Economic Impacts of Decarbonization Pathways Modeling
2021 State Energy Strategy
December 31, 2020

Introduction and Overview

As part of the technical consulting for Washington's 2021 State Energy Strategy, the Clean Energy Transition Institute subcontracted the economic impact analysis to FTI Consulting (FTI). This analysis was provided by Scott Nystrom, Senior Director at FTI, and is based on outputs from the decarbonization pathways modeling that Evolved Energy Research (Evolved) performed to inform the development of the state energy strategy.

This report summarizes the methodology and findings of the economic impacts of the decarbonization pathways modeling. The results of the analysis include a discussion of each of the five main types of findings, which relate to the employment impacts, long-term cost reductions for energy customers in some scenarios, and improved air quality for Washington due to decarbonization.

Methodology and Approach

The economic impact analysis centers on a macroeconomic model called REMI,[1] which is a dynamic, computable general equilibrium (CGE) model of regional economies used to forecast the long-term trajectory of an economy and its responses to stimuli, such as changing consumer preferences, new investments in infrastructure, and an evolving energy sector.

REMI's dynamic structure models changes in demand (e.g., fuels) and supply (e.g., electricity prices). REMI accounts for costs and the benefits described below and generates net economic impacts to metrics, such as jobs and gross domestic product (GDP) for Washington.

This analysis used outputs from Evolved's deep decarbonization modeling of the Washington State energy sector[2] as inputs into the economic impact analysis. Inputs included both the costs and the benefits of a Reference Scenario and five deep decarbonization scenarios:

- **Reference** = Energy infrastructure and emissions based on current policy
- **Electrification** = The lowest-cost Scenario, though it relies on a higher quantity of out-of-state electricity generation compared to **Constrained Resources**
- **Transport Fuels** = The transportation sector would rely more heavily on synthetic fuels, which are more expensive in comparison with electrifying the sector
- **Gas in Buildings** = The building sector retains natural gas in the long-term, which would mean higher costs for the relevant sectors in the late 2030s and the 2040s
- **Behavior Change** = Sensitivity analysis around reduced energy consumption
- **Constrained Resources** = Washington State relies more on in-state power generation from solar, offshore wind, and onshore wind, which have higher costs than imports

---

[1] Model Equations. Regional Economic Models, Inc. 2020. https://www.remi.com/wp-content/uploads/2020/10/PI-Model-Equations.pdf

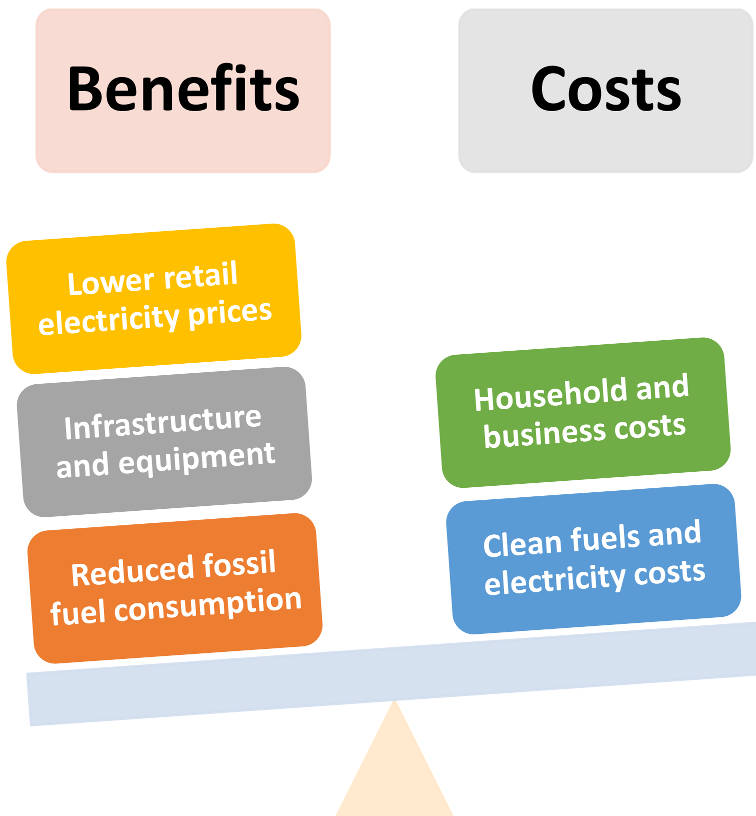
[2] Appendix A – Decarbonization Pathways Modeling Technical Report, December 11, 2020.

The outputs of the decarbonization modeling are inputs into REMI. Examples of REMI inputs for the demand side include construction of clean infrastructure, such as turbines, transmission capacity, or reduced demand for fossil fuel imports to Washington, and for the supply side, electricity prices and net spending on fuel for residential, commercial, and industrial customers.

Figure 1 shows the major benefits and the costs of deep decarbonization. Benefits include lower retail electricity prices, investments in new infrastructure and equipment, and reduced fossil fuel imports into Washington State.

Costs include the equipment and infrastructure to deliver zero-carbon energy to Washington customers, as well as the costs associated with providing clean electricity. These would be increased expenditures on clean fuels and electricity by energy customers and expenditures to upgrade infrastructure and equipment for households and businesses, such as appliances, vehicles, and new power plants, during the period of transition to clean energy from 2020 to 2050

Figure 1 – Major benefits and costs of deep decarbonization modeling



Population Growth and Demographic Change

Washington has a dynamic economy and demographics that are naturally changing now and will continue to change from 2020 to 2050. The REMI economic model incorporates these changes and forecasts them in the Reference Scenario absent the deep decarbonization inputs. Figure 2 shows how Washington's age demographics have changed since 2001 and are projected to change through 2050. Unlike most of the rest of the U.S., Washington State's population is growing in all four age categories.

Figure 2 – Population Growth and Demographic Change in Washington State 2001-2050

