# A Clean Fuel Standard in Washington State
## Revised Analysis with Updated Assumptions

**FINAL REPORT**
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# Abbreviations

| | |
|---|---|
| AEO | Annual Energy Outlook |
| ARB | Air Resources Board |
| B&T | Banking and trading |
| BAU | Business-as-Usual |
| BEV | Battery electric vehicle |
| CEC | California Energy Commission |
| CI | Carbon Intensity |
| CFS | Clean Fuel Standard |
| CNG | Compressed natural gas |
| EER | Energy economy ratio |
| EIA | Energy Information Administration |
| EPA | U.S. Environmental Protection Agency |
| EVSE | Electric vehicle supply equipment |
| FFV | Flex Fuel Vehicle |
| GHG | Greenhouse Gas |
| HDV | Heavy duty |
| HEV | Hybrid electric vehicle |
| ICE | Internal combustion engine |
| ILUC | Indirect land use change |
| LCFS | Low Carbon Fuel Standard |
| LDA | Light duty auto |
| LDT | Light duty truck |
| LDV | Light duty vehicle |
| LFG | Landfill gas |
| LNG | Liquefied natural gas |
| MDV | Medium duty vehicle |
| MGY | Million gallons per year |
| OFM | Washington State Office of Financial Management |
| PADD | Petroleum Administration Defense District |
| PEV | Plug-in electric vehicle |
| PHEV | Plug-in Hybrid Electric Vehicle |
| RD | Renewable diesel |
| RNG | Renewable natural gas |
| RFS | Renewable Fuel Standard |
| TRFC | Washington state Transportation Revenue Forecast Council |
| TTW | Tank-to-Wheel |
| VMT | Vehicle miles travelled |
| WSDOT | Washington State Department of Transportation |
| WSDA | Washington Department of Agriculture |
| WTW | Well-to-Wheel |
| WWT | Wastewater treatment |
| UCO | Used cooking oil |

# Executive Summary

In 2008, the Washington State Legislature established a goal to reduce state greenhouse gas emissions to 1990 levels by 2020 with additional goals for 2035 and 2050.[1] Since the transportation sector is responsible for almost half of the state's greenhouse gas (GHG) emissions, reductions from vehicles and fuels are fundamental to achieving the state goals. In May 2009, Washington's governor directed the Department of Ecology (Ecology) to assess whether a clean fuel standard (CFS) would best meet Washington's GHG emission reduction goals. The objective of a CFS is to reduce the overall carbon intensity of transportation fuels where carbon intensity is defined as the direct well-to-wheel (WTW) GHG emissions and any indirect emissions from land use change per unit energy. A bounding scenario analysis was performed to quantify fuel types and volumes needed for compliance, changes in consumer spending on vehicles and fuel, infrastructure costs, and the corresponding macro-economic impacts. The study concluded that volumes of alternative fuels would increase, petroleum consumption would decrease, state-level GHG emissions from transportation (as captured by assumed carbon intensity ratings and volumes) would decrease, and there would be a small (in most scenarios positive) impact on the state economy relative to the business-as-usual (BAU) projection.

Governor Inslee's Executive Order 14-04, directed the Office of Financial Management (OFM) to commission an update to the earlier analysis to reassess the technical feasibility, costs and benefits, and job impacts of a CFS. This was to be done with advice from subject matter experts, affected industries, and public interests. Since the original analysis in 2009, there have been a number of changes to the underlying assumptions including improvements in vehicle fuel economy, reductions in projected vehicle miles travelled, changes in fuel carbon intensity values, changes in low carbon fuel availability and the emergence of new low carbon fuels. This report summarizes the assumptions, methodology and findings of this update to the 2009 analysis.

The CFS considered here assumes that transportation fuel carbon intensity will be reduced 10 percent from 2012 levels by 2026, with reductions beginning in 2017 at 0.25 percent. The compliance curve assumes a gentle start to the 2026 goal with minimal reductions required in the first several years (please refer to Figure 4-1).

The first step in the analysis was an assessment of the types and volumes of low carbon fuels that could be available for use in Washington state to comply with a CFS. Carbon intensity values were then assigned to each compliance fuel pathway. Next, a business-as-usual (BAU) forecast of vehicle sales and fuel consumption was developed for comparison with a range of compliance scenarios.

There is an infinite number of combinations of fuels and advanced vehicles that could be utilized to comply with a CFS. This analysis attempts to bracket the technological and economic range of possible compliance options. Four compliance scenarios (summarized in Table E-1) were developed to bound potential market responses, given current literature on projections of available fuel pathways and current carbon intensity ratings. Each scenario focuses on a compliance theme: advanced vehicles with mixed biofuels, cellulosic fuels, and minimum cellulosic fuels. Actual compliance with annual standards would be expected to fall somewhere in the middle of the bounding scenarios, possibly including new emerging fuel pathways not part of this analysis, with specifics depending on market conditions that lie outside our modeling framework.

[1] RCW 70.235.020

Table E-1. Description of Bounding Scenarios Used to Evaluate CFS

| | |
|---|---|
| **Scenario A Advanced Vehicles** | Compliance achieved primarily through "ZEV Mandate" levels of electric and hydrogen fuel cell vehicles, and a 50 percent increase in CNG new vehicle market shares. To supplement the low carbon intensity fuels consumed by these vehicles, a balanced mix of additional low carbon biofuels was utilized. |
| **Scenario B Cellulosic Biofuels** | Compliance achieved through BAU levels of advanced vehicles and mixed biofuels in the early years, transitioning to cellulosic ethanol and cellulosic gasoline in later years. |
| **Scenario C Minimum Cellulosic, E85** | Compliance achieved through BAU levels of advanced vehicles and high volumes of non-cellulosic biofuels. To achieve compliance with a minimum of cellulosic biofuels, more volumes of conventional biofuels are needed. To consume this volume of ethanol, flex fuel vehicles consume E85 rather than gasoline. |
| **Scenario D Minimum Cellulosic, E15** | Compliance achieved through BAU levels of advanced vehicles and high volumes of non-cellulosic biofuels. To achieve compliance with a minimum of cellulosic biofuels, more volumes of conventional biofuels are needed. To consume this volume of ethanol, motor gasoline blend level increases from 10% to 15% (E15). |

Each scenario has been evaluated assuming that gasoline and fuels substituting for gasoline comply separately from diesel and fuels substituting for diesel, and that these two fuel pools must comply with the standard each year. We have also evaluated these scenarios assuming that Washington would provide compliance flexibility with banking and trading (B&T) provisions. Banking allows regulated parties to over-comply with the standard in early years and use these banked credits for compliance in later years. Trading allows credits generated in one pool to be freely used for compliance in the other pool.

Figure E-1 compares cumulative fuel use relative to BAU fuel use for a range of low CI fuels. As indicated in the plot, ethanol and biodiesel consumption are key to CFS compliance. It was assumed in all scenarios that by 2026, the statewide average biodiesel blend level would be 15 percent compared to the BAU level of 0.22 percent. Both versions of Scenario C as well as Scenario D without banking and trading assume significant levels of E85 consumption by 2026. Both versions of Scenario D assume that the ethanol blend level in gasoline grows to nearly 15 percent. Despite small cumulative increases in ethanol use relative to the BAU for Scenarios A and B, consumption in 2026 is more than 15 percent lower than the 2016 level due to a projected decrease in gasoline consumption over time (ethanol is a blending component in motor gasoline).

Cumulative electricity and CNG use increase relative to the BAU for Scenario A (advanced vehicles) by 67 percent and 40 percent, respectively. Relative to the previous analysis, the current analysis projects a larger increase in biodiesel and smaller increases in electricity and CNG consumption. Renewable natural gas has a very low CI value, but like electricity, its use is limited by the number of dedicated vehicles on the road. Incentivizing sales of vehicles that use electricity and natural gas would increase the ability to utilize these currently available low CI fuels.

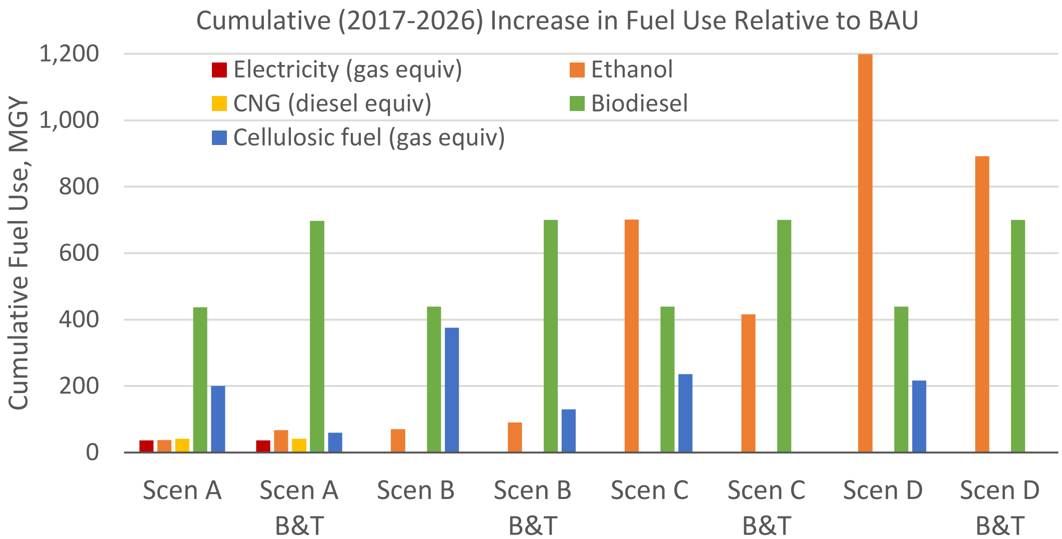


Figure E-1. Cumulative (2017-2026) fuel use relative to BAU.

Without a CFS, improving average fuel economy of the light duty fleet results in a 13 percent reduction in BAU petroleum consumption between 2016 and 2026[2]. The CFS scenarios modeled predict an additional 4 to 11 percent reduction in petroleum consumption from 2016 BAU levels. Figure E-2 provides reductions in petroleum consumption relative to the BAU for 2023 through 2026. The reductions due to the CFS (scenarios compared to BAU) are similar to the reductions estimated in the previous analysis; however the reductions in the BAU from 2016 to 2026 are larger.

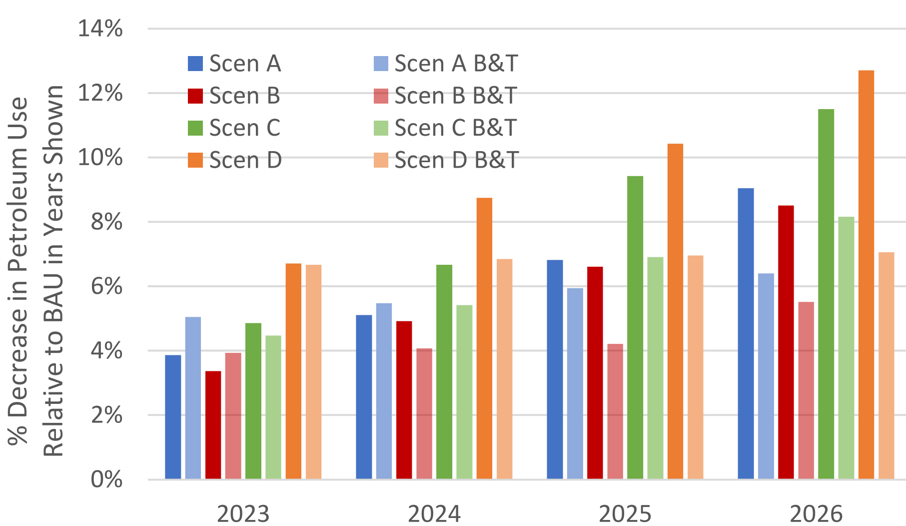


Figure E-2. Reduction in Petroleum Consumption Relative to BAU for 2023-2026.

[2] The VISION model forecasts a 20 percent reduction in gasoline use and a 12 percent increase in diesel consumption from the BAU between 2016 to 2026.

Assuming that average CFS credit prices steadily increase to $100 per tonne and that the entire cost of the credits is added to the price of motor gasoline and diesel, the CFS scenarios with banking and trading considered in this analysis result in a projected range of gasoline price increases of 2 cents in 2020 and 10 cents by 2026. Diesel prices are projected to increase by 2 cents in 2020 and up to 12 cents in 2026 (Figure 7-47 and Figure 7-48)[3]. The credit price would at the same time add value to low carbon fuels, some of which could be passed to the consumer, which would partly offset any price increases for petroleum fuels.

Figure E-3 summarizes the WTW GHG reductions relative to 2026 BAU GHG emissions. These reduction estimates are similar to the previous study. The bank and trade scenarios have lower reductions in 2026 and higher reductions in the early years of the program. They also have larger cumulative reductions because of the analysis criterion of holding a credit balance after the last year of the program equal to 25 percent of the 2026 credit requirement.

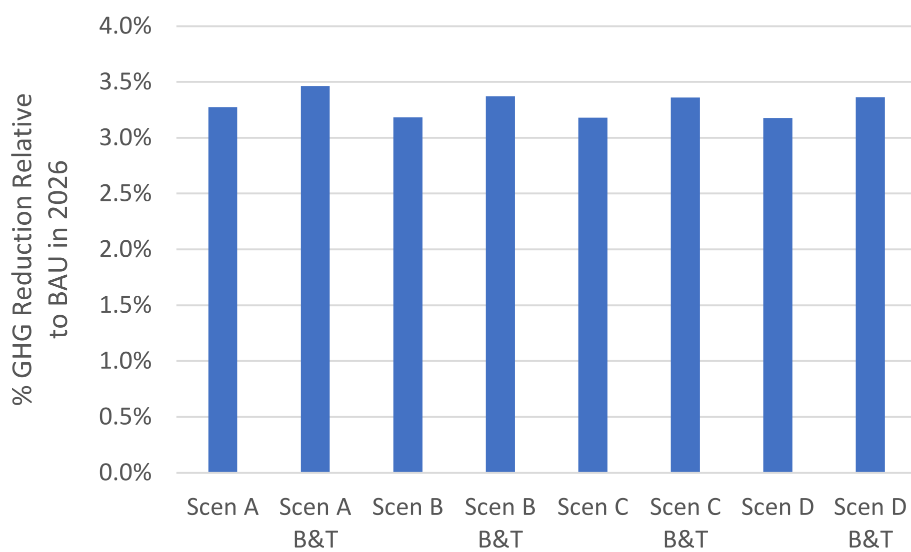


Figure E-3. Decrease in cumulative (2017-2026) WTW GHG emissions relative to BAU.

To quantify the impacts of the compliance scenarios on state macro-economic indicators, the REMI-PI+ model was utilized. Table E-2 summarizes the macro-economic results for the CFS compliance scenarios considered in the analysis. The estimated impacts are small; two of the eight scenarios experience negative impacts for at least one of the metrics while the remaining six scenarios have positive impacts.

[3] Credit prices in ARB's program averaged $17 per tonne in 2012, $55 per tonne in 2013, and averaged $28 per tonne in the most recent quarter.

Table E-2. Range of Macro-Economic Results for Suite of Compliance Scenarios.

| $2010 | Impact Relative to BAU | |
|---|---|---|
| Annual Average Change in Employment | -210 to 1,430 | -0.01% to 0.07% |
| Annual Average Change in Income | -$10 M to $130M | -0.004% to 0.04% |
| Annual Average Change in Gross State Product | -$30M to $140M | -0.01% to 0.05% |
| Gross State Product Impacts in 2016 and 2026 | -$2.3M to $2.8M (2016) | -$90M to $143M (2026) |
| Single-Year Highest and Lowest GSP | $583M in 2022 (Scenario B) | -$127M in 2026 (Scenario A B&T) |

These results are not significantly different than what would have occurred in the BAU case. This represents a small impact on the projected $400 Billion to $500 Billion gross state product projected for the 2016-2026 timeframe

The analysis assumes that up to three cellulosic fuel production plants would be located in state. To quantify the impact that this assumption has on economic indicators, a sensitivity case was run for Scenario B with banking and trading. The base case assumes that 3 plants are built and operated in-state; the sensitivity case assumes that all cellulosic fuel is imported. This analysis shows that GSP, employment and personal income are effectively unchanged from the BAU when cellulosic fuel is imported, while in-state fuel production creates positive impacts both during and after construction of new facilities. If the state implements a CFS, it may want to consider incentivizing in-state production to achieve these benefits.

# 1. Introduction

In 2008, the Washington State Legislature established a goal to reduce state GHG emissions to 1990 levels by 2020 with additional goals for 2035 and 2050.[4] Since the transportation sector is responsible for almost half of the state's greenhouse gas (GHG) emissions, reductions from vehicles and fuels are fundamental to achieving the state goals. One way to reduce GHG emissions from transportation is to implement a Clean Fuel Standard (CFS) in which fuel carbon intensity (CI) is required to meet a declining standard. CI is composed of direct well-to-wheel (WTW) emissions and emissions from indirect land use change (ILUC) per unit of fuel energy content. Direct WTW emissions include the emissions associated with feedstock production/recovery, feedstock transport to the fuel production plant, fuel production, fuel transport to the refueling stations and vehicle emissions. ILUC emissions can occur when land use changes in response to increased demand for biofuel feedstocks.

In 2009-11, Washington Department of Ecology's (Ecology) Air Quality Program commissioned an analysis of the implications of launching a CFS to reduce emissions from the transportation sector.[5] In 2013 a review of the original analysis was conducted to consider the degree to which updated assumptions might alter the original conclusions.[6] Governor Inslee subsequently directed, by Executive Order 14-04, the Office of Financial Management (OFM), with other agencies, and advice from subject matter experts, affected industries, and public interests to evaluate the technical feasibility, costs and benefits, and job implications of requiring the use of lower carbon transportation fuels through standards that reduce the carbon intensity of these fuels over time. In June 2014, OFM entered into contract with Life Cycle Associates, LLC, to carry out the analysis, building on the original work and subsequent review. Specifically Life Cycle Associates was commissioned to:

- Re-evaluate the availability of low carbon fuels and update CI values for transportation fuels
- Using the current version of the VISION model, provide forecasts of fuel consumption, GHG emissions, and spending on fuel and vehicles for the business-as-usual (BAU) case and a range of possible compliance scenarios.
- With the VISION results as inputs, use the REMI PI+ model to estimate the macro-economic effects of implementing a CFS within the state of Washington.
- Identify and assess various policy mechanisms to avoid escalating fuel costs.

This report describes the analysis performed by the Life Cycle Associates team to evaluate the possible effects of a CFS in Washington state. Because regulation of carbon intensity does not dictate specific combinations of fuels and vehicles, compliance with the standard could take many forms, depending upon many market forces. To analyze the impacts of CFS compliance in Washington state, a scenario analysis approach was adopted, with each scenario focused on significant levels of implementation of a particular strategy, with two different program designs considered (with and without banking and trading of program credits). In this way, the analysis attempts to bracket the range of possible compliance; actual compliance would likely have fuel consumption somewhere in between the scenarios and may include new low carbon fuel pathways not currently considered.

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[4] RCW 70.235.020

[5] *A Low Carbon Fuel Standard in Washington: Informing the Decision,* TIAX LLC, 2011

[6] *WA LCFS Analysis: Implication of Updated Assumptions*, Life Cycle Associates, 2013

This analysis has been conducted in a collaborative and transparent manner. A Clean Fuels Technical Workgroup was formed to solicit comments and input from stakeholders and to apprise them of progress and assumptions utilized. Members of the workgroup included state agencies, the Western States Petroleum Association, the National Biodiesel Board, the Union of Concerned Scientists, Natural Resources Defense Council, Climate Solutions, Tesoro, and Abenogoa Bioenergy. Phone conferences were held with the workgroup generally every other week from late June through early October 2014. Webinars were held on July 28th and October 6th with a broader range of stakeholders on interim portions of the analysis.

This is the third and final draft of this report. The first draft of the report utilized the 2013 Washington State Transportation Revenue Forecast Council (TRFC) projections of vehicle miles traveled (VMT). In early October of this year, the TRFC updated their VMT[7] projections, with significantly lower projected VMT than the earlier forecast. These revised VMT estimates were utilized in the VISION model and resulted in significantly lower fuel consumption than the previous forecast (draft 1 of this report). These reduced fuel consumption forecasts were the basis of the analysis presented in the second (October 29, 2014) draft of this report. Because the VISION calculated fuel consumption forecasts (with the 2014 VMT forecast) are significantly lower than the TRFC fuel consumption forecasts, the analysis was revised a third time. In this final version of the analysis, AEO2014 VMT projections were utilized. These VMT projections resulted in a diesel fuel consumption forecast similar to the TRFC forecast. However, the gasoline consumption forecast declines over time due to improving fuel economy in contrast to the TRFC forecast that remains relatively constant over the analysis period[8]. To evaluate the impact of the fuel consumption forecast assumption, a sensitivity case was performed using the TFRC gasoline consumption forecast.

The general approach of the analysis was to develop a business-as-usual (BAU) forecast of fuel consumption and vehicle purchases and compare this to a range of compliance scenario forecasts. In developing the BAU we only included existing policies and drew as much as possible on existing literature for projections of fuel prices, vehicle prices, vehicle sales, advanced vehicle market shares, fuel economy, and VMT. Carbon intensity values for a number of fuels were developed with GREET1_2013 adapted to take into account a range of Washington specific factors. CI values for additional fuels were taken from California's LCFS program.

Section 2 of this report reviews potential supplies of low carbon fuels that could be utilized for compliance, recognizing that there is competition for these fuels from other regions that have and are considering implementing similar standards.

Section 3 provides a discussion of the carbon intensity values for petroleum and alternative fuel pathways utilized in the analysis.

Section 4 describes the assumed structure of the CFS program.

Section 5 provides an overview of potential cost containment measures that might be adopted and their possible implications.

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[7] http://www.ofm.wa.gov/budget/info/Sept14transpovol4.pdf

[8] The Washington state Transportation Revenue Forecast Council fuel consumption modeling is only weakly dependent on fleet fuel economy

Section 6 provides the BAU and compliance scenario definitions, explains how CFS program credits and deficits are calculated, and describes how we incorporate assumed credit price profiles into fuel price projections. Projections of BAU fuel use and vehicle purchases in Washington state are also provided. Finally, the parameters for each compliance scenario evaluated are also provided, including advanced vehicle market shares and volumes of low CI fuels available for compliance.

Section 7 provides the results from the VISION model for each of the compliance scenarios. This includes projections of fuel consumption by type, vehicle sales by technology type, and changes in emissions. Spending on fuel and vehicles is also provided.

Section 8 steps through the estimated infrastructure costs to support low carbon fuels and vehicles.

Section 9 presents the macro-economic modeling methodology and Section 10 provides the results of the macro-economic modeling of each scenario compared to the BAU case, including impacts on employment, gross state product, and personal income.

Appendix A provides supporting material for the VISION modeling effort while Appendix B provides supporting material for the infrastructure cost estimates. Appendix C provides the crude oil carbon intensity values utilized to estimate the gasoline and diesel carbon intensity values utilized in the analysis. Appendix D provides supporting material for the macro-economic analysis.

# 2. Availability of Low Carbon Fuels

Like many energy and environmental policies that have been implemented in the past, clean fuel standards require industry to innovate and supply products that are either currently not available or not available in sufficient quantity. The intent of the regulation is to provide signals to spur the market to respond with the desirable outcome. In the first few years of California's existing CFS, the market has seen a tremendous response with new low carbon fuels emerging that were not anticipated five years ago (e.g. corn oil biodiesel, high solids anaerobic digestion CNG, tallow based renewable diesel).

This analysis consists of evaluating compliance scenarios that bound the range of possible low carbon fuel supply grounded in the current literature on likely fuels and their CIs. The exercise requires us to estimate volumes of low CI fuels that might be available in the future. It is important to recognize that, consistent with the recent California experience, additional low carbon intensity (CI)[9] fuel pathways will emerge over the next five to ten years that will not be captured in the analysis. Future volumes of known low CI fuels, particularly cellulosic fuels, are difficult to predict with certainty since they require strong signals from regulators to provide sufficient stability to encourage investment. We have attempted to quantify volumes produced today and potential volumes that could be produced in the future, again building on existing projections by others in the field, and consider these two bounds in the definition of the compliance scenarios. It is important to note that by design, a CFS encourages further GHG reductions in existing low CI fuel pathways and development of new low CI fuels. Consistent with the overall conservative approach of this analysis, we do not assume reductions in CI for a number of fuel pathways[10] nor do we include new fuel pathways that may emerge during the analysis timeframe.

The following section provides current and projected availability of a variety of low carbon intensity fuels that could be utilized for compliance with a Washington state CFS. For each fuel and feedstock we note how much if any is assumed to be produced in-state. This information is utilized later in the macro-economic modeling since consumption of goods produced in-state has a different economic activity than consumption of imported goods. The CFS is blind to location of fuel production except as it relates to the impact of transport emissions on CI; cost will dictate the source of fuels utilized to comply with a Washington CFS. This analysis does not employ a cost analysis to determine the geographic source of low CI fuel compliance fuels. Rather, it is assumed that when a low CI fuel is needed for compliance, existing in-state fuel production capacity will be utilized where available. To quantify the impact of assuming in-state production on Washington's economy, a sensitivity analysis is performed for one of the scenarios, comparing the effect of three in-state cellulosic biofuel plants to no in-state cellulosic biofuel plants.

The analysis does try to take into account competing needs for low CI fuels. If Washington and Oregon both implement a CFS, three states and British Columbia would require low CI compliance fuels. In several instances, estimates of Washington's share of projected available fuel volumes are required. Because Washington consumes 14 percent of the gasoline and diesel consumed in

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[9] Carbon intensity of a fuel is defined as the total GHG emissions associated with fuel production (includes feedstock production/recovery, feedstock transport, fuel production, fuel transport and vehicle emissions) per unit energy of finished fuel. Typical units are $gCO_2e/MJ$.

[10] As discussed in the next section, carbon intensity values are maintained at constant levels throughout the analysis period with the exception of fuels produced in-state; fuels produced in-state have slight reductions in CI over time due to a lower carbon electricity grid and lower projected lifecycle natural gas GHG emissions.

California, Oregon, Washington and British Columbia[11], and because these four regions would be the main competitors for low CI fuels, it is assumed in a number of instances that 14 percent of projected available low CI fuel volumes could come to Washington State. The actual level of competition/allocation depends on details of individual jurisdiction programs and other market conditions outside the scope of this analysis.

Table 2-1 summarizes the low CI fuel availability assumptions utilized for the scenario analysis exercise. It is important to be clear that the volumes in the table are not projections of fuel volumes that will be needed in Washington State to comply with a CFS; rather these volumes give an upper limit to what could be available if needed. More detailed discussion for each fuel type, including terms used in the table, sources consulted, and rationales for specific assumptions follows in the paragraphs below. Assumptions regarding additional required infrastructure and vehicles to support needed supply appear later in the report.

[11] 2012 Motor gasoline (EIA State Energy Data System), On-road distillate (EIA Adjusted Sales of Distillate Fuel Oil by End Use), http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/trade37c-eng.htm (for BC fuel use).

Table 2-1 Summary of Potential Fuel Supply in 2026

| Fuel Pathway | 2026 Potential Supply | Notes |
|---|---|---|
| Ethanol | Consumption limited by amount that can be blended into motor gasoline and the number of FFVs that can consume high level blends. | |
| Conventional Corn | Abundant | 13 BGY consumed in 2013 |
| Lower CI Corn | Abundant | Of 93 corn ethanol pathways selling into California's market, 80 are modified/low CI |
| Corn/Sorghum/Wheat Slurry (Corn+) | 40 MGY | Over 200 MGY has come to California. Assume supply grows at 3%/year and 14% comes to Washington |
| Sugarcane | 146 MGY | Based on 14% of EIA AEO2014 projection for U.S. imports |
| Molasses | 20 MGY | ARB has registered ~ 100 MGY. Assume capacity grows 3%/yr and that Washington receives up to 14% |
| Cellulosic | 63 – 300 MGY (eth gallons) | Low end is EIA projection for RFS2, high end is UC Davis "Leapfrog" potential. Assumes 50% of total cellulosic volume is as ethanol (in ethanol gallons) |
| Cellulosic "Drop-in" Fuels (Cellulosic Gasoline and Cellulosic Diesel) | 55 – 200 MGY (gasoline equiv) | Low end is EIA projection for RFS2, high end is UC Davis "Leapfrog" potential. Assumes 50% of total cellulosic volume is drop-in fuel (gal gasoline equiv). |
| CNG (gallons gasoline equiv) | | |
| Fossil | Sufficient | Limited by vehicle sales and refueling station capacity |
| Renewable | 170 MGY | 16 MGY existing pipeline injection capacity in-state now; current in-state capacity sufficient for projected CNG consumption through analysis period. |
| Hydrogen | Sufficient | Limited by vehicle sales and refueling station capacity |
| Electricity | Sufficient | Limited by vehicle sales and charging infrastructure |
| Biodiesel (gal biodiesel) | Sufficient | In-state production capacity is 108 MGY. A B15 blend in 2026 requires ~ 73 MGY. |
| Used cooking oil, tallow | 22 MGY | Washington state feedstock supply, though could source from out-of-state |
| Vegetable Oil | 100 MGY | Washington biodiesel production capacity |
| Renewable Diesel | 0 | Assume that California attracts all renewable diesel |

## 2.1 Conventional Ethanol

Washington currently consumes corn ethanol imported from the Midwest in its gasoline. Estimated ethanol blend levels for the past several years, obtained through the Washington State Department of Agriculture's (WSDA's) Fuel Testing program[12] are provided in Table 2-2. Note that in 2013, WSDA completed rulemaking allowing E15 to be sold in-state. E15 is a blend of 15 percent denatured ethanol by volume in motor gasoline. EPA has approved the use of E15 in model year 2001 and newer vehicles. In the BAU we have assumed that motor gasoline contains 9.6 percent denatured ethanol. One of the compliance scenarios assumes that the gasoline blend level increases to nearly E15. The rest of the compliance scenarios assume that motor gasoline is E10.

[12] Jerry Buendel, Washington State Department of Agriculture, Weights and Measures Program

Table 2-2. Recent Washington State Blend Levels in Motor Gasoline

| Year | Motor Gasoline Average Ethanol Content (% vol) |
|---|---|
| 2011 | 9.81% |
| 2012 | 9.72% |
| 2013 | 9.64% |
| 2014 (Jan-June) | 9.47% |

It is assumed that sufficient Midwest corn ethanol will be available for use through the analysis period. In response to California's LCFS, ARB has registered 80 lower carbon corn ethanol pathways submitted by producers. We assume that these volumes are available for use in Washington.

Ethanol can also be produced from sorghum or a mix of corn, sorghum and wheat slurry. California has labeled this category of ethanol "Corn+" and has imported over 200 MGY of this grain ethanol.[13] It may be that available supply of sorghum/wheat ethanol is greater than the amount that has been consumed in California to date. For this analysis, we make the assumption that total volume grows by 3 percent per year (approximately 80 MGY additional supply) and that 14 percent of it could be available to Washington state (40 MGY by 2026).

There are currently four molasses to ethanol pathways registered in California's LCFS program. We assume here that these four plants produce a total of 100 MGY in 2016, and that two additional plants come online by 2026 (an additional 50 MGY), and that Washington could receive up to 14 percent of it. This corresponds to a potential supply of 21 MGY of ethanol from molasses.

Ethanol produced in Brazil from sugarcane has an attractive CI value. California has imported up to 190 MGY, but has recently imported only half of that amount. Figure 2-1 provides DOE's Energy Information Administration projection of U.S. sugarcane ethanol imports.[14] The AEO projection dips after 2022, likely due to uncertainty about continuation of EPA's RFS2[15]. We have smoothed the projection here and assume that up to 14 percent is available for use in Washington state (146 MGY by 2026).

[13] Low Carbon Fuel Standard Reporting Tool Quarterly Summaries
[14] Annual Energy Outlook 2014 (AEO2014)
[15] Please refer to discussion of AEO2014 cellulosic fuel projection in Section 2.4

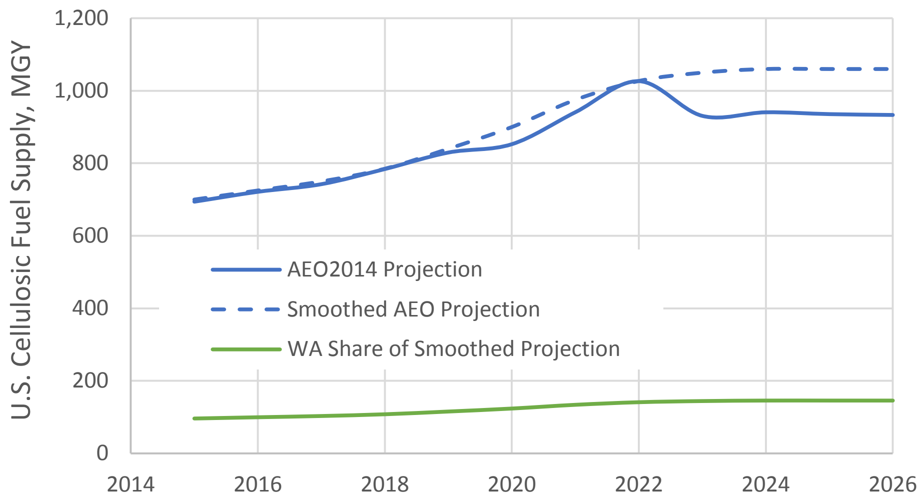


Figure 2-1. Projected sugarcane ethanol imports.

## 2.2 Biodiesel

Biodiesel is produced from waste oils (used cooking oil and tallow) and a variety of vegetable oils (soybean, canola, corn). Despite significant biodiesel production capacity in-state, there has been relatively little biodiesel consumption to date. Estimated on-road biodiesel use is 2 MGY for 2013, which corresponds to a blend level of 0.22 percent.[16] A 15 percent average blend level corresponds to approximately 100 MGY of biodiesel in 2026. It is assumed this biodiesel is consumed as B20 and lower level blends. Washington's installed production capacity is provided in Table 2-3. Because current in-state production capacity is greater than projected demand, we have assumed that all biodiesel consumed is produced in-state.

Table 2-3. In-State Biodiesel Production Capacity

| Plant | Feedstocks | Capacity (MGY) |
|---|---|---|
| Imperium Renewables | Vegetable oils, planning to add used cooking oil and tallow capability | 100 |
| General Biodiesel | Used Cooking Oil | 10 |
| Transmessis | Canola oil (crushing capacity too) | 4 |

For the macro-economic modeling exercise, we need to make assumptions regarding biodiesel feedstock sources. Table 2-4 provides the estimated quantities of in-state feedstock potential. Canola oilseed production in 2013 was 30,600 tons[17], which corresponds to approximately 3.3 MGY of biodiesel. In-state canola oilseed crushing capacity is significantly higher than in-state oilseed production; Transmessis Colombia Plateau and Pacific Coast Canola have a combined crushing capacity of 43 MGY biodiesel equivalent. The oilseeds come from the Pacific Northwest. We assume here that up to 43 MGY of canola oil biodiesel is available for use.

[16] Washington State agencies utilized 0.35 MGY on-road provided by Mary Beth Lang, Washington Department of Agriculture. Imperium Renewables estimates an additional 1.65 MGY non-public vehicles for a total statewide consumption of 2 MGY.

[17] NASS, Crop Production Annual Summary, January 10, 2014, assumes 18.6 wet lbs canola/gal biodiesel

Imperium Renewables has identified 6 to 8 MGY of collectible used cooking oil in-state and 10 to 12 MGY of tallow from Tyson Foods located in Pasco and Agri Beef Company located in Toppenish. For this analysis we have assumed up to 10 MGY of used cooking oil biodiesel by 2026 and 12 MGY of tallow biodiesel are available for use. The 2026 used cooking oil quantity assumes some growth from current estimates of supply.

Table 2-4. Biodiesel Feedstock Supplies

| Feedstock | Current Biodiesel Potential (MGY) |
|---|---|
| Canola oilseeds (2013 WA production = 30,600 tons) | 3.3 |
| Canola oilseed crushing capacity | |
| Transmessis | 4 |
| Pacific Coast Canola | 39 |
| Used cooking oil (in-state potential supply) | 6-8 |
| Tallow (in-state potential supply) | 10-12 |
| Corn oil (Oregon and Idaho) | 3 |
| Oregon and Idaho | 3 |
| U.S. | 140* |
| Midwest soybean oil | 700* |

* 2013 production, EIA Monthly Biodiesel Production Report

Corn oil is available from the Pacific Ethanol plants in Burley, Idaho and Boardman, Oregon (beginning in 2015). Significantly more corn oil for biodiesel production is available from the Midwest. Corn oil extraction is growing rapidly. If we assume 0.53 lb of corn oil per bushel of corn[18] and a corn ethanol production capacity of 14 billion gallons per year[19], then the U.S. has the potential to produce approximately 340 MGY of corn oil for biodiesel production. Assuming that 85 percent of this is produced and that Washington's share of this supply is 14 percent, then up to 40 MGY could be available. Washington currently imports some soybean oil for production of biodiesel. We assume that an unlimited supply of soybean oil is available for use in the state.

## 2.3 Renewable Diesel

Renewable diesel (RD) is comparable to petroleum diesel and can be utilized in existing engines either on its own or as a blending component. It is also compatible with existing fuel storage and dispensing equipment. RD is produced through hydro-treating vegetable or waste oils. California has had significant imports of used cooking oil and tallow based renewable diesel in the last several years for compliance with its LCFS.

In California there is concern that biodiesel blended with CARB diesel causes increased tailpipe NOx emissions; it appears that biodiesel blended into the diesel formulation utilized in Washington state does not have the same effect.[20] ARB is currently working on a rule to address the issue of elevated NOx emissions from biodiesel use. The potential remedies include use of approved NOx control additives, approved biodiesel formulations, or blending with a "B20-ready" diesel fuel.

[18] US Corn Ethanol: Emerging Technologies at the Biorefinery and Field Level, Steffen Mueller, University of Illinois at Chicago, September 2014.
[19] EIA Today in Energy, http://www.eia.gov/todayinenergy/detail.cfm?id=11551
[20] *Effect of Biodiesel Blends on North American Heavy-Duty Diesel Engine Emissions,* Yanowitz and McCormick, Eur. J. Lipid Sci. Technol. 2009, 111, 763–772.

Because RD does not increase NOx emissions, California will likely preferentially utilize RD over biodiesel for compliance with the LCFS. We have therefore assumed in our compliance scenarios that no RD is available in Washington state.

## 2.4 Cellulosic Fuels

Of the low CI fuels, it is the most difficult to predict future volumes of cellulosic fuels that could be available to Washington for compliance with a possible CFS. Future production capacity will only be available if durable regulations are in place to generate a need for it. Therefore, to a certain extent, predicting future capacity based on projections that do not take into account a need for future cellulosic fuel supply is unrealistic. In a rational market, if cellulosic fuels are required for compliance, plants will be built and the fuel will be supplied given that the price signal is sufficient to cover the required investments.

### 2.4.1 Cellulosic Fuel Availability

EIA provides annual projections (Annual Energy Outlook, AEO) of fuel supply based on regulations in place. Over the past several years, projections for cellulosic fuel supply have decreased as EPA has signaled softening future regulatory requirements. Figure 2-2 provides the AEO2013 and AEO2014 "liquids from biomass" projections. The "liquids from biomass" category includes Fischer-Tropsch fuels from biomass feedstocks as well as pyrolysis based gasoline and diesel.[21] Note that EIA projects no increase in these fuels beginning in 2021. This is not a reflection of EIA's opinion on whether cellulosic fuels are producible, rather it is a result of modeling assumptions about future RFS2 cellulosic volume requirements.[22] It is reasonable to assume that with consistent and sufficiently strong regulatory signals, the volumes produced and consumed could increase. With RFS2 2014 final rules still pending, they are not available as a signal for future policy. However, administration commentary and funding from other departments continue to support cellulosic fuel development. For these reasons, we have assumed that supply grows along the AEO2013 projection rather than the AEO2014 flat line. We note here that cellulosic gasoline would need to be registered with EPA and possibly go through a multi-media impact analysis before it could be sold. We assume that EIA has taken this into account in their projections

[21] Telephone conversation with Michael Cole, EIA.

[22] Telephone conversation with Michael Cole, EIA. In their modeling, the cost of credits was set below the cost of cellulosic ethanol so that regulated parties opted to purchase credits rather than purchase cellulosic fuels.

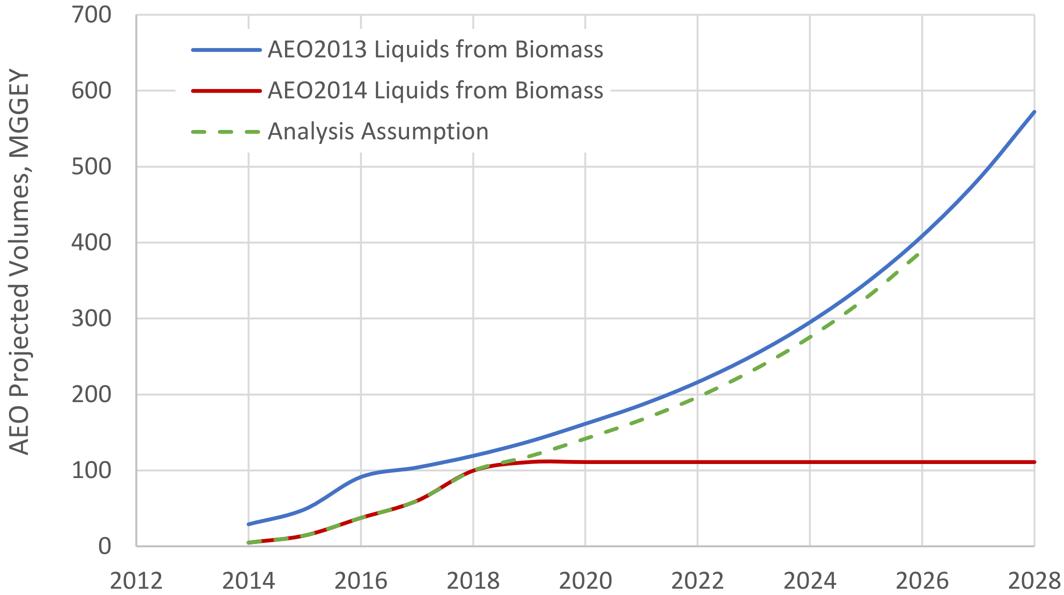



Figure 2-2. EIA cellulosic gasoline and diesel consumption projections.

Figure 2-3 provides the EIA projections of cellulosic ethanol consumption. Again the AEO2014 projection increases until 2021 and then stops growing due to anticipated softening of the RFS2 volume requirements. Because the "liquids from biomass" category includes cellulosic drop-in fuels and because these fuels require similar levels of investment to cellulosic ethanol plants, it serves as a reasonable proxy for potential cellulosic ethanol growth rate. Therefore, we have assumed here that the shape of the increase is similar to the AEO2013 "liquids from biomass" projection (in yellow). This extension results in 450 MGY of cellulosic ethanol in 2026.

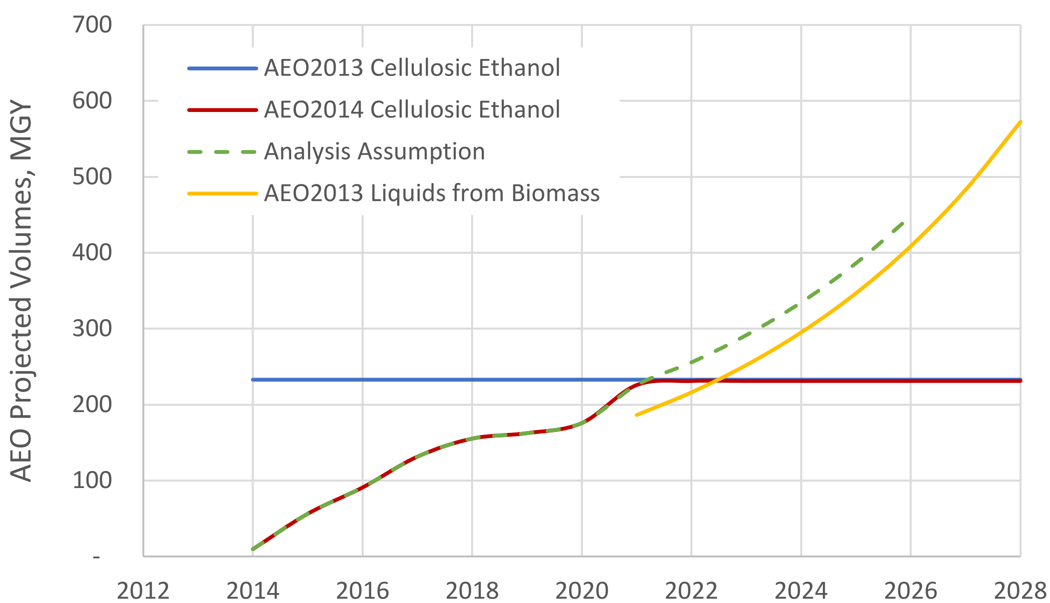



Figure 2-3. EIA projections of cellulosic ethanol consumption.

In addition to EIA projections, other organizations have projected U.S. cellulosic fuel volumes. For example, E2[23] tracks cellulosic biofuel capacity and predicts that in 2016 there will be 750 MGY of cellulosic ethanol production in the U.S. This corresponds to 500 MGY on a gasoline equivalent basis. This value includes projected U.S. capacity for active projects at the time of the report, and assumes these volumes come online. This value is utilized as our optimistic upper bound for the near term. Researchers at UC Davis[24] recently found that up to 2.8 BGY (gasoline equivalent basis) of cellulosic fuels could be produced by 2025 if the "Leapfrog" approach were adopted. The Leapfrog approach assumes major breakthroughs in cellulosic technology at standalone refineries. This provides an upper bound on the amount of cellulosic fuel that could be available to regulated entities in a Washington CFS. Figure 2-4 compares the EIA projection to the E2 and UC Davis optimist projections.

Applying the 14 percent factor discussed above to the EIA (lower bound) and E2/UC Davis (upper bound) projections results in a range of 2026 cellulosic volumes available to Washington state of 100 to 400 MGY in gasoline equivalent gallons.

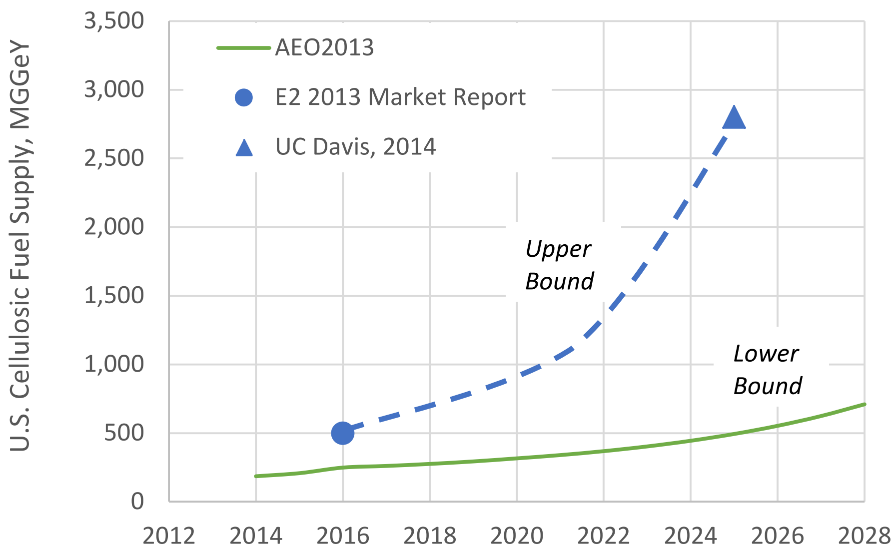



Figure 2-4. Range of predicted cellulosic biofuel availability.

23 "Advanced Biofuel Market Report 2013", Mary Solecki, Bob Epstein Environmental Entrepreneurs and Anna Scodel, Goldman School of Public Policy

24 "Three Routes Forward for Biofuels: Incremental, Transitional, and Leapfrog", Lew Fulton, Geoff Morrison, Nathan Parker, Julie Witcover, Dan Sperling, UC Davis, July 2014.

### 2.4.2 Washington State Cellulosic Fuel Feedstock Potential

Washington state has two main cellulosic biofuel feedstocks of interest: wheat straw and forest residue. Wheat straw is amenable to cellulosic ethanol production while forest residue is better suited to cellulosic gasoline and diesel production through pyrolysis. To assess the quantity of sustainably removed field residues (wheat and barley straw), several studies are utilized. Muth et al.[25] have projected that by 2030, 2.24 million dry tonnes of sustainably removed straw could be available for use as a biofuel feedstock. Assuming a 70 gal/ton conversion rate, this corresponds to 170 MGY of cellulosic ethanol potential. Similarly, DOE's updated billion-ton study[26] estimates 163 MGY of cellulosic ethanol potential in 2024 assuming 70 gal/ton yield and over $65 per ton for feedstock.

In terms of woody biomass, the Billion-Ton Update estimates that 2.5 million bone dry tons of woody biomass are available ($60 per bone dry ton) on an annual basis in Washington state. The Washington Department of Natural Resources[27] estimates that by 2025 between 1.2 and 2 million bone dry tons of woody biomass could be available for use as a biofuel feedstock. Using this more conservative estimate and an assumed yield of 50 gal per bone dry ton results in 60 to 100 MGY of cellulosic gasoline potential.

In summary, Washington state has the potential to supply feedstock for approximately 165 MGY of cellulosic ethanol from agricultural residues and 60 to 100 MGY of cellulosic gasoline from waste wood. In our base scenarios, we have assumed from zero to three plants with a capacity of 30 MGY each are built in Washington. This represents approximately one third of available agricultural and forest residue potential. It is important to note that this assumption is only based on the fact that there is sufficient in-state feedstock supply, not on the basis of a comparative economic analysis. To quantify the impact of this assumption, a sensitivity case has been run to compare the impact of three plants in-state to no plants in-state.

## 2.5 CNG

One of the lower CI fuels considered for transportation in the scenario analysis is natural gas. Because the VISION model does not have an LNG vehicle category we have made the simplifying assumption that CNG is a proxy for any natural gas consumed as LNG. The carbon intensity values are similar and the quantities are likely low in the short-run, so the impact of this assumption on the analysis results is negligible. The quantity of compressed natural gas (CNG) consumed is dictated by the number of CNG vehicles on the road and the number of CNG refueling locations available. We assume for this analysis that sufficient CNG will be available either from fossil or renewable natural gas (RNG) to fuel all of the CNG vehicles in the inventory.

RNG from landfill gas (LFG), wastewater treatment (WWT) anaerobic digestion, and high solids anaerobic digestion (HSAD) that is cleaned, injected into the pipeline and compressed at a CNG station is a very low CI fuel. Washington state already has pipeline injected RNG to CNG pathways registered with the California LCFS. Table 2-5 summarizes the current and potential pipeline quality RNG production in equivalent diesel gallons. Currently, more than 16 MGY is injected into

[25] "Sustainable agricultural residue removal for bioenergy: A spatially comprehensive US national assessment", D.J. Muth Jr., K.M. Bryden, R.G. Nelson, October 2012.

[26] U.S. Department of Energy. 2011. U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry. R.D. Perlack and B.J. Stokes (Leads), ORNL/TM-2011/224. Oak Ridge National Laboratory, Oak Ridge, TN.

[27] Washington Forest Biomass Supply Assessment, Washington Department of Natural Resources March 2012.

pipelines. For the BAU case, the CNG consumption is projected to be 13 MGY diesel equivalent in 2026. There is significantly more potential supply than ability for vehicles to consume it, and current supplies of LFG and WWT RNG are more than sufficient for projected 2026 consumption. Like electricity, the consumption of low CI RNG is dictated by the number of advanced vehicles sold. Complementary policies incentivizing sales of PEV and CNG vehicles would allow the state to take advantage of these available low CI fuels.

Table 2-5. Washington State Pipeline Quality RNG Current Supply and Potential

| Feedstock | Current Capacity pipeline injection MGY diesel equivalent | Potential Capacity MGY diesel equivalent |
|---|---|---|
| Landfill Gas[1,2] | 15 | 136 |
| Wastewater Treatment[1,3] | 1.4 | 12 |
| Municipal Solid Waste (HSAD)[1,4] | 0 | 20-24 |

1. *Roadmap for Biogas Development in Washington State*, supplied by Peter Moulton
2. 15 MGY current production at Cedar Hills Landfill, ongoing project for 7 MGY additional supply at LRI 34th Street Landfill.
3. http://www.kingcounty.gov/environment/wastewater/ResourceRecovery/Energy/Renewable.aspx
4. *2009 Washington Statewide Waste Characterization Study*, ECY 10-07-023, July 2010

## 2.6 Electricity and Hydrogen

Similar to CNG, the quantity of electricity and hydrogen consumed is dictated by assumptions about the number of plug-in electric vehicles (PEVs) and hydrogen fuel cell vehicles (FCVs), respectively. In both cases we assume that sufficient fuel will be supplied (with investment in infrastructure) to fuel the projected vehicle population. Note that electricity consumed by electric rail is not included here; California has a proposed amendment to allow electric rail to opt-in to the program, generating credits for use in compliance.

## 3. Carbon Intensity Estimates

When comparing alternative fuel GHG emissions, direct and indirect emissions occurring over the entire fuel cycle need to be considered, not just vehicle emissions. Direct fuel cycle emissions are also referred to as well-to-wheel (WTW) emissions and can be broken down into two parts: well-to-tank (WTT) and tank-to-wheel (TTW). The WTT portion of the fuel cycle includes all emissions associated with fuel production while TTW emissions are essentially vehicle tailpipe emissions. WTT emissions include feedstock production/recovery, transport of the feedstock and other inputs to the fuel production plant, emissions from the fuel production plant, and transport of the fuel to the vehicle. For example, the WTT emissions associated with ethanol production from corn include all of the farming inputs (tractor fuel use, fertilizer and other agricultural chemical production and transport emissions), transport by truck to the ethanol plant, fuel production emissions (fuel combustion, electricity use, credits for displacing soybean meal with co-products), transport of the ethanol to the fuel terminal, and then transport by truck to refueling stations. The relative significance of the WTT portion of the fuel cycle varies with fuel type. For electricity, all of the WTW GHG emissions are in the WTT portion while for petroleum fuels, most of the GHG emissions come from combustion of the fuel in the vehicle (TTW portion). Fuel cycle GHG emissions are typically expressed in terms of carbon intensity – the WTW grams of equivalent $CO_2$ emitted per energy unit of finished fuel produced (e.g. $gCO_2e/MJ$); carbon intensity is referred to as CI throughout this report.

To estimate WTT CI values for a selection of transportation fuels, the most recent version of Argonne National Laboratory's Greenhouse Gases, Regulated Emissions and Energy Use in Transportation (GREET) Model was utilized (GREET1_2013 released in October 2013).[28] GREET is a widely used, publicly available, Microsoft Excel based model. EPA and ARB have used GREET to support transportation policy. ARB adapted an earlier version of the GREET model for use in establishing CI values for the California LCFS. This model is referred to as CA-GREET. ARB is in the process of transitioning to CA-GREET2 which is an adaptation of the GREET1_2013 version of the model. Because GREET's default inputs are average values for the U.S., we have made modifications to reflect Washington state conditions.

The GREET model is utilized to quantify WTT emissions. TTW emissions are assumed to consist of $CO_2$, $N_2O$ and $CH_4$. $CO_2$ emissions are dictated by fuel carbon content and published emission factors for tailpipe $N_2O$ and $CH_4$ emissions are utilized. WTT and TTW emissions are direct emissions. Indirect emissions associated with land use change (ILUC) are also included where appropriate. ILUC emissions arise when demand for a feedstock (e.g. soybeans for biodiesel production) diverts crops away from their prior use (food/feed) to fuel. To compensate for the loss of soybeans to fuel production, cultivation of some other crop occurs on other land. This incremental cultivation may result in carbon emissions that are an indirect result of biofuel production. Quantification of ILUC values requires the use of general equilibrium models. ARB and EPA have both estimated ILUC values for biofuels. For this analysis we have utilized preliminary updated ILUC values presented by ARB in March of 2013. Recent ARB updates to the ILUC estimates are lower than the March values utilized in this analysis. Lower ILUC values would mean that we have over-estimated the quantity of low CI biofuels needed for compliance.

[28] Argonne has released a new version of the GREET model since this analysis was initiated; GREET1_2014 was released on October 3, 2014.

Throughout this report, CI values are used to refer to these estimates of lifecycle carbon intensity used in the policy (which may deviate from actual impacts due to measurement error, or uncaptured variation and market feedback effects). The following sections describe the carbon intensity values utilized in the scenario analysis exercise.

## 3.1 Petroleum

There are five petroleum refineries located on Washington's west coast (Table 3-1) and approximately half of the gasoline and diesel refined is exported. These refineries produce most of the finished gasoline and diesel consumed in the state, though some is imported by pipeline from Montana and Utah for use in eastern Washington.

Table 3-1. Refineries in Washington State

| Company | Location | Operable Capacity bbl per calendar day |
|---|---|---|
| BP West Coast Products | Blaine | 225,000 |
| Phillips 66 | Ferndale | 101,000 |
| Tesoro West Coast | Anacortes | 120,000 |
| Shell Oil Products U.S. | Anacortes | 145,000 |
| U.S. Oil and Refining Company | Tacoma | 40,700 |

U.S. EIA State Energy Data System

The methodology employed to quantify gasoline and diesel carbon intensity values consisted of the following steps:

1. Determine refining location for finished petroleum fuels consumed
2. Determine sources of crude oil for each refining location
3. Quantify crude oil recovery and transport emissions
4. Quantify refining and finished fuel transport emissions

Each of these steps is discussed in detail below.

### 3.1.1 Refining Locations

The first step in quantifying the carbon intensity values for gasoline and diesel is to determine where these fuels are refined. Table 3-2 indicates total gasoline and diesel consumption for 2011 and 2012. Fuel consumption for 2013 was not available at the time of the analysis so the baseline carbon intensity values for 2016 are developed using 2012 data as a proxy. The pipeline deliveries from Montana and Utah for gasoline and diesel are also shown; Washington refined gasoline and diesel are determined by difference. As shown, 79 percent of the gasoline and 73 percent of the diesel consumed in Washington was refined in Washington in 2012. Therefore, carbon emissions must be quantified for three distinct pathways: crude recovery and transport to Washington for refining and distribution in Washington; crude recovery and transport to Montana for refining in Montana and transport/distribution to Washington; crude recovery and transport to Utah for refining in Utah and transport/distribution to Washington.

Table 3-2. Consumption and sources of gasoline and diesel in Washington.

| Washington State Consumption & Supply Million Gallons | Gasoline Blendstock 2011 | **2012** | 2013 | On-Road Diesel 2011 | **2012** | 2013 |
|---|---|---|---|---|---|---|
| Consumption[a] | 2,417 | **2,405** | n/a | 599 | **613** | n/a |
| Supply[b] | | | | | | |
| Tesoro pipeline | 224 | **222** | 171 | 186 | **94** | 112 |
| Yellowstone pipeline | 303 | **290** | 322 | 65 | **74** | 71 |
| Total pipeline supply | 527 | **513** | 493 | 251 | **168** | 183 |
| In-State refiners (difference) | 1,890 | **1,892** | | 348 | **445** | |
| Supply Shares | | | | | | |
| Tesoro pipeline (UT) | 9% | **9%** | | 31% | **15%** | |
| Yellowstone pipeline (MT) | 13% | **12%** | | 11% | **12%** | |
| Washington state refineries | 78% | **79%** | | 58% | **73%** | |

a. EIA State Energy Data System (SEDS) "WA State Historic Fuel Consumption - Transportation"

b. Pipeline imports supplied by Tony Usibelli (COM).

### 3.1.2 Sources of Crude Oil

The carbon intensity of crude oil extraction and transport depends on the source of the crude oil. In this step of the analysis, the sources of the crude oils refined in each of the three refining locations were determined.

#### *Crudes Refined in Washington*

Foreign imports of crude oil were determined for 2012 from EIA databases.[29] In 2012 there were no imports from other PADDs[30] into Washington, however there were shipments from Alaska to other PADD 5 states which include Washington, Oregon, California, Arizona, Nevada, Alaska, and Hawaii. Since there is no refining capacity in Oregon, Arizona, and Nevada and only a small amount in Hawaii, we assume that Washington receives all of the shipments to PADD 5 less the shipments to California. California receipts from Alaska are provided by the California Energy Commission.[31] Table 3-3 provides the sources of crude utilized in Washington in 2012 while Figure 3-1 provides the same data with individual countries grouped into regions.

Table 3-3. Sources of crude supplied to Washington Refineries in 2012.

| Source | Share | Source | Share |
|---|---|---|---|
| Algeria | 0.5% | Eq. Guinea | 0.3% |
| Angola | 3.3% | Nigeria | 1.4% |
| Argentina | 1.1% | Oman | 0.9% |
| Brazil | 0.3% | Russia | 5.4% |
| Canada | 26.1% | Saudi Arabia | 2.9% |
| Colombia | 0.3% | Alaska | 57.3% |
| Congo | 0.3% | | |

[29] EIA Company Level Imports http://www.eia.gov/petroleum/imports/companylevel

[30] PADD = Petroleum Administration Defense District; the U.S. is divided into 5 PADDs.

[31] http://energyalmanac.ca.gov/petroleum/statistics/2012_monthly_oil_sources.html

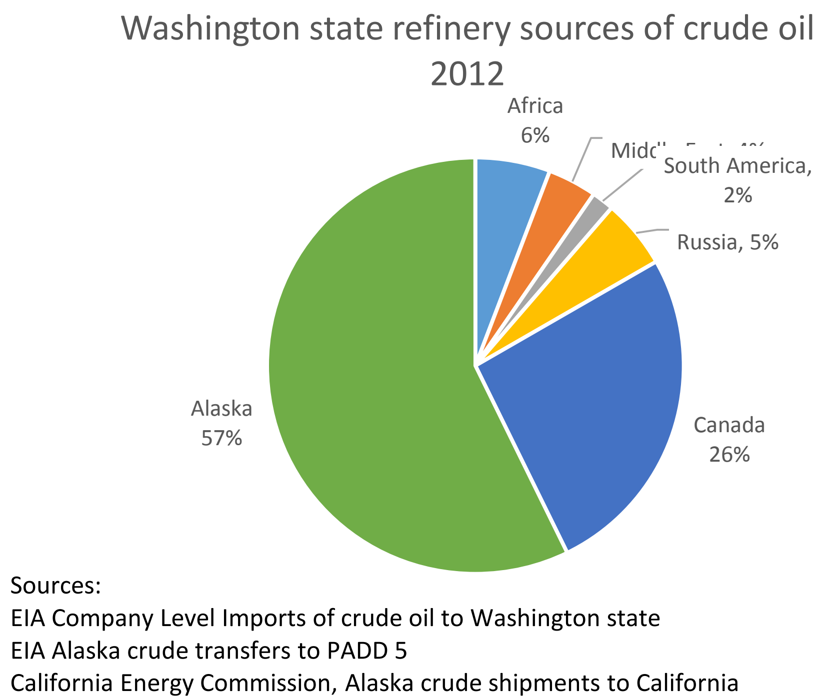



Figure 3-1. Sources of Crude Oil Supplied to Washington State in 2012 by Region.

It is also important to determine how much of the crude oil sourced from Canada is conventional and how much is oil sands crude because recovery of oil sands crude is more energy intensive than recover of conventional fuels. Canada's National Energy Board posts amounts of each type of crude oil that is exported by PADD. Figure 3-2 provides the exports to PADD 5 in 2012. Almost no Canadian crude went to California in 2012[32], so this mix is representative of the Canadian crude in Washington. Approximately half of the crude is conventional, half is from oil sands.

[32] http://energyalmanac.ca.gov/petroleum/statistics/2012_crude_by_rail.html

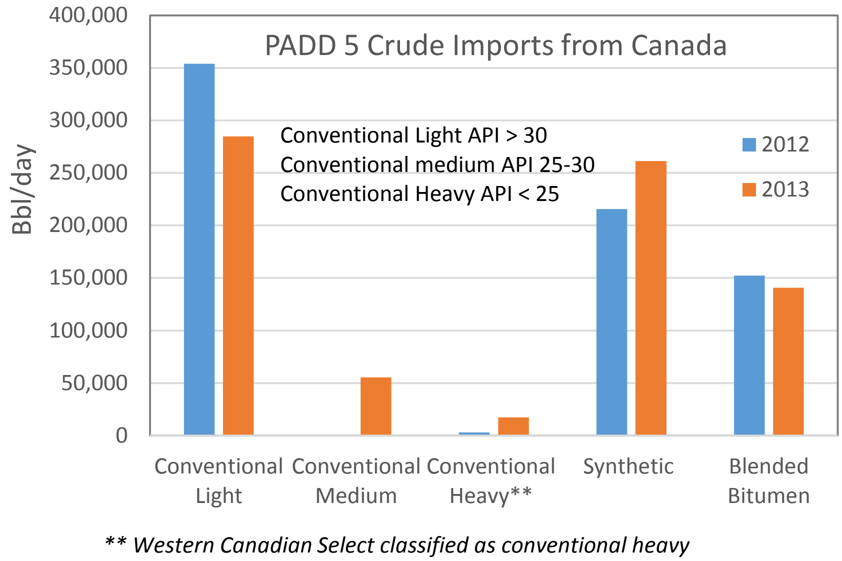



Figure 3-2. PADD 5 crude imports from Canada by type.

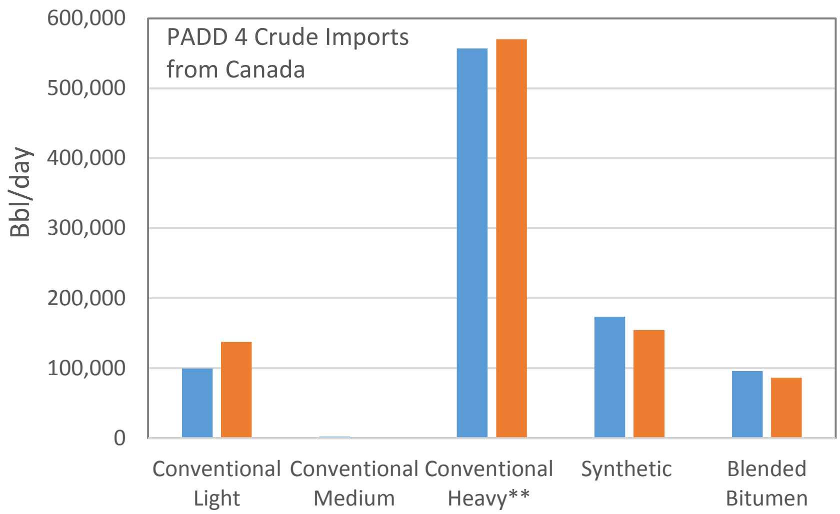
### *Crudes Refined in Montana*

Refineries in Montana refine crude oil produced in Montana, Wyoming, and Canada. Table 3-4 provides the sources of crude oil refined in Montana during 2012.[33] The types of crude oil imported from Canada into PADD 4[34] are shown in Figure 3-3. We assume that Montana receives the average mix of imports into PADD 4. Most of the crude imported from Canada is heavy conventional crude.

Table 3-4. Sources of crude oil refined in Montana in 2012

| Company | Crude Source | | |
|---|---|---|---|
| | Montana | Wyoming | Canada |
| CHS inc | 1,467,560 | 1,737,442 | 17,273,372 |
| Phillips 66 | 192,053 | 103,164 | 19,238,377 |
| ExxonMobil | | 5,565,743 | 12,004,809 |
| Calumet | | | 3,674,548 |
| Total | 1,659,613 | 7,406,349 | 52,191,106 |
| Share | 3% | 12% | 85% |

[33] Annual Review 2012, Oil and Gas Conservation Division, Department of Natural Resources and Conservation of the State of Montana
[34] PADD 4 consists of Montana, Idaho, Utah, Wyoming, and Colorado




*** Western Canadian Select classified as conventional heavy*

Figure 3-3. Types of crude oil imported from Canada to PADD 4.

### *Crudes Refined in Utah*

Table 3-5 provides pipeline crude oil receipts by source.[35] Most of the crude comes from Utah and Wyoming. A small amount comes from Canada; the Canadian crudes are assumed to have the same mix as in Montana (Figure 3-3) because Utah is also PADD 4. The crude data available does not include any receipts by truck, but this is assumed to be a small share of the total crude oil.

