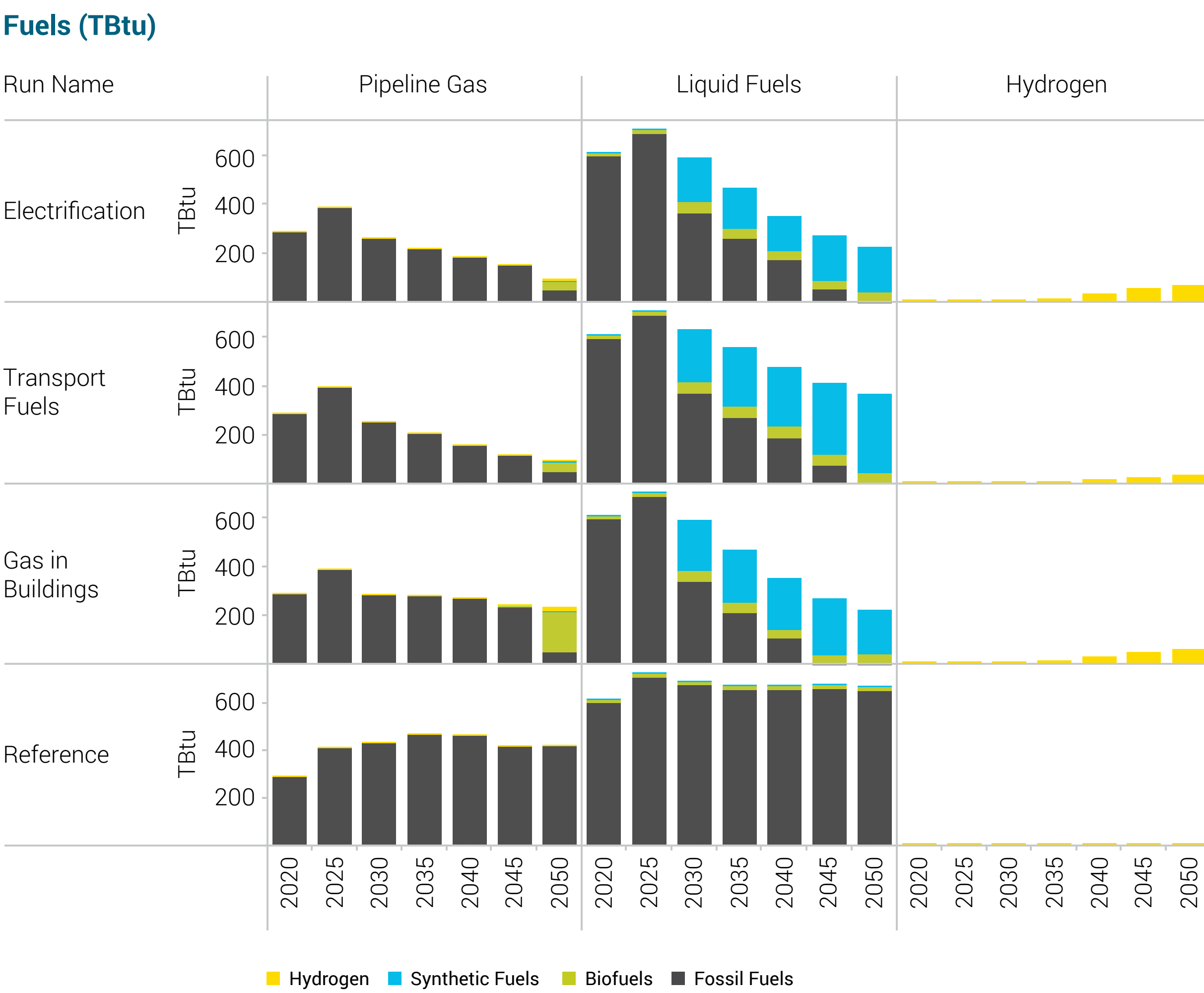
[36] Ibid, p. 40.

*2.3.2. Decarbonizing Fuels to Meeting the Emissions Limits*

Another critical finding is the importance of clean fuels to achieving the 2030 and 2050 greenhouse gas reduction limits. In all decarbonization scenarios, liquid fuels are not eliminated, but they are fully decarbonized by 2050 with a combination of synthetic fuels, biofuels and hydrogen. These fuels are produced using renewable electricity, biomass or other biogenic feedstocks and, in some cases, carbon captured from industrial processes. Clean fuels substitute for fossil-based gasoline, diesel and jet fuel.

The need for clean liquid fuels to meet the 2030 emissions limits is driven in part by restrictions on the rate at which the transportation fleet can be converted to battery electric or hydrogen vehicles and the rate that end uses in buildings can be electrified. The 2030 limit requires significant expansion of the clean fuels industry to reduce emissions from transportation. Figure 11 shows how fossil fuels are decarbonized in three of the decarbonization scenarios compared to the Reference Scenario.

## FIGURE 11. CLEAN FUELS ARE IMPORTANT TO REACH DECARBONIZATION LIMITS




Source: Appendix A – Deep Decarbonization Pathways Modeling Report, December 11, 2020 (p. 42).