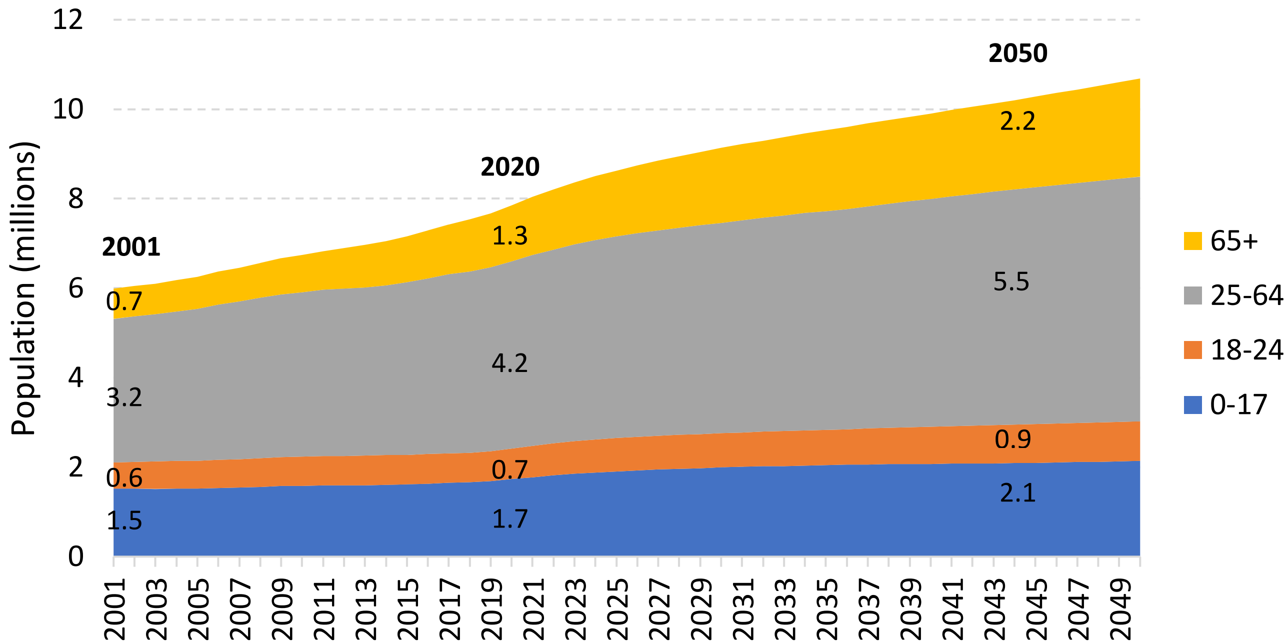
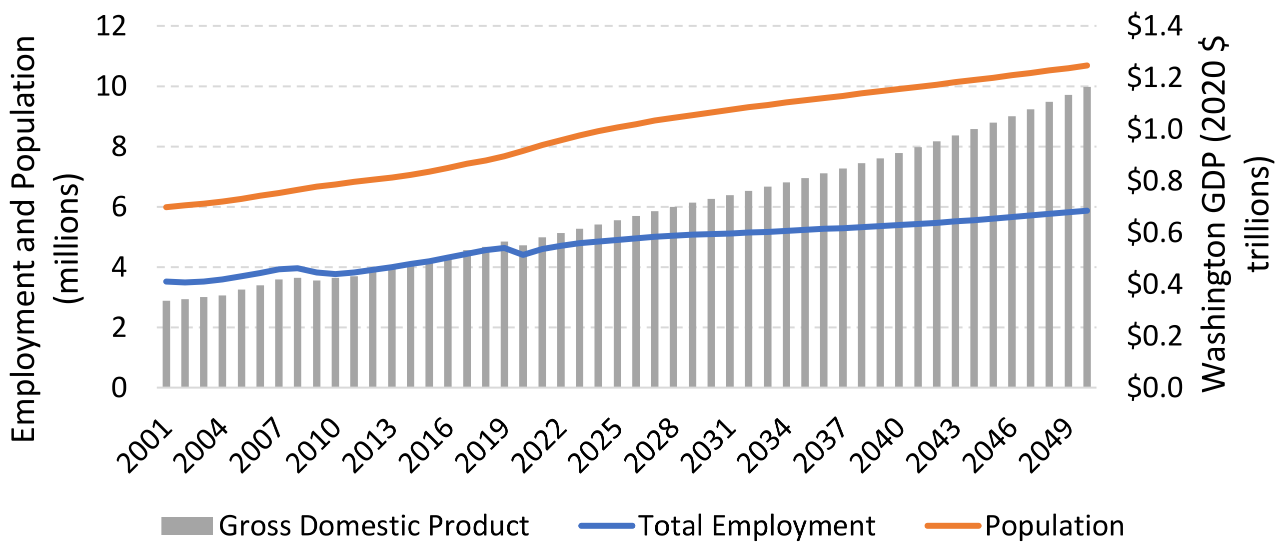


Figure 3 shows historical employment and GDP in Washington State. It includes the impacts of the Great Recession in 2008, as well as the impacts of COVID-19 in 2020. The model projects gradual economic and population growth in Washington State for the next three decades.

Figure 3 – Economic and Population Growth through 2050 in Washington State



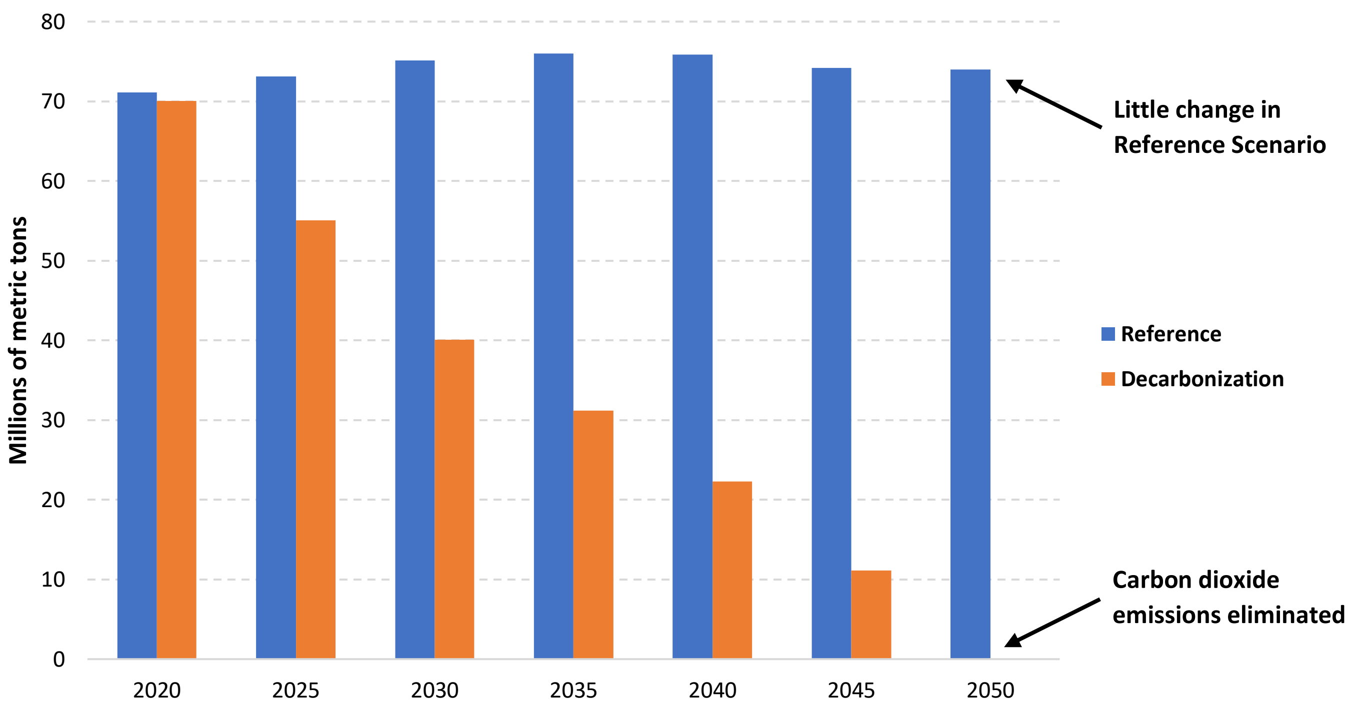
Summary of Results

Five main findings characterize the results of the deep decarbonization/energy sector modeling and the REMI/economic impact modeling, each of which are described in this section with additional context on the differences between the modeled scenarios for decarbonization.

Washington Would Achieve Net-Zero CO_2 Emissions by 2050

For all scenarios, Washington achieves net-zero carbon dioxide (CO_2) emissions by 2050 and meets the intermediate decarbonization goal for 45% below 1990 levels in 2030. These would meet the state's greenhouse gas emissions limits set by the Legislature (see the results in Figure 4).[3] In addition to modeling how to achieve these emission reduction goals, Evolved also examined the impact on net costs and the Washington economy, as discussed below.