Table 3-5. Sources of Utah refinery crude oil receipts

| Year | Colorado | Wyoming | Canada | Utah | Total Refinery Receipts |
|---|---|---|---|---|---|
| 2010 | 6,525 | 20,144 | 4,278 | 20,690 | 51,637 |
| 2011 | 6,997 | 20,536 | 3,894 | 24,473 | 55,900 |
| 2012 | 7,805 | 20,769 | 4,394 | 26,185 | 59,153 |
| 2012, % | 13% | 35% | 7% | 44% | |

### 3.1.3 Crude Recovery and Transport Emissions

Crude oil recovery emissions can vary widely depending on many factors including amount and type of artificial lift utilized, fluid injection quantities, and whether gas flooding or steam injection is required. In addition, fugitive emissions can significantly impact crude recovery carbon intensity values. Researchers at Stanford University have developed the Oil Production Greenhouse Gas Emission Estimator (OPGEE) model[36] to quantify carbon intensity for crude oil recovery and transport by oil field. We utilized the most recent version of the OPGEE model (Version 1.1 Draft

[35]Utah Geological Survey, http://geology.utah.gov/emp/energydata/oildata.htm#refinery

[36] https://pangea.stanford.edu/researchgroups/eao/research/opgee-oil-production-greenhouse-gas-emissions-estimator

C) to estimate carbon intensity for the crude oils utilized in Washington, Montana, and Utah. In cases where OPGEE estimates CI for multiple fields in a given location, we employ a simple un-weighted average. Only transport distance inputs have been adjusted from default values.

Figure 3-4 through Figure 3-6 provide the weighted average carbon intensities for crude oil recovery and transport for each of the three refining locations (Washington, Montana, and Utah). Please refer to Appendix B for crude oil CI values for each field.

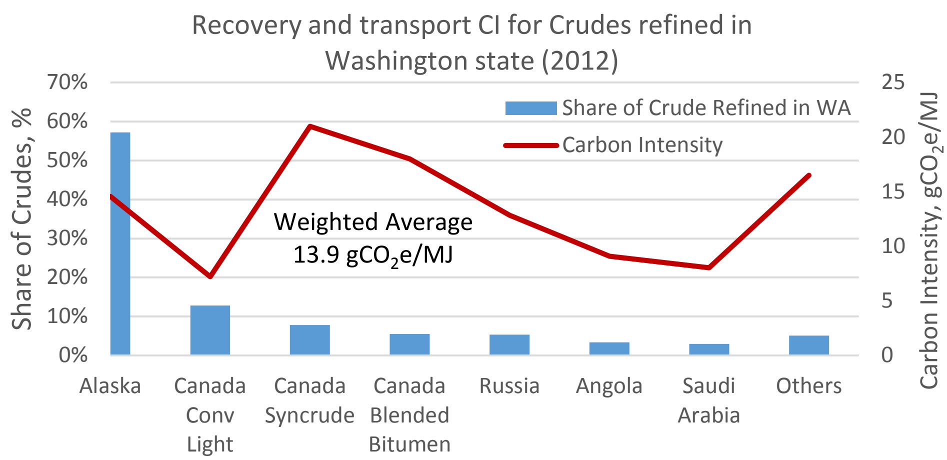



Figure 3-4. Average CI for crude oils refined in Washington.

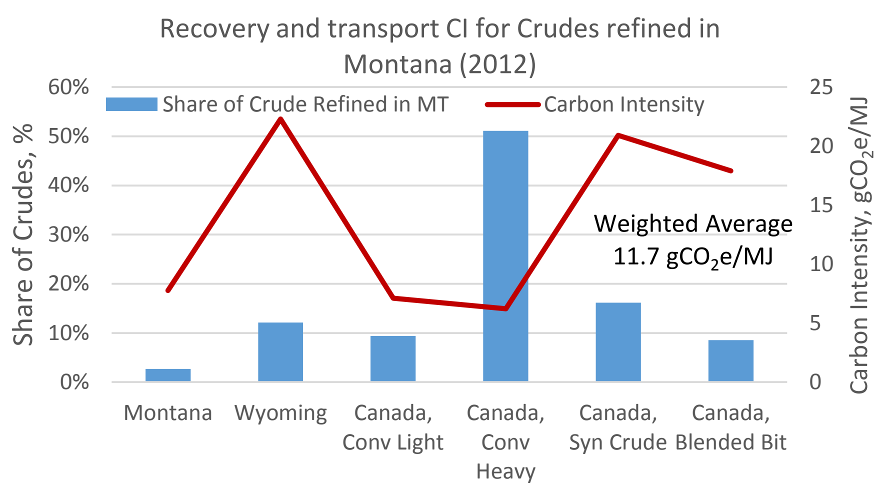



Figure 3-5. Average CI for crude oils refined in Montana

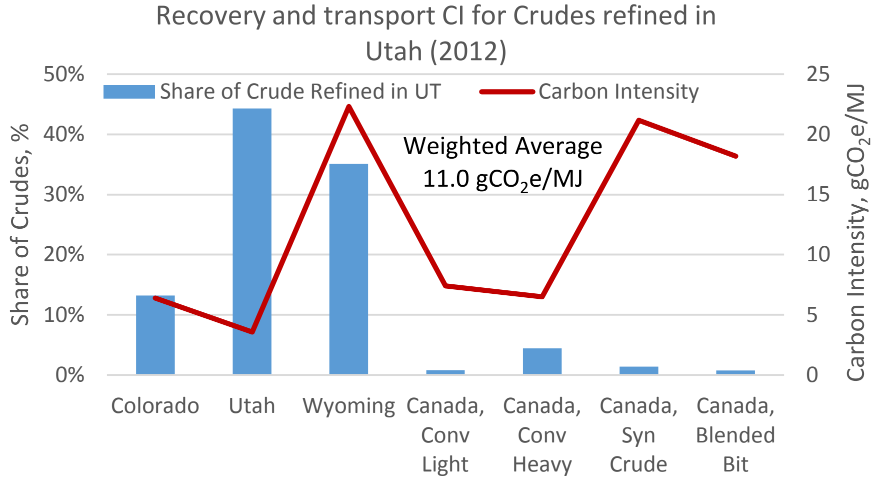



Figure 3-6. Average CI for crude oils refined in Utah.

The OPGEE model does not yet calculate CI for crude oils that are recovered with hydraulic fracturing. For the 2012 baseline, only Montana utilized a small amount (3 percent from Montana) of crude that may have been recovered using hydraulic fracturing. Since gasoline and diesel from Montana represent only 12 percent of the fuel consumed in Washington, no more than 0.36% of the fuels consumed in Washington in 2012 were produced from crude oil recovered with hydraulic fracturing. Moreover, since crude recovery is a small fraction of the total gasoline and diesel lifecycle carbon emissions, if carbon emissions from hydraulic fracturing are significantly different from conventional recovery, only a small error would be introduced into the baseline values.

Although the most recent complete set of petroleum data (2012) did not include delivery of North Dakota crude by rail to Washington, we note that Washington is currently receiving shale oil from North Dakota and this is anticipated to continue. If Washington adopts a CFS, the petroleum carbon intensity values utilized for compliance could be updated regularly. The 2016 baseline carbon intensity values (based on 2012 data as a proxy) might also be updated.

### 3.1.4 Refining and Finished Fuel Transport Emissions

The WA-GREET1 model was utilized to calculate crude refining and transport carbon emissions per unit of fuel produced. Carbon emissions for gasoline and diesel production are based on an assumed value for refining efficiency. Refining efficiency dictates the amount of fuel consumed per unit of fuel produced. The GREET model calculates refining efficiency based on crude API and sulfur content. If these values are unknown, GREET supplies average API and sulfur content values depending on crude oil source. The GREET calculated refining efficiencies based on crude oil source are presented in Table 3-6. It is interesting to note that the gasoline refining efficiency was lower than the diesel refining efficiency in earlier versions of GREET.

Table 3-6. GREET calculated refining efficiencies.

| Refinery Location | Gasoline | Ultra Low Sulfur Diesel |
|---|---|---|
| Washington | 89.2% | 89.2% |
| Montana | 88.4% | 88.4% |
| Utah | 89.4% | 89.4% |

The total fuel consumed (calculated from refining efficiency) is divided between a number of different process fuel types including natural gas and electricity. The natural gas and electricity carbon intensity values were modified for each refining location. Natural gas utilized in the western half of the state comes from the northeastern portion of British Columbia and travels south and west, connecting to the northwest pipeline system in Sumas. The pipeline distance is estimated at 700 miles. To date there has been no commercial hydraulic fracturing in Canada[37], so we have assumed that all natural gas consumed in Washington is conventional natural gas.

Montana is a net exporter of natural gas, but because of infrastructure limitations, all natural gas consumed is from Alberta.[38] The pipeline transmission distance from Alberta to Butte and then Billings is estimated at 700 miles; the natural gas is recovered conventionally. Natural gas utilized in Utah refineries is from the Uinta basin[39] and is all recovered through hydraulic fracturing. The assumed pipeline transport distance is 100 miles.

The electricity grid mix for Washington state is described in Section 3.5. The 2012 mix is shown in Table 3-7 along with the resource mixes for Montana and Utah. The Montana and Utah mixes are taken from EIA databases.[40]

Table 3-7. Refinery electricity grid mixes

| Resource | Washington | Montana | Utah |
|---|---|---|---|
| Residual Oil | | 2% | |
| Natural Gas | 8% | 2% | 17% |
| Coal | 13% | 50% | 78% |
| Nuclear | 5% | | |
| Biomass | 1% | | |
| Other non-combustion | 73% | 46% | 5% |
| Total | 100% | 100% | 100% |

The transport assumptions for finished fuel from the refinery to the petroleum terminal and refueling station are presented in Table 3-8. Table 3-9 provides the GREET estimated refining and transport carbon intensity estimates.

Table 3-8. Finished fuel transport assumptions.

| Refinery Location | Terminal Location | WA Share % | Pipeline Miles | Barge Miles | Truck Miles |
|---|---|---|---|---|---|
| Western Washington | Seattle | 88% | 75 | 0 | 75 |
| Western Washington | Pasco-Spokane | 11% | 150 | 200 | 75 |
| Western Washington | Spokane | 1% | | | 150 |
| Billings | Spokane | | 540 | | 75 |
| Salt Lake City | Pasco-Spokane | | 670 | | 75 |

[37] http://www.capp.ca/canadaIndustry/naturalGas/ShaleGas/Pages/default.aspx
[38] http://deq.mt.gov/ClimateChange/Energy/EnergySupply/OilGasProduction.mcpx
[39] Phone conversation with Carolyn Williams, State of Utah, Department of Natural Resources, 6-20-14
[40] http://www.eia.gov/electricity/data/state/

Table 3-9. GREET calculated refining and transport carbon intensity

| Refinery Location $gCO_2e/MJ$ | Gasoline | Ultra Low Sulfur Diesel |
|---|---|---|
| Washington | 12.3 | 12.2 |
| Montana | 14.8 | 14.6 |
| Utah | 15.1 | 14.9 |

### 3.1.5 Vehicle Emissions

Tailpipe GHG pollutants consist of $CO_2$, $N_2O$ and $CH_4$. The tailpipe emissions for gasoline and diesel are provided in Table 3-10.

Table 3-10. Assumed tailpipe emission factors

| Pollutant | Units | Gasoline | Diesel | Source |
|---|---|---|---|---|
| $CO_2$ | g/MJ | 72.8 | 74.9 | GREET Fuel Properties |
| $CH_4$ | $gCO_2e/MJ$ | 0.06 | 0.01 | EPA RFS2 |
| $N_2O$ | $gCO_2e/MJ$ | 1.6 | 0.7 | EPA RFS2 |
| $CO_2e$ | $gCO_2e/MJ$ | 74.5 | 75.6 | |

EPA RFS2 Docket File: EPA-HQ-OAR-2005-0161-0925.1.xls

### 3.1.6 Summary of Gasoline and Diesel Carbon Intensity Estimates

Table 3-11 summarizes gasoline and diesel carbon intensity value estimates for 2012, which are used as a proxy for the 2016 CFS baseline. The crude recovery values shown in the table have refining and transport loss factors applied, so are slightly higher than the values shown above. The weighted averages for gasoline blendstock and diesel in 2012 are estimated at 100.7 and 101.7 $gCO_2e/MJ$, respectively. These values are utilized as a proxy for the 2016 baseline. Because electricity and natural gas CI values decrease over time (see sections below), gasoline and diesel refining emissions decrease. Gasoline blendstock decreases to 100.6 g/MJ in 2020 while diesel decreases to 101.6 g/MJ. We set the 2015 values equal to the 2012 values and assumed a linear decrease to the 2020 values, remaining constant thereafter.

Table 3-11. Summary of estimated gasoline and diesel 2012 carbon intensity, $gCO_2e/MJ$

| CI, $gCO_2e/MJ$ | Refining Location | | | Weighted Average |
|---|---|---|---|---|
| | Washington | Montana | Utah | |
| Gasoline | | | | |
| Crude Recovery & Transport | 14.0 | 11.7 | 11.0 | |
| Refining & Transport | 12.3 | 14.8 | 15.1 | |
| Vehicle | 74.5 | 74.5 | 74.5 | |
| Total | 100.7 | 100.9 | 100.6 | |
| % of Washington Consumption | 79% | 12% | 9% | 100.7 |
| Diesel | | | | |
| Crude Recovery & Transport | 13.9 | 11.7 | 11.0 | |
| Refining & Transport | 12.1 | 14.6 | 14.9 | |
| Vehicle | 75.6 | 75.6 | 75.6 | |
| Total | 101.7 | 101.9 | 101.5 | |
| % Consumed in Washington | 73% | 12% | 15% | 101.7 |

## 3.2 Ethanol

For the scenario analysis exercise, ethanol produced from a range of feedstocks was considered. Because denatured ethanol (ethanol blended with a small amount of gasoline) rather than neat ethanol is blended with gasoline blendstock to produce motor gasoline, we present denatured ethanol carbon intensity values here. For the analysis we assumed that denatured ethanol consists of 2% gasoline and 98% neat ethanol on a volume basis. The quantification methodology and CI value for each ethanol feedstock type (on a denatured basis) are provided in Table 3-12.

Table 3-12. Summary of denatured ethanol carbon intensity values utilized in analysis

| Feedstock | Calculation Methodology | 2015 CI $gCO_2e/MJ$ |
|---|---|---|
| Avg MW Corn | WA-GREET1 with preliminary ARB ILUC[a] | 89.0 |
| CA LCFS Average Corn | Average of corn ethanol used in California in 2013[b] | 85.2 |
| Corn+ | Average of corn+ ethanol used in California in 2013[c] | 58.0 |
| Avg Brazil Sugarcane | WA-GREET1 with preliminary ARB ILUC[a] | 43.6 |
| Brazil Molasses | Average of ARB Method 2B applications | 30.0 |
| Cellulosic | Average of GREET1 default for corn stover and forest residue | 15.0 |

a. ARB ILUC Workshop on March 10, 2013 (23.2 g/MJ)
b. Subtract out previous ILUC value (30 g/MJ) and add preliminary value (23.2 g/MJ)
c. Subtract out previous ILUC value (30 g/MJ) and add preliminary sorghum ILUC (17.5 g/MJ)

The GREET model defaults were utilized to estimate the carbon intensity of average Midwest corn and Brazil sugarcane ethanol. Transportation modes and distances were modified to reflect transport to Washington. The model output is utilized as the 2015 CI value. The GREET model forecasts that the average corn ethanol pathway decreases by 2.8 $gCO_2e/MJ$ in 2020 while the sugarcane pathway decreases by 6.4 $gCO_2e/MJ$. We have assumed a linear decrease from the 2015 value to the 2020 value, holding constant thereafter.

The carbon intensity values for the low carbon corn and corn+ pathways are based on reported average values for fuels sold in California,[41] Because this is an approximation and because the transportation portion of the pathway is small, we have not adjusted the transport distances for these pathways to reflect transport to Washington instead of California. Although it is possible that the CI values for low carbon corn and corn+ could be reduced further during the analysis period, there are no published projections, so we have kept these values constant through 2026.

The molasses ethanol pathway CI is a simple average of four Method 2B applications received by ARB for the California LCFS. We have assumed that this value remains constant over time.

At the time the CI values were set in the analysis, ARB had not posted any cellulosic fuel pathways, so the GREET1 default values for corn stover (proxy for wheat straw) and forest residue ethanol were utilized (15 g/MJ). ARB has recently posted a cellulosic ethanol pathway at 7 $gCO_2e/MJ$, so 15 $gCO_2e/MJ$ assumed for the analysis is slightly higher, but a conservative value is appropriate given the uncertainty associated with the range of feedstocks that could be used for future cellulosic

[41] Status Review of California's Low Carbon Fuel Standard, January 2013, UC Davis ITS

ethanol production. The default value assumes 800 rail miles of transportation to the petroleum terminal and 30 miles by truck to the refueling station, adding approximately 1 g $CO_2$e/MJ. We have conservatively assumed that this value remains constant throughout the analysis period. Neither of these feedstocks induce ILUC emissions, though other cellulosic feedstocks might.

### 3.3 Cellulosic Gasoline and Diesel

Consistent with the methodology employed for the cellulosic ethanol pathway, we have utilized the average GREET1_2013 default value for production of cellulosic gasoline from corn stover and forest residue via pyrolysis. This value is 17 g$CO_2$e/MJ and we have conservatively assumed that it stays constant over the analysis period. These feedstocks do not induce land use change emissions though other feedstocks could. No cellulosic diesel fuel was utilized in the scenarios, so a carbon intensity value is not required for analysis.

### 3.4 Biodiesel

The biodiesel fuel pathways included in the scenario analysis consist of biodiesel produced in Washington from a range of feedstocks indicated in For the canola pathway, there are several choices for CI values. The GREET1_2013 default pathway for rapeseed results in WTT emissions of 31.7 g$CO_2$e/MJ. The ARB internally developed canola biodiesel WTT value is 27.54 gCO2e/MJ. The GREET1_2013 model adapted for Washington state using inputs provided by S&T2 yields a WTT value of 26.4 gCO2e/MJ. We have selected the ARB internally developed value.

Table 3-13. For the canola and soybean pathways, feedstock and crushing energy and emissions were allocated between the oil and the meal on a mass basis (following ARB methodology). For all pathways, esterification energy and emissions were allocated between the biodiesel and glycerin on an energy basis, again following ARB methodology. Because all biodiesel is assumed to be produced in-state, the electricity grid mix and natural gas consumed utilize Washington specific inputs (described above in the petroleum refining section). All transport modes and distances were modified to reflect transport of feedstocks to and within Washington state and transport of biodiesel within the state.

Table 3-13. Summary of biodiesel carbon intensity values utilized in analysis

| Feedstock | Calculation Methodology | 2015 CI g$CO_2$e/MJ |
|---|---|---|
| Canola Seed | ARB canola biodiesel internally developed pathway with preliminary ARB ILUC value.[a] | 73.1 |
| Soybean Oil | WA-GREET1 soybean pathway with preliminary ARB ILUC value.[b] All oil from Midwest, all fuel produced in Washington | 60.7 |
| Used Cooking Oil | WA-GREET1 UCO pathway, feedstock collected from Washington state and fuel produced in-state. | 18.3 |
| Tallow | WA-GREET1 Tallow pathway, feedstock collected from Washington state and fuel produced in-state | 29.7 |
| Corn Oil | Average of two Method 2B pathways posted on ARB LCFS website for corn oil produced at plants with dry DGS. | 14.0 |

a. ARB preliminary ILUC value for canola biodiesel is 41.6 gCO2e/MJ, March 2014 workshop
b. ARB preliminary ILUC value for soybean biodiesel is 30.2 gCO2e/MJ, March 2014 workshop

For the canola pathway, there are several choices for CI values. The GREET1_2013 default pathway for rapeseed results in WTT emissions of 31.7 g$CO_2$e/MJ. The ARB internally developed canola biodiesel WTT value is 27.54 gCO2e/MJ. The GREET1_2013 model adapted for Washington state using inputs provided by S&T2[42] yields a WTT value of 26.4 gCO2e/MJ. We have selected the ARB internally developed value.

The soybean, tallow and used cooking oil (UCO) CI values were calculated with WA-GREET1. For soybean and tallow, the GREET1_2013 defaults for energy use and yield were utilized. For the UCO pathway, ARB energy use and fuel shares for the "cooking" case were utilized. The CI values for pathways calculated with the WA-GREET1 model decrease from the 2015 value shown above by 0.2 g/MJ in 2020 due to reduced CI electricity and natural gas. We assume a linear decrease between 2015 and 2020, with the CI constant thereafter.

Several years ago ARB produced an "internally developed pathway" for corn oil from corn ethanol plants in the Midwest producing dry DGS, transported to California and refined to biodiesel. This internally developed pathway has a CI of 4.0 g/MJ due to a large credit for avoided DGS drying. In the past six months, two new Method 2B dry DGS pathways have been posted to ARB's website[43]. The CI values for these plants are 11.1 and 16.6 g/MJ. In conversations with ARB staff, it appears that the credit for avoided DGS drying may have been overstated and will be revised in future. For this analysis we utilize a CI of 14 g/MJ, which is an average of the two Canadian pathways.

Vehicle emissions consist of tailpipe $CO_2$, $CH_4$ and $N_2O$. Most of the carbon content of the fuel is biogenic and therefore not counted, however in esterification, fossil methanol is consumed as a feedstock (46 Btu/MJ biodiesel). Therefore, the carbon content of the fossil methanol is included in vehicle $CO_2$ emissions. The $N_2O$ and $CH_4$ emission factors are taken from EPA.

Table 3-14. Assumed tailpipe emission factors

| Pollutant | Units | Biodiesel | Source |
|---|---|---|---|
| $CO_2$ | g/MJ | 3.3 | GREET Fuel Properties |
| $N_2O + CH_4$ | g$CO_2$e/MJ | 0.7 | EPA RFS2 |
| $CO_2$e | g$CO_2$e/MJ | 4.0 | |

EPA RFS2 Docket File: EPA-HQ-OAR-2005-0161-0938.1.xls

### 3.5 CNG

The CNG pathways included in the scenario analysis utilize fossil natural gas and a variety of pipeline quality renewable natural gas (RNG). The RNG feedstocks are landfill gas (LFG), wastewater treatment (WWT) anaerobic digestion gas, and food and green waste high solids anaerobic digestion (HSAD) gas. These fuels are recovered, cleaned to pipeline quality and injected into existing pipelines. We have utilized the pipeline injection pathway for RNG because this method is already practiced in Washington state. The WA-GREET1 model with Washington fossil natural gas inputs (discussed above in gasoline and diesel section) and electricity generation resource mix was utilized to quantify the CI for all pathways except the HSAD pathway. Table 3-15 summarizes the calculation methodology and estimated CI values.

[42] Inputs provided by email from Don O'Conner.

[43] BIOX Canada and Methes-Ontario

For fossil CNG, the GREET defaults for recovery, processing, and compression efficiency were utilized. Note that this newer version of the GREET model estimates higher CI values than the previous version originally utilized by ARB due to increased estimates of methane leakage. ARB's updated values calculated with the CA-GREET2 are also higher than the previous values.

For LFG, the ARB inputs for LFG recovery energy use and fuel shares were utilized. For WWT, the GREET defaults for energy use were utilized. The HSAD value developed by ARB[44] was utilized directly; HSAD has much lower CI than LFG because it receives a credit for avoiding the landfill entirely (methane leakage and flaring) while the LFG pathway receives a credit for avoided flaring only.

ARB estimates of tailpipe $N_2O$ and $CH_4$ emissions were utilized (2.5 $gCO_2e/MJ$). These values are based on old Climate Action Registry g/mi emission factors; re-evaluating and updating these values would be a worthwhile exercise.

Table 3-15. Summary of CNG carbon intensity values utilized in the analysis

| Feedstock | Calculation Methodology | 2015 CI $gCO_2e/MJ$ |
|---|---|---|
| Fossil | WA-GREET1 Model default inputs | 77.6 |
| Landfill Gas | WA-GREET1 Model with ARB inputs for LFG recovery energy use and fuel shares | 7.7 |
| Wastewater Plant | WA-GREET1 Model default inputs | 9.6 |
| High Solids AD | ARB LCFS Pathway | -15.3 |

## 3.6 Electricity

Due to large amounts of hydro, Washington enjoys some of the lowest carbon electricity in the country. Figure 3-7 provides the 2012 resource mix. Despite the low carbon grid mix, Washington has an existing renewable portfolio standard (RPS) which requires 15 percent of the load to be serviced by new renewables by 2020. Figure 3-8 illustrates the RPS requirement through 2020. The GREET calculated CI value (without EER applied) for 2016 through 2019 is 49.4 $gCO_2/MJ$, decreasing to 44.0 $gCO_2e/MJ$ for 2020 through 2026. These values have been utilized to calculate CI values of fuels produced in-state (gasoline, diesel, CNG, biodiesel). With the assumed EER of 3.4,[45] this corresponds to a CI for electric vehicles of 14.5 $gCO_2e/MJ$ and 13.0 $gCO_2e/MJ$ for 2016 through 2019 and 2020 through 2026, respectively.

[44] Proposed Low Carbon Fuel Standard (LCFS) Pathway for the Production of Biomethane from High Solids Anaerobic Digestion (HSAD) of Organic (Food and Green) Wastes
[45] Consistent with ARB's LCFS assumption. Please refer to Vehicle Fuel Economy section in the Appendix for more information on EERs.

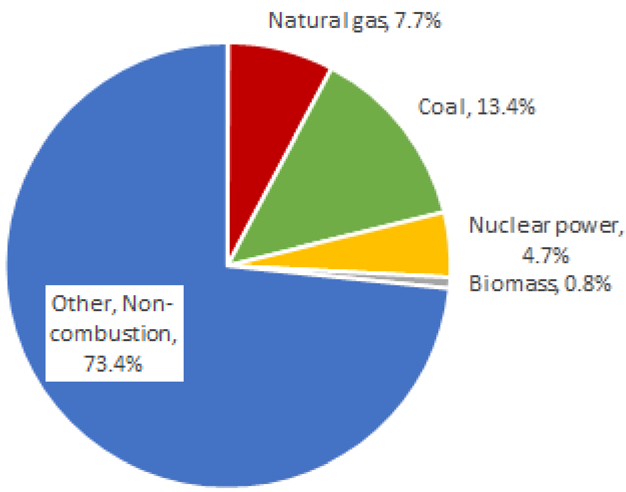



Figure 3-7. Washington State 2012 electricity resource mix.

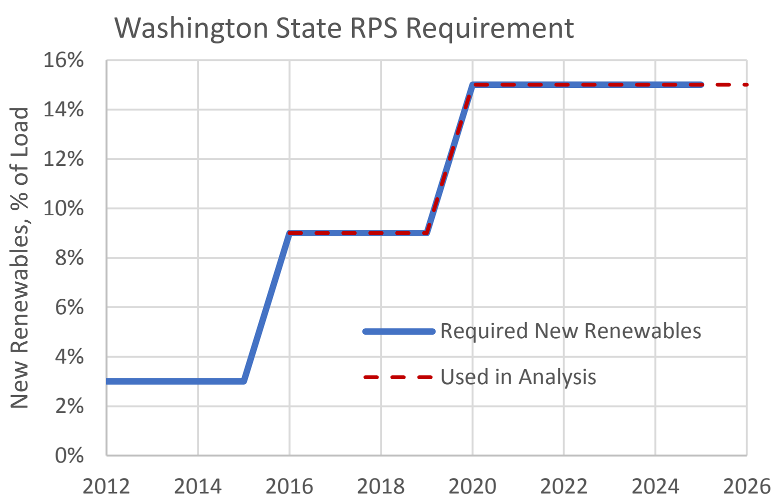



Figure 3-8. Renewable Portfolio Standard requirement.

The California LCFS Lookup Table provides two electricity CI values. One value reflects the estimated average grid resource mix and the other value is a "marginal" mix. The marginal mix was developed to reflect the resources that would come online to service a new sustainable long-term load. It was determined that these resources are combined cycle natural gas turbines combined with new renewables needed to comply with California's renewable portfolio standard. For electric utilities creating LCFS credits, either the average or marginal value may be utilized.

The electricity CI values developed for Washington state reflect the average grid mix. Determining the resource mix that corresponds to "marginal" depends upon the definition of marginal. Marginal could mean the resources that are online when electric vehicles are charged. If this is the definition of marginal, then the resource mix would consist of hydro and nuclear, nearly zero carbon resources. However, not all EVs charge at night, and as workplace charging becomes more common place, daytime charging will be more prevalent. If marginal is defined as the generation that would come online to service a new sustained load, it could be natural gas combined cycle combined with RPS, the ARB marginal approach. However, the Northwest Power and Conservation Council[46] evaluated several very aggressive EV penetration scenarios and found that no new generation capacity would need to be installed to support the load. All new demand would be met by ongoing conservation efforts. We assume here that conservation, results in an even reduction in generation across resource type, so in this definition of marginal, the average grid mix is appropriate.

## 3.7 Hydrogen

We have assumed on-site natural gas reforming as the hydrogen pathway for the scenario analysis. We utilized WA-GREET1 with the Washington specific natural gas transmission distance and electricity grid mix. All default process efficiency values were utilized. The estimated carbon intensities are 102.4 $gCO_2e/MJ$ and 101.6 $gCO_2e/MJ$ in 2015 and 2020, respectively. With the assumed EER of 2.5 (taken from ARB), this corresponds to 40.9 $gCO_2e/MJ$ and 40.6 $gCO_2e/MJ$ for 2015 and 2020, respectively.

## 3.8 Summary of Carbon Intensity Values Utilized in Scenario Analysis

Table 3-16 summarizes the carbon intensity estimates for 2015 described in the paragraphs above. Values for 2020 are also provided. All values are assumed constant from 2020 through 2026. This assumption results in a slight over-prediction of the quantity of low CI fuels required for compliance vis-a-vis the expectation that CIs may continue to decline in response to policy signal.

[46] Northwest Power and Conservation Council Sixth Power Plan (pp 3-12 – 3-15)

Table 3-16. Summary of Carbon Intensity Values Utilized in Scenario Analysis

| Fuel Pathway | 2015 | | | | | 2020 |
|---|---|---|---|---|---|---|
| | WTT | TTW | WTW | ILUC | Total | Total |
| Petroleum | | | | | | |
| Gasoline Blendstock | 26.2 | 74.5 | 100.7 | 0.0 | 100.7 | 100.6 |
| Low Sulfur Diesel | 26.0 | 75.6 | 101.7 | 0.0 | 101.7 | 101.6 |
| Denatured Ethanol | | | | | | |
| Average MW Corn | 63.4 | 3.1 | 66.5 | 22.5 | 89.0 | 86.2 |
| CA LCFS Average Corn | | | 62.7 | 22.5 | 85.2 | 85.2 |
| Corn+ | | | 40.5 | 17.5 | 58.0 | 58.0 |
| Brazil Sugarcane | 14.9 | 3.1 | 17.9 | 25.7 | 43.6 | 37.2 |
| Molasses | | | 30.0 | 0.0 | 30.0 | 30.0 |
| Cellulosic | | | 15.0 | 0.0 | 15.0 | 15.0 |
| Cellulosic Gasoline | | | 17.0 | 0.0 | 17.0 | 17.0 |
| CNG | | | | | | |
| Fossil | 14.8 | 58.8 | 73.6 | 0.0 | 73.6 | 73.5 |
| LFG | -51.1 | 58.8 | 7.7 | 0.0 | 7.7 | 7.2 |
| WWT | -49.3 | 58.8 | 9.6 | 0.0 | 9.6 | 11.1 |
| HSAD | | | | | -15.3 | -15.3 |
| Electricity (w/o EER) | 49.4 | 0.0 | 49.4 | 0.0 | 49.4 | 44.0 |
| Hydrogen (w/o EER) | 102.4 | 0.0 | 102.4 | 0.0 | 102.4 | 101.6 |
| Biodiesel | | | | | | |
| MW Soybean | 26.6 | 4.0 | 30.5 | 30.2 | 60.7 | 60.4 |
| Canola | 27.5 | 4.0 | 31.5 | 41.6 | 73.1 | 73.1 |
| UCO | 14.3 | 4.0 | 18.3 | 0.0 | 18.3 | 18.1 |
| Tallow | 25.7 | 4.0 | 29.7 | 0.0 | 29.7 | 29.4 |
| Corn Oil (dry DGS) | 10.0 | 4.0 | 14.0 | 0.0 | 14.0 | 14.0 |

# 4. Assumed Structure of the CFS

For the purposes of this analysis, we assume that a Washington CFS would be an eleven year program, beginning in 2016 and would result in a 10 percent reduction in carbon intensity by 2026. Year 1 (2016) would be a reporting year only, with no carbon intensity reduction required. Fuels would be divided into two pools: a gasoline pool and a diesel pool. The gasoline pool consists of all gasoline utilized as well as compliance fuels consumed by light and medium duty vehicles (ethanol, cellulosic gasoline, electricity, hydrogen, and CNG). The diesel pool consists of all diesel fuel utilized as well as compliance fuels consumed by heavy duty vehicles (biodiesel, CNG). This analysis includes only on-road transportation fuels; marine, rail, aviation and off-road equipment fuel use is not included.

Although the baseline year is 2016, the most recent complete set of data to establish baseline CI values is 2012. Therefore 2012 is the data year for the baseline; this may be updated with 2016 data at a later date if desired. The baseline CI values include ethanol blended into gasoline and biodiesel blended into diesel. Table 4-1 provides the baseline CI values for gasoline and diesel. In 2012, motor gasoline contained an average of 9.72% ethanol on a volume basis[47]. It is assumed that this ethanol was average Midwest corn ethanol with a carbon intensity of 89 $gCO_2e/MJ$. This results in a baseline gasoline value of 99.9 $gCO_2e/MJ$, and a 2026 target of 89.9 $gCO_2e/MJ$. Note that following California methodology, opt-in fuels (electricity, CNG) are not included in the baseline.

The diesel carbon intensity value for 2012 is 101.7 $gCO_2e/MJ$. It is estimated that diesel contained 0.22% biodiesel in 2012[48] and that the biodiesel was 50% soybean, and 25% used cooking oil, and 25% canola.[49] The resulting average biodiesel CI is 53.3 gCO2e/MJ. When blended with diesel, the on-road diesel baseline value is 101.6 gCO2e/MJ. Figure 4-1 provides the assumed shape of the compliance curve, showing annual percentage CI reductions required relative to the 2016 gasoline and diesel baselines.

Table 4-1. Baseline carbon intensity values

| | Baseline CI $gCO_2e/MJ$ | Target CI $gCO_2e/MJ$ |
|---|---|---|
| Motor Gasoline | | |
| Gasoline Blendstock | 100.7 | |
| Denatured Ethanol | 89.0 | |
| **Motor Gasoline[1]** | **99.9** | **89.9** |
| Diesel | | |
| Diesel | 101.7 | |
| Biodiesel | 53.3 | |
| **On-Road Diesel Blend[2]** | **101.6** | **91.4** |

1. Motor gasoline in 2012 contained 9.72% denatured ethanol by volume (6.68% by energy)
2. On-road diesel in 2012 contained 0.22% biodiesel by volume (0.20% by energy)

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[47] Jerry Buendel, Washington State Department of Agriculture, Weights and Measures Program
[48] Washington State agencies utilized 0.35 MGY on-road, estimate an additional 1.65 MGY non-public vehicles for a total statewide consumption of 2 MGY.
[49] Biodiesel Shares from Leidos CLEW Report, Oct 2013.

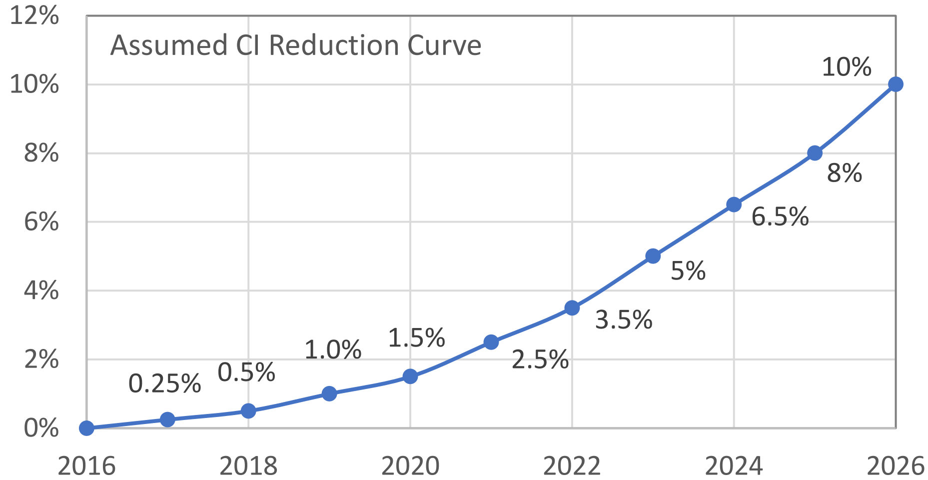

Figure 4-1. Assumed shape of the CFS compliance curve.

In the scenario analysis that will be described below, it is assumed that the gasoline and diesel pools will comply with the standard each year, separately. This results in conservative estimates of required low CI fuel volumes. The separate compliance and adherence to the standard each year is conservative because Washington state representatives have indicated that if a CFS was adopted, the standard would allow credit trading between the gasoline and diesel pools and would also allow regulated parties to bank credits generated through over-compliance in early years for use at a later date. To estimate the required low CI fuel volumes under this more flexible program, we have also run the compliance scenarios with banking and trading in place.

# 5. CFS Cost Containment Mechanisms

In a CFS, regulated parties are required to reduce the average carbon intensity of the fuels they provide over a given period; in the case of this analysis a time period of 10 years is utilized. For each energy unit of fuel sold, either credits or debits are generated. If the fuel sold has a carbon intensity below the standard, then credits denominated in tonnes are generated[50]. Conversely, if the fuel CI is higher than the standard, then debits are generated. At the end of each compliance year, regulated parties must offset all debits with credits. Any surplus credits may be sold or traded to another regulated party for use in compliance. Please refer to Section 6.4 for details on credit and debit calculations.

One potential concern with a CFS is whether it might cause fuel prices to increase as a result of insufficient supplies of low CI fuels. An insufficient supply of low CI fuels may cause the price of credits to increase. Regulated parties purchasing credits may pass the costs along to consumers in the form of higher gasoline and diesel prices. Washington state has signaled that if a CFS is implemented, it would have credit banking and trading provisions to increase compliance flexibility. Trading provisions would allow credits created in the diesel pool to be utilized for compliance in the gasoline pool and vice versa. Banking provisions allow extra credits created in the early years of the program through over compliance to be used for compliance in later years. The flexibility offered by banking and trading is likely to lower the average cost of compliance and reduce credit price volatility.[51] In addition to banking and trading provisions, other cost containment mechanisms can be employed to help contain costs. This section of the report describes mechanisms currently being considered by ARB for California's LCFS and discusses the potential implications of these mechanisms.

## 5.1 Description of Cost Containment Provisions

ARB and UC Davis recently reviewed several different cost containment mechanisms; this section of the report describes the two leading mechanisms considered by ARB: the credit window option and the credit clearance option.

### *Credit Window Option*

In the credit window option, if credits are not available in the market for purchase, regulators would provide credits for sale at a predetermined price. Revenue from credit sales would subsequently be utilized to incentivize production of low CI fuels[52]. The credit window price acts as a cap on credit prices. The cap provides certainty to the market with a known maximum cost of compliance and also incentivizes investment in low CI fuel production. However, this mechanism does not ensure that actual CFS GHG emission reductions occur. If the CFS is a subset of a larger suite of GHG reduction policies that includes a cap and trade program, the reductions originally planned for the transportation sector would be provided by a different sector. Another potential disadvantage of the credit window option is that the regulator would need to administer distribution of credit window revenue.

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[50] The quantity of credits is simply the difference in g/MJ between the standard and the CI of the fuel (adjusted for vehicle efficiency differences) sold multiplied by the quantity of fuel displaced (in MJ) divided by 1 million grams per tonne.

[51] *Tradable credits system design and cost savings for a national low carbon fuel standard for road transport*, Jonathan Rubin and Paul Leiby, May 2013 Energy Policy 56: 16-28. http://www/sciencedirect.com/science/article/pii/S0301421512004430

[52] A third mechanism, the non-compliance penalty mechanism, charges a fee per tonne of deficit not offset by credits. In practice, this mechanism is equivalent to the credit window mechanism and is not discussed here.

*Credit Clearance Option*

In the credit clearance option, regulators establish a maximum credit price (credit cap). At the end of each reporting period, regulated parties would report the number of additional credits they need for compliance. If an overall credit shortage exists, regulators would issue a call for available credits at the cap. Credit holders pledge the number of credits they will supply at up to the price cap. The regulated parties then negotiate directly with credit holders to purchase credits. If more credits are pledged by credit holders than are needed, then all regulated parties will be in compliance after purchasing these credits at a price not to exceed the cap. If there are not enough credits pledged, then each regulated party purchases their share of the pledged credits. The remaining deficit would roll forward and be added to any new deficit generated the following year.

The credit clearance option is similar to the credit window option in that the maximum cost of compliance is known in any given year, but because the liability can roll forward, the ultimate cost is difficult to quantify. There could also be a social cost associated with possible negative stockholder response to rolling forward a liability.

The main benefit of the credit clearance option over the credit window option is that in the long run, all CFS GHG emission reductions are achieved. Because this mechanism ultimately requires all CI reductions to occur, the regulation is more durable, stimulating investment in low CI fuel production capacity. Another feature of this mechanism is that it allows direct negotiation between the regulated parties and the low CI fuel providers, possibly fostering mutually beneficial relationships. Additionally, the low CI fuel producers remain the direct beneficiaries of credit revenue, resulting in a market based allocation of investment in contrast to the credit window option in which regulators must decide how to distribute funds. There is no assurance how these funds may be allocated.

Each of the mechanisms discussed here employs a cost ceiling to mitigate the potential effects of credit price spikes. Setting the price of the cap is extremely difficult. The cap needs to be high enough so that it incentivizes investment in low CI fuel production capacity. It also needs to be high enough so that it is not routinely triggered or triggered for sustained periods of time. However, the cap shouldn't be set so high that it increases the price of fuel above acceptable levels if triggered. Once set, regulators may decide to grow the cap over time at the rate of inflation.

## 5.2 Credit Price Floors

In theory, a price cap, even if not triggered, would lower the expected value of credit prices because some of the upward portion of the credit price distribution is truncated. To leave the market signal as transmitted by expected prices unaffected, a floor (minimum price for credits) could theoretically 'undo' this lowering effect by truncating the other side of the distribution. Establishing a floor also provides low CI fuel producers with certainty on minimum returns, facilitating financing for installation of new production capacity. However, a credit price floor is difficult to implement in practice. If credit prices drop below the floor, then the regulator would need to reduce supply of credits. This could be accomplished by purchasing and retiring credits or by reducing the face value of credits. This seems to be a difficult and potentially costly mechanism for the regulator to administer. Regulators would need legal authority and financial resources to purchase credits. Like the price ceiling, it would be difficult to set the value of the floor. If the floor is too high, it artificially inflates the cost of low CI fuels and compliance. If it is too low, it does not incentivize investment in low CI fuel production.

## 5.3 Cost Containment Implications

This section explores the impact of cost containment on compliance with a CFS. We consider the credit window and credit clearance options with a pre-determined cap, but no credit price floor. As described in more detail in Section 6.5, we assume in this analysis that the total cost of CFS credits purchased to cover deficits generated by regulated parties is passed on to consumers in the form of increased gasoline and diesel prices.

The credit window and credit clearance mechanisms both involve setting a cap on credit prices which effectively limits the potential price impact at the pump. Figure 5-1 illustrates a hypothetical situation in which credit prices fluctuate over time, but never reach the cap (this notional example is not meant to be predictive, forecasting of a trend, or singling out one trend as ideal). In this situation, the CFS GHG reduction goals are achieved and costs stay below the cap.

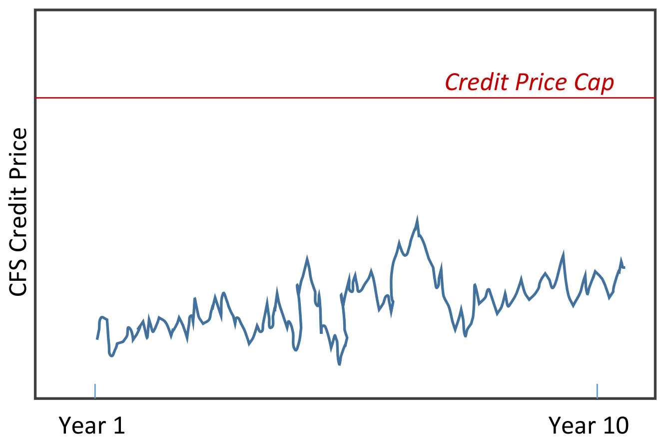


Figure 5-1. Hypothetical example of CFS credit prices remaining below the cap.

A second possibility is that a short-term low CI fuel supply shortage (or expectation of one due to banking) results in a credit price spike up to the cap that then resettles once the supply shortage is resolved. Figure 5-2 illustrates this hypothetical situation (again, this is not meant to be predictive or indicative of a trend). It is important to note that not all of the credits utilized for compliance in a year when the market price for credits reaches the cap would be purchased at the cap price. Regulated parties might have sufficient banked credits to cover their compliance needs, and credit prices may not trigger the cap for the entire compliance year. As a result, the average credit price for the compliance year would not necessarily be the price at the cap, so gasoline and diesel price changes due to the program would be no higher than the maximum level determined when the cap was set. With the credit window option, regulated parties that do not hold enough credits for compliance would be able to purchase credits from the regulator at the credit price cap. The tonnes of credits purchased from the credit window represent emission reductions that would not be achieved by the program. If the CFS program is supplemented by an overall cap and trade program, these emission reductions would be achieved in other sectors.

If the credit clearance mechanism is utilized, there are two main possible outcomes. One outcome is that the call for credits at up to the credit price cap results in sufficient credits coming to the market in the short-run. In this situation, the CFS GHG reduction goals are met in the current compliance year. The average price of credits could range up to the price of the cap (depending on the number of credits that had to be called), resulting in gasoline and diesel prices potentially increasing by up to the maximum level. The other outcome is that not all of the required credits come to market. In this case, the CFS GHG reduction goals are not met in the current year, but are rolled to subsequent years. Once credit prices return to manageable levels, the credit deficits would be eliminated through CI reductions below the standard in the year the credits are generated.

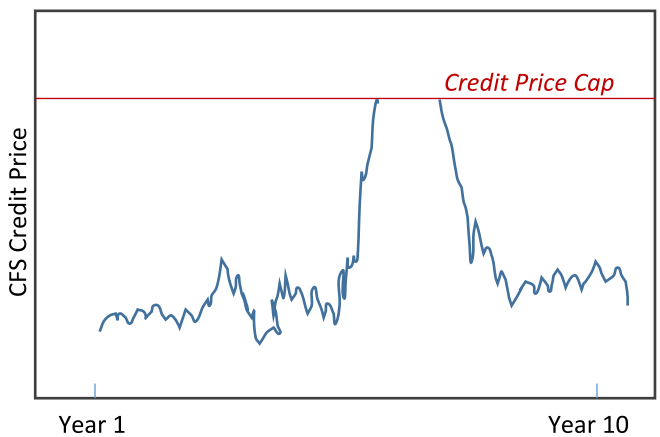


Figure 5-2. Hypothetical example of CFS credit prices with a short-term price spike.

A third possibility is that there is a sustained shortage of low CI fuels, resulting in high credit prices (i.e., at the cap) for a sustained period of time. Figure 5-3 illustrates this bounding situation of higher overall cost impact (note that this is not meant to be a prediction or indicative of a trend). The average credit price would likely reach the credit cap price, resulting in the maximum acceptable increase in gasoline and diesel fuel prices due to the program. In the credit window option, depending on how many credits are purchased at the window as opposed to generated from low CI fuel use, the CFS would fall short of its GHG reduction goals. In the credit clearance option, the deficits would continue to roll forward, creating a growing liability in the face of increasingly stringent requirements. Some of this expected cost might also get passed to consumers. If the market fails to respond to the sustained price signal, regulators would likely need to assess whether the credit price cap adequately reflects the ability of the alternative fuels market to meet the stringency of the CFS.

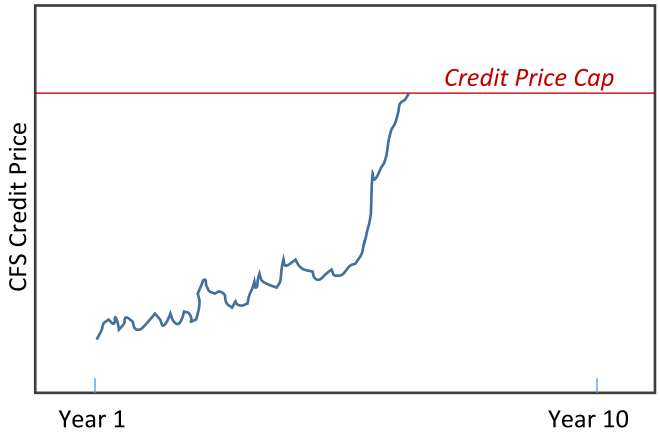

Figure 5-3. Hypothetical example of a sustained increased in CFS credit prices.

# 6. BAU and Scenario Definition

To better understand the range of possible economic effects if a CFS was adopted in Washington state, a scenario analysis was conducted. First, a business-as-usual (BAU) projection of vehicle sales and fuel consumption was developed. Next, rather than trying to project the actual fuel mix that achieves compliance with the standard, a set of compliance scenarios was designed to be technologically feasible and to bound the range of possible compliance strategies given the constraints of available fuel volumes and CIs described earlier. The VISION model was utilized to estimate fuel volumes, vehicle populations, and corresponding expenditures on fuels and vehicles as well as CI and emissions for each scenario relative to the BAU. These data were subsequently utilized in the REMI macro-economic model to determine the macro-economic impact of each scenario on the State's economy.

## 6.1 Business-as-Usual Forecast

The VISION[53] model was utilized to forecast fuel consumption and vehicle purchases for the Business-as-Usual (BAU) and each of the compliance scenarios. The VISION model was modified to reflect transportation in Washington state. Please refer to Appendix A for a detailed discussion of assumptions on vehicle sales, vehicle technology market shares, vehicle miles traveled (VMT), fuel economy, and fuel price projections. Based on these assumptions, the VISION model quantifies annual fuel consumption by type (gasoline, diesel, ethanol, natural gas) through 2026. For this analysis, we have added CI calculations to the model. The user specifies the mix of fuel pathways for each fuel type (e.g. shares of corn, sugarcane and cellulosic ethanol), and then the model calculates the resulting gasoline and diesel pool CI levels.

To project fuel consumption for the BAU we have made several key assumptions. We assume that ethanol in gasoline will remain at the 2013/2014 estimated blend level of 9.6 percent volume and that all ethanol consumed is average Midwest corn ethanol. We further assume that no E85 is consumed. For biodiesel, we assume that the current blend (estimated at 0.22 percent volume) is maintained. The feedstocks used to produce biodiesel are based on the CLEW mix cited earlier which is half soybean oil with the other half split between canola oil and UCO, transitioning to 35 percent soybean oil, 30 percent UCO, 30 percent canola, and 5 percent corn oil in 2020. We assume all CNG use is fossil based; all developed pipeline RNG is sold into CFS markets elsewhere.

These assumptions result in slight carbon intensity declines in the BAU, mainly for the gasoline pool, due to increased sales of EVs and CNG vehicles (Figure 6-1). The figure also provides corresponding GHG[54] emission reductions calculated based on assumed CI values for the fuels used. The gasoline pool emissions decrease because of reduced gasoline consumption (improved fuel economy) while diesel pool emissions increase slightly due to projected increases in diesel consumption (please refer to Appendix A for fuel consumption projections). The BAU achieves 1.3 percent CI reduction in the gasoline pool and 0.3 percent CI reduction in the diesel pool by 2026, compared to the 10 percent that would be achieved by a CFS.

[53] Argonne National Laboratory model for on-road transportation

[54] GHG emission factors include both WTW and ILUC emissions

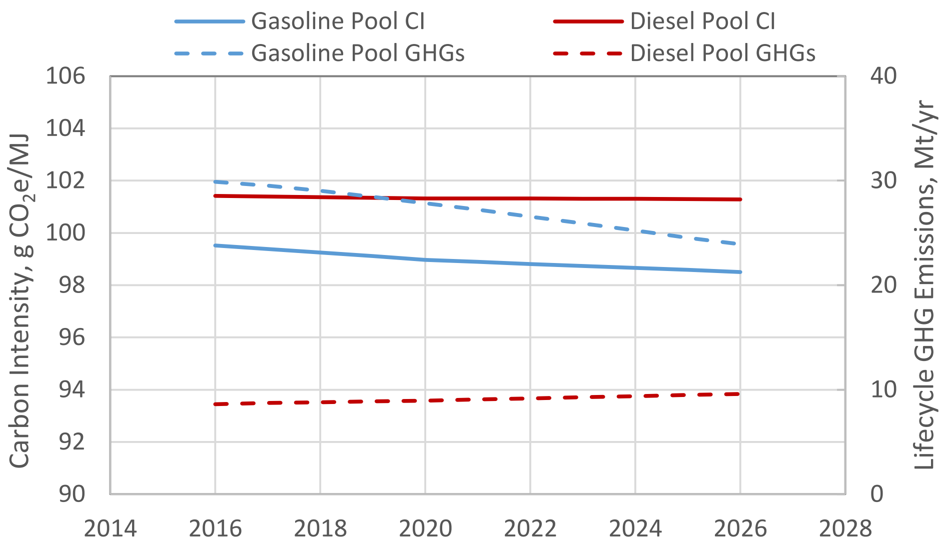

Figure 6-1. BAU Carbon Intensity and Lifecycle GHG Emission Forecasts.

## 6.2 Compliance Scenario Definition

Because the CFS is a flexible market based standard, there are many possible combinations of advanced vehicles and low carbon fuels that result in compliance each year. Because the compliance scenarios are mainly intended to give an idea of maximum compliance volumes required and the macro-economic impacts to the state, it is most effective to evaluate combinations of fuels and vehicles that bound the possible range of compliance. We have therefore selected three main compliance themes:

Scenario A – Advanced Vehicles
Scenario B – Cellulosic Biofuels
Scenario C – Minimum Cellulosic Biofuels, E85
Scenario D – Minimum Cellulosic Biofuels, E15

In Scenario A, it is assumed that more plug-in electric vehicles (PEVs), hydrogen fuel cell vehicles (FCVs), and CNG vehicles are sold. Scenario B is a bounding scenario that explores compliance with higher volumes of cellulosic biofuels. Scenario C is another bounding scenario that explores compliance with minimum supplies of cellulosic biofuels. Because the CI of non-cellulosic ethanol is higher than cellulosic ethanol, more ethanol is needed for compliance; this scenario requires FFVs to consume E85[55]. Scenario D is also a minimum cellulosic fuel scenario, but instead of utilizing E85, it allows up to 15 percent ethanol blended into gasoline for model year 2001 and newer vehicles. This is modeled by reducing the overall ethanol blend by the percent of older vehicles still in the fleet. In reality, since older vehicles have lower VMT than newer vehicles on average[56], this is a conservative assumption.

[55] The term E85 refers to the use of high level ethanol blends; in our analysis we assume 75% denatured ethanol.
[56] Both VISION and ARB's EMFAC models employ declining VMT with vehicle age.

Table 6-1 depicts the vehicle populations and biofuel blend levels for each of these scenarios. The table also summarizes available quantities of low CI fuel outlined in Section 2 of this report above; not all of these volumes are required for each of the scenarios. For example, even though the upper bound for cellulosic ethanol is 300 MGY, Scenario B, the cellulosic fuel focused scenario, utilizes less than one third of this upper bound.

Table 6-1. Compliance Scenario Bounds

| | **Scenario A** Advanced Vehicles | **Scenario B** Max Cellulosic | **Scenario C** Min Cellulosic with E85 | **Scenario D** Min Cellulosic with E15 |
|---|---|---|---|---|
| Max Gasoline Ethanol % | 10% | 10% | 10% | **15%** |
| Share of Fuel use by FFVs that is E85 | Up to 85% if needed | **0%** | Up to 85% if needed | Up to 85% if needed |
| Max Biodiesel Blend % | Up to 15% | Up to 15% | Up to 15% | Up to 15% |
| Ethanol Volumes | | | | |
| Average MW Corn | Balance | Balance | Balance | Balance |
| CA LCFS Corn | Up to 250 MGY | Up to 250 MGY | Up to 250 MGY | Up to 250 MGY |
| Corn+ | Up to 40 MGY | Up to 40 MGY | Up to 40 MGY | Up to 40 MGY |
| Sugarcane | Up to 146 MGY | Up to 146 MGY | Up to 146 MGY | Up to 146 MGY |
| Molasses | Up to 20 MGY | Up to 20 MGY | Up to 20 MGY | Up to 20 MGY |
| Cellulosic | 63 to 300 MGY | 63 to 300 MGY | < 63 MGY | < 63 MGY |
| Cell Gasoline and Diesel | 55 to 200 MGY (gasoline equiv) | 55 to 200 MGY (gasoline equiv) | < 55 MGY (gasoline equiv) | < 55 MGY (gasoline equiv) |
| Biodiesel | | | | |
| Soybean | As needed | As needed | As needed | As needed |
| Canola | Up to 42 MGY | Up to 42 MGY | Up to 42 MGY | Up to 42 MGY |
| UCO | Up to 10 MGY | Up to 10 MGY | Up to 10 MGY | Up to 10 MGY |
| Tallow | Up to 12 MGY | Up to 12 MGY | Up to 12 MGY | Up to 12 MGY |
| Corn Oil | Up to 35 MGY | Up to 35 MGY | Up to 35 MGY | Up to 35 MGY |
| RNG | Up to 16 MGY (diesel equiv) | Up to 12 MGY (diesel equiv) | Up to 12 MGY (diesel equiv) | Up to 12 MGY (diesel equiv) |
| Vehicle Populations | | | | |
| CNG | 1.5 X BAU | BAU | BAU | BAU |
| EV/PHEV | CA ZEV | BAU | BAU | BAU |
| H2 FCV | CA ZEV | BAU | BAU | BAU |

We have evaluated these four scenarios in two different ways: strict compliance with the separate gasoline and diesel standards each year, and more flexible compliance that allows banking and trading of credits. In the bank and trade scenarios, unlimited trading of excess credits between the gasoline and diesel pools is allowed. Because the ARB LCFS has experienced significant trading from the diesel pool to the gasoline pool and because at present low CI fuels substituting for diesel are more available than low CI fuels for the gasoline pool, all of our trading scenarios trade excess credits from the diesel pool to the gasoline pool.

In addition, credits accumulated from over-compliance with the standard in early years may be banked for use in future years. Because the program would not end at the end of the analysis period (2026), we have required that a credit balance equal to 25 percent of the total number of compliance credits required in 2026 remain in the bank at the end of 2026 for use in future years. This bank balance criteria was selected somewhat arbitrarily because program stringency after the first 10 years is unknown. While the credit banking provision provides compliance flexibility if sufficient volumes of low CI fuels do not emerge when needed, these fuels must be available by 2026 for the program to achieve continued reductions beyond the analysis period. The scenarios without banking and trading demonstrate compliance with the standard each year and demonstrate long-run program feasibility.

Determining the volumes of low CI fuels each year to meet the standard consisted of substituting increasing volumes of lower CI fuel each year, reserving the lowest CI fuels until later in the program when they could be more available, and attempting to keep a balanced mix of low CI fuels rather than consuming as much as possible of one type of low CI fuel.

For the advanced vehicle scenarios (Scenario A and Scenario A with Banking and Trading) we have utilized the California Zero Emission Vehicle (ZEV) "Likely Compliance Scenario" market shares[57] for BEVs, PHEVs, and hydrogen FCVs. Although Washington state does not have a ZEV rule it currently experiences BEV and PHEV market shares that are similar to California's ZEV program. Adoption of a ZEV Program in Washington state would help increase the utilization of ZEVs. Figure 6-2 provides the new vehicle market shares for the three affected ZEV types. Figure 4-4 compares the assumed BAU and Scenario A new vehicle market shares for light duty vehicles (light duty auto combined with light duty trucks). For Scenario A we have also assumed that CNG market shares are 50 percent higher than BAU levels. Please refer to Appendix A for more details on new vehicle market share assumptions.

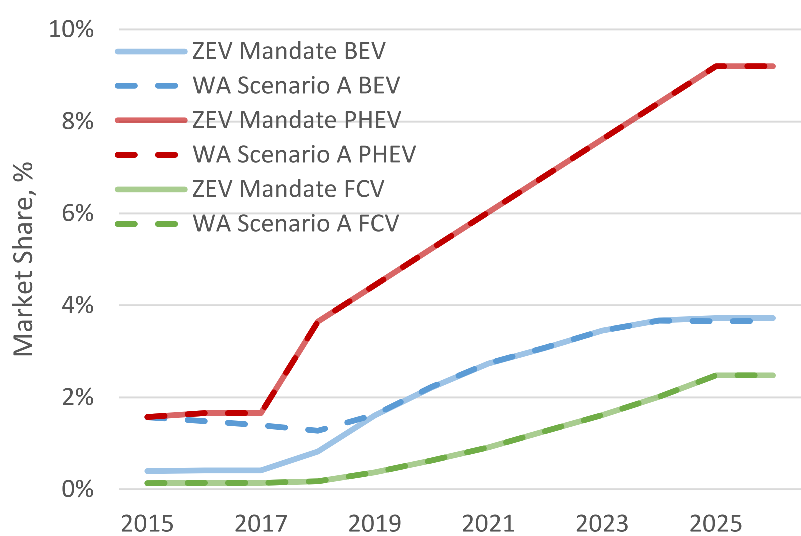


Figure 6-2. Scenario A and Scenario A with B&T light vehicle market shares.

[57] ZEV Initial Statement of Reasons, Likely Compliance Scenario Table 3-6, December 2011.

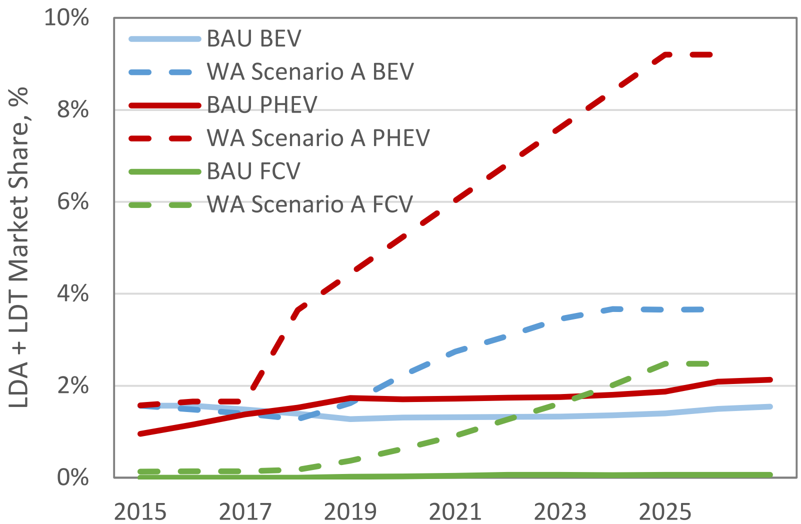

Figure 6-3. Comparison of Scenario A and BAU LDV Market Shares.

## 6.3 Opt-in Volumes

Because only parties that sell gasoline and diesel are regulated parties in a CFS, low CI fuel suppliers must "opt-in" to the program to make the credits generated by use of their fuels available for compliance. The opt-in fuels are electricity, CNG, and hydrogen. According to ARB,[58] all of the electric utilities have opted into the California LCFS, so all residential charging is captured. Companies that provide commercial charging are still negotiating metering arrangements, but will soon be able to opt into the program. The EV Project[59] reports that 80 percent of charging events occur at home; since home charging events are longer, we assume here that 90 percent of the electricity comes from home charging. Electricity consumed at home is provided by the electric utilities. Since we assume 100% of utilities will opt-in, we therefore assume that 90 percent of electricity opts in by 2017, ramping up to 94 percent in 2018, and 98 percent for 2019 and beyond.

Based on ARB's experience, 100 percent of the RNG sold as transportation fuel would opt into a Washington LCFS program. Large fleets utilizing fossil natural gas have now opted into California's LCFS program, but smaller fleets have not. We therefore assume 100 percent of RNG opts in and 50 percent of fossil natural gas opts in. We conservatively assume that this low opt-in rate holds for the analysis period.

Finally, there has been very little hydrogen fuel use to date. We assume that 50 percent opts in by 2017, increasing to 90 percent by 2021 and 95 percent for 2022 and beyond.

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[58] Conversation with Manisha Singh, ARB

[59] The EV Project is a DOE program established to deploy electric vehicles and charging equipment. Charging data for program participants may be found here: http://www.theevproject.com/documents.php

## 6.4 Credit and Deficit Calculation

The overall carbon intensity of each compliance pool is determined by summing the product of fuel consumption and carbon intensity for each fuel and dividing by total fuel consumption. The total fuel consumption in the denominator is multiplied by the EER, which is the ratio of the alternative fuel vehicle's energy consumption per mile to the gasoline vehicle's energy consumption per mile. The following two equations[60] provide the calculations for overall carbon intensity in $gCO_2e/MJ$. The values labeled "MJ" are shorthand for total energy consumed in MJ.[61] Multiplying g/MJ by MJ yields grams. To convert to tonnes, one must divide by 1 million. Note that EER is shown in the equation only when they are assumed to be different than 1.

$$Gasoline\ Pool\ CI = \frac{CI_{gas} \times MJ_{gas} + CI_{eth} \times MJ_{eth} + CI_{CNG} \times MJ_{CNG} + CI_{Elec} \times MJ_{Elec} + CI_{Cell\ Gas} \times MJ_{Cell\ Gas} + CI_{H} \times MJ_{H}}{MJ_{gas} + MJ_{eth} + MJ_{CNG} + MJ_{Elec} \times EER_{Elec} + MJ_{Cell\ Gas} + MJ_{H} \times EER_{H}}$$

$$Diesel\ Pool\ CI = \frac{CI_{dsl} \times MJ_{dsl} + CI_{BD} \times MJ_{BD} + CI_{CNG} \times MJ_{CNG} + CI_{Cell\ Dsl} \times MJ_{Cell\ Dsl}}{MJ_{dsl} + MJ_{BD} + MJ_{CNG} \times EER_{CNG} + MJ_{Cell\ Dsl}}$$

To calculate number of deficits created by gasoline or diesel (gasoline in this example):

$$Deficits = MJ_{gasoline} \times CI_{Standard} - MJ_{gasoline} \times CI_{gasoline}$$

To calculate the number of credits created by low CI fuels (electricity in this example):

$$Electricity\ Credits = \left(CI_{std} - \frac{CI_{elec}}{EER_{elec}}\right) \times MJ_{elec} \times EER_{elec}$$

## 6.5 Effect of CFS Credit Prices

In a CFS, regulated parties will need to acquire credits to offset deficits generated by the sale of fuels with CI values greater than the standard. Regulated parties may directly purchase credits from credit holders and submit them for compliance. Alternatively, regulated parties may generate credits by purchasing low carbon fuels to blend with gasoline and diesel, or generating those credits themselves. In this case, the price paid by the regulated party for the low carbon fuel has an implicit credit price built in, so the price of the fuel theoretically increases proportionally with the number of credits the fuel generates. The lower the CI, the more the regulated parties would pay for the fuel at a given credit price. In either case, the credit price and the fuel CI determine value added to the low CI fuel, accruing to the low CI fuel provider. Table 6-2 provides the value of CFS credits for a range of compliance fuels in 2026 at $100 and $250 per tonne based on CI values utilized in this analysis. For example, at a credit price of $100 per tonne, cellulosic ethanol providers would receive $0.92 per gallon of gasoline equivalent. For a 30 MGY cellulosic ethanol plant, this represents approximately $18 million of revenue for that year.

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[60] Note that all electricity and hydrogen is in the gasoline pool. CNG consumed by light and medium duty vehicles is in the gasoline pool. CNG consumed by heavy duty vehicles is in the diesel pool.

[61] All fuel energy densities utilized are lower heating values from the GREET model. Consistent with ARB.

