Appendix A: Carbon Intensity Analysis

WA-GREET Methodology

A Washington-specific GREET model was developed by Life Cycle Associates in 2013 that was based on the Argonne National Laboratory (ANL) GREET model version GREET1_2013. ICF and the Agency agreed that this model is outdated with assumptions and data from prior to 2013. Instead of using the 2013 model, ICF recommended modifying the California Air Resources Board's (CARB) CA-GREET3.0 model. It was agreed this would be the most relevant and expedient solution to developing a current, Washington-specific GREET model. CA-GREET3.0 is currently used for fuel pathways in California's Low Carbon Fuel Standard (LCFS) and would allow for consistency in overall assumptions and modeling framework between a Washington model and the LCFS. The modifications of the CA-GREET3.0 to develop a WA-GREET are summarized in the following sections.

Electricity Grid Mix Update

ICF updated the Electricity Generation Mixes with EPA's Emissions & Generation Resource Integrated Database (eGRID) 2016 data[103]. Since it is unlikely to be used, ICF replaced the user's option for Hawaii HICC Miscellaneous eGRID subregion with a Washington State option. ICF replaced all HICC data with Washington State data. This includes regional combustion technology shares, regional power plant energy conversion efficiencies, and the electric generation mix of the state of Washington.[103] ICF compared the generation mix of the utilities serving the Puget Sound counties[104] with the Washington State average. Due to Puget Sound Energy's significant use of coal generation, the carbon intensity of electricity from utilities in the four county Puget Sound region was calculated to be over two times greater than the Washington State average. Table 37 and Table 38 below provide a comparison of the electricity mixes in Puget Sound versus the Washington average. Table 37 does not include a few smaller utilities serving communities in Pierce County. Since the service areas of these utilities would only be a small fraction of the total service area in Puget Sound (less than 5%), they were excluded. They are conceptually represented by Lakeview and Peninsula. The excluded utilities are Fircrest, Milton, Elmhurst Mutual, Parkland, Ruston, and Steilacoom.

[103] US EPA, Emissions and Generated Resource Integrated Database 2016. Available at: https://www.epa.gov/energy/emissions-generation-resource-integrated-database-egrid; released 2/15/2018
[104] Puget Sound Clean Air Agency, Greenhouse Gas Emissions Inventory, Tables 5 & 6, 2018. Available at: http://www.pscleanair.org/DocumentCenter/View/3328/PSCAA-GHG-Emissions-Inventory

Table 37: Reported Fuel Mix of Electric Utilities in PSCAA Region, 2017[104]

Fuel	Puget Sound Energy[105]	Seattle City[106]	Snohomish[107]	Tacoma[108]	Peninsula[109]	Lakeview[110]	Weighted Average
Residual Oil/Fossil fuels	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0%
Natural gas	21.0%	1.0%	0.4%	1.0%	1.0%	0.9%	10%
Coal	38.0%	1.0%	0.4%	1.5%	1.0%	2.4%	17%
Nuclear	0.6%	4.0%	9.0%	6.1%	8.0%	10.2%	4%
Biomass	0.3%	1.0%	0.2%	0.2%	0.0%	0.2%	0%
Hydroelectric	33.0%	91.0%	90.0%	84.0%	83.0%	86.3%	65%
Geothermal	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0%
Wind	6.0%	1.0%	0.0%	7.0%	7.0%	0.0%	4%
Solar PV	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0%
Others (purchased)	1.0%	1.0%	0.0%	0.2%	0.0%	0.1%	1%
Proportion Based on kWh Consumed	43.58%	25.06%	17.04%	12.09%	1.54%	0.69%	
GREET CI [g CO_2e/MJ]	150.47	4.90	2.00	6.27	4.75	8.76	68.03
Pathway CI for LD BEV[111]	**44.3**	**1.44**	**0.59**	**1.84**	**1.40**	**2.58**	**20.0**

[105] Accessed via https://www.pse.com/pages/energy-supply/electric-supply
[106] Accessed via http://www.seattle.gov/light/FuelMix/
[107] Accessed via https://www.snopud.com/PowerSupply.ashx?p=1105
[108] Accessed via https://www.mytpu.org/tacomapower/about-tacoma-power/dams-power-sources/
[109] Accessed via https://www.penlight.org/energy-services/power-resources/
[110] Accessed via https://lakeviewlight.com/wp-content/uploads/LLP-Spring-2017-Newsletter_Final_Production-Ready.pdf
[111] This is the estimated pathway for a light-duty BEV accounting for the Energy Economy Ratio (EER) of 3.4.

Table 38: Washington State Average Electricity Generation Mix and CI

Fuel	% Generation Mix
Residual Oil/Fossil fuels	0%
Natural gas	10%
Coal	4%
Nuclear	8%
Biomass	2%
Hydroelectric	69%
Geothermal	0%
Wind	7%
Solar PV	0%
Others (purchased)	0%
GREET WA CI [g CO_2e/MJ]	**28.8**

As an alternate scenario, ICF projected Puget Sound's electricity grid mix carbon intensity to 2030 assuming major changes to Puget Sound Energy's generation mix. Table 39 provides the estimated generation mix for Puget Sound Energy based on the following assumptions:

- 2025: Assumed that coal generation is replaced entirely by natural gas
- 2030: 60% of total generation from renewable sources
  - Natural gas is replaced by renewable sources
  - Type of renewable sources grow proportionally to the current mix

Table 39 presents the carbon intensity of the PSCAA jurisdiction's electricity generation resulting from these changes to PSE's mix. The carbon intensity values of the other utilities are not projected to change due to their already high rates of renewable generation. The values in Table 40 are calculated based on the assumption that the relative demand for electricity from each utility remains consistent with 2017 demand. By 2030, the carbon intensity of the PSCAA's counties drop to the current CI of the state of Washington. Taking into account Puget Sound Energy's agreement to permanently retire a portion of the coal generation mix by July 1, 2022 and shut down another coal plant in 2025[112], ICF used the Washington State Mix in the fuel pathway analysis. While it is beyond the time horizon of this analysis, it is worth noting that the CI of electricity will continue to decrease under a state law passed in 2019—with a goal of being carbon-free in 2045.[113]

[112] http://www.seattleweekly.com/news/puget-sound-energy-to-retire-some-coal-fired-power/ ; https://www.pse.com/pages/carbon-reduction-plan

[113] Washington State Legislature. SB5116 2019. https://app.leg.wa.gov/billsummary?BillNumber=5116&Year=2019.

Table 39: Puget Sound Energy Generation Mix and Carbon Intensity Projection

Fuel	2017	2020	2025	2030
Nonrenewable Sources	60.0%	60.0%	50.0%	40.0%
Residual Oil/Fossil fuels	0.1%	0.1%	0.1%	0.1%
Natural gas	21.0%	35.3%	49.0%	39.0%
Coal	38.0%	23.8%	0.0%	0.0%
Nuclear	0.6%	0.6%	0.6%	0.6%
Biomass	0.3%	0.3%	0.3%	0.3%
Renewable Sources	40.0%	40.0%	50.0%	60.0%
Hydroelectric	33.0%	33.0%	41.3%	49.5%
Geothermal	0.0%	0.0%	0.0%	0.0%
Wind	6.0%	6.0%	7.5%	9.0%
Solar PV	0.0%	0.0%	0.0%	0.0%
Others (purchased)	1.0%	1.0%	1.2%	1.5%
PSE GREET CI [g CO_2e/MJ]	**150.47**	**128.27**	**75.83**	**60.4**

Table 40: Projected PSCAA-area Electricity Generation Mix and CI

Fuel	2017	2020	2025	2030
Residual Oil/Fossil fuels	0%	0%	0%	0%
Natural gas	10%	16%	22%	18%
Coal	17%	12%	1%	1%
Nuclear	4%	4%	4%	4%
Biomass	0%	0%	0%	0%
Hydroelectric	65%	64%	67%	71%
Geothermal	0%	0%	0%	0%
Wind	4%	4%	4%	5%
Solar PV	0%	0%	0%	0%
Others (purchased)	1%	0%	1%	1%
GREET CI [g CO_2e/MJ]	**68.03**	**58.4**	**35.5**	**28.8**

Refining Efficiency Update

The WA-GREET model can be used to calculate the carbon emissions from crude refining and transport, based on an assumed value for refining efficiency. The GREET model computes a refining efficiency based on the crude API gravity and sulfur content. API gravity is an index of density created by the American Petroleum Institute. [114] ICF estimated crude API gravity and sulfur content based on the 2015 crude slate to Washington refineries. For each crude identifier, the API gravity was assumed to be consistent with values used as OPGEE inputs for the CA-

[114] https://www.mckinseyenergyinsights.com/resources/refinery-reference-desk/api-gravity/

LCFS Crude Oil Lifecycle Assessments. [115] The API gravity and sulfur content (wt %) were determined based on a weighted average, as seen in Table 41. The resulting refining efficiencies of Washington gasoline and diesel are presented in Table 42.