Figure 4 – Deep decarbonization eliminates Washington's CO_2 emissions by 2050



Decarbonization Would Reduce Consumers' Net Costs in the Long Term

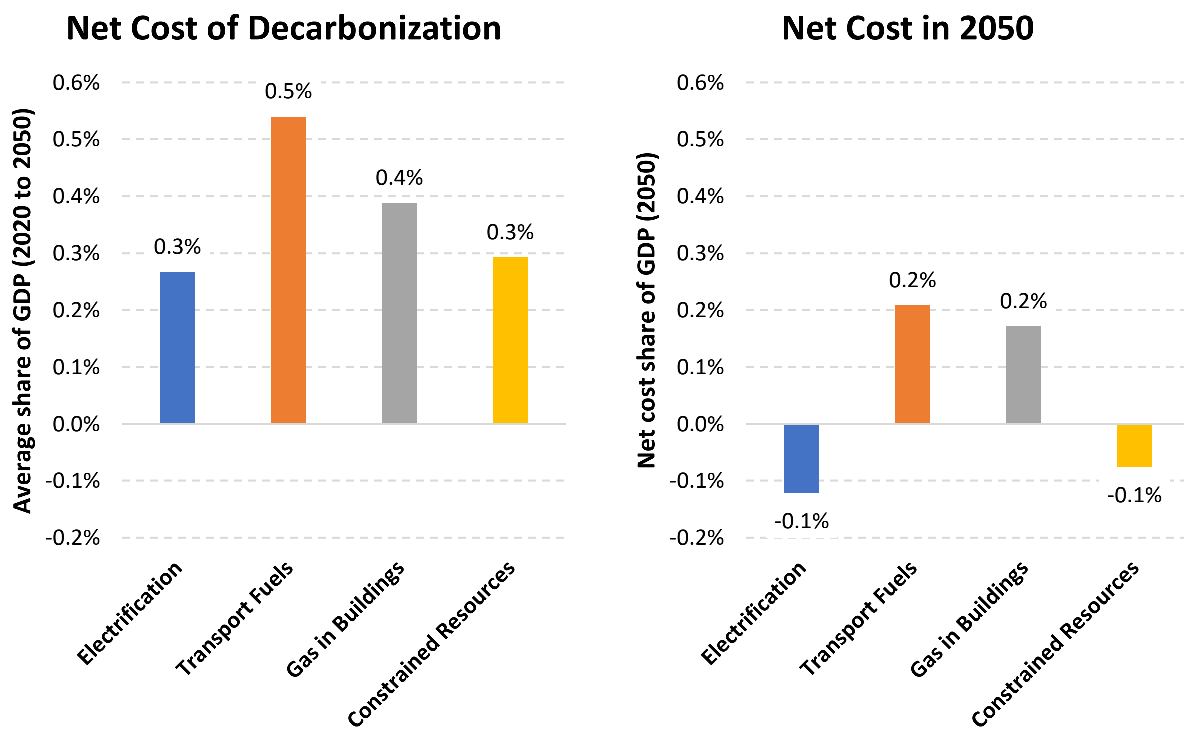
Deep decarbonization would increase net energy costs in the near term (around 1% of GDP in 2030) but would ultimately lower them by 2050 and thereafter in some Scenarios. The near-term increase and long-term reduction in net costs follows from two main factors.

First, decarbonization requires significant investment in new zero-carbon energy – mostly electricity and clean fuels – throughout the 2020s and 2030s. Second, decarbonization leads to a reduction in the consumption of fossil fuels in Washington and the associated transportation costs for customers and reducing energy imports into the Washington State economy.

[3] Chapter 43.21F.090 RCW.

Figure 5 reveals that, between 2020 and 2050, average net energy costs increase from between 0.3% of GDP and 0.5% of GDP across the four scenarios. By 2050, the Electrification Scenario (-0.1% of GDP) and the Constrained Resources Scenario (-0.1% of GDP) show a net *decrease* in energy costs for Washington State's energy customers, while the Transport Fuels Scenario and the Gas in Buildings Scenario have higher net costs (0.2% of GDP) but costs that are lower than their 30-year averages. These long-term trends of lower net costs from the decarbonization pathways modeling influence the economic impact analysis.

Figure 5 – Net cost of decarbonization in 2050



Decarbonization Would be a Net Creator of Jobs

According to the economic impact model, decarbonization would increase jobs and GDP in Washington for most years and scenarios. The exception would be in the late 2020s and early 2030s when costs are at their highest because of construction of transmission capacity and distribution infrastructure and their associated labor costs. Impacts in other years are positive for two reasons:

1. The energy sector transition delivers benefits to the rest of the economy, more than offsetting the higher costs for energy and resulting in overall net benefits. If those higher costs go towards producing a useful asset, such as replacing old heating equipment with new, efficient, and electrified equipment or constructing a solar farm, then they have macroeconomic benefits and costs. The REMI modeling accounts for both sides of the ledger.

2. According to the energy sector model, Washington spends approximately 1.5% of its GDP each year on importing fossil fuels.[4] After decarbonization, these dollars no longer exit the economy to purchase fossil fuels and instead have a higher possibility of remaining local when spent on other goods and services, potentially bolstering Washington's economy.

These two factors would combine to increase Washington's employment and GDP compared to the Reference Scenario in both the short term (2020 through the late 2020s) and the long term (2030s to 2050). A high concentration of these new jobs would be in construction, which are often middle-class jobs that require two-year degrees or apprenticeships and not university educations.

Economic modeling shows that decarbonization would boost employment in the 2020s and grow the workforce in the long term. The initial boost comes from investments made to build, transport, install and maintain the clean energy infrastructure needed for decarbonization. Employment takes a dip in the late 2020s and early 2030s as the economic benefits of deploying this infrastructure have yet to catch up to costs of the energy transition. Employment would then regain speed, outperforming the Reference Scenario by as much as 1.2% (Figure 6). All impacts are relative to the Reference Scenario.

[4] According to the U.S. Energy Information Administration, Washington has no commercial fossil fuel extraction, https://www.eia.gov/state/seds/sep_prod/pdf/P5A.pdf