Table 6-2. Value of CI rating per gasoline gallon equivalent as a function of credit price in 2026

| | Fuel Carbon Intensity | Gasoline Pool Standard in 2026 (10% CI reduction) | Credits Generated | Value of CI at Credit Price: 100 $/tonne | Value of CI at Credit Price: 250 $/tonne |
|---|---|---|---|---|---|
| | $gCO_2e/MJ$ | $gCO_2e/MJ$ | $gCO_2e/MJ$ | $/gge | $/gge |
| Sugarcane Ethanol[1] | 37.2 | 89.9 | 52.7 | 0.65 | 1.61 |
| Cellulosic Ethanol[1] | 15.0 | 89.9 | 74.9 | 0.92 | 2.29 |
| Fossil CNG[2] | 81.8 | 89.9 | 8.1 | 0.10 | 0.25 |
| Canola Biodiesel | 73.1 | 89.9 | 16.8 | 0.21 | 0.51 |
| Electricity[2] | 14.5 | 89.9 | 75.4 | 0.92 | 2.31 |
| Gasoline Blendstock | 100.6 | 89.9 | -10.7 | -0.13 | -0.33 |

1. Denatured
2. EER Corrected

In this analysis we have assumed that the total cost to regulated parties for credit purchases each year (total credits required multiplied by credit price) is divided by the total amount of gasoline and diesel sold and added to the price of gasoline blendstock and diesel. In reality, not all of the credit costs would translate to an increase in gasoline and diesel price, but without a detailed economic analysis of fuel pricing to provide a more accurate estimate, a conservative modeling approach was adopted so that potential cost effects are not underestimated (the effects of this revenue to low CI producers are discussed in the next paragraph). The resulting impact on gasoline and diesel prices as a function of credit price is provided in Figure 6-4 for 2026 (the year that requires a 10 percent reduction in CI). A credit price of $50 per tonne would cause prices to increase by 6 to 7 cents per gallon while a credit price of $100 per tonne would increase prices by 13 to 14 cents per gallon in 2026. Credit prices in ARB's program averaged $17 per tonne in 2012, $55 per tonne in 2013 and averaged $28 per tonne in the most recent quarter[62]. To be clear, an economic analysis to predict gasoline and diesel prices has not been conducted. Rather, we have calculated the total CFS credit costs each year based on an assumed mix of fuels and their CI values, divided by the total gallons of diesel and gasoline, and added this cost per gallon to EIA's gasoline and diesel price forecasts.

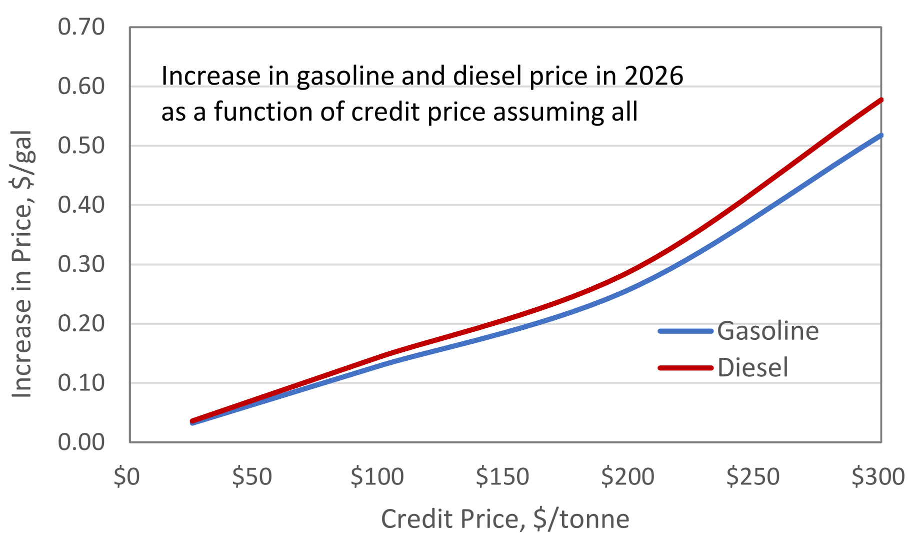


Figure 6-4. Effect of credit price on 2026 gasoline and diesel price.

[62] http://www.arb.ca.gov/fuels/lcfs/credit/20141110_octcreditreport.pdf

NOTE: Depending on fuel type and market conditions, a portion of the revenue received by low CI fuel producers for credit sales could be passed on to consumers in the form of ***reduced prices***. Additional conservatism has been built into this analysis since we have not assumed any price decreases for low CI fuels due to increased credit revenues to low CI fuel providers; in our set-up this additional revenue is either utilized to cover production costs or is realized as profit, depending on the credit price and the fuel type. If the credit revenue is realized as profit, the low CI fuel providers might lower their prices in the presence of competition. For example, if there was a sufficiently high credit price to more than cover canola biodiesel production costs, those producers would be in a position to lower the price of their canola biodiesel to better compete for a share of biodiesel demand.

Credit price is a reflection of relative availability of low CI fuels relative to the standard. If there is a shortage of low CI fuels, the credit price would be bid upwards. As credit prices rise, more low CI fuels become profitable to bring to the market and would enter into the mix. The resulting increased supply puts downward pressure on credit prices. It is impossible to predict with certainty the value of credit prices during the analysis period. For the scenario analysis we have assumed a credit price profile that starts at $15 per tonne of $CO_2$e and increases over time as the CFS becomes more stringent (Figure 6-5), ultimately hitting a price of $100 per tonne. As mentioned in Section 5.3, this price trajectory pattern is a bounding scenario; this is consistent with our analysis approach of bounding the anticipated range of inputs for compliance scenarios. Because the maximum credit price experienced ($100 per tonne) and the trajectory to it are somewhat arbitrary selections, we have also run sensitivity cases with credit price profiles shown in Figure 6-6.

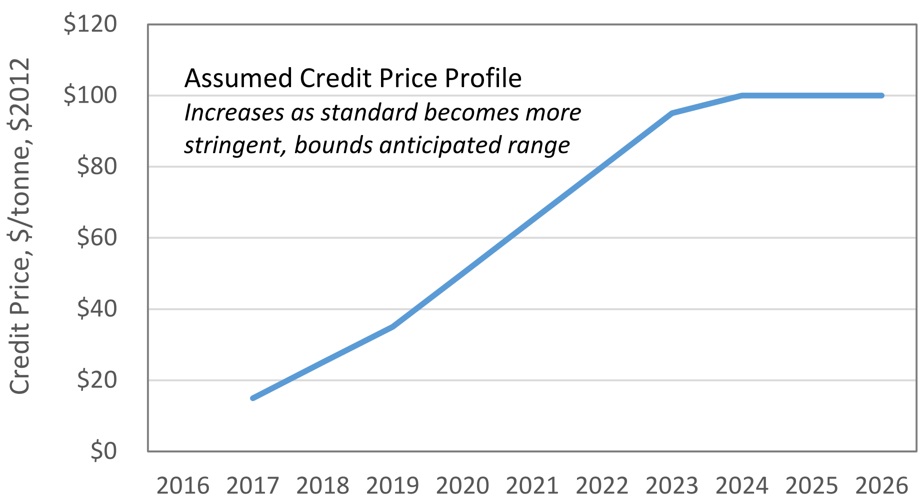


Figure 6-5. Assumed CFS credit price profile.

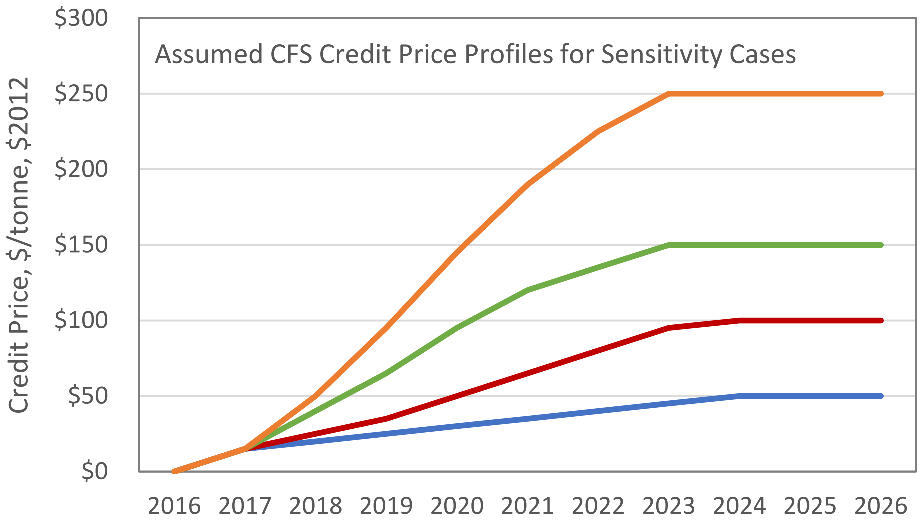


Figure 6-6. Assumed credit price profiles for sensitivity cases.

The dampening effect of higher gasoline and diesel prices on fuel purchases is taken into account by applying an elasticity to vehicle miles travelled. We have selected an elasticity of -0.17,[63] which results in a decrease in gasoline and diesel use of 0.17 percent for each percent increase in fuel price. This results in slightly lower volumes of low CI fuel required for compliance.

[63] "Understanding Transport Demands and Elasticities", Victoria Transport Policy Institute, March 2013. Value selected is from Table 18, the Gillingham (2010) study of California from 2005-2008, average of medium run fuel price sensitivity results. Value is at high end of Brand short-run elasticity values for 2007-2008.

# 7. Scenario Analysis VISION Model Results

This section of the report provides the VISION model results for the BAU and each of the scenarios. These results include low CI fuel volumes, petroleum consumption, GHG and criteria pollutant emission reductions, vehicle expenditures, fuel expenditures and infrastructure costs.

## 7.1 Biofuel Blend Levels and E85 Use

All compliance scenarios except Scenario D assume a 9.6 percent (volume) blend of denatured ethanol in motor gasoline in 2016, increasing to 10 percent by 2019 and remaining constant at 10 percent throughout the analysis period. Scenario D, the minimum cellulosic E15 scenario, increases to a statewide average of 14 percent by 2021 and then slowly increases to slightly less than E15 by 2024. Since EPA has approved E15 use for MY2001 and newer vehicles, we have reduced the blend level by the percent of VMT by older vehicles still in the fleet, but use the term E15 in the narrative. Table 7-1 provides the VISION estimated share of VMT for vehicles older than MY2001, the corresponding maximum allowable blend level, and the blend level utilized in the analysis. Note that by 2025, VISION groups all vehicles MY2000 and older with MY1999, so the exact number of vehicles MY2000 and older isn't available.

Table 7-1. Maximum allowable average ethanol blend level in gasoline

| Calendar Year | MY2000 and Older % of Total LDA VMT | Maximum Allowable Ethanol Blend Level | Blend Level Used in Analysis |
|---|---|---|---|
| 2020 | 7.1% | 14.1% | 12.5% |
| 2021 | 5.7% | 14.3% | 14.3% |
| 2022 | 4.1% | 14.5% | 14.5% |
| 2023 | 2.6% | 14.7% | 14.7% |
| 2024 | 1.3% | 14.9% | 14.9% |
| 2025 | n/a | | 14.9% |
| 2026 | n/a | | 14.95% |

The banking and trading variant of Scenario D has an earlier transition to E14 and a similar ramp to E15. Although this may be an aggressive schedule for required refueling station modifications, it is assumed that in the banking and trading scenarios, regulated parties would increase lower CI fuel blend levels as rapidly as possible to bank early credits. Figure 7-1 provides the ethanol blend levels for the two Scenario D cases.

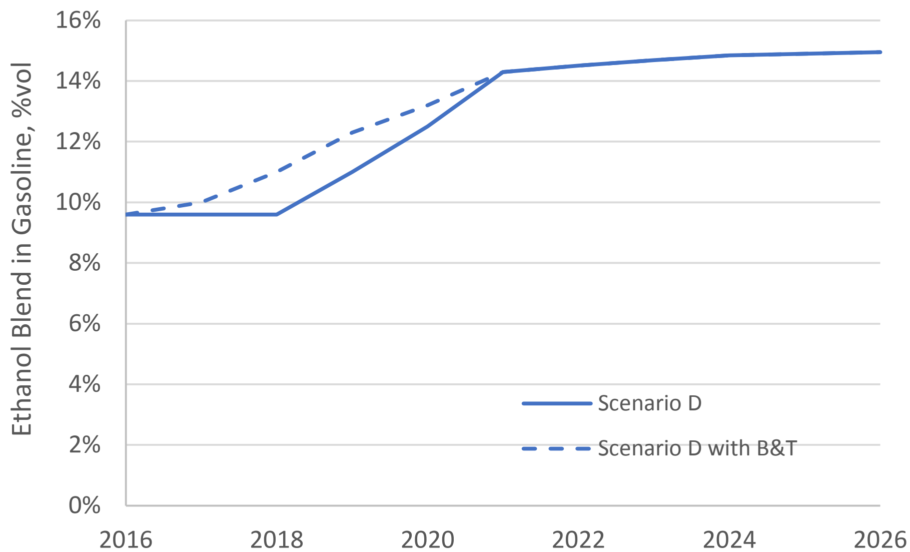


Figure 7-1. Ethanol blend levels in gasoline for Scenario D (all other scenarios E10).

Figure 7-2 provides the assumed biodiesel blend levels for each of the scenarios. For all scenarios, it is assumed that biodiesel blend level increases to 15 percent. All banking and trading scenarios ramp to 15 percent blend earlier than the base scenarios to take advantage of credit trading/banking provisions. Please refer to Appendix B for infrastructure requirements to increase the biodiesel blending levels in Washington state.

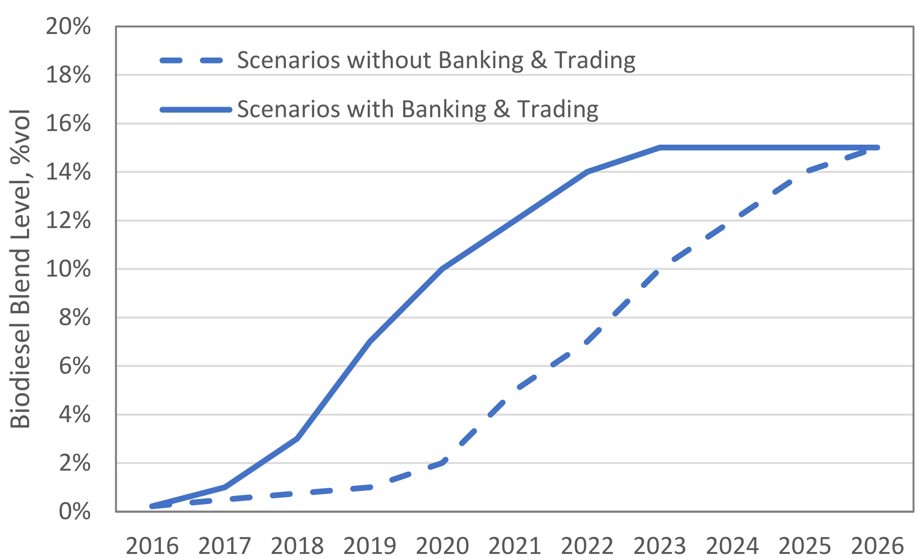


Figure 7-2. Assumed biodiesel blend levels.

For the minimum cellulosic scenarios, the average ethanol CI value is lower, so more ethanol is required to achieve compliance. One way to achieve increased ethanol consumption is through E85 use by the flex fuel vehicle (FFV) fleet. Note that none of the scenarios has increased FFV populations over the BAU case. It was assumed that E85 is a 75 percent blend of ethanol in gasoline as at this level no additional blending components are required[64]. Figure 7-3 provides the shares of FFV E85 use for Scenario C with and without banking and trading and Scenario D. Scenario C requires up to 85 percent of FFV fuel use to be E85. Scenario C with banking and trading required up to 75 percent of FFV fuel use to be E85. Please refer to Appendix B for a discussion of the infrastructure requirements to support E85 use.

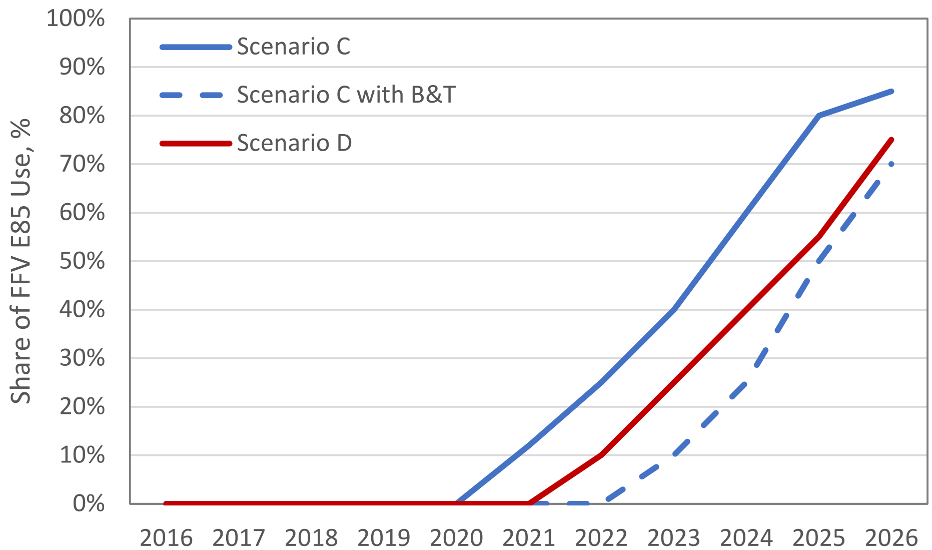


Figure 7-3. Assumed FFV E85 use.

## 7.2 Low CI Fuel Volumes

Figure 7-4 through Figure 7-11 illustrate the volumes of different types of low CI fuels utilized for gasoline pool compliance while Figure 7-12 through Figure 7-19 illustrate the low CI fuels utilized for diesel pool compliance.

[64] *E85 Demonstration Program*, Jim Uihlein, Chevron, May 2011

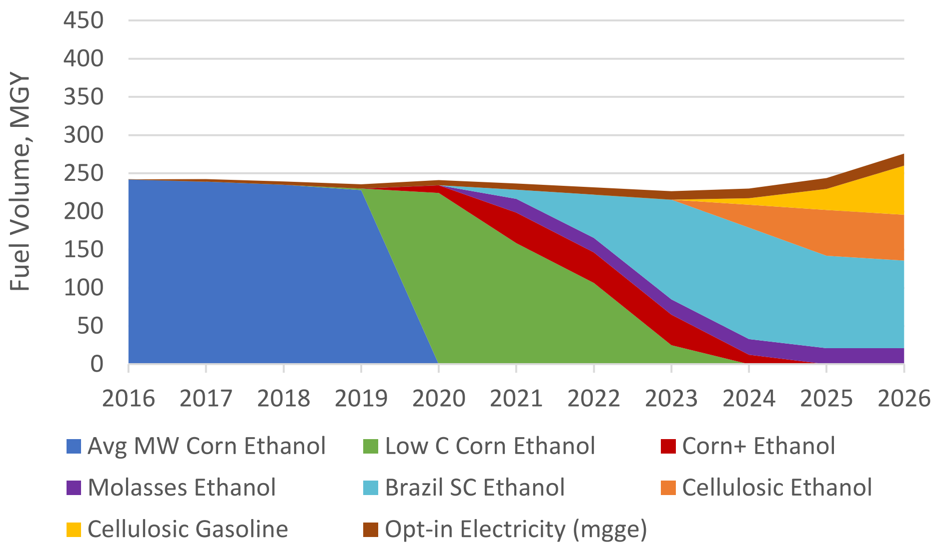


Figure 7-4. Gasoline pool compliance fuels for Scenario A.

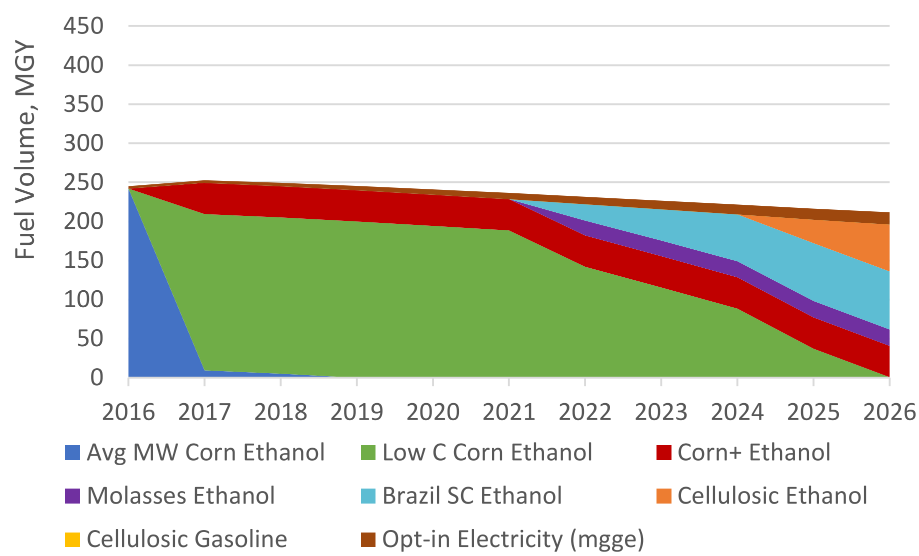


Figure 7-5. Gasoline pool compliance fuels for Scenario A with B&T.

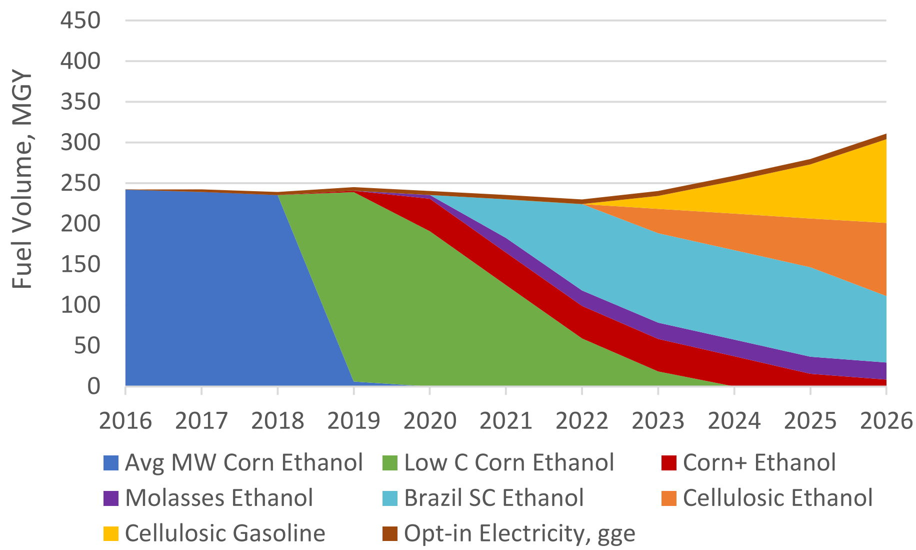


Figure 7-6. Gasoline pool compliance fuels for Scenario B.

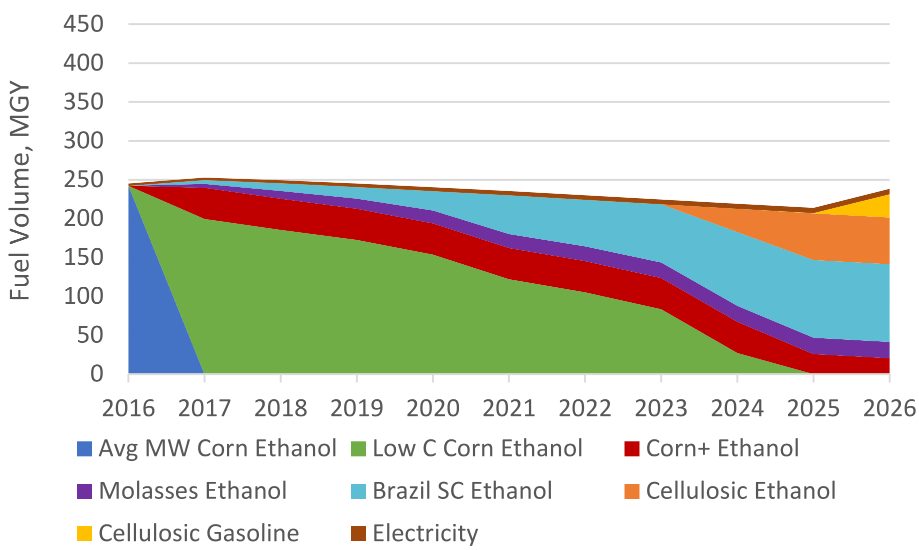


Figure 7-7. Gasoline pool compliance fuels for Scenario B with B&T.

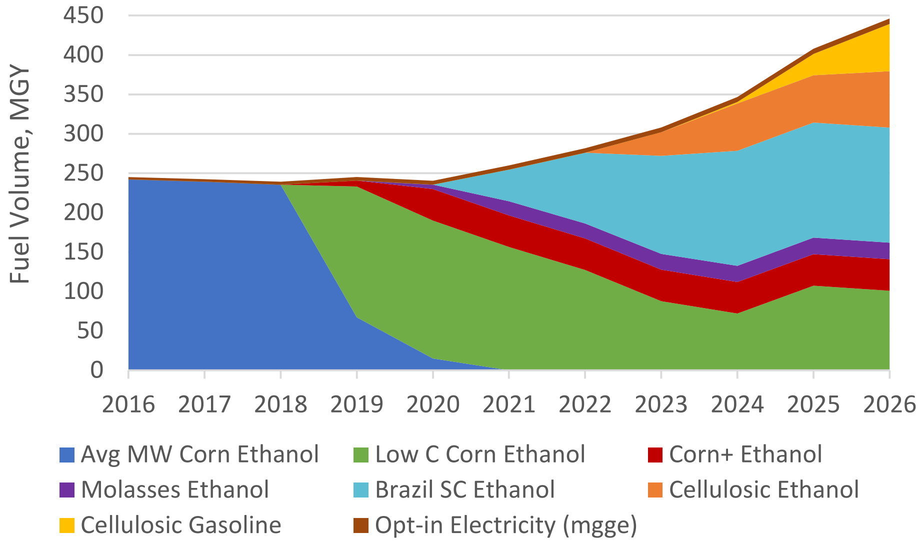


Figure 7-8. Gasoline pool compliance fuels for Scenario C.

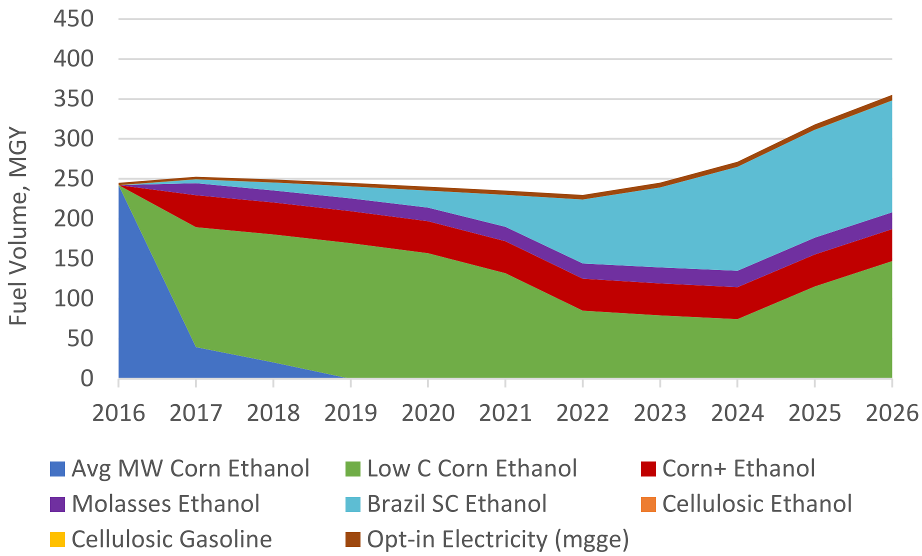


Figure 7-9. Gasoline pool compliance fuels for Scenario C with B&T.

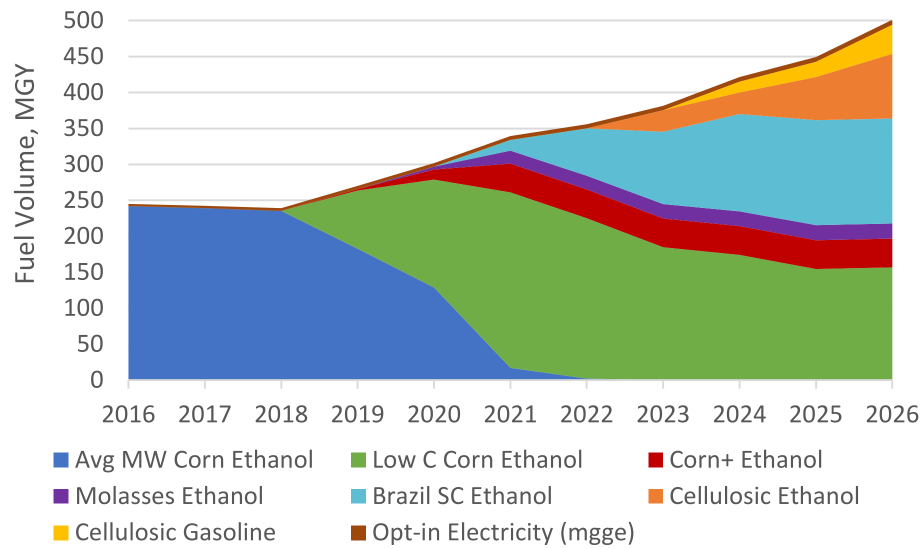


Figure 7-10. Gasoline pool compliance fuels for Scenario D.

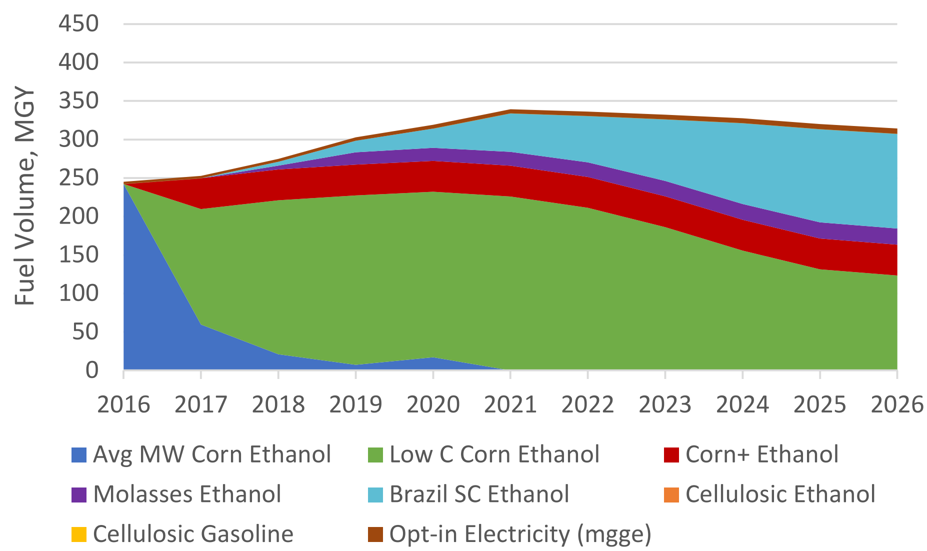


Figure 7-11. Gasoline pool compliance fuels for Scenario D with B&T.

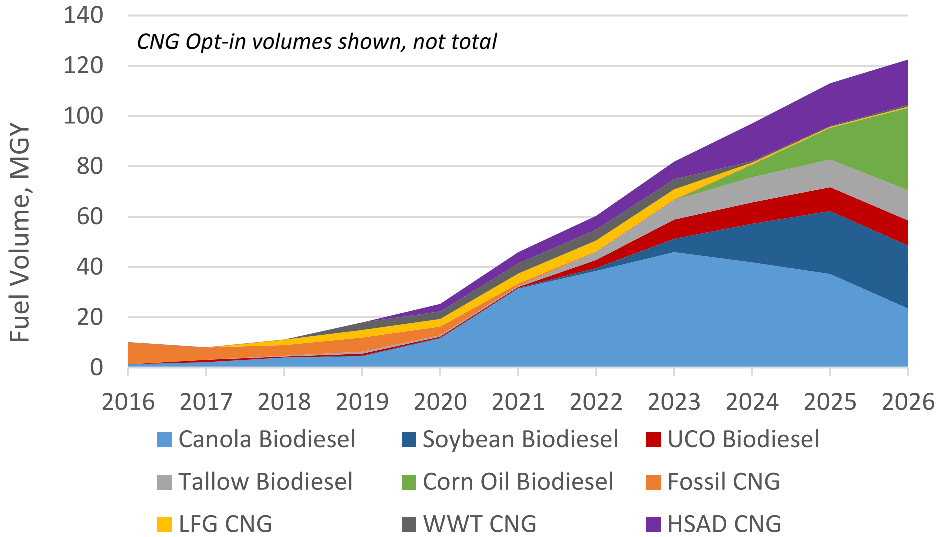


Figure 7-12. Diesel pool compliance fuels for Scenario A.

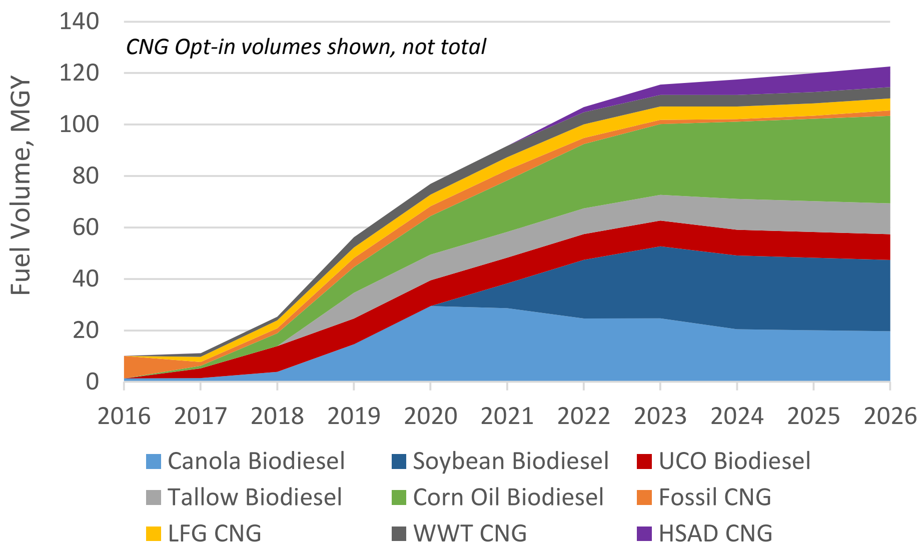


Figure 7-13. Diesel pool compliance fuels for Scenario A with B&T.

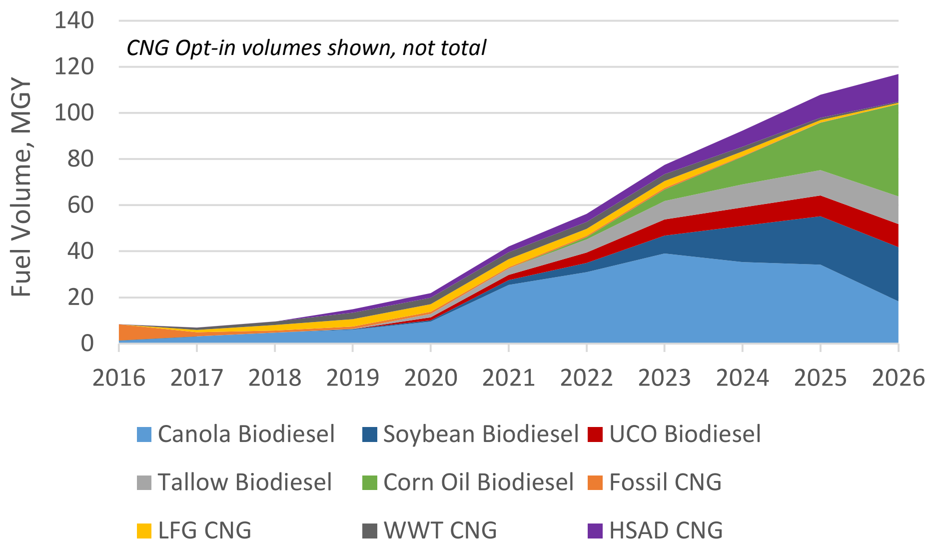


Figure 7-14. Diesel pool compliance fuels for Scenario B.

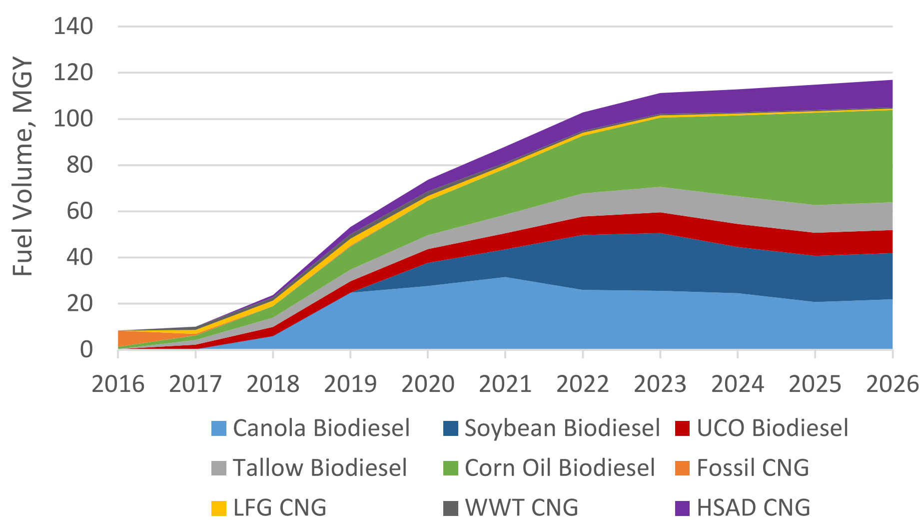


Figure 7-15. Diesel pool compliance fuels for Scenario B with B&T.

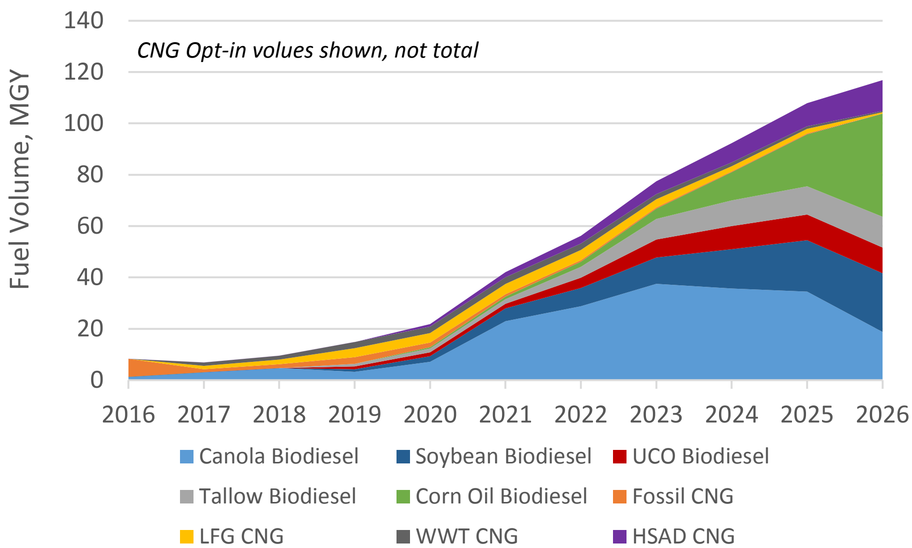

Figure 7-16. Diesel pool compliance fuels for Scenario C.

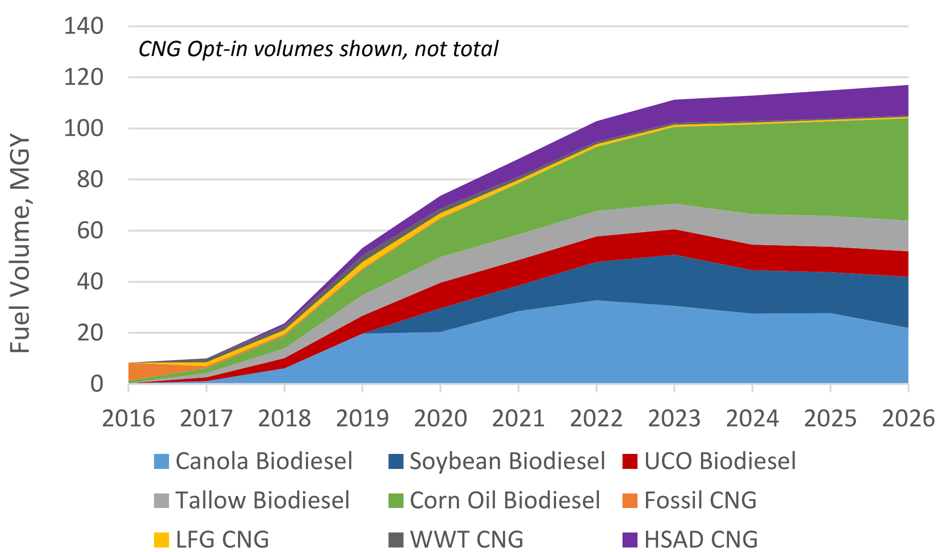

Figure 7-17. Diesel pool compliance fuels for Scenario C with B&T.

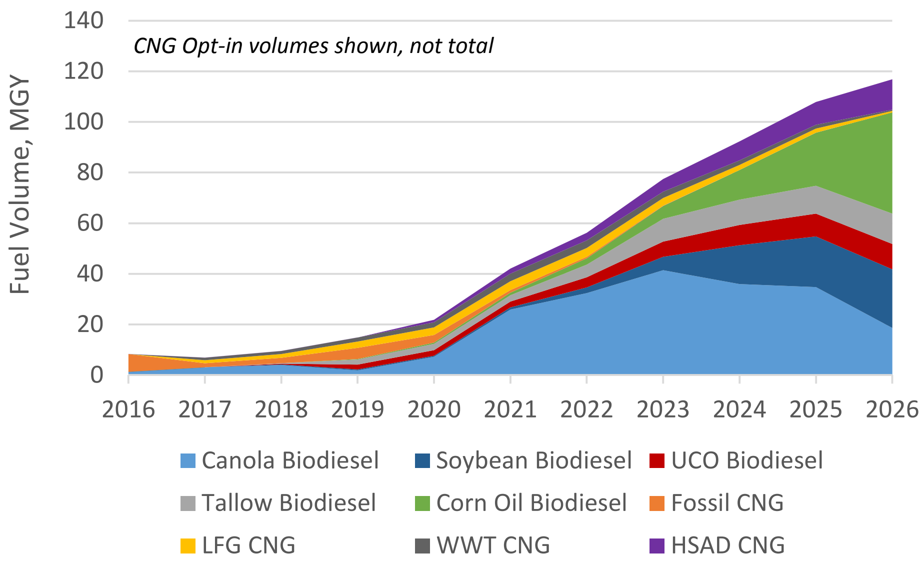

Figure 7-18. Diesel pool compliance fuels for Scenario D.

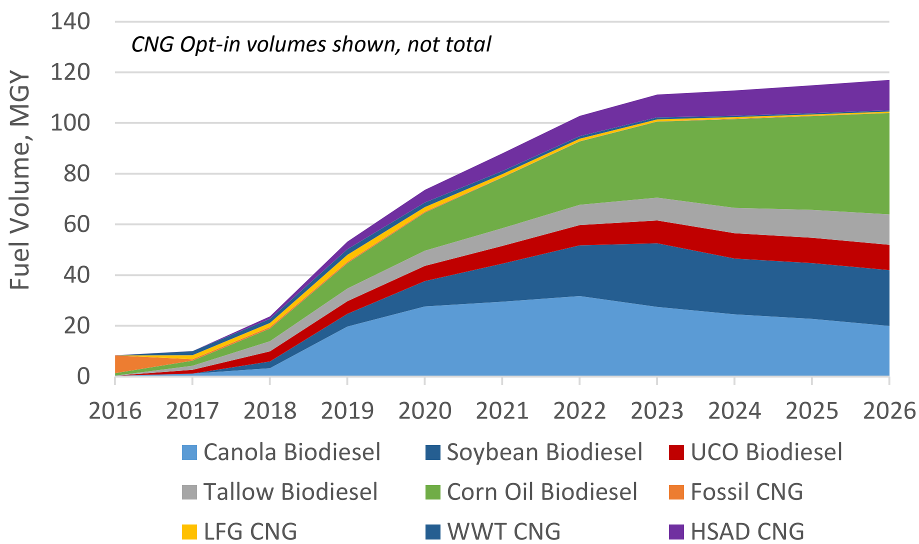

Figure 7-19. Diesel pool compliance fuels for Scenario D with B&T.

Recall from Section 2 that total cellulosic fuel volumes anticipated to be available in Washington state by 2026 ranged from 100 to 400 MGY (gasoline equivalent gallons). The lower end is based on EIA AEO2013/2014 projections and the upper bound was based on recent UC Davis estimates. Figure 7-20 provides the total cellulosic fuel volumes required in the compliance scenarios evaluated. Note that for all scenarios except Scenario B (cellulosic fuels) without banking and trading, total cellulosic fuel consumption ranges from 0 to 104 MGY (gasoline equiv). The two minimum cellulosic scenarios (C and D) with banking & trading did not require any cellulosic fuel to comply with the standard. Even though we have assumed a 25 percent bank balance for 2027 in the banking and trading scenarios, cellulosic fuel volumes (or another type of fuel with CI levels similar to cellulosic fuels) will need to be available to allow for compliance in 2027 and beyond.

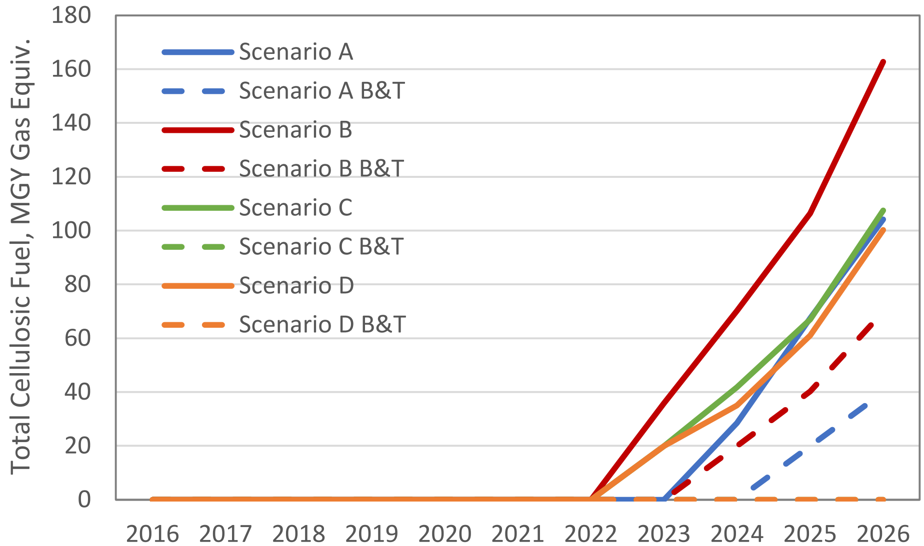

Figure 7-20. Total cellulosic fuel volumes required, MGY (gas equiv).

The macro-economic modeling presented in Sections 8 and 9 of this report makes an assumption that by 2026, zero to three cellulosic biofuel plants each producing up to 30 MGY of fuel are operating in Washington state. Because the location of production is uncertain, a sensitivity case for Scenario B with banking and trading was run with no in-state production of cellulosic fuel to determine the magnitude of this impact. Please refer to Section 9 of this report for the macro-economic results. Figure 7-5 summarizes the in-state and imported cellulosic ethanol and gasoline for each of the scenarios. The number of in-state cellulosic plants is indicated.

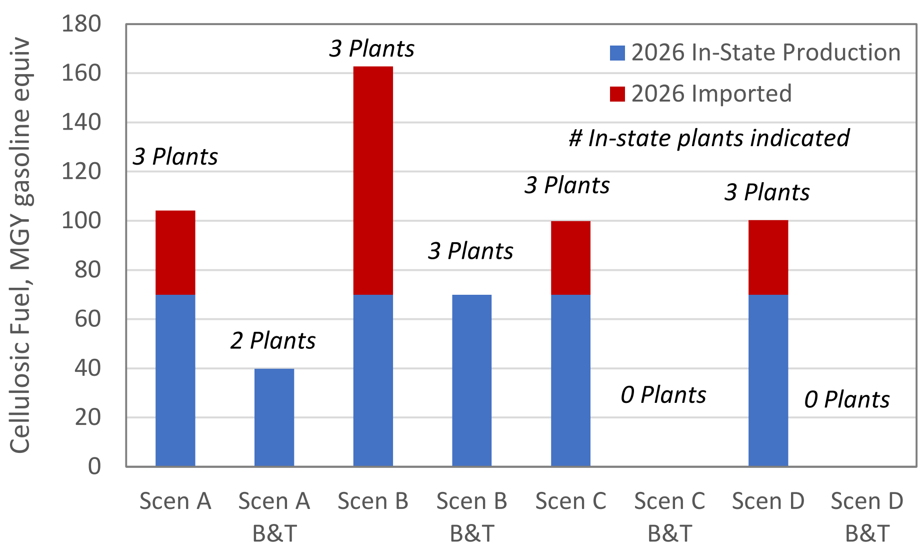

Figure 7-21. Assumed Source of Cellulosic Ethanol and Gasoline in 2026.

Consumption of sugarcane ethanol is provided in Figure 7-22. Washington's share of the EIA projection for RFS2 is estimated at 146 MGY. The maximum amount of sugarcane ethanol utilized in the compliance scenarios ranges from 80 MGY to 146 MGY.

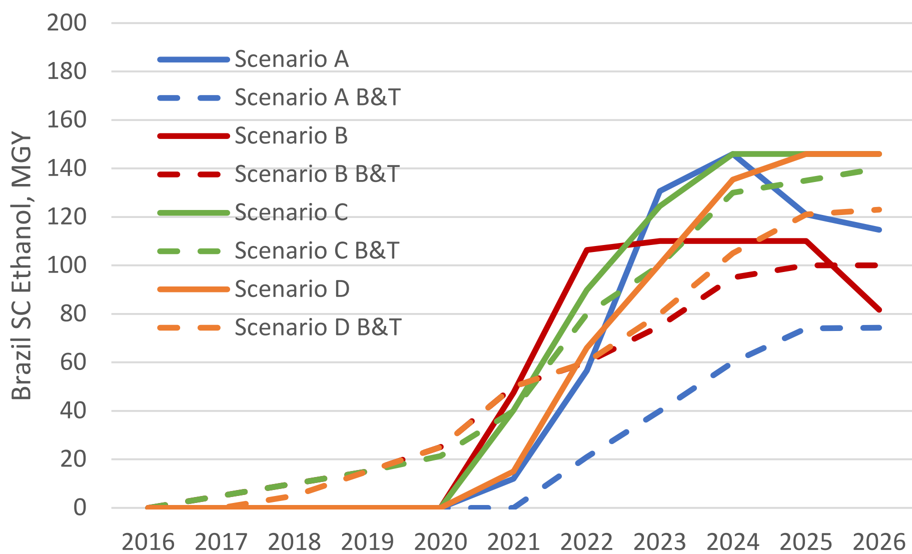


Figure 7-22. Brazil Sugarcane Ethanol Consumption.

Figure 7-23 provides the opt-in electricity volumes. Electricity consumption with the ZEV Mandate vehicle market shares scenarios (Scenario A and A with banking & trading) is more than twice the electricity consumption in the BAU and other compliance scenarios by 2026.

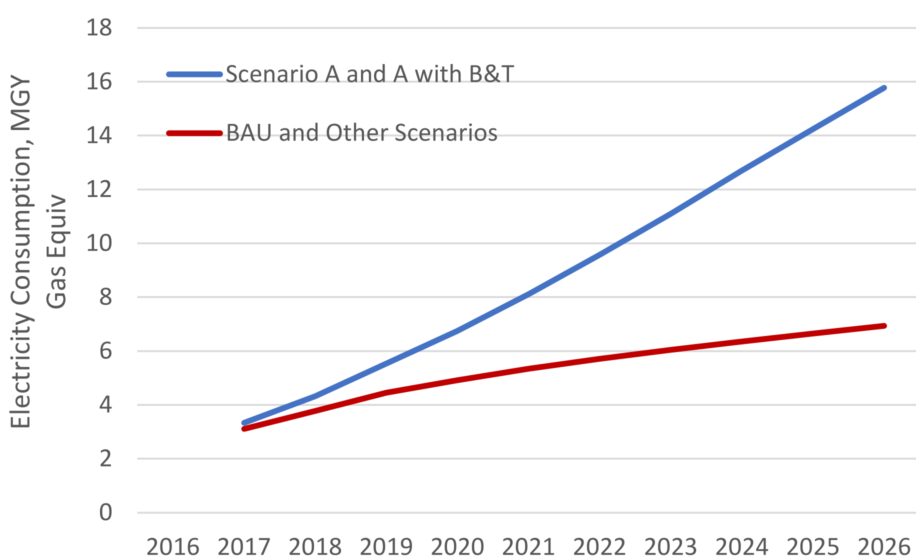


Figure 7-23. Electricity consumption, MGY (gas equiv).

Volumes of used cooking oil and tallow based biodiesel are not shown, but in each scenario, these biodiesel volumes increase to a total of 22 MGY (combined), the upper end of projected in-state feedstock supply. Finally, RNG consumption is provided in Figure 7-24. Up to 13 MGY are utilized by the CNG fleet in the Advanced Vehicles scenarios, with total volumes less than 9 MGY in the other cases. There is currently approximately 12 MGY diesel equivalent of pipeline RNG capacity in-state (please refer to Section 2). The bank and trade versions of the scenarios switch to RNG from CNG earlier than the base scenarios to take advantage of banking provisions.

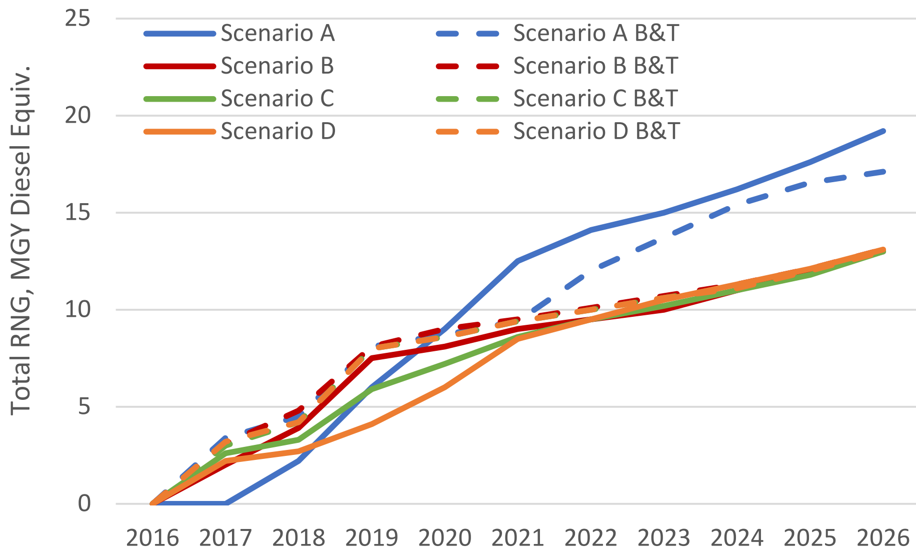


Figure 7-24. Total RNG Consumption, MGY Diesel Equivalent.

## 7.3 CFS Credits

Figure 7-25 through Figure 7-36 summarize the contribution made by each fuel type to 2026 compliance. For the banking and trading version of each scenario a chart indicating annual deficits and credits along with the cumulative credits is provided. Recall that the credit bank at the end of the analysis period (2026) is not drawn down to zero; cumulative credits in 2026 are set to 25 percent of the total credits required in 2026. As mentioned in Section 6.2, while the banking & trading scenarios allow the introduction of very low CI fuels to be delayed, they will be required post 2026. To clarify the labels in the figures, cellulosic gasoline refers to "drop-in" gasoline produced from cellulosic feedstocks. The ethanol category includes all types of ethanol including ethanol produced from cellulose. The biodiesel category includes all biodiesel and the CNG category includes all CNG produced from fossil and renewable natural gas.

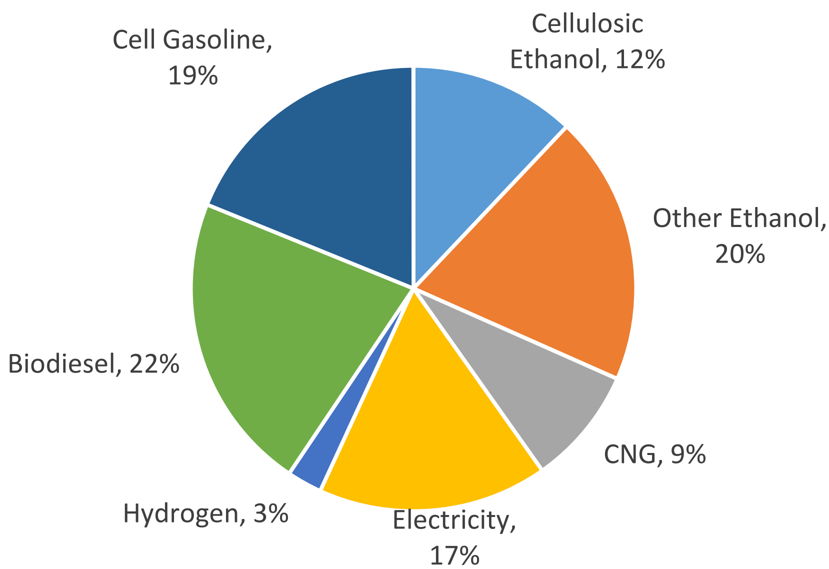

Figure 7-25. Relative contributions to compliance in 2026, Scenario A (Advanced Vehicles).

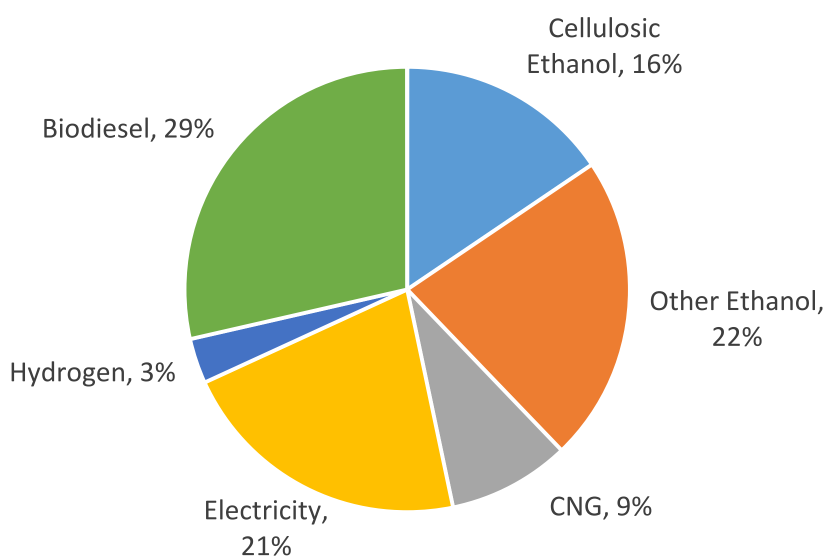

Figure 7-26. Relative contribution to compliance in 2026, Scenario A with B&T.

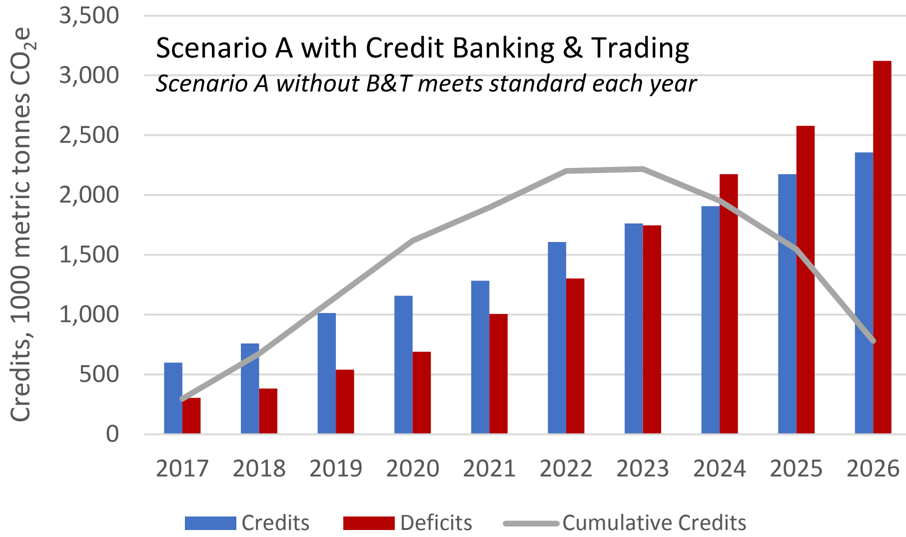


Figure 7-27. Credits, debits, and cumulative credits for Scenario A with B&T.

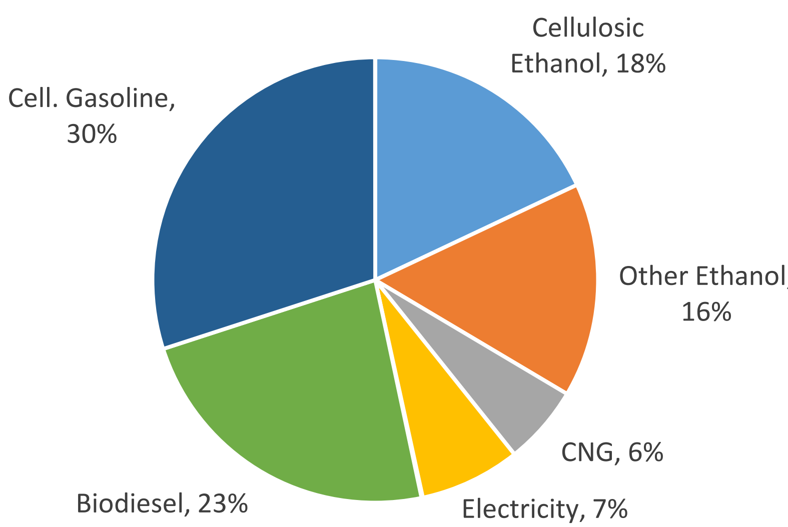


Figure 7-28. Relative contribution to compliance in 2026, Scenario B (abundant cellulosic).

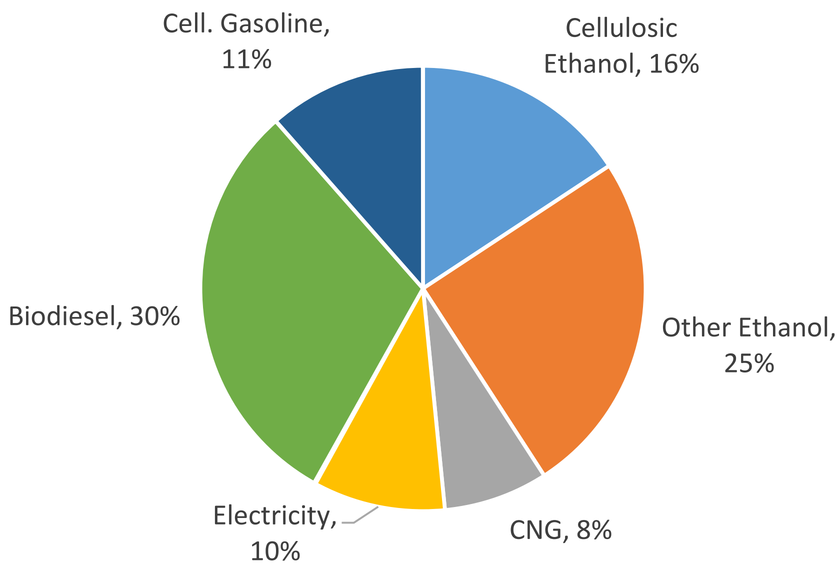

Figure 7-29. Relative contribution to compliance in 2026, Scenario B with B&T.

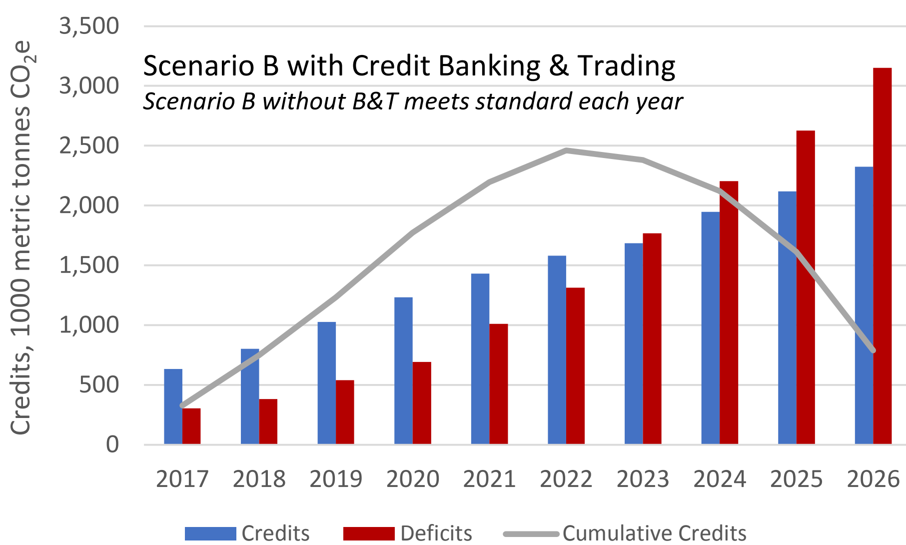

Figure 7-30. Credits, debits, and cumulative credits for Scenario B with B&T.