Table 41: API Gravity and Sulfur Content of Washington Crude

Crude Source	% of Crude Slate	API Gravity	S Content (wt %)
Canadian Oil Sands Bitumen	6%	20.9	3.58%
Canadian SynCrude	5%	32	0.38%
Canadian Conventional Light	25%	30	0.65%
Bakken Crude	24%	40	0.19%
Alaska North Slope	38%	28.3	0.19%
Other foreign imports	2%	30.7	0.96%
Average Washington Crude		**30.75**	**0.81%**

Table 42: GREET Calculated Refining Efficiencies for WA Crude

Gasoline Refining Efficiency	89.0%
Diesel Refining Efficiency	91.2%
Jet Fuel Refining Efficiency	95.7%

Finished Fuel Transport Assumptions

The transport assumptions for fuel from the Washington refineries to the petroleum terminal and refueling stations are shown in Table 43 below, as assumed in the 2013 WA- GREET model developed by Life Cycle Associates, LLC.[116] The total can be over 100% because some of the fuel is transported by multiple transportation modes.

Table 43: Washington Gasoline & Diesel GREET Transportation and Distribution Assumptions

T& D Inputs	WA Product	
	Share	Miles
Tanker	0%	0
Barge	11%	200
Pipeline	99%	82
Rail	0%	0
Truck	100%	76

[115] CARB. Low Carbon Fuel Standard. OPGEE Model and Supporting Information, MCON Inputs Spreadsheet for Crude Lookup Table. Available at: https://www.arb.ca.gov/fuels/lcfs/crude-oil/lookup_table_mcon_inputs_opgee_v2.0_2018-0306.xlsm

[116] Life Cycle Associates, LLC. A Clean Fuel Standard in Washington State Revised Analysis with Updated Assumptions, Table 3-8. 2014. https://ofm.wa.gov/sites/default/files/public/legacy/reports/Carbon_Fuel_Standard_evaluation_2014_final.pdf

Washington Crude Carbon Intensity

To calculate the upstream carbon intensity of gasoline and diesel produced in Washington, ICF utilized the OPGEE results from California's LCFS Crude Oil Life Cycle Assessments[117]. ICF estimated a Washington Crude Oil Production and Transport CI by using the average LCFS reported crude carbon intensities, weighted by the proportion of each source. The upstream gasoline and diesel CI is estimated to be 12.96 g CO_2e/MJ, as shown in Table 44.

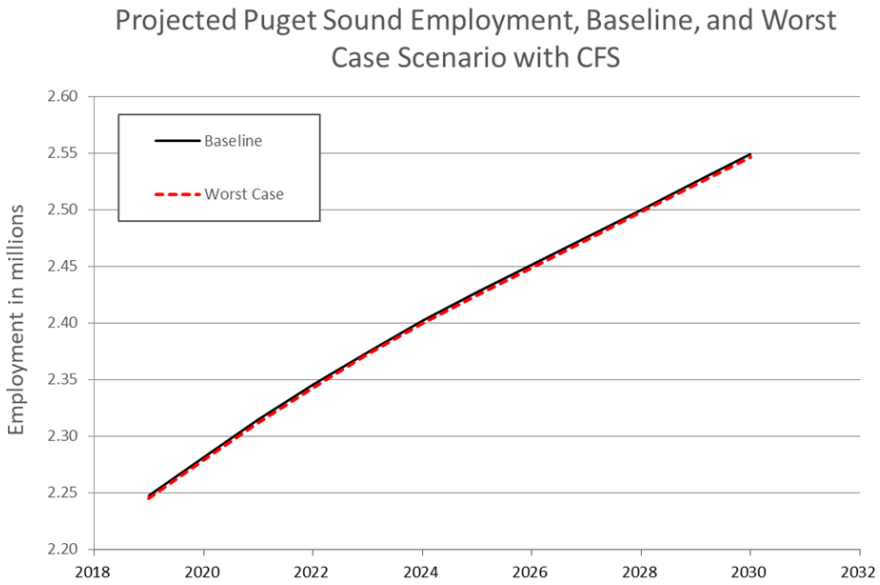
Table 44: Washington Crude Oil Production and Transportation Carbon Intensity

Crude Source	LCFS Crude Identifier	LCFS CI [g CO_2e/MJ]	Average CI	% WA Crude Slate
Canadian Oil Sands Bitumen	Christina Dilbit Blend	12.71	14.56	6%
	Statoil Cheecham Dilbit	16.41		
Canadian SynCrude	Albian Heavy Synthetic (all grades)	23.68	29.64	5%
	CNRL Light Sweet Synthetic	25.27		
	Hardisty Synthetic	32.66		
	Long Lake Light Synthetic	40.12		
	Premium Albian Synthetic	29.49		
	Premium Synthetic	27.38		
	Shell Synthetic (all grades)	29.49		
	Suncor Synthetic (all grades)	27.09		
	Syncrude Synthetic (all grades)	31.62		
Canadian Conventional Light	Canadian Conventional Light	8.11	8.11	25%
Bakken Crude	US North Dakota Bakken	9.73	9.73	24%
Alaska North Slope	Alaska North Slope	15.91	15.91	38%
All foreign imports	Weighted Average of all others	12.96	12.96	2%
WA Crude Mix CI			13.13	

[117] CARB Low Carbon Fuel Standard Final Regulation Order, Table 9: Carbon Intensity Lookup Table for Crude Oil Production and Transport. 2018. Available at: https://www.arb.ca.gov/regact/2018/lcfs18/frolcfs.pdf?_ga=2.246951810.766619030.1548198089-546402948.1536794631

Appendix B: Full Results for Economic Impact Modeling

For context, as discussed in the REMI Modeling Results, the employment and GRP impact values reported are on top of (in addition to) the regional growth. From 2018 to 2030, the region is forecast to have a roughly 13% increase in GRP – (about $50 billion) reaching about $450 billion, and a growth of 330,000 jobs, reaching about 2.6 million jobs.[118] The results for each Scenario in the tables and plots below are added or subtracted to these baseline values. As shown in the figure below, even the worst case value from the modeling (-0.1%) is difficult to distinguish from



the baseline and is within the uncertainty of the modeling work (GRP is similar).

The projected employment in 2030, broken down by county, was estimated by projecting current employment estimates (proportioned from regional employment by current county population)[119] and a linear extrapolation to projected employment extracted from REMI. It is shown in the table below:

[118] Estimated from https://www.ofm.wa.gov/sites/default/files/public/dataresearch/pop/stfc/stfc_2018.pdf
[119] https://www.psrc.org/sites/default/files/economicanalysiswithcover.pdf

County	2016	2030 Projected
Kitsap	151,000	180,000
Snohomish	409,000	480,000
King	1,140,000	1,350,000
Pierce	452,000	540,000
Region	2,150,000	2,550,000

The employment impact results for each scenario are presented in a series of tables and graphs in the sub-sections below; in each figure, there are seven categories or factors that are plotted to what drives the overall trend. The table below lists the categories and provides a brief description of what each category represents.