## 2.4. Costs and Benefits of Decarbonization

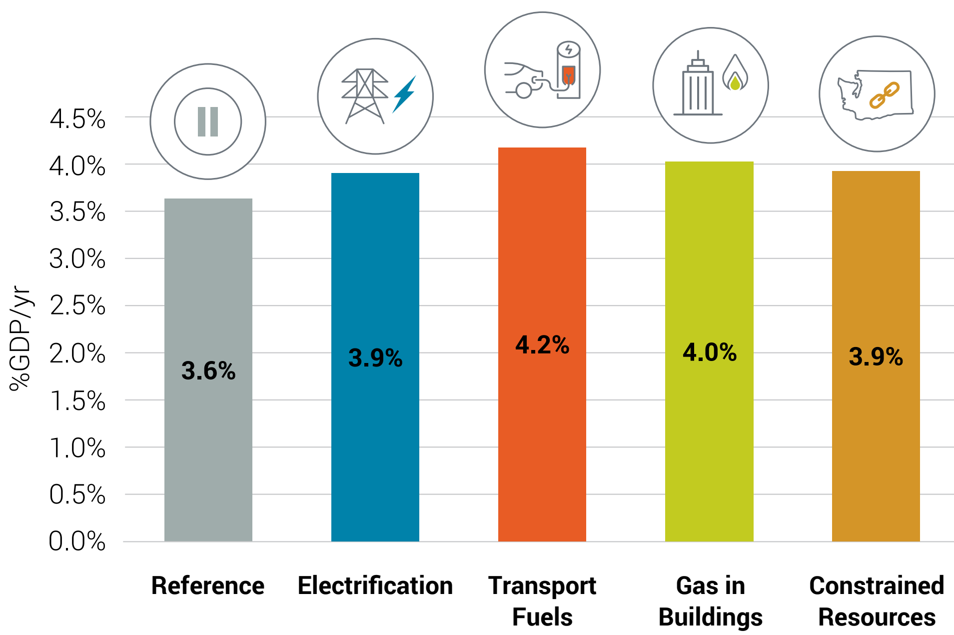
Energy costs include investments in supply-side equipment, such as wind and gas turbines, transmission and clean fuels production infrastructure, and operating costs of the equipment, such as operations and maintenance and fuel. In the decarbonization scenarios, energy costs also include investments in more efficient or electrified demand-side equipment, such as electric vehicles and heat pumps.

The costs of decarbonization include investments in these categories that are greater than in the Reference Scenario. For example, expanding the electricity sector with rapid electrification of end uses requires more investment than in the Reference Scenario, where loads stay relatively consistent.

Additional equipment costs for decarbonization are largely offset by savings from the avoided purchase of fossil fuels. The decarbonization costs are the net difference in costs between the decarbonization scenarios and the Reference Scenario. There are additional costs and benefits not included in this calculation — the analysis considers only direct infrastructure and operating costs and does not include other categories, such as growth in jobs. Health benefits to Washington residents from improved air quality are also not included in these totals.

Annual energy spending[37] as a percentage of GDP averaged over the 30-year period from 2020 to 2050 is only slightly higher than the Reference Scenario for the decarbonization scenarios as Figure 12 shows. Rapid electrification and efficiency measures, transmission expansion and access to out-of-state resources achieve the lowest costs in the Electrification Scenario.

### FIGURE 12. AVERAGE ANNUAL ENERGY EXPENDITURE (%GDP/YR)




Source: Appendix A – Deep Decarbonization Pathways Modeling Report, December 11, 2020 (p. 52).

[37] Annual energy spending is reported in this section as the levelized investment in infrastructure plus operating costs, such as for fuels and operations and maintenance.

The Transport Fuels Scenario, where fewer vehicles are electrified or transition to hydrogen, requires more clean fuels, which drives higher costs. But the slower transition to EVs means fewer demand-side equipment costs. Not pursuing building electrification in the Gas in Buildings Scenario avoids investments in electricity distribution but relies on higher consumption of more costly clean fuels. Leaving gas in buildings in the short term will require even more clean fuel investment in the future.

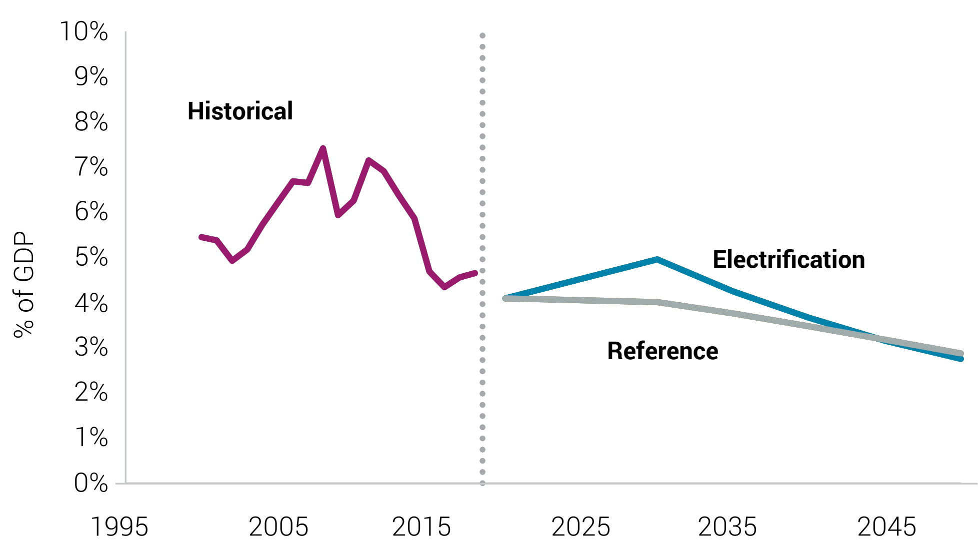
The Constrained Resources Scenario yields cost results that are approximately the same as the Electrification Scenario, albeit with different investments in different locations. The Electrification Scenario invests in new transmission capacity to access high-quality wind and solar resources in other states. The Constrained Resources Scenario invests less in transmission but spends more to build renewable resources in and off-shore from Washington.

Even in the Constrained Resources Scenario, Washington relies on large quantities of imported energy. Based on forecasted prices additional investments in offshore wind in 2045 and 2050 are reasonably competitive against out-of-state onshore wind and the investment in transmission to access it.