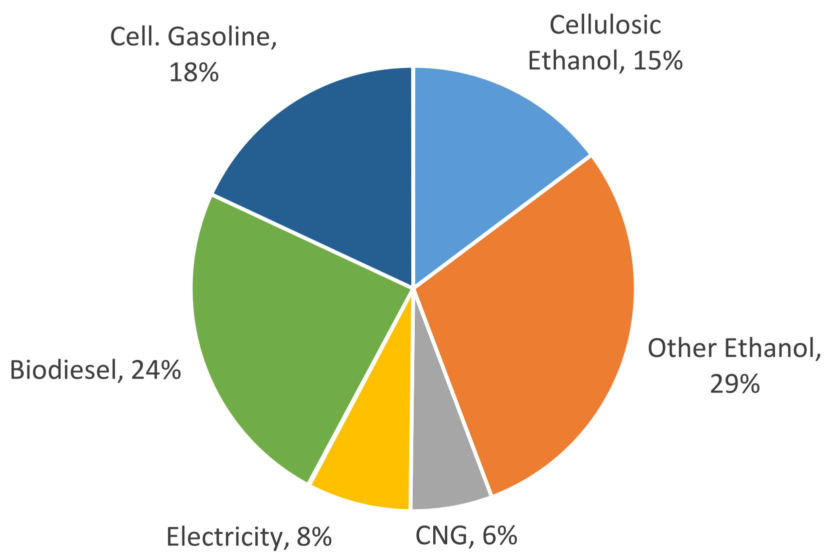

Figure 7-31. Relative contribution to compliance in 2026, Scenario C (minimum cellulosic)

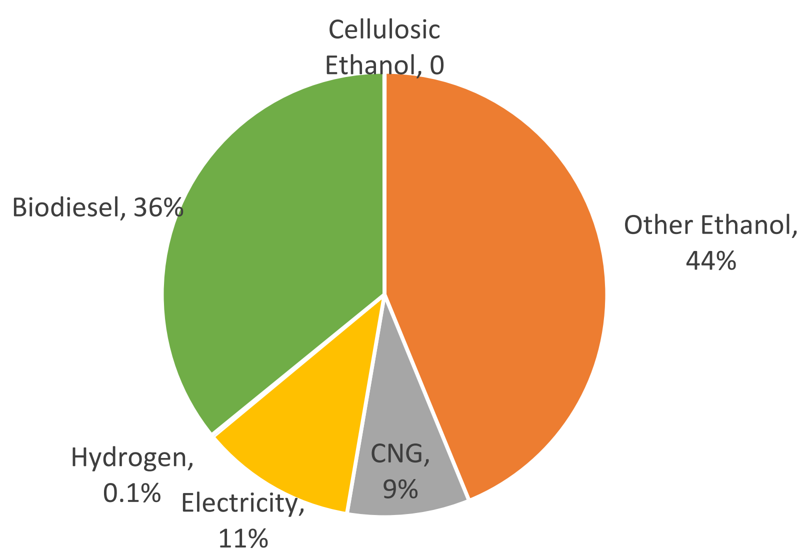

Figure 7-32. Relative contribution to compliance in 2026, Scenario C with B&T

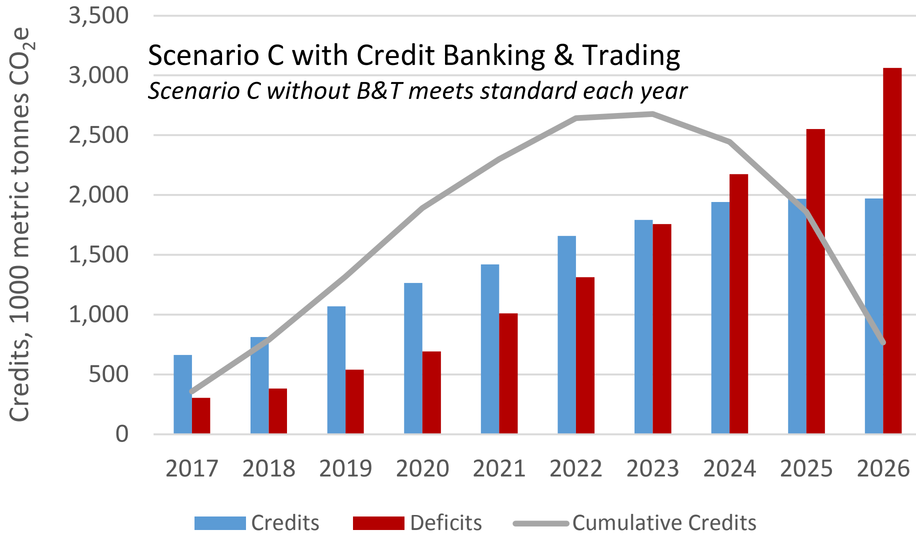


Figure 7-33. Credits, debits, and cumulative credits for Scenario C with banking & trading

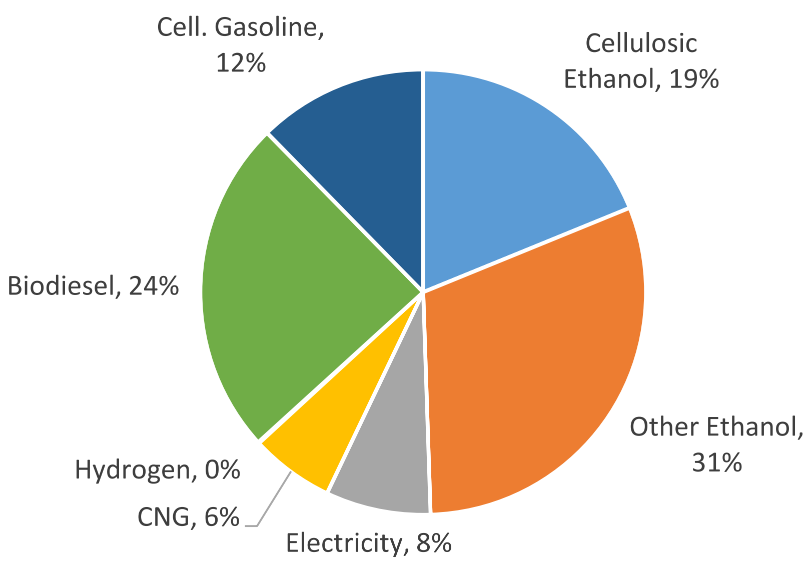


Figure 7-34. Relative contribution to compliance in 2026, Scenario D (low cellulosic E15)

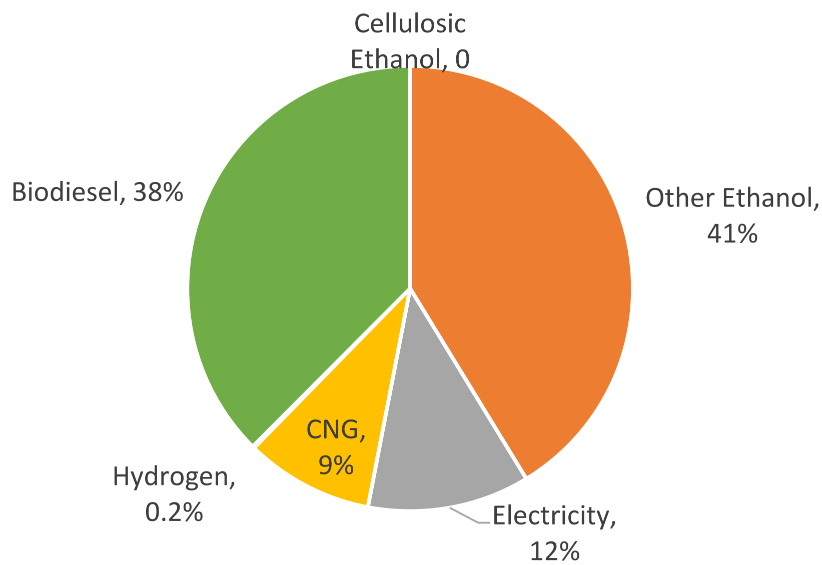

Figure 7-35. Relative contribution to compliance in 2026, Scenario D with B&T

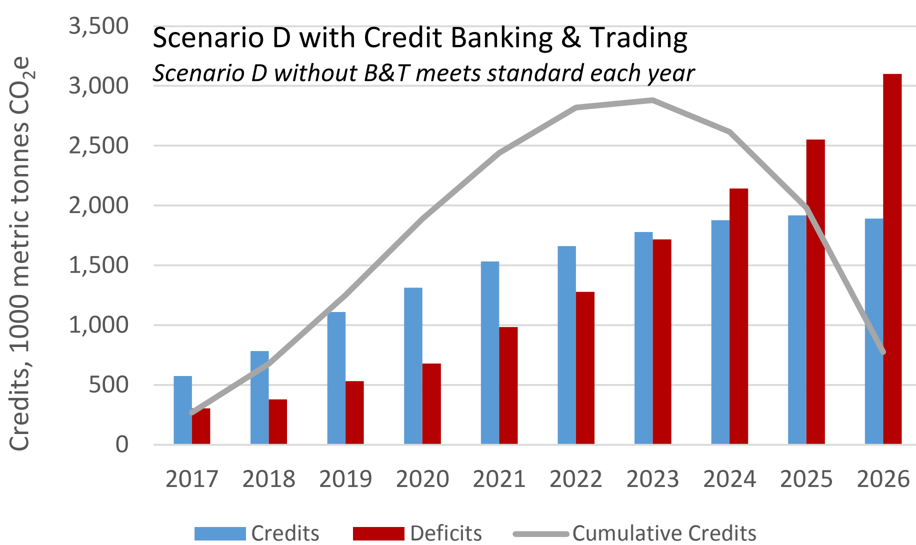

Figure 7-36. Credits, debits, and cumulative credits for Scenario D with banking & trading

## 7.4 Petroleum Consumption

Higher fuel economy standards result in reduced gasoline consumption through the analysis period. Figure 7-37 shows the projected gasoline blendstock consumption while Figure 7-38 provides the percent reduction relative to year 2016. Without a CFS, gasoline consumption is projected to decrease by 20 percent from 2016 levels by 2026. With a CFS, a 20 to 30 percent decrease from 2016 levels is projected for the scenarios analyzed. The largest decreases are for the minimum cellulosic scenarios; the advanced vehicles and high cellulosic scenarios result in similar consumption levels.

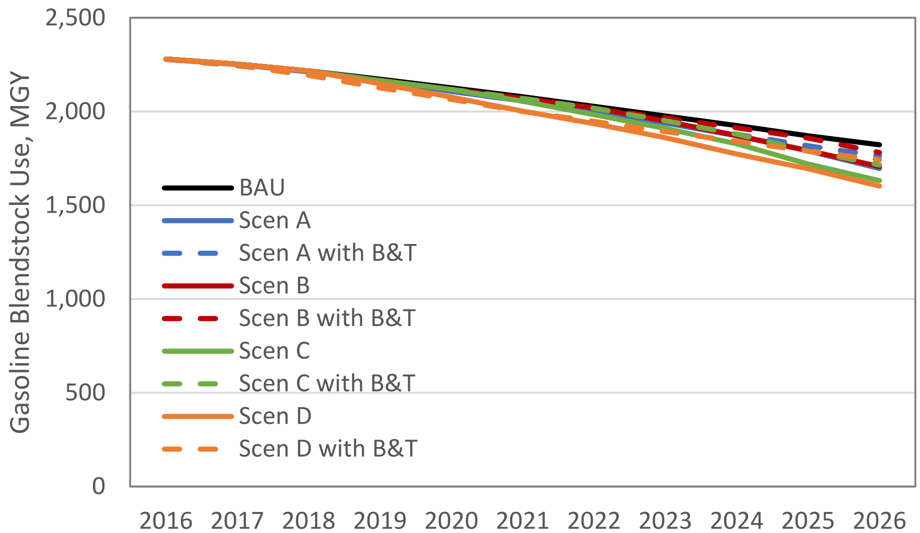


Figure 7-37. Projected Gasoline Blendstock Consumption.

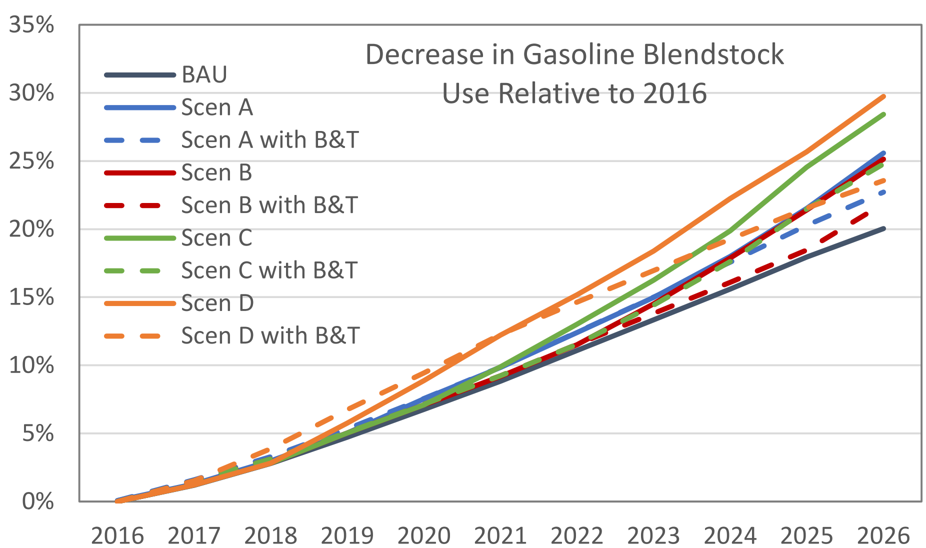


Figure 7-38. Percent Reduction in Gasoline Blendstock Use Relative to 2016.

Figure 7-39 provides the projected diesel consumption for the BAU and compliance scenarios. By 2026, diesel consumption is expected to increase by 12 percent over the analysis period for the BAU case, and decrease by 4 percent for the compliance scenarios from 2016 levels.

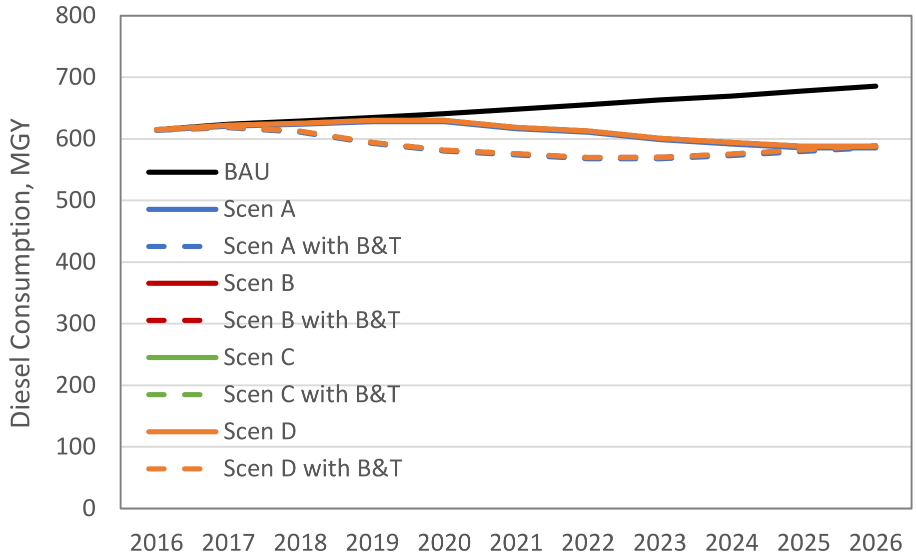


Figure 7-39. Projected on-road diesel consumption.

## 7.5 GHG Emissions

Figure 7-40 provides the GHG emission reductions relative to the BAU. Note that these emission reductions include both WTW and ILUC emissions. Table 7-2 provides the cumulative GHG reductions for each scenario relative to the BAU. GHG emissions are calculated by multiplying the carbon intensity (g/MJ) by the total fuel consumption (MJ). All scenarios without banking and trading have the same cumulative emission reduction relative to the BAU except for the advanced vehicle cases (Scenario A). This is because total fuel consumption in the advanced vehicle scenarios is lower than the other scenarios, resulting in lower total emissions. The scenarios with banking and trading have more cumulative emission reductions than the scenarios without banking & trading due to the requirement to have a 25 percent bank balance at the end of 2026.

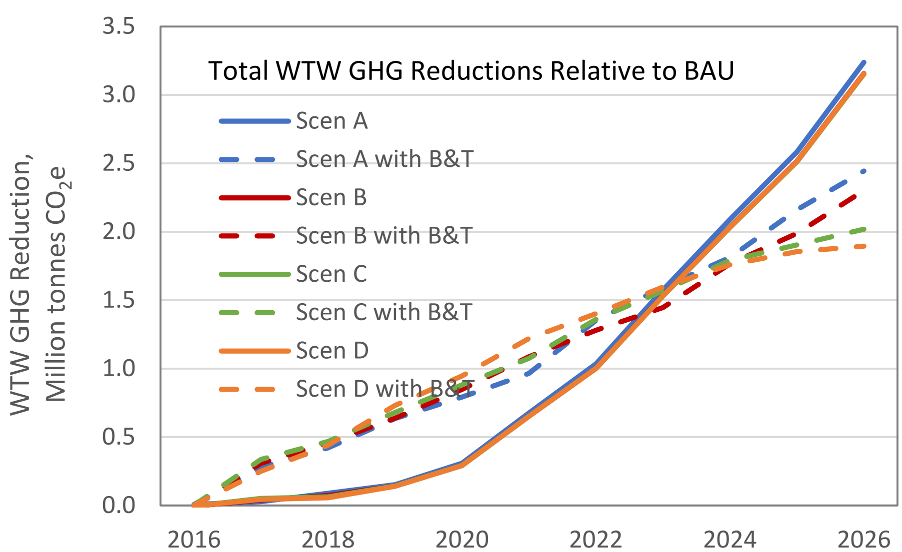


Figure 7-40. WTW GHG Emission Reductions Relative to BAU

Table 7-2. Cumulative WTW GHG Reductions Relative to BAU (Million tonnes)

| Scen A | Scen A with B&T | Scen B | Scen B with B&T | Scen C | Scen C with B&T | Scen D | Scen D with B&T |
|---|---|---|---|---|---|---|---|
| 11.8 | 12.5 | 11.4 | 12.1 | 11.4 | 12.1 | 11.4 | 12.1 |

## 7.6 Criteria Pollutant Emissions

Changing vehicles and fuel types in Washington state will impact criteria pollutant emissions. While new fuel production plants and increased truck transportation of fuels to terminals will impact criteria pollutant emissions, quantifying this WTW impact did not fit into the budget or time schedule for the present analysis. The change in vehicle (TTW) emissions have been quantified. To estimate the impact of the compliance scenarios on TTW criteria pollutant emissions, emission factors from EPA's MOVES model[65] for Washington state were utilized. The MOVES model provides emission factors for gasoline, diesel and E85 for LDA and LDT categories. Factors for gasoline and diesel were provided for medium duty vehicles; for heavy duty vehicles, factors were provided for gasoline, diesel and CNG. The following assumptions were made:

- Vehicles consuming E15 utilize the same emission factors as motor gasoline
- Light vehicles consuming CNG utilize the same emission factors as motor gasoline
- Vehicles consuming biodiesel blends utilize the same emission factors as diesel vehicles
- Medium duty CNG vehicles utilize the same emission factors as diesel

These simplifying assumptions may underestimate emissions of reactive and total organic gases from CNG vehicles.

Only the two versions of Scenario A (advanced vehicles) and the scenarios with E85 consumption (both versions of Scenario C and Scenario D) have projected vehicle emission reductions relative to the BAU; the other scenarios have the same projected emissions as the BAU. Figure 7-41 through Figure 7-44 provide the percent reduction relative to the BAU projection for these scenarios.

[65] Provided by Sally Otterson, Washington State Department of Ecology.

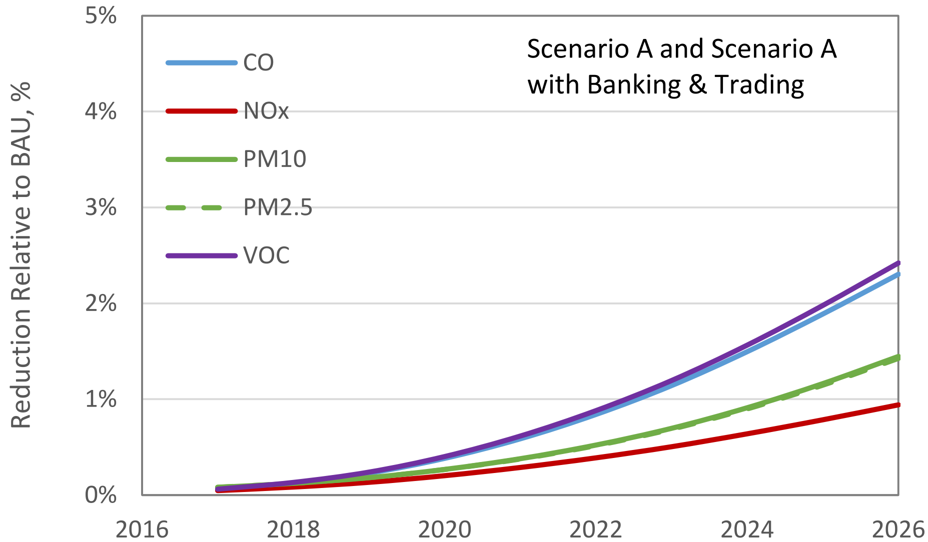


Figure 7-41. Emission reductions relative to BAU for both versions of Scenario A.

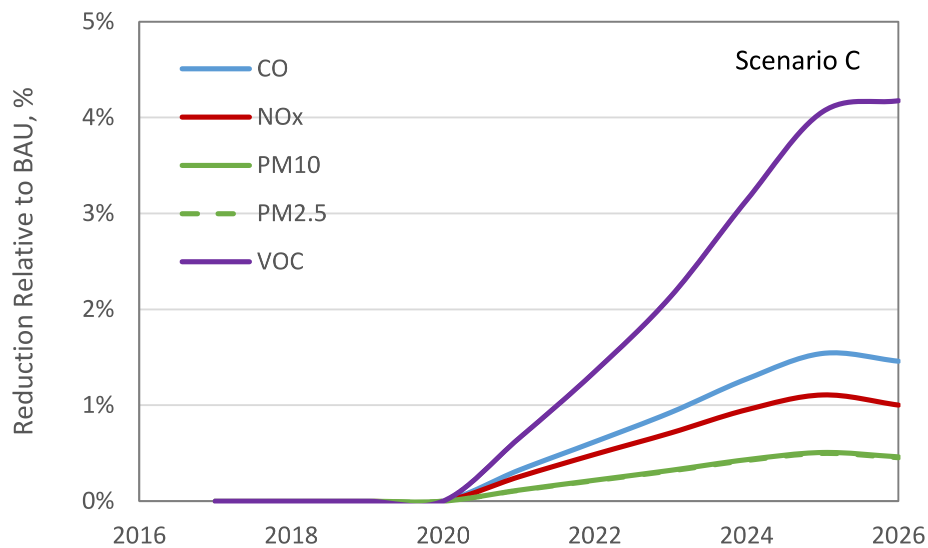


Figure 7-42. Emission reductions relative to BAU for Scenario C

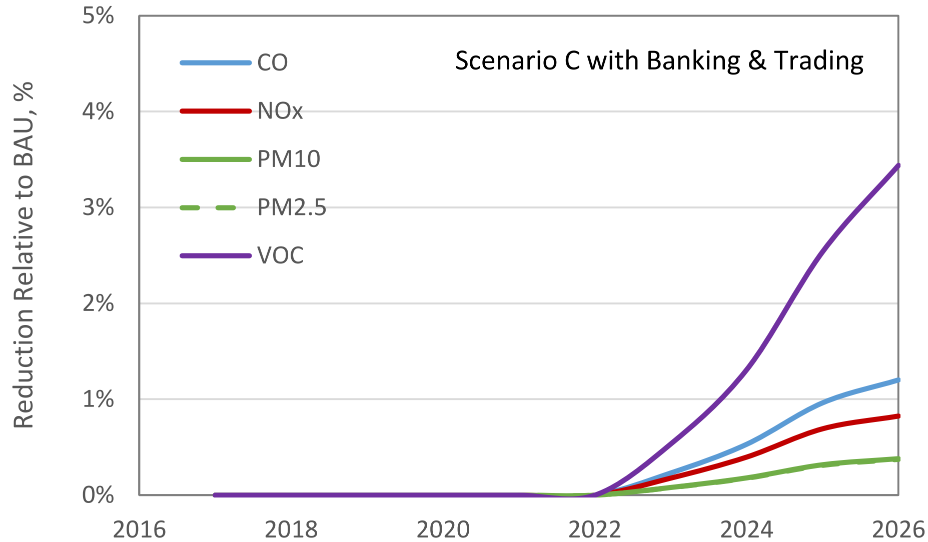

Figure 7-43. Emission reductions relative to BAU for Scenario C with Banking & Trading.

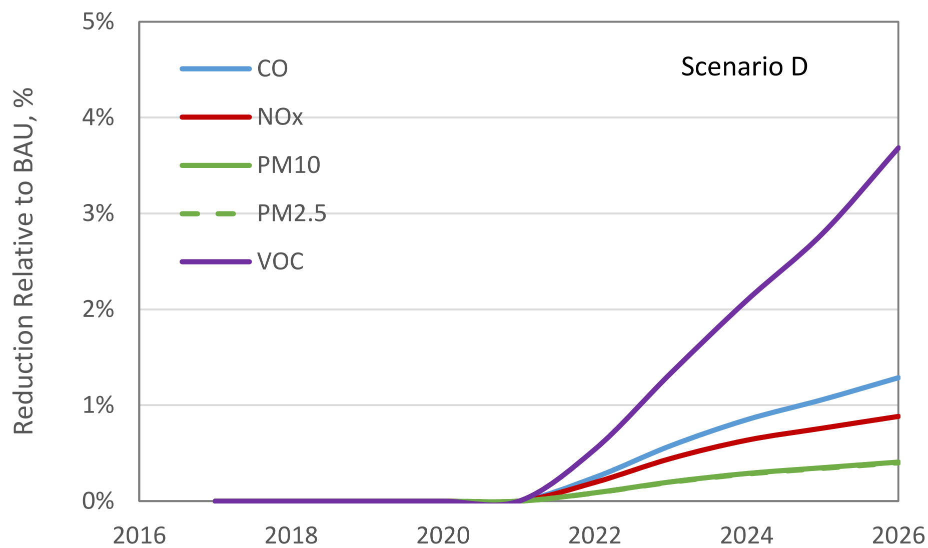

Figure 7-44. Emission reductions relative to BAU for Scenario D.

## 7.7 Vehicle Expenditures

Appendix A provides the vehicle market share assumptions for the BAU and compliance scenarios; all compliance scenarios have the same vehicle populations as the BAU except for Scenario A and Scenario A with banking and trading. In Scenario A, the market share of advanced vehicles is assumed to be the same as California's ZEV "Likely Compliance Scenario"; please refer to Section 6.2 for the market share estimates of EVs, PHEVs, and hydrogen FCVs. It is worth noting that a CFS does not directly influence the types of vehicles sold, and the CFS is not presumed to be the primary driver for an advanced vehicle future. Therefore, the increased consumer spending on vehicles in Scenario A is not principally attributable to the CFS, but rather to an alternate BAU case or to some other program (ZEV Mandate or incentives) implemented by Washington state.

Appendix A provides projected incremental vehicle prices for each vehicle technology relative to the base vehicle price. For light duty vehicles, the increments are relative to gasoline internal combustion engines (ICEs). For medium and heavy duty vehicles, the increment is relative to diesel vehicles. Each year, vehicle sales are multiplied by the incremental price above the base vehicle price to determine incremental consumer spending on vehicles. Vehicle expenditures for all scenarios except the two advanced vehicle scenarios are the same as the BAU expenditures. Figure 7-45 provides incremental consumer spending relative to the BAU on vehicles for both Scenario A cases. Up to $250 million ($2012) is spent on vehicles by 2026 with most spent on PHEVs. Table 7-3 compares cumulative spending on vehicles for the BAU and Scenarios B, C, and D to Scenario A.

Table 7-3. Cumulative spending on vehicles

| Cumulative Spending, 2017 - 2026 | $Million (2012) | | |
|---|---|---|---|
| | Scen A | BAU & Scen B, C, D | Scen A Incremental |
| Light Duty Auto | 1,601 | 646 | 955 |
| Light Duty Truck | 1,736 | 940 | 796 |
| Medium Duty Vehicles | 91 | 60 | 30 |
| Heavy Duty Vehicles | 94 | 62 | 31 |
| Total | 3,521 | 1,709 | 1,813 |

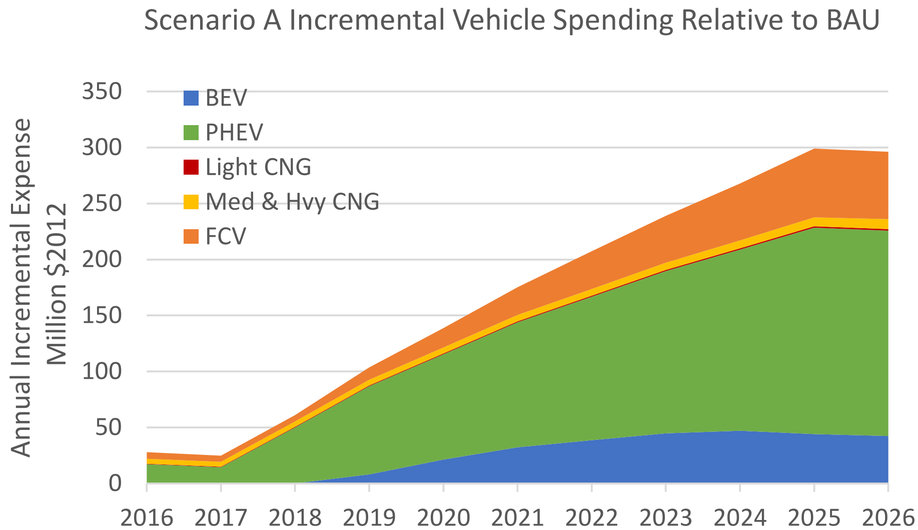


Figure 7-45. Incremental consumer spending on vehicles relative to BAU for Scenario A

## 7.8 Fuel Expenditures

The fuel consumption for each scenario above was combined with the assumed fuel price projections provided in Appendix A to arrive at annual consumer fuel expenditures. Spending increases relative to BAU spending is provided in Figure 7-46. Scenario A has the lowest fuel expenditures because of the increased electricity and CNG use. Scenario D (E15) has the highest costs because ethanol sold as a gasoline blend component is more expensive than ethanol sold as E85. The cases with banking and trading have higher costs earlier in the program and lower costs later because more credits are generated earlier in the program and added to gasoline and diesel prices. Scenario B (cellulosic) and Scenario C (low cellulosic) have similar costs; the diesel pool costs are approximately the same and Scenario C's higher ethanol costs are offset by Scenario B's higher cellulosic gasoline costs.

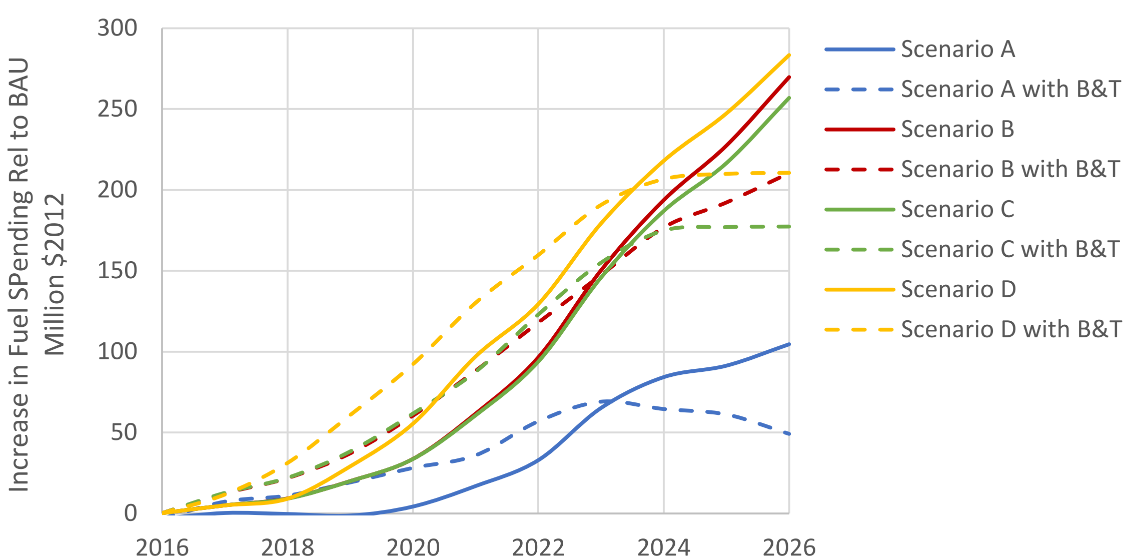


Figure 7-46. Increases in consumer spending on fuel relative to BAU.

Note that gasoline and diesel prices include the costs associated with the assumed CFS credit price profile. Figure 7-47 and Figure 7-48 illustrate the effect of the assumed CFS credit price profile on gasoline blendstock and diesel prices, respectively. For our assumed CFS credit price profile (Figure 6-5), gasoline blendstock prices increase by 9 to 13 cents per gallon in 2026 while diesel prices increase by 10 to 14 cents per gallon. The credit banking and trading scenarios have higher price increases in the middle years of the standard and lower prices at the end of the analysis period because more credits are generated earlier in the standard and fewer are generated at the end of the analysis period. Because each of the scenarios without banking and trading have the same overall CI each year (they meet the standard each year), the resulting fuel price is the same. The banking and trading scenarios all have slightly different CI values each year, so do not have the same fuel price increase profile.

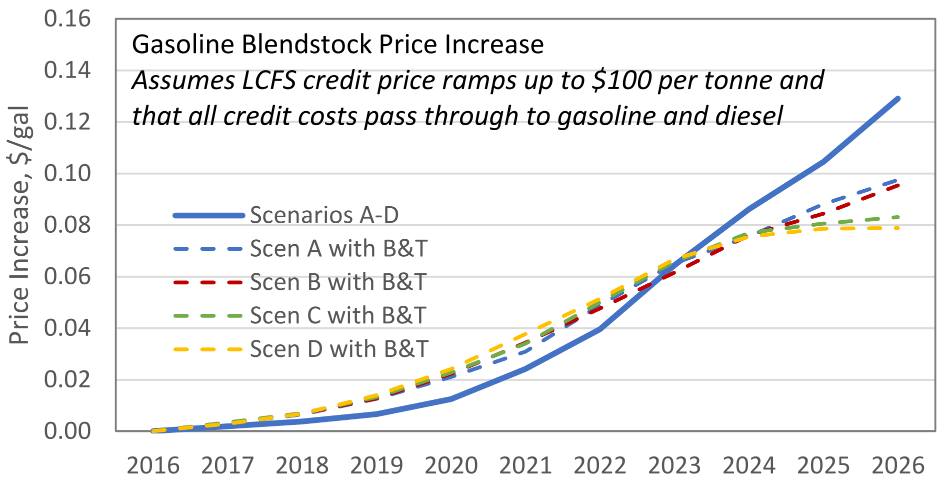


Figure 7-47. Increase in gasoline price resulting from assumed CFS credit price.

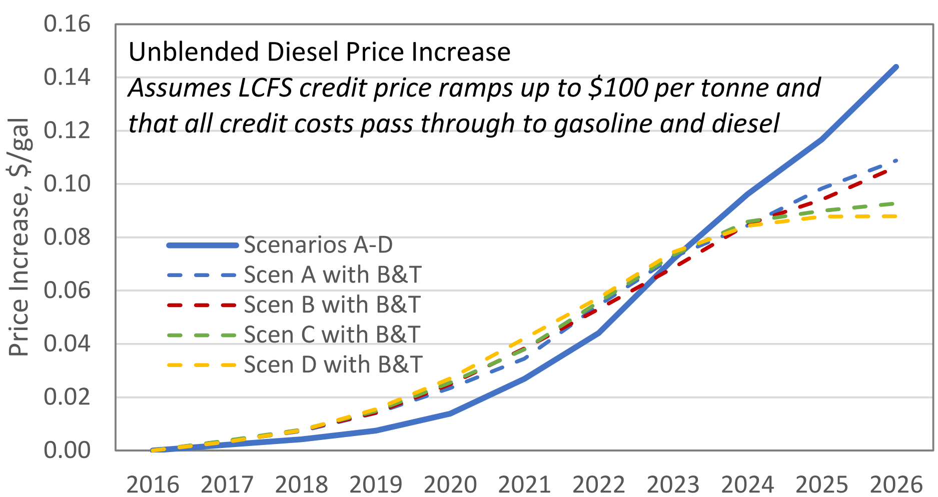


Figure 7-48. Increases in diesel price resulting from assumed CFS credit price.

To evaluate the impact of higher credit prices on macro-economics, sensitivity runs with credit prices capped at $50, $150, and $250 per tonne CO2e were performed for Scenario C (minimum cellulosic, E85) with Banking and Trading. The credit cost profiles for these cases are shown in Figure 6-6. The analysis assumes that all of the costs incurred by the regulated parties in the form of CFS credit prices are passed on to the consumer in the form of increased gasoline and diesel prices. Figure 7-49 and Figure 7-50 provide the corresponding impact of the assumed credit prices on gasoline blendstock and diesel prices, respectively. Again, the analysis is conservative in that all of the cost associated with credit purchases is passed on to gasoline and diesel consumers while potential reductions in low CI fuel prices were not included.

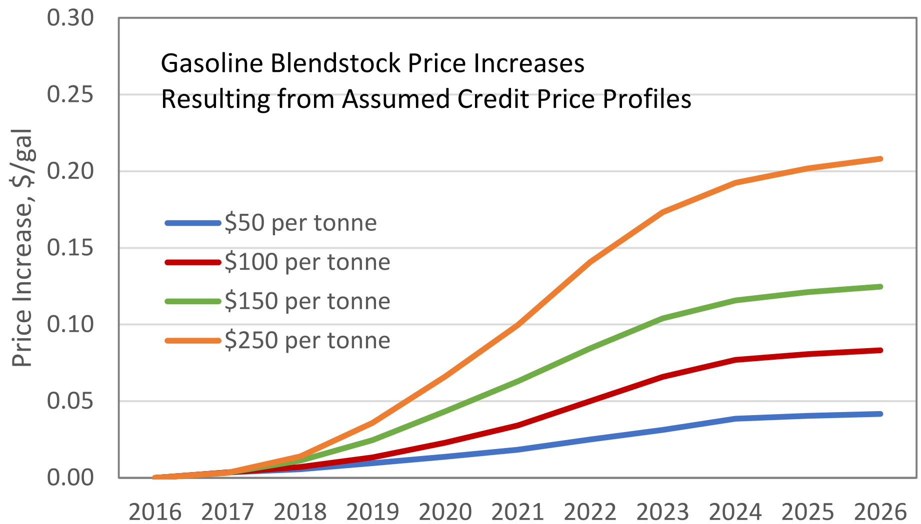


Figure 7-49. Impact of credit price on gasoline blendstock prices for Scenario C with B&T.

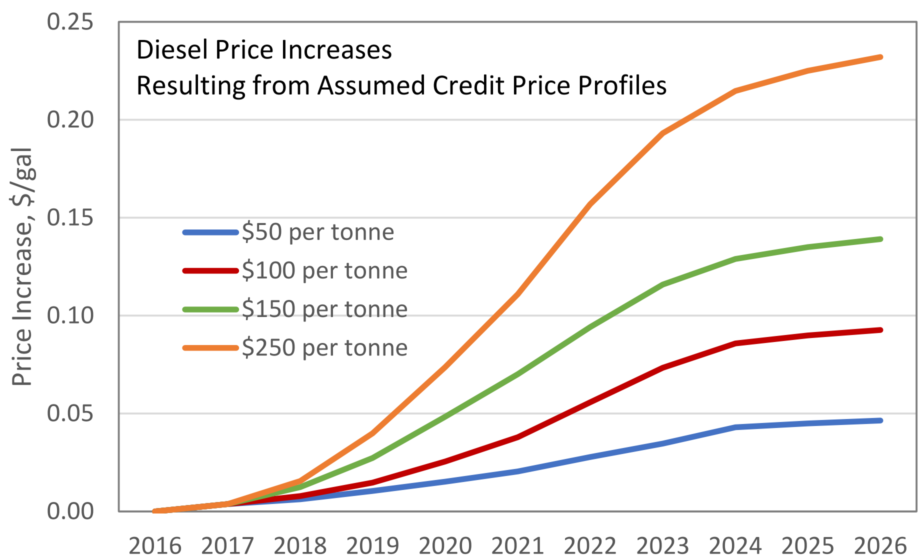


Figure 7-50. Impact of credit price on unblended diesel prices for Scenario C with B&T.

## 7.9 Fuel Use Forecast Sensitivity Case

As mentioned in the Introduction and Appendix A, projections of fuel consumption through 2026 are a VISION model output based on vehicle sales, VMT, and fuel economy projections. As detailed in Appendix A, this analysis uses AEO2014 projected vehicle sales, VMT forecasts, and fuel economy projections, resulting in declining gasoline consumption and increasing diesel consumption. The AEO2014 projections result in a diesel fuel consumption forecast similar to the November 2014 Washington State Transportation Revenue Forecast Council (TRFC) projection. However, the gasoline consumption forecast declines over time due to improving light duty fuel economy in contrast to the TRFC forecast that remains relatively constant. The TRFC forecast model primarily relies on economic indicators and is only weakly dependent on fuel economy. To evaluate the impact of the fuel consumption forecast assumption, a sensitivity case was performed. The following paragraphs step through the results of modeling a BAU case and Scenario C with Banking and Trading using the TRFC gasoline forecast.

Figure 7-51 illustrates gasoline blendstock consumption projections for the two different cases. The base case assumes a 20 percent reduction in gasoline consumption over the analysis period in contrast to a 2 percent reduction forecast by the TRFC. In the base case, Scenario C with banking and trading did not require any cellulosic ethanol or gasoline to achieve compliance with the standard. However, with the TRFC gasoline use projection, larger volumes of gasoline require larger volumes of compliance fuels. Because we have constrained the supply of sugarcane and molasses ethanol, cellulosic ethanol is required for compliance. Figure 7-52 illustrates the gasoline pool compliance fuel volumes required. Referring back to Figure 7-9 shows that the TRFC fuel use case requires 75 MGY of cellulosic ethanol compared to the base case that required no cellulosic fuel.

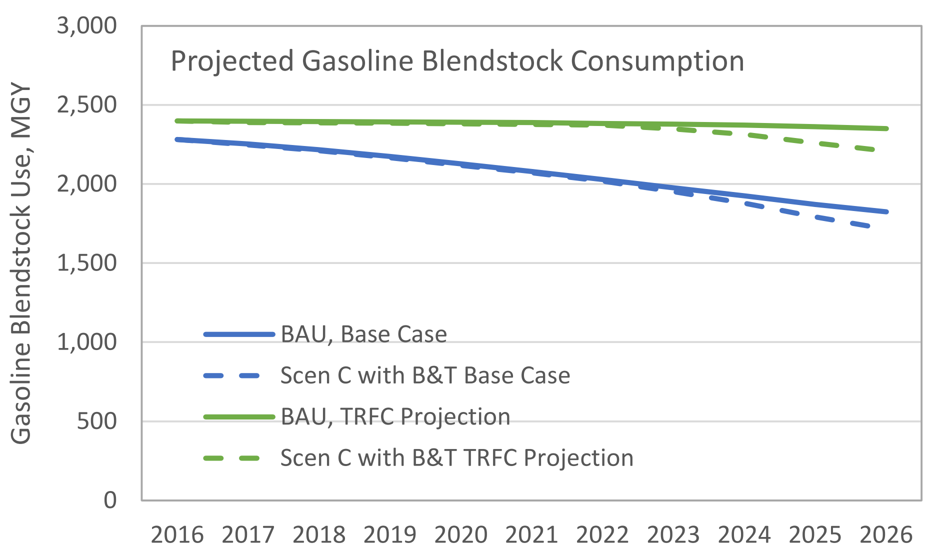


Figure 7-51. Projected gasoline blendstock use for the base case and TRFC projection.

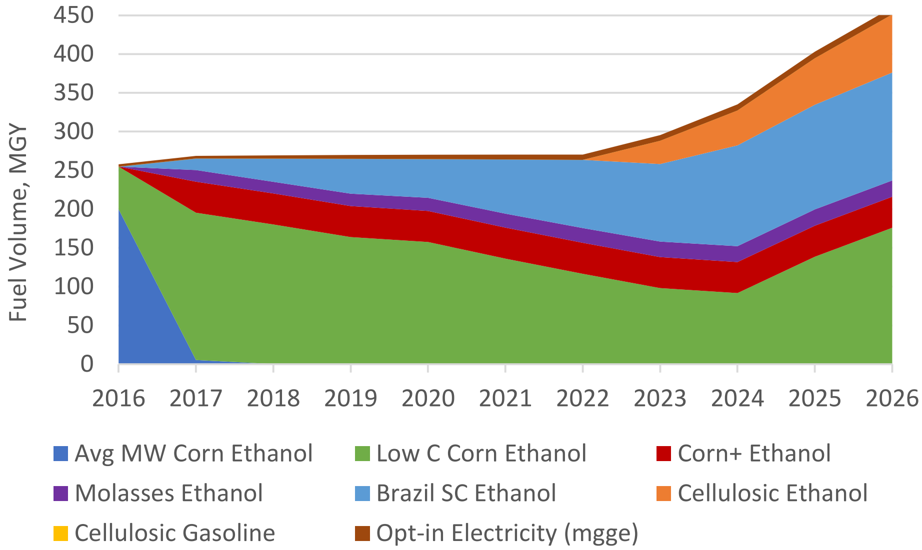


Figure 7-52. Gasoline pool low CI fuel volumes utilizing the TRFC gasoline projection.

Higher fuel consumption results in more GHG emissions, so a 10 percent reduction achieves more tonnes of GHG savings with the TRFC projection case than for the base case. Figure 7-53 provides the estimated GHG (WTW + ILUC) reductions for the TRFC projection and the base case. Cumulative reductions for the base case are 12.1 million tonnes; 14.2 million tonnes are reduced in the TRFC case.

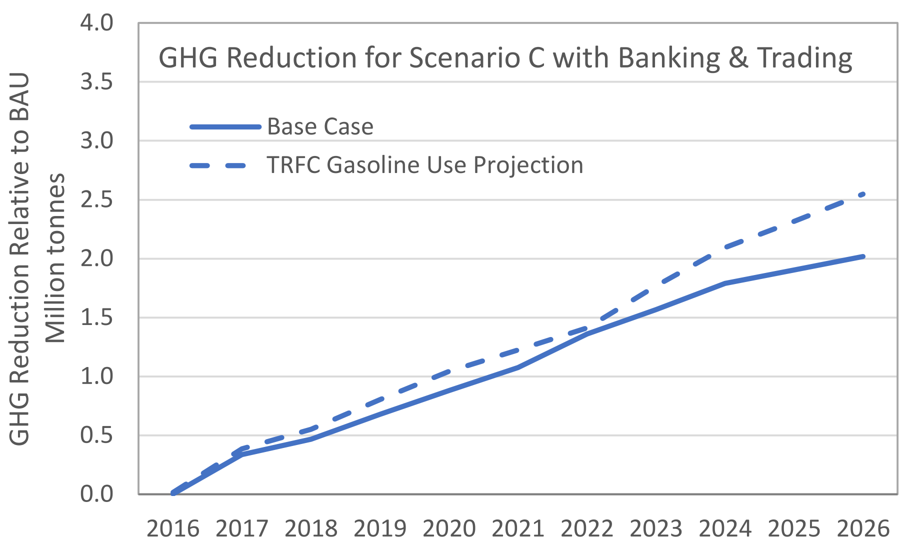


Figure 7-53. Comparison of GHG reductions relative to BAU.

Using the same assumptions about CFS credit prices, the impact on gasoline and diesel prices were determined and are shown in Figure 7-54 and Figure 7-55. More credits are required in the TRFC scenario, but the cost is spread over more gallons of fuel, so the overall impact on gasoline and diesel prices is very small.

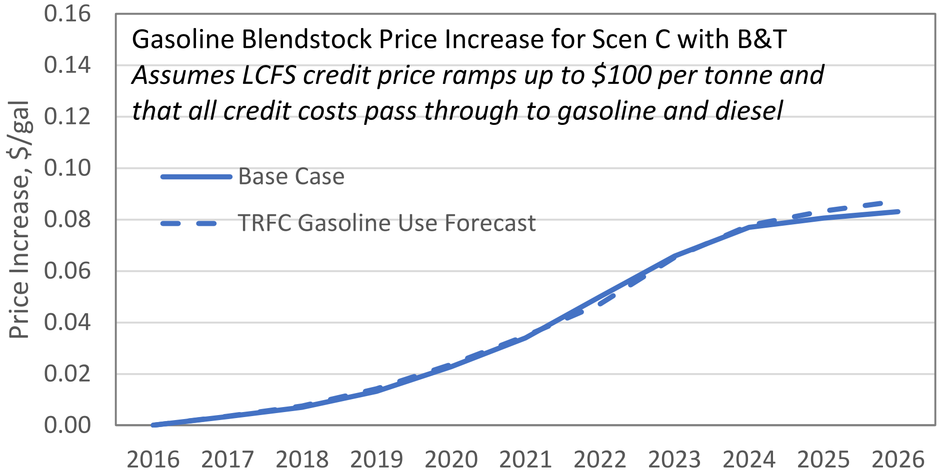


Figure 7-54. Comparison of gasoline price impacts for assumed credit price profile.

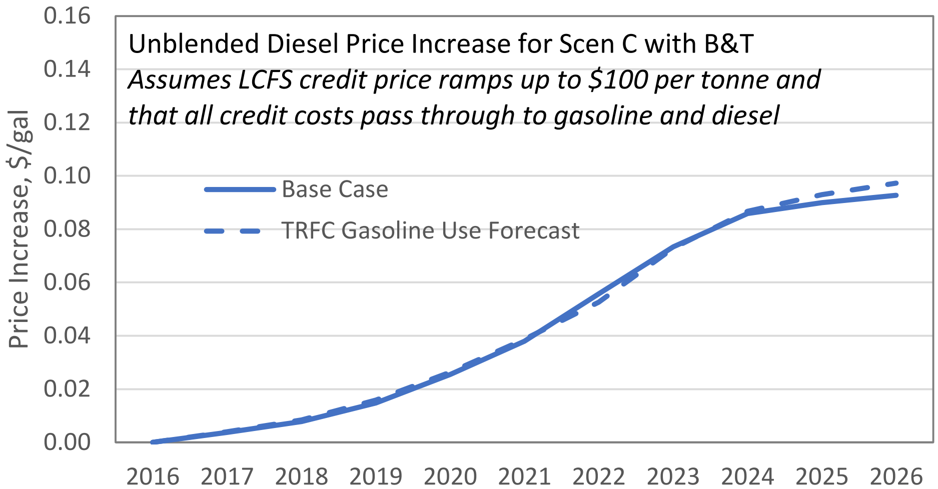


Figure 7-55. Comparison of diesel price impacts for assumed credit price profile.

## 8. Infrastructure Costs

To support alternative fuel use, a significant amount of infrastructure investment is required. Figure 8-1 summarizes the infrastructure costs for each scenario. The sections below provide results for each fuel type while Appendix B provides the assumptions underlying the results presented here. The following paragraphs step through estimated infrastructure expenditures to support advanced vehicle refueling (Scenario A), pipeline quality RNG production plant costs, cellulosic biofuel plant costs, and infrastructure costs to support increased biodiesel and ethanol consumption. Note that similar to the consumer spending on vehicles, costs to support PEV, hydrogen FCV and CNG refueling for Scenario A should primarily be assigned to an alternate BAU or to a State program that incentives or requires sales of advanced vehicles.

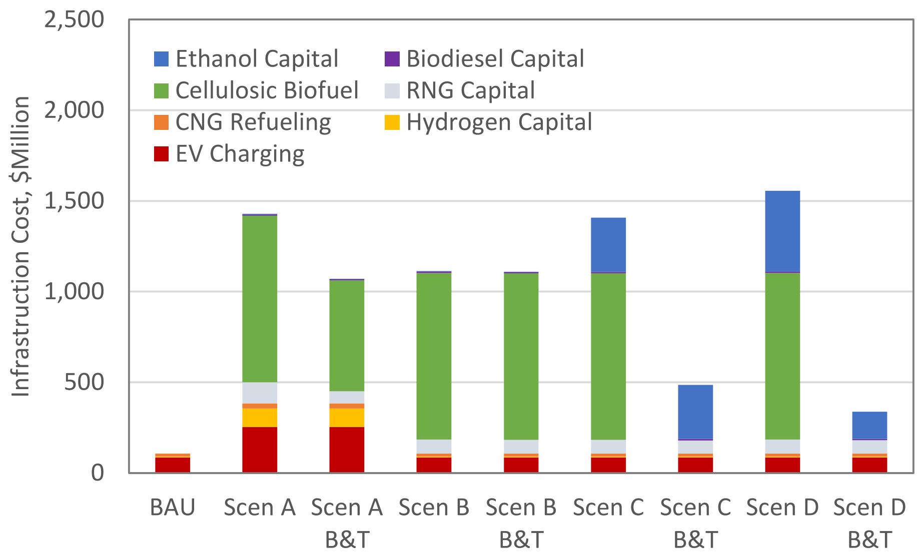


Figure 8-1. Summary of infrastructure investment required for each scenario.

### *EV Charging Infrastructure*

Table 8-1 and Figure 8-2 summarize the estimated EV charging infrastructure costs for Scenario A (advanced vehicles) and BAU (and all other compliance scenarios) in current dollars. Please refer to Appendix B for the assumptions underlying these estimates.

Table 8-1. Summary of Charging Infrastructure Costs for the BAU and Scenario A

| | Residential | | Non-Residential | | DC Fast Charge | | Total | |
|---|---|---|---|---|---|---|---|---|
| | BAU | Scen A | BAU | Scen A | BAU | Scen A | BAU | Scen A |
| | $Million | $Million | $Million | $Million | $Million | $Million | $Million | $Million |
| 2017 | 4.8 | 5.2 | 6.8 | 24.6 | 0.8 | 1.1 | 12.4 | 30.9 |
| 2018 | 4.5 | 6.6 | 6.8 | 24.6 | 0.6 | 1.0 | 12.0 | 32.2 |
| 2019 | 4.6 | 8.2 | 5.1 | 18.5 | 0.5 | 0.8 | 10.2 | 27.5 |
| 2020 | 4.6 | 10.4 | 4.3 | 15.4 | 0.3 | 0.6 | 9.1 | 26.4 |
| 2021 | 4.6 | 12.4 | 3.4 | 12.3 | 0.2 | 0.5 | 8.2 | 25.3 |
| 2022 | 4.6 | 14.0 | 2.6 | 9.2 | 0.2 | 0.4 | 7.4 | 23.6 |
| 2023 | 4.7 | 15.7 | 1.7 | 6.2 | 0.2 | 0.3 | 6.6 | 22.1 |
| 2024 | 4.9 | 17.0 | 1.4 | 4.9 | 0.2 | 0.2 | 6.4 | 22.1 |
| 2025 | 5.3 | 17.9 | 1.0 | 3.7 | 0.1 | 0.1 | 6.4 | 21.7 |
| 2026 | 5.6 | 18.2 | 1.0 | 3.7 | 0.1 | 0.2 | 6.7 | 22.1 |

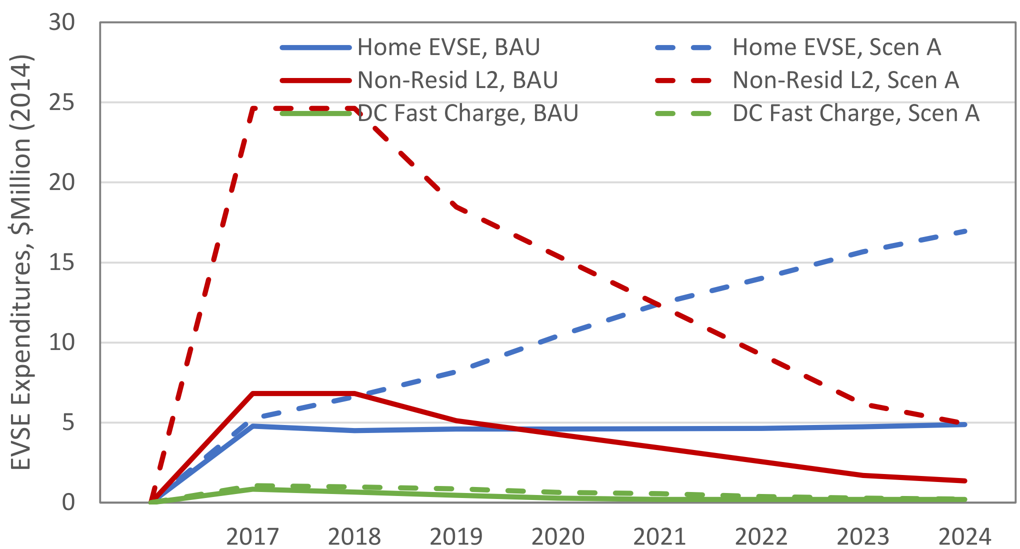


Figure 8-2. EVSE Expenditures for BAU and Scenario A.

### *Hydrogen Refueling Infrastructure*

Scenario A with and without banking and trading are the only scenarios with more hydrogen fuel cell vehicles than the BAU. For the analysis we have assumed on-site natural gas steam reforming. Please refer to Appendix B for details on the number of stations required and assumed cost per station. Figure 8-3 provides the BAU and Scenario A annual expenses for hydrogen refueling stations.

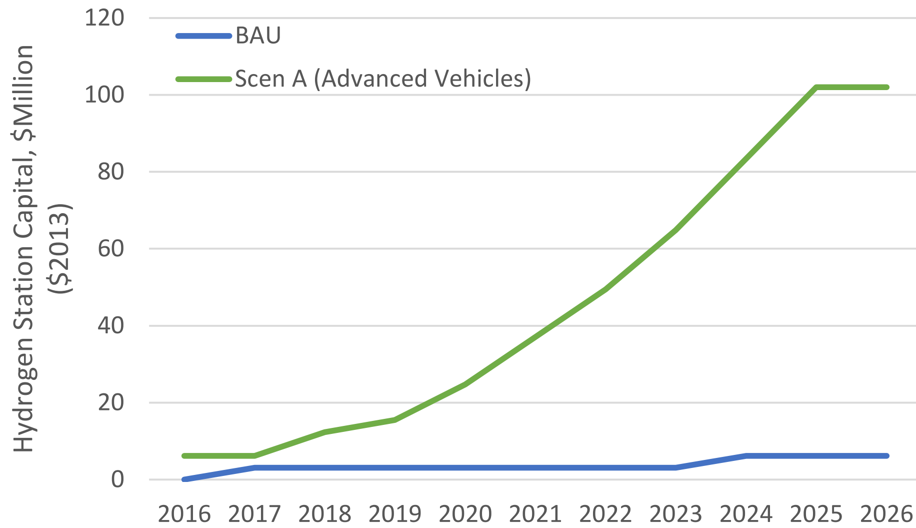


Figure 8-3. Cumulative hydrogen refueling station costs for BAU and Scenario A

***CNG Refueling Infrastructure***

Scenario A with and without banking and trading is the only scenario with increased CNG utilization relative to the BAU. Appendix B provides assumptions on number of CNG refueling stations and cost. Figure 8-4 summarizes cumulative expenditures on refueling stations.

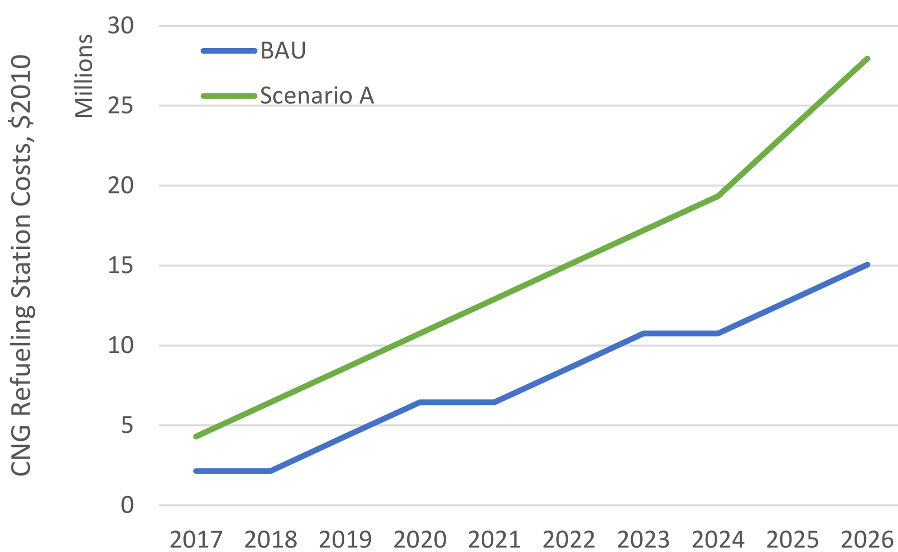


Figure 8-4. Projected cumulative CNG refueling infrastructure spending.

*Pipeline RNG Plant Costs*

All compliance scenarios assume some level of renewable natural gas utilized as a feedstock for CNG. RNG is recovered, cleaned and injected into the local natural gas distribution pipeline. There is already slightly more LFG to RNG capacity in Washington than is utilized in the compliance scenarios. However, additional capacity for RNG produced from WWT and HSAD gas is needed. For estimates of numbers of plants and plant cost, please refer to Appendix B. Figure 8-5 provides the cumulative costs for pipeline RNG capital for each compliance scenario. These costs are incremental to BAU costs as there is no spending required in the BAU for RNG.

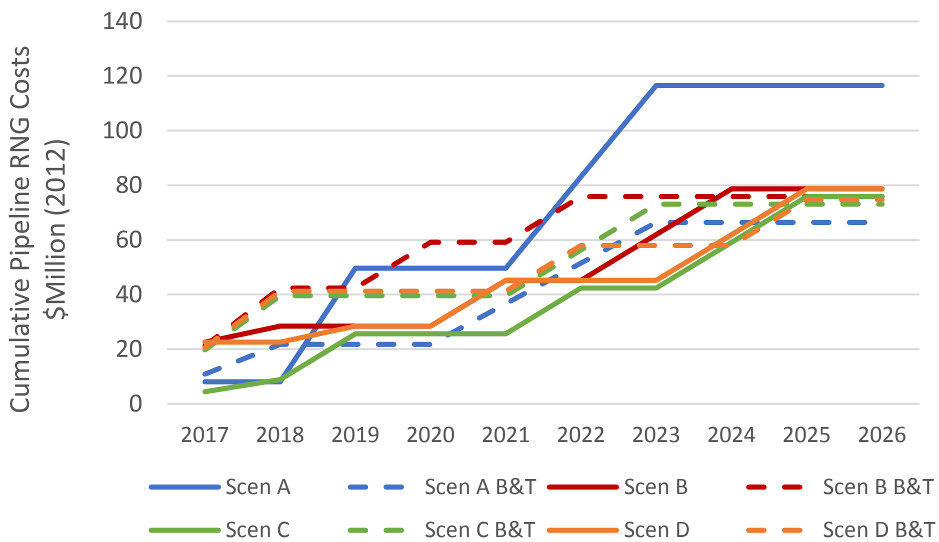


Figure 8-5. Cumulative costs for pipeline RNG projects.

*Cellulosic Biofuel Plant Costs*

Each compliance scenario utilizes some volume of cellulosic biofuel, and it has been assumed that all of these volumes will be produced in newly built production plants. For this analysis we have assumed that up to three cellulosic biofuel plants will be built in Washington state and if additional volumes are required, they would be imported. To evaluate the impact of this assumption on macro-economics, a sensitivity test for Scenario B considers all plants built out of state. For assumptions on the number of plants required for each scenario and the associated capital cost, please refer to Appendix B. Figure 8-6 provides the cumulative capital costs for building cellulosic biofuel plants ($2014).

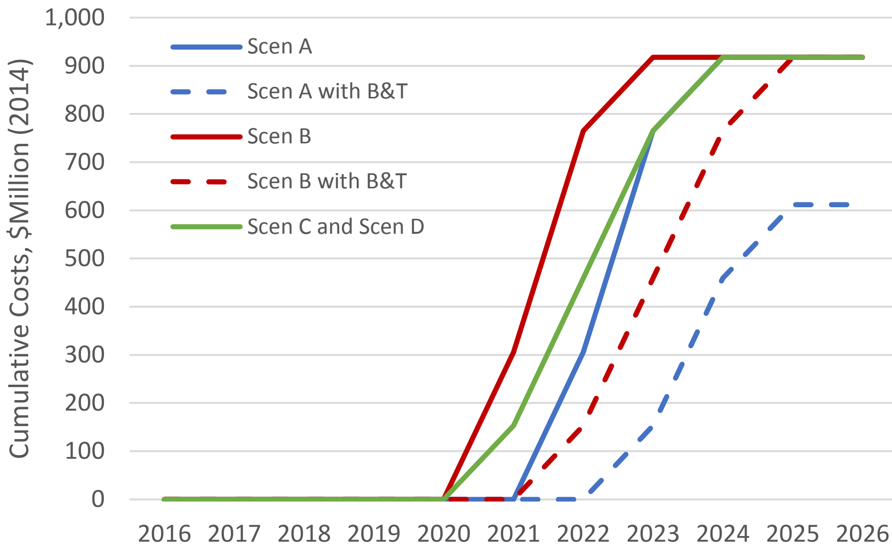


Figure 8-6. Cumulative costs for cellulosic biofuel plant construction in Washington state.

### *Infrastructure to Support Changes in Ethanol Use*

Several different infrastructure cost categories were considered in response to changes in ethanol consumption:

- Marine, rail, and petroleum terminal
- Trucks for transport from blending terminal to refueling
- E15 infrastructure
- E85 infrastructure

The underlying assumptions for costs in each of these categories are provided in Appendix B. Figure 8-7 provides cumulative costs for ethanol related infrastructure relative to the BAU case. Scenario D has the highest costs because it requires both E15 and E85 infrastructure.

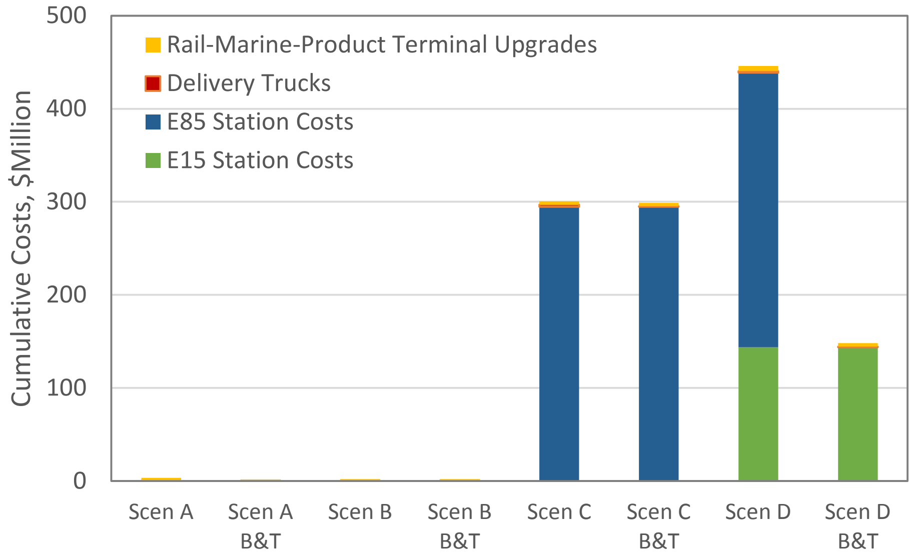


Figure 8-7. Cumulative ethanol infrastructure costs relative to BAU.

### *Infrastructure to Support Increased Biodiesel Use*

Additional infrastructure required to support increased biodiesel use consists of more trucks to transport biodiesel to the petroleum terminals and upgrades at petroleum terminals; no spending at refueling stations is required. Appendix B provides the assumptions utilized to calculate these infrastructure costs. Approximately 5.8 million dollars ($2014) is required for terminal upgrades and an additional $1.6 million ($2014) is required for trucks.

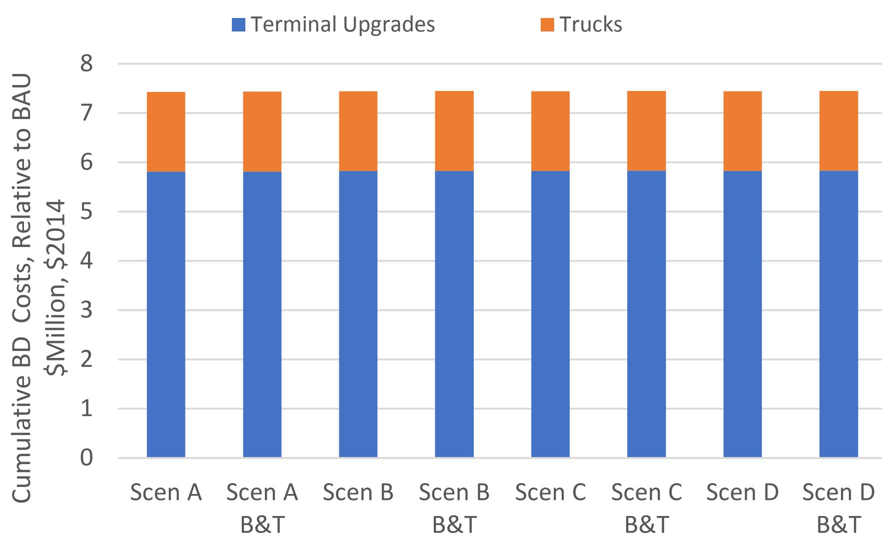


Figure 8-8. Total biodiesel infrastructure costs relative to BAU

# 9. Macro-Economic Modeling Methodology

Impact analyses are always framed within the context of "with" and "without" (benchmark) perspectives. The impact of an exogenous event, such as the application of a CFS, is defined and measured in terms of the differences between the state of the economy with and without the change. Thus, impact analysis requires the ability to forecast a reference case. In ex post analyses, the only forecast required is of what the economy would have been without the change, since the state with the change is directly observable. In ex ante analyses such as the present study, research is required to estimate what the economy is expected to look like in both the "with" and "without" scenarios. This framework is required whether the analysis is qualitative or quantitative. Impacts cannot be ascertained otherwise.

All impact analyses require an explicit or implicit model that explains how the economy is affected by a variety of factors determined outside the control of private decision makers. Because there is a wide range of opinions on the likely direction of energy use and travel, it may be wise to define alternative benchmark scenarios that will meet the CFS. To complete the analysis of the Washington state CFS scenarios, the project team created a reference case forecast that includes not only the fuel mix today, but the mix in each year between the current year and a forecast year without the potential Washington state CFS. The end year for this analysis is 2026. The reference case, or BAU case, is described in the Sections above and in Appendix A of this report. In future studies, Washington state might want to consider extending the analysis over a longer term, such as 2035 or even 2050. The longer term horizon might reveal trends that are not anticipated. For example, hydrogen fuel is unlikely to play a major role in meeting the current goal, but may be an important option in the longer term, with implications for policy action in the nearer term. This analysis develops baseline and annual alternative impacts only over the period from 2017 to 2026.

Many issues must be considered in the baseline, including the underlying growth in Washington state population and economic activity. For this analysis we are utilizing REMI PI+ which is the same model used by OFM to predict the future structure of the Washington economy. This growth in income and employment will include the expected change in demand for gasoline and diesel fuel to power transportation. These expectations are in the baseline scenario (referred to as the "Business-As-Usual" or "BAU" scenario). The baseline scenario changes will proceed in a dynamic fashion, the pace of which will be crucial in defining the impact and viability of a lower carbon intensity fuel driven Washington state economy. Note that there are both microeconomic and macroeconomic baseline considerations. As such, both the VISION (vehicle inventory and use) and REMI (Input-Output, Computable General Equilibrium, and Economic Geography) tools must generate a baseline from which scenarios under consideration can be evaluated in later steps. These modeling tools and their application are discussed below.

## 9.1 Types of Economic Impacts

The estimation of economic impacts due to public policy often focuses on three types of impacts. Direct economic impacts refer to the changes in behavior and costs that result from actions to comply with the CFS. For example, the development of distilling resources to produce fuel ethanol would be a direct impact. Indirect economic impacts are defined as the behavior and costs that result in the economy to facilitate the direct impacts. An example of indirect impacts is the economic impact resulting from the likely changes in spending on labor and materials, which are needed to collect forest wastes that will serve as feedstock for an ethanol production facility. The spending on labor and materials needed to build and run such a facility produce other indirect impacts as the businesses and workers engaged earn money from the sales and wages. Finally, induced economic impacts are the behavior and expenditures by households and businesses given the changes in income earned as a result of both direct and indirect activities. Their additional spending, often in sectors entirely unrelated to the initial direct impact (such as retail spending, housing or educational spending for consumers, or professional services for businesses) mean that induced impacts from a narrow policy may occur across the entire economy.