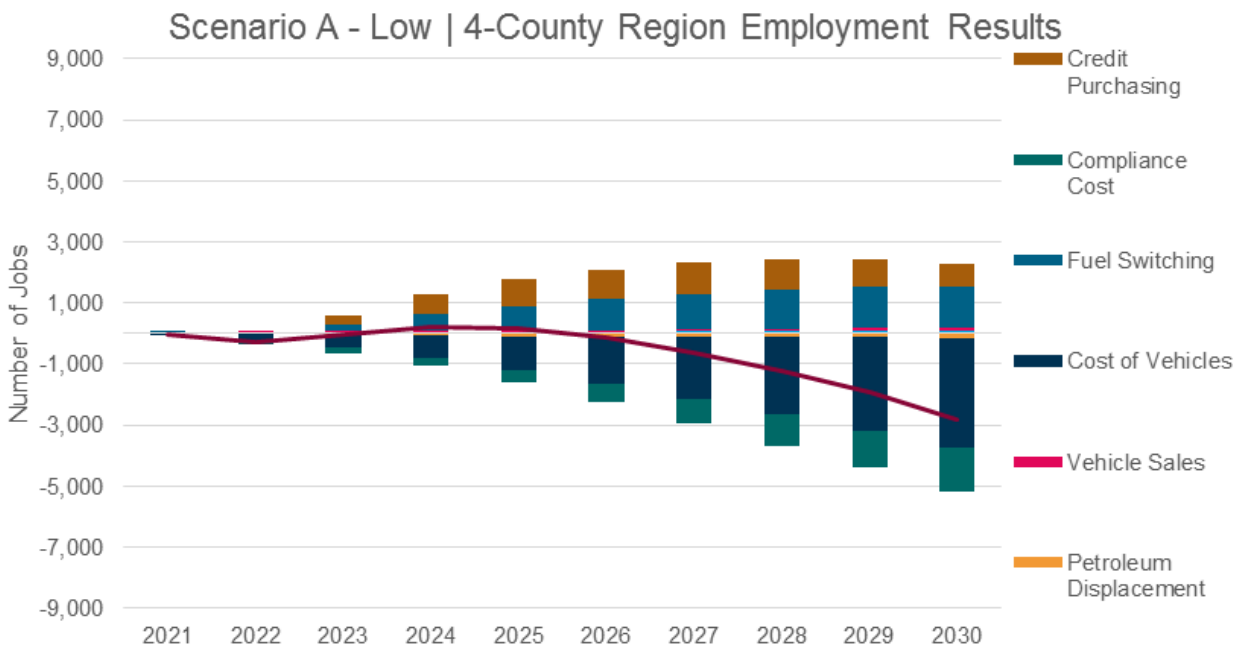
Impact Category	Description
Credit Purchasing	• Reflects the increased revenue to low carbon fuel providers based on the value of credits generated via the deployment of the lower carbon fuels in the Puget Sound region.
Compliance Cost	• Accounts for the assumption that the compliance cost (i.e., purchasing credits) will be passed through to consumers.
Fuel Switching	• Low carbon fuels like electricity and natural gas have a lower price than petroleum-based fuels, yielding a lower total cost of ownership. These lower fuel costs are reflected in this category.
Cost of Vehicles	• Alternative fuel vehicles, like EVs and NGVs, tend to be more expensive than their conventional counterparts that use combustion engines. As a result, there are increased expenditures by consumers and commercial and industrial sectors that for light-duty vehicles and MD/HD vehicles, respectively. ICF assumed that EV pricing over time, but even
Vehicle Sales	• The increased costs of alternative fuel vehicles also yields increased investment by the vehicle manufacturing sector, thereby increasing economic activity in the sector and associated economic sectors.
Petroleum Displacement	• The implementation of a Puget Sound CFS will reduce the amount of petroleum consumed in the region, thereby decreased regional demand for petroleum. This will have a negative impact on the refining industry—and this category reflects the decrease in revenue to refineries as a result of either displaced product, or higher transportation costs to export the product out of the region.
Retail Fuel and Charging Infrastructure	• Low carbon fuels will require investment in new or modified retail fueling infrastructure—these investments include converting existing petroleum-based fueling infrastructure to accommodate higher biofuel blends to providing and deploying EV charging infrastructure.

Scenario A: Biofuel Blending

Scenario A, Low Credit Price

Employment Impact (# of Jobs) - Scenario A - Low										
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Snohomish	-3	-50	-23	-6	-36	-102	-201	-316	-450	-609
King	0	-155	64	289	329	230	13	-261	-621	-1,084
Pierce	-5	-68	-57	-60	-107	-202	-333	-495	-683	-903
Kitsap	-4	-19	-17	-19	-35	-62	-98	-139	-184	-235
Rest of Washington	3	-25	25	84	123	141	148	142	116	75
Total Washington	-9	-317	-8	288	273	5	-472	-1,069	-1,823	-2,756
Total 4-County Region	-12	-292	-33	204	150	-135	-620	-1,210	-1,939	-2,831

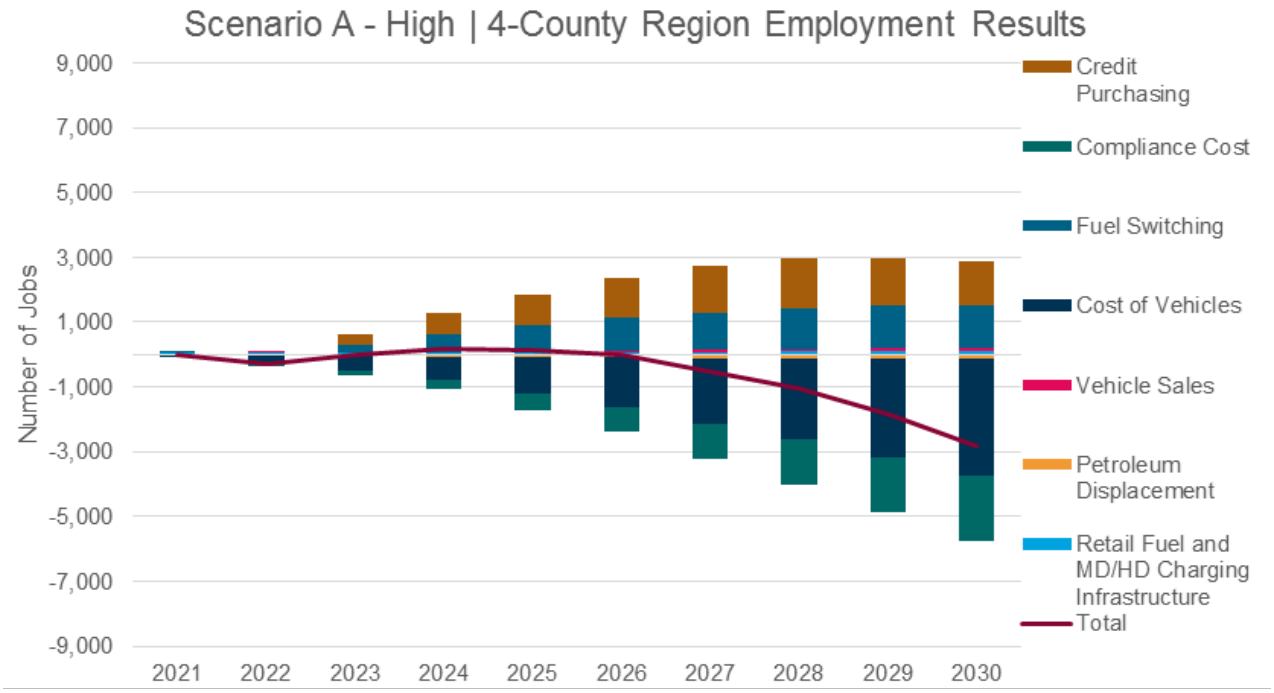
GRP Impact (Millions 2018$) - Scenario A - Low										
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Snohomish	0.0	-4.1	-2.1	-1.0	-4.3	-11.2	-21.8	-34.6	-49.8	-67.8
King	0.6	-17.6	10.9	41.9	50.7	41.0	14.9	-21.2	-71.8	-138.8
Pierce	-0.4	-10.4	-15.1	-24.2	-37.7	-57.9	-82.9	-113.4	-148.7	-188.1
Kitsap	-0.2	-1.2	-0.7	-0.4	-1.2	-2.7	-5.0	-7.6	-10.7	-14.5
Rest of Washington	2.9	-25.1	25.0	83.7	122.8	140.8	147.6	141.6	116.0	74.8
Total Washington	2.8	-58.4	18.0	99.9	130.3	110.0	52.9	-35.3	-165.0	-334.4
Total 4-County Region	-0.1	-33.3	-7.0	16.2	7.5	-30.8	-94.8	-176.9	-281.0	-409.2



Scenario A, High Credit Price

Employment Impact (# of Jobs) - Scenario A - High										
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Snohomish	-3	-50	-23	-8	-43	-94	-198	-310	-459	-637
King	0	-155	64	279	318	325	132	-77	-468	-980
Pierce	-5	-68	-57	-62	-114	-202	-345	-515	-734	-990
Kitsap	-4	-19	-17	-19	-38	-61	-99	-139	-188	-244
Rest of Washington	3	-25	25	84	133	179	204	216	188	139
Total Washington	-9	-317	-8	273	256	147	-306	-825	-1,660	-2,711
Total 4-County Region	-12	-292	-33	189	123	-32	-510	-1,041	-1,848	-2,850

GRP Impact (Millions 2018$) - Scenario A - High										
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Snohomish	0.0	-4.1	-2.1	-1.2	-4.9	-10.5	-21.5	-34.2	-51.0	-71.3
King	0.6	-17.6	10.9	40.7	50.1	55.5	34.6	9.6	-43.2	-115.1
Pierce	-0.4	-10.4	-15.1	-24.3	-38.4	-60.0	-88.4	-123.8	-166.1	-213.8
Kitsap	-0.2	-1.2	-0.7	-0.5	-1.3	-2.5	-4.8	-7.3	-10.7	-14.7
Rest of Washington	2.9	-25.1	25.0	84.0	133.1	179.4	204.4	216.2	187.9	139.1
Total Washington	2.8	-58.4	18.0	98.6	138.5	161.9	124.3	60.6	-83.1	-275.9
Total 4-County Region	-0.1	-33.3	-7.0	14.7	5.5	-17.5	-80.1	-155.7	-271.0	-414.9