Figure 6 – Economic impact to employment in Washington State

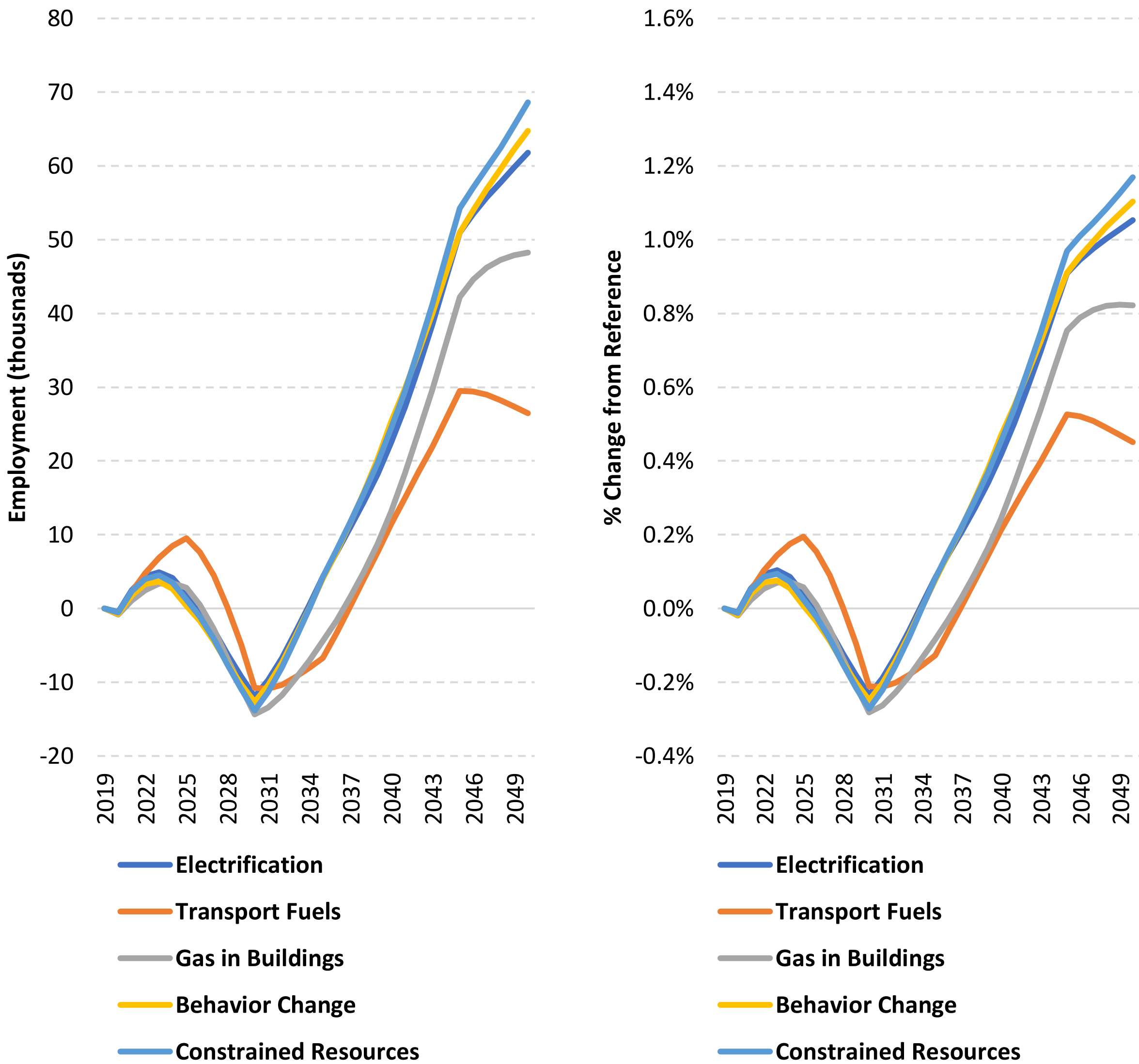
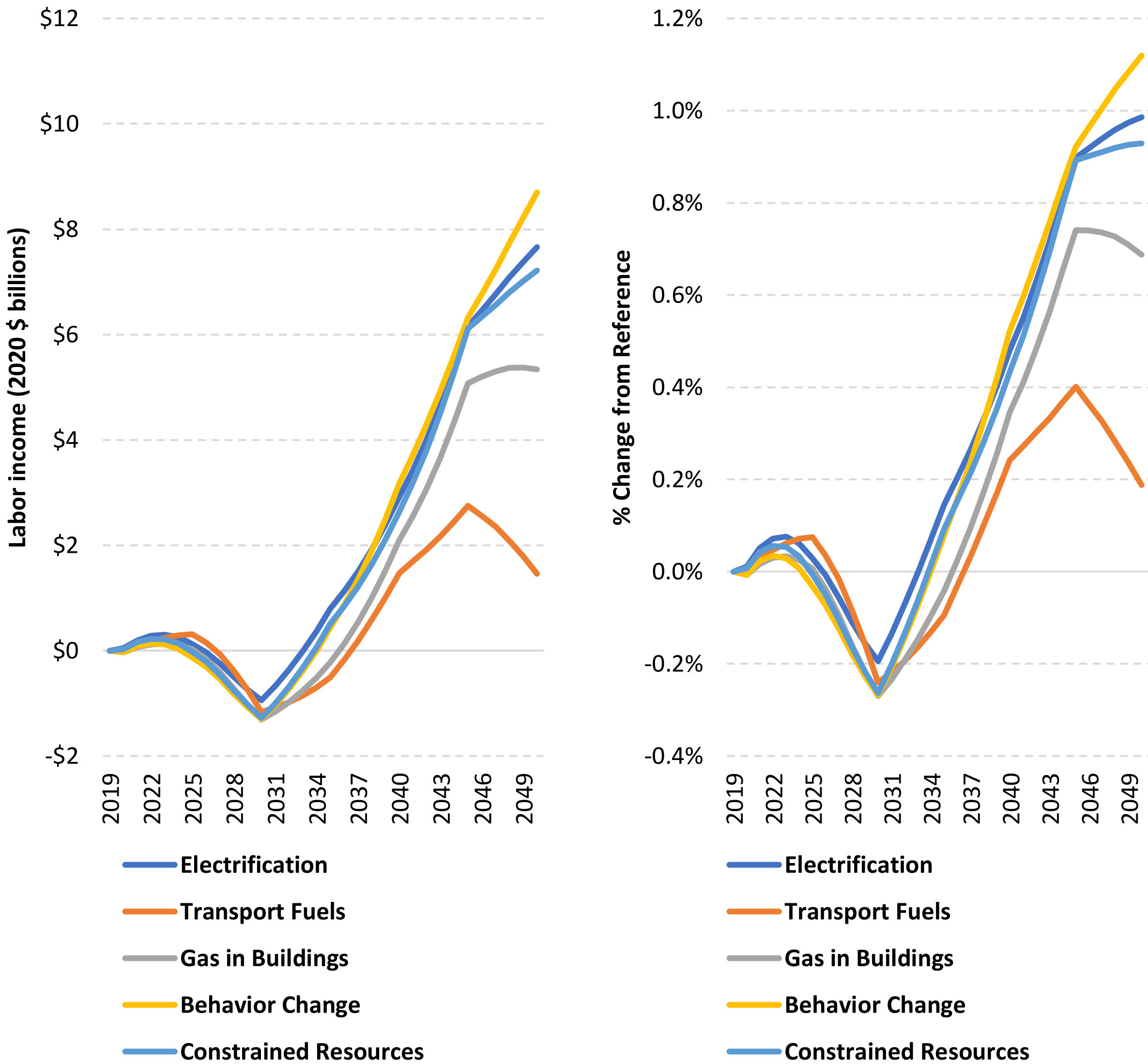


Figure 7 shows the economic impact to labor income in Washington State in response to the analyzed deep decarbonization scenarios. Labor income is the sum of all household income types. These include wages and salaries, investment income and fringe benefits (mostly health insurance), adjusted for any changes in the cost of living, such as to energy prices or housing prices. The patterns for labor income are like those for employment and GDP across scenarios and through time.

Figure 3 – Economic impact to labor income in Washington State



To illustrate this point further, the Figure 8 below shows the employment forecast from the REMI modeling for the decarbonization scenarios in Figure 6 and Figure 7. The graph shows the total employment in Washington for each scenario, with the Reference Scenario in black. The Washington State economy would continue its dynamic changes into the future no matter the decarbonization pathway, and the total impacts relative to the size of the economy would remain diminutive.