### 2.4.1. Decarbonization Spending across the Scenarios

Net direct economic benefits exceed costs by the 2040s relative to the Reference Scenario, based on the assumed resource prices used in the model. Decarbonization requires a significant investment between 2020 and 2030 to reach the stringent 2030 emissions reductions target, but energy spending in the lowest cost Electrification Scenario drops below the Reference Scenario in the 2040s (Figure 13).

## FIGURE 13. TOTAL LEVELIZED ENERGY SYSTEM COST AS A PERCENTAGE OF WASHINGTON GDP RELATIVE TO HISTORICAL



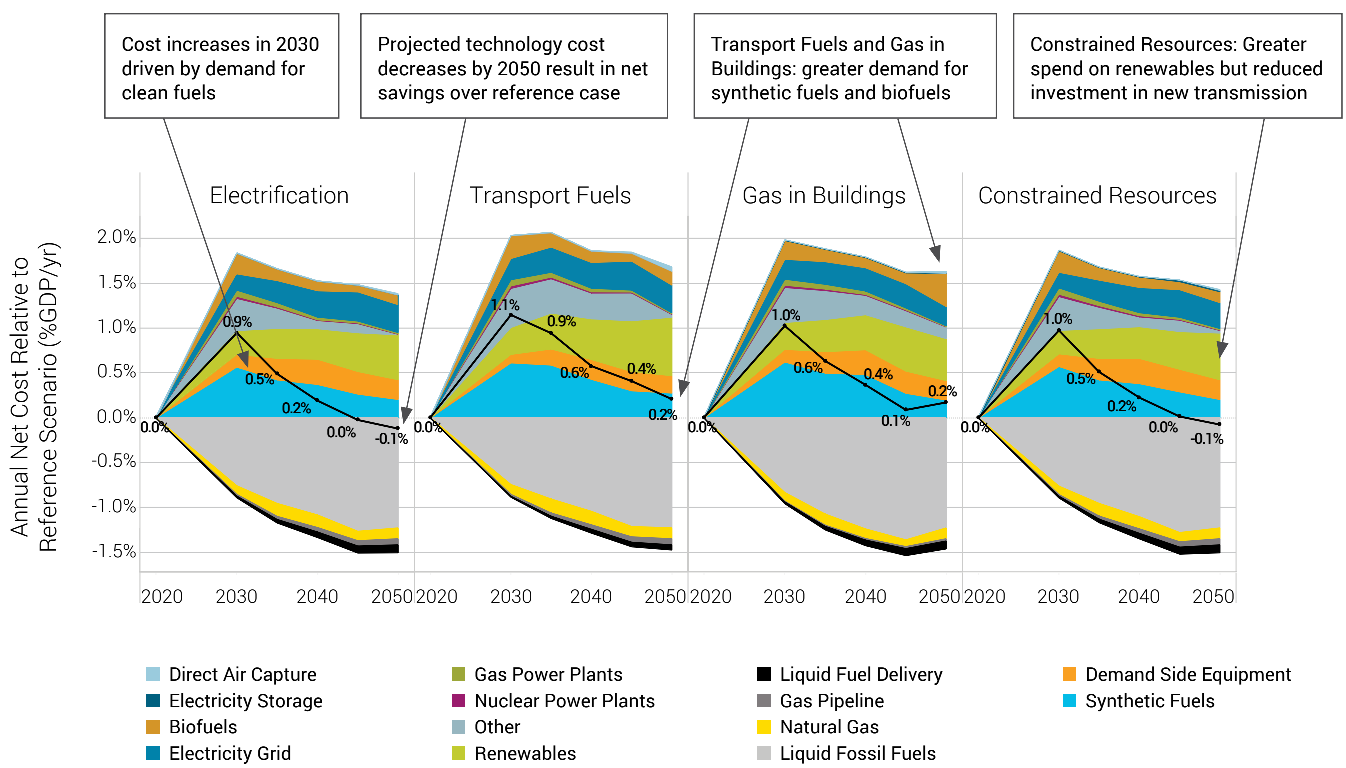

Source: Appendix A – Deep Decarbonization Pathways Modeling Report, December 11, 2020 (p. 55).

Demand for clean fuels drives cost increases in the short term, but the projected decrease in decarbonization technology costs results in savings over the Reference Scenario in 2050 as seen in Figure 14. Decarbonization costs are projected to remain below the historical average of energy spending.

The economy is forecasted to grow at a faster rate than energy consumption between 2020 and 2050 lowering energy costs as a share of total GDP. Price spikes in energy spending in the last two decades are caused by fuel price volatility and the 2008-2009 recession. Decarbonizing the economy acts as a hedge against future fuel price volatility by reducing the fraction of energy spending on fossil fuel imports and therefore reducing exposure.

> Clean fuels are the key to achieving the 2030 and 2050 greenhouse gas reduction limits. The rate at which vehicles can be converted to battery electric and building energy usage can be electrified is the critical factor.

## FIGURE 14. COST COMPONENTS OF DECARBONIZING RELATIVE TO REFERENCE SCENARIO




Source: Appendix A – Deep Decarbonization Pathways Modeling Report, December 11, 2020 (p. 54).