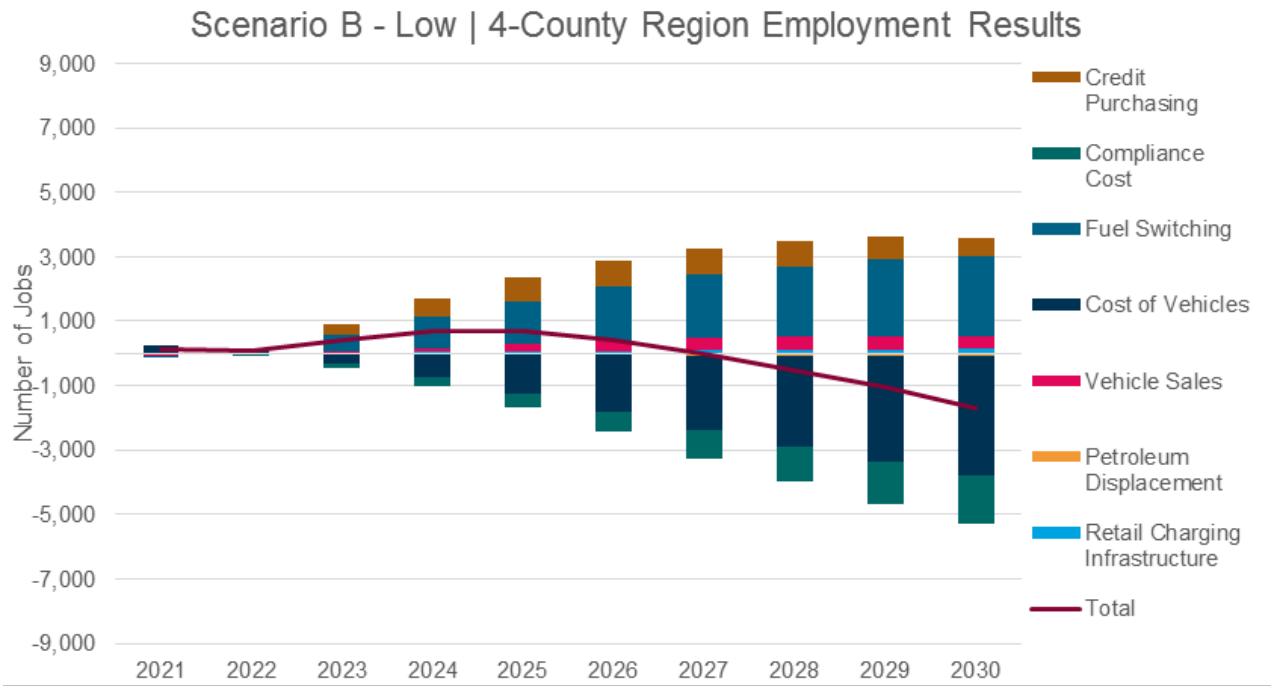


Scenario B: Aggressive Electrification

Scenario B, Low Credit Price

Employment Impact (# of Jobs) - Scenario B - Low										
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Snohomish	21	8	59	95	80	28	-51	-141	-237	-352
King	85	45	311	547	585	485	294	70	-175	-492
Pierce	26	7	39	46	3	-90	-212	-362	-520	-698
Kitsap	6	1	12	17	6	-15	-44	-77	-111	-150
Rest of Washington	14	7	62	115	145	154	154	142	122	93
Total Washington	151	68	483	820	820	562	140	-368	-921	-1,600
Total 4-County Region	138	61	421	704	675	408	-14	-510	-1,043	-1,693

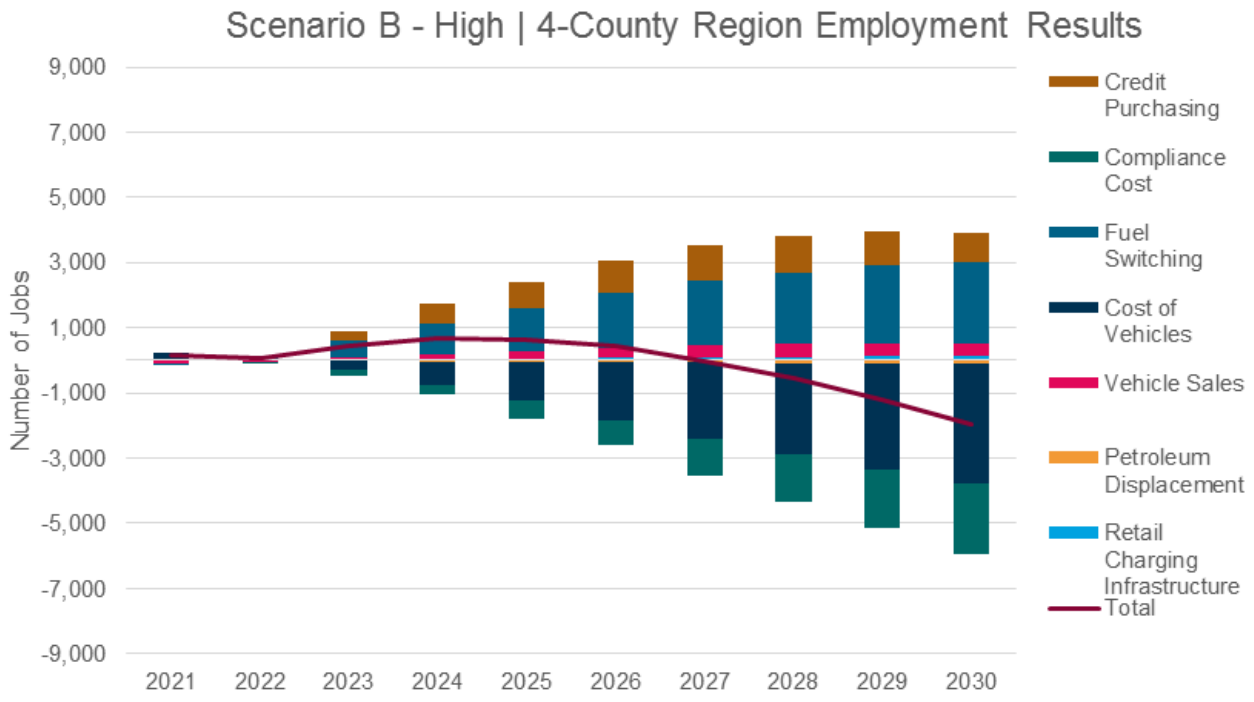
GRP Impact (Millions 2018$) - Scenario B - Low										
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Snohomish	1.7	0.7	4.9	7.7	5.9	0.2	-8.4	-18.8	-30.3	-44.0
King	9.0	5.3	40.4	73.0	81.5	70.9	47.0	15.6	-21.0	-69.7
Pierce	2.4	-1.4	-3.4	-11.6	-25.3	-46.3	-72.0	-104.6	-139.8	-177.8
Kitsap	0.4	0.2	1.1	1.8	1.4	0.2	-1.6	-3.7	-6.0	-8.9
Rest of Washington	13.8	6.8	61.6	115.4	145.4	153.6	154.3	141.8	121.9	92.5
Total Washington	27.4	11.6	104.7	186.3	208.9	178.7	119.4	30.3	-75.2	-207.9
Total 4-County Region	13.6	4.8	43.1	70.9	63.5	25.1	-34.9	-111.4	-197.1	-300.4



Scenario B, High Credit Price

Employment Impact (# of Jobs) - Scenario B - High										
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Snohomish	21	8	59	92	72	32	-57	-150	-263	-399
King	85	45	311	537	565	536	328	116	-179	-559
Pierce	26	7	39	43	-7	-103	-251	-428	-625	-848
Kitsap	6	1	12	16	4	-15	-47	-80	-119	-164
Rest of Washington	14	7	62	116	154	181	190	182	153	110
Total Washington	151	68	483	804	787	631	163	-360	-1,033	-1,858
Total 4-County Region	138	61	421	688	633	449	-27	-542	-1,185	-1,969

GRP Impact (Millions 2018$) - Scenario B - High										
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Snohomish	1.7	0.7	4.9	7.5	5.2	0.4	-9.3	-20.4	-34.0	-50.2
King	9.0	5.3	40.4	71.8	79.4	78.6	53.2	24.0	-19.3	-76.5
Pierce	2.4	-1.4	-3.4	-11.7	-26.3	-50.4	-81.9	-122.9	-167.8	-216.5
Kitsap	0.4	0.2	1.1	1.7	1.3	0.4	-1.6	-3.7	-6.4	-9.6
Rest of Washington	13.8	6.8	61.6	115.7	153.7	181.2	190.3	181.9	152.8	110.5
Total Washington	27.4	11.6	104.7	185.0	213.2	210.2	150.7	58.9	-74.6	-242.3
Total 4-County Region	**13.6**	**4.8**	**43.1**	**69.3**	**59.6**	**28.9**	**-39.6**	**-123.0**	**-227.4**	**-352.8**