Figure 8 – Employment forecasts for Washington State from 2020-2050, in millions

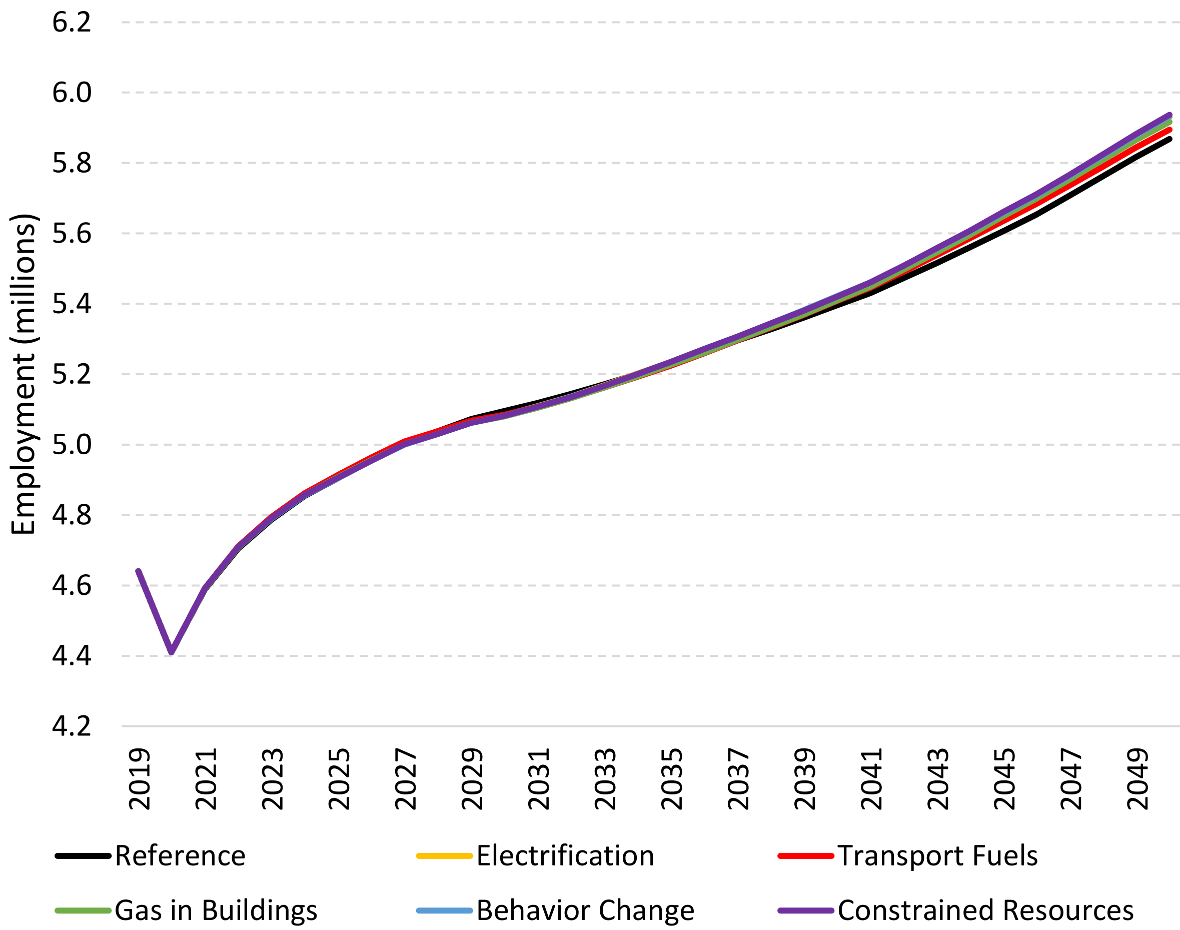
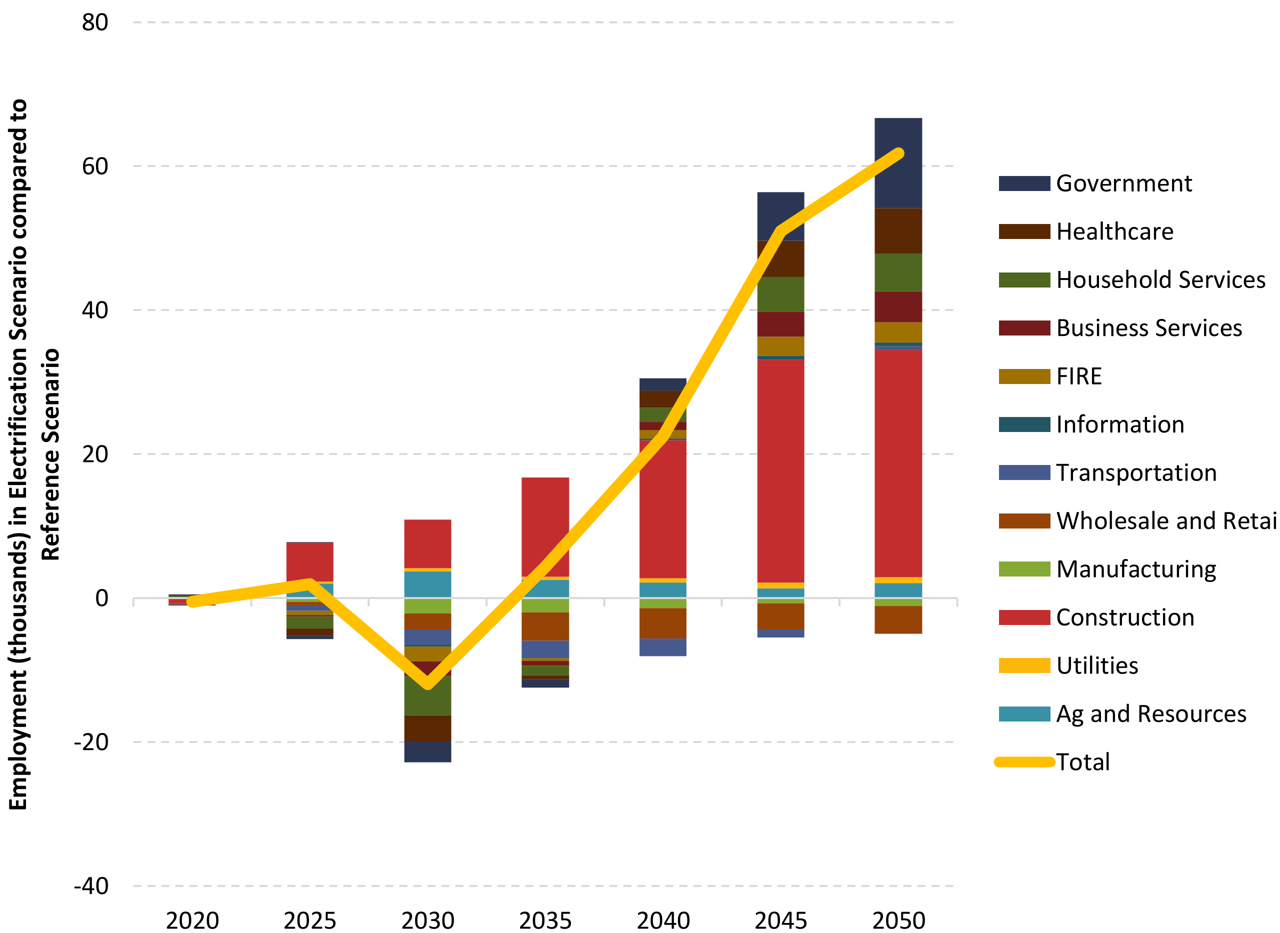


Figure 9 shows the distribution of the employment impact across the economic sectors of Washington for the Electrification Scenario. This graph only shows that one scenario, but the general patterns are similar across all decarbonization scenarios as demonstrated in Figure 8.

Figure 9 – Employment impacts by sector in the Electrification Scenario compared to the Reference Scenario



In 2025 and subsequent years, the construction and agriculture and natural resources sectors would have a net increase in employment, mostly because of increased investments in various types of clean energy infrastructure. During this early phase, most other sectors would experience a negative employment impact because of the higher net costs for household and business energy customers means less available money to spend on other goods and services.

Over time, as the net annual costs decrease, the other economic sectors modelled (e.g., government, healthcare, household services, business services and "FIRE" for finance/insurance/real estate, etc.) would see an increase in their net employment. Construction continues to increase in the long term, a function of increased investments made within the state and the labor and maintenance needed to upkeep expanded electricity and clean energy infrastructure in the long term.

Construction is persistently strong throughout the Scenarios because of ongoing expenditures to build, install, maintain, and operate clean infrastructure throughout Washington, such as upgrading the infrastructure to transmit and distribute electricity. In the later years of the modeling, the larger economy and increase in state population would create more demand for commercial space and residential homes, further increasing the impact to the construction sector.

Economic Impacts by Occupational Category

The economic impact modeling includes impacts to 823 occupations and associated compensation, which we grouped into deciles to exam the socioeconomic impacts and implications of the employment impacts described in previous results. Occupation is generally a better way to describe socioeconomic status than industry because workers of different socioeconomic strata can work for the same industry, such as executives of construction firms and front-line laborers.

Occupations across industries, however, tend to have similar characteristics, working conditions, and wages because they require similar skills and workers can move between industries and keep the same occupation.

Figure 10 shows the top occupations impacted in 2050 in the Electrification Scenario. The occupations with the most positive impacts (e.g., increases in employment) include those related to construction (those building and retrofitting for clean infrastructure and equipment) and in agriculture, which relates to the increased demand for biofuels that Evolved's modeling found.

Agricultural jobs appear large in their number, but the occupational categories have less detail for agricultural jobs compared to the level of specification for construction-related occupations, which moves the former higher in the rankings relative to the latter categories.

Figure 10 – Top 25 occupations impacted by change in employment in 2050 in the Electrification Scenario

Rank	Occupation	Employment
1	Farmworkers and Laborers, Crop, Nursery, and Greenhouse	1,676
2	Construction Laborers	781
3	Carpenters	551
4	Electricians	464
5	First-Line Supervisors of Construction Trades and Extraction Workers	418
6	Logging Equipment Operators	355
7	Plumbers, Pipefitters, and Steamfitters	329
8	Operating Engineers and Other Construction Equipment Operators	224
9	Heating, Air Conditioning, and Refrigeration Mechanics and Installers	209
10	Construction Managers	207
11	Agricultural Equipment Operators	176
12	Painters, Construction and Maintenance	167
13	Cement Masons and Concrete Finishers	163
14	Farmworkers, Farm, Ranch, and Aquaculture Animals	138
15	First-Line Supervisors of Farming, Fishing, and Forestry Workers	130
16	Roofers	118
17	Cost Estimators	107
18	Electrical Power-Line Installers and Repairers	103
19	Drywall and Ceiling Tile Installers	93
20	Fallers	84
21	Sheet Metal Workers	79
22	Helpers-Electricians	66
23	Structural Iron and Steel Workers	63
24	Graders and Sorters, Agricultural Products	58
25	Brick Masons and Block Masons	56

The employment increases by type of occupation are indicative of Washington State undergoing a transition through 2030 to build out clean energy infrastructure. These skilled laborers and artisans, most of whom have either two-year degrees, apprenticeships or "on the job" experience, or no formal training at all would experience the largest impact, which one can see in the decile results. High-skilled jobs, such as engineers or construction managers, are created as well.