Environmental regulations can result in higher production costs for the regulated industries. For example, tailpipe emissions regulations require additional vehicle emissions control technology which increases the production cost of the vehicle. Air quality regulations that limit plant emissions require production modifications or emissions post production processing to comply with emissions limits. The additional cost of compliance is compared to the benefits of reduced emissions such as improved health, quality of life, the avoided costs of pollution response, and many other benefits. If the benefits of the regulation are deemed to exceed the costs, the regulation is considered cost effective.

The proposed Washington state CFS is distinct in its economic impact from typical environmental regulation, as it provides an opportunity for economic gains as domestic and in-state production of replacement fuels stimulates the U.S. and Washington state economies. This stimulus results from a reduction in petroleum imports and an increase in domestic investment to provide feedstock and production/generation facilities for the replacement fuels. In this study, alternative fuel supply investment within Washington state is deemed to come from capital outside the state, though it includes a sensitivity analysis (assuming half the necessary capital comes from within the state) to explore the importance of this assumption. This external investment in productive facilities in Washington state creates employment, income and state product greater than would exist without this stimulation. We also investigate alternative investment structures that include a split of investment between state and external sources. In-state alternative fuel production investments are deemed to crowd out other in-state investments and may result in some economic losses, particularly in the early years.

The potential decision by Washington state to institute a CFS will provide opportunities for economic development within Washington state that would not occur in the absence of such a standard. Such investments will likely not occur in the absence of the standard, as investors would have no guarantee that the market for alternative fuels would materialize. Indeed, the petroleum sector could strategically modify delivery prices in areas where such investments were made to make these investments uneconomic. However, with the standard in place, low carbon fuel suppliers are effectively guaranteed a market of some size for their product (determined by the stringency of the standard and level of conventional fuel consumption) as the fuel mix is required to meet the carbon intensity requirements of the standard.

The level of investment assumed in the macroeconomic model is considered fixed in the baseline. Thus, new investment from outside of Washington state will increase economic activity in Washington state in the scenarios. This is particularly true in the short run as there is very little alternative transportation fuel produced in Washington state today. If these investments, or even a portion of these investments, came from within Washington state, they would replace other Washington state investments. The economic impacts would then be measured as the impacts of the new investment less that of the displaced investment. This origin of capital analysis is undertaken in the sensitivities analysis. In the sensitivity analysis of capital origins, the measured economic impacts are likely to be positive, as only a portion of the investments would displace existing investments and the impacts of the displaced and new investments are likely to be similar in aggregate. Also, regardless of the source of the investment dollars, the CFS policy (under most scenarios) would achieve a displacement of imports by domestically-produced fuels (i.e. produced in Washington), which allows the state to gain economic benefits associated with the production and sale of fuels – benefits currently enjoyed primarily by out-of-state providers.

This analysis considers impacts to over 160 distinct sectors of the economy. The nature of the expected impacts under the scenarios considered suggests that certain specific sectors would be likely to see significant impacts. The anticipation of the construction of new biofuels refining facilities suggests likely gains for the construction sector. Because construction is labor-intensive work (when considered in terms of the number of full-time-equivalent positions per dollar expended in the sector), employment is also anticipated to rise, and as a further consequence, incomes and consumer spending are expected to rise as well. Petroleum production would be expected to show a loss in economic activity as alternative fuels displace gasoline and diesel fuel.

The modeling and analyses produced results which agree with these expectations. The consumption and production increases for each particular alternative fuel are also expected in those scenarios where that fuel is anticipated to serve as one of the alternatives replacing conventional fuels. To the extent that a domestically-produced fuel is envisioned to serve as such an alternative, the supply-side benefits from the production and sale of this fuel would also come into effect. To the extent that any new infrastructure was required, the construction of that infrastructure would bring both positive influences on the overall economy (such as the employment gains in construction during the construction phase) and negative influences (such as the displacement of capital, in whole or in part, from the state's other needs).

## 9.2 Scenario Development

This scenario analysis is not a forecasting effort. Forecasting economic conditions in a particular year is a challenging prospect. Projections of future economic conditions depend on the expected growth in population and in economic activities, but are subject to the effects of natural, economic and political conditions during the forecast period that are impossible to predict with precision. Natural disasters, international banking collapses, war, embargos and many other unpredictable events will determine the future level of economic activity. The best that can be done is to develop a state economic forecast that is consistent with the national forecast and recognizes any unique characteristics of the Washington state economy. This forecast is the BAU scenario, without a CFS either in Washington state or nationwide.  However, the forecast does rely on federal data and forecasts which incorporate larger trends in the relevant sectors, including impacts from existing policies such as the Federal Renewable Fuel Standard and the California Low Carbon Fuel Standard (LCFS). Fortunately, this analysis requires only a baseline, and not a full economic forecast, to assess the impacts of the standard.

The transportation fuel supply industry in Washington state will have a range of options available to it to supply transportation fuel to the state while meeting the CFS. The OFM and Ecology, working with the advisory committee and LCA, developed a set of compliance scenarios that are believed to bracket the range of potential fuel supply options. All of the selected compliance scenarios result in compliance with the CFS, and they are expected to bracket a range of realistic assumptions regarding the low carbon fuels available in the future. These scenarios do not intend to foreclose the possibility for unintended effects to result in different or modified fuel pathways. They intend, rather, to demonstrate the range of likely impacts from this policy.

A compliance scenario combines information from a fuels assessments and the calculation of carbon intensities to estimate the volume of various low carbon fuels that would be needed to achieve the CFS each year in the projection. There are several purposes for developing compliance scenarios:

- Scenarios allow the State to estimate the quantity of low carbon fuels needed for compliance with a CFS
- Scenarios allow the State to identify any gaps in alternative fuel availability that would need to be filled to have a feasible program. This allows regulators to identify investment needs and economic development opportunities for Washington state to increase the availability of lower carbon alternatives fuels by 2026.
- The different compliance scenarios allow the state to evaluate the reasonable range of possible economic impacts associated with different compliance options, including potential benefits of additional incentives for in-state production, if needed.

Impacts are measured by comparing each compliance scenario to the BAU scenario. The direct, indirect, and induced impacts are catalogued for each scenario compared to the BAU for macroeconomic variables such as employment, personal income, and state product.

## 9.3 Macro-Economic Modeling Input Assumptions

Macro- and micro-economic models seek to evaluate economic activity at two very different levels. Micro analysis is concerned with activities for individuals or small groups of economic factors such as households, firms or agencies. In this case, the modeling seeks to understand how the demand for transportation fuel is impacted by vehicle technology changes, driving patterns and fuel choice. VISION, while not a microeconomic or benefit-maximizing decision prediction model, includes a full accounting of spending on two major cost elements (vehicles and fuels) in the base year and in each forward year through 2026. It keeps track of the fleet over time so that the amount of fuel used, by type, is accounted for. It does not attempt to model the bases for the choices of fuels or vehicles (or the economic decisions that drive total travel volumes), but relies on historical data on all three as well as forecasts consistent with those of other agencies such as the Department of Energy and Federal Highway Administration to establish the baseline of behavior from which to measure the impacts of scenarios. Nevertheless, the model produces (based on these consistent forecasts) a valuable basis for estimating the direct changes in financial flows that would result from changes in the fuels and technologies that are most prevalent in the on-road transportation sector.

While the VISION model is a valuable tool for measuring the impacts of changes to vehicle fleets and fuels, it does not produce macroeconomic impacts that show how such changes might reverberate through the broader economy. Macroeconomic models are broad aggregates of the economy. Sectors in the macro model include many products and industries collected and measured together. Significant increases in the consumption of biofuels, particularly of biofuels produced in-state, can be expected to impact forestry, farming, and agricultural sectors of the economy. Significant shifts away from petroleum-based fuels (gasoline and diesel) can be expected to have impacts on businesses involved in oil production, refining, and transportation. Significant new utilization of natural gas or electricity produced in-state would also affect related industries. Macroeconomic models seek to estimate these broader impacts. Thus, both scenario modeling tools and macroeconomic models are required to simulate the economic impacts of the CFS. These models can be separate stand-alone models or they can be combined in a single program that translates and transfers the micro changes caused by this regulation to the macro model. In this case, we took advantage of the detail of the VISION model, which estimates vehicle sales and fuel consumption for 28 different vehicle types and several distinct fuel types, and the capacity for macroeconomic aggregation of the REMI PI+ model. Other individual and combined models are available, but none offers more detail than those applied.

As mentioned above, VISION provides projections of consumer spending on fuels and vehicles, but these are not the only values necessary to fully inform the REMI PI+ model of the direct economic expenditures expected under the different scenarios. The team has also developed estimates for infrastructure investment for each scenario, presented above in Section 8 and Appendix B.

In addition, effective macroeconomic modeling involves knowing the character of each change in a financial flow, and the origin and destination of each financial flow. Understanding whether a change represents a price change or demand change, and whether it is a purchase by consumers or an investment in capital, is important to modeling scenarios accurately. For example, consumer spending changes resulting from rising prices (an inflationary change) have different impacts on an economy than do capital-investment changes resulting from an incentive program. Also, in-state production of a good or service for an in-state consumer has different consequences than would scenarios where either production or consumption occurs out of state, even when the total dollars involved are the same. Even the effects of taxation are very dependent upon who is taxed and how the tax revenue collected is spent – new tax money collected simply to pay down past debt (moving money away from the state, in large part) will differ in impacts from tax revenue collected and used to reduce other fees charged (thus mitigating the total tax impact) or hiring new employees (thus increasing income and employment).

Another important observation is that the models do not operate in a feedback loop – changes resulting in the macro model do not return to redesign the model inputs. As a result, attempts to model a scenario accurately call upon the analyst to consider whether any significant changes require adjustments to the approach in order to reflect changes not captured in an input-response approach.

The following are inputs for the macroeconomic analysis:

- Change in expected spending on gasoline and diesel, identified separately
- Changes in expected spending on the following fuels from in-state sources and separately from out-of-state sources, each as its own separate input to the model:
  - Ethanol in as a motor gasoline blending component (E10/E15)
  - Ethanol as a high level blend for FFVs (E75)
  - Cellulosic gasoline
  - Biodiesel
  - Electricity
  - Compressed Natural Gas
  - Hydrogen

- A net fuel spending change based on all of the above, to be allocated to general personal consumption (adjusted downward to avoid double-counting of impacts from model's treatment of new in-state sales).
- The total cost of price increases of new vehicles
- Expected new spending on the following infrastructure:
  - EV charging stations
  - Upgrades to fueling stations to allow sales of natural-gas fuels, E15 and E75 ethanol fuel, biodiesel, and hydrogen fuels
  - Construction of Cellulosic Biofuel production facilities
  - Specialized transportation vehicles for new fuels
  - Inland and marine terminals for fuel distribution
- Assumptions of capital-funding source (50% or 100% funding from out of state) and resulting partial displacement of existing capital availability within Washington

This analysis did not attempt to quantify frequently anticipated effects that result from reduction in emissions of air pollutants, such as health impacts or other cost reductions. With a reliable, well-sourced estimate, however, such inputs would be entirely appropriate for this analysis

# 10. Macro-Economic Modeling Results

The macroeconomic analysis was accomplished with the use of the REMI PI+ model, Version 1.6.5. The model's default assumptions were relied upon to serve as the baseline for policy analysis (the BAU case). The basis for this decision is the focus of this analysis on the nature of the change the policy might create under these scenarios, and not on the total size of the economy as a result of these scenarios. For each scenario, a model run was conducted and the results were compared to the BAU. Two sensitivity tests were conducted to evaluate the impact of assumed CFS credit prices, and to quantify the economic impact of cellulosic fuel production plants located in-state as opposed to locating out of state. The analysis focused on change in employment, personal income and gross state product, but more detailed comparisons are available for each economic sector characterized in the 160 sector REMI as well as all categories of final demand. The following sections provide results for the eight compliance scenarios and the sensitivity tests on credit price and location of cellulosic biofuel plants[66].

## 10.1 Compliance Scenario Results

The eight compliance scenarios were designed to include a wide range of potential compliance scenarios for the Washington fuel supply sector. The graphs below indicate how macroeconomic variables such as income, employment and state product vary across scenarios. All three macro variables move together as the scenarios alter the low carbon fuel mix. In all cases the Washington economy and fuel supply system is treated as the responder to the CFS as it purchases and supplies the needs of Washington vehicles for fuel that meets the standard. The advanced vehicle scenario is a variant, where other policies have motivated high levels of adoption of these vehicles, and LCFS compliance occurs within that context. No national CFS is assumed. The potential supply of fuel from each source is determined in the scenario and limited in the scenario design if there is a practical capacity constraint. This limitation informs the inputs to the macroeconomic analysis. The macroeconomic results of this analysis for the CFS compliance scenarios considered are summarized below in Table 10-1.

Table 10-1. Summary of Economic Impacts for CFS Compliance Scenarios

| | Range of Impact Relative to BAU | |
|---|---|---|
| Annual Average Change in Employment | -210 Lost to 1,430 Added | -0.01% to 0.07% |
| Annual Average Change in Income (2010$) | -$10 M Lost to $130M Added | -0.004% to 0.04% |
| Annual Average Change in Gross State Product (2010$) | -$30M to $140M Added | -0.01% to 0.05% |
| GSP Impacts in Start and End Years | -$2.3M Lost to $2.8M Added (2016) | -$90M Lost to $143M Added (2026) |
| Single-Year Highest & Lowest GSP | $583M in 2022 (Scenario B) | -$127M in 2026 (Scenario A with B&T) |

[66] Compliance scenarios consider the possibility of a west coast regional low carbon fuel market. REMI simulations do not do the same, and so do not account for potential rebound effects from regional decrease in petroleum fuels due to standards not part of macro analysis, which focuses on in-state effects alone.

These results are not significantly different than what would have occurred in the BAU case This represents a small impact on the projected $400 Billion to $500 Billion gross state product projected for the 2016-2026 timeframe.

All scenarios that rely on liquid fuels demonstrate similar macro impacts. Investment in new plants and equipment to produce these fuels and the required infrastructure stimulates the Washington economy in the years when plants are built and in their continuing operation. Positive economic impacts in Washington stem from reduced crude oil imports and its replacement with Washington produced products. To the extent that the Washington CFS reduces national petroleum imports, similar economic impacts will be realized, but without more analysis of any price effects due to these programs, it is difficult to say how much of the statewide reduction translates into US reduction. In the longer term, vehicle fuel economy is expected to continue improving, resulting in further reductions in petroleum consumption through 2030. This is independent of the CFS, but forms the baseline from which fuel-demand changes are estimated.

The macroeconomic modeling analysis produced estimates of overall economic impacts, as well as specific impacts to approximately 160 different sectors of the economy, for each of the compliance scenarios. The full results are included in this report as Appendix D. Appendix D shows annual impacts for selected indicators, across sectors.

The first metric utilized to evaluate macroeconomic impacts is gross state product (GSP). Figure 10-1 demonstrates the change in GSP relative to the BAU for each scenario without banking and trading. Figure 10-2 provides the change in GSP for the scenarios with banking and trading. Each line can be understood by two characteristics: its general trend and scale of that trend, and the timing of spikes caused by short term intense levels of capital investment in new manufacturing plants. Most scenarios also contain a rapid upward jump shortly after 2020 as the construction of major biofuel manufacturing facilities (each costing $300-$350 million) are constructed. Where construction spending for the three plants commonly envisioned in these scenarios ends up holding constant for two years, the spike becomes a two-year plateau. Where the plant construction is separated by a year or more, the line for that indicator for that scenario is characterized by two separate spikes. Note that Scenarios C and D with banking and trading do not utilize cellulosic fuels, so there are no spikes associated with cellulosic biofuel plant construction.

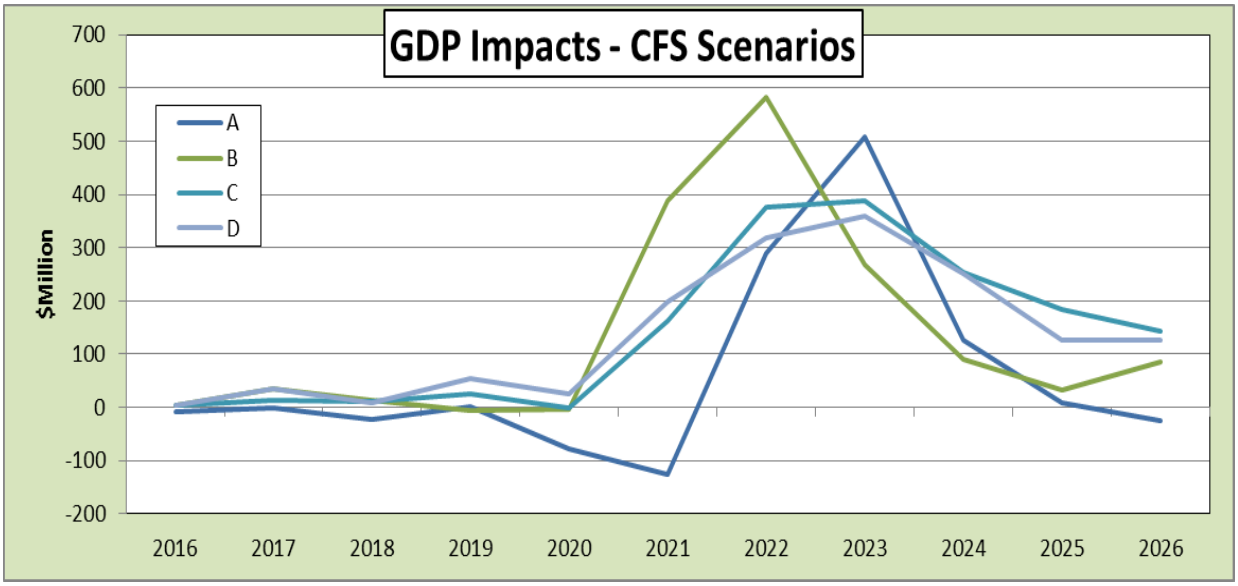

Figure 10-1. Change in GSP Relative to BAU for Scenarios without Banking and Trading.

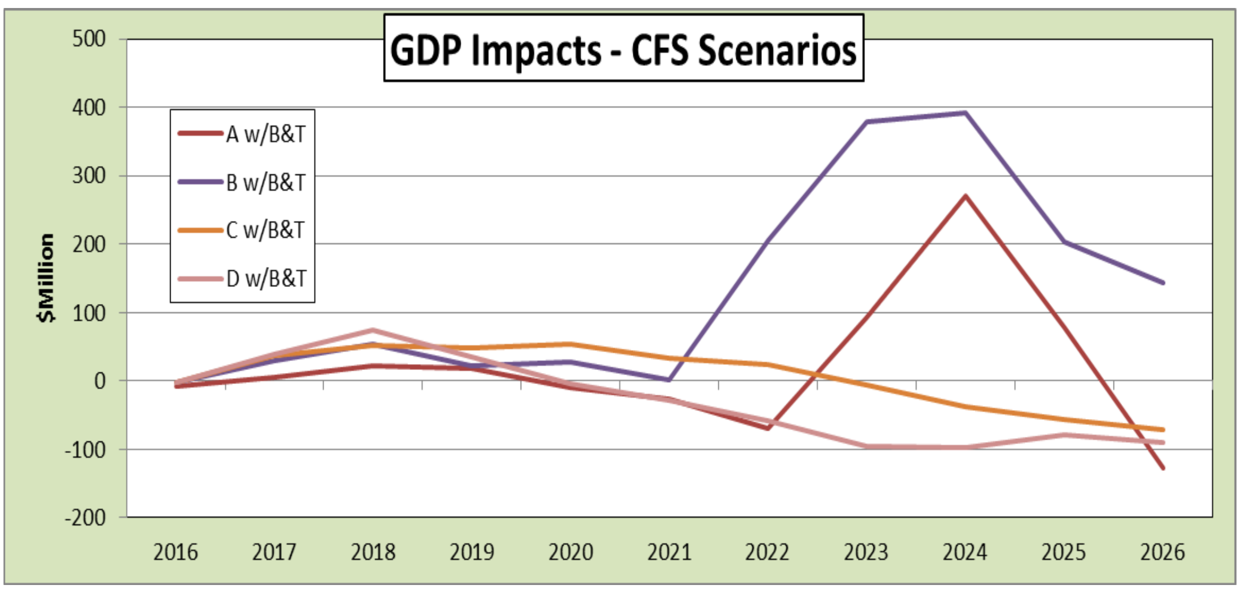

Figure 10-2. Change is GSP Relative to BAU for Scenarios with Banking and Trading.

The eight different scenarios represent four different possible market responses to the CFS, and a variation on each of those four which assumes that credit banking and trading are in place. Their overall impact in GSP over the entire 2016-2026 period is visualized below in Figure 10-3. The banking and trading scenarios consistently produce results showing less favorable macroeconomic outcomes, though the scale of the differences are not consistent. In Scenario B, it appears to make little difference, while in Scenarios C and D it makes a dramatic difference. This is because in Scenarios C and D with banking and trading, no cellulosic fuel is required, so there is no economic activity associated with constructing and operating new cellulosic fuel production plants.

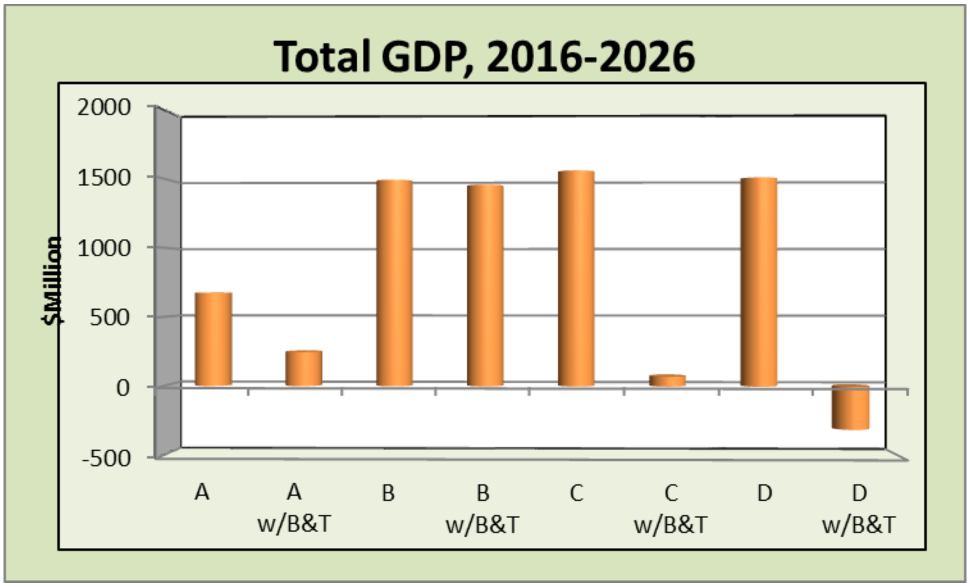

Figure 10-3. Cumulative GSP Relative to the BAU.

Two other metrics used to evaluate macroeconomic impacts are employment and overall income levels. Figure 10-4 and Figure 10-5 provide annual employment impacts (measured in jobs) for the scenarios with and without banking and trading. As with GSP, employment impacts are less positive in the banking and trading scenarios than they are in the scenarios where no such trading mechanism is present.

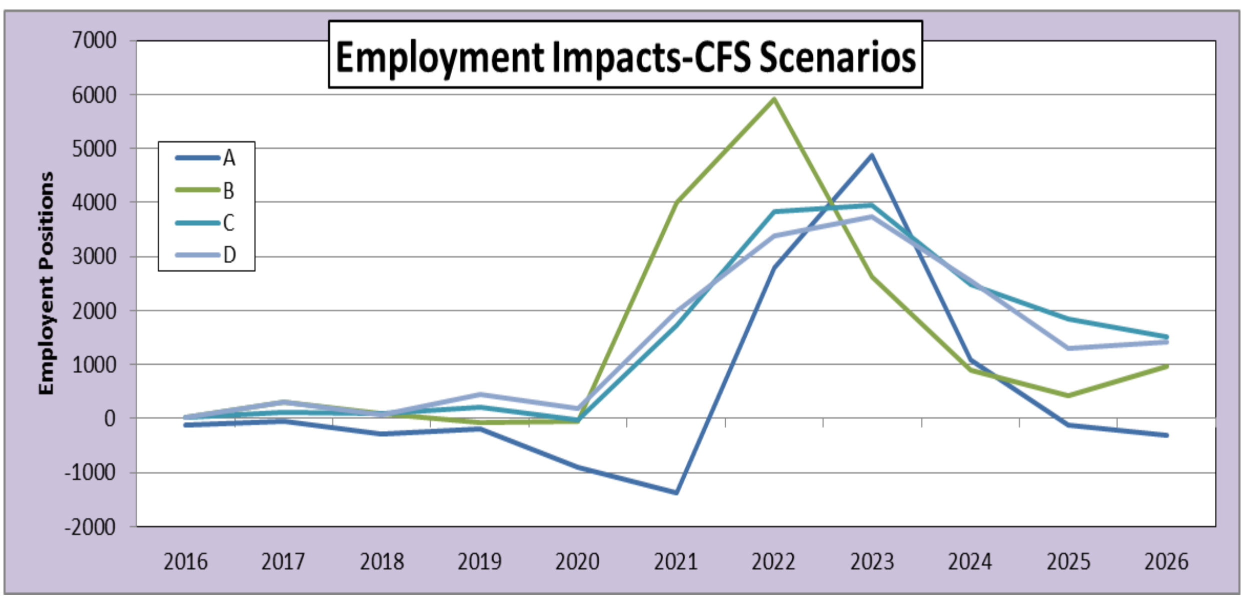

Figure 10-4. Change in Employment Relative to BAU for Scenarios without B&T.

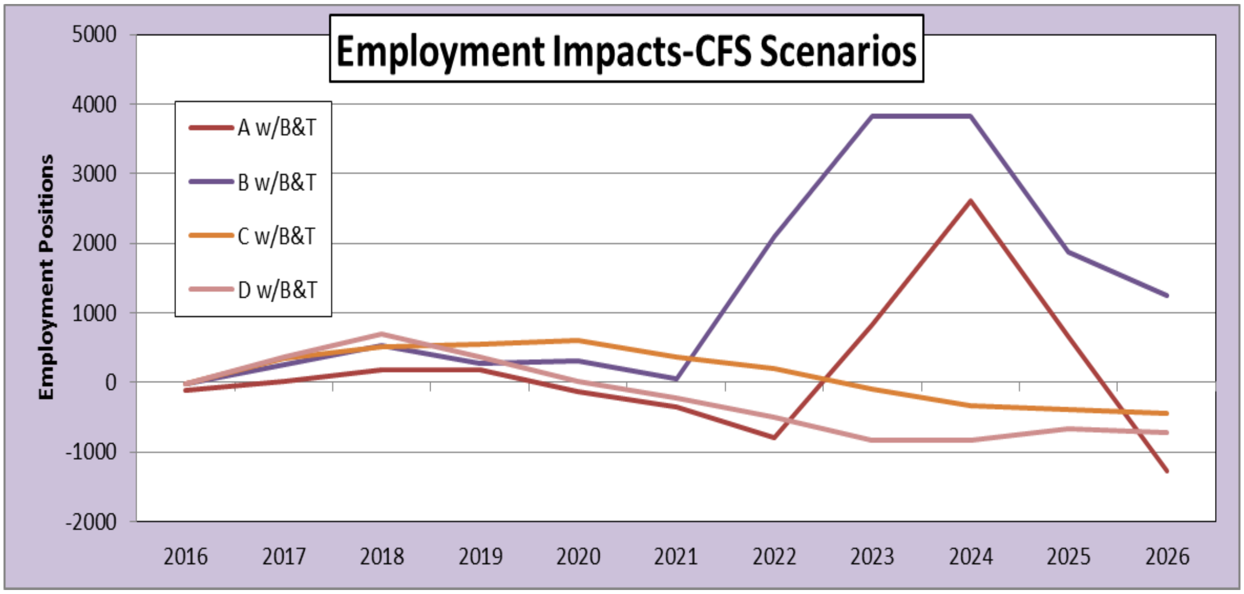


Figure 10-5. Change in Employment Relative to BAU for Scenarios with Banking and Trading.

The scenarios reflect a correlation between the intensity of investment, which tracks with the timing of refinery construction, and increases in employment. Once plants are built, they directly employ relatively small numbers of people (below 100 per plant). During the construction phase, by contrast, the spending involved works through the economy to create employment for thousands of people. Income levels (Figure 10-6 and Figure 10-7) again follow a familiar pattern. Additional employment drives income changes at equivalent points in time across the analysis period.

It is interesting to note that for all three major indicators, Scenario A (advanced vehicles) produces a temporary reduction below baseline levels in the early years, rather than gains from the earliest years that characterize the other scenarios. The major driver of the early negative results for that scenario is the increase in costs for new vehicles, which constitute a price effect that lowers the available money that consumers who buy cars have available for other spending and savings behavior. This remains the most important factor for the first three to five years, until the positive effects from the in-state production of biodiesel and the construction of plants overwhelm this downward pressure before the halfway point of the 2016-2026 period.  However, this price impact returns in the end years, bringing the indicators again below baseline by the final year of analysis.

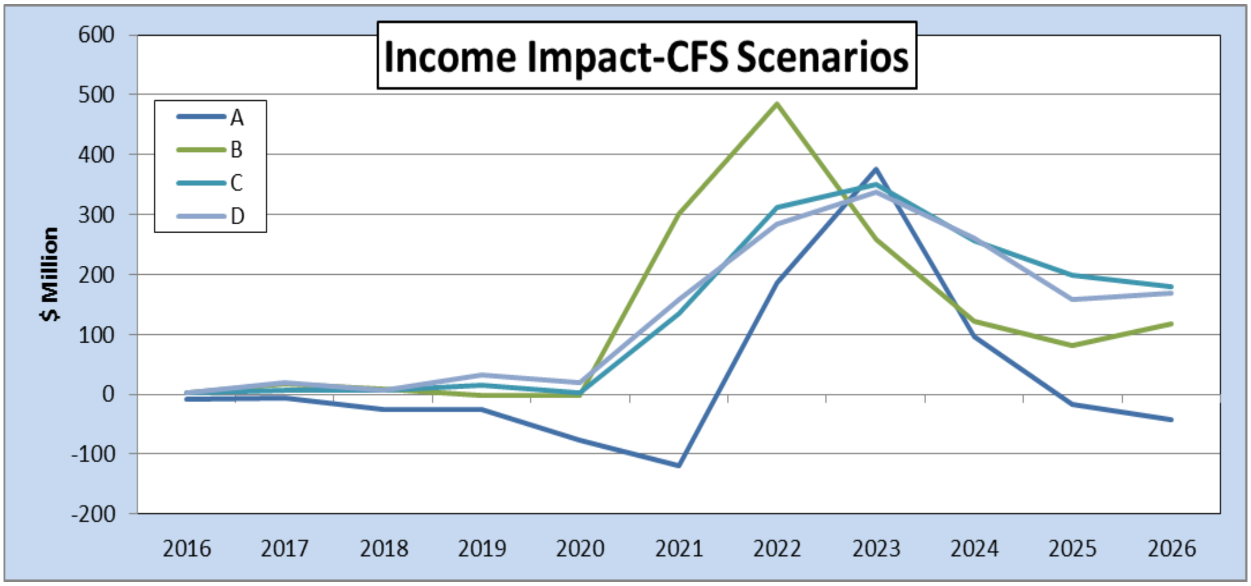


Figure 10-6. Change in Personal Income Relative to BAU for Scenarios without B&T.

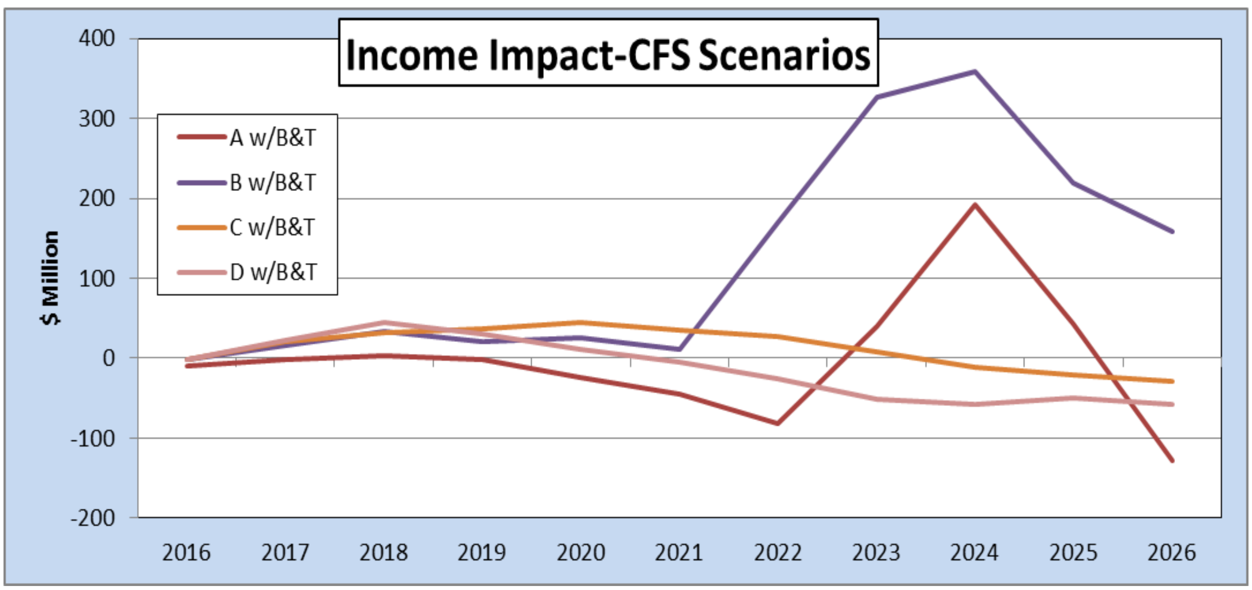


Figure 10-7. Change in Personal Income Relative to BAU for Scenarios with B&T.

Certain sectors fared especially well, while others fared less well. Identifying the most prominent changes – both positive and negative – in incomes, types of employment (by job classification) and output within sectors allows us to better understand the overall results. The following discussion provides sector-level results for Scenario C (the scenario that results in the most positive impacts overall) and Scenario D with banking and trading (the scenario with the least desirable impacts). Results for the other scenarios may be found in Appendix D.

Table 10-2 and Table 10-3 show sector-level output results for Scenario C and Scenario D with banking and trading, respectively. Output is the total quantity of goods and services provided; the top five and bottom five sectors are shown.

Table 10-2. Scenario C average yearly output for the highest and lowest sectors.

| **Highest 5 Sectors, $Millions** | | **Lowest 5 Sectors, $Millions** | |
|---|---|---|---|
| Construction | $105 | Museums, historical sites, zoos, and parks | $0 |
| Chemical manufacturing | $102 | Private households | $0 |
| Real estate | $13 | Other transportation equipment manufacturing | $0 |
| Professional, scientific, technical services | $12 | Oil and gas extraction | -$4 |
| Retail trade | $11 | Petroleum, coal products manufacturing | -$116 |

Table 10-3. Scenario D with B&T average yearly output for the highest and lowest sectors.

| **Output, Highest 5 Sectors, $Millions** | | **Output, Lowest 5 Sectors, $Millions** | |
|---|---|---|---|
| Chemical manufacturing | $84 | Real estate | -$5 |
| Construction | $14 | Ambulatory health care services | -$5 |
| Management of companies and enterprises | $1 | Oil and gas extraction | -$6 |
| Fabricated metal product manufacturing | $0 | Retail trade | -$8 |
| Rail transportation | $0 | Petroleum, coal products manufacturing | -$162 |

The largest gainers and losers are driven by the direct effects of the policy – increases are large for construction of the new facilities, chemical manufacturing for the alternative fuels production spurred within the state by the mandate (at least, as these scenarios envision it), and decreases for petroleum extraction and production occur as other fuels displace gasoline and diesel. The other sectors here represent indirect and induced effects, which though still significant are an order of magnitude smaller. (This is not true of the employment impacts below, however.) Even so, they are telling: the gain or decline in retail trade and real estate speaks to the directional change of the buying power of consumers and businesses, and the gain or decline in professional services also represent losses away from the fuels sector that result from the net changes in GDP, employment and incomes that the scenario produces.

Table 10-4 and Table 10-5 provide the top five and bottom five sectors in terms of change in yearly employment. The sectors that see the largest changes in total employment follow a similar pattern of larger direct impacts followed by smaller but still important indirect and induced impacts around the economy. The largest change here is the dramatic difference in needs for construction labor – Scenario C involves construction of multiple new fuel production facilities while Scenario D with B&T have no new fuel production facitlities. Both scenarios require some additional infrastructure as well as increases in domestic production of biofuels (though the increase is much higher in Scenario C), keeping the manufacturing numbers positive in both cases. The "Mining" category captures oil extraction, which is why it incurs a loss in both cases, and the larger loss in D+B&T reflects the larger displacement of petroleum fuels. Retail trade shows large impacts in both scenarios primarily because it is a labor-intensive business – far more so than petroleum production. Despite its small change in output compared to directly-affected sectors, its job-creation/job-loss potential is especially high, as shown in these tables.

Table 10-4. Scenario C average change in yearly employment

| **Highest 5 Sectors, number of jobs** | | **Lowest 5 Sectors, number of jobs** | |
|---|---|---|---|
| Construction | 643 | Management of Companies and Enterprises | 8 |
| Retail Trade | 106 | Information | 8 |
| Manufacturing | 88 | Utilities | 1 |
| Health Care and Social Assistance | 86 | Forestry, Fishing, and Related Activities | 0 |
| Professional, Scientific, Technical Services | 77 | Mining | -15 |

Table 10-5. Scenario D with B&T average change in yearly employment

| **Highest 5 Sectors, number of jobs** | | **Lowest 5 Sectors, number of jobs** | |
|---|---|---|---|
| Manufacturing | 39 | Accommodation and Food Services | -20 |
| Construction | 28 | Mining | -24 |
| Management of Companies and Enterprises | 5 | Other Services, except Public Administration | -32 |
| Transportation and Warehousing | 1 | Health Care and Social Assistance | -57 |
| Forestry, Fishing, and Related Activities | 0 | Retail Trade | -75 |

One more informative sector-level comparison is that of job categories affected. Simple statements about numbers of jobs created or lost beg the question of what type of jobs are gained or lost. Table 10-6 and Table 10-7 provide the top and bottom five changes in average yearly employment by job classification for Scenario C and Scenario D with B&T. Notably, Scenario C has no category that produced an average job loss over the 2016-2026 period. The presence of "Military" at its ever-constant zero point establishes a clear boundary between gains and losses – the model produced no changes in the number of total military force in any scenario. In Scenario D with B&T, by contrast, "Military" is in the top 5, indicating only four job categories had any gains at all. Scenario C thus paints a picture of a rising tide lifting all boats, to a greater or lesser extent, while Scenario D with B&T shows the slight downward trend of total economic activity (again, a few hundredths of one percent of the total) causing losses fairly broadly through the skilled-labor and service job categories within the state.

Table 10-6. Scenario C changes in average yearly employment by job classification

| **Highest 5 Job Descriptions, number of jobs** | | **Lowest 5 Job Descriptions, number of jobs** | |
|---|---|---|---|
| Construction and extraction occupations | 407 | Community and social service occupations | 12 |
| Sales and related, office and administrative support occupations | 301 | Life, physical, and social science occupations | 10 |
| Management, business, and financial occupations | 138 | Legal occupations | 8 |
| Installation, maintenance, and repair occupations | 93 | Farming, fishing, and forestry occupations | 1 |
| Building and grounds cleaning and maintenance, personal care and service occupations | 77 | Military | 0 |

Table 10-7. Scenario D with B&T changes in average yearly employment by job classification

| **Highest 5 Job Descriptions, number of jobs** | | **Lowest 5 Job Descriptions, number of jobs** | |
|---|---|---|---|
| Production occupations | 13 | Management, business, and financial occupations | -16 |
| Construction and extraction occupations | 11 | Food preparation and serving related occupations | -22 |
| Life, physical, and social science occupations | 2 | Building and grounds cleaning/maintenance personal care and service occupations | -34 |
| Farming, fishing, and forestry occupations | 0 | Healthcare occupations | -37 |
| Military | 0 | Sales and related, office and administrative support occupations | -89 |

## 10.2 Impact of Credit Price

If Washington state adopts a CFS and implements a cost containment mechanism that involves a credit cap, it is of interest to estimate the impact of different credit price caps on macro-economic indicators. As mentioned in Section 6.5, all of the scenarios were evaluated with the assumed credit price profile shown in Figure 6-5 with a maximum price (cap) at $100 per tonne. In addition, Scenario C with banking and trading was evaluated according to three additional credit price profiles (shown in Figure 6-6) with credit prices capping out at $50, $150 and $250 per tonne. Recall that this scenario experiences one of the poorer economic outcomes because no cellulosic fuel is utilized and as a result experiences no economic activity due to construction of cellulosic fuel production plants.

Figure 10-8 through Figure 10-10 summarize GSP, jobs and personal income as a function of maximum credit price. These three indicators show that this Scenario starts out with an economic impact in which gains and losses nearly cancel out (with a slight overall loss in later years). The variations in the potential maximum credit price (modeled as differences in conventional-fuel prices) show that over the range of potential maximum credit prices, economic-impact prospects become poorer as credit prices rise. This is because the credit value is absorbed into the cost of the conventional fuel, and passed through as described in earlier sections to the fuel purchaser.

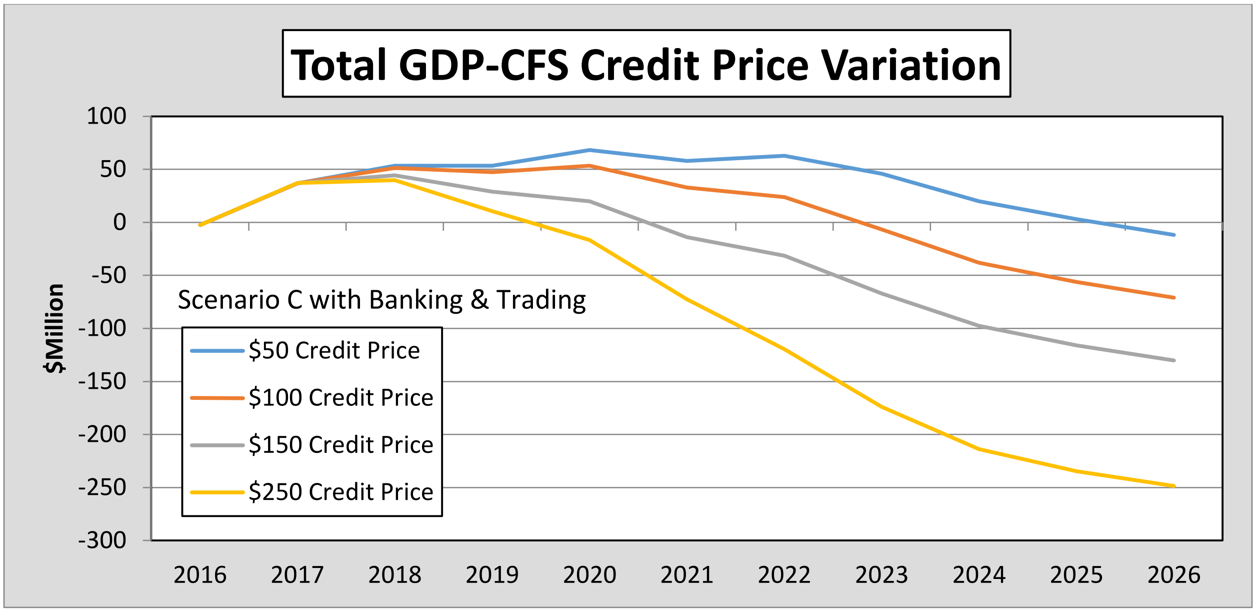


Figure 10-8. Change in GSP Relative to BAU as a function of credit price.

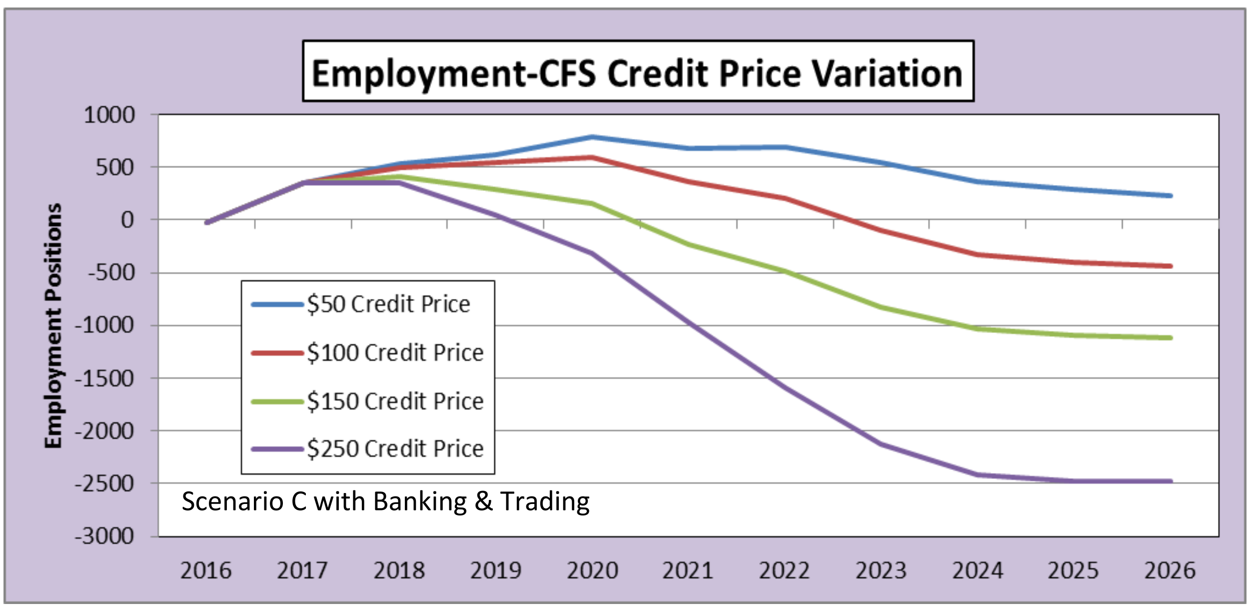


Figure 10-9. Change in Employment Relative to BAU as a function of credit price.

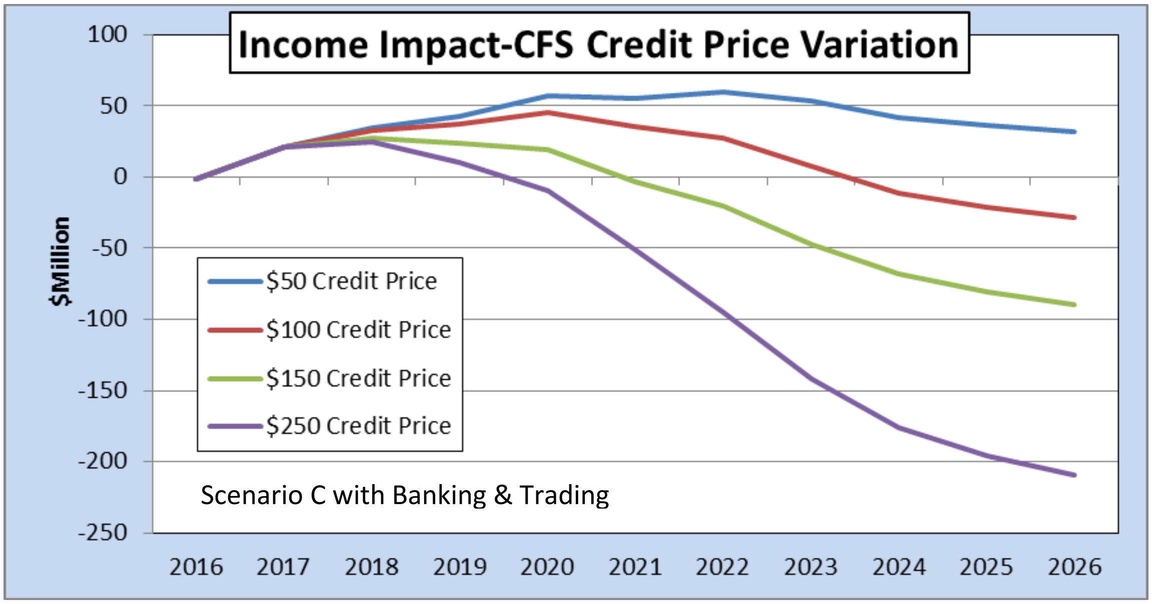


Figure 10-10. Change in Personal Income Relative to BAU as a function of credit price.

## 10.3 Impact of In-State vs Out-of-State Cellulosic Plants

An additional sensitivity test was performed to quantify the impact of having cellulosic production capacity within Washington state. Recall that the base assumption was that up to three cellulosic plants would be sited in-state. Figure 10-11 through Figure 10-13 provide economic indicators for Scenario B with banking & trading for the base case (three cellulosic fuel plants in-state) and assuming that all cellulosic fuel is imported into Washington. This analysis shows that GSP, employment and personal income are effectively unchanged from the BAU when cellulosic fuel is imported, while in-state fuel production is beneficial in creating positive spikes both during and after construction of new facilities (as indicated by the above-zero values for all major indicators in 2026 – two years after the plant construction is completed and no longer stimulating the economy). If the state implements a CFS, it may want to consider incentivizing in-state production to achieve these benefits (especially if financed with a significant share of out-of-state capital).

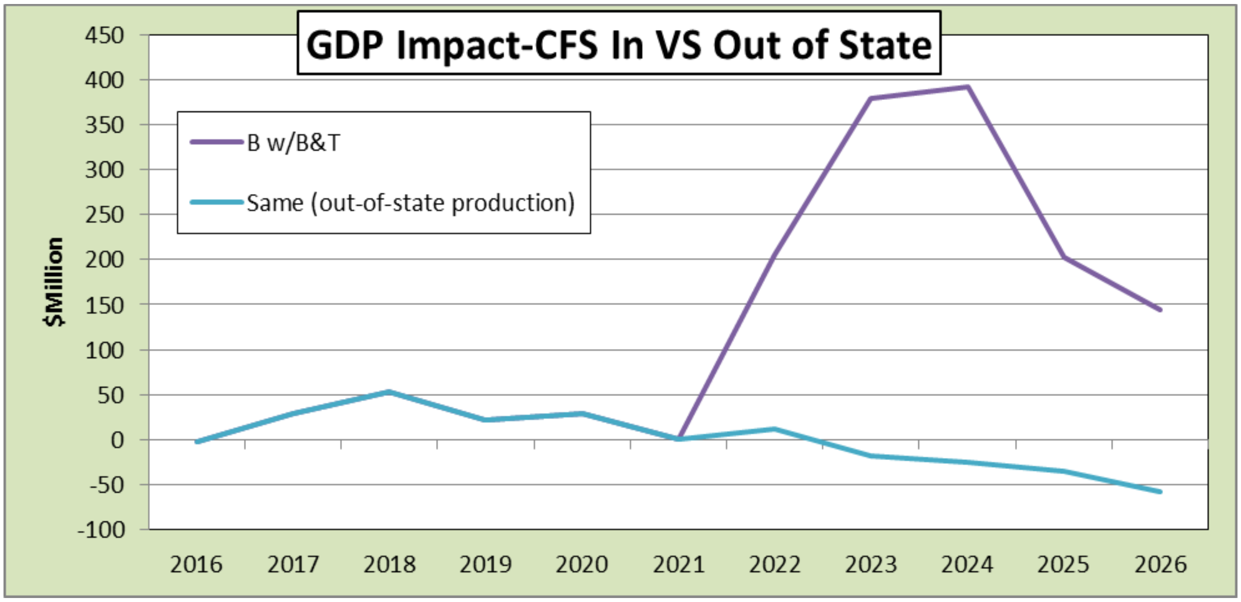


Figure 10-11. Effect of in-state cellulosic fuel production on GSP Relative to BAU.

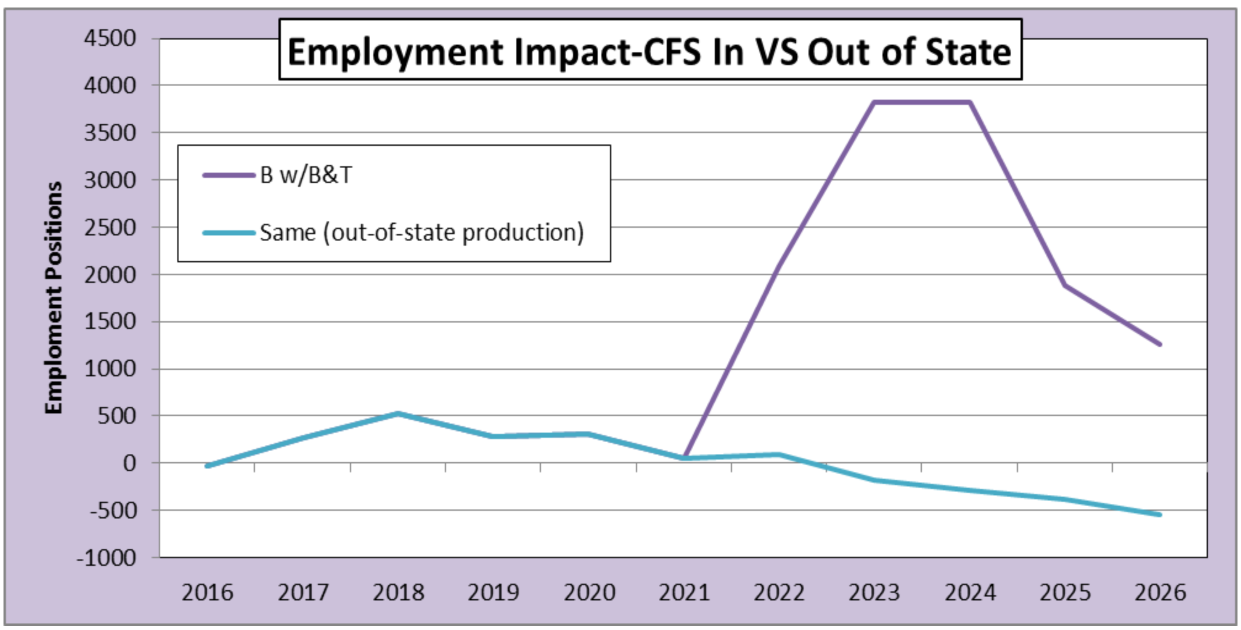


Figure 10-12. Effect of in-state cellulosic fuel production on employment relative to BAU.

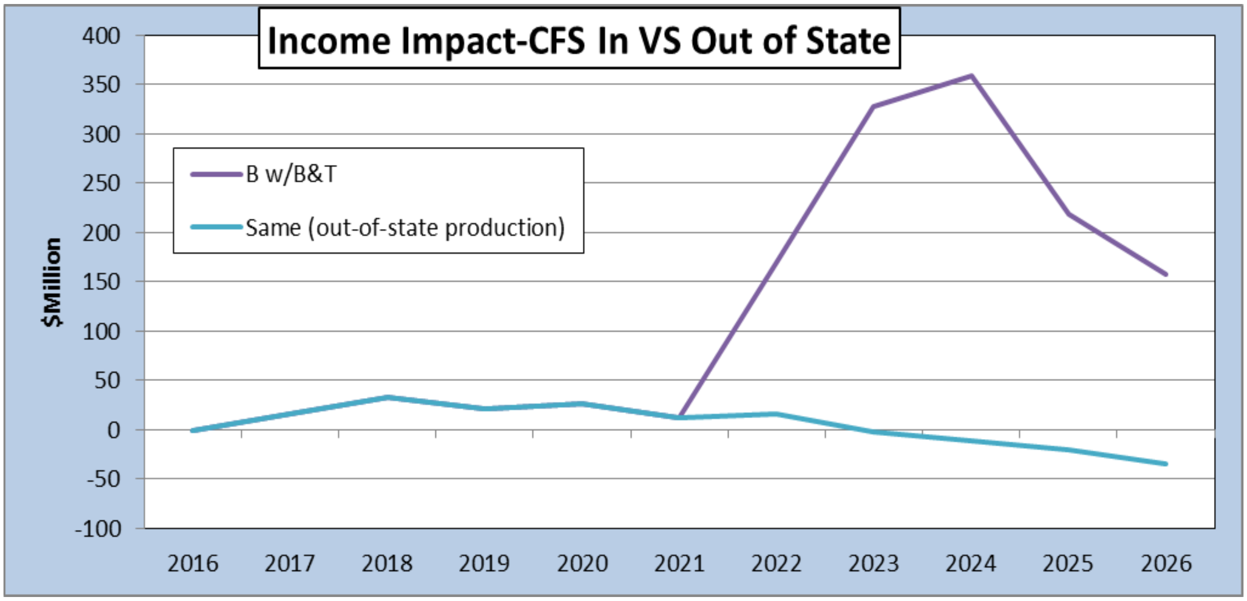

Figure 10-13. Effect of in-state cellulosic fuel production on personal income relative to BAU.

# Appendix A – VISION Model Input Assumptions

The VISION model is a U.S. on-road transportation fleet turnover model developed and maintained by Argonne National Laboratory. It provides forecasts of vehicle energy consumption, consumer spending on fuel and vehicles, and vehicle populations by vehicle class and technology type through the year 2100. VISION uses historic U.S. sales data, combined with annual U.S. fleet turnover data by model year to estimate vehicle survival and age-dependent fuel use for the existing fleet (1970 to present). To project characteristics of the future fleet, the model uses assumptions about future sales of conventional and alternative fuel vehicles, fuel economy, and VMT based on the most recent EIA Annual Energy Outlook (AEO) forecast. The current version of the model reflects the AEO2013 projections through 2030. Some of the assumptions have been modified for this analysis and these modifications are explained in the following paragraphs.

## Vehicle Populations by Class

The VISION model divides vehicles into four classes: light duty auto (lda), light duty truck (ldt), medium duty vehicles (MDV, class 3-6), and heavy duty vehicles (HDV, class 7 & 8). The first step in modifying the VISION model to reflect the Washington fleet is to replace the U.S. vehicle sales for each of these four categories with Washington state vehicle sales for the legacy fleet. We have utilized the sales data for 1978-2007 from the analysis done in 2009 and added sales for 2008-2013 provided by the Washington State Department of Licensing.

To project future sales by class, we apply the ratio of Washington state sales to U.S. sales to the VISION U.S. sales projections. Table A-1 provides the five-year average ratio of Washington to U.S. vehicle sales by class. Figure A-1 provides the historic and projected total vehicle sales utilized in the BAU and all compliance scenarios.

Table A-1. Ratio of Washington State vehicle sales to U.S. vehicle sales.

| | LDA | | | LDT | | | MDV | | | HDV | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | WA | U.S. | WA % | WA | U.S. | WA % | WA | U.S. | WA % | WA | U.S. | WA % |
| 2009 | 89,663 | 4,987,176 | 1.8% | 77,142 | 5,200,478 | 1.5% | 4,290 | 177,505 | 2.4% | 2,440 | 133,885 | 1.8% |
| 2010 | 91,252 | 5,682,258 | 1.6% | 92,953 | 5,513,693 | 1.7% | 4,451 | 208,697 | 2.1% | 2,404 | 151,920 | 1.6% |
| 2011 | 84,448 | 6,521,729 | 1.3% | 115,791 | 6,099,211 | 1.9% | 7,080 | 256,911 | 2.8% | 1,670 | 197,414 | 0.8% |
| 2012 | 113,227 | 7,278,122 | 1.6% | 92,901 | 6,663,358 | 1.4% | 7,845 | 242,781 | 3.2% | 2,552 | 220,784 | 1.2% |
| 2013 | 103,495 | 7,494,247 | 1.4% | 108,400 | 7,086,260 | 1.5% | 8,883 | 257,068 | 3.5% | 2,890 | 235,831 | 1.2% |
| Average | | | 1.5% | | | 1.6% | | | 2.8% | | | 1.3% |

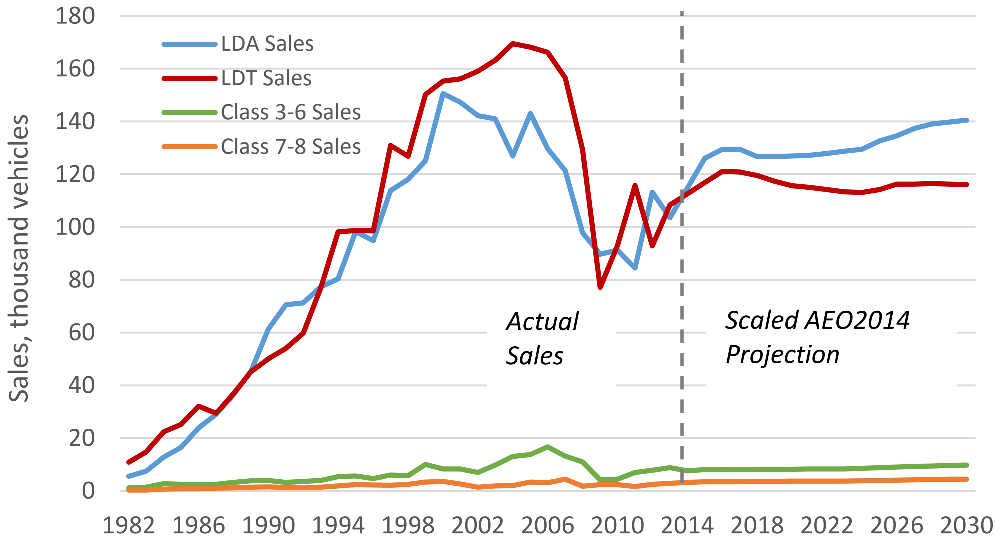


Figure A-1. Projected vehicle sales in Washington State by class.

### Vehicle Technology Market Shares

After total vehicle sales by class for Washington state have been projected, the vehicle technology market shares need to be determined. For light auto plug-in electric vehicles (PEVs), we set the population in 2020 to be consistent with the Washington state PEV goal[67] of 50,000 cumulative vehicle sales by 2020. The VISION model default (AEO2013 projection) assumes ~25/75 split between BEVs/PHEVs while Washington sales data for 2011-2013 shows a 75/25 BEV/PHEV split. For this analysis we assume a 50/50 BEV/PHEV split and smooth from most recent actual data (2013) to this point by 2018. We feel that it is reasonable to decrease the BEV share despite strong performance to date; this early surge in BEV market shares relative to PHEV shares may be anomalous relative to long term trends due to early model availability and favorable leasing terms. These assumptions yield the market shares shown in Figure A-2. In the figure, historic sales are solid lines, large dashes are AEO2014 Pacific projections, and small dots are the projections used for the current analysis. Note that current Washington state PEV sales are more than two times higher than AEO values.

[67] Results Washington Electric Vehicle Action Plan, Goal 5.2.3.b

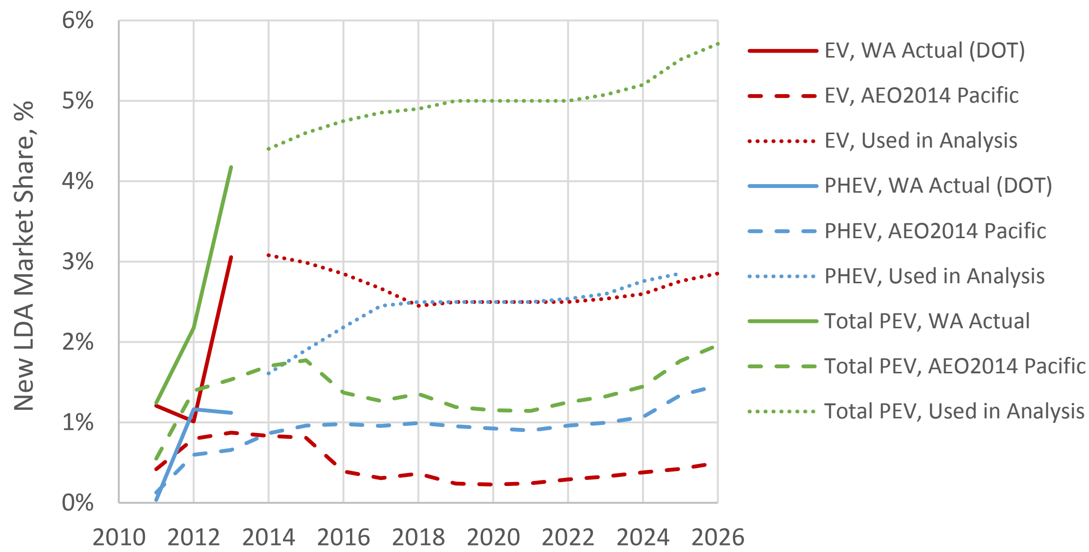

Figure A-2. Forecast light auto PEV Market Shares for Washington State

Figure A-3 provides market share forecasts utilized for light auto hybrid electric vehicles (HEVs), diesel and ethanol FFVs. For HEVs, the historic market share in Washington state is 2.6 times the AEO2014 Pacific projection. For the analysis we apply a factor of 2.6 to the AEO projection. For diesel and FFVs, we utilize the AEO projection.

Figure A-4 provides LDA market shares for CNG and hydrogen FCVs. Washington's current market share for CNG vehicles is much lower than the AEO market shares for 2011-2013. Based on discussions with Washington's Department of Transportation, CNG refueling investment is occurring, so we assume here that market shares gradually approach AEO levels. For hydrogen FCVs, we have assumed half of the AEO market share because Washington is not a ZEV state; we assume most of these vehicles in AEO's projection will be sold into California. For diesel HEVs, we utilize the AEO forecast.

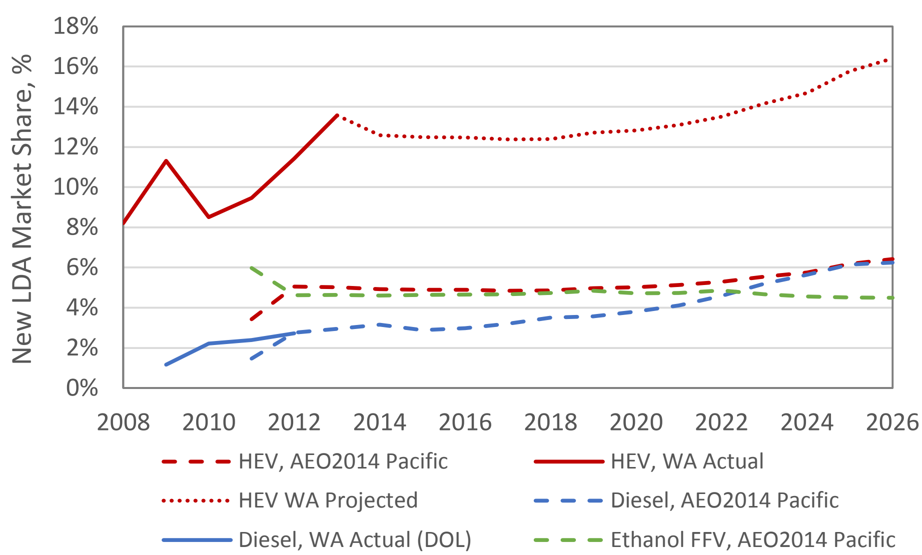

Figure A-3. LDA market shares for HEVs, diesel and ethanol FFVs.

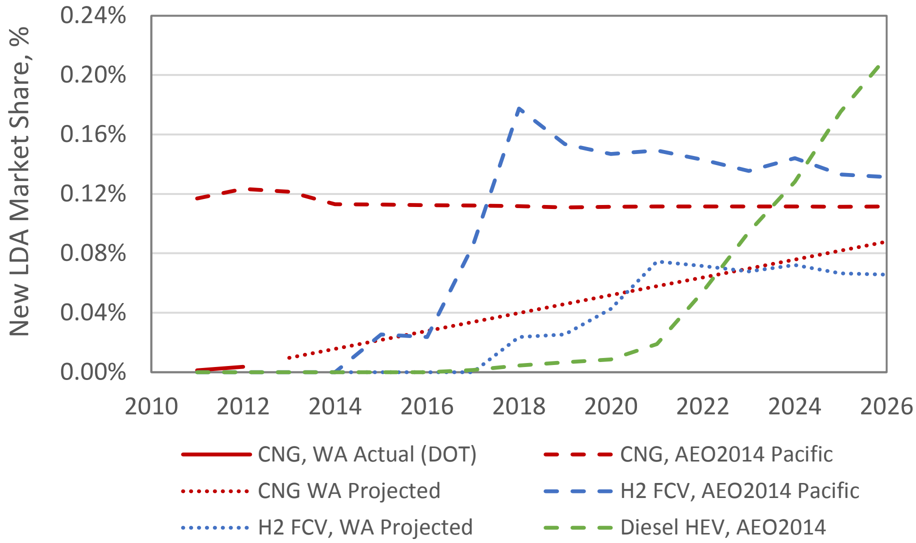


Figure A-4. LDA market shares for CNG, H2 FCV, and diesel HEVs.