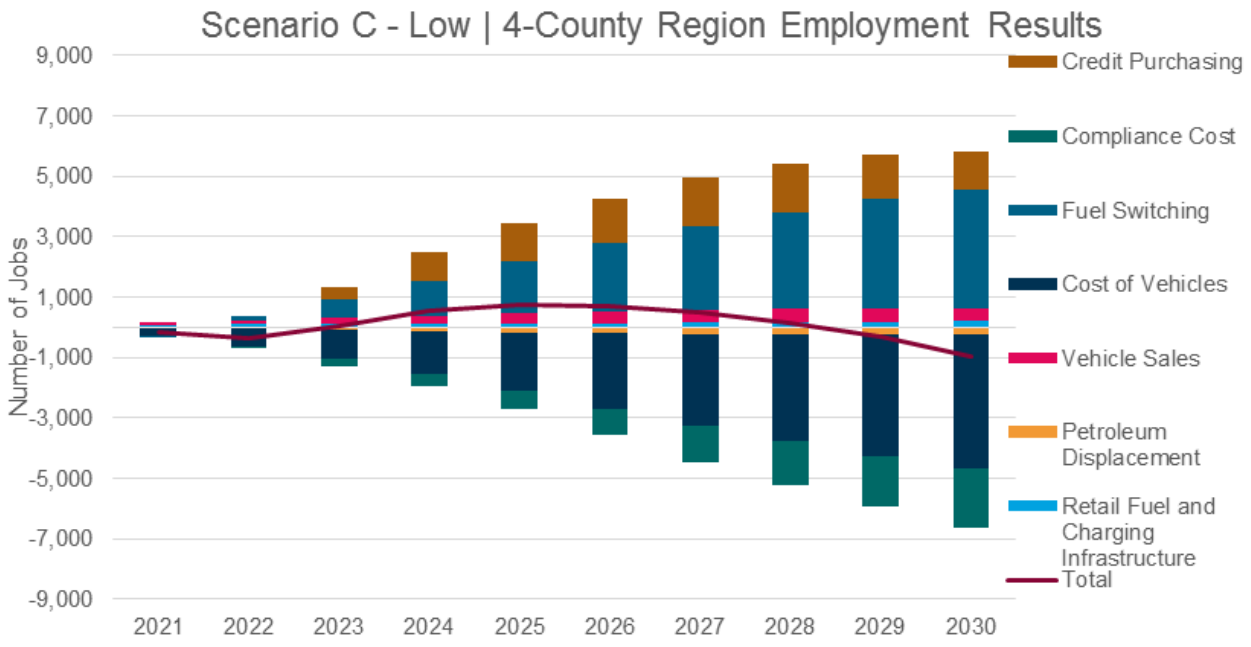


Scenario C: Mixed Technology Scenario

Scenario C, Low Credit Price

Employment Impact (# of Jobs) - Scenario C - Low										
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Snohomish	-28	-51	-4	58	72	53	7	-58	-134	-239
King	-97	-180	112	513	712	762	719	581	379	58
Pierce	-36	-91	-73	-48	-64	-133	-223	-357	-509	-690
Kitsap	-11	-20	-10	2	1	-9	-27	-49	-74	-107
Rest of Washington	-13	-44	12	90	144	168	187	174	135	74
Total Washington	-185	-386	36	616	865	841	664	291	-203	-905
Total 4-County Region	-172	-342	25	526	720	673	477	117	-338	-979

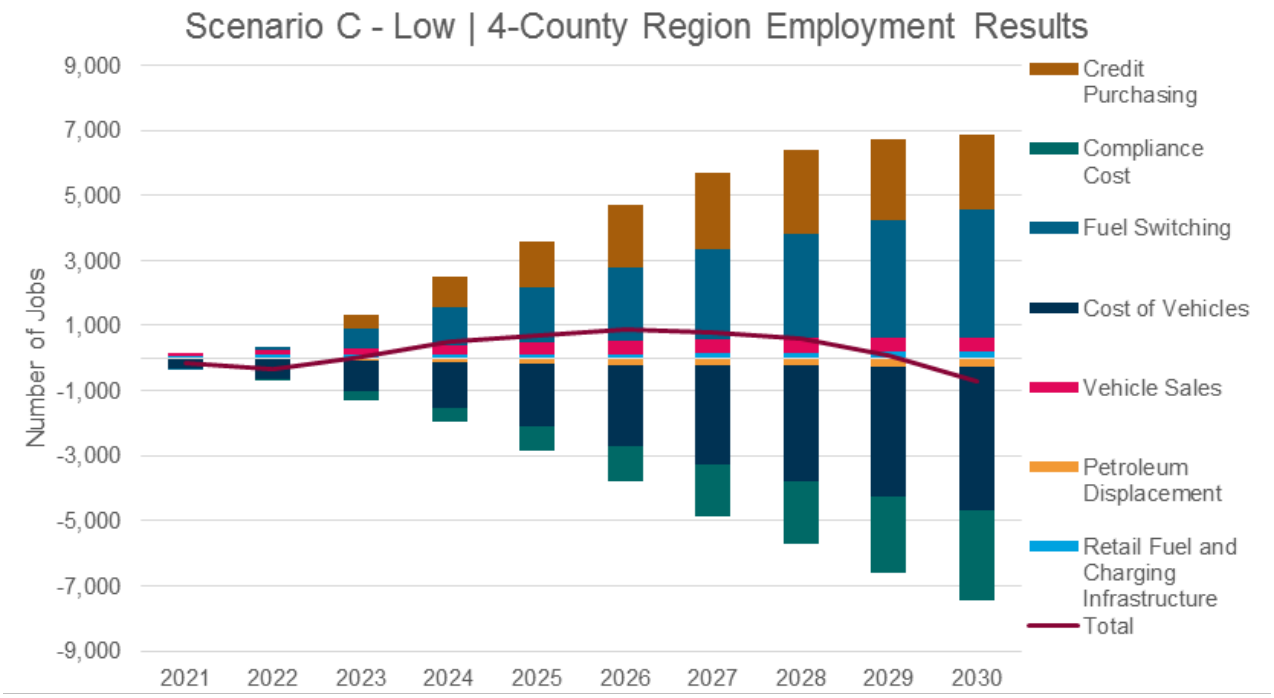
GRP Impact (Millions 2018$) - Scenario C - Low										
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Snohomish	-2.1	-4.1	-0.2	5.1	6.1	3.9	-1.2	-8.9	-18.3	-30.9
King	-10.0	-19.7	19.3	74.8	107.4	120.5	121.6	107.0	80.2	34.1
Pierce	-3.4	-16.9	-23.7	-33.7	-47.8	-70.2	-94.1	-127.9	-166.0	-207.9
Kitsap	-0.7	-1.3	-0.4	0.8	1.0	0.6	-0.3	-1.7	-3.5	-5.9
Rest of Washington	-12.8	-43.9	11.7	89.6	144.2	167.7	187.4	173.7	134.7	73.9
Total Washington	-28.9	-85.9	6.6	136.6	210.9	222.5	213.3	142.1	27.2	-136.8
Total 4-County Region	-16.2	-42.0	-5.0	47.0	66.7	54.8	25.9	-31.6	-107.5	-210.6



Scenario C, High Credit Price

Employment Impact (# of Jobs) - Scenario C - High										
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Snohomish	-28	-51	-4	54	62	71	28	-25	-121	-253
King	-97	-180	112	498	701	951	1,002	1,003	767	375
Pierce	-36	-91	-73	-51	-73	-115	-201	-329	-512	-737
Kitsap	-11	-20	-10	1	-3	-6	-24	-44	-75	-115
Rest of Washington	-13	-44	12	90	161	236	294	312	264	180
Total Washington	-185	-386	36	592	848	1,137	1,099	917	322	-550
Total 4-County Region	-172	-342	25	502	687	901	805	605	59	-730

GRP Impact (Millions 2018$) - Scenario C - High										
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Snohomish	-2.1	-4.1	-0.2	4.8	5.4	5.8	1.2	-5.3	-16.7	-32.4
King	-10.0	-19.7	19.3	73.0	107.1	149.1	167.1	176.4	149.3	97.7
Pierce	-3.4	-16.9	-23.7	-33.9	-48.3	-70.2	-95.7	-132.6	-177.7	-228.3
Kitsap	-0.7	-1.3	-0.4	0.7	0.9	1.1	0.2	-0.8	-2.9	-5.8
Rest of Washington	-12.8	-43.9	11.7	90.0	160.8	235.9	294.0	312.3	263.8	180.2
Total Washington	-28.9	-85.9	6.6	134.7	225.8	321.6	366.9	350.0	215.8	11.4
Total 4-County Region	-16.2	-42.0	-5.0	44.6	65.0	85.8	72.9	37.7	-47.9	-168.8