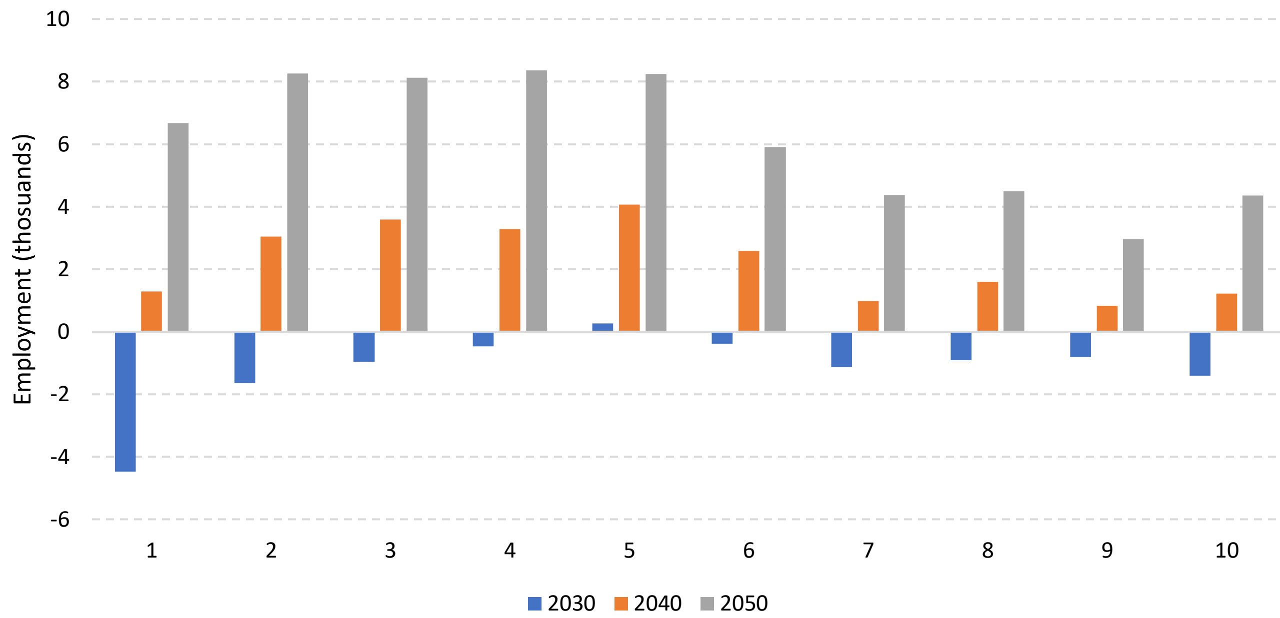
Figure 11 shows the results of employment by decile for the Electrification Scenario, although trends and patterns throughout the other scenarios are generally similar. The decile analysis shows the impact to jobs based on prevailing compensation. The lowest-wage jobs are in the first decline in Figure 11, to the furthest left, while the highest-wage jobs are in the 10^{th} decile to the far right.

A consistent pattern emerges across the years on the socioeconomic impact in the labor market. More of the job creation takes place in the lower-middle (the 3^{rd}, 4^{th}, and 5^{th} deciles) over the long term (2040-50), and these deciles have results closer to neutral in the 2030s.

By 2040, all deciles would have a net increase in employment for the Electrification Scenario. The results for 2050 are even more positive than those for 2040. While there is less creation of high-wage, high-educational attainment jobs than there are jobs situated in the lower/middle wage levels, there is still a positive long-term impact for that stratum of employment as well.

Much of the increase in lower/middle wage jobs comes from the construction sector, which has high-wage jobs, such as executives and engineers, as well as the bulk of its employment in middle-skilled trades and laborers, leading to the outcomes in Figure 11. The negative impact to the lowest decile in 2030 comes mostly from the retail sector (with relatively low paid workers compared to other occupations). This is because of the higher costs of energy for households and businesses at this point of the modeling, which affects overall retail spending and, therefore, employment.

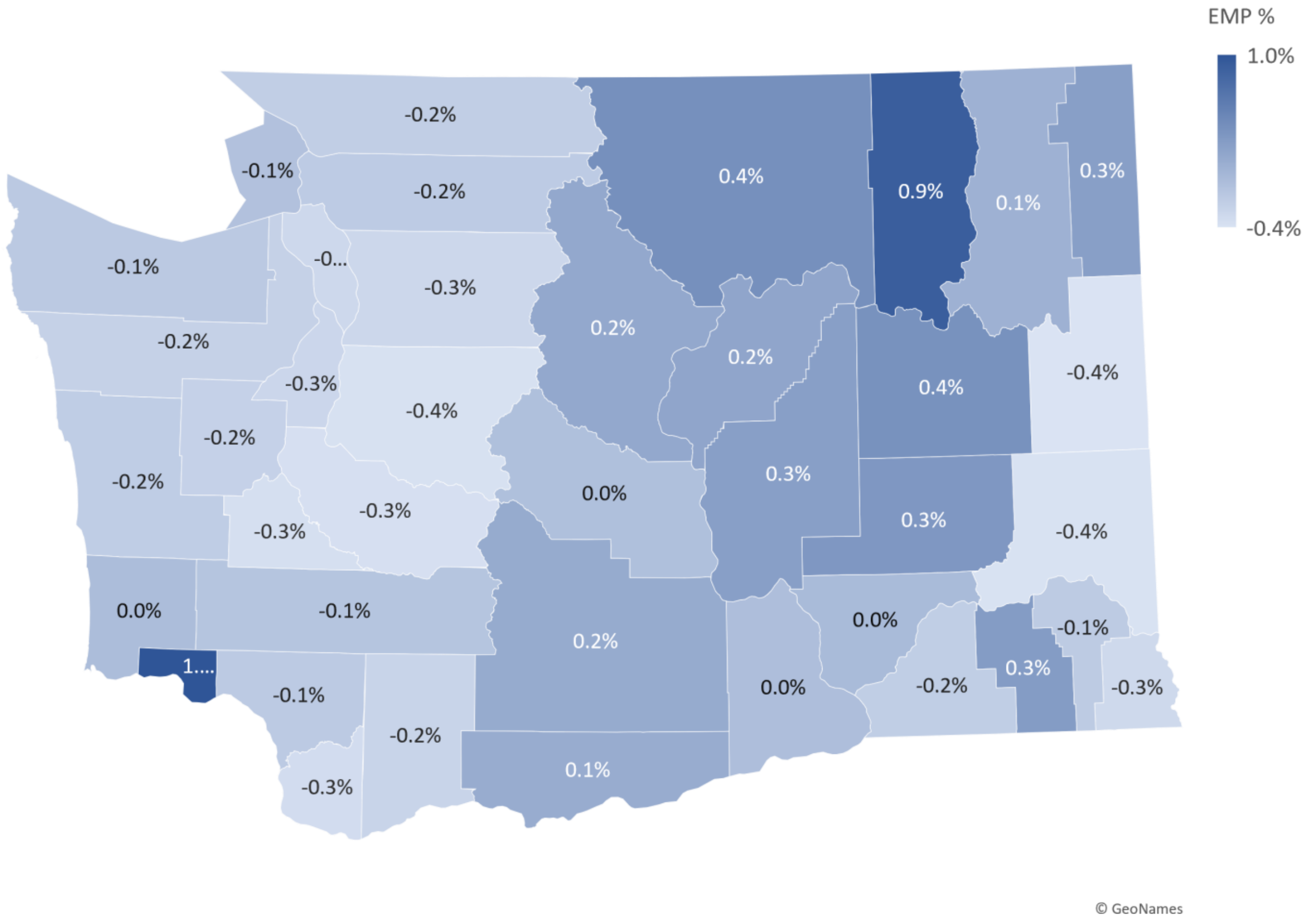
Figure 11 – Economic impact of employment by decile for Electrification Scenario (1 is the 10% of workers with the lowest compensation, and 10 is the 10% of workers with the highest compensation)



Geographic Distribution of Jobs

The map in Figure 12 shows the employment results by county for 2030 with the difference between the Electrification Scenario and the Reference Scenario.

Figure 12 – Employment results by county (2030, % difference from Reference Scenario for Electrification Scenario)

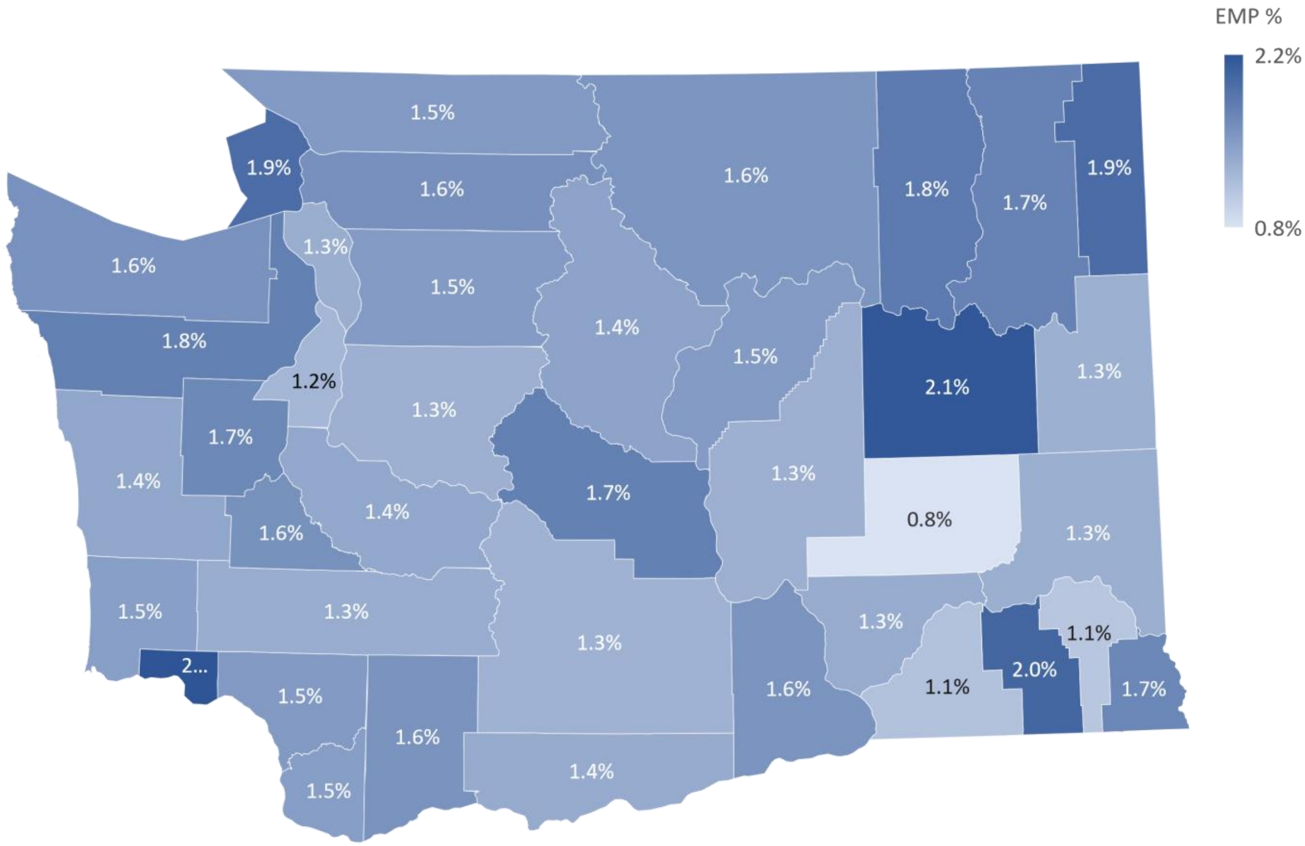


In general, the urbanized counties in the Puget Sound region, the southwest, and the far east of the state have the least positive impacts, tipping into negative impacts. The central region of the state has the most positive impacts. The reason for this pattern has to do with the costs and the infrastructure demanded to transition the state over to clean energy resources.

Higher net costs in 2030 more strongly affect areas with large population pools that rely on consumer spending to drive their economies, and the higher net costs in 2030 would reduce consumer spending and would raise business costs. Deep decarbonization would increase the demand for agricultural products, such as biofuels, which creates the positive impacts in the central region of the state. These regions also have stronger potential for onshore wind and solar resources.

The map in Figure 13 shows the economic impact results by county (measuring the percent change in jobs relative to the Reference Scenario) for the Electrification Scenario for 2050, when all counties would have a positive employment impact. Some counties would have slightly higher or lower positive impacts, though most counties are between 1.0% and 2.0% of their current job totals. Lincoln County and Adams County are the highest and lowest, respectively, and they are coincidentally near to each other on the map.

Figure 13 – Employment results by county (2050, % difference from Reference Scenario for Electrification Scenario)



Differences in Impacts by Scenario

Based on Evolved's analysis as inputs to the economic impact modeling, the **Transport Fuels Scenario** has more positive results in in the near term. However, its results in the long term would be the least positive of all Scenarios. In the short term, investments in the infrastructure to support clean fuels would benefit the Washington State economy, such as with construction. Once this is in place, the higher costs of these fuels compared to the alternatives in other Scenarios would degrade the impact.

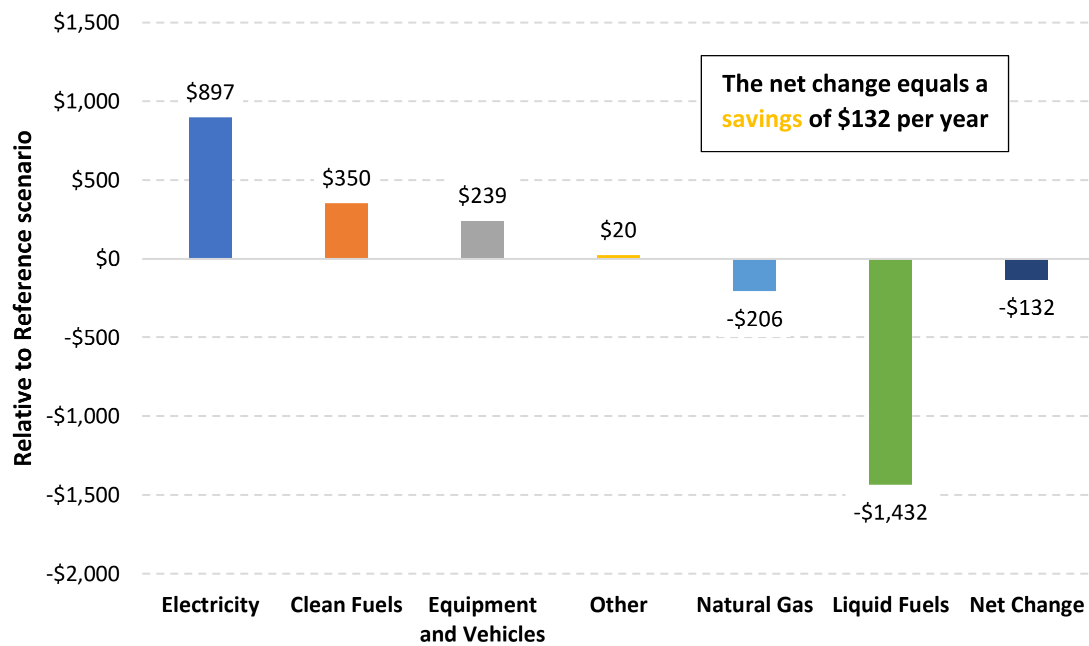
According to the Evolved analysis, the **Gas in Buildings Scenario** would have the highest costs in the long run compared to the other Scenarios. The higher costs would translate into higher costs of living and higher costs of production for businesses in the REMI model, which reduces the real incomes and purchase power of consumers and the competitiveness of industry.