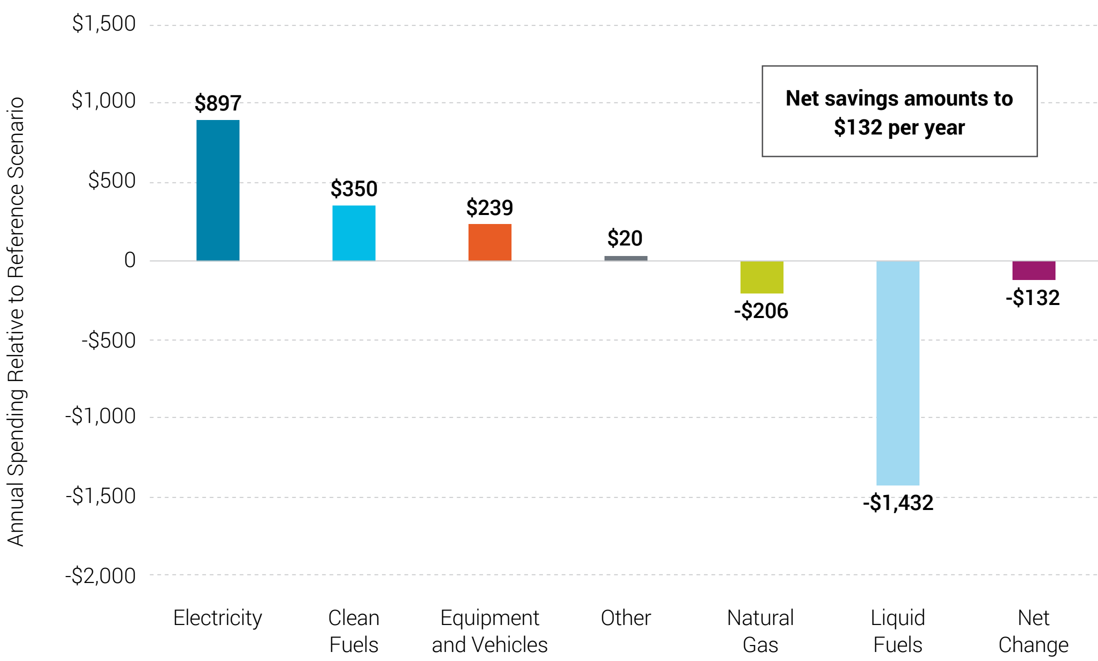
Relative to the Electrification Scenario, spending in the other decarbonization scenarios is higher, as shown in Figure 15. Retaining fuel use in transportation or in buildings requires greater investment in clean fuel production, which is more costly than the electrification of end uses in the Electrification Scenario. Restricting the expansion of Washington's interties in the Constrained Resources Scenario is also more expensive.

The Behavior Change Scenario points to significant savings with actions that incentivize people to use less energy. Behavior changes might include choosing housing with a shorter commute distance or operating a building at a lower thermostat setting. However, a lack of information about the costs to achieve changes in behavior hampers full understanding of the savings. It is recommended that the state further study options for cost-effective behavioral measures that would decrease demand for energy.[38]

On a per capita basis, by 2050 the Electrification Scenario would save the average energy customer in Washington approximately $132 per year, and the Constrained Resources would save about $83 per year, as seen in Figure 15, based on forecasted technology costs and fuel prices.

The costs reported above include investments in energy demand and supply-side equipment, fuels and other operating costs. Beyond these direct costs, Washington will experience benefits from decarbonization, including reduced impacts from the changing climate if the rest of the world also decarbonizes and improved air quality.[39] Displacing fossil power generation with renewables and electrifying the vehicle fleet both contribute to cleaner air for Washingtonians.

## FIGURE 15. CHANGE IN AVERAGE SPENDING PER PERSON IN THE ELECTRIFICATION SCENARIO (2050)




Source: Appendix E – Economic Impacts of Decarbonization Modeling, December 31, 2020 (p. 16).

[38] Ibid, p. 57.

[39] Global Co-Benefits of Decarbonisation" (University of Cambridge, Centre for Climate Change Mitigation Research), accessed November 30, 2020, https://www.4cmr.group.cam.ac.uk/filecab/global-co-benefits.pdf.

Figure 16 summarizes the air quality improvements associated with decarbonization from 2020 compared to 2050, which include elimination of mercury emissions and over 90% reductions in nitrogen ($NO_x$) and sulfur dioxide ($SO_2$) emissions from power generation, as well as significant reductions in particulate matter and $NO_x$ emissions from transportation.

Figure 17 shows how decarbonization would greatly improve Washington's air quality.

> Significant savings in both emissions and costs could occur if people were incentivized to use less energy.


*EV charging station. stanvpetersen*

## FIGURE 16. SUMMARY OF WASHINGTON AIR QUALITY IMPROVEMENTS FROM DECARBONIZATION

| Sector Source | Pollutant | Emissions in 2020 | Emissions in 2050 | Percent Change |
|---|---|---|---|---|
| Power Generation | Mercury (kilograms) | 21.1 | 0.0 | -100.0% |
| Power Generation | $NO_x$[40] (metric tons) | 8.959 | 0.739 | -91.8% |
| Power Generation | $SO_2$[41] (metric tons) | 8.985 | 0.024 | -99.7% |
| Transportation | $PM_{2.5}$[42] (metric tons) | 0.635 | 0.354 | -44.2% |
| Transportation | $NO_x$ (metric tons) | 21.839 | 10.165 | -53.5% |