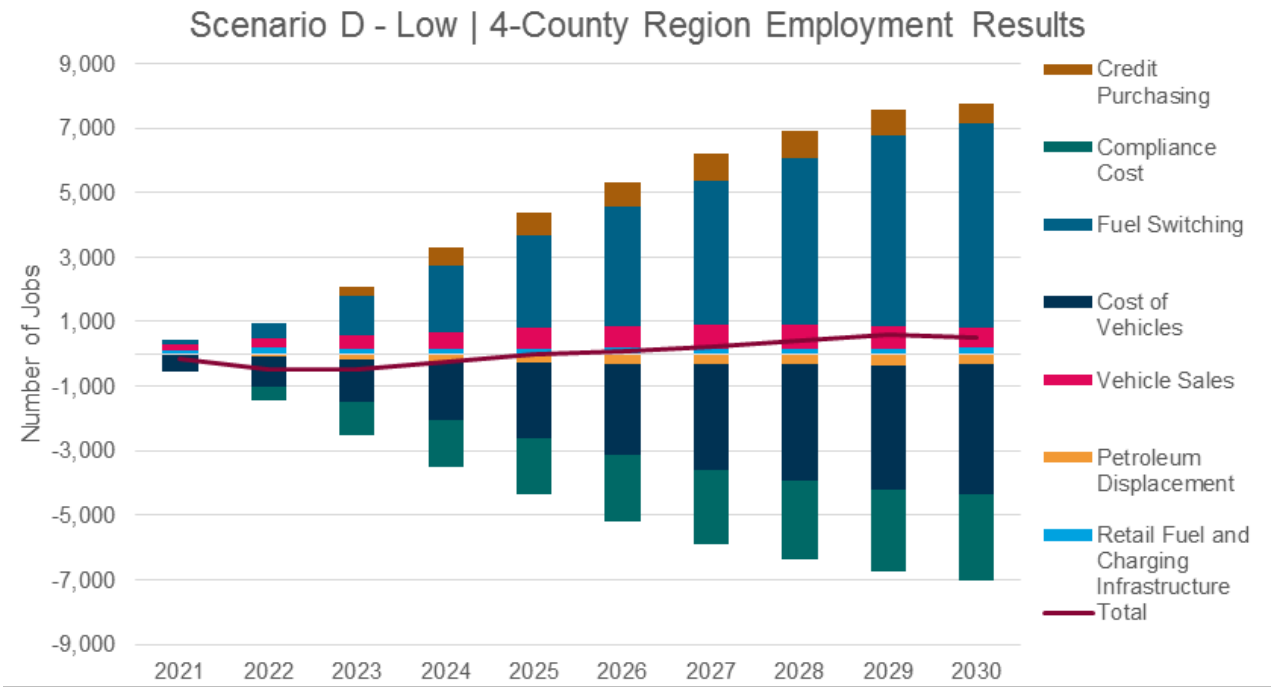


Scenario D: All-In, Maximum Feasible Reduction

Scenario D, Low Credit Price

Employment Impact (# of Jobs) - Scenario D - Low										
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Snohomish	-16	-51	-38	10	58	83	113	149	187	173
King	-79	-263	-174	101	346	478	628	801	957	905
Pierce	-34	-133	-241	-353	-443	-524	-574	-590	-596	-651
Kitsap	-7	-17	-11	4	20	31	44	58	72	68
Rest of Washington	-14	-56	-13	34	40	15	-20	-57	-102	-174
Total Washington	-151	-520	-478	-204	22	83	191	361	519	321
Total 4-County Region	-136	-463	-465	-238	-18	69	211	418	620	495

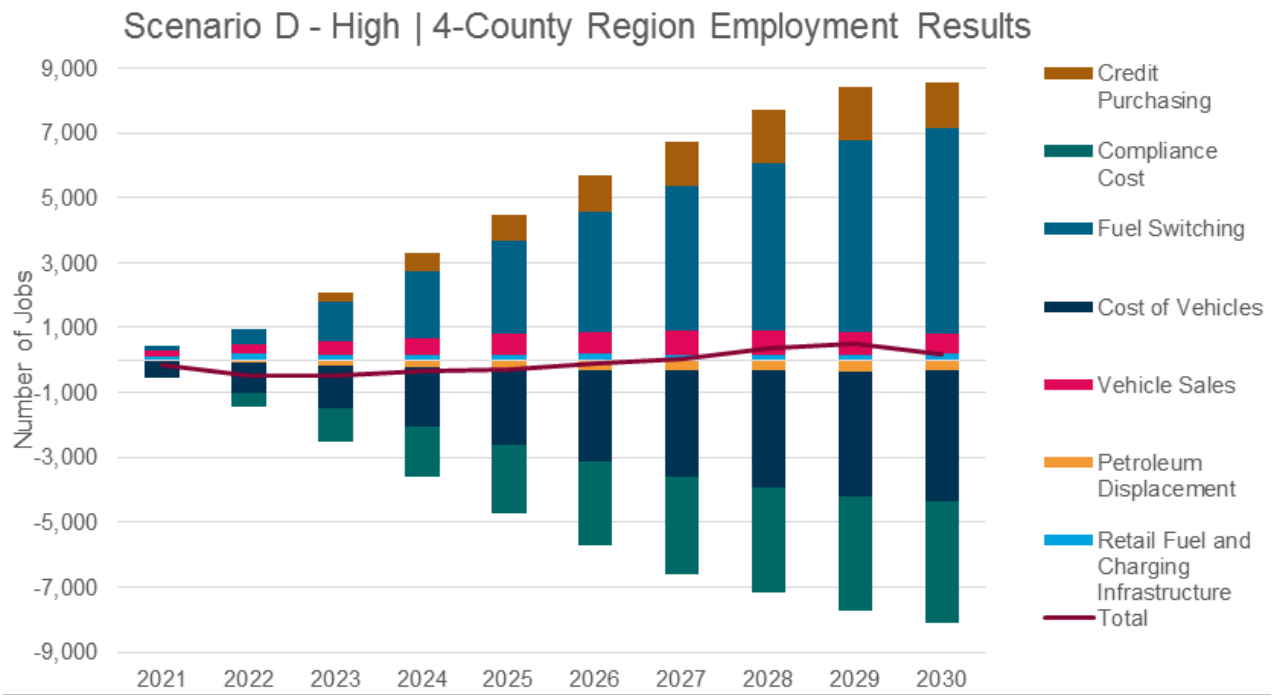
GRP Impact (Millions 2018$) - Scenario D - Low										
	-0.8	-3.5	-3.0	-0.1	2.8	3.9	5.4	7.6	10.2	7.4
Snohomish	-6.5	-26.1	-11.6	26.2	61.2	82.7	107.1	133.8	156.9	148.1
King	-3.3	-26.3	-53.0	-92.6	-133.6	-171.1	-203.6	-229.2	-251.8	-277.9
Pierce	-0.5	-1.3	-0.9	0.2	1.5	2.3	3.3	4.4	5.5	5.3
Kitsap	-14.4	-56.4	-13.2	33.9	40.2	14.7	-19.7	-56.9	-101.5	-173.9
Rest of Washington	-25.6	-113.5	-81.8	-32.4	-28.0	-67.5	-107.5	-140.2	-180.8	-291.0
Total Washington	-11.2	-57.2	-68.6	-66.3	-68.1	-82.3	-87.8	-83.4	-79.2	-117.1
Total 4-County Region	-0.8	-3.5	-3.0	-0.1	2.8	3.9	5.4	7.6	10.2	7.4



Scenario D, High Credit Price

Employment Impact (# of Jobs) - Scenario D - High										
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Snohomish	-16	-51	-38	-4	10	45	62	110	130	86
King	-79	-263	-174	47	185	439	617	933	1,060	915
Pierce	-34	-133	-241	-366	-501	-605	-689	-709	-748	-855
Kitsap	-7	-17	-11	0	5	17	25	41	48	35
Rest of Washington	-14	-56	-13	35	56	63	37	2	-81	-213
Total Washington	-151	-520	-478	-288	-245	-41	53	377	408	-31
Total 4-County Region	-136	-463	-465	-323	-301	-104	15	375	489	181

GRP Impact (Millions 2018$) - Scenario D - High										
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Snohomish	-0.8	-3.5	-3.0	-1.3	-1.4	0.2	0.4	3.4	3.9	-2.3
King	-6.5	-26.1	-11.6	19.9	42.6	81.7	112.7	162.3	184.6	164.9
Pierce	-3.3	-26.3	-53.0	-93.3	-138.8	-185.0	-226.5	-259.4	-290.6	-327.9
Kitsap	-0.5	-1.3	-0.9	0.0	0.5	1.5	2.3	3.7	4.4	3.6
Rest of Washington	-14.4	-56.4	-13.2	35.3	55.9	63.3	37.1	1.5	-80.9	-212.6
Total Washington	-25.6	-113.5	-81.8	-39.4	-41.3	-38.3	-74.1	-88.5	-178.7	-374.4
Total 4-County Region	-11.2	-57.2	-68.6	-74.7	-97.2	-101.5	-111.2	-90.1	-97.8	-161.7



Appendix C: Supplemental Data Available

The following data and files have been supplied to PSCAA to support this project:

- WA-GREET
- C-LINE run output and receptor concentrations
- Population and BenMAP results
- AQ Data layers

Appendix D: Erratum

November 7, 2019

Subsequent to the release of the final report:

ICF discovered that there was an error in the code that was used to develop the compliance scenario model used in the analysis as part of the work for the Puget Sound Clean Air Agency. The error was linked to the increased use of natural gas (primarily renewable) as a transportation fuel in heavy-duty trucks (Class 7-8). In short, as natural gas consumption increased, the model included a displacement of conventional diesel at a rate that was inconsistent with (greater than) what should be considered. This error manifested itself when natural gas as a transportation fuel consumption was modeled to increase over baseline usage—which was most significant in Scenario D, with small increases in Scenario C. There was no increase in the use of natural gas above baseline in Scenario A nor Scenario B. For Scenario C and D, this error led to less-than-anticipated diesel consumption. After fixing this error, ICF identified the following high-level impacts on our results, with a focus on the compliance curve and potential economic impacts.