Results for the Electrification Scenario, Behavior Change Scenario, and Constrained Resources Scenario are similar. The Electrification Scenario would perform the best based on the economic impacts in the short-term because it has lower cost out-of-state power. The Constrained Resources Scenario would have stronger results in the long-term because of its relative reliance on in-state generation of power, which would engender significant construction activity in Washington State.

Savings for Washington Consumers

According to Evolved's analysis, on a per capita basis, by 2050 the Electrification Scenario would save the average energy customer in Washington approximately $132 per year, as seen in Figure 14, based on forecasted technology costs and fuel prices from the decarbonization modeling.

Figure 14. Per capita spending by average Washington energy customer in the Electrification Scenario (2050)



These results are implied by Evolved's net cost modeling. By 2050 in the Electrification Scenario, customers would spend more on electricity, clean fuels, and appliances/equipment/vehicles but less on natural gas and liquid fuels. Netted out together, the average customer (on a per capita basis, so the amount attributable to the average Washingtonian) would save $132 that year.

The costs reported above include investments in energy demand and supply side equipment, fuels, and other operating costs. Beyond these 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.[5] Displacing fossil power generation with renewables and electrifying the vehicle fleet both contribute to cleaner air for Washingtonians by 2050.

Air Quality Improvements by 2050

One of the technological approaches for decarbonization is electrification and generating clean electricity. In 2019, Governor Jay Inslee signed bills into law "to combat climate change headlined by legislation **to rid Washington's electric grid of fossil power by 2045**, a move that makes the state a leader in the clean power movement."[6] The goals of decarbonization and improving air quality are

---

[5] "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.

[6] https://www.seattletimes.com/seattle-news/politics/inslee-signs-package-of-long-sought-climate-bills-that-include-a-phase-out-of-coal-and-natural-gas-fired-power-plants/

inherently linked[7] in that removing coal and natural gas power generation from Washington's fuel mixture would also improve air quality.

Evolved's deep decarbonization modeling included the results for emissions of CO_2 aimed at meeting Washington State's limits as well as associated "co-benefits" of reduced air pollution. Evolved's model does this by identifying the pollutant emissions associated with the operation of a piece of equipment or energy infrastructure, such as a thermal power plant or different types of vehicles with and without electric drive trains and given mileage requirements.

Figure 15 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 sulphur dioxide (SO_2) emissions from power generation, as well as significant reductions in particulate matter and NO_x emissions from transportation. This shows how decarbonization would greatly improve Washington's air quality.

Figure 15. Summary of air quality Impacts from decarbonization

Sectoral Source	Compound	Emissions in 2020	Emissions in 2050	Percent Change
Power Generation	Mercury (kilograms)	21.1	0.0	**-100.0%**
Power Generation	NO_x[8] (metric tons)	8.959	0.739	**-91.8%**
Power Generation	SO_2[9] (metric tons)	8.985	0.024	**-99.7%**
Transportation	$PM_{2.5}$[10] (metric tons)	0.635	0.354	**-44.2%**
Transportation	NO_x (metric tons)	21.839	10.165	**-53.5%**

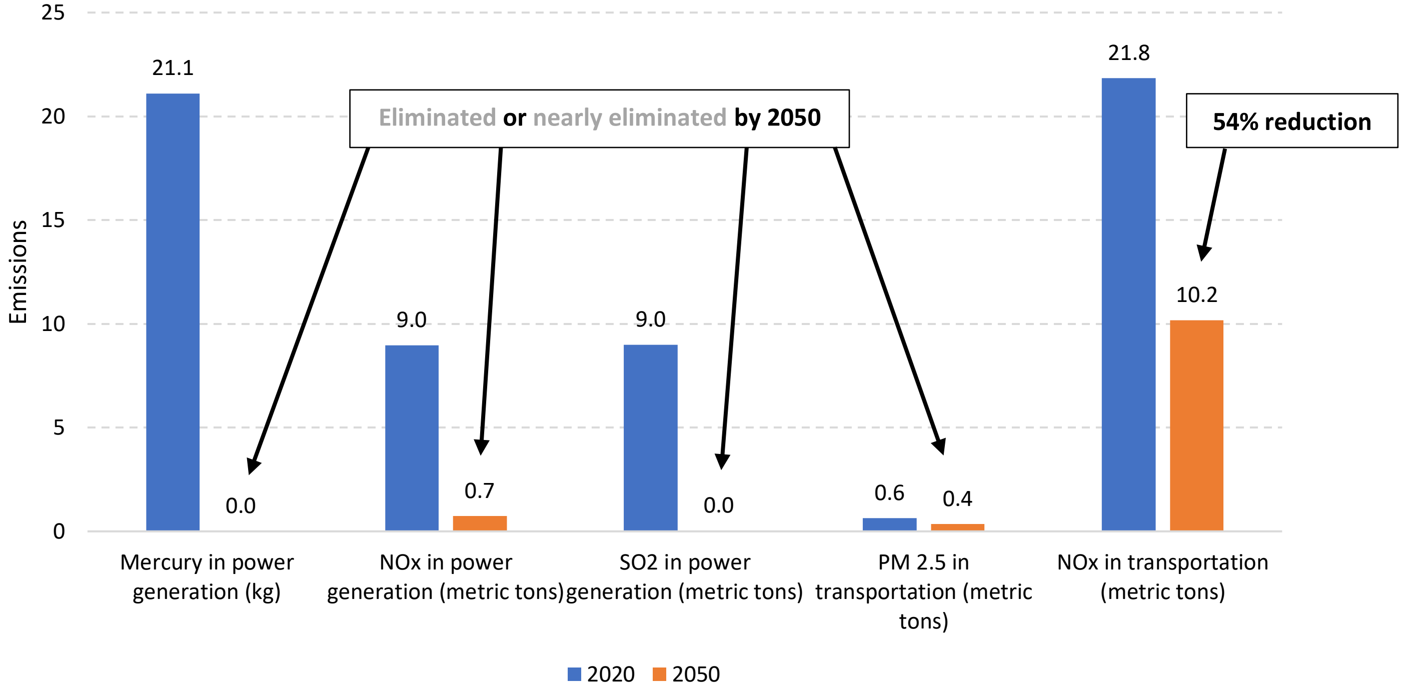
Evolved provided the data on the pollutants shown in Figure 15 and Figure 16 derived from its decarbonization modeling. These are the emissions for the Reference Scenario in 2020 compared to the emissions averaged across the five decarbonization scenarios for 2050.

Over time, Washington State would see an elimination of mercury emissions from power generation and over a 90% reduction of NO_x and SO_2 emissions from the same. For the transportation sector, the state would have an approximately 44% reduction in $PM_{2.5}$ emissions and about a 54% decrease in NO_x from transportation.

Figure 16 graphically display air quality improvements from decarbonization.

[7] https://www.4cmr.group.cam.ac.uk/filecab/global-co-benefits.pdf
[8] Various nitrogen oxides, which have negative respiratory and cardiovascular effects.
[9] Sulfur dioxide, which has negative respiratory effects and is a component of acid rain.
[10] Particulate matter generally smaller than 2.5 micrometers, which can cause lung and cardiovascular disease.

Figure 16 – Decarbonization greatly Improves Washington's air quality



Conclusion

The energy and economic analyses presented here support the conclusion that Washington State can achieve its long-term emissions reduction limits while maintaining a healthy economy. The required investments in equipment and technology provide employment opportunities during their deployment as well as long-term reductions in expenditures for out-of-state fossil fuels. The change in employment is dispersed broadly across the state with agriculture and construction as the occupations experiencing the largest increases in employment levels.