Forecast market shares for light truck BEV, CNG and hydrogen FCVs are illustrated in Figure A-5. We utilize the AEO forecast for BEVs. We adopt the LDA approach for FCVs (1/2 AEO) and CNG vehicles (slow ramp to AEO forecast). Figure A-6 provides the market shares for light truck HEVs and diesel vehicles. We assume that HEV shares ramp to the AEO forecast. For diesel light trucks, sales in Washington state have been 1.8 times higher than the AEO estimates for 2010-2012. For this analysis, we apply a factor of 1.8 to the AEO diesel projections.

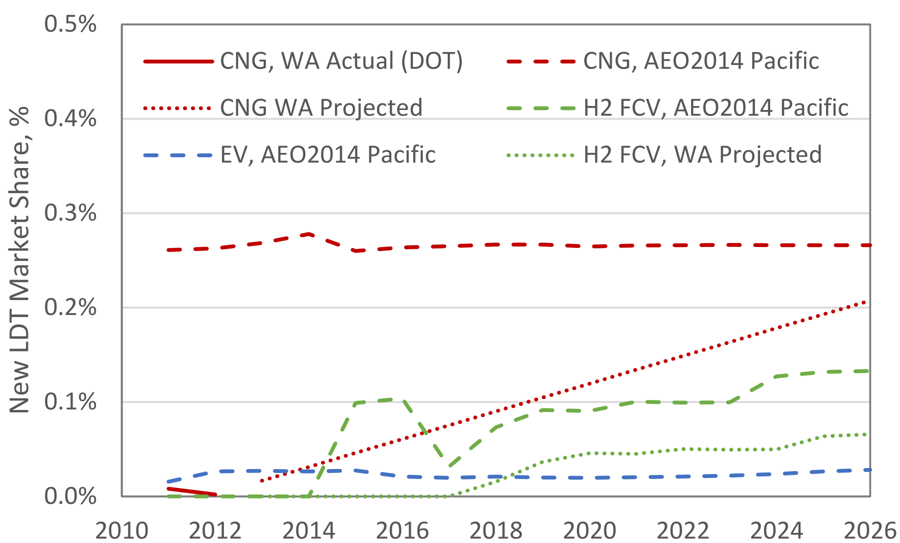


Figure A-5. Light truck market share projections for BEVs, CNG and FCVs

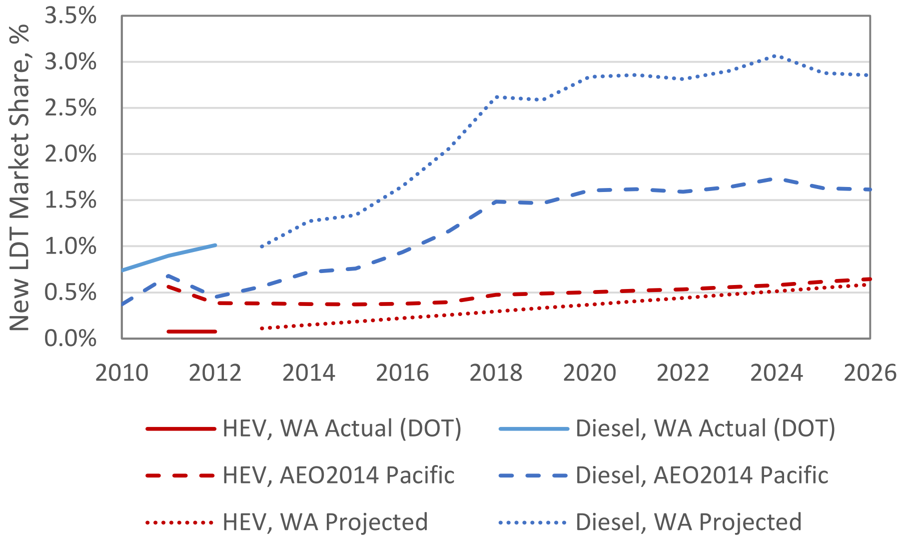


Figure A-6. Light truck market share projections for HEV and diesel

For medium duty vehicles (MDVs), we utilize historic shares for gasoline (36%). Similar to light duty CNG vehicles, we assume a gradual ramp up to the AEO projected market share. AEO does not have a forecast for diesel HEVs, so we utilize a recent publication by Navigant.[68] The resulting market shares are provided in Figure A-7. The balance of vehicles are diesel.

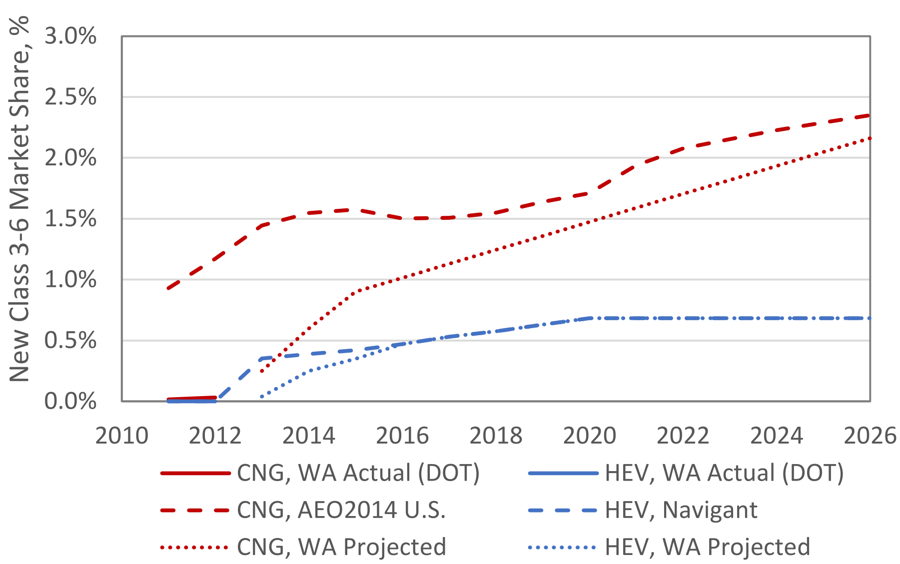


Figure A-7. MDV market share forecasts for HEV and CNG vehicles.

For heavy duty vehicles, we utilize historic shares for gasoline (2.4%). For CNG, we set 2013 at the 2008-2012 average, and then follow the AEO projection. Figure A-8 provides these forecasts. The balance of vehicles sold are diesel.

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[68] http://www.truckinginfo.com/channel/fuel-smarts/article/story/2014/03/the-latest-developments-in-hybrid-electric-medium-duty-trucks.aspx

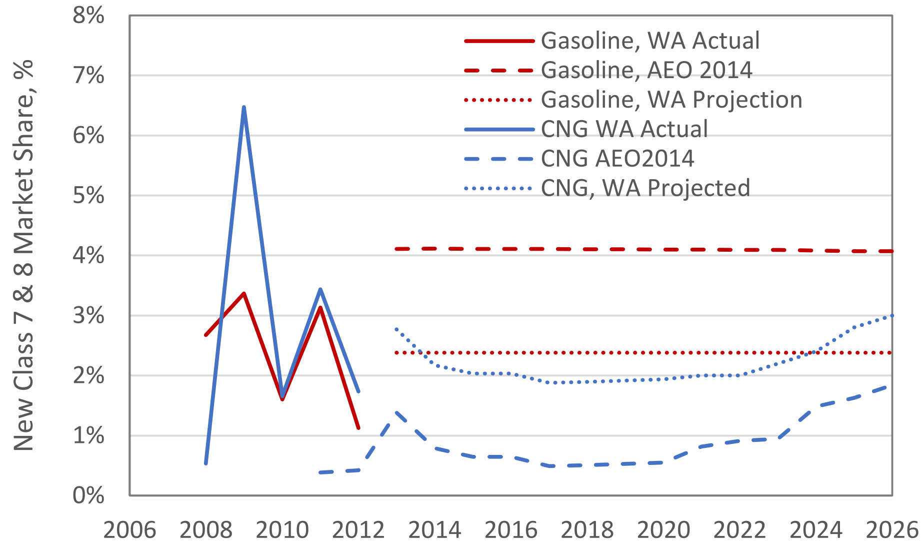


Figure A-8. HDV market share forecasts for gasoline and CNG vehicles.

Total vehicle sales forecasts by class (discussed in the previous section) combined with market share forecasts yield vehicle sales by technology type shown in Figures A-9 through A-12. Table A-2 provides BAU alternative vehicle populations.

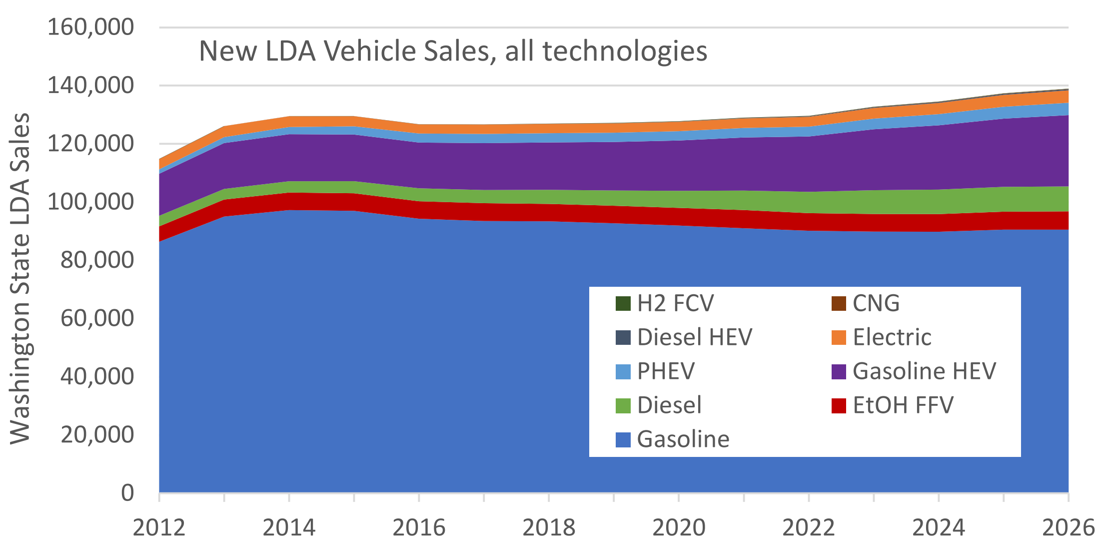


Figure A-9. Forecast light duty auto vehicle sales.

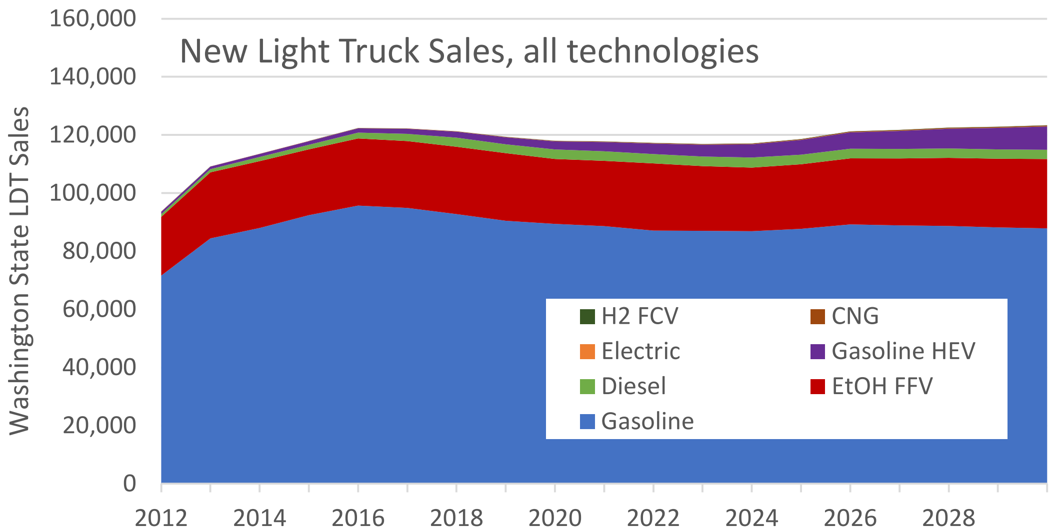


Figure A-10. Forecast light duty truck vehicle sales.

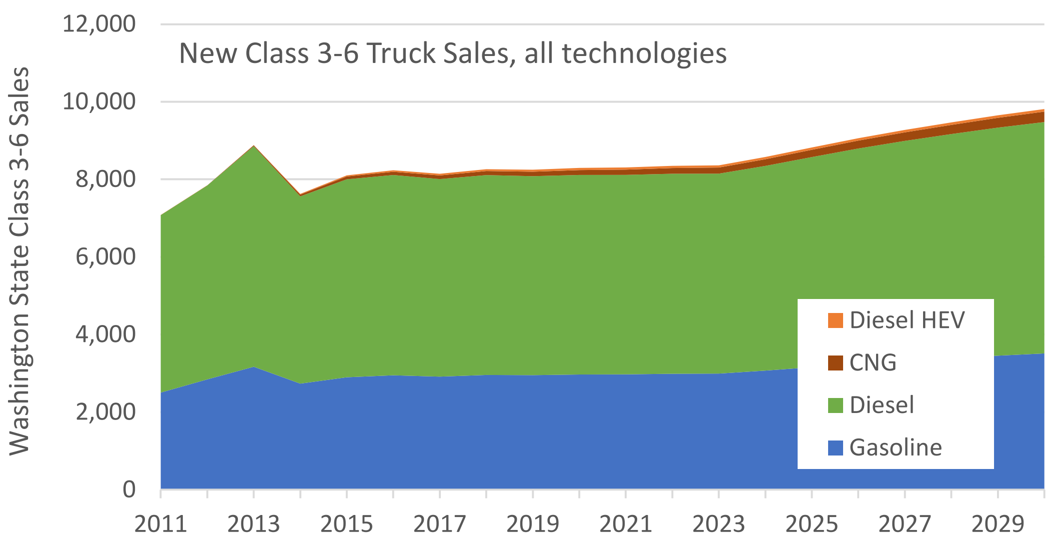


Figure A-11. Forecast medium duty vehicle sales.

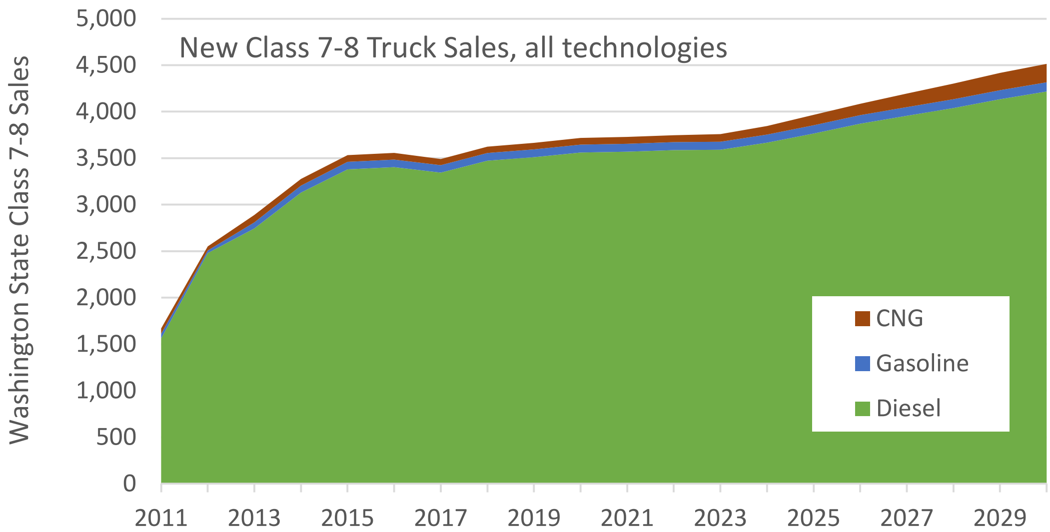


Figure A-12. Forecast heavy duty vehicle sales.

Table A-2. BAU Alternative Fuel Light Duty Vehicle Population Projections

| BAU | LDA | | | | LDT | | | |
|---|---|---|---|---|---|---|---|---|
| | CNG | BEV | PHEV | FCV | CNG | BEV | PHEV | FCV |
| 2016 | 246 | 16,335 | 9,401 | 0 | 245 | 278 | 5 | 0 |
| 2017 | 279 | 19,695 | 12,475 | 0 | 333 | 293 | 10 | 0 |
| 2018 | 320 | 22,596 | 15,812 | 33 | 437 | 309 | 16 | 19 |
| 2019 | 369 | 25,424 | 19,157 | 69 | 556 | 322 | 22 | 64 |
| 2020 | 427 | 28,106 | 22,408 | 129 | 689 | 332 | 27 | 119 |
| 2021 | 493 | 30,632 | 25,547 | 234 | 836 | 342 | 33 | 174 |
| 2022 | 566 | 33,015 | 28,565 | 334 | 997 | 352 | 40 | 233 |
| 2023 | 639 | 35,304 | 31,501 | 429 | 1,169 | 361 | 47 | 290 |
| 2024 | 701 | 37,526 | 34,398 | 530 | 1,354 | 371 | 54 | 346 |
| 2025 | 805 | 39,876 | 37,455 | 622 | 1,553 | 383 | 62 | 417 |
| 2026 | 916 | 42,241 | 40,519 | 711 | 1,768 | 397 | 71 | 491 |

### Vehicle Fuel Economy

The VISION model utilizes sales weighted averages of AEO fuel economy projections. The fuel economy values are EPA rated fuel economies; the VISION model applies EIA's degradation factors to arrive at on-road fuel economy. We have utilized the AEO projections for most of the vehicles, but have utilized ARB's LCFS energy economy ratios (EERs) for several vehicles. The EER is a ratio of energy input per mile for the conventional vehicle over the energy input per mile for the alternative fuel vehicle. These ratios are applied to the conventional vehicle fuel economy to estimate alternative fuel vehicle fuel economy. Table A-3 provides the EER values utilized here to project fuel economy. Figures A-13 through A-15 provide the fuel economy projections for light autos, light trucks, and trucks.

Table A-3. EER values utilized to project alternative vehicle fuel economy

| Vehicle Technology | EER |
|---|---|
| Light and medium duty CNG | 1.0 |
| Light duty ethanol FFV | 1.0 |
| Light duty EV (and electric portion of PHEV) | 3.4 |
| Light duty hydrogen FCV | 2.5 |
| Heavy duty CNG | 0.9 |

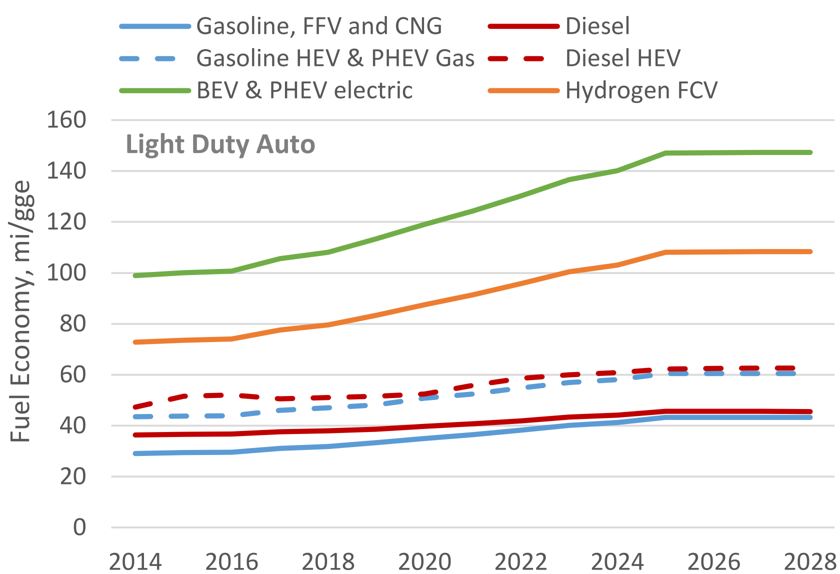


Figure A-13. Projected light duty auto fuel economy.

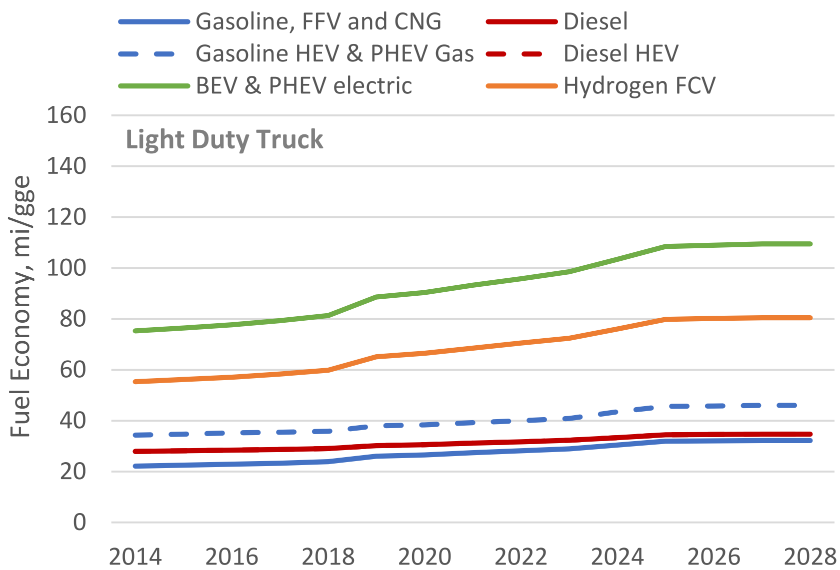


Figure A-14. Projected light duty truck fuel economy.

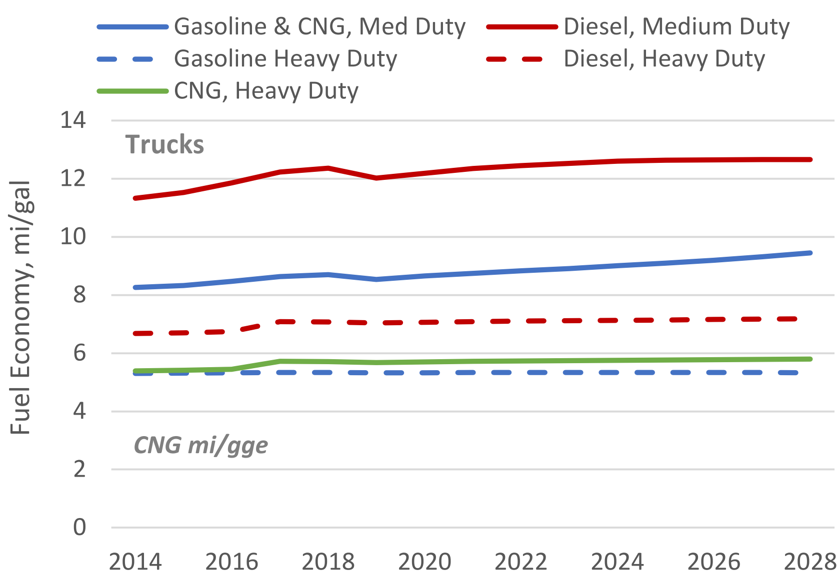


Figure A-15. Projected medium and heavy truck fuel economy.

### Vehicle Miles Traveled and Fuel Consumption

The VISION model calculates total vehicle miles traveled (VMT) by vehicle class based on population and a VMT per vehicle estimate which declines as vehicles age. Total VMT for each vehicle technology is combined with the fuel economy estimate (provided above) to determine fuel consumption by fuel type and vehicle class. The VISION predicted gasoline and diesel consumption for 2008-2013 can be compared to actual gasoline and diesel consumption; we apply factors to the VMT estimates to calibrate the VISION model so that calculated gasoline and diesel use match actual gasoline and diesel use. We apply the calibration factors to 2014-2026 VMT estimates to project Washington gasoline and diesel use.

In the first draft of this analysis, we utilized WSDOT's 2013 projections of VMT; however in late September the 2014 projections were published showing significant decreases in VMT. For the second draft of the analysis, we utilized the WSDOT 2014 VMT projections, which resulted in significant decreases in (primarily diesel) fuel consumption. Since the October 29 draft of this report, WSDOT has indicated that the modeling effort should not rely on its 2014 VMT projections. In this final version of the analysis, we have utilized AEO2014 VMT per vehicle projections. Figure A-16 provides the 2014 WSDOT light duty VMT forecast and the VISION forecast based on AEO2014 projections and the Washington vehicle population projection. Figure A-17 compares the Washington State Transportation Revenue Forecast Council (TRFC) 2014 projected gasoline consumption to the VISION calculated gasoline consumption. The VISION projected 2026 gasoline consumption decreases over time due to improving average light vehicle fuel economy. The TRFC forecast uses economic indicators to project fuel consumption and is only weakly dependent on fuel economy. As a result, the TRFC gasoline consumption projection is relatively flat. The VISION projected gasoline consumption is approximately 20 percent lower than the TRFC projected consumption in 2026.

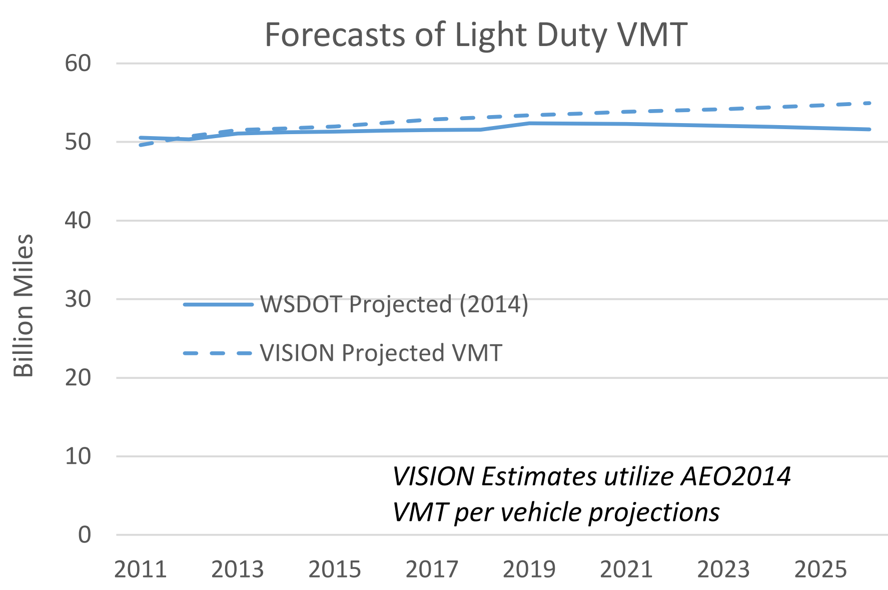


Figure A-16. Light duty VMT forecasts (updated to WSDOT 2014 projection).

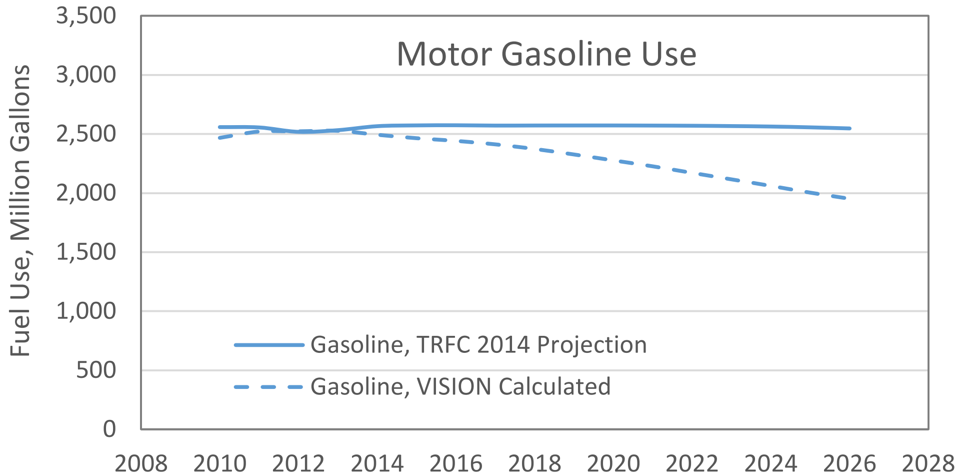


Figure A-17. Actual and calculated gasoline consumption.

The heavy duty VMT was adjusted in a similar fashion to calibrate the model to accurately predict diesel consumption. Figures A-18 and A-19 provide the medium and heavy duty VMT forecasts and corresponding diesel fuel consumption.

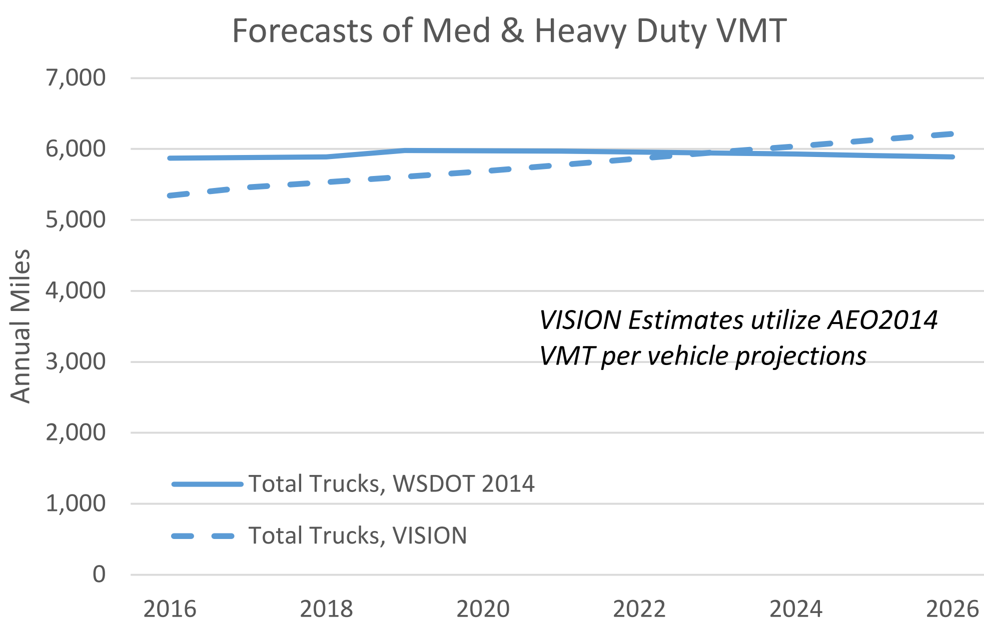


Figure A-18. Medium and heavy duty VMT forecasts.

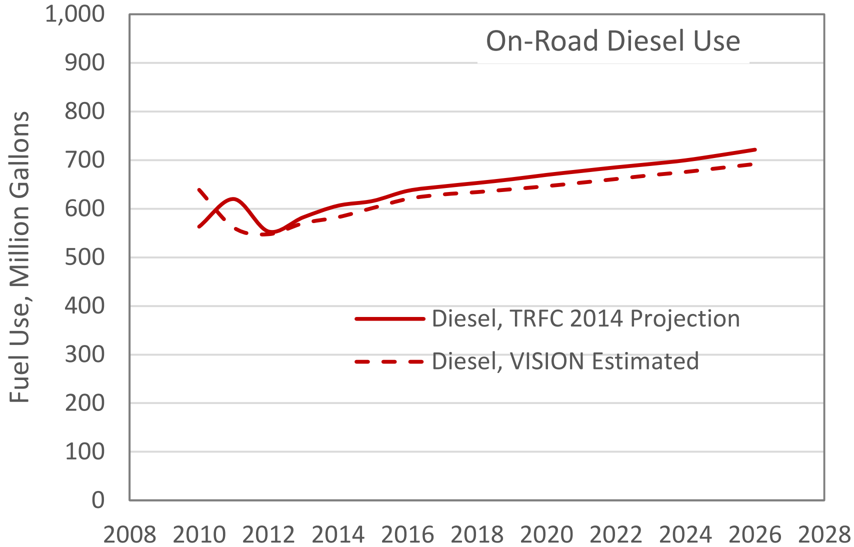


Figure A-19. Actual and calculated diesel consumption.

### Vehicle Prices

The macro-economic model will evaluate the effect of incremental consumer spending on vehicles relative to the BAU. As discussed above, the VISION model quantifies the number of vehicles sold by class and technology each year. Incremental spending on vehicles relative to a base vehicle can be quantified for the BAU and each compliance scenario by multiplying the sales by the assumed incremental vehicle cost. Only Scenario A (with and without banking and trading) has different vehicle populations than the BAU, so the following discussion only applies to incremental vehicle spending in Scenario A. Only populations of BEVs, PHEVs, FCVs, and CNG vehicles have been modified for Scenario A, so these are the incremental vehicle price assumption presented here.

For light duty vehicles, we have utilized incremental prices from a recent National Academy of Sciences (NAS)[69] study. The NAS analysis compares like vehicles to establish incremental retail prices. Figures A-20 and A-21 provide the incremental fuel prices utilized in this analysis. The NAS incremental prices for hydrogen FCVs is substantially lower than the BEV increment in 2010. Preliminary pricing announced by Honda and Toyota for the first FCVs to be sold in 2015 is $69,000, at the suggestion of the workgroup we have set the FCV price in 2016 at the same incremental price as the BEV and then allow it to approach the NAS value in 2030.

We have reduced the incremental prices shown for BEVs and PHEVs to reflect the federal tax credit of $7,500 (~$3,000 of PHEV20s). This tax credit phases out for each manufacturer when that manufacturer sells 200,000 vehicles in the U.S. To date approximately 63,000 Chevy Volts and 55,000 Nissan Leafs have been sold. Although the credit for Leafs is anticipated to expire by 2017, there are other EV manufacturers that will not hit the 200,000 mark by then. We assume that the tax credit begins to phase out in 2018.

[69] Transitions to Alternative Vehicles and Fuels, National Academy of Sciences, 2013

The Washington state Washington state exemption on vehicle use and sales tax expires in 2015. Although efforts are underway to extend this benefit for EVs, FCVs and CNG vehicles, the extension is not on the books so is not included in this analysis.

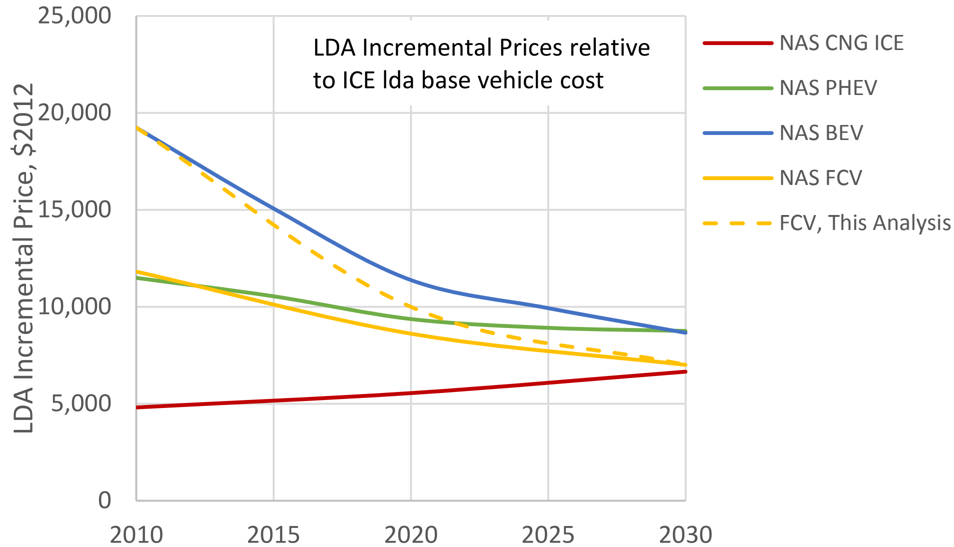


Figure A-20. Light duty auto incremental vehicle prices.

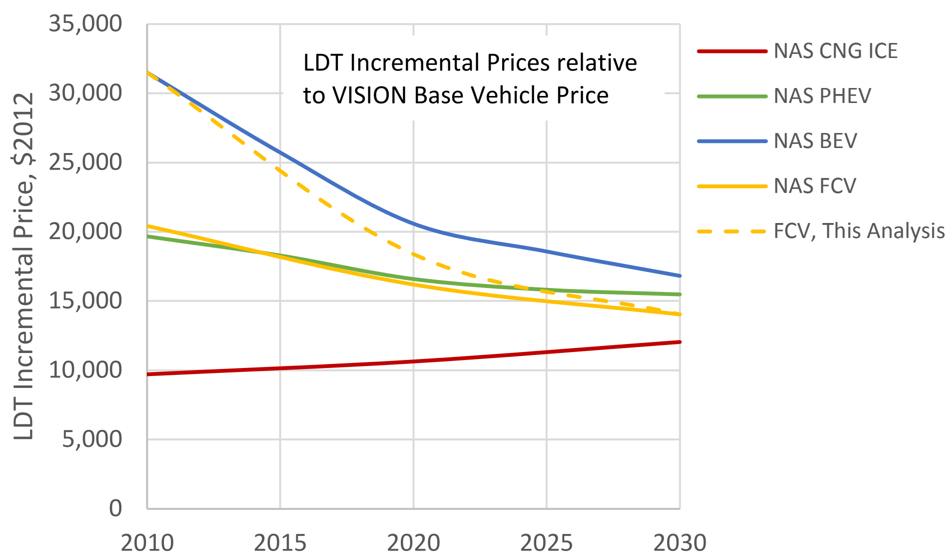


Figure A-21. Light duty truck incremental vehicle prices.

Finally, all BEVs must pay an annual $100 registration fee[70] to make up for lost fuel tax revenue. These costs are provided in Table A-4.

Table A-4. Annual Registration Fees Paid for BEVs

| | BAU, Scen B-D | | Scen A | |
|---|---|---|---|---|
| | Number of BEVs | Reg Fees Paid | Number of BEVs | Reg Fees Paid $ |
| 2016 | 16,613 | $1,661,300 | 16,613 | $1,661,300 |
| 2017 | 19,988 | $1,998,800 | 19,988 | $1,998,800 |
| 2018 | 22,905 | $2,290,500 | 22,905 | $2,290,500 |
| 2019 | 25,746 | $2,574,600 | 26,513 | $2,651,300 |
| 2020 | 28,438 | $2,843,800 | 31,408 | $3,140,800 |
| 2021 | 30,974 | $3,097,400 | 37,381 | $3,738,100 |
| 2022 | 33,367 | $3,336,700 | 44,013 | $4,401,300 |
| 2023 | 35,665 | $3,566,500 | 51,380 | $5,138,000 |
| 2024 | 37,897 | $3,789,700 | 59,088 | $5,908,800 |
| 2025 | 40,259 | $4,025,900 | 66,675 | $6,667,500 |
| 2026 | 42,638 | $4,263,800 | 74,128 | $7,412,800 |

[70] http://app.leg.wa.gov/rcw/default.aspx?cite=46.17.323

### Fuel Price Projections

One key assumption for the economic analysis is consumer spending on transportation fuel. The assumptions made to quantify fuel consumption with the VISION model have been provided above. Fuel consumption and fuel price projections yield projected consumer spending on fuel. This section provides the fuel price projections utilized. All fuel prices shown are in $2012 and do not include the effects of any CFS credit prices.

We have utilized EIA's AEO2014 fuel price projections for the pacific region where available. Figure A-22 provides the projected gasoline and diesel prices. Gasoline prices are forecast to increase to approximately $4.50 per gallon by 2016 and diesel prices are forecast to increase to $5.50 per gallon. Because cellulosic gasoline is indistinguishable from fossil gasoline at the pump, we assume that cellulosic gasoline has the same price as fossil gasoline.

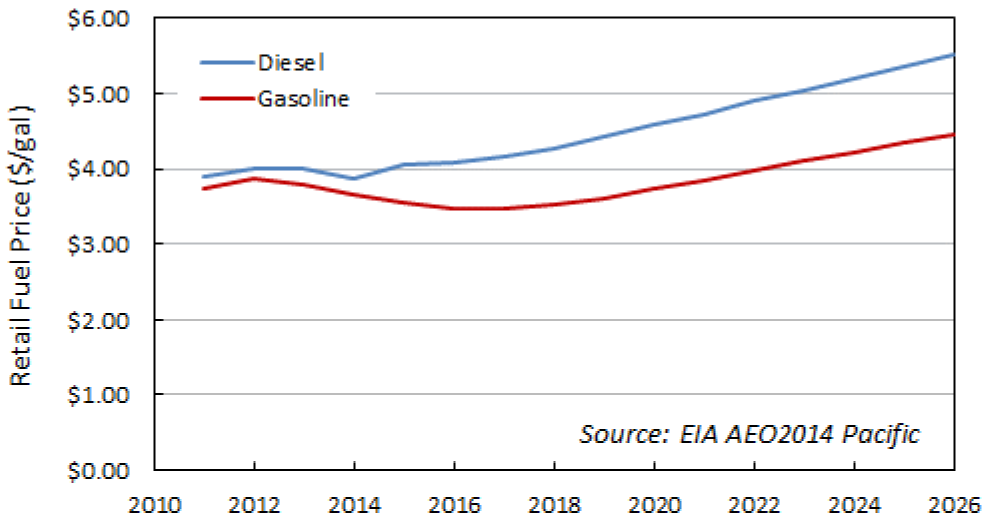


Figure A-22. EIA Gasoline and diesel fuel price projections.

Figure A-23 provides the ratio of EIA's forecast of ethanol prices (E85) and forecast gasoline prices. Historical data indicates that on an energy basis, ethanol has been price at a premium to gasoline. EIA projects that by 2017 ethanol (as E85) prices will be at parity with gasoline on an energy basis. We have assumed a ratio of 1 for 2017 through the end of the analysis period.

EIA does not provide a price estimate for ethanol sold as a blending component with gasoline. For this analysis we assume the price starts at the current E85 premium (on an energy basis) and that this premium declines at a rate of 5% per year. Figure A-24 provides the assumed price projection for ethanol sold as a gasoline blending component. Although the price per gallon is lower than that for gasoline, a large premium on an energy basis persists. Ethanol as a blending component does add value an octane enhancer.

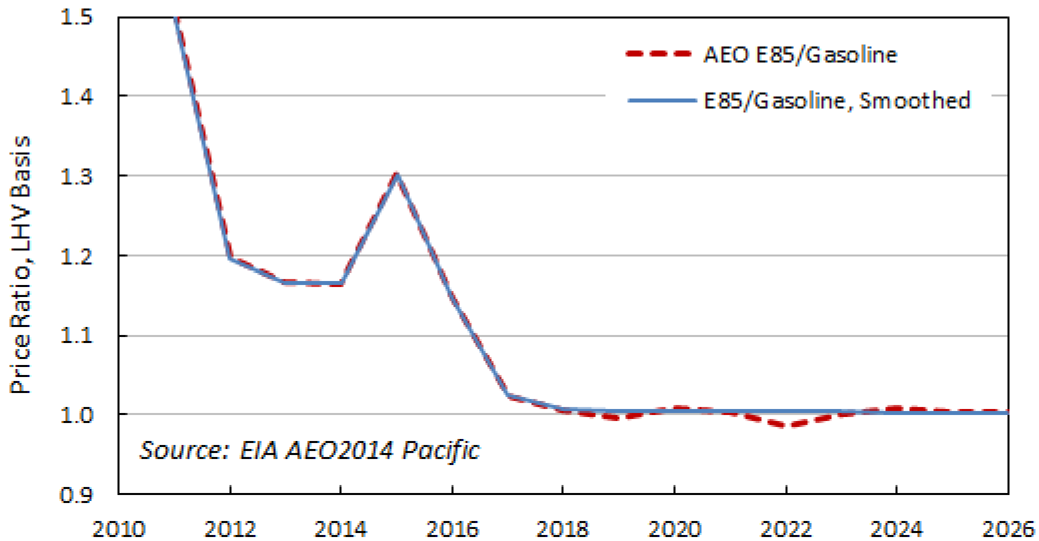

Figure A-23. EIA forecast of ethanol prices sold as E85.

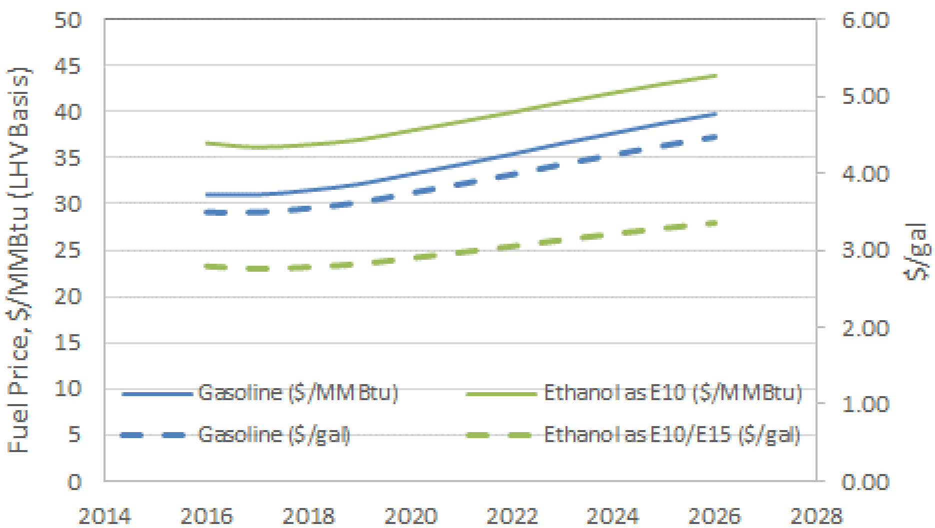

Figure A-24. Price projection for ethanol sold as E10/E15.

EIA does not project prices of biodiesel, however data show that biodiesel prices have tracked the price of diesel, generally with a price premium over diesel. The magnitude of the price premium has been due to the valuation of RINs, CFS credits, and other market factors. Volatility in the RIN market has resulted in volatility in the price spread between biodiesel and diesel. Based on discussions with biodiesel producers, energy traders, and representatives of the National Biodiesel Board, the net price after the value of RINs must be lower than that for diesel fuel on a volumetric basis. Biodiesel blenders do not realize any additional value related to the properties of biodiesel. In fact, the energy content is slightly lower than that of conventional diesel. However, this difference in energy content does not appear to affect marketing or pricing. Based on discussions with market agents, we have assumed a 25 cent per gallon discount (excluding the value of RINs and CFS credits). Figure A-25 provides the biodiesel price projection compared to the diesel price projection.

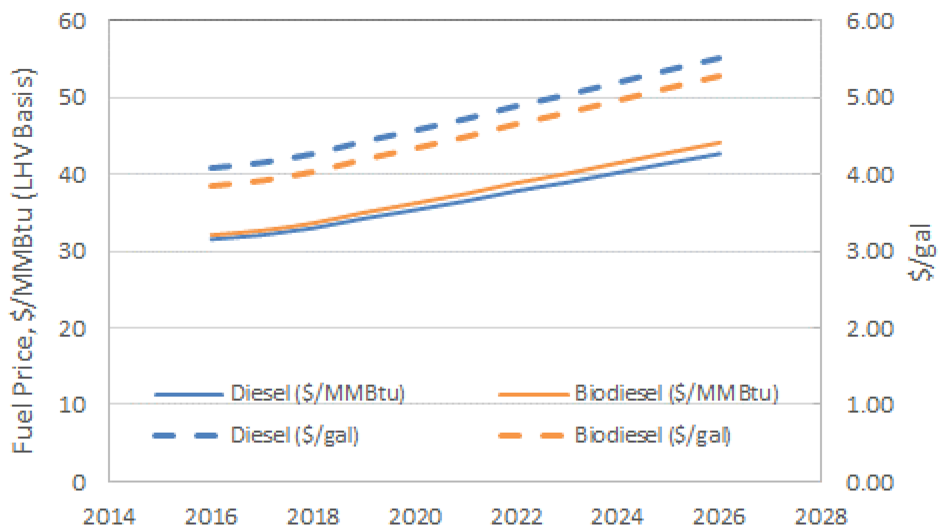

Figure A-25. Assumed biodiesel price projection.

We have utilized AEO's forecast for CNG prices. Figure A-26 provides the forecast CNG price compared to the gasoline price and commercial natural gas prices. On an energy basis, CNG is approximately 60 percent of the price of gasoline.

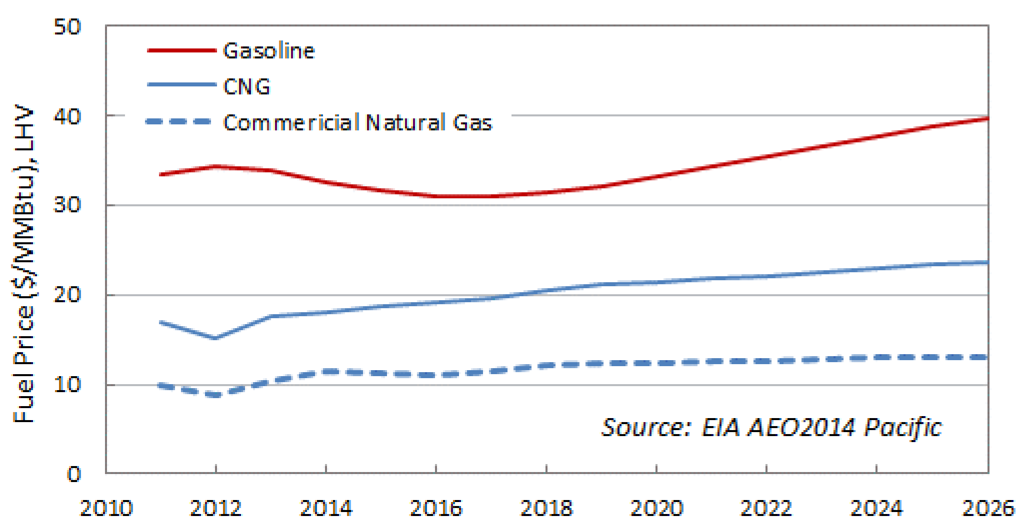

Figure A-26. Forecast CNG prices.

Washington electricity prices for transportation have historically been 78 percent of EIA's pacific prices.[71] We assume this discount persists and have applied a factor of 0.78 to EIA's projected electricity prices for this analysis. The forecast prices are provided in Figure A-27. Prices are shown in $/kWh and $/MMBtu with the EER (3.4) applied.

[71] U.S. Energy Information Administration, Form EIA-861, "Annual Electric Power Industry Report."

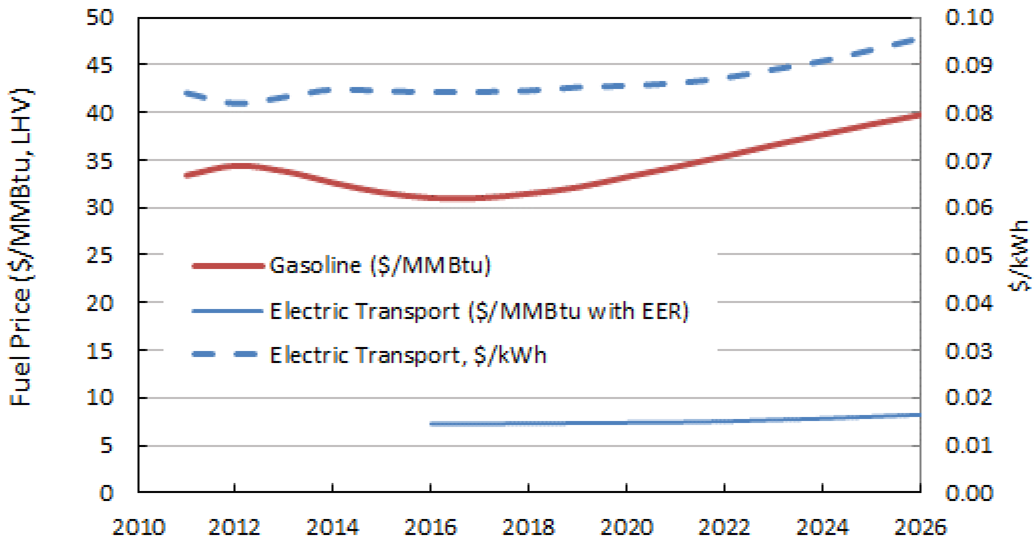


Figure A-27. Forecast electricity price.

## Appendix B - Infrastructure Requirements

To support increased utilization of low carbon fuels, significant investment in infrastructure is required. The following sections provide the assumptions utilized to quantify the needed infrastructure spending relative to the BAU for each compliance scenario.

### EV Charging

Only Scenario A with and without banking and trading had different PEV populations than the BAU case, so these assumptions are only utilized to estimate differences between Scenario A and the BAU. Several classifications of electric vehicle supply equipment (EVSE) were considered: residential, urban area public Level 2, workplace Level 2, and DC fast chargers. For residential charging equipment, it was assumed that for each BEV sold, 90% purchased Level 2 charging equipment and that for each PHEV sold, 30% purchased Level 2 charging equipment.[72] Level 1 charging equipment comes with the vehicle and can simply be plugged into a standard electrical outlet, so no additional costs are incurred for Level 1. These estimates may over-estimate costs as some PEV buyers may be purchasing a second PEV.

To quantify workplace Level 2 charging equipment, we utilized the CEC estimate of workplace charging for 15% of the PEV population with 2.4 charges per day per unit. To estimate the amount of urban area public charging equipment needed for the BAU and Scenario A, a recent CEC PEV infrastructure assessment[73] estimated number of EVSEs per 100 square miles of urban space for two scenarios:  home dominant and high public access. Table A-5 provides the EVSE density recommendations. For the BAU scenario, we have assumed that the number per 100 square feet is the average of the home dominant and high public access scenarios. For Scenario A we assume that more public access would be needed, so utilize the high public access EVSE density values. The urban area in Washington state is provided in Table A-6.

To estimate the number of DC fast charge stations located along major highways, we assume 40 miles between chargers for the BAU case (consistent with Washington's portion of the West Coast Green Highway) and 25 miles between chargers for Scenario A. Table A-7 provides the estimated miles of major highways in Washington state. Table A-8 summarizes the total annual sales of EVSE.

Installed costs for residential Level 2 EVSE, public Level 2 EVSE, and DC fast charge stations are assumed to be $1,200,[74] $8,700,[75] and $92,000[65] respectively. For the analysis we have assumed these costs are constant through 2026 although they may decrease due to learning and/or scaling.

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[72] Center for Sustainable Energy PEV Owner Survey, Feb 2014

[73] "California Statewide Plug-in Electric Vehicle Infrastructure Assessment", CEC-600-2014-003, May 2014

[74] Rocky Mountain Institute, "Pulling back the Veil on EV Charging Station Costs", May 2014

[75] *New Approaches to Financing the Publicly Available Electric Vehicle Charging Network,* Center for Climate Energy Solutions, materials utilized in Washington State Legislature Joint Transportation Committee Study of Business Models to Sustain Electric Vehicle Charging Station Networks, 2014.

Table A-5. Urban Area EVSE Density Assumptions.

| Urban Area Chargers per 100 sq. miles | Home Dominant | High public access | BAU | Scenario A |
|---|---|---|---|---|
| Level 2 Public | 127 | 294 | 211 | 294 |
| DC-FC Stations | 3.5 | 9.8 | 7 | 9.8 |

CEC-600-2014-003

Table A-6. Washington State Urban Area (Sq. Miles)

| City Center | Sq Miles |
|---|---|
| Seattle | 142 |
| Bellevue | 34 |
| Tacoma | 63 |
| Everett | 48 |
| Port Orchard | 5 |
| Bellingham | 32 |
| Spokane | 58 |
| Vancouver | 46 |
| Olympia | 18.5 |
| Tri-cities | 92.5 |
| Yakima | 20 |
| Total | 559 |

Table A-7. Major Highway Miles in Washington State.

| Highway | | Miles | # Chargers | |
|---|---|---|---|---|
| | | | BAU | Scen A |
| I-5 | Vancouver to Blaine | 246 | 7 | 11 |
| I-90 | Spokane Valley to Seattle | 297 | 8 | 13 |
| I-82 | Ellensburg to Umatilla | 137 | 4 | 6 |
| 195 | Spokane to Lewiston | 118 | 4 | 6 |
| 395 | Spokane to Christina Lake | 116 | 4 | 6 |
| 20 | Kettle Falls to Anacortes | 430 | 12 | 18 |
| 16 | Tacoma to Kitsap | 44 | 2 | 3 |
| | Total | 1388 | 41 | 63 |

Table A-8 Summary of Annual EVSE Sales for BAU and Scenario A

| | Residential L2 | | Workplace L2 | | Urban L2 | | Urban DC Fast | | Highway DC Fast | |
|---|---|---|---|---|---|---|---|---|---|---|
| | BAU | Scen A | BAU | Scen A | BAU | Scen A | BAU | Scen A | BAU | Scen A |
| 2017 | 3,981 | 4,374 | 715 | 2,671 | 67 | 161 | 3 | 5 | 6 | 10 |
| 2018 | 3,750 | 5,510 | 715 | 2,671 | 67 | 161 | 1 | 4 | 6 | 10 |
| 2019 | 3,824 | 6,812 | 536 | 2,003 | 51 | 120 | 1 | 4 | 4 | 8 |
| 2020 | 3,831 | 8,668 | 447 | 1,669 | 42 | 100 | 0 | 3 | 3 | 6 |
| 2021 | 3,839 | 10,355 | 358 | 1,336 | 34 | 80 | 0 | 2 | 2 | 6 |
| 2022 | 3,863 | 11,669 | 268 | 1,002 | 25 | 60 | 0 | 2 | 2 | 3 |
| 2023 | 3,945 | 13,059 | 179 | 668 | 17 | 40 | 0 | 1 | 2 | 3 |
| 2024 | 4,065 | 14,132 | 143 | 534 | 13 | 32 | 0 | 1 | 2 | 2 |
| 2025 | 4,419 | 14,940 | 107 | 401 | 10 | 24 | 0 | 0 | 1 | 1 |
| 2026 | 4,640 | 15,192 | 107 | 401 | 10 | 24 | 0 | 1 | 1 | 2 |

### CNG Refueling

Only Scenario A with and without banking and trading has different CNG vehicle populations than the BAU case, so these assumptions compare only Scenario A to the BAU. The CNG refueling station costs utilized in the previous version of this analysis are utilized here. Clean Energy Fuels stated that average station size is 8,000 gge/day and operates at a 30 percent capacity factor. We divide the CNG consumption by the station throughput to determine number of stations required. The result is a station cost of $2.15 million ($2010), installed. Table A-9 provides the number of new stations required each year.

Table A-9. Number of new CNG refueling stations each year.

| | CNG Use, MMBtu/yr | | Total # Stations | | # New Stations | |
|---|---|---|---|---|---|---|
| | BAU | Scen A | BAU | Scen A | BAU | Scen A |
| 2016 | 906,596 | 1,131,215 | 8 | 10 | | |
| 2017 | 974,794 | 1,262,946 | 9 | 12 | 1 | 2 |
| 2018 | 1,036,973 | 1,383,764 | 9 | 13 | 0 | 1 |
| 2019 | 1,101,018 | 1,503,087 | 10 | 14 | 1 | 1 |
| 2020 | 1,165,204 | 1,619,052 | 11 | 15 | 1 | 1 |
| 2021 | 1,233,608 | 1,738,254 | 11 | 16 | 0 | 1 |
| 2022 | 1,304,525 | 1,858,969 | 12 | 17 | 1 | 1 |
| 2023 | 1,381,437 | 1,987,240 | 13 | 18 | 1 | 1 |
| 2024 | 1,464,107 | 2,123,983 | 13 | 19 | 0 | 1 |
| 2025 | 1,571,633 | 2,296,159 | 14 | 21 | 1 | 2 |
| 2026 | 1,690,497 | 2,484,377 | 15 | 23 | 1 | 2 |

### Hydrogen Refueling

Only Scenario A with and without banking and trading had different hydrogen fuel cell vehicle populations than the BAU case, so these assumptions compare only Scenario A to the BAU. For simplicity, we have assumed all hydrogen is produced from on-site natural gas steam reforming. The number and cost of on-site natural gas reforming stations needed (Table A-10) is based on recent H2A efforts[76] and utilizes the "more stations" or second wave cost estimates. The costs are assumed to remain constant throughout the analysis period.

Table A-10. Hydrogen infrastructure cost estimates.

| $2,013 | H2 Use, kg/day | | Tot# Plants | | Tot# Plants | | # New Plants | | Capital $Million | |
|---|---|---|---|---|---|---|---|---|---|---|
| | BAU | Scen A | BAU | Scen A | BAU | Scen A | BAU | Scen A | BAU | Scen A |
| 2016 | 0 | 431 | 0.0 | 1.3 | 0 | 2 | | | | |
| 2017 | 0 | 649 | 0.0 | 1.4 | 0 | 2 | 0 | 0 | 0.0 | 0.0 |
| 2018 | 29 | 913 | 0.1 | 2.0 | 1 | 2 | 1 | 0 | 3.1 | 0.0 |
| 2019 | 74 | 1,425 | 0.2 | 3.1 | 1 | 4 | 0 | 2 | 0.0 | 6.2 |
| 2020 | 135 | 2,265 | 0.3 | 5.0 | 1 | 5 | 0 | 1 | 0.0 | 3.1 |
| 2021 | 211 | 3,454 | 0.5 | 7.6 | 1 | 8 | 0 | 3 | 0.0 | 9.3 |
| 2022 | 287 | 5,052 | 0.6 | 11.1 | 1 | 12 | 0 | 4 | 0.0 | 12.4 |
| 2023 | 357 | 7,013 | 0.8 | 15.4 | 1 | 16 | 0 | 4 | 0.0 | 12.4 |
| 2024 | 426 | 9,382 | 0.9 | 20.6 | 1 | 21 | 0 | 5 | 0.0 | 15.5 |
| 2025 | 497 | 12,201 | 1.1 | 26.8 | 2 | 27 | 1 | 6 | 3.1 | 18.5 |
| 2026 | 568 | 15,033 | 1.2 | 33.0 | 2 | 33 | 0 | 6 | 0.0 | 18.5 |

### RNG Production

Capital required to recover, treat and inject biogas into natural gas pipeline system is estimated for WWT and HSAD gases. Sufficient RNG from LFG production capacity exists in-state to satisfy demand in each of the compliance scenarios. All cost estimates are taken from a recent report by the National Petroleum Council.[77] The cost for both WWT and HSAD pipeline injected RNG production is 1 $/gge. If we assume a capital recovery factor of 0.2, this results in 5 $/gge/yr of capacity. Table A-11 provides the capacity and cost to produce the volumes of WWT and HSAD RNG utilized in each of the compliance scenarios.

[76] "Hydrogen Station Cost Estimates Comparing Hydrogen Station Cost Calculator Results with other Recent Estimates", M. Melaina and M. Penev, NREL/TP-5400-56412, September 2013

[77] National Petroleum Council Report, "Advancing Technology for America's Transportation Future", 2012

Table A-11. WWT and HSAD RNG capacity and capital spending schedule

| $Million | Scenario A | | Scenario A B&T | | Scenario B | | Scenario B B&T | | Scenario C | | Scenario C B&T | | Scenario D | | Scenario D B&T | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ($2012) | WWT | HSAD | WWT | HSAD | WWT | HSAD | WWT | HSAD | WWT | HSAD | WWT | HSAD | WWT | HSAD | WWT | HSAD |
| Capacity | 3.2 | 20.1 | 4.4 | 8.9 | 2.3 | 13.4 | 1.8 | 13.4 | 1.8 | 13.4 | 1.2 | 13.4 | 2.3 | 13.4 | 1.6 | 13.4 |
| Cost | 16.2 | 100.4 | 21.8 | 44.6 | 11.7 | 66.9 | 8.9 | 66.9 | 8.9 | 66.9 | 6.1 | 66.9 | 11.7 | 66.9 | 7.8 | 66.9 |
| 2017 | 8.1 | | 10.9 | | 5.9 | 16.7 | 4.5 | 16.7 | 4.5 | | 3.1 | 16.7 | 5.9 | 16.7 | 3.9 | 16.7 |
| 2018 | | | 10.9 | | 5.9 | | 4.5 | 16.7 | 4.5 | | 3.1 | 16.7 | | | 3.9 | 16.7 |
| 2019 | 8.1 | 33.5 | | | | | | | | 16.7 | | | 5.9 | | | |
| 2020 | | | | | | | | 16.7 | | | | | | | | |
| 2021 | | | | 14.9 | | 16.7 | | | | | | | | 16.7 | | |
| 2022 | | 33.5 | | 14.9 | | | | 16.7 | | 16.7 | | 16.7 | | | | 16.7 |
| 2023 | | 33.5 | | 14.9 | | 16.7 | | | | | | 16.7 | | | | |
| 2024 | | | | | | 16.7 | | | | 16.7 | | | | 16.7 | | |
| 2025 | | | | | | | | | | 16.7 | | | | 16.7 | | 16.7 |
| 2026 | | | | | | | | | | | | | | | | |

## Cellulosic Biofuel Production

Each of the compliance scenarios except for the minimum cellulosic scenarios with banking and trading utilizes some volume of cellulosic biofuel. It is assumed that up to three plants with capacity of 30 MGY could be built in Washington state and that the balance of the cellulosic biofuel volumes are imported. Table A-12 provides the number of plants assumed to be built in Washington state the year the capacity is needed. Note that a sensitivity case was run on Scenario B to compare the impact of in-state production and out-of-state projection on the state economy.

Table A-12. Number of new cellulosic biofuel plants needed in year shown.

| | Number of new cellulosic plants needed in year shown | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | A | A w/B&T | B | B w/B&T | C | C w/B&T | D | D w/B&T |
| 2016 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2017 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2018 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2019 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2020 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2021 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2022 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2023 | 0 | 0 | 2 | 0 | 1 | 0 | 1 | 0 |
| 2024 | 2 | 0 | 1 | 1 | 1 | 0 | 1 | 0 |
| 2025 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 |
| 2026 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| Total | 3 | 2 | 3 | 3 | 3 | 0 | 3 | 0 |

To estimate capital cost of the biofuel production plants, we utilize a survey of published installed plant costs.[78] The average installed cost (Table A-13) is $10.2 per gallon of capacity. Members of the Washington CFS workgroup advised that this number represents first-of-a-kind plant costs and that 8 years from now when the plants that would supply a Washington CFS are built, the costs could be as low as $8 per gallon. We have utilized the higher value for this analysis to be conservative and to reflect that these plants could still be pioneer plants at that point.

The plant capacity needed for each scenario is multiplied by $10.2 per gallon to arrive at the capital needed each year for new plants. The spending is shifted forward to allow two years for construction and commissioning.

Table A-13. Installed cost of cellulosic biofuel plants

| Plant | Cost $Million | Size MGY | Cost $/gal |
|---|---|---|---|
| KiOR Natchez Facility | 350 | 41 | 8.5 |
| ClearFuels Collinwood | 200 | 20 | 10.0 |
| Sundrop, Louisiana | 500 | 50 | 10.0 |
| Zeachem | 391 | 25 | 15.6 |
| Abengoa Hugoton | 350 | 25 | 14.0 |
| Beta Renewables, NC | 170 | 20 | 8.5 |
| DuPont, Iowa | 276 | 25 | 11.0 |
| Poet, Iowa | 250 | 20 | 12.5 |
| Mascoma Kinross | 232 | 40 | 5.8 |
| Volume weighted Avg | | | 10.2 |

## Ethanol Infrastructure

To support changes in ethanol consumption, infrastructure investments are needed in several areas: marine and rail terminals, petroleum terminals, trucks, and refueling station upgrades.

All of the compliance scenarios utilize some amount of sugarcane ethanol from Brazil. Marine terminals in Seattle and Tacoma currently have the ability to receive shipments of ethanol from Brazil.[79] It is therefore assumed that piping, pumps, vapor handling exists, so the only costs required at marine terminals are for increased storage capacity. We assume here that the marine terminals need capacity to store a 10-day supply and that existing storage capacity is 500,000 gallons. Figure A-28 provides the additional storage required at marine terminals for each compliance scenario. To estimate the cost of the additional storage, we assume $40 ($2014) per bbl of ethanol stored[80] and apply this to the incremental amount of storage needed each year.