- **There is no discernable impact on ICF's modeled compliance.** After correcting for the error regarding diesel consumption, there were an increased number of deficits calculated. However, both biodiesel and renewable diesel are calculated as a percent blend in the model (as opposed to a fixed volume to prevent blending at a rate too high over time). In other words, as the diesel volumes were corrected, increased volumes of biodiesel and renewable diesel effectively offset the deficit generation with credit generation.
- **ICF estimates no discernable impact on the economic modeling results.** As noted throughout the report, the economic modeling results are small across all scenarios. There are several reasons for our estimates that there are no impacts on the modeling results.
    - **Small change in the compliance cost pass-through (compliance cost).** ICF models the compliance cost to consumers as a full pass-through of the compliance cost associated with illustrative credit price curves used in the analysis. This pass-through cost is modeled as the cost of all deficits. The compliance cost is calculated as the product of the sum of all deficits generated in a given year and the credit price in that year. After correcting for the error, more deficits were generated, but the impact is spread over a larger volume of fuel. On a net basis, the compliance cost pass-through assumption increases, but the per gallon change is unaffected. Impact: small negative economic impacts.
    - **Small change to refinery impacts (petroleum displacement).** As noted in the report, ICF accounts for displaced diesel (and gasoline) as a net negative impact to the refining industry—by displacing half the product and assuming the other half is shipped out of the region at a higher cost. Our modeling over-stated diesel displacement and as a result over-states the impacts on the refining industry. Impact: small positive economic impacts.
    - **Small change to biofuel impacts (credit purchasing).** Both renewable diesel and biodiesel are linked as a percentage blend to total diesel consumption in our modeling. As a result, when the diesel volumes were too low, the amount of renewable diesel and biodiesel blended was also too low. When correcting the

error, both volumes increased, as did credit generating activity for both fuels. ICF links the value generated by those credits back to the corresponding low carbon fuel industry, so there would be increased flow of that revenue in the corrected model. Impact: small positive economic impacts.

- **No other change.** There are no other anticipated changes in the economic modeling results, as the corrected change has no impact on vehicle sales or cost of vehicles, infrastructure investments, or fuel switching.

Summary. The identified error has no impact on ICF conclusions regarding the carbon intensity reduction of 26% achieved in Scenario D. Further, ICF estimates that there will be no discernible change to economic modeling results as a result of fixing the identified error in the scenario modeling analysis because the two small positive impacts outlined above are expected to offset the small negative impact.

The error also has no impact on the air quality analysis because that analysis was derived from the projected vehicle fleet composition, activity, and emission factors, not the total fuel volumes.

The following, corrected figures replace Figures 11-15 (on pages 38-42). For a quantitative comparison, the corrected (and old) Cumulative Credit Bank values in 2030 are:

- for Scenario C, 5.22 (4.93) million credits
- for Scenario D (with a 26% CI reduction target), 5.24 (4.89) million credits
- for Scenario D (with a 20% CI reduction target), 9.76 (9.01) million credits

Figure 27 Replaces Figure 11: Balance of Credits and Deficits Generated in Scenario C

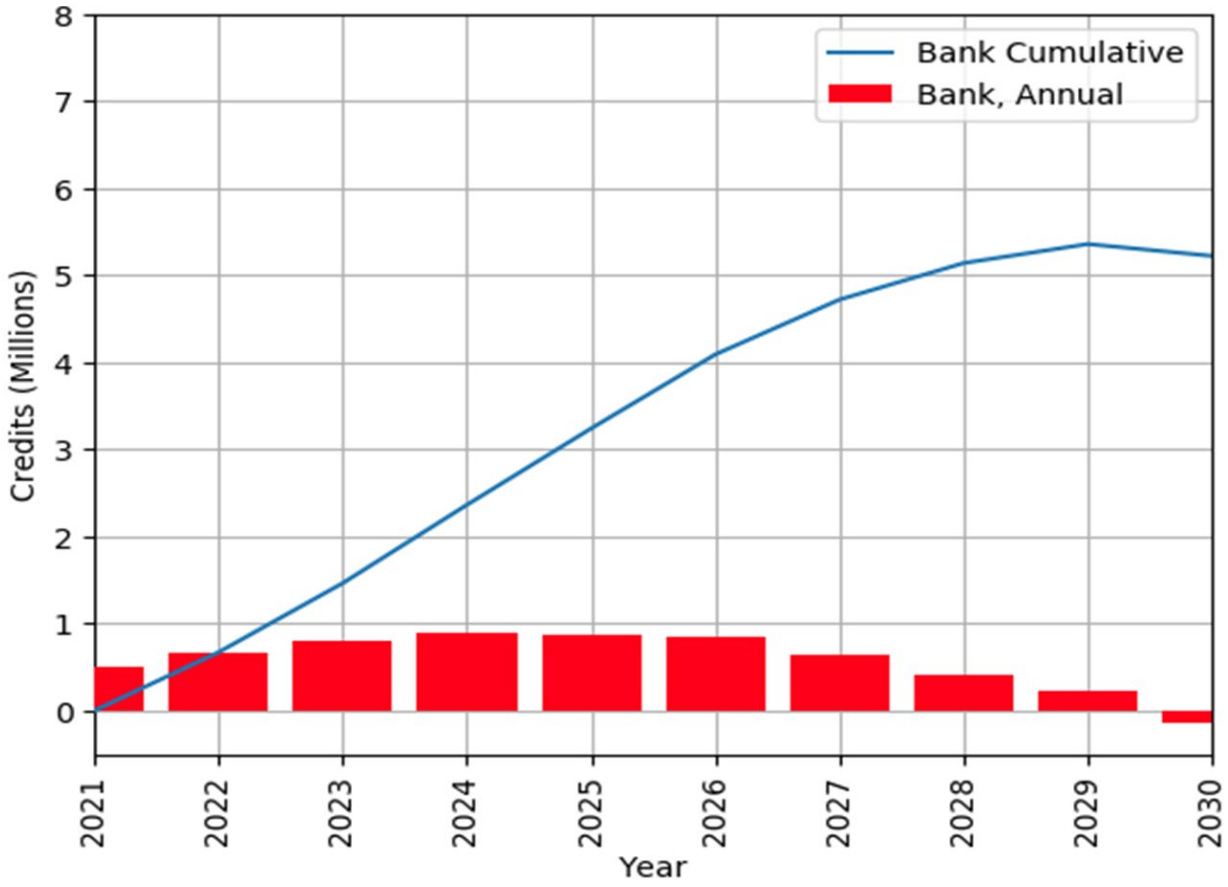


Figure 28 Replaces Figure 12 Alternative Fuel Contributions to CFS Compliance in Scenario C