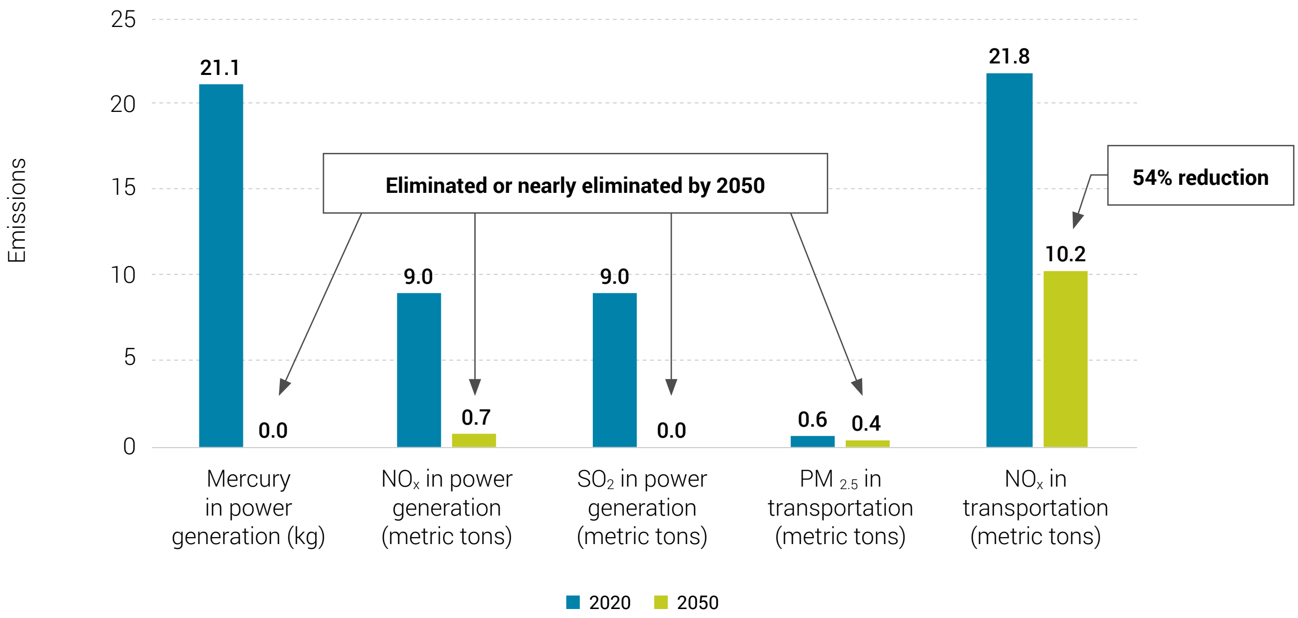
Source: Appendix E – Economic Impacts of Decarbonization Modeling, December 31, 2020 (p. 17).

[40] Various nitrogen oxides, which have negative respiratory and cardiovascular effects.

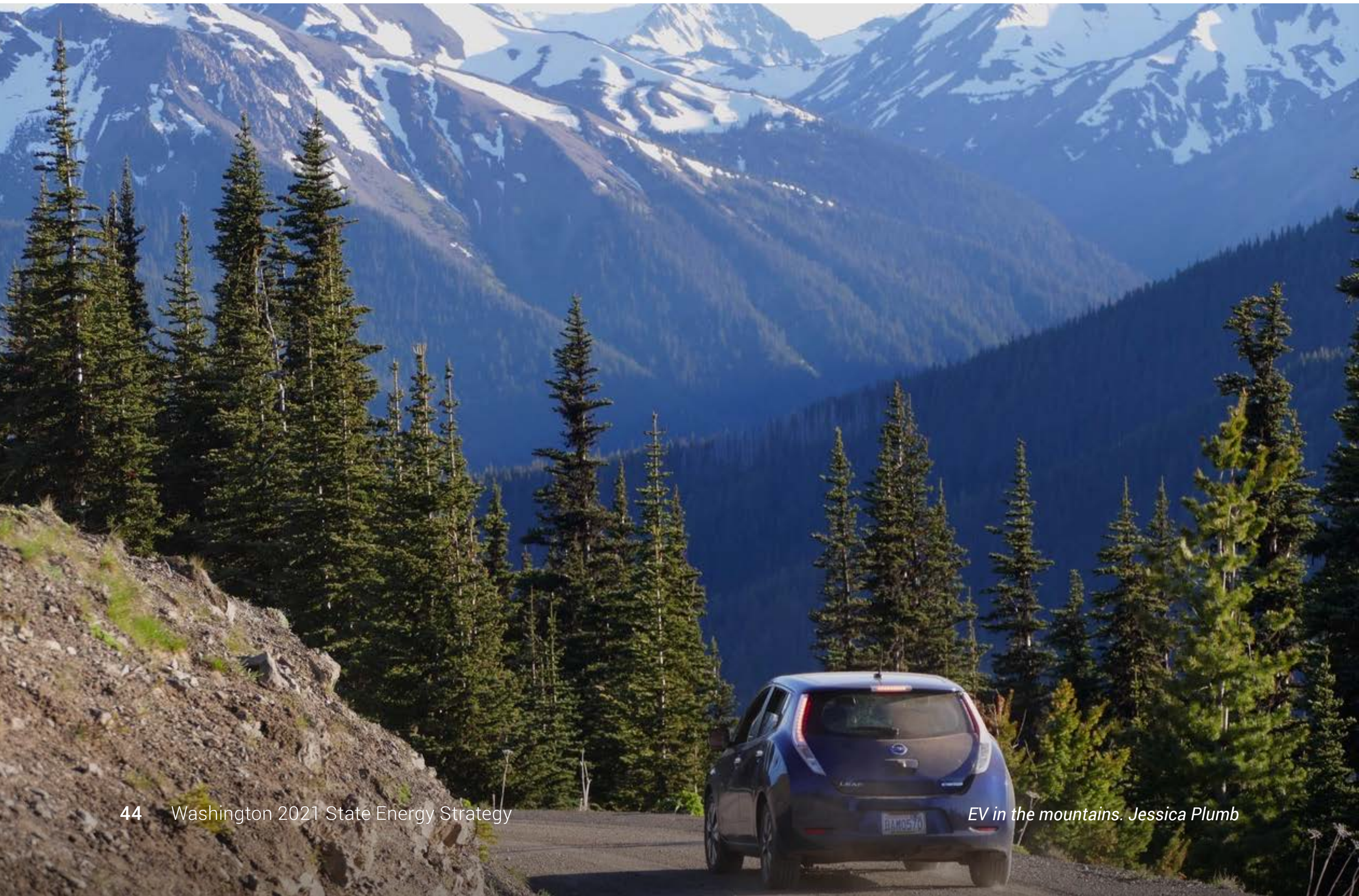
[41] Sulfur dioxide, which has negative respiratory effects and is a component of acid rain.

[42] Particulate matter generally smaller than 2.5 micrometers, which can cause lung and cardiovascular disease.

## FIGURE 17. DECARBONIZATION GREATLY IMPROVES WASHINGTON'S AIR QUALITY




Source: Appendix E – Economic Impacts of Decarbonization Modeling, December 31, 2020 (p. 18).



*EV in the mountains. Jessica Plumb*

*2.4.2. Addressing Uncertainties*

The costs and benefits presented here are subject to the uncertainties inherent in future technology price forecasts, fuel price forecasts, technology availability and many other factors. Uncertainty increases further into the future and the cost of decarbonization is more sensitive to some costs than others.

For example, electric vehicle forecasts have one of the largest impacts on decarbonization costs. Vehicles are the largest energy-consuming infrastructure purchase that many customers and businesses make. Small changes in vehicle cost projections have large impacts on forecasted decarbonization costs. A 10% change in electric vehicle prices impacts decarbonization costs by 0.25% of GDP in 2030 and 0.2% of GDP in 2050. In recent years, forecasts for electric vehicle costs have dropped year to year. If this trend continues and electric vehicles are cheaper in the future than current forecasts suggest, total decarbonization costs will be reduced.

## 3. Modeling Implications for Washington's Energy Policy

The modeling offers insights for pathways to achieve the state's emissions reductions limits. Meeting these limits will require a clean electricity grid by 2030, doubling down on energy efficiency to reduce energy use and electrifying as many energy end uses as practical. These actions alone do not achieve the 2030 emissions target in any of the modeled scenarios. To further reduce emissions and meet the limits, clean fuels must displace a portion of fossil fuel use in the economy.

Energy efficiency and electrification require significant investments in new technology and infrastructure. They are dependent on customers replacing inefficient appliances, processes and vehicles with efficient or electrified options.

The process of replacing technologies, such as appliances and vehicles, takes time and meanwhile cleaner fuels will reduce emissions from gasoline and diesel vehicles that remain on the road. Accelerating development of a clean fuels industry in the next 10 years is critical to meeting Washington's 2030 limits. In the Electrification Scenario, by 2030 a third of all liquid fuels in Washington are from clean sources, either bio or synthetic replacements for conventional fossil fuels.

> Accelerating development of a clean fuels industry in the next 10 years is critical to meeting Washington's 2030 limits.

In the longer run, as more of the vehicle fleet electrifies, clean fuels may play a diminished role in decarbonization in Washington but will remain key to decarbonizing air travel and other applications where electrification is more challenging.

Additional sector-specific insights from the modeling include:

### 3.1. Transportation Sector-Specific Results

Key conclusions from the modeling regarding the transportation sector are:

- The Transport Fuels Scenario with lower levels of transport electrification is more costly than the Electrification Scenario with higher levels of transport electrification. Pursuing faster rates of transportation electrification should lower the cost of meeting the state's greenhouse gas limits.
- While electrifying passenger vehicles is a cost-effective strategy to achieve economy-wide net zero emissions by 2050 and helps reduce the need to invest in clean energy technologies for economy-wide decarbonization, demand for fuels remains high in 2030 even in the Electrification Scenario. In 2030, 73% of vehicles on the road are still internal combustion engines using gasoline in the Electrification Scenario. This is because it takes time for long-lived assets, such as cars and trucks, to come to the end of their useful lives and be replaced by new electric vehicles.[43]

[43] Appendix A – Deep Decarbonization Modeling Technical Report, December 11, 2020, p. 30.

*Insulation worker.*

- For heavy-duty trucks, we assume demand for hydrogen for long-distance hauling by 2050, including electric trucks. This drives the need for hydrogen refueling and delivery infrastructure. Whether hydrogen fuel cells are favored for some transportation applications in the future will depend on the relative development of propulsion technologies. For short-haul trucks, we assume a transition to 100% electric.[44]

#### *3.1.1. Implications for State Energy Policy*

- Transportation electrification is key to cost effectively decarbonize Washington's economy. The sooner the state can electrify vehicles, the greater the avoided investment in more expensive clean fuels, including their associated infrastructure and feedstocks. The more the state can reduce VMT and encourage sustainable mobility, the less scale will be required in expanding the clean fuels industry, which is still in early stages of development. Taking early action now to reduce the 2030 need for clean fuels has significant cost benefits. Costs are on average 0.2% lower as a percentage of GDP in the Electrification Scenario than in the Transport Fuels Scenario, where less electrification is achieved.
- Because there are fewer current low-carbon alternatives for aviation — electrification technology is still nascent — clean fuel production for air travel could provide both a near-term and long-term strategy, given that significant demand for jet fuel is likely to remain through 2050.

### 3.2. Building Sector-Specific Results

Key conclusions from the modeling regarding the building sector are:

- The Gas in Buildings Scenario is more costly than the Electrification Scenario in 2030 and beyond, particularly when approaching net zero emissions in 2050. This is because greater quantities of clean fuels are required to offset the emissions from gas in the Gas in Buildings Scenario. The cost of those additional clean fuels is higher than the cost of the electrification measures in the Electrification Scenario.
- Decarbonizing liquid fuels rather than pipeline gas is more cost effective because fossil liquid fuels are more costly. This means higher savings from clean liquid fuels alternatives.
- Building electrification and efficiency measures drive a 26% reduction in final energy demand in the Electrification Scenario and a 13% reduction in the Gas in Buildings Scenario versus the Reference Scenario in 2050 in the building sector. However, the pace of stock rollover to new efficient technologies limits action by 2030, with reductions of 6.5% in final energy demand in the Electrification Scenario and 3.5% in the Gas in Buildings Scenario versus the Reference Scenario in the building sector.

#### *3.2.1. Implications for State Energy Policy*

- Converting building end uses to electricity is less expensive and more energy efficient than a strategy focused on creating synthetic pipeline gas, even if buildings convert to high-efficiency gas equipment. To decarbonize the economy while retaining fossil gas use in buildings, clean gas would need to displace fossil gas in the pipeline. Producing clean gas requires investment in infrastructure and feedstocks. At present fore-

[44] Ibid, p. 31.

casted prices for these processes versus electrification of appliances, the electrification option results in a 0.3% of GDP savings annually by 2050 when comparing the Electrification Scenario to the Gas in Buildings Scenario.

- The benefits of measures in buildings that reduce energy use are high in both the near term and long term. This points to the value of early and aggressive action to improve energy efficiency, including electrification and other efficiency measures in buildings.
- Many more energy efficiency measures will be cost effective in a decarbonizing world. By reducing energy use through energy efficiency, the state will reduce the need for investment in infrastructure resulting in cost savings.

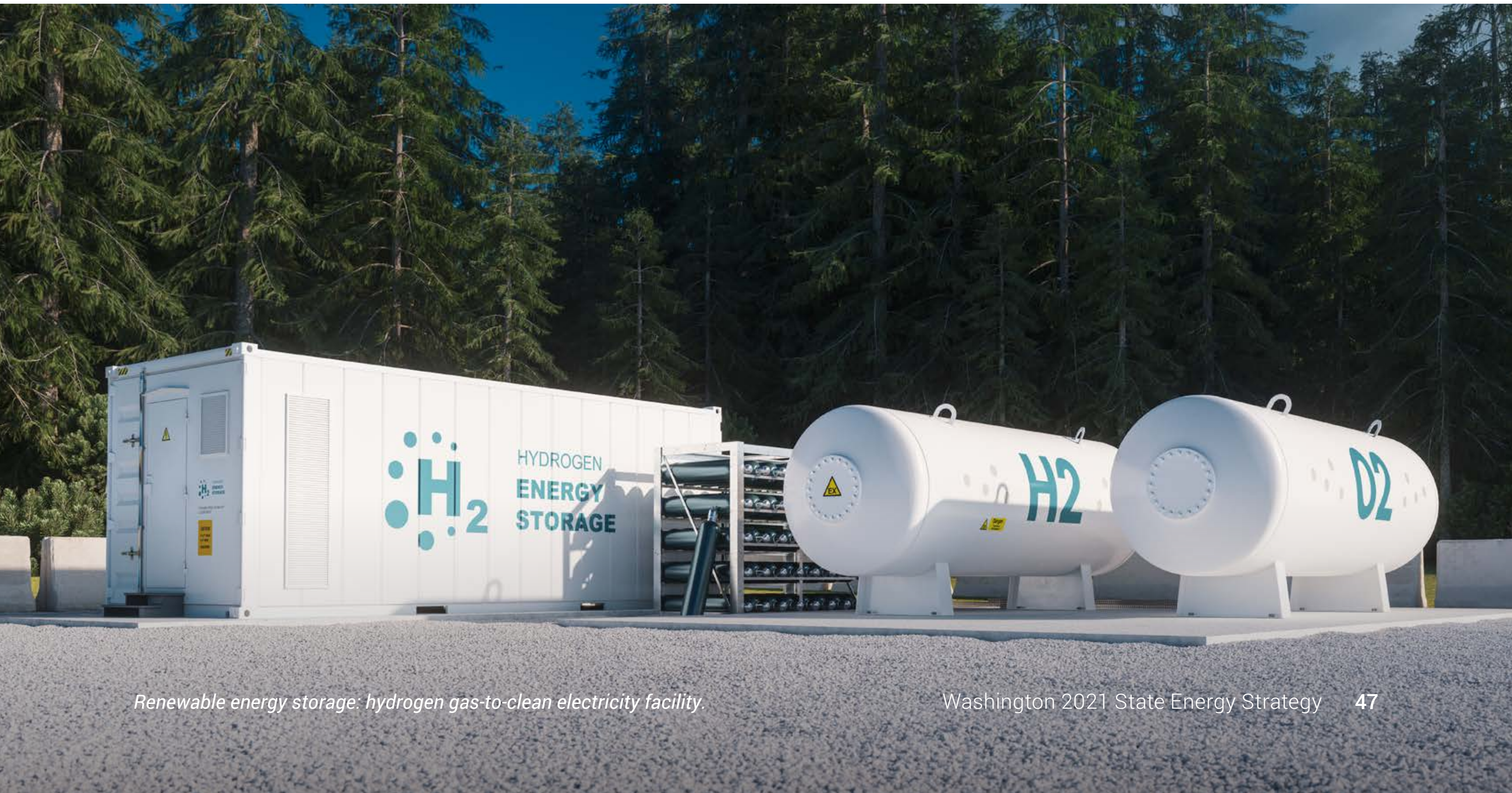
### 3.3. Industry Sector-Specific Results

Key conclusions from the modeling regarding the industrial sector are:

- All the decarbonization scenarios included the same assumptions for the industrial sector, therefore we cannot draw any direct conclusions about one industrial strategy versus another. When comparing the Electrification Scenario to the Transport Fuels and Gas in Buildings Scenarios, we know that lowering energy consumption through electric vehicle purchases or electrified building end uses lowers total costs by avoiding expensive clean fuels. Lowering energy consumption in industry will also avoid expensive clean fuels with significant cost savings. Electrification and other efficiency measures in industry will be cost effective so long as their implementation is cheaper than the production of the clean fuels they avoid.

#### *3.3.1. Implications for State Energy Policy*

- As with the other sectors, cost-effective electrification and/or efficiency measures will lower total decarbonization costs by avoiding expensive infrastructure investments.
- Industrial carbon capture can provide a significant fraction of the carbon stream used to produce synthetic fuels, which points to the need for determining how much carbon capture potential exists in Washington state.
- Industrial flexible loads could be a major new industry in the future, producing hydrogen through electrolysis that is used in production of clean fuels.




*Renewable energy storage: hydrogen gas-to-clean electricity facility.*

### 3.4. Electricity Sector-Specific Results

Key conclusions from the modeling regarding the electricity sector are:

- Increasing electricity demand through electrification and expanding the electricity system to serve those demands with clean electricity is a cost-effective decarbonization strategy. Comparing the Electrification Scenario to the Transport Fuels and Gas in Buildings Scenarios shows that the greater levels of electrification in the Electrification Scenario result in cost savings.
- Washington imports 43% of its clean energy from inland wind-rich states (Montana and Wyoming) in the Electrification Scenario in 2050. The increased energy flows across multiple states and balancing areas will require investment in new transmission and the efficient use of imports as a balancing resource. Efficient dispatch, akin to a single balancing authority for western grid operations, is assumed in the model.
- Transmission expansion across the West is a key part of lowering costs in the model results. Expanding transmission, however, is a long, difficult process with many hurdles to overcome. Early planning and determination of feasible projects and project costs should begin now to prepare for transmission in the future. Updated feasible path expansions and associated costs can be used in future state energy strategies to reevaluate the economics. While the additional costs resulting from no transmission expansion into Washington in the Constrained Resource Scenario are relatively small ($0.5B/yr by 2050), expansion in the rest of the western states still occurs in that scenario.
- Washington has limited build of in-state renewable resources in all decarbonization scenarios until 2040. Prior to that, it is more cost effective to import clean energy from cheaper out-of-state sources. Between 2040 and 2050, Washington adds solar and offshore wind (12 GW and 4 GW, respectively, in the Electrification Scenario).
- Synthetic fuels produced through electrolysis will play a major role in decarbonizing the Washington economy, increasing electricity demand and providing long-term balancing capabilities for the electricity grid.
- Absent technology breakthroughs in zero-carbon alternatives, the Northwest builds 11 GW of gas plants, 3 GW of which are in Washington, for reliability by 2050. Gas generators in Washington burn de minimis quantities of gas after 2030 because of the need to reduce emissions and the large balancing capabilities of both the hydro system and electrolysis built for fuels production by 2030. However, these gas generators provide capacity during infrequent reliability events. CETA requires 100% clean electricity delivered to loads by 2045 in Washington. By 2045, all gas burned during these events is clean gas.

> Early planning and determination of feasible projects and project costs should begin now to prepare for transmission in the future.

#### *3.4.1. Implications for State Energy Policy*

The twin challenges of decarbonization in Washington are pace (to reach 2030) and scale (to reach 2050). Rapid change across all sectors of the economy is required to meet the 2030 challenge. Pace applies to the electricity sector in two ways. The first is to meet the need for new infrastructure to support electrification of end uses with clean electricity. The second is production of synthetic fuels that may be a component of providing clean fuels to reach 2030 targets.

Scale over a longer time period requires infrastructure investments supporting a doubling of electric load in Washington. Resource availability across the West will drive Washington from being a net exporter of electricity to importing a significant fraction of resources (43% in the Electrification Scenario).

- Rapidly electrifying end uses, wherever possible, will drive down the need for clean fuels production and reduce the investment in the infrastructure needed to produce them. This will drive expansion of the electricity sector.
- Planning for transmission expansion at the distribution and transmission levels is key to enabling this shift in the power sector. Distribution planning will support the

*Engineer installing solar panel.*

shift to electric vehicles and electrified end uses in buildings. Pursuing transmission expansion of interties now allows Washington to maintain the option of importing additional low-cost renewables in future. While the savings from expanding Washington's interties are relatively low ($0.5B/yr by 2050), planning to expand interties ensures Washington retains multiple decarbonization pathway options. By doing so the state reduces the risk that future challenges to implementation in any one pathway jeopardize achieving Washington's emission limits.

- The model determines resource adequacy as if the West were a single balancing area. While not a replacement for detailed resource adequacy studies, the model shows greater coordination and energy flows will require resource adequacy determination on a regional rather than local basis. Resource adequacy modeling will also have to evolve to incorporate energy-constrained, as well as capacity-constrained, conditions to ensure reliability during periods of low energy availability. This includes treatment of large industrial flexible loads as resources for reliability.
- Furthermore, transmission expansion and greater interregional energy flows — taking advantage of geographic and renewable resource diversity, and interregional balancing using large new flexible loads found in the modeling results — will only be possible with better regional coordination. The benefits of regional integration will increase in the future as the emissions limits become tighter and electricity loads grow through electrification and electrolysis.

The modeling results determine in-state investments in new resources. However, the model does not have a representation of the distribution system and the potential benefits from deferral of investment in distribution infrastructure from locating resources close to load. Renewable potential assessments will determine how in-state resources should be sited to maximize net benefits, including indirect benefits such as equity, job growth and environmental protection.

> The benefits of regional integration will increase in the future as the emissions limits become tighter and electricity loads grow through electrification and electrolysis.