[78] "Commercial-scale cellulosic biofuels projects in the United States", Tristan R. Brown and Robert C. Brown, Iowa State University, March 2013
[79] EIA State Energy Data System
[80] EPA RFS2 Final Feb 2010 page 787

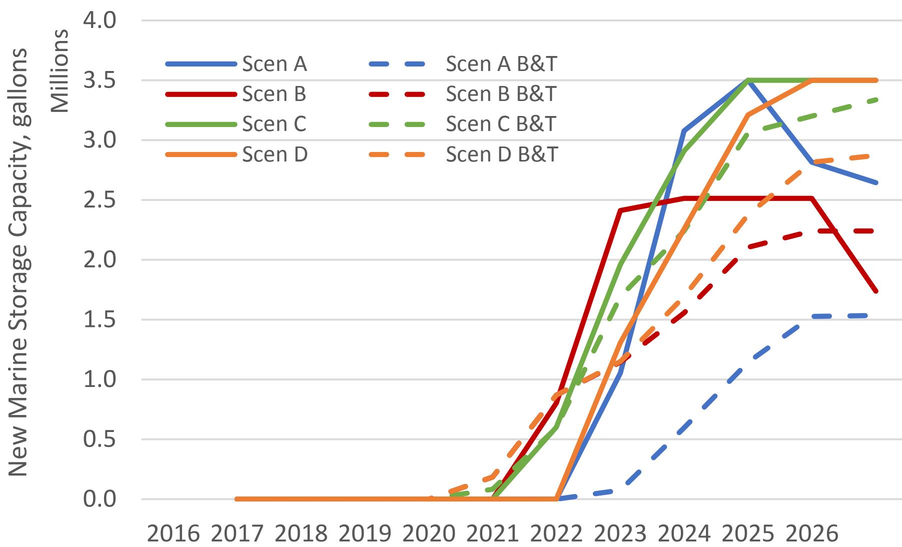


Figure A-28. Additional marine terminal storage capacity needed for a 10 day supply.

Ethanol is also delivered by rail, so we next considered additional storage required at rail terminals. The total rail receipts of ethanol is anticipated to decrease in the long-run, however there are sizeable increases for Scenario C and D. Table A-14 provides the increase in weekly gallons expected to be received by rail for each scenario relative to the BAU case. To estimate the cost of increased storage needs at rail terminals, the incremental storage required each year was multiplied by the $40 per barrel cost previously mentioned. Table A-15 provides the estimated total capital investment needed at rail and marine terminals.

Table A-14. Estimated increase in U.S. rail receipts over 2016 BAU

| Gallons per wk | Scen A | Scen A B&T | Scen B | Scen B B&T | Scen C | Scen C B&T | Scen D | Scen D B&T |
|---|---|---|---|---|---|---|---|---|
| 2016 | | | | | | | | |
| 2017 | | 138,804 | | 46,921 | | 46,670 | | 143,142 |
| 2018 | | 56,694 | | | | | | 458,775 |
| 2019 | | | | | | | 452,140 | 791,746 |
| 2020 | | | | | | | 1,052,402 | 903,267 |
| 2021 | | | | | | | 1,479,331 | 802,816 |
| 2022 | | | | | | | 807,442 | 540,404 |
| 2023 | | | | | | | 50,784 | 76,166 |
| 2024 | | | | | | | | |
| 2025 | | | | | | | | |
| 2026 | | | | | | | 108,252 | |

Table A-14. Estimated cumulative costs for increased rail and marine terminal storage.

| $Million 2014 | Scen A | Scen A B&T | Scen B | Scen B B&T | Scen C | Scen C B&T | Scen D | Scen D B&T |
|---|---|---|---|---|---|---|---|---|
| 2017 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 |
| 2018 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.4 |
| 2019 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 0.8 |
| 2020 | 0.0 | 0.1 | 0.0 | 0.2 | 0.0 | 0.1 | 1.8 | 1.1 |
| 2021 | 0.0 | 0.1 | 0.8 | 0.9 | 0.6 | 0.6 | 1.8 | 1.7 |
| 2022 | 1.0 | 0.2 | 2.3 | 1.2 | 1.9 | 1.7 | 3.1 | 2.0 |
| 2023 | 3.0 | 0.7 | 2.4 | 1.6 | 2.8 | 2.1 | 3.9 | 2.5 |
| 2024 | 3.3 | 1.2 | 2.4 | 2.0 | 3.3 | 2.9 | 4.9 | 3.1 |
| 2025 | 3.3 | 1.6 | 2.4 | 2.1 | 3.3 | 3.0 | 5.2 | 3.5 |
| 2026 | 3.3 | 1.6 | 2.4 | 2.1 | 3.3 | 3.1 | 5.2 | 3.6 |

At the petroleum terminals, infrastructure costs associated with a shift from gasoline storage to ethanol storage for some of the scenarios needs to be estimated. Total volumes of gasoline and ethanol consumption decrease from 2016 to 2026 in all scenarios, therefore no increase in total storage is needed, however some storage may need to be converted from gasoline to diesel. Total ethanol consumption increases above the 2016 BAU level in Scenarios C and D with and without banking and trading. Total ethanol decreases below 2016 BAU levels in the other scenarios. If we assume that the current tanks are 300,000 gallons and that a 6 day capacity is required, Table A-15 provides the total number of tanks converted and the incremental number of tanks converted each year. A cost of $20,750 ($2007) to convert each tank[81] is utilized to quantify required capital.

Table A-15. Conversion of tanks at petroleum terminals from gasoline to ethanol

| | Total Tanks Converted | | | | Tanks converted each year | | | |
|---|---|---|---|---|---|---|---|---|
| | Scen C | Scen C B&T | Scen D | Scen D B&T | Scen C | Scen C B&T | Scen D | Scen D B&T |
| 2016 | 0 | 0 | 0 | 0 | | | | |
| 2017 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 |
| 2018 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 1 |
| 2019 | 1 | 1 | 2 | 4 | 1 | 0 | 2 | 2 |
| 2020 | 1 | 1 | 4 | 5 | 0 | 0 | 2 | 1 |
| 2021 | 2 | 1 | 6 | 6 | 1 | 0 | 2 | 1 |
| 2022 | 3 | 0 | 7 | 6 | 1 | 0 | 1 | 0 |
| 2023 | 5 | 2 | 9 | 6 | 2 | 2 | 2 | 0 |
| 2024 | 7 | 3 | 11 | 6 | 2 | 1 | 2 | 0 |
| 2025 | 10 | 6 | 12 | 6 | 3 | 3 | 1 | 0 |
| 2026 | 10 | 8 | 14 | 6 | 0 | 2 | 2 | 0 |

[81] EPA RFS2 RIA final, 2007

The number of trucks needed to transport ethanol from marine/rail terminals and in-state production plants and to transport gasoline and E85 from the blending terminals to the refueling stations is considered. Assuming that each truck carries 8000 gallons of fuel and that it can make 5 trips per day from the marine/rail terminal or in-state production plant to the blending terminal, the number of new trucks needed each year is provided in Table A-16.

Table A-16. New trucks for ethanol transport from marine/rail terminals and cellulosic plants.

| New Trucks | Scen A | Scen A B&T | Scen B | Scen B B&T | Scen C | Scen C B&T | Scen D | Scen D B&T |
|---|---|---|---|---|---|---|---|---|
| 2016 | | | | | | | | |
| 2017 | | 1 | | 1 | | 1 | | 1 |
| 2018 | | | | | | | | 1 |
| 2019 | | | | | | | 2 | |
| 2020 | 1 | | | | | | 2 | |
| 2021 | | | | | 2 | | 3 | |
| 2022 | | | | | 2 | | | |
| 2023 | | | | | 2 | | | |
| 2024 | | | | | 3 | | | |
| 2025 | | | | | 2 | | | |
| 2026 | | | | | 1 | | | |

New trucks are also needed to transport gasoline and E85 from the petroleum terminals to the refueling stations. If we assume 8000 gallons per truck and 5 trips per day, Table A-17 provides the total number of trucks required. Relative to the BAU, very few additional trucks are required. Each truck is assumed to cost $180,000 in current dollars.

Table A-17. Total trucks needed for E10/E15/E85 transport to refueling stations.

| Trucks | BAU | Scen A | Scen A B&T | Scen B | Scen B B&T | Scen C | Scen C B&T | Scen D | Scen D B&T |
|---|---|---|---|---|---|---|---|---|---|
| 2016 | 173 | 173 | 173 | 173 | 173 | 173 | 173 | 173 | 173 |
| 2017 | 171 | 171 | 171 | 171 | 171 | 171 | 171 | 171 | 171 |
| 2018 | 168 | 168 | 168 | 168 | 168 | 168 | 168 | 168 | 169 |
| 2019 | 165 | 164 | 164 | 165 | 165 | 165 | 165 | 165 | 166 |
| 2020 | 161 | 160 | 160 | 161 | 161 | 161 | 161 | 163 | 163 |
| 2021 | 158 | 156 | 156 | 158 | 158 | 158 | 158 | 160 | 160 |
| 2022 | 154 | 152 | 152 | 154 | 154 | 155 | 154 | 157 | 156 |
| 2023 | 150 | 148 | 148 | 148 | 150 | 152 | 150 | 153 | 152 |
| 2024 | 146 | 142 | 143 | 143 | 146 | 148 | 147 | 149 | 148 |
| 2025 | 142 | 136 | 138 | 137 | 142 | 143 | 144 | 145 | 144 |
| 2026 | 138 | 130 | 134 | 131 | 136 | 138 | 141 | 141 | 140 |

Scenario D with and without banking and trading assumes a ramp up to E15 by 2024. The Petroleum Equipment Institute[82] has surveyed refueling station owners on estimated costs to accommodate selling E15. Table A-18 summarizes the results. We have assumed here that half of the stations retrofit dispensers and hanging hardware only and that the other half replaces a tank, retrofits dispensers, and replaces hanging hardware. We also assume that on average the stations have 4 dispensers and that 100% of the 1,914[83] refueling stations in Washington make these modifications. These assumptions result in a total cost of $143.9 Million in $2013.

Table A-18. Summary of PEI Station Costs to Accommodate E15 ($2013).

| | Retrofit Dispensers and replace hanging hardware | Retrofit Dispensers only, keep hanging hardware | Replace Tank, retrofit dispensers, replace hanging hardware |
|---|---|---|---|
| 2 dispenser | $7,600 | $6,452 | $126,170 |
| 4 dispenser | $15,200 | $13,000 | $135,200 |
| 6 dispenser | $22,800 | $19,500 | $152,800 |
| 10 dispenser | $38,000 | $32,500 | $188,000 |

Scenarios C and C with banking and trading and Scenario D utilize significant volumes of E85. We assume that by 2024, 100% of refueling stations will offer E85. In the RIA for RFS2[84], EPA estimated that the cost for a new 2 nozzle dispenser with a new 15,000 gallon tank (installed) is $154,000. Total cumulative costs for these scenarios is $293 million.

### Biodiesel Infrastructure

Infrastructure to support increased biodiesel use includes increased storage capacity, and blending equipment, and piping at storage terminals, and station upgrades. We have assumed that 6 days of storage is required at petroleum terminals. Some storage capacity currently exists,[85] that is estimated to be approximately 450,000 gallons. Table A-19 provides the estimated additional storage required for each of the compliance scenarios.

There are 19 petroleum terminals in Washington state, and blending, piping and ancillary equipment is in place at 14 of these terminals (3 in Seattle, 3 in Vancouver, 3 in Spokane, 3 in Pasco, 2 in Tacoma). Therefore, 5 terminals need to install blending, piping and ancillary equipment. The installed cost for heated and insulated biodiesel storage tanks was estimated by EPA[86] to be $70 per barrel. For blending, piping and ancillary equipment, EPA estimated $400,000 per terminal for blending equipment, $60,000 per terminal for piping, 500,000 per terminal for ancillary receiving, blending and storage equipment. The National Biodiesel Board (NBB)[87] has advised that these estimates are accurate except for the blending equipment estimate; blending equipment is approximately $200,000 per terminal. We have utilized all of the EPA cost estimates, but have substituted $200,000 for blending equipment, for a total cost of $760,000 per terminal at 5 terminals. All costs are in current dollars.

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[82] Letter from Robert Renkes of PEI to Todd Campbell of USDA dated September 6, 2013
[83] http://www.eia.gov/state/print.cfm?sid=WA
[84] EPA RFS2 Final RIA, Feb 2010
[85] Todd Ellis, Imperium Renewables estimates that sufficient storage and blending capacity exists to support B5.
[86] EPA RFS2 Final RIA, February 2010
[87] Provided by NBB Petroleum Liaison to Shelby Neal (NBB), email dated September 11, 2014

Table A-19. Estimated increase in biodiesel storage needed for a 6-day supply at terminals.

| Gallons | Scen A | Scen A B&T | Scen B | Scen B B&T | Scen C | Scen C B&T | Scen D | Scen D B&T |
|---|---|---|---|---|---|---|---|---|
| 2016 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2017 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2018 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2019 | 0 | 240,002 | 0 | 242,007 | 0 | 241,990 | 0 | 241,968 |
| 2020 | 0 | 566,318 | 0 | 569,506 | 0 | 569,480 | 0 | 569,422 |
| 2021 | 40,182 | 793,442 | 41,974 | 797,592 | 41,974 | 797,606 | 41,974 | 797,419 |
| 2022 | 262,600 | 1,026,019 | 265,339 | 1,031,597 | 265,340 | 1,031,463 | 265,341 | 1,031,379 |
| 2023 | 600,425 | 1,153,539 | 604,701 | 1,160,196 | 604,702 | 1,159,938 | 604,703 | 1,159,879 |
| 2024 | 832,834 | 1,168,809 | 838,432 | 1,175,798 | 838,434 | 1,175,748 | 838,436 | 1,175,833 |
| 2025 | 1,073,282 | 1,187,412 | 1,080,510 | 1,195,384 | 1,080,513 | 1,195,604 | 1,080,515 | 1,195,719 |
| 2026 | 1,204,335 | 1,206,104 | 1,212,856 | 1,214,755 | 1,212,859 | 1,215,452 | 1,212,860 | 1,215,694 |

Table A-20. Annual spending required to increase terminal biodiesel storage capacity.

| 2014$ | Scen A | Scen A B&T | Scen B | Scen B B&T | Scen C | Scen C B&T | Scen D | Scen D B&T |
|---|---|---|---|---|---|---|---|---|
| 2017 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2018 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2019 | 0 | 400,003 | 0 | 403,344 | 0 | 403,317 | 0 | 403,281 |
| 2020 | 0 | 543,861 | 0 | 545,833 | 0 | 545,817 | 0 | 545,756 |
| 2021 | 66,971 | 378,540 | 69,956 | 380,143 | 69,956 | 380,209 | 69,957 | 379,994 |
| 2022 | 370,695 | 387,627 | 372,276 | 390,009 | 372,277 | 389,762 | 372,278 | 389,933 |
| 2023 | 563,043 | 212,534 | 565,603 | 214,332 | 565,603 | 214,126 | 565,604 | 214,167 |
| 2024 | 387,348 | 25,450 | 389,552 | 26,003 | 389,554 | 26,350 | 389,555 | 26,590 |
| 2025 | 400,747 | 31,006 | 403,464 | 32,643 | 403,466 | 33,092 | 403,464 | 33,144 |
| 2026 | 218,422 | 31,153 | 220,576 | 32,285 | 220,576 | 33,081 | 220,576 | 33,292 |

Table A-21. Costs for blending, piping and ancillary equipment at terminals for biodiesel handling.

| $ | Scen A | Scen A B&T | Scen B | Scen B B&T | Scen C | Scen C B&T | Scen D | Scen D B&T |
|---|---|---|---|---|---|---|---|---|
| 2017 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2018 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2019 | 0 | 756,159 | 0 | 757,046 | 0 | 756,560 | 0 | 756,342 |
| 2020 | 0 | 1,028,105 | 0 | 1,024,485 | 0 | 1,023,868 | 0 | 1,023,550 |
| 2021 | 126,786 | 715,587 | 131,508 | 713,498 | 131,507 | 713,212 | 131,509 | 712,669 |
| 2022 | 701,786 | 732,764 | 699,827 | 732,016 | 699,827 | 731,132 | 699,828 | 731,309 |
| 2023 | 1,065,931 | 401,771 | 1,063,254 | 402,284 | 1,063,252 | 401,668 | 1,063,252 | 401,664 |
| 2024 | 733,312 | 48,110 | 732,303 | 48,806 | 732,305 | 49,429 | 732,306 | 49,868 |
| 2025 | 758,678 | 58,613 | 758,456 | 61,269 | 758,458 | 62,075 | 758,454 | 62,160 |
| 2026 | 413,508 | 58,892 | 414,653 | 60,597 | 414,650 | 62,055 | 414,650 | 62,438 |

To transport biodiesel from the production plants (all located in Washington state) to the petroleum terminals it is assumed that half travels by rail and half by truck. It is further assumed that any additional rail cars required are available from the rail industry. To estimate the number of new trucks required, we assume an 8,000 gallon capacity and 2 trips per day. These assumptions result in up to 9 additional trucks at $180,000 each for the compliance scenarios.

Table B-x. Annual costs for new trucks to transport biodiesel.

| 2014$ | Scen A | Scen A B&T | Scen B | Scen B B&T | Scen C | Scen C B&T | Scen D | Scen D B&T |
|---|---|---|---|---|---|---|---|---|
| 2016 | | | | | | | | |
| 2017 | 0 | 180,000 | 0 | 180,000 | 0 | 180,000 | 0 | 180,000 |
| 2018 | 0 | 180,000 | 0 | 180,000 | 0 | 180,000 | 0 | 180,000 |
| 2019 | 180,000 | 360,000 | 180,000 | 360,000 | 180,000 | 360,000 | 180,000 | 360,000 |
| 2020 | 0 | 360,000 | 0 | 360,000 | 0 | 360,000 | 0 | 360,000 |
| 2021 | 360,000 | 180,000 | 360,000 | 180,000 | 360,000 | 180,000 | 360,000 | 180,000 |
| 2022 | 180,000 | 180,000 | 180,000 | 180,000 | 180,000 | 180,000 | 180,000 | 180,000 |
| 2023 | 360,000 | 180,000 | 360,000 | 180,000 | 360,000 | 180,000 | 360,000 | 180,000 |
| 2024 | 180,000 | 0 | 180,000 | 0 | 180,000 | 0 | 180,000 | 0 |
| 2025 | 180,000 | 0 | 180,000 | 0 | 180,000 | 0 | 180,000 | 0 |
| 2026 | 180,000 | 0 | 180,000 | 0 | 180,000 | 0 | 180,000 | 0 |

A number of states have begun selling significant amounts of biodiesel. For example Minnesota allows blends of up to B20 to be dispensed from existing diesel dispensers as long as they are calibrated to the blend that is being sold.[88] In addition, blends of up to B20 may be stored in existing diesel fuel storage tanks. Therefore, the costs incurred at refueling stations are limited to labeling costs. Required labeling to reflect the BD blend level being sold consists of attaching stickers to the pumps. The stickers are provided free of charge.

[88] http://www.cleanairchoice.org/pdf/BDFAQMinnesota.pdf

# Appendix C – Crude Oil Carbon Intensity Estimates

As mentioned in Section 3.1, OPGEE version 1 draft C was utilized to estimate crude oil recovery and transport emissions. The transport distances were modified to reflect transport to Washington state rather than California. The CI values for each field are provided in Table B-1.

Table B-1. Estimated Crude Oil Recovery and Transport Carbon Intensity ($gCO_2e/MJ$)

| | |
|---|---|
| Algeria - Saharan | **11.0** |
| Angola | |
| Cabinda | 9.4 |
| Dalia | 9.0 |
| Gimboa | 9.1 |
| Girassol | 9.7 |
| Greater Plutonia | 9.1 |
| Hungo | 8.5 |
| Kissanje | 9.0 |
| Mondo | 9.2 |
| Nemba | 9.5 |
| Pazflor | 8.3 |
| Angola Average | **9.1** |
| Argentina | |
| Canadon Seco | 7.4 |
| Escalante | 7.4 |
| Hydra | 6.2 |
| Medanito | 8.4 |
| Argentina Average | **7.3** |
| Brazil | |
| Albacora Leste | 5.8 |
| Bijupira-Salema | 7.5 |
| Frade | 5.3 |
| Jubarte | 7.5 |
| Lula | 9.3 |
| Marlim | 7.0 |
| Marlim Sul | 8.0 |
| Ostra | 5.7 |
| Polvo | 5.6 |
| Roncador (Snorer) | 6.9 |
| Roncador Heavy | 6.3 |
| Sapinhoa (Guara) | 7.9 |
| Average | **6.9** |
| Canada Conv. Light & Med | **7.2** |
| Canada Conv. Heavy | **6.3** |
| Canada Diluted Bitumen | |
| Christina Lake | 14.4 |
| Jackfish | 16.9 |
| Cold Lake | 18.5 |
| Borealis | 18.7 |
| Cold Lake | 18.5 |
| Peace River Heavy | 20.9 |
| Canada Dil-Bit Average | **18.0** |
| Canada Synthetic Crudes | **21.0** |
| Colombia | |
| Cano Limon | 8.8 |
| Castilla | 9.0 |
| Cusiana | 10.0 |
| Magdalena | 21.6 |
| Rubiales | 8.6 |
| South Blend | 8.3 |
| Vasconia | 8.7 |
| Colombia Average | **10.7** |
| Congo | |
| Azurite | 10.9 |
| Djeno | 11.2 |
| Congo Average | **11.0** |
| Equatorial Guinea | |
| Ceiba | 10.2 |
| Zafiro | 20.9 |
| Eq. Guinea Average | **15.6** |
| Oman | |
| Conventional | 8.3 |
| Steam Flood | 27.2 |
| Oman Average | **17.7** |
| Russia | |
| ESPO | 12.7 |
| Sokol | 9.5 |
| Vityaz | 10.8 |
| M100 | 18.3 |
| Russia Average | **12.8** |
| Saudi Arabia | |
| Arab Extra Light | 8.4 |
| Arab Light | 8.2 |
| Arab Medium | 7.7 |
| Arab Heavy | 7.8 |
| Saudi Arabia Average | **8.0** |
| United States | |
| Alaska North Slope | **14.6** |
| Colorado | **6.4** |
| Utah | |
| Utah Covenant | 2.4 |
| Utah | 4.7 |
| Utah Average | **3.6** |
| Wyoming | **22.3** |
| North Dakota* | **7.8** |
| ** used as surrogate for MT crude. 100 mile pipeline transport* | |
| Nigeria | |
| Chevron | 18.6 |
| Total E&P | 17.3 |
| Addax | 34.1 |
| Other | 19.0 |
| SNEPCO | 5.8 |
| Bonny Light SPDC | 14.3 |
| Bonny Light Chevron | 19.9 |
| Bonny LightTotal E&P | 18.6 |
| Bonny LightOther | 20.2 |
| SPDC | 14.3 |
| Chevron | 19.9 |
| NAOC Phillips | 111.2 |
| Addax | 35.4 |
| AENR | 49.9 |
| Other | 20.2 |
| SPDC EA | 5.6 |
| Esso Erha | 9.9 |
| Escravos Chevron | 19.9 |
| Escravos Other | 20.2 |
| Forcados SPDC | 14.3 |
| Forcados NAOC Phillips | 111.2 |
| Forcados Pan Ocean | 115.1 |
| Forcados NPDC | 28.2 |
| Forcados Other | 20.2 |
| Okono NPDC | 26.9 |
| OKWB Addax | 34.1 |
| Pennington | 25.6 |
| Pennington Other | 19.0 |
| Qua Iboe Mobil | 14.6 |
| Yoho Mobil | 14.6 |
| Nigeria Average | **29.9** |

## Appendix D – Detailed Macro-Economic Modeling Results

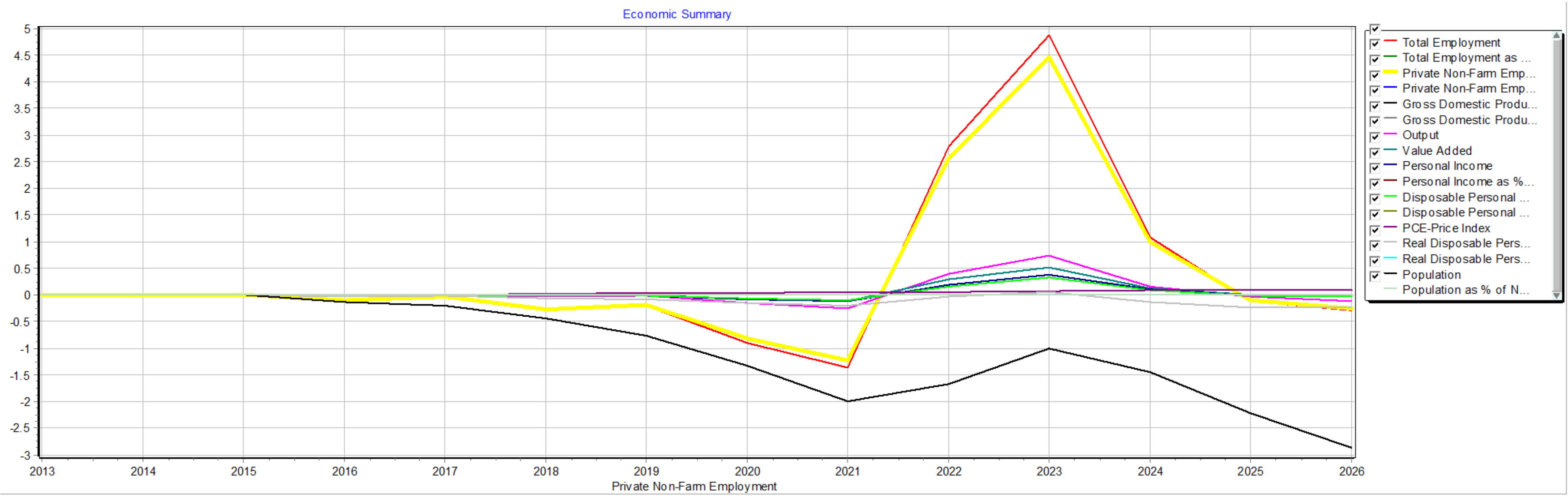
This appendix contains detailed model results for each scenario analyzed using the REMI PI+ v. 1.6 model specific to the State of Washington (identified as build 3750 by REMI). This appendix also includes a full list of sectors for which results can be identified within this model, to illuminate the model's level of detail.

Part 1: Detailed Scenario Results – Major Indicators

Note that some of these values are total dollar amounts, others are percent changes, and others are percent of total national values. Also, the bottom of many graphs includes the name of one variable – this simply represents which line on the graph had been currently highlighted at the time the visual was captured; it is not a descriptor of the entire graph.

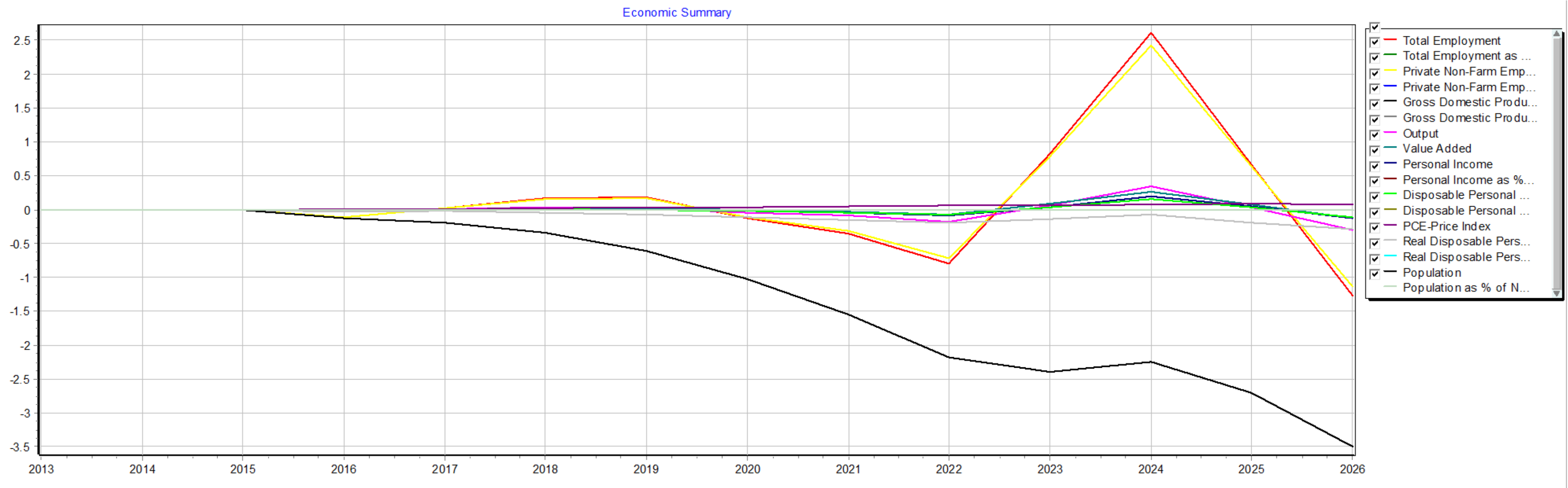
Scenario A:

| 12/8/2014 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Scenario B+BT.rwb | | | | | | | | | | | | |
| Regional Simulation 1 compared to Standard Regional Control - Difference | | | | | | | | | | | | |
| Region = Washington | | | | | | | | | | | | |
| Browser | | | | | | | | | | | | |
| REMI PI+ State of Washington v1.6.5 (Build 3750) | | | | | | | | | | | | |
| Category | Units | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 |
| Total Employment | Thousands (Jobs) | -0.11816406 | -0.03759766 | -0.29541016 | -0.19970703 | -0.90820313 | -1.36767578 | 2.79248047 | 4.87304688 | 1.07519531 | -0.11425781 | -0.29785156 |
| Total Employment as % of Nation | Percent | -6.175E-05 | -1.955E-05 | -0.00015163 | -0.00010204 | -0.00046062 | -0.00068998 | 0.00139952 | 0.00242877 | 0.00053263 | -5.6505E-05 | -0.00014615 |
| Private Non-Farm Employment | Thousands (Jobs) | -0.1081543 | -0.03466797 | -0.26831055 | -0.18847656 | -0.8190918 | -1.22949219 | 2.57177734 | 4.46655273 | 0.99023438 | -0.09936523 | -0.25 |
| Private Non-Farm Employment as % of Nation | Percent | -6.5804E-05 | -2.0504E-05 | -0.0001595 | -0.00011134 | -0.00048089 | -0.00071621 | 0.00148606 | 0.00256228 | 0.00056386 | -5.6028E-05 | -0.00014043 |
| Gross Domestic Product | Billions of Fixed (2009) Dollars | -0.00778198 | 0 | -0.02191162 | 0.00018311 | -0.07791138 | -0.12496948 | 0.29022217 | 0.50744629 | 0.12692261 | 0.00802612 | -0.02542114 |
| Gross Domestic Product (GDP) as % of Nation | Percent | -4.4584E-05 | 0 | -0.00011945 | 9.5367E-07 | -0.00040555 | -0.00063562 | 0.00144339 | 0.00246859 | 0.00060463 | 3.7432E-05 | -0.00011635 |
| Output | Billions of Fixed (2009) Dollars | -0.01605225 | -0.00073242 | -0.04058838 | -0.00964355 | -0.1519165 | -0.25012207 | 0.39685059 | 0.73931885 | 0.14886475 | -0.02600098 | -0.11920166 |
| Value Added | Billions of Fixed (2009) Dollars | -0.00759888 | -3.0518E-05 | -0.02197266 | 0.00024414 | -0.07788086 | -0.12481689 | 0.29016113 | 0.50744629 | 0.12686157 | 0.00787354 | -0.02545166 |
| Personal Income | Billions of Current Dollars | -0.00912476 | -0.00549316 | -0.0249939 | -0.02474976 | -0.07705688 | -0.11911011 | 0.18695068 | 0.37548828 | 0.0960083 | -0.01721191 | -0.04199219 |
| Personal Income as % of Nation | Percent | -5.579E-05 | -3.1948E-05 | -0.00013876 | -0.00013161 | -0.00039268 | -0.00058103 | 0.00087404 | 0.00168347 | 0.00041318 | -7.1287E-05 | -0.00016642 |
| Disposable Personal Income | Billions of Current Dollars | -0.00787354 | -0.00485229 | -0.02172852 | -0.02182007 | -0.06704712 | -0.10369873 | 0.15856934 | 0.32086182 | 0.08129883 | -0.0166626 | -0.03869629 |
| Disposable Personal Income as % of Nation | Percent | -5.5313E-05 | -3.2425E-05 | -0.00013876 | -0.00013351 | -0.00039291 | -0.00058174 | 0.00085258 | 0.00165415 | 0.00040245 | -7.9155E-05 | -0.00017643 |
| PCE-Price Index | 2009=100 (Nation) | 0.00813293 | 0.00672913 | 0.0170517 | 0.02895355 | 0.03814697 | 0.04737854 | 0.05828857 | 0.07124329 | 0.079422 | 0.08578491 | 0.08262634 |
| Real Disposable Personal Income | Billions of Fixed (2009) Dollars | -0.02655029 | -0.02069092 | -0.06015015 | -0.09002686 | -0.14840698 | -0.1991272 | -0.0295105 | 0.05355835 | -0.14459229 | -0.23156738 | -0.23898315 |
| Real Disposable Personal Income as % of Nation | Percent | -0.00020862 | -0.00015759 | -0.00044799 | -0.00065517 | -0.00105572 | -0.00138402 | -0.00020051 | 0.00035596 | -0.00094199 | -0.00147724 | -0.00149345 |
| Population | Thousands | -0.12890625 | -0.20068359 | -0.44775391 | -0.77587891 | -1.32470703 | -2.00732422 | -1.67871094 | -1.01074219 | -1.46044922 | -2.22265625 | -2.87158203 |
| Population as % of Nation | Percent | -3.9816E-05 | -6.175E-05 | -0.00013685 | -0.00023532 | -0.00039911 | -0.00060058 | -0.00049877 | -0.00029826 | -0.0004282 | -0.00064731 | -0.00083065 |


Economic Summary
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
Private Non-Farm Employment
Total Employment
Total Employment as ...
Private Non-Farm Emp...
Private Non-Farm Emp...
Gross Domestic Produ...
Gross Domestic Produ...
Output
Value Added
Personal Income
Personal Income as %...
Disposable Personal ...
Disposable Personal ...
PCE-Price Index
Real Disposable Pers...
Real Disposable Pers...
Population
Population as % of N...

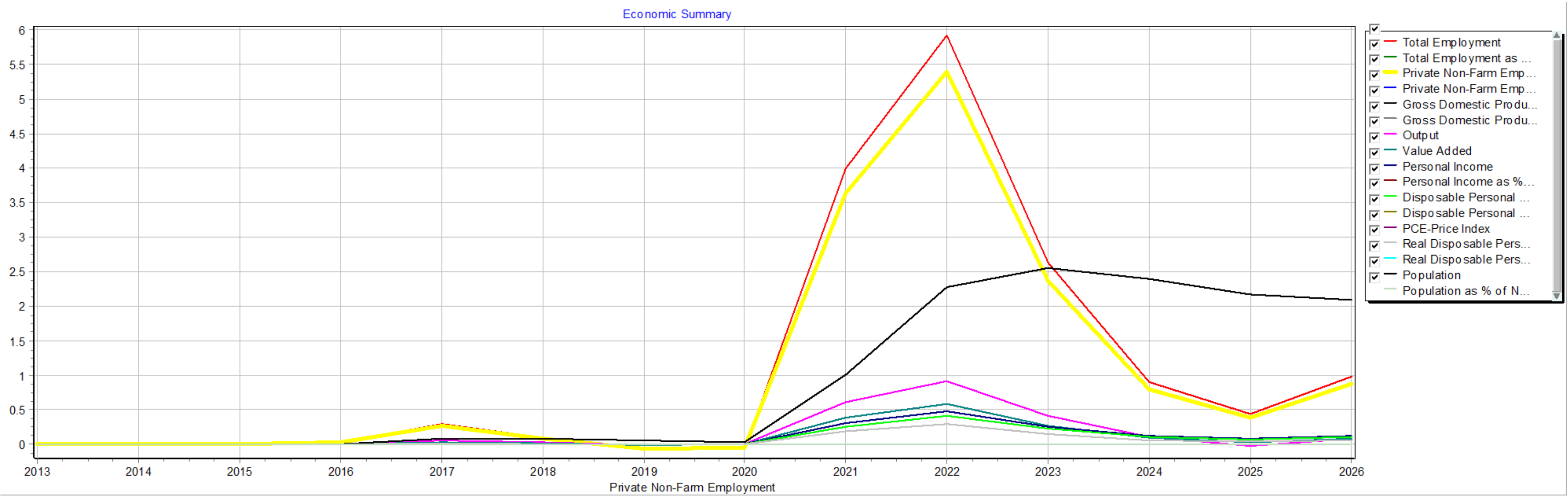
## Scenario A with Banking & Trading:

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12/11/2014 | | | | | | | | | | | | | | | |
| Untitled.rwb | | | | | | | | | | | | | | | |
| Regional Simulation 1 compared to Standard Regional Control - Difference | | | | | | | | | | | | | | | |
| Region = Washington | | | | | | | | | | | | | | | |
| Browser | | | | | | | | | | | | | | | |
| REMI PI+ State of Washington v1.6.5 (Build 3750) | | | | | | | | | | | | | | | |
| Category | Units | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 |
| Total Employment | Thousands (Jobs) | 0 | 0 | 0 | -0.11865234 | 0.02246094 | 0.17138672 | 0.17724609 | -0.12890625 | -0.35791016 | -0.80078125 | 0.83154297 | 2.61279297 | 0.66162109 | -1.27099609 |
| Total Employment as % of Nation | Percent | 0 | 0 | 0 | -6.2227E-05 | 1.1444E-05 | 8.8215E-05 | 9.0361E-05 | -6.5327E-05 | -0.00018048 | -0.0004015 | 0.00041437 | 0.00129461 | 0.00032592 | -0.00062346 |
| Private Non-Farm Employment | Thousands (Jobs) | 0 | 0 | 0 | -0.10864258 | 0.02050781 | 0.15429688 | 0.16577148 | -0.10791016 | -0.31494141 | -0.71313477 | 0.78491211 | 2.42285156 | 0.63305664 | -1.13037109 |
| Private Non-Farm Employment as % of Nation | Percent | 0 | 0 | 0 | -6.6042E-05 | 1.2398E-05 | 9.203E-05 | 9.799E-05 | -6.3419E-05 | -0.00018358 | -0.00041199 | 0.00045013 | 0.00137949 | 0.0003581 | -0.00063491 |
| Gross Domestic Product | Billions of Fixed (2009) Dollars | 0 | 0 | 0 | -0.00784302 | 0.00512695 | 0.0222168 | 0.01855469 | -0.00930786 | -0.02731323 | -0.06954956 | 0.09286499 | 0.2701416 | 0.07858276 | -0.1272583 |
| Gross Domestic Product (GDP) as % of Nation | Percent | 0 | 0 | 0 | -4.5061E-05 | 2.861E-05 | 0.00012112 | 9.8705E-05 | -4.8399E-05 | -0.00013876 | -0.00034571 | 0.00045156 | 0.00128698 | 0.00036669 | -0.00058174 |
| Output | Billions of Fixed (2009) Dollars | 0 | 0 | 0 | -0.01611328 | 0.00482178 | 0.03399658 | 0.02478027 | -0.04266357 | -0.09033203 | -0.17437744 | 0.06585693 | 0.33789063 | 0.02905273 | -0.30175781 |
| Value Added | Billions of Fixed (2009) Dollars | 0 | 0 | 0 | -0.00762939 | 0.00509644 | 0.02212524 | 0.01867676 | -0.0093689 | -0.02719116 | -0.06948853 | 0.09283447 | 0.27017212 | 0.07858276 | -0.12731934 |
| Personal Income | Billions of Current Dollars | 0 | 0 | 0 | -0.00915527 | -0.00180054 | 0.00314331 | -0.00109863 | -0.02368164 | -0.04495239 | -0.08218384 | 0.04016113 | 0.19177246 | 0.04296875 | -0.12768555 |
| Personal Income as % of Nation | Percent | 0 | 0 | 0 | -5.6028E-05 | -1.049E-05 | 1.7643E-05 | -5.722E-06 | -0.00012064 | -0.00021935 | -0.00038433 | 0.00018001 | 0.00082541 | 0.00017738 | -0.0005064 |
| Disposable Personal Income | Billions of Current Dollars | 0 | 0 | 0 | -0.00790405 | -0.00167847 | 0.00238037 | -0.00146484 | -0.02111816 | -0.03979492 | -0.07226563 | 0.03219604 | 0.16223145 | 0.03436279 | -0.11279297 |
| Disposable Personal Income as % of Nation | Percent | 0 | 0 | 0 | -5.5552E-05 | -1.1206E-05 | 1.5259E-05 | -9.0599E-06 | -0.00012374 | -0.00022316 | -0.00038838 | 0.00016594 | 0.00080299 | 0.00016356 | -0.00051451 |
| PCE-Price Index | 2009=100 (Nation) | 0 | 0 | 0 | 0.00813293 | 0.00682068 | 0.01739502 | 0.02945709 | 0.03895569 | 0.04885864 | 0.05697632 | 0.0660553 | 0.07626343 | 0.08529663 | 0.08157349 |
| Real Disposable Personal Income | Billions of Fixed (2009) Dollars | 0 | 0 | 0 | -0.02658081 | -0.01828003 | -0.04144287 | -0.07510376 | -0.11465454 | -0.15408325 | -0.19885254 | -0.14486694 | -0.07836914 | -0.19439697 | -0.28741455 |
| Real Disposable Personal Income as % of Nation | Percent | 0 | 0 | 0 | -0.00020885 | -0.00013947 | -0.00030851 | -0.00054646 | -0.00081563 | -0.00107098 | -0.00135183 | -0.00096369 | -0.00051069 | -0.00124002 | -0.00179601 |
| Population | Thousands | 0 | 0 | 0 | -0.12792969 | -0.18798828 | -0.33544922 | -0.61328125 | -1.03076172 | -1.54296875 | -2.17871094 | -2.39599609 | -2.25097656 | -2.69824219 | -3.49511719 |
| Population as % of Nation | Percent | 0 | 0 | 0 | -3.9577E-05 | -5.7936E-05 | -0.00010252 | -0.00018597 | -0.00031066 | -0.00046158 | -0.00064731 | -0.00070715 | -0.00065994 | -0.00078583 | -0.00101137 |


Economic Summary
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
Total Employment
Total Employment as ...
Private Non-Farm Emp...
Private Non-Farm Emp...
Gross Domestic Produ...
Gross Domestic Produ...
Output
Value Added
Personal Income
Personal Income as %...
Disposable Personal ...
Disposable Personal ...
PCE-Price Index
Real Disposable Pers...
Real Disposable Pers...
Population
Population as % of N...

## Scenario B:

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12/11/2014 | | | | | | | | | | | | |
| Untitled.rwb | | | | | | | | | | | | |
| Regional Simulation 1 compared to Standard Regional Control - Difference | | | | | | | | | | | | |
| Region = Washington | | | | | | | | | | | | |
| Browser | | | | | | | | | | | | |
| REMI PI+ State of Washington v1.6.5 (Build 3750) | | | | | | | | | | | | |
| Category | Units | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 |
| Total Employment | Thousands (Jobs) | 0.03173828 | 0.29785156 | 0.1015625 | -0.06298828 | -0.05664063 | 3.99121094 | 5.92138672 | 2.62939453 | 0.89941406 | 0.43505859 | 0.97558594 |
| Total Employment as % of Nation | Percent | 1.6689E-05 | 0.00015402 | 5.2214E-05 | -3.2425E-05 | -2.861E-05 | 0.00201297 | 0.00296783 | 0.00131059 | 0.0004456 | 0.00021434 | 0.00047827 |
| Private Non-Farm Employment | Thousands (Jobs) | 0.02783203 | 0.26464844 | 0.08837891 | -0.05859375 | -0.05395508 | 3.64208984 | 5.39916992 | 2.3737793 | 0.79711914 | 0.38378906 | 0.87866211 |
| Private Non-Farm Employment as % of Nation | Percent | 1.6928E-05 | 0.00015903 | 5.2691E-05 | -3.4571E-05 | -3.171E-05 | 0.00212169 | 0.00311971 | 0.00136161 | 0.00045371 | 0.00021696 | 0.00049353 |
| Gross Domestic Product | Billions of Fixed (2009) Dollars | 0.00280762 | 0.03424072 | 0.01226807 | -0.00494385 | -0.00335693 | 0.38879395 | 0.58364868 | 0.26849365 | 0.09011841 | 0.0317688 | 0.08633423 |
| Gross Domestic Product (GDP) as % of Nation | Percent | 1.6212E-05 | 0.00019121 | 6.6757E-05 | -2.6226E-05 | -1.7643E-05 | 0.00197721 | 0.00290227 | 0.00130606 | 0.00042939 | 0.0001483 | 0.00039458 |
| Output | Billions of Fixed (2009) Dollars | 0.00592041 | 0.05938721 | 0.02398682 | -0.00842285 | -0.0022583 | 0.60552979 | 0.9161377 | 0.41113281 | 0.10693359 | -0.01824951 | 0.07733154 |
| Value Added | Billions of Fixed (2009) Dollars | 0.00286865 | 0.03421021 | 0.01223755 | -0.00497437 | -0.00338745 | 0.3888855 | 0.58361816 | 0.26861572 | 0.09002686 | 0.03167725 | 0.0864563 |
| Personal Income | Billions of Current Dollars | 0.00170898 | 0.01824951 | 0.00817871 | -0.00125122 | -0.00100708 | 0.30078125 | 0.48394775 | 0.25921631 | 0.12237549 | 0.08129883 | 0.11828613 |
| Personal Income as % of Nation | Percent | 1.049E-05 | 0.00010586 | 4.5538E-05 | -6.4373E-06 | -5.2452E-06 | 0.00146723 | 0.00226235 | 0.00116229 | 0.00052691 | 0.00033593 | 0.00046945 |
| Disposable Personal Income | Billions of Current Dollars | 0.00146484 | 0.01568604 | 0.00708008 | -0.00097656 | -0.00079346 | 0.25848389 | 0.41687012 | 0.22503662 | 0.10775757 | 0.0723877 | 0.10400391 |
| Disposable Personal Income as % of Nation | Percent | 1.0252E-05 | 0.00010467 | 4.53E-05 | -6.1989E-06 | -4.7684E-06 | 0.00144982 | 0.0022409 | 0.00116014 | 0.00053334 | 0.00034404 | 0.00047445 |
| PCE-Price Index | 2009=100 (Nation) | 0 | 0.00031281 | 0.00039673 | 0.00019073 | 0.00010681 | 0.00288391 | 0.00753784 | 0.00843811 | 0.00645447 | 0.00482178 | 0.00392151 |
| Real Disposable Personal Income | Billions of Fixed (2009) Dollars | 0.0012207 | 0.01220703 | 0.00476074 | -0.00128174 | -0.00088501 | 0.19006348 | 0.29275513 | 0.14352417 | 0.0609436 | 0.03863525 | 0.06173706 |
| Real Disposable Personal Income as % of Nation | Percent | 9.5367E-06 | 9.3222E-05 | 3.5524E-05 | -9.2983E-06 | -6.4373E-06 | 0.00132132 | 0.00199056 | 0.00095439 | 0.00039673 | 0.00024652 | 0.00038576 |
| Population | Thousands | 0.00732422 | 0.07714844 | 0.08447266 | 0.05566406 | 0.03369141 | 1.00830078 | 2.27197266 | 2.55322266 | 2.39697266 | 2.17041016 | 2.09277344 |
| Population as % of Nation | Percent | 2.1458E-06 | 2.3603E-05 | 2.5749E-05 | 1.6928E-05 | 1.0014E-05 | 0.0003016 | 0.00067544 | 0.00075364 | 0.00070262 | 0.00063205 | 0.00060534 |


Economic Summary
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
Private Non-Farm Employment
Total Employment
Total Employment as ...
Private Non-Farm Emp...
Private Non-Farm Emp...
Gross Domestic Produ...
Gross Domestic Produ...
Output
Value Added
Personal Income
Personal Income as %...
Disposable Personal ...
Disposable Personal ...
PCE-Price Index
Real Disposable Pers...
Real Disposable Pers...
Population
Population as % of N...

## Scenario B with Banking & Trading:

12/8/2014

Scenario B+BT.rwb

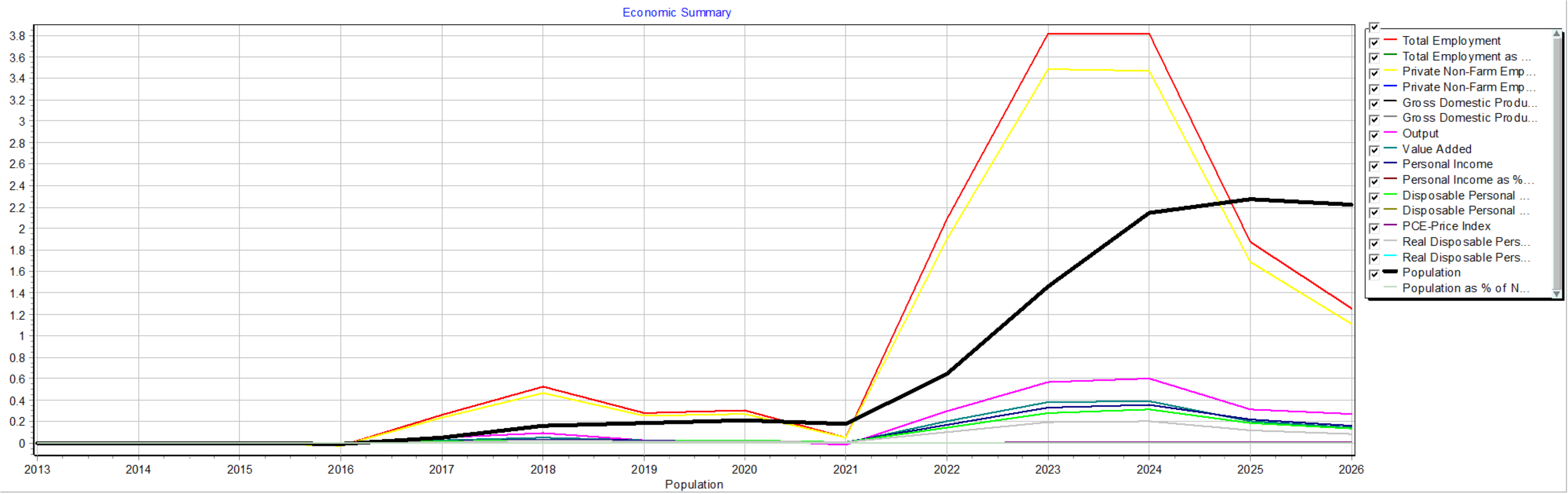
Regional Simulation 1 compared to Standard Regional Control - Difference

Region = Washington

Browser

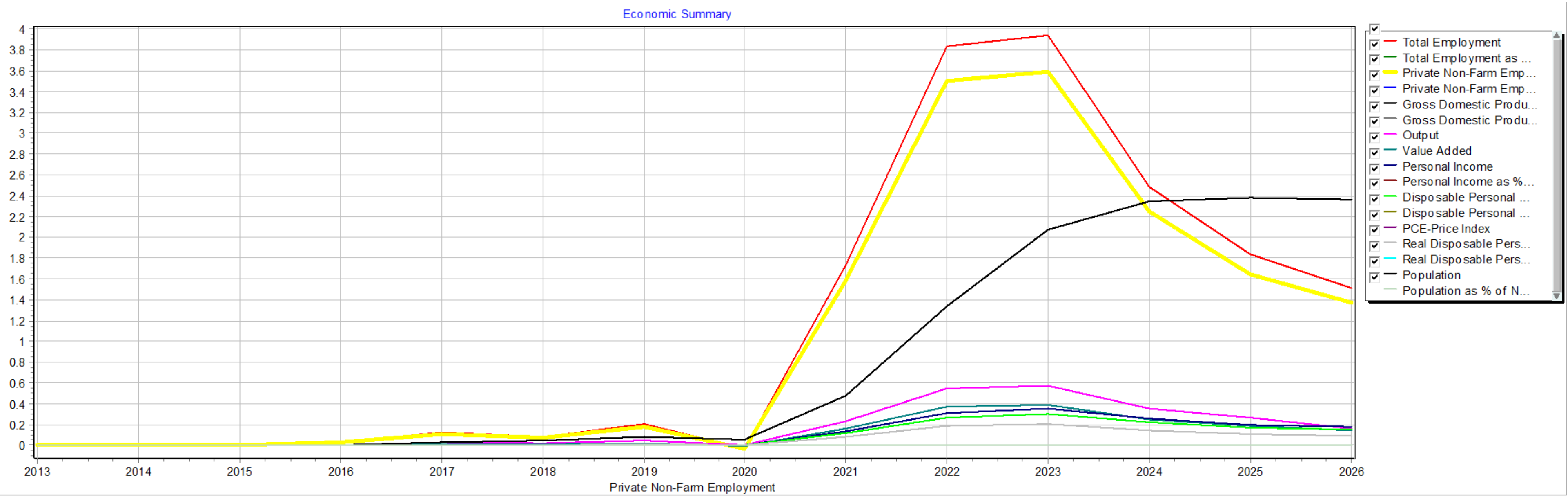
REMI PI+ State of Washington v1.6.5 (Build 3750)

| Category | Units | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total Employment | Thousands (Jobs) | -0.02539063 | 0.26220703 | 0.5234375 | 0.27880859 | 0.30273438 | 0.05224609 | 2.08642578 | 3.81689453 | 3.81689453 | 1.87744141 | 1.25439453 |
| Total Employment as % of Nation | Percent | -1.3113E-05 | 0.00013566 | 0.0002687 | 0.0001421 | 0.00015378 | 2.6226E-05 | 0.0010457 | 0.00190234 | 0.00189137 | 0.0009253 | 0.00061488 |
| Private Non-Farm Employment | Thousands (Jobs) | -0.02270508 | 0.23388672 | 0.4699707 | 0.25488281 | 0.27368164 | 0.04907227 | 1.90332031 | 3.48364258 | 3.47290039 | 1.68774414 | 1.10888672 |
| Private Non-Farm Employment as % of Nation | Percent | -1.3828E-05 | 0.00014043 | 0.0002799 | 0.00015068 | 0.00016046 | 2.861E-05 | 0.00109982 | 0.00199842 | 0.00197721 | 0.00095439 | 0.00062275 |
| Gross Domestic Product | Billions of Fixed (2009) Dollars | -0.00234985 | 0.02944946 | 0.05349731 | 0.02166748 | 0.02832031 | 0.00115967 | 0.20571899 | 0.3788147 | 0.39135742 | 0.20227051 | 0.1439209 |
| Gross Domestic Product (GDP) as % of Nation | Percent | -1.3351E-05 | 0.00016451 | 0.00029159 | 0.00011539 | 0.00014734 | 5.9605E-06 | 0.00102305 | 0.00184274 | 0.00186467 | 0.00094414 | 0.0006578 |
| Output | Billions of Fixed (2009) Dollars | -0.0045166 | 0.04705811 | 0.09136963 | 0.02459717 | 0.02520752 | -0.01885986 | 0.29907227 | 0.5723877 | 0.60498047 | 0.31359863 | 0.26977539 |
| Value Added | Billions of Fixed (2009) Dollars | -0.0022583 | 0.02932739 | 0.05340576 | 0.02163696 | 0.02828979 | 0.00128174 | 0.20562744 | 0.37893677 | 0.39126587 | 0.20236206 | 0.1439209 |
| Personal Income | Billions of Current Dollars | -0.00131226 | 0.01599121 | 0.0333252 | 0.02145386 | 0.02597046 | 0.01174927 | 0.16946411 | 0.32702637 | 0.35858154 | 0.21899414 | 0.15795898 |
| Personal Income as % of Nation | Percent | -7.8678E-06 | 9.2983E-05 | 0.00018525 | 0.0001142 | 0.00013256 | 5.7459E-05 | 0.00079226 | 0.00146627 | 0.00154328 | 0.00090504 | 0.0006268 |
| Disposable Personal Income | Billions of Current Dollars | -0.00112915 | 0.01373291 | 0.02862549 | 0.01855469 | 0.02249146 | 0.01031494 | 0.14584351 | 0.2817688 | 0.30978394 | 0.19055176 | 0.13818359 |
| Disposable Personal Income as % of Nation | Percent | -8.1062E-06 | 9.1553E-05 | 0.00018287 | 0.00011349 | 0.00013185 | 5.7936E-05 | 0.00078392 | 0.00145268 | 0.00153327 | 0.00090575 | 0.00063038 |
| PCE-Price Index | 2009=100 (Nation) | -2.2888E-05 | 0.00016785 | 0.00056458 | 0.00074768 | 0.00076294 | 0.00064087 | 0.00183105 | 0.00463867 | 0.00691223 | 0.00688171 | 0.00561523 |
| Real Disposable Personal Income | Billions of Fixed (2009) Dollars | -0.00091553 | 0.01095581 | 0.02182007 | 0.0128479 | 0.015625 | 0.0062561 | 0.10446167 | 0.19482422 | 0.20501709 | 0.11663818 | 0.08096313 |
| Real Disposable Personal Income as % of Nation | Percent | -7.1526E-06 | 8.3685E-05 | 0.0001626 | 9.346E-05 | 0.0001111 | 4.3631E-05 | 0.00071025 | 0.0012958 | 0.00133538 | 0.0007441 | 0.00050592 |
| Population | Thousands | -0.00585938 | 0.05322266 | 0.15869141 | 0.18554688 | 0.21191406 | 0.17675781 | 0.64257813 | 1.45605469 | 2.14697266 | 2.27587891 | 2.21972656 |
| Population as % of Nation | Percent | -1.9073E-06 | 1.6451E-05 | 4.8399E-05 | 5.6505E-05 | 6.3896E-05 | 5.2929E-05 | 0.00019097 | 0.00042987 | 0.00062943 | 0.0006628 | 0.00064206 |


Economic Summary
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
Population
Total Employment
Total Employment as ...
Private Non-Farm Emp...
Private Non-Farm Emp...
Gross Domestic Produ...
Gross Domestic Produ...
Output
Value Added
Personal Income
Personal Income as %...
Disposable Personal ...
Disposable Personal ...
PCE-Price Index
Real Disposable Pers...
Real Disposable Pers...
Population
Population as % of N...

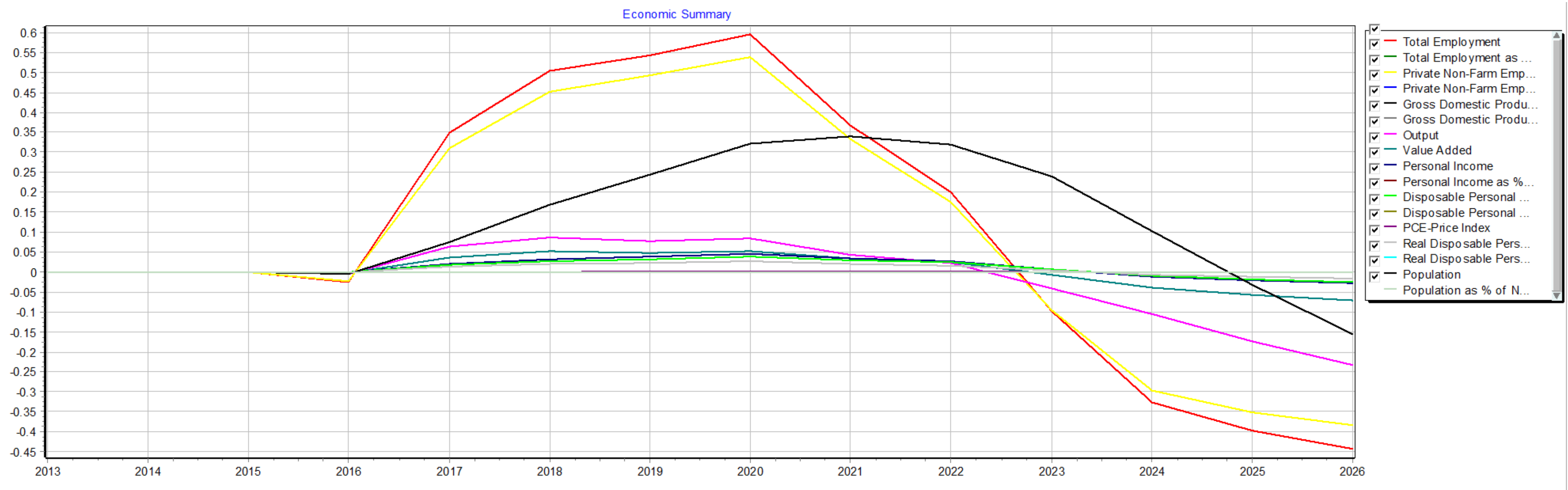
## Scenario C:

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12/11/2014 | | | | | | | | | | | | |
| Untitled.rwb | | | | | | | | | | | | |
| Regional Simulation 1 compared to Standard Regional Control - Difference | | | | | | | | | | | | |
| Region = Washington | | | | | | | | | | | | |
| Browser | | | | | | | | | | | | |
| REMI PI+ State of Washington v1.6.5 (Build 3750) | | | | | | | | | | | | |
| Category | Units | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 |
| Total Employment | Thousands (Jobs) | 0.03173828 | 0.12451172 | 0.08105469 | 0.20166016 | -0.03125 | 1.72851563 | 3.83642578 | 3.94140625 | 2.48632813 | 1.83251953 | 1.51513672 |
| Total Employment as % of Nation | Percent | 1.6689E-05 | 6.4135E-05 | 4.1723E-05 | 0.00010276 | -1.5736E-05 | 0.00087166 | 0.00192285 | 0.00196457 | 0.00123215 | 0.00090313 | 0.00074291 |
| Private Non-Farm Employment | Thousands (Jobs) | 0.02832031 | 0.11132813 | 0.07104492 | 0.17749023 | -0.03100586 | 1.58300781 | 3.50390625 | 3.59375 | 2.25195313 | 1.64770508 | 1.36767578 |
| Private Non-Farm Employment as % of Nation | Percent | 1.7166E-05 | 6.6996E-05 | 4.22E-05 | 0.0001049 | -1.8358E-05 | 0.0009222 | 0.00202465 | 0.00206161 | 0.00128222 | 0.00093174 | 0.00076818 |
| Gross Domestic Product | Billions of Fixed (2009) Dollars | 0.00280762 | 0.01342773 | 0.01000977 | 0.02478027 | -0.00091553 | 0.16253662 | 0.37487793 | 0.38830566 | 0.25234985 | 0.18429565 | 0.14303589 |
| Gross Domestic Product (GDP) as % of Nation | Percent | 1.6212E-05 | 7.4863E-05 | 5.4598E-05 | 0.00013185 | -5.0068E-06 | 0.0008266 | 0.00186419 | 0.00188899 | 0.00120234 | 0.00086021 | 0.00065374 |
| Output | Billions of Fixed (2009) Dollars | 0.00592041 | 0.02642822 | 0.02020264 | 0.04370117 | 0.00231934 | 0.23095703 | 0.54956055 | 0.57110596 | 0.35559082 | 0.26318359 | 0.16534424 |
| Value Added | Billions of Fixed (2009) Dollars | 0.00292969 | 0.0133667 | 0.00991821 | 0.02487183 | -0.00085449 | 0.16259766 | 0.37478638 | 0.38830566 | 0.25238037 | 0.18432617 | 0.14303589 |
| Personal Income | Billions of Current Dollars | 0.00170898 | 0.00762939 | 0.006073 | 0.01473999 | 0.00152588 | 0.13470459 | 0.31228638 | 0.35131836 | 0.25567627 | 0.19909668 | 0.17974854 |
| Personal Income as % of Nation | Percent | 1.049E-05 | 4.4346E-05 | 3.3855E-05 | 7.844E-05 | 7.8678E-06 | 0.00065708 | 0.00145984 | 0.00157523 | 0.00110054 | 0.00082254 | 0.00071335 |
| Disposable Personal Income | Billions of Current Dollars | 0.00146484 | 0.00656128 | 0.00521851 | 0.01269531 | 0.00140381 | 0.11584473 | 0.26885986 | 0.30331421 | 0.22189331 | 0.17346191 | 0.15704346 |
| Disposable Personal Income as % of Nation | Percent | 1.0252E-05 | 4.3631E-05 | 3.3379E-05 | 7.7486E-05 | 8.1062E-06 | 0.00064969 | 0.00144529 | 0.00156379 | 0.00109816 | 0.00082445 | 0.00071645 |
| PCE-Price Index | 2009=100 (Nation) | 0 | 0.00013733 | 0.00019836 | 0.0002594 | 0.00021362 | 0.00137329 | 0.00428772 | 0.00686646 | 0.00733948 | 0.00662231 | 0.00585938 |
| Real Disposable Personal Income | Billions of Fixed (2009) Dollars | 0.0012207 | 0.00509644 | 0.00375366 | 0.00942993 | 0.00054932 | 0.08496094 | 0.1902771 | 0.20495605 | 0.14071655 | 0.10525513 | 0.09338379 |
| Real Disposable Personal Income as % of Nation | Percent | 9.5367E-06 | 3.8862E-05 | 2.7895E-05 | 6.8665E-05 | 3.8147E-06 | 0.0005908 | 0.00129366 | 0.00136328 | 0.00091648 | 0.00067163 | 0.00058341 |
| Population | Thousands | 0.00732422 | 0.03222656 | 0.04541016 | 0.08251953 | 0.05859375 | 0.47802734 | 1.33447266 | 2.07373047 | 2.34130859 | 2.38476563 | 2.36279297 |
| Population as % of Nation | Percent | 2.1458E-06 | 9.7752E-06 | 1.359E-05 | 2.5272E-05 | 1.7643E-05 | 0.00014305 | 0.00039673 | 0.00061202 | 0.00068641 | 0.00069451 | 0.00068355 |


Economic Summary
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
Private Non-Farm Employment
Total Employment
Total Employment as ...
Private Non-Farm Emp...
Private Non-Farm Emp...
Gross Domestic Produ...
Gross Domestic Produ...
Output
Value Added
Personal Income
Personal Income as %...
Disposable Personal ...
Disposable Personal ...
PCE-Price Index
Real Disposable Pers...
Real Disposable Pers...
Population
Population as % of N...