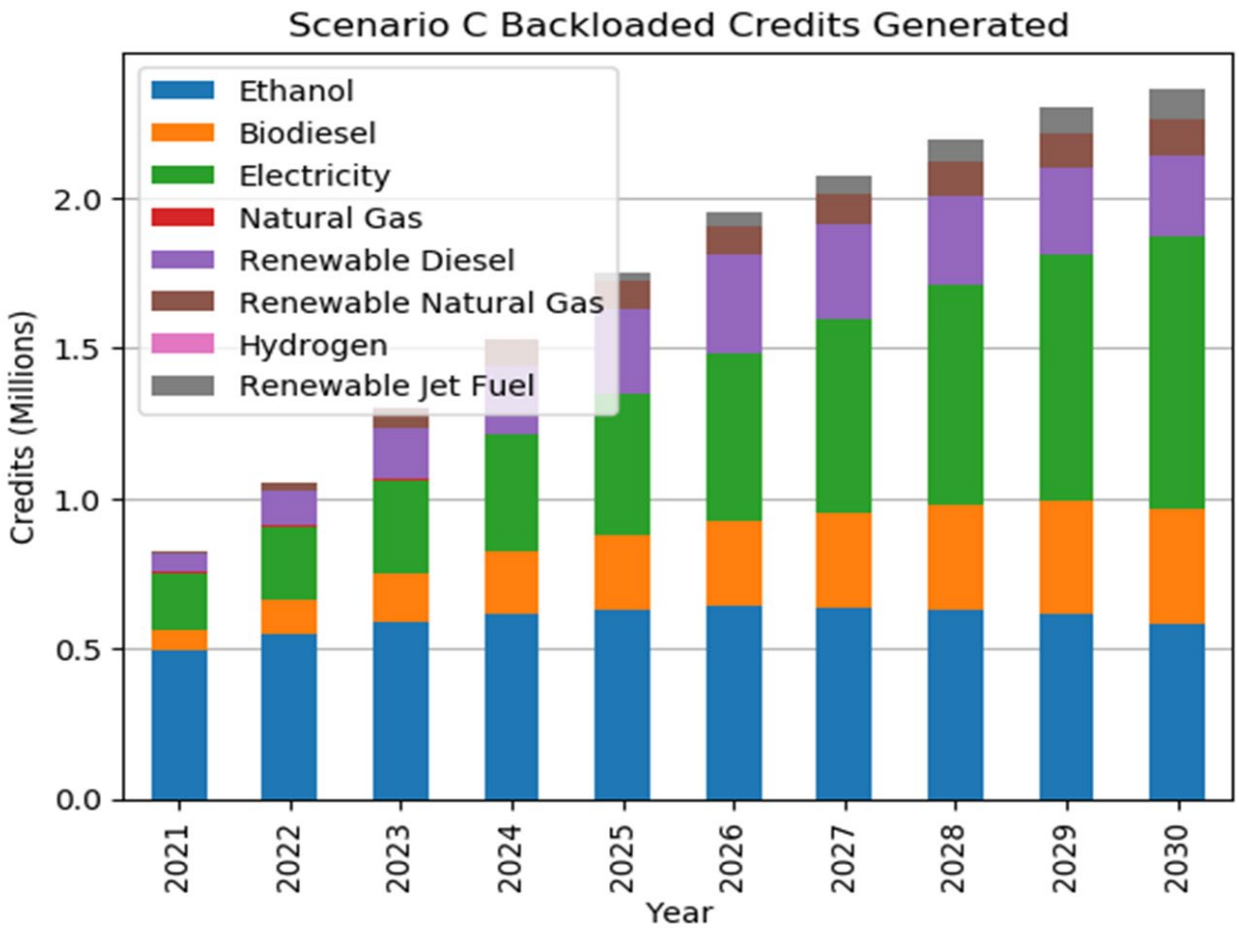


Figure 29 Replaces Figure 13 Balance of Credits and Deficits Generated in Scenario D with a 26% CI standard

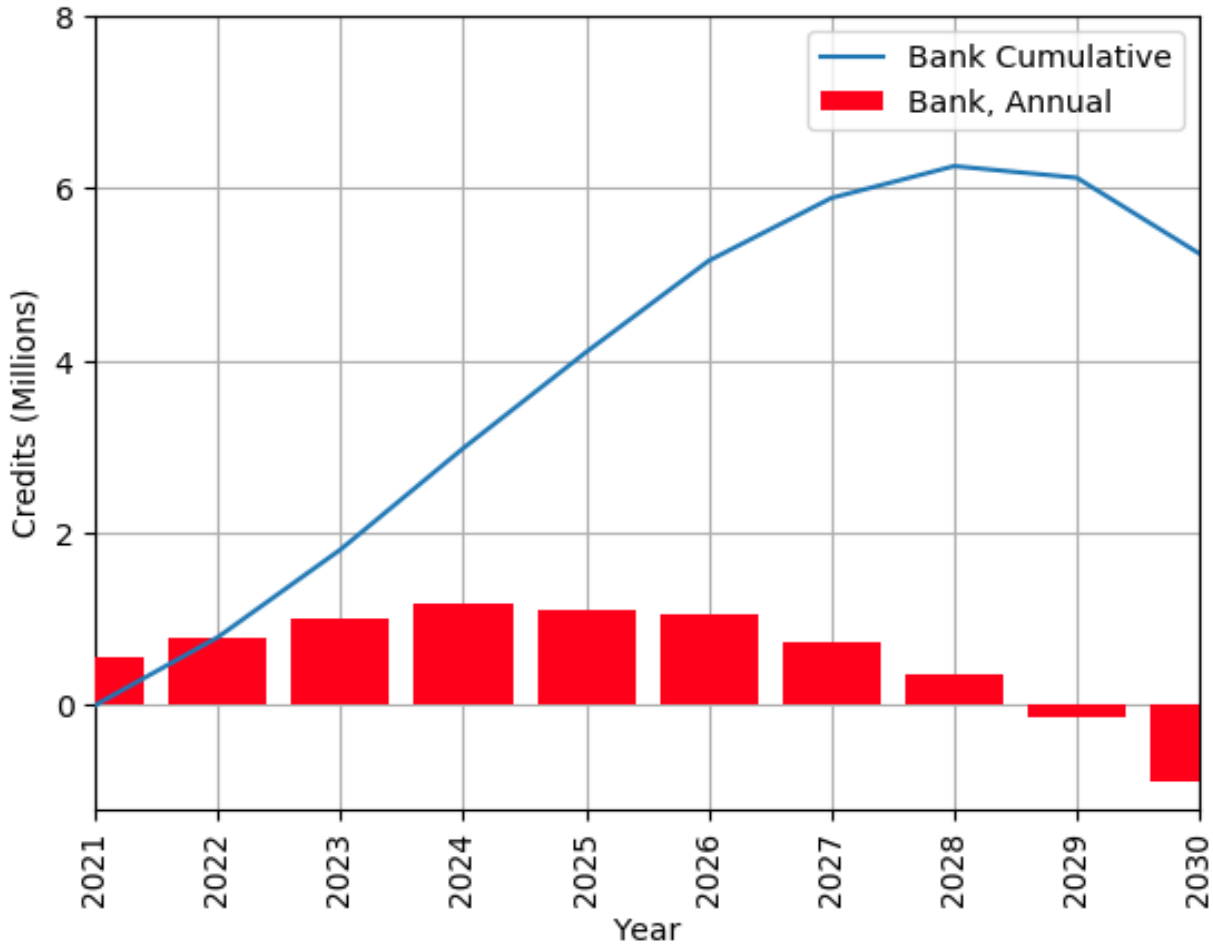


Figure 30 Replaces Figure 14 Balance of Credits and Deficits in Scenario D with a 20% CI standard

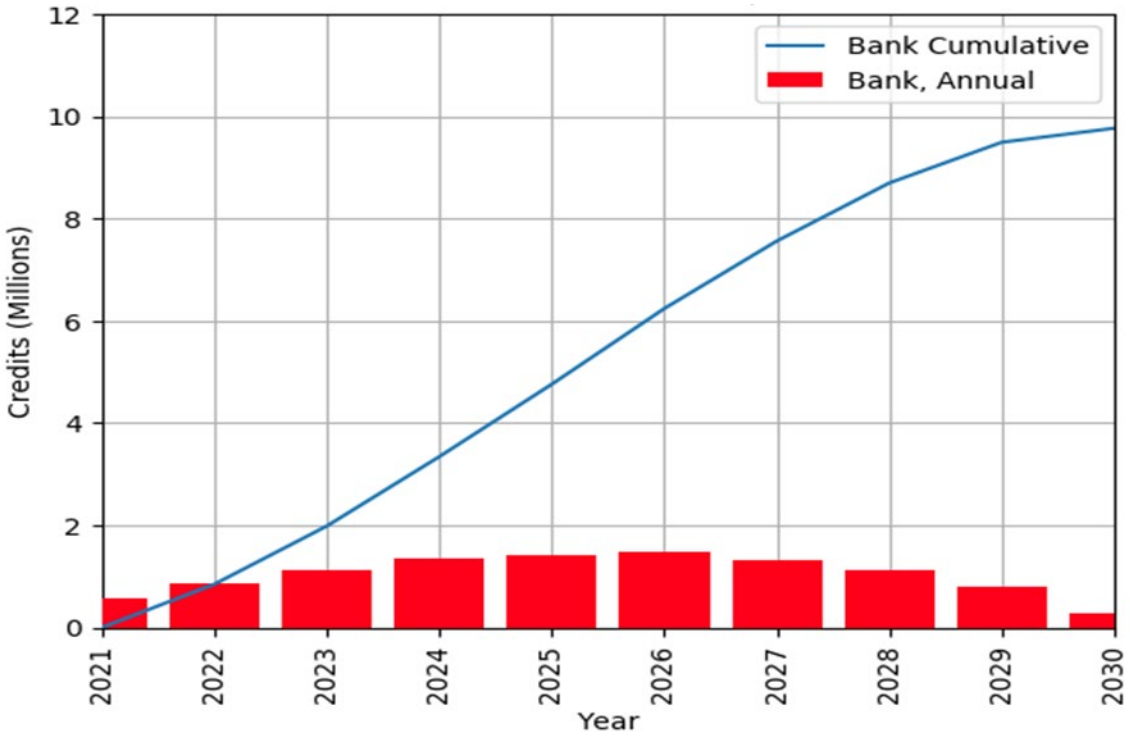


Figure 31 Replaces Figure 15 Alternative Fuel Contributions to CFS Compliance in Scenario D with a 26% CI standard