## Scenario C with Banking & Trading:

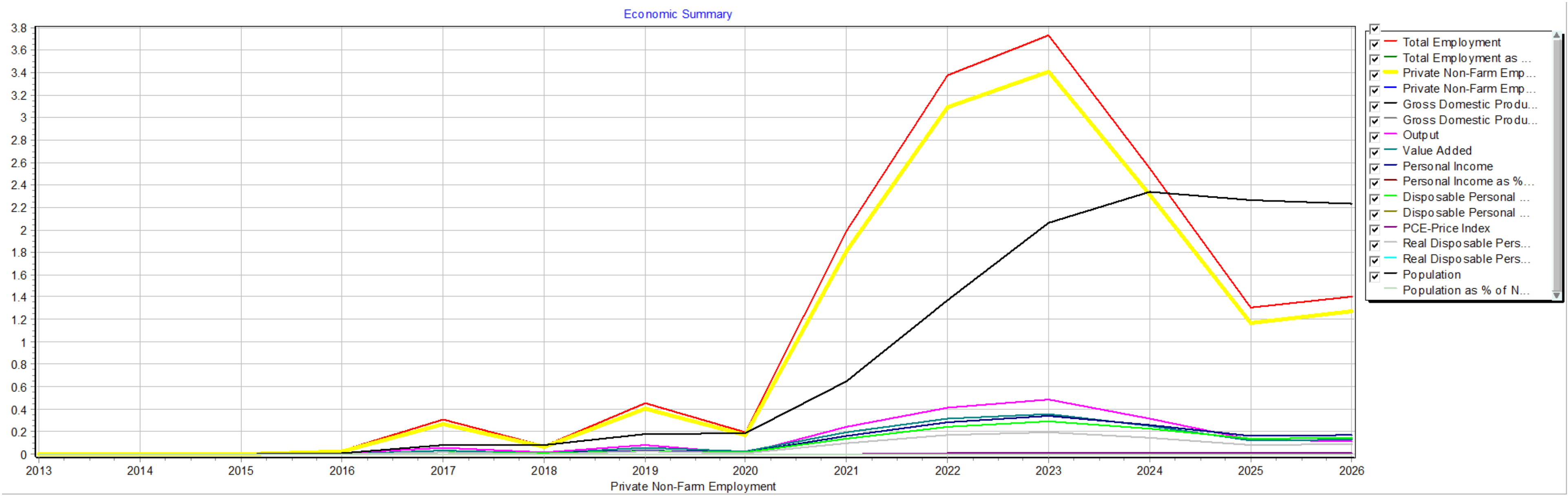
| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12/11/2014 | | | | | | | | | | | | |
| Untitled.rwb | | | | | | | | | | | | |
| Regional Simulation 1 compared to Standard Regional Control - Difference | | | | | | | | | | | | |
| Region = Washington | | | | | | | | | | | | |
| Browser | | | | | | | | | | | | |
| REMI PI+ State of Washington v1.6.5 (Build 3750) | | | | | | | | | | | | |
| Category | Units | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 |
| Total Employment | Thousands (Jobs) | -0.02490234 | 0.34814453 | 0.50292969 | 0.54199219 | 0.59521484 | 0.36767578 | 0.20019531 | -0.09912109 | -0.32763672 | -0.39648438 | -0.44287109 |
| Total Employment as % of Nation | Percent | -1.3113E-05 | 0.00018001 | 0.00025845 | 0.00027657 | 0.00030208 | 0.00018525 | 0.00010014 | -4.9353E-05 | -0.00016236 | -0.00019526 | -0.0002172 |
| Private Non-Farm Employment | Thousands (Jobs) | -0.02246094 | 0.31079102 | 0.45141602 | 0.4921875 | 0.53930664 | 0.33203125 | 0.17456055 | -0.09667969 | -0.29736328 | -0.3515625 | -0.3840332 |
| Private Non-Farm Employment as % of Nation | Percent | -1.359E-05 | 0.00018668 | 0.0002687 | 0.00029087 | 0.00031638 | 0.00019336 | 0.00010085 | -5.5552E-05 | -0.00016928 | -0.0001986 | -0.00021577 |
| Gross Domestic Product | Billions of Fixed (2009) Dollars | -0.00231934 | 0.03692627 | 0.05130005 | 0.0473938 | 0.05325317 | 0.03289795 | 0.02383423 | -0.00683594 | -0.03799438 | -0.05627441 | -0.07107544 |
| Gross Domestic Product (GDP) as % of Nation | Percent | -1.3113E-05 | 0.00020623 | 0.00027966 | 0.00025249 | 0.00027704 | 0.00016737 | 0.00011873 | -3.3379E-05 | -0.0001812 | -0.0002625 | -0.00032496 |
| Output | Billions of Fixed (2009) Dollars | -0.0045166 | 0.06359863 | 0.08746338 | 0.07769775 | 0.08465576 | 0.04394531 | 0.02160645 | -0.04211426 | -0.10522461 | -0.17474365 | -0.23309326 |
| Value Added | Billions of Fixed (2009) Dollars | -0.00222778 | 0.0369873 | 0.05117798 | 0.0473938 | 0.05319214 | 0.03295898 | 0.02380371 | -0.00683594 | -0.03796387 | -0.05636597 | -0.07104492 |
| Personal Income | Billions of Current Dollars | -0.00131226 | 0.0206604 | 0.0324707 | 0.03747559 | 0.0451355 | 0.03503418 | 0.0274353 | 0.00762939 | -0.01135254 | -0.02099609 | -0.02850342 |
| Personal Income as % of Nation | Percent | -7.8678E-06 | 0.00012016 | 0.00018048 | 0.00019932 | 0.00023007 | 0.00017095 | 0.00012827 | 3.4094E-05 | -4.8637E-05 | -8.6784E-05 | -0.00011301 |
| Disposable Personal Income | Billions of Current Dollars | -0.00112915 | 0.01773071 | 0.02789307 | 0.0322876 | 0.03897095 | 0.03039551 | 0.0239563 | 0.00695801 | -0.00939941 | -0.0178833 | -0.02441406 |
| Disposable Personal Income as % of Nation | Percent | -8.1062E-06 | 0.00011849 | 0.00017834 | 0.00019741 | 0.0002284 | 0.00017047 | 0.00012875 | 3.5763E-05 | -4.6253E-05 | -8.4877E-05 | -0.00011134 |
| PCE-Price Index | 2009=100 (Nation) | -2.2888E-05 | 0.00027466 | 0.00070953 | 0.00102234 | 0.00125122 | 0.0012207 | 0.00094604 | 0.00065613 | 0.00033569 | -4.5776E-05 | -0.00030518 |
| Real Disposable Personal Income | Billions of Fixed (2009) Dollars | -0.00091553 | 0.01400757 | 0.02087402 | 0.02310181 | 0.0272522 | 0.02011108 | 0.01553345 | 0.00344849 | -0.00762939 | -0.01251221 | -0.01611328 |
| Real Disposable Personal Income as % of Nation | Percent | -7.1526E-06 | 0.00010705 | 0.00015545 | 0.00016809 | 0.00019383 | 0.00013995 | 0.00010562 | 2.2888E-05 | -4.9829E-05 | -7.9632E-05 | -0.00010085 |
| Population | Thousands | -0.00537109 | 0.07519531 | 0.16845703 | 0.24462891 | 0.32080078 | 0.33984375 | 0.31933594 | 0.24023438 | 0.10253906 | -0.03222656 | -0.15429688 |
| Population as % of Nation | Percent | -1.6689E-06 | 2.3127E-05 | 5.126E-05 | 7.4387E-05 | 9.656E-05 | 0.00010157 | 9.4891E-05 | 7.081E-05 | 3.0041E-05 | -9.5367E-06 | -4.4823E-05 |



Economic Summary
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
-0.3
-0.35
-0.4
-0.45
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
Total Employment
Total Employment as ...
Private Non-Farm Emp...
Private Non-Farm Emp...
Gross Domestic Produ...
Gross Domestic Produ...
Output
Value Added
Personal Income
Personal Income as %...
Disposable Personal ...
Disposable Personal ...
PCE-Price Index
Real Disposable Pers...
Real Disposable Pers...
Population
Population as % of N...

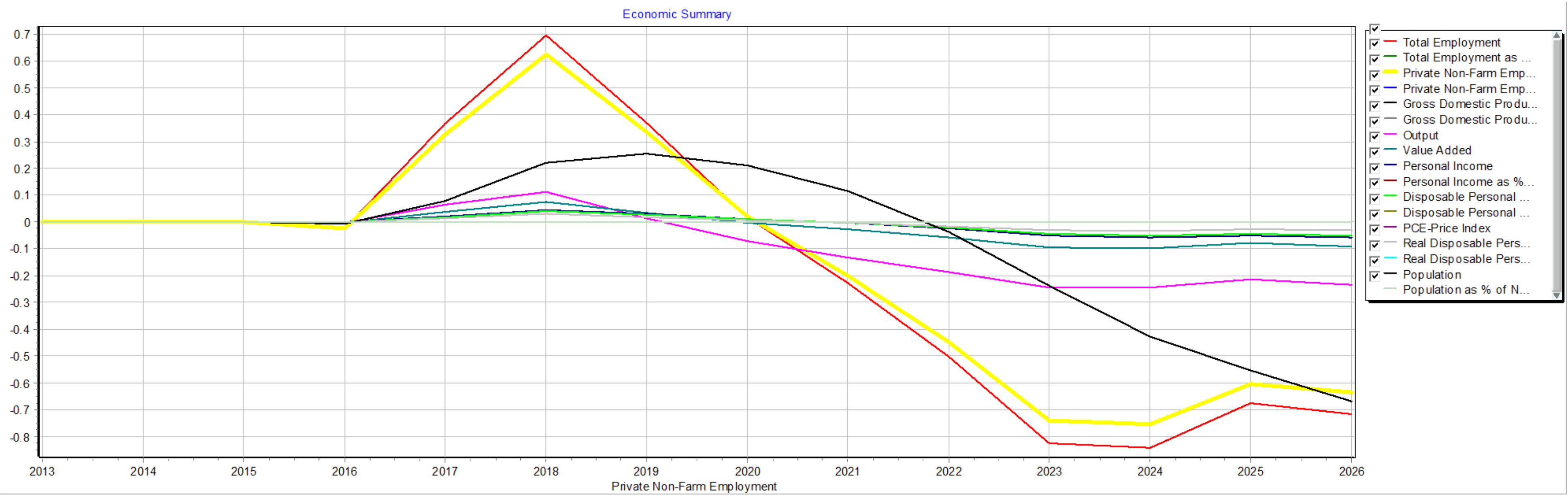
## Scenario D:

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12/11/2014 | | | | | | | | | | | | |
| Untitled.rwb | | | | | | | | | | | | |
| Regional Simulation 2 compared to Standard Regional Control - Difference | | | | | | | | | | | | |
| Region = Washington | | | | | | | | | | | | |
| Browser | | | | | | | | | | | | |
| REMI PI+ State of Washington v1.6.5 (Build 3750) | | | | | | | | | | | | |
| Category | Units | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 |
| Total Employment | Thousands (Jobs) | 0.03173828 | 0.3046875 | 0.07421875 | 0.45458984 | 0.19189453 | 1.98779297 | 3.37597656 | 3.73291016 | 2.55029297 | 1.30712891 | 1.40722656 |
| Total Employment as % of Nation | Percent | 1.6689E-05 | 0.00015759 | 3.8147E-05 | 0.00023174 | 9.7513E-05 | 0.00100231 | 0.00169206 | 0.00186062 | 0.00126386 | 0.00064421 | 0.00068998 |
| Private Non-Farm Employment | Thousands (Jobs) | 0.02832031 | 0.27099609 | 0.06420898 | 0.40332031 | 0.16772461 | 1.8112793 | 3.09399414 | 3.41015625 | 2.31567383 | 1.17236328 | 1.2746582 |
| Private Non-Farm Employment as % of Nation | Percent | 1.7166E-05 | 0.00016284 | 3.8385E-05 | 0.00023842 | 9.8228E-05 | 0.001055 | 0.00178766 | 0.00195622 | 0.00131822 | 0.00066304 | 0.00071597 |
| Gross Domestic Product | Billions of Fixed (2009) Dollars | 0.00280762 | 0.03497314 | 0.00817871 | 0.05395508 | 0.02520752 | 0.19830322 | 0.31814575 | 0.36029053 | 0.25039673 | 0.12515259 | 0.12649536 |
| Gross Domestic Product (GDP) as % of Nation | Percent | 1.6212E-05 | 0.00019526 | 4.4584E-05 | 0.00028729 | 0.00013113 | 0.00100851 | 0.00158215 | 0.00175261 | 0.00119305 | 0.00058413 | 0.00057817 |
| Output | Billions of Fixed (2009) Dollars | 0.00592041 | 0.06072998 | 0.01843262 | 0.08007813 | 0.01153564 | 0.24163818 | 0.41430664 | 0.48571777 | 0.31658936 | 0.13354492 | 0.11700439 |
| Value Added | Billions of Fixed (2009) Dollars | 0.00292969 | 0.03485107 | 0.00808716 | 0.05395508 | 0.02523804 | 0.19836426 | 0.31817627 | 0.3604126 | 0.25039673 | 0.12509155 | 0.12643433 |
| Personal Income | Billions of Current Dollars | 0.00170898 | 0.01864624 | 0.0062561 | 0.03234863 | 0.01968384 | 0.15838623 | 0.28503418 | 0.33746338 | 0.2598877 | 0.15936279 | 0.1685791 |
| Personal Income as % of Nation | Percent | 1.049E-05 | 0.00010824 | 3.4809E-05 | 0.00017214 | 0.00010037 | 0.00077271 | 0.00133252 | 0.001513 | 0.00111866 | 0.00065851 | 0.000669 |
| Disposable Personal Income | Billions of Current Dollars | 0.00146484 | 0.01602173 | 0.00543213 | 0.02783203 | 0.01708984 | 0.13632202 | 0.2456665 | 0.29147339 | 0.22549438 | 0.1394043 | 0.14733887 |
| Disposable Personal Income as % of Nation | Percent | 1.0252E-05 | 0.00010681 | 3.4809E-05 | 0.00016999 | 0.00010014 | 0.00076461 | 0.0013206 | 0.00150275 | 0.00111604 | 0.00066257 | 0.0006721 |
| PCE-Price Index | 2009=100 (Nation) | 0 | 0.00031281 | 0.00035858 | 0.00055695 | 0.00076294 | 0.0019989 | 0.00460815 | 0.00675964 | 0.00726318 | 0.00624084 | 0.0052948 |
| Real Disposable Personal Income | Billions of Fixed (2009) Dollars | 0.0012207 | 0.01248169 | 0.00350952 | 0.02072144 | 0.01141357 | 0.09899902 | 0.17211914 | 0.19656372 | 0.14352417 | 0.08221436 | 0.08813477 |
| Real Disposable Personal Income as % of Nation | Percent | 9.5367E-06 | 9.5367E-05 | 2.6226E-05 | 0.00015068 | 8.1062E-05 | 0.00068831 | 0.0011704 | 0.00130725 | 0.00093484 | 0.00052452 | 0.00055075 |
| Population | Thousands | 0.00732422 | 0.078125 | 0.07910156 | 0.17626953 | 0.18945313 | 0.65039063 | 1.36914063 | 2.05761719 | 2.33789063 | 2.26074219 | 2.234375 |
| Population as % of Nation | Percent | 2.1458E-06 | 2.408E-05 | 2.408E-05 | 5.3644E-05 | 5.6982E-05 | 0.00019455 | 0.00040698 | 0.00060725 | 0.00068521 | 0.00065827 | 0.00064635 |


Economic Summary
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
Private Non-Farm Employment
Total Employment
Total Employment as ...
Private Non-Farm Emp...
Private Non-Farm Emp...
Gross Domestic Produ...
Gross Domestic Produ...
Output
Value Added
Personal Income
Personal Income as %...
Disposable Personal ...
Disposable Personal ...
PCE-Price Index
Real Disposable Pers...
Real Disposable Pers...
Population
Population as % of N...

## Scenario D with Banking & Trading:

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12/8/2014 | | | | | | | | | | | | | | | |
| Scenario D+BT.rwb | | | | | | | | | | | | | | | |
| Regional Simulation 1 compared to Standard Regional Control - Difference | | | | | | | | | | | | | | | |
| Region = Washington | | | | | | | | | | | | | | | |
| Browser | | | | | | | | | | | | | | | |
| REMI PI+ State of Washington v1.6.5 (Build 3750) | | | | | | | | | | | | | | | |
| Category | Units | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 |
| Total Employment | Thousands (Jobs) | 0 | 0 | 0 | -0.02539063 | 0.36523438 | 0.6953125 | 0.37060547 | 0.01855469 | -0.22802734 | -0.50146484 | -0.82519531 | -0.84130859 | -0.67382813 | -0.71435547 |
| Total Employment as % of Nation | Percent | 0 | 0 | 0 | -1.3113E-05 | 0.00018883 | 0.00035715 | 0.00018907 | 9.5367E-06 | -0.00011516 | -0.00025153 | -0.00041127 | -0.00041699 | -0.00033212 | -0.00035048 |
| Private Non-Farm Employment | Thousands (Jobs) | 0 | 0 | 0 | -0.02270508 | 0.32666016 | 0.62304688 | 0.33544922 | 0.02075195 | -0.20141602 | -0.44799805 | -0.74023438 | -0.75341797 | -0.6027832 | -0.63330078 |
| Private Non-Farm Employment as % of Nation | Percent | 0 | 0 | 0 | -1.3828E-05 | 0.00019622 | 0.00037098 | 0.00019813 | 1.1921E-05 | -0.00011754 | -0.00025868 | -0.00042486 | -0.00042915 | -0.0003407 | -0.00035572 |
| Gross Domestic Product | Billions of Fixed (2009) Dollars | 0 | 0 | 0 | -0.00234985 | 0.03872681 | 0.07467651 | 0.03503418 | -0.00482178 | -0.02890015 | -0.05865479 | -0.09573364 | -0.09750366 | -0.07913208 | -0.09039307 |
| Gross Domestic Product (GDP) as % of Nation | Percent | 0 | 0 | 0 | -1.3351E-05 | 0.00021625 | 0.00040722 | 0.00018644 | -2.5272E-05 | -0.00014687 | -0.00029182 | -0.00046587 | -0.00046468 | -0.00036907 | -0.00041318 |
| Output | Billions of Fixed (2009) Dollars | 0 | 0 | 0 | -0.0045166 | 0.06591797 | 0.11126709 | 0.01409912 | -0.07299805 | -0.13171387 | -0.18792725 | -0.2456665 | -0.24432373 | -0.21484375 | -0.2333374 |
| Value Added | Billions of Fixed (2009) Dollars | 0 | 0 | 0 | -0.0022583 | 0.03863525 | 0.07467651 | 0.03509521 | -0.00482178 | -0.02883911 | -0.05883789 | -0.09567261 | -0.09765625 | -0.07913208 | -0.09042358 |
| Personal Income | Billions of Current Dollars | 0 | 0 | 0 | -0.00131226 | 0.02163696 | 0.04541016 | 0.03060913 | 0.01074219 | -0.00469971 | -0.02514648 | -0.05200195 | -0.05853271 | -0.05047607 | -0.05755615 |
| Personal Income as % of Nation | Percent | 0 | 0 | 0 | -7.8678E-06 | 0.00012565 | 0.00025225 | 0.00016284 | 5.4836E-05 | -2.2888E-05 | -0.00011754 | -0.00023317 | -0.00025177 | -0.00020862 | -0.00022817 |
| Disposable Personal Income | Billions of Current Dollars | 0 | 0 | 0 | -0.00112915 | 0.01855469 | 0.03900146 | 0.02648926 | 0.00952148 | -0.00375366 | -0.0213623 | -0.04458618 | -0.05041504 | -0.04370117 | -0.04992676 |
| Disposable Personal Income as % of Nation | Percent | 0 | 0 | 0 | -8.1062E-06 | 0.00012374 | 0.00024915 | 0.00016189 | 5.579E-05 | -2.0981E-05 | -0.00011468 | -0.00022984 | -0.00024939 | -0.00020766 | -0.00022769 |
| PCE-Price Index | 2009=100 (Nation) | 0 | 0 | 0 | -2.2888E-05 | 0.00028992 | 0.00080109 | 0.00101471 | 0.00083923 | 0.00053406 | 9.1553E-05 | -0.00045776 | -0.00090027 | -0.00102234 | -0.00108337 |
| Real Disposable Personal Income | Billions of Fixed (2009) Dollars | 0 | 0 | 0 | -0.00091553 | 0.01464844 | 0.02966309 | 0.01852417 | 0.00531006 | -0.00424194 | -0.01620483 | -0.03155518 | -0.03393555 | -0.02819824 | -0.03170776 |
| Real Disposable Personal Income as % of Nation | Percent | 0 | 0 | 0 | -7.1526E-06 | 0.00011182 | 0.00022101 | 0.00013471 | 3.767E-05 | -2.9325E-05 | -0.00011015 | -0.00021005 | -0.00022125 | -0.00017977 | -0.00019836 |
| Population | Thousands | 0 | 0 | 0 | -0.00585938 | 0.07714844 | 0.22167969 | 0.25585938 | 0.20996094 | 0.11376953 | -0.03759766 | -0.23779297 | -0.42626953 | -0.55273438 | -0.66992188 |
| Population as % of Nation | Percent | 0 | 0 | 0 | -1.9073E-06 | 2.3603E-05 | 6.7711E-05 | 7.7724E-05 | 6.3181E-05 | 3.4094E-05 | -1.0967E-05 | -7.0095E-05 | -0.00012493 | -0.00016093 | -0.00019383 |


Economic Summary
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
Private Non-Farm Employment
Total Employment
Total Employment as ...
Private Non-Farm Emp...
Private Non-Farm Emp...
Gross Domestic Produ...
Gross Domestic Produ...
Output
Value Added
Personal Income
Personal Income as %...
Disposable Personal ...
Disposable Personal ...
PCE-Price Index
Real Disposable Pers...
Real Disposable Pers...
Population
Population as % of N...

Part 2: List of All Sectors

The table below represents the output results for all sectors for which the REMI PI+ v1.6 model reports results.

12/11/2014

Scenario C compared to Standard Regional Control - Difference

Region = Washington

Browser

REMI PI+ State of Washington v1.6.5 (Build 3750)

| Category | Units | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Forestry; Fishing, hunting, trapping | Billions of Fixed (2009) Dollars | 2.861E-06 | 1.1206E-05 | 8.5831E-06 | 1.8597E-05 | 1.2398E-05 | 4.1485E-05 | 8.8453E-05 | 0.00010538 | 9.9182E-05 | 0.00021195 | 0.00020456 |
| Logging | Billions of Fixed (2009) Dollars | 2.1458E-06 | 1.4663E-05 | 1.2159E-05 | 3.5405E-05 | 3.4571E-06 | 9.0241E-05 | 0.00022018 | 0.00020599 | 0.00014496 | 0.00012851 | 8.1301E-05 |
| Support activities for agriculture and forestry | Billions of Fixed (2009) Dollars | 3.5763E-07 | 1.1921E-06 | 4.7684E-07 | 1.1325E-06 | -7.7486E-07 | 5.1856E-06 | 1.1802E-05 | 8.1658E-06 | -9.5367E-07 | 4.9472E-06 | 1.4901E-06 |
| Oil and gas extraction | Billions of Fixed (2009) Dollars | 2.1935E-05 | 6.3181E-05 | 2.1458E-05 | -0.00023532 | -0.00045061 | -0.00210667 | -0.00338799 | -0.0050686 | -0.00730741 | -0.0106681 | -0.01369071 |
| Coal mining | Billions of Fixed (2009) Dollars | 1.4678E-06 | 5.3048E-06 | 3.5986E-06 | -3.6657E-06 | -1.318E-05 | -7.8171E-05 | -0.00012554 | -0.00017893 | -0.00025798 | -0.00035919 | -0.00047015 |
| Metal ore mining | Billions of Fixed (2009) Dollars | 5.3272E-07 | 2.2203E-06 | 1.9222E-06 | 4.15E-06 | 3.6582E-06 | 9.4399E-06 | 2.0027E-05 | 2.8536E-05 | 3.3312E-05 | 5.2847E-05 | 5.3532E-05 |
| Nonmetallic mineral mining and quarrying | Billions of Fixed (2009) Dollars | 1.3471E-05 | 5.9068E-05 | 5.3644E-05 | 0.00011092 | 9.9361E-05 | 6.3419E-05 | 9.2089E-05 | 0.00033391 | 0.00066286 | 0.00132078 | 0.00134289 |
| Support activities for mining | Billions of Fixed (2009) Dollars | 1.5944E-06 | 6.482E-06 | 6.713E-06 | 8.9258E-06 | 2.1607E-06 | 1.3456E-05 | 4.8652E-05 | 6.4284E-05 | 4.2975E-05 | 3.7E-05 | 4.217E-06 |
| Electric power generation, transmission, and distribution | Billions of Fixed (2009) Dollars | 2.2888E-05 | 8.8692E-05 | 6.6757E-05 | 0.0001359 | 6.5565E-05 | 0.00040889 | 0.00099468 | 0.00129366 | 0.00123334 | 0.00187039 | 0.00180006 |
| Natural gas distribution | Billions of Fixed (2009) Dollars | 8.0466E-06 | 3.1203E-05 | 2.6524E-05 | 4.6879E-05 | 3.6806E-05 | 4.7863E-05 | 0.00013119 | 0.00022328 | 0.00024998 | 0.00047928 | 0.00043315 |
| Water, sewage, and other systems | Billions of Fixed (2009) Dollars | 7.8231E-07 | 2.6301E-06 | 1.6093E-06 | 3.4049E-06 | 2.3097E-07 | 1.5363E-05 | 3.7976E-05 | 4.5925E-05 | 4.0241E-05 | 5.9329E-05 | 5.7295E-05 |
| Construction | Billions of Fixed (2009) Dollars | 0.00029373 | 0.00584793 | 0.00587463 | 0.01935577 | 0.00070953 | 0.16345215 | 0.35211563 | 0.34418869 | 0.20207214 | 0.04251862 | 0.01664734 |
| Sawmills and wood preservation | Billions of Fixed (2009) Dollars | 6.9141E-06 | 4.7445E-05 | 4.22E-05 | 0.00012159 | 2.4796E-05 | 0.00024748 | 0.0006299 | 0.00064445 | 0.00057387 | 0.0006249 | 0.00050402 |
| Veneer, plywood, and engineered wood product manufacturing | Billions of Fixed (2009) Dollars | 4.53E-06 | 3.01E-05 | 2.6107E-05 | 7.6234E-05 | 1.0729E-06 | 0.00034201 | 0.00081944 | 0.00083113 | 0.00057113 | 0.00034273 | 0.00021124 |
| Other wood product manufacturing | Billions of Fixed (2009) Dollars | 9.5367E-06 | 6.7234E-05 | 5.6028E-05 | 0.00017118 | -2.9802E-06 | 0.00031662 | 0.00091481 | 0.00093031 | 0.00082386 | 0.00084007 | 0.0005908 |
| Clay product and refractory manufacturing | Billions of Fixed (2009) Dollars | 1.1474E-06 | 4.5747E-06 | 3.0249E-06 | 7.4655E-06 | -2.1309E-06 | 0.00035216 | 0.00072756 | 0.00073557 | 0.00038873 | 7.388E-05 | 5.576E-05 |
| Glass and glass product manufacturing | Billions of Fixed (2009) Dollars | 6.7949E-06 | 2.4676E-05 | 1.4424E-05 | 3.624E-05 | -7.0333E-06 | 0.00019372 | 0.00047791 | 0.00051856 | 0.00038064 | 0.00049734 | 0.0004499 |
| Cement and concrete product manufacturing | Billions of Fixed (2009) Dollars | 9.0599E-06 | 0.00013149 | 0.00012839 | 0.0004164 | 1.8477E-05 | 0.00235677 | 0.00529659 | 0.00518799 | 0.00329995 | 0.00111437 | 0.00054717 |
| Lime, gypsum and other nonmetallic mineral product manufacturing | Billions of Fixed (2009) Dollars | 2.2948E-06 | 2.3782E-05 | 2.2233E-05 | 7.093E-05 | 3.5763E-06 | 0.00018072 | 0.00046575 | 0.00045913 | 0.00036585 | 0.00024819 | 0.00015092 |
| Iron and steel mills and ferroalloy manufacturing | Billions of Fixed (2009) Dollars | 2.2054E-06 | 1.5378E-05 | 1.3113E-05 | 3.9101E-05 | 4.6492E-06 | 0.00011057 | 0.00025666 | 0.00024229 | 0.00018102 | 0.00014693 | 0.0001055 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Steel product manufacturing from purchased steel | Billions of Fixed (2009) Dollars | 7.0035E-07 | 5.2601E-06 | 4.4256E-06 | 1.3411E-05 | 3.8743E-07 | 3.8385E-05 | 9.4458E-05 | 9.1732E-05 | 6.8158E-05 | 5.2631E-05 | 3.466E-05 |
| Alumina and aluminum production and processing | Billions of Fixed (2009) Dollars | 2.3842E-06 | 1.0371E-05 | 7.7486E-06 | 2.1219E-05 | 1.3113E-06 | 0.0001812 | 0.00037205 | 0.00036311 | 0.00021207 | 0.00011826 | 9.2387E-05 |
| Nonferrous metal (except aluminum) production and processing | Billions of Fixed (2009) Dollars | 1.3709E-06 | 6.4969E-06 | 5.1856E-06 | 1.359E-05 | 3.9935E-06 | 5.6565E-05 | 0.00012553 | 0.00013268 | 0.00010288 | 0.0001145 | 0.00010574 |
| Foundries | Billions of Fixed (2009) Dollars | 1.5497E-06 | 9.5367E-06 | 7.7486E-06 | 2.0266E-05 | 3.0994E-06 | 0.00021327 | 0.00044501 | 0.00044036 | 0.00025499 | 0.00011408 | 9.0122E-05 |
| Forging and stamping | Billions of Fixed (2009) Dollars | 5.9605E-07 | 2.2352E-06 | 1.3709E-06 | 3.3528E-06 | -9.0897E-07 | 1.9565E-05 | 4.5091E-05 | 4.4361E-05 | 2.6971E-05 | 2.7612E-05 | 2.1949E-05 |
| Cutlery and handtool manufacturing | Billions of Fixed (2009) Dollars | 5.2154E-07 | 1.5348E-06 | 6.333E-07 | 1.3784E-06 | -1.2815E-06 | 6.1542E-06 | 1.6958E-05 | 1.7509E-05 | 1.134E-05 | 2.3618E-05 | 2.0102E-05 |
| Architectural and structural metals manufacturing | Billions of Fixed (2009) Dollars | 6.6757E-06 | 7.4983E-05 | 7.1883E-05 | 0.00022519 | 1.4186E-05 | 0.00149798 | 0.0033046 | 0.00322044 | 0.0019784 | 0.00068045 | 0.00038409 |
| Boiler, tank, and shipping container manufacturing | Billions of Fixed (2009) Dollars | 8.6427E-07 | 8.3596E-06 | 7.9125E-06 | 2.4557E-05 | 5.0068E-06 | 9.6738E-05 | 0.00021125 | 0.00020444 | 0.000149 | 0.00010097 | 8.4549E-05 |
| Hardware manufacturing | Billions of Fixed (2009) Dollars | 1.0431E-06 | 5.1856E-06 | 3.6359E-06 | 1.049E-05 | -1.2815E-06 | 4.3452E-05 | 0.00010449 | 0.00010261 | 6.9112E-05 | 6.3032E-05 | 4.7117E-05 |
| Spring and wire product manufacturing | Billions of Fixed (2009) Dollars | 4.0978E-07 | 2.8014E-06 | 2.4214E-06 | 7.2718E-06 | -1.6391E-07 | 3.5986E-05 | 8.5726E-05 | 8.5101E-05 | 5.573E-05 | 3.0905E-05 | 1.9386E-05 |
| Machine shops; turned product; and screw, nut, and bolt manufacturing | Billions of Fixed (2009) Dollars | 3.6359E-06 | 1.6451E-05 | 1.4007E-05 | 3.612E-05 | 1.5855E-05 | 0.00017035 | 0.00036985 | 0.00040817 | 0.00032681 | 0.00033945 | 0.00032771 |
| Coating, engraving, heat treating, and allied activities | Billions of Fixed (2009) Dollars | 3.5763E-06 | 1.9193E-05 | 1.7524E-05 | 4.4465E-05 | 2.4676E-05 | 0.00014079 | 0.00031126 | 0.00036973 | 0.00035906 | 0.00044721 | 0.00044906 |
| Other fabricated metal product manufacturing | Billions of Fixed (2009) Dollars | 3.0696E-06 | 1.4842E-05 | 1.0967E-05 | 5.132E-05 | 1.967E-06 | 0.0004971 | 0.00101507 | 0.00103968 | 0.00061005 | 0.00029004 | 0.0001967 |
| Agriculture, construction, and mining machinery manufacturing | Billions of Fixed (2009) Dollars | 5.9605E-07 | 2.2054E-06 | 1.9372E-06 | 2.8312E-06 | 5.9605E-07 | 8.8513E-06 | 2.3693E-05 | 1.7762E-05 | 8.4639E-06 | 1.4961E-05 | 8.5831E-06 |
| Industrial machinery manufacturing | Billions of Fixed (2009) Dollars | 6.0797E-06 | 2.4438E-05 | 2.2292E-05 | 4.3273E-05 | 4.2081E-05 | 0.00012112 | 0.00024557 | 0.00030649 | 0.00027251 | 0.0002991 | 0.00021207 |
| Commercial and service industry machinery manufacturing | Billions of Fixed (2009) Dollars | 4.6194E-06 | 1.5408E-05 | 7.3612E-06 | 1.7375E-05 | -1.5229E-05 | 6.3002E-05 | 0.00018817 | 0.00018996 | 0.00012356 | 0.00023788 | 0.00019556 |
| Ventilation, heating, air-conditioning, and commercial refrigeration equipment manufacturing | Billions of Fixed (2009) Dollars | 5.5432E-06 | 3.2306E-05 | 2.9266E-05 | 7.6413E-05 | 2.5749E-05 | 0.00070316 | 0.0014624 | 0.00149351 | 0.00095779 | 0.00053871 | 0.00049609 |
| Metalworking machinery manufacturing | Billions of Fixed (2009) Dollars | 1.5497E-06 | 6.7353E-06 | 6.0201E-06 | 1.2934E-05 | 6.5565E-06 | 8.893E-05 | 0.00018811 | 0.00020045 | 0.00013632 | 0.00010622 | 9.4712E-05 |
| Engine, turbine, power transmission equipment manufacturing | Billions of Fixed (2009) Dollars | 4.4703E-07 | 1.4454E-06 | 8.0466E-07 | 1.6838E-06 | -7.3016E-07 | 1.1444E-05 | 2.5973E-05 | 2.5377E-05 | 1.3262E-05 | 1.3039E-05 | 9.0003E-06 |
| Other general purpose machinery manufacturing | Billions of Fixed (2009) Dollars | 2.5034E-06 | 1.4067E-05 | 1.2279E-05 | 3.1114E-05 | 2.0266E-06 | 0.0011009 | 0.00222731 | 0.00220609 | 0.00114167 | 0.00012314 | 7.8797E-05 |
| Computer and peripheral equipment manufacturing | Billions of Fixed (2009) Dollars | 5.8413E-06 | 1.8239E-05 | 5.722E-06 | 9.2983E-06 | -3.314E-05 | 4.9353E-05 | 0.00010967 | -4.22E-05 | -0.00035048 | -0.00029302 | -0.0004375 |
| Communications equipment manufacturing | Billions of Fixed (2009) Dollars | 2.2054E-06 | 6.3181E-06 | 3.0398E-06 | 4.7088E-06 | -6.6757E-06 | 1.663E-05 | 4.369E-05 | 1.3471E-05 | -5.0485E-05 | -3.4511E-05 | -6.8843E-05 |
| Audio and video equipment manufacturing | Billions of Fixed (2009) Dollars | 1.9372E-06 | 5.3346E-06 | 6.5565E-07 | 4.4703E-07 | -1.4514E-05 | 1.4871E-05 | 4.1276E-05 | -1.1384E-05 | -0.0001078 | -7.0572E-05 | -0.00011611 |
| Semiconductor and other electronic component manufacturing | Billions of Fixed (2009) Dollars | 8.5831E-06 | 3.3855E-05 | 2.3365E-05 | 5.6267E-05 | 3.6001E-05 | 0.00016809 | 0.00030136 | 0.00028777 | 0.00018167 | 0.00050402 | 0.00051713 |
| Navigational, measuring, electromedical, and control instruments manufacturing | Billions of Fixed (2009) Dollars | 3.8147E-06 | 1.5974E-05 | 1.0252E-05 | 2.0742E-05 | -8.8215E-06 | 3.6955E-05 | 8.8453E-05 | 2.6226E-06 | -0.0001483 | -0.00016236 | -0.00026178 |
| Manufacturing and reproducing magnetic and optical media | Billions of Fixed (2009) Dollars | 1.4305E-06 | 4.4107E-06 | 1.7583E-06 | 3.6061E-06 | -5.0962E-06 | 2.116E-05 | 5.3227E-05 | 4.4435E-05 | 7.9572E-06 | 3.1292E-05 | 1.5825E-05 |
| Electric lighting equipment manufacturing | Billions of Fixed (2009) Dollars | 7.0035E-07 | 7.3016E-06 | 6.3926E-06 | 2.0936E-05 | -8.6427E-07 | 0.00092626 | 0.0018896 | 0.00188027 | 0.00097203 | 6.5267E-05 | 3.6508E-05 |
| Household appliance manufacturing | Billions of Fixed (2009) Dollars | 4.7684E-07 | 1.6391E-06 | 8.9407E-07 | 1.6987E-06 | -1.0729E-06 | 6.1989E-06 | 2.0623E-05 | 2.1964E-05 | 1.5587E-05 | 2.5481E-05 | 2.0653E-05 |
| Electrical equipment manufacturing | Billions of Fixed (2009) Dollars | 5.0664E-07 | 3.4273E-06 | 3.0696E-06 | 8.3745E-06 | 1.4901E-06 | 3.4064E-05 | 7.6354E-05 | 7.2956E-05 | 4.7266E-05 | 2.9743E-05 | 1.8984E-05 |
| Other electrical equipment and component manufacturing | Billions of Fixed (2009) Dollars | 1.4901E-06 | 5.8413E-06 | 3.8743E-06 | 9.3579E-06 | -1.0133E-06 | 4.9233E-05 | 0.00011128 | 0.00010973 | 6.7532E-05 | 7.4029E-05 | 5.9962E-05 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Motor vehicle manufacturing | Billions of Fixed (2009) Dollars | 1.657E-05 | 4.7922E-05 | 1.967E-05 | 3.8147E-05 | -5.2691E-05 | 0.00022495 | 0.00064909 | 0.00069928 | 0.00045025 | 0.00084317 | 0.00072145 |
| Motor vehicle body and trailer manufacturing | Billions of Fixed (2009) Dollars | 1.803E-06 | 5.2899E-06 | 2.2203E-06 | 4.217E-06 | -5.6028E-06 | 2.4244E-05 | 6.9216E-05 | 7.3865E-05 | 4.6968E-05 | 8.6784E-05 | 7.306E-05 |
| Motor vehicle parts manufacturing | Billions of Fixed (2009) Dollars | 9.8944E-06 | 3.0518E-05 | 1.3947E-05 | 3.2306E-05 | -2.5749E-05 | 0.00015903 | 0.00042713 | 0.0004456 | 0.00029135 | 0.00048506 | 0.00041115 |
| Aerospace product and parts manufacturing | Billions of Fixed (2009) Dollars | 3.8147E-06 | 1.1444E-05 | -3.8147E-06 | -7.6294E-06 | -4.1962E-05 | -3.0518E-05 | -9.5367E-05 | -0.00037384 | -0.00069809 | -0.00076294 | -0.0008812 |
| Railroad rolling stock manufacturing | Billions of Fixed (2009) Dollars | 5.5879E-08 | 2.3097E-07 | 2.2352E-07 | 4.1351E-07 | 2.2724E-07 | 1.1772E-06 | 2.7604E-06 | 3.2634E-06 | 2.7753E-06 | 3.133E-06 | 2.5965E-06 |
| Ship and boat building | Billions of Fixed (2009) Dollars | 3.0994E-06 | 9.2983E-06 | 3.0994E-06 | 7.1526E-06 | -1.0252E-05 | 3.6478E-05 | 9.799E-05 | 8.6546E-05 | 2.9802E-05 | 7.9632E-05 | 5.1737E-05 |
| Other transportation equipment manufacturing | Billions of Fixed (2009) Dollars | 1.0431E-06 | 2.861E-06 | 1.0431E-06 | 2.0862E-06 | -3.5167E-06 | 1.4037E-05 | 3.8236E-05 | 3.7432E-05 | 1.9073E-05 | 3.7968E-05 | 2.9922E-05 |
| Household and institutional furniture and kitchen cabinet manufacturing | Billions of Fixed (2009) Dollars | 1.353E-05 | 4.0472E-05 | 1.4663E-05 | 3.3736E-05 | -4.8757E-05 | 0.0001834 | 0.00052732 | 0.00053942 | 0.00032735 | 0.00064957 | 0.00054228 |
| Office furniture (including fixtures) manufacturing; Other furniture related product manufacturing | Billions of Fixed (2009) Dollars | 3.5763E-06 | 1.1206E-05 | 5.6326E-06 | 1.1057E-05 | -9.1493E-06 | 7.2092E-05 | 0.00018948 | 0.00020191 | 0.00013018 | 0.00018218 | 0.00014794 |
| Medical equipment and supplies manufacturing | Billions of Fixed (2009) Dollars | 6.0797E-06 | 1.7762E-05 | 7.5102E-06 | 1.4067E-05 | -1.6212E-05 | 7.391E-05 | 0.00020468 | 0.0002116 | 0.00012279 | 0.00023413 | 0.00018704 |
| Other miscellaneous manufacturing | Billions of Fixed (2009) Dollars | 1.0133E-05 | 2.6464E-05 | 1.0848E-05 | 2.563E-05 | -1.4067E-05 | 0.00013256 | 0.00036347 | 0.0004034 | 0.000283 | 0.00058079 | 0.00053692 |
| Animal food manufacturing | Billions of Fixed (2009) Dollars | 4.9174E-07 | 1.4752E-06 | 6.8545E-07 | 1.4156E-06 | -1.4603E-06 | 9.4175E-06 | 2.6882E-05 | 3.2112E-05 | 2.5764E-05 | 3.8385E-05 | 3.5286E-05 |
| Grain and oilseed milling | Billions of Fixed (2009) Dollars | 8.4639E-06 | 3.3736E-05 | 3.1322E-05 | 6.6131E-05 | 7.9185E-05 | 0.00012463 | 0.00024208 | 0.00045854 | 0.00067064 | 0.00118458 | 0.00127959 |
| Sugar and confectionery product manufacturing | Billions of Fixed (2009) Dollars | 1.8179E-06 | 5.3644E-06 | 2.8312E-06 | 5.8711E-06 | -3.2783E-06 | 3.475E-05 | 9.3848E-05 | 0.00011355 | 9.5367E-05 | 0.00012994 | 0.00011903 |
| Fruit and vegetable preserving and specialty food manufacturing | Billions of Fixed (2009) Dollars | 7.1526E-06 | 1.955E-05 | 9.0599E-06 | 1.8597E-05 | -1.812E-05 | 0.00012159 | 0.0003233 | 0.00035715 | 0.00024986 | 0.00034952 | 0.00029135 |
| Dairy product manufacturing | Billions of Fixed (2009) Dollars | 4.53E-06 | 1.3888E-05 | 7.2718E-06 | 1.5259E-05 | -9.656E-06 | 9.799E-05 | 0.00026166 | 0.00030601 | 0.00024211 | 0.00031316 | 0.00027943 |
| Animal slaughtering and processing | Billions of Fixed (2009) Dollars | 7.6294E-06 | 2.3842E-05 | 1.2636E-05 | 2.408E-05 | -1.7166E-05 | 0.00015593 | 0.00042081 | 0.00050044 | 0.00040436 | 0.00054145 | 0.00048518 |
| Seafood product preparation and packaging | Billions of Fixed (2009) Dollars | 1.1921E-06 | 2.861E-06 | 0 | 1.1921E-06 | -5.9605E-06 | 1.5736E-05 | 3.5524E-05 | 1.4544E-05 | -2.9325E-05 | -2.9802E-05 | -4.8399E-05 |
| Bakeries and tortilla manufacturing | Billions of Fixed (2009) Dollars | 5.4836E-06 | 1.6928E-05 | 8.7023E-06 | 1.8001E-05 | -1.0848E-05 | 0.00011396 | 0.00030434 | 0.00036383 | 0.00029993 | 0.00039423 | 0.00035834 |
| Other food manufacturing | Billions of Fixed (2009) Dollars | 4.2915E-06 | 1.2398E-05 | 6.5565E-06 | 1.2755E-05 | -8.7023E-06 | 7.7963E-05 | 0.00021029 | 0.00024962 | 0.0002023 | 0.00027895 | 0.00025141 |
| Beverage manufacturing | Billions of Fixed (2009) Dollars | 1.4067E-05 | 4.077E-05 | 2.2173E-05 | 4.4346E-05 | -3.0041E-05 | 0.00027585 | 0.00077295 | 0.00096679 | 0.00084949 | 0.00113535 | 0.00105214 |
| Tobacco manufacturing | Billions of Fixed (2009) Dollars | 1.695E-07 | 5.5693E-07 | 3.4459E-07 | 7.4878E-07 | -3.7253E-08 | 3.9376E-06 | 9.628E-06 | 1.1189E-05 | 9.1735E-06 | 1.1992E-05 | 1.1208E-05 |
| Textile mills and textile product mills | Billions of Fixed (2009) Dollars | 6.6161E-06 | 1.806E-05 | 5.5432E-06 | 1.2279E-05 | -2.11E-05 | 7.2241E-05 | 0.00019193 | 0.00017679 | 7.6175E-05 | 0.00018674 | 0.00013995 |
| Apparel manufacturing; Leather and allied product manufacturing | Billions of Fixed (2009) Dollars | 1.3709E-06 | 1.0282E-06 | -2.7567E-06 | -4.1872E-06 | -1.2711E-05 | -8.9854E-06 | -3.0071E-05 | -0.00010391 | -0.0001962 | -0.0002279 | -0.0002822 |
| Pulp, paper, and paperboard mills | Billions of Fixed (2009) Dollars | 5.722E-06 | 2.1696E-05 | 1.502E-05 | 3.8624E-05 | 6.9141E-06 | 0.00016809 | 0.00038671 | 0.00042892 | 0.00035691 | 0.00047159 | 0.00045419 |
| Converted paper product manufacturing | Billions of Fixed (2009) Dollars | 5.8413E-06 | 2.4796E-05 | 1.8835E-05 | 4.6968E-05 | 1.7166E-05 | 0.00022161 | 0.00048864 | 0.00055408 | 0.00047147 | 0.00057042 | 0.00056422 |
| Printing and related support activities | Billions of Fixed (2009) Dollars | 7.987E-06 | 2.6703E-05 | 1.5497E-05 | 3.6597E-05 | -5.2452E-06 | 0.00020969 | 0.00049794 | 0.00054157 | 0.00039852 | 0.0004884 | 0.00044549 |
| Petroleum and coal products manufacturing | Billions of Fixed (2009) Dollars | 0.00017262 | 0 | -0.00101852 | -0.00957489 | -0.015625 | -0.05988216 | -0.09649563 | -0.14891243 | -0.21504879 | -0.3253727 | -0.40512943 |
| Basic chemical manufacturing | Billions of Fixed (2009) Dollars | 0.00207901 | 0.00829411 | 0.00778913 | 0.01575923 | 0.01964557 | 0.0226562 | 0.04254687 | 0.09504473 | 0.15247405 | 0.28389955 | 0.31112063 |
| Resin, synthetic rubber, and artificial synthetic fibers and filaments manufacturing | Billions of Fixed (2009) Dollars | 5.6028E-06 | 2.4438E-05 | 2.405E-05 | 5.573E-05 | 6.786E-05 | 0.00013512 | 0.00024775 | 0.0004254 | 0.00060225 | 0.00099942 | 0.00110841 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pesticide, fertilizer, and other agricultural chemical manufacturing | Billions of Fixed (2009) Dollars | 2.414E-06 | 1.0371E-05 | 9.6858E-06 | 2.1338E-05 | 2.2709E-05 | 4.5776E-05 | 9.1016E-05 | 0.00014782 | 0.0001986 | 0.00033015 | 0.00035834 |
| Pharmaceutical and medicine manufacturing | Billions of Fixed (2009) Dollars | 4.1127E-06 | 1.0967E-05 | 2.861E-06 | 6.4373E-06 | -1.4365E-05 | 4.4703E-05 | 0.00012445 | 0.00011784 | 5.2392E-05 | 0.00013381 | 0.00010622 |
| Paint, coating, and adhesive manufacturing | Billions of Fixed (2009) Dollars | 3.7849E-06 | 1.9193E-05 | 1.8835E-05 | 4.9233E-05 | 4.0472E-05 | 0.00013834 | 0.0002858 | 0.00039345 | 0.00047344 | 0.00068605 | 0.00074708 |
| Soap, cleaning compound, and toilet preparation manufacturing | Billions of Fixed (2009) Dollars | 1.3113E-06 | 4.2915E-06 | 2.7418E-06 | 5.9009E-06 | 1.0729E-06 | 2.8521E-05 | 7.0065E-05 | 9.0569E-05 | 8.7321E-05 | 0.0001294 | 0.00013077 |
| Other chemical product and preparation manufacturing | Billions of Fixed (2009) Dollars | -9.5025E-05 | -9.8929E-05 | 0.00020912 | 0.00135726 | 0.00239548 | 0.00883681 | 0.01404256 | 0.02002031 | 0.02658585 | 0.03464907 | 0.04432774 |
| Plastics product manufacturing | Billions of Fixed (2009) Dollars | 2.4557E-05 | 0.000103 | 7.844E-05 | 0.00019145 | 7.0572E-05 | 0.00059915 | 0.0013833 | 0.00163484 | 0.00155306 | 0.00222135 | 0.00217342 |
| Rubber product manufacturing | Billions of Fixed (2009) Dollars | 1.6391E-06 | 5.3197E-06 | 2.4885E-06 | 6.3926E-06 | -3.6359E-06 | 2.405E-05 | 6.4924E-05 | 6.6191E-05 | 4.5955E-05 | 7.3761E-05 | 6.1721E-05 |
| Wholesale trade | Billions of Fixed (2009) Dollars | 0.0002594 | 0.00092888 | 0.00055695 | 0.00131607 | -2.6703E-05 | 0.00726318 | 0.01713562 | 0.01942444 | 0.01533127 | 0.02066422 | 0.01990128 |
| Retail trade | Billions of Fixed (2009) Dollars | 0.0004921 | 0.00140381 | 0.0005455 | 0.00112534 | -0.00162125 | 0.00727844 | 0.02080154 | 0.02340317 | 0.01684952 | 0.02932739 | 0.02610779 |
| Air transportation | Billions of Fixed (2009) Dollars | 3.5763E-06 | 1.4782E-05 | 1.3351E-05 | 2.9802E-05 | 7.8678E-06 | 0.00016069 | 0.00043392 | 0.00051284 | 0.00043488 | 0.00054955 | 0.00050545 |
| Rail transportation | Billions of Fixed (2009) Dollars | 1.2875E-05 | 5.6267E-05 | 5.0783E-05 | 0.00011575 | 0.00011134 | 0.00029027 | 0.00059223 | 0.00087821 | 0.00108528 | 0.00175023 | 0.00188351 |
| Water transportation | Billions of Fixed (2009) Dollars | 8.5831E-06 | 2.4199E-05 | 1.0252E-05 | 2.1815E-05 | -1.8597E-05 | 0.00011468 | 0.00030684 | 0.00032711 | 0.00022268 | 0.00041914 | 0.00037336 |
| Truck transportation | Billions of Fixed (2009) Dollars | 4.1485E-05 | 0.00015831 | 0.00010681 | 0.00026321 | 4.1485E-05 | 0.00153303 | 0.00341368 | 0.00369549 | 0.00270033 | 0.00298548 | 0.00280094 |
| Couriers and messengers | Billions of Fixed (2009) Dollars | 1.0371E-05 | 3.5644E-05 | 1.8358E-05 | 4.3869E-05 | -1.5974E-05 | 0.00025487 | 0.00061631 | 0.00065565 | 0.00044584 | 0.00059795 | 0.00052881 |
| Transit and ground passenger transportation | Billions of Fixed (2009) Dollars | 2.6822E-06 | 9.2089E-06 | 5.424E-06 | 1.1981E-05 | -2.7716E-06 | 6.6847E-05 | 0.00016764 | 0.00019056 | 0.00014734 | 0.00017869 | 0.00015992 |
| Pipeline transportation | Billions of Fixed (2009) Dollars | 5.1782E-07 | 2.3432E-06 | 1.7285E-06 | 2.6897E-06 | -1.3299E-06 | 7.7784E-06 | 2.5317E-05 | 2.034E-05 | -2.8349E-06 | -2.1465E-05 | -3.9525E-05 |
| Scenic and sightseeing transportation and support activities | Billions of Fixed (2009) Dollars | -6.4373E-06 | -2.3842E-06 | 1.5259E-05 | 4.6968E-05 | 5.6267E-05 | 6.5088E-05 | 0.00012016 | 0.00016522 | 0.0002625 | 0.00012112 | 0.00014019 |
| Warehousing and storage | Billions of Fixed (2009) Dollars | 8.5831E-06 | 2.8729E-05 | 1.5497E-05 | 3.6001E-05 | -7.987E-06 | 0.00019515 | 0.00047874 | 0.00053334 | 0.00040257 | 0.0005877 | 0.00054753 |
| Newspaper, periodical, book, and directory publishers | Billions of Fixed (2009) Dollars | 2.1935E-05 | 6.4611E-05 | 2.9564E-05 | 6.6757E-05 | -5.2929E-05 | 0.00043488 | 0.00110006 | 0.00117254 | 0.00078583 | 0.00113106 | 0.00099134 |
| Software publishers | Billions of Fixed (2009) Dollars | 1.5259E-05 | 4.9591E-05 | 7.6294E-06 | 1.5259E-05 | -0.0001297 | 0.0001564 | 0.00041962 | -4.9591E-05 | -0.00098038 | -0.00073242 | -0.00120544 |
| Motion picture, video, and sound recording industries | Billions of Fixed (2009) Dollars | 3.5763E-06 | 1.0252E-05 | 3.4571E-06 | 7.5698E-06 | -1.6034E-05 | 5.7697E-05 | 0.00016791 | 0.00017363 | 9.6321E-05 | 0.00021547 | 0.00018567 |
| Data processing, hosting, related services, and other information services | Billions of Fixed (2009) Dollars | 2.861E-05 | 0.000103 | 6.485E-05 | 0.00014782 | -3.624E-05 | 0.00091076 | 0.00234318 | 0.00280762 | 0.00234222 | 0.00293922 | 0.00279331 |
| Broadcasting (except internet) | Billions of Fixed (2009) Dollars | 6.9141E-06 | 2.2769E-05 | 1.2875E-05 | 3.016E-05 | -6.6757E-06 | 0.00019217 | 0.00045836 | 0.00050437 | 0.00037134 | 0.00045598 | 0.00042009 |
| Telecommunications | Billions of Fixed (2009) Dollars | 0.00011635 | 0.00037956 | 0.00020981 | 0.0004921 | -0.00022507 | 0.00319672 | 0.00788307 | 0.00862312 | 0.00624466 | 0.00754356 | 0.00675964 |
| Monetary authorities, credit intermediation, and related activities | Billions of Fixed (2009) Dollars | 0.00010967 | 0.00035763 | 0.00019073 | 0.00045204 | -0.00016212 | 0.00247192 | 0.00615978 | 0.00676918 | 0.00500679 | 0.006073 | 0.00531769 |
| Funds, trusts, and other financial vehicles | Billions of Fixed (2009) Dollars | 8.7619E-06 | 2.2084E-05 | 6.3777E-06 | 1.3381E-05 | -2.5809E-05 | 9.0212E-05 | 0.00025216 | 0.00025669 | 0.00015196 | 0.00030151 | 0.00025371 |
| Securities, commodity contracts, and other financial investments and related activities | Billions of Fixed (2009) Dollars | 6.3419E-05 | 0.00018597 | 7.0572E-05 | 0.00016117 | -0.00018454 | 0.00099945 | 0.00261068 | 0.00267267 | 0.0016098 | 0.0026722 | 0.00223446 |
| Insurance carriers | Billions of Fixed (2009) Dollars | 5.3406E-05 | 0.00015926 | 7.2479E-05 | 0.0001545 | -0.00012493 | 0.00091171 | 0.00241661 | 0.00272655 | 0.0020628 | 0.00293636 | 0.00259781 |
| Agencies, brokerages, and other insurance related activities | Billions of Fixed (2009) Dollars | 1.359E-05 | 3.8624E-05 | 1.8358E-05 | 4.0054E-05 | -2.9325E-05 | 0.00023031 | 0.0006032 | 0.0006671 | 0.00048637 | 0.00068641 | 0.00060105 |
| Real estate | Billions of Fixed (2009) Dollars | 0.00034332 | 0.00110626 | 0.00068665 | 0.00140381 | -0.00051117 | 0.00897217 | 0.02391052 | 0.0293808 | 0.02468872 | 0.02864838 | 0.02535248 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Automotive equipment rental and leasing | Billions of Fixed (2009) Dollars | 5.126E-06 | 2.6822E-05 | 2.5153E-05 | 6.4254E-05 | 3.2067E-05 | 0.00023937 | 0.00054657 | 0.00066805 | 0.00064588 | 0.00071836 | 0.00071919 |
| Consumer goods rental and general rental centers | Billions of Fixed (2009) Dollars | 1.6749E-05 | 5.0008E-05 | 2.0146E-05 | 4.8876E-05 | -5.2691E-05 | 0.00028825 | 0.00076711 | 0.00079858 | 0.00052094 | 0.00082898 | 0.00071049 |
| Commercial and industrial machinery and equipment rental and leasing | Billions of Fixed (2009) Dollars | 5.6028E-06 | 5.8472E-05 | 5.5194E-05 | 0.00017613 | 1.4484E-05 | 0.00092804 | 0.00207466 | 0.00204754 | 0.00135893 | 0.00064218 | 0.0004499 |
| Lessors of nonfinancial intangible assets (except copyrighted works) | Billions of Fixed (2009) Dollars | 3.5763E-06 | 1.3709E-05 | 1.1742E-05 | 2.5392E-05 | 2.0504E-05 | 9.3162E-05 | 0.00020093 | 0.00026661 | 0.00027645 | 0.00040197 | 0.00042218 |
| Legal services | Billions of Fixed (2009) Dollars | 2.8133E-05 | 0.00011158 | 7.4863E-05 | 0.00018644 | -2.1935E-05 | 0.0017333 | 0.00385904 | 0.00407696 | 0.00270176 | 0.00201607 | 0.0017643 |
| Accounting, tax preparation, bookkeeping, and payroll services | Billions of Fixed (2009) Dollars | 1.5259E-05 | 6.1512E-05 | 4.22E-05 | 0.00010514 | 1.1921E-06 | 0.00093031 | 0.00204539 | 0.00215983 | 0.00143194 | 0.00112271 | 0.00101042 |
| Architectural, engineering, and related services | Billions of Fixed (2009) Dollars | 4.4823E-05 | 0.00034618 | 0.00032616 | 0.00093651 | 0.00013638 | 0.00444031 | 0.01008606 | 0.01055336 | 0.00760174 | 0.00471592 | 0.00359726 |
| Specialized design services | Billions of Fixed (2009) Dollars | 5.0664E-06 | 1.8716E-05 | 1.2159E-05 | 2.9266E-05 | -1.3709E-06 | 0.00017321 | 0.00040764 | 0.00044751 | 0.00032818 | 0.00036222 | 0.00032747 |
| Computer systems design and related services | Billions of Fixed (2009) Dollars | 3.1471E-05 | 0.0001297 | 0.00010109 | 0.00020981 | 1.1444E-05 | 0.00109482 | 0.00266361 | 0.00307846 | 0.00232983 | 0.00252342 | 0.0022049 |
| Management, scientific, and technical consulting services | Billions of Fixed (2009) Dollars | 2.3603E-05 | 8.9407E-05 | 5.7697E-05 | 0.00014067 | 1.1444E-05 | 0.00076342 | 0.00178146 | 0.00199366 | 0.00154305 | 0.00187302 | 0.00177288 |
| Scientific research and development services | Billions of Fixed (2009) Dollars | 3.3855E-05 | 0.0001359 | 0.00012398 | 0.00028324 | 0.00030184 | 0.00076675 | 0.00151539 | 0.00241137 | 0.0031476 | 0.00513172 | 0.00566387 |
| Advertising and related services | Billions of Fixed (2009) Dollars | 2.2173E-05 | 7.2002E-05 | 4.1962E-05 | 0.00010037 | -1.812E-05 | 0.00063729 | 0.00151181 | 0.00166273 | 0.00122118 | 0.00148726 | 0.00138044 |
| Other professional, scientific, and technical services | Billions of Fixed (2009) Dollars | 2.7895E-05 | 8.8453E-05 | 4.4346E-05 | 0.00010347 | -4.5776E-05 | 0.00061464 | 0.00149655 | 0.00161505 | 0.00115442 | 0.00164223 | 0.00150752 |
| Management of companies and enterprises | Billions of Fixed (2009) Dollars | 4.7684E-05 | 0.00019932 | 0.00015831 | 0.00039101 | 0.00026989 | 0.00151253 | 0.00318909 | 0.00405788 | 0.00411606 | 0.00602531 | 0.00643444 |
| Office administrative services; Facilities support services | Billions of Fixed (2009) Dollars | 5.722E-06 | 2.2173E-05 | 1.4424E-05 | 3.4332E-05 | -4.8876E-06 | 0.00025463 | 0.00058401 | 0.00061727 | 0.00041127 | 0.00038266 | 0.00033343 |
| Employment services | Billions of Fixed (2009) Dollars | 1.8597E-05 | 6.7949E-05 | 4.1962E-05 | 0.00010443 | -2.718E-05 | 0.00075626 | 0.00175428 | 0.00185013 | 0.00122166 | 0.00116253 | 0.00099182 |
| Business support services; Investigation and security services; Other support services | Billions of Fixed (2009) Dollars | 2.1458E-05 | 7.3195E-05 | 4.0531E-05 | 9.7275E-05 | -3.0756E-05 | 0.00053239 | 0.00129437 | 0.00137877 | 0.00096631 | 0.00121522 | 0.00106072 |
| Travel arrangement and reservation services | Billions of Fixed (2009) Dollars | 1.3709E-05 | 4.1485E-05 | 1.7643E-05 | 3.9101E-05 | -3.8862E-05 | 0.00039744 | 0.00094199 | 0.00097156 | 0.00058866 | 0.0006783 | 0.00058579 |
| Services to buildings and dwellings | Billions of Fixed (2009) Dollars | 3.5048E-05 | 0.00013232 | 8.5592E-05 | 0.00020647 | 4.2915E-06 | 0.00101185 | 0.00241375 | 0.00270939 | 0.00215054 | 0.0027113 | 0.00254726 |
| Waste management and remediation services | Billions of Fixed (2009) Dollars | 1.7643E-05 | 7.5817E-05 | 5.579E-05 | 9.8228E-05 | -1.1921E-05 | 0.00035858 | 0.00093412 | 0.00090265 | 0.00026989 | -5.1975E-05 | -0.00051117 |
| Educational services | Billions of Fixed (2009) Dollars | 1.5974E-05 | 4.8161E-05 | 2.7895E-05 | 5.3167E-05 | -3.2425E-05 | 0.00033998 | 0.00096035 | 0.00122309 | 0.00109196 | 0.0014205 | 0.00131226 |
| Offices of health practitioners | Billions of Fixed (2009) Dollars | 0.00032616 | 0.00089264 | 0.00025558 | 0.00057793 | -0.00117302 | 0.00397682 | 0.01121902 | 0.01135635 | 0.00654411 | 0.01395035 | 0.0119648 |
| Outpatient, laboratory, and other ambulatory care services | Billions of Fixed (2009) Dollars | 3.5763E-05 | 9.9182E-05 | 4.1962E-05 | 8.6308E-05 | -0.000103 | 0.00057936 | 0.00165415 | 0.00195503 | 0.00155544 | 0.00241899 | 0.00223494 |
| Home health care services | Billions of Fixed (2009) Dollars | 3.4571E-06 | 1.0073E-05 | 4.7684E-06 | 9.656E-06 | -9.1195E-06 | 6.6221E-05 | 0.00019103 | 0.00023687 | 0.00020295 | 0.00029492 | 0.00027829 |
| Hospitals | Billions of Fixed (2009) Dollars | 5.5313E-05 | 0.00016785 | 8.4877E-05 | 0.00016403 | -0.0001421 | 0.00111198 | 0.00315189 | 0.00391579 | 0.00339317 | 0.00473595 | 0.00442886 |
| Nursing and residential care facilities | Billions of Fixed (2009) Dollars | 1.7643E-05 | 5.1498E-05 | 2.4796E-05 | 4.7684E-05 | -4.3869E-05 | 0.00032187 | 0.00091171 | 0.00111294 | 0.00093031 | 0.00131941 | 0.00121832 |
| Individual and family services; Community and vocational rehabilitation services | Billions of Fixed (2009) Dollars | 1.2636E-05 | 3.9577E-05 | 2.1696E-05 | 4.1246E-05 | -3.1948E-05 | 0.0002749 | 0.00077796 | 0.00097823 | 0.00085998 | 0.00117731 | 0.00110173 |
| Child day care services | Billions of Fixed (2009) Dollars | 6.7949E-06 | 1.9431E-05 | 1.0014E-05 | 1.955E-05 | -1.5974E-05 | 0.00012839 | 0.00036061 | 0.00044537 | 0.00038207 | 0.00053144 | 0.00049174 |
| Performing arts companies; Promoters of events, and agents and managers | Billions of Fixed (2009) Dollars | 6.5565E-06 | 2.0266E-05 | 1.0848E-05 | 2.3007E-05 | -1.2159E-05 | 0.00013757 | 0.00036883 | 0.00044358 | 0.00036991 | 0.00050294 | 0.00046492 |
| Spectator sports | Billions of Fixed (2009) Dollars | 7.093E-06 | 2.11E-05 | 9.656E-06 | 2.11E-05 | -1.6749E-05 | 0.00012952 | 0.00034273 | 0.00038493 | 0.00028813 | 0.00042069 | 0.00037789 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Independent artists, writers, and performers | Billions of Fixed (2009) Dollars | 3.4571E-06 | 1.1861E-05 | 6.7949E-06 | 1.6212E-05 | -4.5896E-06 | 0.00010228 | 0.0002473 | 0.00026977 | 0.00019407 | 0.00023407 | 0.00021088 |
| Museums, historical sites, and similar institutions | Billions of Fixed (2009) Dollars | 1.5497E-06 | 4.5598E-06 | 2.265E-06 | 4.53E-06 | -4.1127E-06 | 3.0458E-05 | 8.6069E-05 | 0.0001055 | 8.893E-05 | 0.00012422 | 0.0001142 |
| Amusement, gambling, and recreation industries | Billions of Fixed (2009) Dollars | 2.1696E-05 | 6.0081E-05 | 2.1935E-05 | 4.6015E-05 | -6.5565E-05 | 0.00029945 | 0.0008316 | 0.00090957 | 0.00063896 | 0.00105786 | 0.00092435 |
| Accommodation | Billions of Fixed (2009) Dollars | 3.0994E-05 | 9.5844E-05 | 4.8637E-05 | 0.00011063 | -6.628E-05 | 0.000597 | 0.0016017 | 0.00184536 | 0.00145721 | 0.00208044 | 0.00188303 |
| Food services and drinking places | Billions of Fixed (2009) Dollars | 8.3923E-05 | 0.00027561 | 0.00015259 | 0.00032234 | -0.00015068 | 0.00201416 | 0.00542641 | 0.00667 | 0.00577736 | 0.00750542 | 0.00697136 |
| Automotive repair and maintenance | Billions of Fixed (2009) Dollars | 1.9789E-05 | 7.5102E-05 | 5.0545E-05 | 0.00012684 | -9.7752E-06 | 0.00054312 | 0.00135779 | 0.0015521 | 0.00130916 | 0.00155544 | 0.00142169 |
| Electronic and precision equipment repair and maintenance | Billions of Fixed (2009) Dollars | 4.2915E-06 | 1.9044E-05 | 1.2755E-05 | 3.5286E-05 | -3.0398E-06 | 0.00013518 | 0.00032389 | 0.000328 | 0.00023627 | 0.00026 | 0.00021678 |
| Commercial and industrial machinery and equipment (except automotive and electronic) repair and maintenance | Billions of Fixed (2009) Dollars | 3.8743E-06 | 2.4766E-05 | 2.0891E-05 | 5.9456E-05 | 1.0133E-05 | 0.00020051 | 0.00044784 | 0.00044665 | 0.00034556 | 0.0003162 | 0.00026944 |
| Personal and household goods repair and maintenance | Billions of Fixed (2009) Dollars | 8.7023E-06 | 2.9743E-05 | 1.4961E-05 | 3.8981E-05 | -1.8895E-05 | 0.00017428 | 0.0004288 | 0.00042307 | 0.00027478 | 0.000377 | 0.00031221 |
| Personal care services | Billions of Fixed (2009) Dollars | 3.4213E-05 | 9.3102E-05 | 2.5511E-05 | 5.8293E-05 | -0.00012732 | 0.00040615 | 0.00113106 | 0.00111127 | 0.0006063 | 0.00135636 | 0.0011394 |
| Death care services | Billions of Fixed (2009) Dollars | 1.3858E-06 | 3.7849E-06 | 1.6987E-06 | 3.2932E-06 | -3.4571E-06 | 2.1964E-05 | 6.0812E-05 | 7.1794E-05 | 5.7623E-05 | 8.2478E-05 | 7.4014E-05 |
| Drycleaning and laundry services | Billions of Fixed (2009) Dollars | 7.7784E-06 | 2.2173E-05 | 7.5102E-06 | 1.7345E-05 | -2.4498E-05 | 0.00010794 | 0.0002861 | 0.00028837 | 0.00017345 | 0.00031245 | 0.00026339 |
| Other personal services | Billions of Fixed (2009) Dollars | 1.9789E-05 | 5.3048E-05 | 1.5736E-05 | 3.4928E-05 | -6.5446E-05 | 0.0002296 | 0.00062454 | 0.00062883 | 0.00037229 | 0.00073802 | 0.00062454 |
| Religious organizations; Grantmaking and giving services, and social advocacy organizations | Billions of Fixed (2009) Dollars | 1.8358E-05 | 5.6267E-05 | 3.0994E-05 | 5.8651E-05 | -4.5776E-05 | 0.0003953 | 0.00112295 | 0.00141621 | 0.00124836 | 0.00170708 | 0.00159454 |
| Civic, social, professional, and similar organizations | Billions of Fixed (2009) Dollars | 1.0252E-05 | 3.5286E-05 | 2.1338E-05 | 4.828E-05 | -1.5736E-05 | 0.00023687 | 0.00060666 | 0.00068855 | 0.00055265 | 0.00068295 | 0.00060034 |
| Private households | Billions of Fixed (2009) Dollars | 1.0639E-05 | 2.8938E-05 | 7.9274E-06 | 1.7673E-05 | -3.9339E-05 | 0.00012058 | 0.00033593 | 0.0003264 | 0.00017095 | 0.00038898 | 0.00032246 |
| State and Local Government | Billions of Fixed (2009) Dollars | 0.00033951 | 0.00154877 | 0.00117874 | 0.00279236 | 2.2888E-05 | 0.01721573 | 0.03969193 | 0.04177475 | 0.0284729 | 0.02256393 | 0.01822662 |
| Federal Civilian | Billions of Fixed (2009) Dollars | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Federal Military | Billions of Fixed (2009) Dollars | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |