Washington's Clean Fuel Future

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Summary

As of the start of 2019, Washington is bordered to the north (British Columbia) and South (Oregon and California) by active Clean Fuel Programs (also referred to as Low Carbon Fuel Standards) but does not yet have its own regulation to mandate reductions in the carbon intensity of the fuel supplied for transportation. This may change in the near future, with proposed legislation having been introduced to the Washington State Legislature in 2018 (House Bill 2338) and renewed interest in such policies, inspired in part by the success of the programs in California and other jurisdictions.

This report presents scenario modeling for potential supply of lower carbon energy and consequent achievement of carbon intensity reductions if Washington State were to introduce a Clean Fuel Program, similar to the existing programs elsewhere, with compliance targets starting in 2022 requiring a 10% carbon intensity reduction from transportation fuel by 2028. The scenario analysis is undertaken using a model developed for previous analysis of potential low carbon fuel supply in California (Malins, 2018b) and for the whole Pacific Region of North America (Malins et al., 2015). The model is used to present scenarios for carbon savings delivered for a given set of reasonable vehicle pool and fuel supply assumptions, but does not include any estimation of the resultant price of CO_2e credits within the Clean Fuel Program, or feedback mechanisms that would relate the volumes of fuel supplied in the scenarios to the presumed compliance requirements of a program.

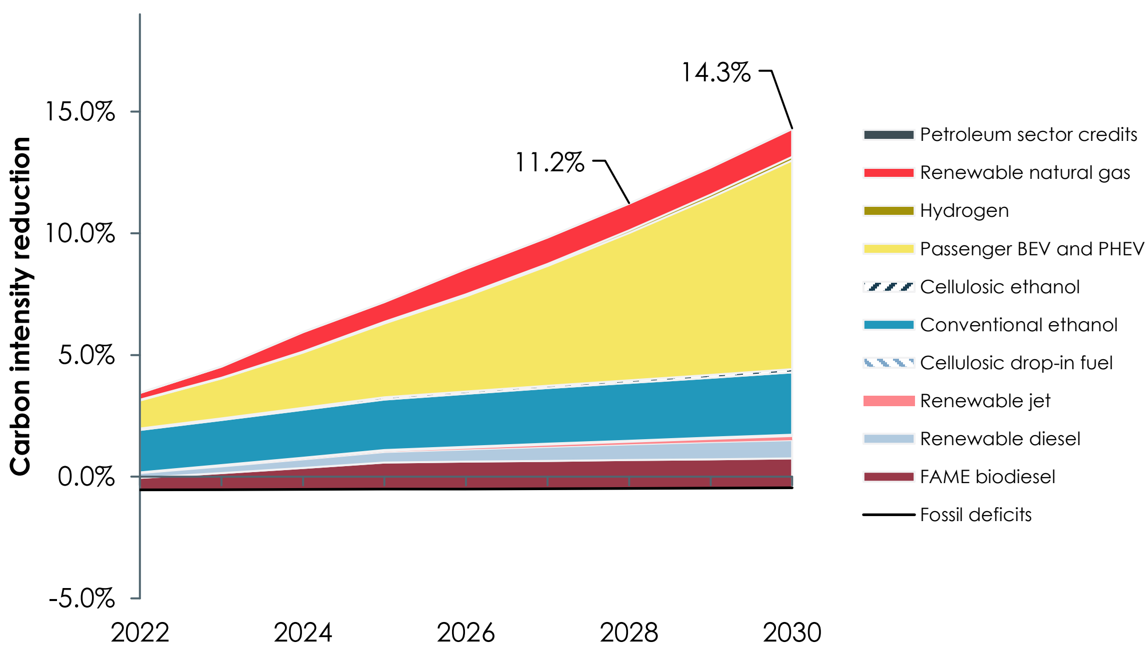

Figure A Carbon savings against baseline delivered in *Steady Progress* scenario

Four scenarios are presented: *Steady Progress; Accelerated Progress; High EV;* and *Delayed EV*. Carbon intensity reduction options considered in the scenario analysis include first and second generation biofuels, zero emission vehicles, and (in the *Accelerated Progress* scenario) the use of renewable natural gas for refinery process energy.

The results of the analysis for the *Steady Progress* scenario are shown in Figure A. While in the early years of the program the largest carbon savings are delivered by first generation biofuels, in later years the expected growth in the fleet of battery electric and plug-in hybrid vehicles in Washington increases the consumption of electricity for road transportation, and given the large proportion of renewable energy in the Washington State electricity supply delivers considerable carbon savings. The modelling also assumes more modest increases in the supply of alternatives to diesel fuel – biodiesel, renewable diesel and renewable natural gas for trucks. In 2028, an 11% carbon reduction is delivered compared to the baseline. In all years the carbon intensity of the energy supply in this scenario is below an illustrative linear compliance trajectory for 2022-2028, and hence if this fuel supply were achieved we would expect a significant banking of compliance credits for future use by obligated parties.

In the more aggressive *Accelerated Progress* scenario, marginal increases in the deployment and carbon performance of biodiesel, ethanol and renewable natural gas, plus additional credits from the use of renewable natural gas at the refinery, result in even larger emissions reductions, as illustrated in Figure B.

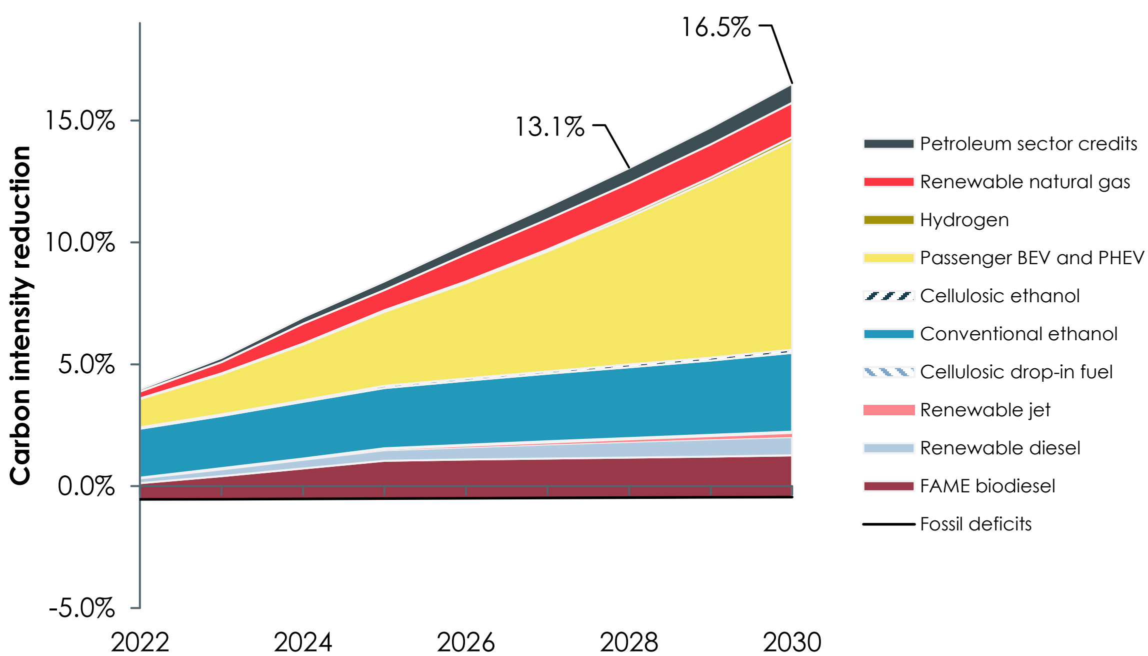

Figure B Carbon savings against baseline delivered in *Accelerated Progress* scenario

The other two scenarios presented consider cases with more and less rapid increases in sales of electric vehicles in Washington State. In the *Steady Progress* scenario, we assumed that sales fractions of zero emission vehicles would lag the rates expected for California (as detailed by Malins, 2018b) by two years in 2030. In the *High EV* scenario, it is assumed that there is no difference in sales fractions between the states by 2030, with over 700,000 vehicles on the road by 2030, compared to 600,000 in the *Steady Progress* scenario. Credit generation is therefore increased, delivering an outcome comparable to that shown for the *Accelerated Progress* scenario. In the *Low EV* scenario, in contrast, it is assumed that there is a longer lag of five years behind California sales fractions. In this scenario, there are fewer than 400,000 zero emission vehicles on the road by 2030, and in 2028 the carbon intensity of the supplied fuel is only 9% below the baseline. Even so, due to over-compliance against the illustrative compliance trajectory in the early years of the program, in this scenario banked credits could be used to comply with the 2028 requirement.

The four scenarios presented demonstrate that given moderate increases in alternative fuel supply and continued growth in electric vehicle sales, compliance could be readily achieved with a 10% carbon intensity reduction target for 2028 under a Clean Fuels Program for Washington State. The increasing size of the electric vehicle fleet makes total credit generation quite sensitive to assumptions about the rate of sales growth, and therefore it may be appropriate for a Washington State Clean Fuels Program to include a degree of flexibility for the administrator to adjust the stringency of requirements in response to realized electric vehicle sales.

Contents

1. Introduction

The possibility of introducing a Clean Fuels Program in Washington State has been under discussion for several years. A Clean Fuels Program, henceforth abbreviated to CFP, is a regulatory tool that allows policy makers to encourage the gradual decarbonization of the transportation sector by setting increasingly stringent targets for the greenhouse gas intensity of the fuel supply (Farrell et al., 2007). To date, policies of this sort have been implemented in California[1], where it is called the Low Carbon Fuel Standard (CA-LCFS), Oregon[2] and British Columbia[3]. A program is being developed at the federal level in Canada[4], and the European Union's Fuel Quality Directive[5] contains similar regulatory elements. A CFP creates a performance based framework to reduce the climate impact of the use of energy in transport and therefore it can provide technology-neutral support for a variety of decarbonization technologies. These can include renewable fuels such as biofuels, the use of electricity in electric vehicles and the delivery of greenhouse gas intensity reductions in the petroleum supply chain, among other potential options.

In the United States, CFPs often complement other existing policies. For example, CFPs support the goals of the Renewable Fuel Standard and complement policies such as zero emission vehicle programs. CFPs create direct financial incentives for alternative fuel producers and suppliers to continuously improve the greenhouse gas performance of their processes and thereby of the fuels supplied, gradually enhancing the climate and other air quality benefits of alternative fuel use.

Implementing a CFP in Washington State would create a region of implemented low carbon fuel standards along the Pacific Coast of North America (Malins et al., 2015). House Bill 2338, which would have created the legal framework for a Washington CFP, was considered in the Washington State Legislature in early 2018 but has yet to pass the House and Senate.[6] House Bill 2338 called for the introduction of targets starting from January 2020, requiring that the greenhouse gas intensity of the fuels used for transportation in Washington be reduced by10% by 2028.

In this report, we introduce a model of alternative fuel supply in Washington and the resultant potential for generation of clean fuel credits under a Washington Clean Fuels Program[7]. We thereby assess the potential to meet targets such as those proposed under House Bill 2338. We assume that a CFP for Washington would generally follow the model provided by the Low

1 The California Low Carbon Fuel Standard, https://www.arb.ca.gov/Fuels/Lcfs/Lcfs.htm

2 The Oregon Clean Fuels Program, https://www.oregon.gov/deq/aq/programs/Pages/Clean-Fuels.aspx

3 The British Columbia Renewable & Low Carbon Fuel Requirements Regulation, https://www2.gov.bc.ca/gov/content/industry/electricity-alternative-energy/transportation-energies/renewable-low-carbon-fuels

4 Canada Clean Fuel Standard, https://www.canada.ca/en/environment-climate-change/services/managing-pollution/energy-production/fuel-regulations/clean-fuel-standard.html

5 https://ec.europa.eu/clima/policies/transport/fuel_en

6 http://apps2.leg.wa.gov/billsummary?BillNumber=2338&Year=2017

7 Henceforth referred to as 'CFP credits', each credit is presumed to represent a metric ton of CO2e emission reductions.

Carbon Fuel Standard already in effect in California, and we use the fuel carbon intensity (CI) values already estimated under the California LCFS in this assessment.

The fuel supply model used in this analysis is developed from a model described in several previous papers (Malins, 2018b, 2018c; Malins et al., 2015), which is built on the VISION model of the Argonne National Laboratory.[8] The 2015 study considered fuel supply for a CFP in the whole Pacific region, while the 2018 study considered California only. For this study, the model has been rescaled to reflect the Washington transportation sector and the input data has been adjusted to better reflect the Washington State vehicle and fuel markets. Further details of the model are provided in section 4.

Our analysis suggests that given reasonable assumptions on deployment of alternative fuels and development of the fleet of electric drive vehicles, a 10% target for 2028 would be eminently achievable for the State.

1.1. Modeled policy structure

The modeling in this study is based on the type of CFP policy framework that would be required if House Bill 2338 was adopted. To summarize, the Bill includes the following requirements:

1. The average greenhouse gas emissions attributable to each unit of covered transportation fuel (the carbon intensity) should be reduced to 10 percent below 2017 levels by 2028.
2. The program should start on 1 January 2020.
3. Liquid and gaseous fuels and electricity for motor vehicles are covered by the program.
4. Transportation fuel used for aircraft, locomotives or vessels should be exempt from the program requirements, unless associated suppliers opt-in to participate.
5. Exported transportation fuels should not be covered.
6. Carbon intensity of fuels and energy should be assessed by lifecycle analysis.
7. Only transportation fuels with carbon intensity at least 20% below the 2017 baseline should be able to generate credits.
8. Compliance should be demonstrated through the retirement of bankable and tradable credits.
9. A cost containment mechanism should be put in place.

The Bill allows for the Department of Ecology to, "consider and rely on carbon intensity calculations for transportation fuels used by similar programs in other states." In the modeling in this report we have therefore relied on lifecycle carbon intensity values estimated by the California Air Resources Board for the California Low Carbon Fuel Standard.

8 https://www.anl.gov/es/vision-model

1.2. Illustrative compliance trajectories

The Bill does not propose a compliance trajectory between 2020 and 2028. Indeed, given that it is now 2019, we would not anticipate that a program would be ready to come into effect at the start of 2020. Allowing a year for a rulemaking process, and assuming a year of registration and reporting to introduce the system before mandatory compliance targets would be introduced, we model compliance targets starting from January 2022.

When the scenario results are presented we compare the carbon intensity reduction results against a simple linear compliance trajectory, in which the compliance requirement increases by an equal amount (1.43%) each year between 2022 and 2028. The compliance trajectory is illustrated in Figure 1.

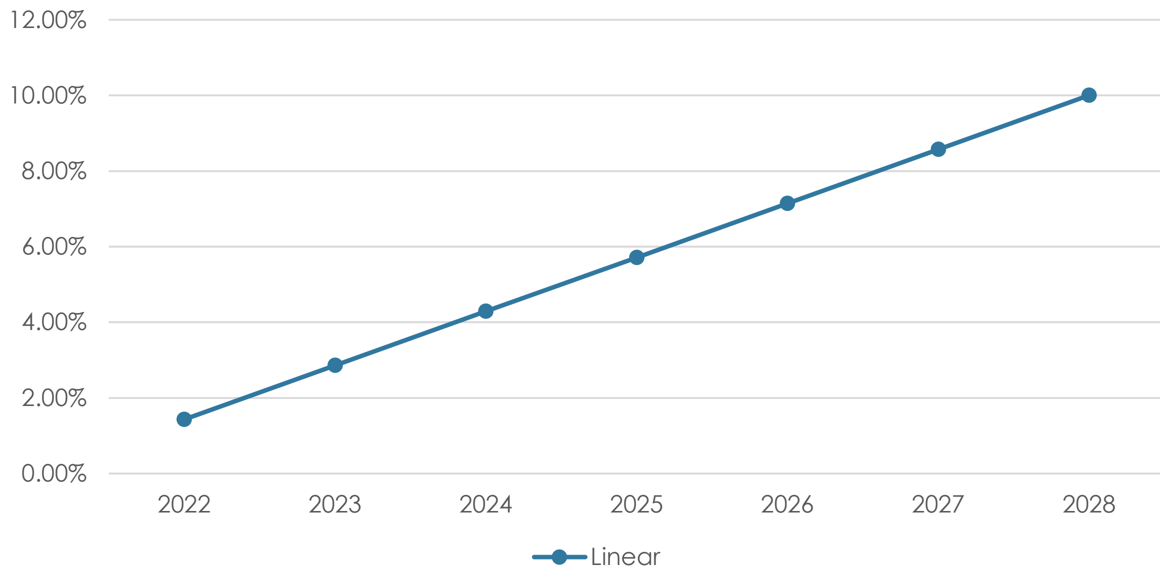

Figure 1. Illustrative compliance trajectory

2. Value available to clean fuels and vehicles from a CFP

A CFP can drive adoption of new fuel and vehicle technologies and innovation in the fuel supply chain by transferring value to those parties able to deliver carbon reductions to allow obligated parties to comply with the standard. In this section, we briefly review the value proposition potentially available to several compliance options, considering first renewable fuels, then zero emission vehicles (ZEVs)[9], and finally investments to reduce the carbon intensity of the petroleum industry. One CFP credit will be awarded for every metric ton of CO_2 reductions delivered, and can then be sold to an obligated supplier to meet a compliance obligation.

Credit prices recorded in California's LCFS can be taken as an indicator of what credit prices may be experienced under a Washington CFP. In California, LCFS credit prices in the early years of the program were held artificially low due to legal uncertainty that prevented targets from being raised as planned, but since the last legal challenges to the LCFS were resolved prices have stabilized and now provide a clear investment signal. The average traded credit prices in 2015, 2016 and 2017 were in the range $62-101 per metric ton CO_2e, and in 2018 the average traded price is likely to be above $150 per metric ton (CARB, 2018). We would anticipate that the California LCFS will continue to stretch fuel suppliers for the foreseeable future, and therefore that credit prices between now and 2030 are likely to generally remain closer to the higher price levels seen in 2018 than to the lower prices observed earlier in the operation of the standard.

In Oregon, where the CFP is still relatively new, reported credit prices through 2017 and 2018 fell in the range from $40-100 per metric ton CO_2e[10].

A Washington CFP would not come into operation at the relatively high level of stringency the California program has reached, but with a stable regulation, challenging over the decade as a whole and implementing a credit banking system, it would seem reasonable to expect credit prices of at least $50 per metric ton CO_2e in the early years, rising later in the decade to approach the prices in California, probably achieving at least $100 per metric ton CO_2e. In the discussion below we therefore take $100 per metric ton CO_2e as a central indicative estimate of future CFP credit prices, and consider $150 and $50 per metric ton CO_2e as upper and lower cases.

2.1. Value to renewable fuels

Renewable liquid fuels, and in particular biofuels, are one of the main beneficiaries of the value from CFPs. Based on the presumed carbon intensities of renewable fuels from the modeling,

9 In this report, we include in the ZEV category battery electric vehicles (BEVs), plug-in hybrid vehicles (PHEVs) and fuel cell vehicles (FCVs). While PHEVs are not strictly zero emissions they are able to travel zero-emissions miles, and we therefore follow the California ZEV Program (California Air Resources Board, 2018d)hydrogen fuel cell, and plug-in hybrid-electric vehicles. The ZEV regulation is part of a broader package of regulations called Advanced Clean Cars, a set of tailpipe regulations put in place to limit smog-forming and greenhouse gas (GHG terminological convention by counting them in the ZEV category.

10 https://www.oregon.gov/deq/aq/programs/Pages/Clean-Fuels-Data.aspx

the expected compliance schedule and illustrative CFP credit prices it is possible to assess the value that could be returned to various alternative fuel producers.[11]

Table 2 shows the value proposition to several potential compliance fuels from a Washington CFP delivering credit prices of \$50, \$100 or \$150 per metric ton of CO_2e. For comparison, D6 RINs under the federal RFS (for renewable fuel such as corn ethanol) have varied in value between 20 cents and \$1 per gallon since the start of 2016, while D4 RINs (for biomass based diesel) have ranged in value over the same period between 50 cents and \$1.60 per physical gallon of biodiesel.

Table 1. Potential value to renewable fuel production in 2028 from CFP credits (\$ per gallon)

Fuel (assumed CI in parentheses)	Assumed 2028 CFP credit value (\$/tCO_2e):		
	\$150	\$100	\$50
Corn ethanol (65 gCO_2e/MJ)	\$0.30	\$0.20	\$0.10
Ethanol from woody residues (20 gCO_2e/MJ)	\$0.85	\$0.57	\$0.28
Soy biodiesel (50 gCO_2e/MJ)	\$0.78	\$0.52	\$0.26
Yellow grease biodiesel (14 gCO_2e/MJ)	\$1.47	\$0.98	\$0.49
Soy oil based renewable jet fuel (54 gCO_2e/MJ)	\$0.59	\$0.39	\$0.20
Renewable jet fuel from woody residues (20 gCO_2e/MJ)	\$1.26	\$0.84	\$0.42

For corn ethanol, which delivers a relatively modest carbon intensity reduction, the per-gallon value proposition is relatively weak, at 20 cents per gallon for a \$100 CFP credit. This is comparable to the current value of a D6 RIN[12] (averaging 21 cents per gallon in October 2018[13]), and would represent a useful revenue stream. For a 100 million gallon per year plant, a \$100 CFP credit price would represent an additional \$20 million annual revenue. The value signal is stronger for fuels delivering better emissions reductions, and should provide a significant additional

11 Alternative fuel producers would not necessarily receive this full value, some of which could also be passed along to consumers through lower fuel pricing, retained by fuel distributors or spent on administration costs.

12 Under the Renewable Fuel Standard, 'Renewables Identification Numbers' or RINs are issued for every gallon of renewable fuel supplied. Corn ethanol receives D6 renewable RINs, soy biodiesel receives D4 biomass-based diesel RINs, and so on (Christensen, Searle, & Malins, 2014)gasoline and diesel fuel mixtures.

13 https://www.epa.gov/fuels-registration-reporting-and-compliance-help/rin-trades-and-price-information

incentive to invest. For instance, a 50 million gallon per year facility producing renewable jet from woody residues would be able to earn an additional $42 million a year if the credit price was stable around $100 per metric ton CO_2e.

2.1.1. Value of reductions to ethanol CI

One of the strengths of a Clean Fuels Program as a regulatory structure is that, unlike a renewable fuel standard, it returns value to fuel producers for delivering marginal improvements in the carbon intensity of their processes, for instance by increasing the energy efficiency of production, switching to lower carbon energy sources or capturing carbon dioxide emissions. By 2028, given a 10% carbon intensity reduction requirement, the number of credits and hence value delivered by supplying corn ethanol in a Washington CFP could be substantially increased by adopting best practices to reduce the carbon intensity of supplied ethanol. In 2028, given a baseline gasoline pool carbon intensity of 99.9 gCO_2e/MJ and a resulting compliance requirement of 90 gCO_2e/MJ, supplying ethanol with a reduced CI of 65 gCO_2e/MJ would deliver nearly twice as many certificates as supplying ethanol with a CI of 75 gCO_2e/MJ.

For a credit price of $100 per metric ton CO_2e, reducing the carbon intensity of fuel production by 10 gCO_2e/MJ would deliver an additional value of 8 cents per gallon. For a 100 million gallon per year plant, that represents $8 million per year.

The availability of CFP credits may also be a driver of adoption of carbon capture and sequestration (CCS) at ethanol plants. CCS applied to CO_2 released during fermentation can reduce the carbon intensity of ethanol production by over 30 gCO_2e/MJ (Sanchez, Johnson, McCoy, Turner, & Mach, 2018), making it probably the most significant single change most ethanol refineries could make to increase their rate of CFP credit generation. At $100 per metric ton of CO_2e, CCS could therefore deliver 24 cents per gallon of ethanol produced. This is well above the estimated cost of implementing CO_2 capture at an ethanol plant as reported by the Global CCS Institute (Irlam, 2017), which is only about 8 cents per gallon.

Note though that this cost is based on a levelised cost assessment with a 30 year payback period. This can be contrasted to Fulton, Morrison, Parker, Witcover, & Sperling (2014), which reports that for incremental emissions reduction technologies ethanol plant operators may only consider investments with a two year payback. One should therefore be cautious of drawing direct comparison between levelised costs over a long project lifetime and the value expected from CFP credits with a somewhat uncertain future value, although certainly CCS does not constitute an incremental investment. In any event, it is clear that the value from a CFP has significant potential to drive adoption of CCS at ethanol plants (as is assumed in Malins, 2018b).

2.1.2. Value to HVO renewable diesel

In California's LCFS, hydrotreated vegetable oil (HVO) renewable diesel has become one of the more flexible marginal compliance options, and its use is expected to grow significantly in the California market. Pont, Unnasch, Lawrence, & Williamson (2014), however, assumed that the California compliance market would absorb fully available supplies of hydrotreated renewable diesel so that none would be available to Washington State. This was on the basis that the lower NOx emissions from renewable diesel as compared to biodiesel would make it especially appealing in the California market, and that the compliance credit price in California is likely to exceed the Washington value as the California standard is more stringent in the short to medium term.

While this logic is reasonable insofar as it goes, assuming that Washington will not be an appealing market for HVO fuels may have been an oversimplification. Currently Oregon and California both have CFPs, and while California is certainly the larger market for HVO Oregon has started to report small volumes being used for CFP compliance (Oregon DEQ, 2018). Globally, HVO renewable diesel capacity is increasing[14], and REG and Phillips 66 have recently announced a new facility to be built alongside the Ferndale refinery in Washington State[15]. To explore the potential for a Washington CFP to attract HVO fuels we developed a simple cost of production model for renewable diesel from soy oil, in order to investigate what CFP credit price would make it profitable to produce for the Washington market.

Production cost modeling by Pearlson (2011) suggests that the production cost of HVO is about 70 cents per gallon plus the cost of feedstock. Other sources (e.g. Tao, Milbrandt, Zhang, & Wang, 2017) suggest that this may underestimate real costs a little, and therefore we considered a high and low cost scenario, with the high production cost set 40 cents per gallon above the estimate derived from Pearlson (2011). By combining these renewable diesel production cost assumptions with information on RIN prices from EPA[16] and soy oil and diesel prices as documented in the Iowa State biodiesel profitability model[17] it is possible to derive high and low estimates of the CFP credit value that would make hydrotreated renewable diesel (or similarly renewable jet) supply in Washington viable. While the production cost of soy HVO was consistently above the price of diesel during the period 2011-2017, even in the low cost case, the value available from the D4 RIN under the RFS improves the economics significantly, at times by enough to justify renewable diesel supply without further support. When the D4 RIN does not cover the full price gap to fossil diesel, a CFP credit (or of course the existing CA-LCFS credit) may make the difference.

Figure 2 shows the results for the CFP price that would have made soy HVO supply to Washington State potentially profitable over the past 7 years. For most of the period, a $50 CFP credit price would have been enough when coupled to the value of the D4 RIN to cover the price gap for both the high and low cost cases, and a $100 CFP credit would at all times have covered the low estimate production cost, and covered the high estimate production cost at all times except briefly in 2016 when fossil diesel prices got as low as $1 per gallon.

14 https://www.iea.org/renewables2018/transport/

15 https://investor.phillips66.com/financial-information/news-releases/news-release-details/2018/Phillips-66-and-Renewable-Energy-Group-Announce-Plans-for-Large-Scale-Renewable-Diesel-Facility-on-West-Coast/default.aspx

16 https://www.epa.gov/fuels-registration-reporting-and-compliance-help/rin-trades-and-price-information

17 https://www.extension.iastate.edu/agdm/energy/html/d1-15.html

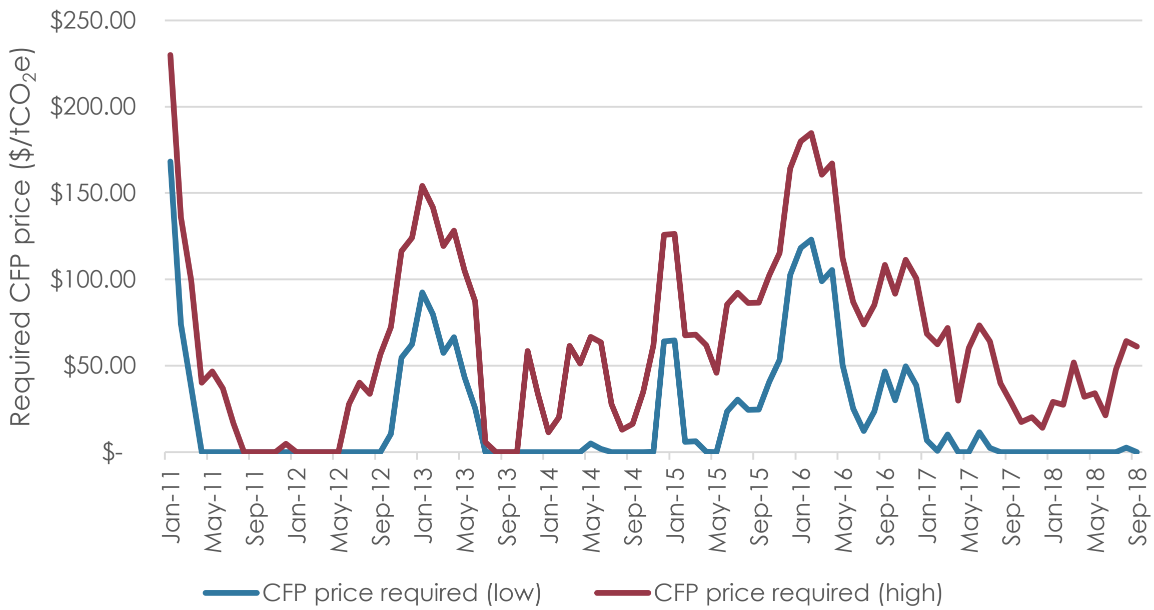

Figure 2. CFP credit price that would have been required to make HVO supply profitable in Washington State, 2011-2018

This analysis does not have the sophistication necessary to fully refute the argument from Pont et al. (2014). It does not consider any additional costs to supply renewable diesel to Washington instead of California or other markets, it does not take direct account of total HVO capacity, and it does not provide a prediction of exactly which markets might take available HVO supplies. It does, however, clearly suggest that the existence of the Washington CFP will create a business case to supply HVO fuels to Washington in the case that extra production capacity is available, or could be developed.

2.2. Value to zero emission vehicles

As the ZEV fleet expands, consumption of electricity and hydrogen in ZEVs will play an increasingly large role in reducing transportation carbon emissions, and in generating credits to allow compliance with CFP mandates. In the case of electric vehicles, in the California system credits are issued to public utility companies, but the proceeds of credit sales must be returned to EV-driving residential consumers. There are several potential targets to return CFP certificate value – the vehicle; the charging infrastructure; and the electricity supply – and examples of using each route to deliver value to drivers are found in the California system (Union of Concerned Scientists, 2018). These measures already include one-off rebates of up to $1,000[18], free chargers and annual rebates of $50, and the value of rebates is expected to increase to around $2,000 per vehicle later in 2019[19] as new state-wide rules are introduced (California Air Resources Board, 2018c).

18 https://evrebates.sce.com/cleanfuel

19 https://www.forbes.com/sites/danielsperling/2018/10/17/how-almost-everyone-came-to-love-low-carbon-fuels-in-california/#60de0eea5e84

Using the electric vehicle deployment and activity assumptions from the VISION model, it is possible to explore scenarios for the value that could be delivered by an electric vehicle under a WA CFP. Table 3 shows results from the *Steady Progress* scenario (detailed further in section 5.1) for the number of new ZEVs sales each year and the number of CFP credits generated by ZEVs in that year. It then shows the value of the rebate that could be returned per new vehicle if those credits were sold for $100 per metric ton of CO_2e reductions, and the entire revenue stream was used for vehicle rebates. In practice, the amount of revenue available to rebates may be less. Firstly, revenue may not be fully redirected to rebates – for instance, in the California scheme charging station operators are able to claim credits from non-residential charging. Some revenue may also be required to cover operating costs, and utilities may not be obliged to transfer the full value of credits back to vehicle purchasers. The values in Table 3 therefore represent the maximum potential rebates given an average $100 CFP credit value.

Table 2. Potential rebate to new vehicle purchases under the *Steady Progress* scenario

	Thousands of new ZEVs	Credits awarded (million metric tons CO_2e)	Potential value of rebate (for $100 CFP credit)
2022	23.4	0.5	$2,230
2023	32.6	0.7	$2,229
2024	42.9	1.0	$2,294
2025	52.6	1.3	$2,446
2026	60.7	1.6	$2,667
2027	70.2	2.0	$2,845
2028	79.8	2.4	$3,024
2029	87.8	2.9	$3,312
2030	94.3	3.4	$3,643

The value that could be returned to new ZEV purchases through rebates based on this calculation is over $2,000 in 2022, comparable to the level of rebate expected in the California scheme. By 2030, given the rate of ZEV deployment modeled, the potential rebate increases to $3,600.

In practice, the level of support available could be further differentiated based on the type of ZEV purchased. For instance, in the California scheme the auto industry and utilities have proposed that rebates could be scaled relative to battery size for the vehicle purchased (Joint Auto & Utility Recommendation, 2018).

3. Credit generation options

Assuming that a CFP for Washington follows the example of existing programs in California and Oregon, it would provide rewards to a range of fuel decarbonization technologies. These include conventional and advanced biofuels, the expansion of electricity and hydrogen use in a growing electric drive vehicle fleet, and the use of natural gas (especially if renewable) for transportation. It may also allow the generation of additional credits through decarbonization technologies introduced in the petroleum sector, as has been implemented in California (cf. Malins, 2018b).

This section provides a brief overview of the decarbonization options considered and of our assumptions about the availability of those options in Washington State in the period 2020-2030. Below, scenarios are presented for compliance credit generation for different technology deployment cases. Unless otherwise stated, any assumptions discussed in this section apply to the modeled *Steady Progress* scenario. The other scenarios involve differences from the *Steady Progress* scenario as detailed below in section 5

3.1. Biofuels

3.1.1. First generation ethanol

As in the rest of the United States, the standard ethanol blend delivered to drivers in Washington State is E10, consisting of up to 10% anhydrous ethanol by volume. Based on Department of Energy SEDS reporting[20] ethanol currently constitutes 9.4% of Washington motor gasoline by volume, which is used as the 2020 starting ethanol blend in the model. By 2030, given that there will likely be several options available to increase the supply of ethanol including E15 blends and potentially high-octane mid-blends of E20 or E30, we assume an increase in average ethanol content to 12.5%.

It is assumed that corn ethanol will continue to dominate the first generation ethanol market in Washington under a Clean Fuels Program, with a modest increase in supply of lower CI sugarcane ethanol imported from Brazil to generate additional marginal credits as the program becomes more stringent towards 2028. It is assumed that the carbon intensity of delivered corn ethanol will fall between now and 2030 as production efficiency improves towards best current industry performance across the board.

For the scenario analysis, similar assumptions have been used to those documented by Malins (2018b). Recognizing that California may preferentially receive the lowest CI ethanol in the early stages of a Washington CFP, the starting carbon intensity is set at 75 gCO_2e/MJ (slightly above the current average performance of corn ethanol at 71 gCO_2e/MJ under the CA-LCFS).

The 2030 carbon intensity set at 60 gCO_2e/MJ. This assumes that by 2030 the average carbon intensity performance of ethanol supplied in Washington will reach the lowest CI values currently documented under the CA-LCFS for corn ethanol that uses neither biogas for energy nor carbon capture and storage (California Air Resources Board, 2018b). Unlike the assumptions for California in Malins (2018b), there is no explicit assumption of utilization of

20 https://www.eia.gov/state/seds/

carbon capture and sequestration (CCS) for corn ethanol in the *Steady Progress* case in this analysis, although some deployment of CCS could contribute to reducing the average CI for corn ethanol. This reflects an assumption that California will continue to tend to preferentially attract the lowest CI ethanol through the next decade. E85 use is assumed to be low, with a reduction in E85 vehicle sales between now and 2030 but slight increase in the rate at which E85 vehicle owners use E85 fuels, reaching 4% of fuel consumed in E85 vehicles by 2030. For the *Accelerated Progress* scenario, it is assumed that a further 5 gCO_2e/MJ reduction in the CI of corn ethanol can be achieved, which would likely require additional use of either biogas for process energy or of CCS.

3.1.2. First generation biodiesel

Pont et al. (2014) document that historical biodiesel use in Washington State has been low compared to the rest of the country, with only 0.22% use by volume in the diesel supply reported for 2013. WSDA Weights and Measures reports that the Washington State average biodiesel blend remains lower than the national average, at less than 0.5% based on sampling[21]. This is well below the current U.S. national average biodiesel blend, at 4.4% by volume based on DoE data for 2016[22].

One reason for this relatively low biodiesel blend is the lack of the market driver from a CFP (in contrast to Oregon and California to the south and British Columbia to the north), which results in biodiesel produced in the region being utilized outside Washington. The introduction of a CFP would create a clear market driver for local biodiesel consumption, and therefore it is assumed that this blend would increase to 7% by volume (B7) by 2025. This is well below the B15 average blend assumed by 2026 in Pont et al. (2014).

It is unclear what the current feedstock mix for Washington biodiesel is. The 100 million gallon per year biodiesel plant at Grays Harbor reportedly uses primarily soy and canola oils[23,24]. The smaller 2.3 million gallon per year General Biodiesel facility in Seattle processes used cooking oil feedstock. For the scenario analysis we have assumed a lower fraction of waste-based biodiesel use than was considered in the California modeling by Malins (2018b), with 20% waste and residual oils in the feedstock mix and the rest from canola and soy. This allows for up to 40 million gallons of supply of waste-based biodiesel. If LCFS credits in California have a higher value than CFP credits in Washington, which seems plausible in the near term, lower CI biodiesel may be selectively drawn to the California market, in which case this level of supply of waste-oils may still be optimistic. The modeling does not assume any efficiency improvements over time for biodiesel production. This is informed by the fact that existing soy-biodiesel pathways registered under the CA-LCFS have much less variability in CI than corn ethanol pathways, suggesting that the space for efficiency improvements is more limited[25].

21 Based on correspondence with Washington Department of Commerce.

22 https://www.eia.gov/totalenergy/data/monthly/index.php#renewable

23 https://www.renewableenergyworld.com/articles/2006/11/imperium-renewables-begins-100-mgy-biodiesel-production-facility-46463.html

24 REG identify Grays Harbor as using 'low free fatty acid' feedstocks, which suggests virgin rather than waste oils https://regi.com/about-reg/locations/biorefineries/production-mode/reg-grays-harbor-llc

25 https://www.arb.ca.gov/fuels/lcfs/fuelpathways/pathwaytable.htm

3.1.3. Renewable diesel and jet fuel

As noted above, HVO renewable diesel, gasoline and jet fuels are a potentially appealing compliance option under a Washington CFP, able to be used at high blends without infrastructure concerns. This is, however, set against potential competition for these fuels from other states in the region with their own CFPs, notably California.

Washington State has no targets for renewable diesel use, but the Port of Seattle has set an aspirational goal for the use of renewable jet at regional airports. The target is for 70 million gallons a year of renewable jet use in Washington State by 2027. Unless second generation biomass to jet fuel technologies are commercialized quickly, this target would likely have to be met with HVO jet fuel.

For the scenario analysis below, we therefore assume that under a CFP Washington State would attract a fraction of the total amount of HVO consumed on the West Coast. Consumption in Washington State in 2030 is set at 65 million gallons. This is calculated based on the volume of fuel supply assumed for California in Malins (2018b), scaled to the relative diesel consumption of the States and then divided by two to reflect that we expect the market pull from Washington to be weaker. We assume that California will preferentially consume the lowest CI HVO, from waste and residual feedstocks, and that any renewable diesel and jet fuel consumed in Washington would therefore utilize virgin vegetable oils, soy and canola. The modeling assumes that the fraction of HVO consumed as renewable jet increases through the period, so that by 2030 a quarter of HVO is supplied as renewable jet fuel. The model therefore does not assume that the Port of Seattle goal is met by 2027.

3.1.4. Cellulosic biofuels

The cellulosic biofuel supply is based on the cellulosic supply model developed by Malins et al. (2015), as modified by Malins (2018b,c). It is assumed that California will be the dominant market for such fuels in the medium term, but that Washington State will have access to 5% of the U.S. supply of cellulosic fuels and no imported cellulosic fuels. Washington State represents 13% of the fuel market in the West Coast region, and thus assuming that Washington State receives 5% of the national available supply represents an assumption that cellulosic fuels will be supplied into the West Coast region by the value from CFPs, but that higher credit values under the CA-LCFS will draw a disproportionate fraction of that fuel to California. This supply of cellulosic fuel reaches 9 million gallons by 2030 in total, similar to the output of a single commercial scale cellulosic ethanol plant. This could be produced at Washington facilities using local supplies of woody residues (U.S. Department of Energy, 2015), or imported from other states.

In principle, the local cellulosic biofuel industry could expand significantly more rapidly than this. Crawford et al. (2016) model production costs for renewable jet fuel from poplar biomass, identifying a minimum sale price of $4.60 per gallon to deliver payback at a 100 million gallon per year facility assuming 15% cash flow discounting. Given reported D3 RIN and diesel prices, this fuel production process would have been profitable with a $50 CFP credit price since August 2016, and indeed for most of that period would not have needed additional support from a CFP to be profitable. One major challenge for investment in cellulosic fuels has been a lack of long-term investor confidence in the value of fuel support incentives (cf. Malins, 2018a). While the value proposition for such fuels is currently very strong, the RIN price is potentially highly variable over the lifetime of a project. Adding additional regional CFPs expands the potential market for such fuels, and should partially offset the inherent uncertainty of relying on a single support framework.

3.2. Renewable natural gas vehicles

In the California analysis by Malins (2018b) the consumption of renewable natural gas in heavy duty natural gas vehicles is an important credit generation pathway, contextualized by strong assumptions about growth in the fleet of heavy duty natural gas vehicles. Expectations for natural gas vehicle sales in Washington State appear to be more modest, and the existing fleet much smaller than that in California. Washington State Department of Licensing (2016) reported that as of 2014 there were about 1000 natural gas vehicles in Washington State. While we were not able to find data on the exact composition of the Washington State heavy duty fleet, it seems reasonable to make sales assumptions in the *Steady Progress* scenario for Washington much more cautious than in California modeling.

The latest Annual Energy Outlook (EIA, 2018) gives 2016 national averages of 2.1% sales of natural gas vehicles in heavy duty[26], and only 0.15% sales in medium duty[27]. These national average sales would imply a larger current heavy duty NG fleet than is identified by Washington State Department of Licensing (2016). We therefore assume that initial Washington State NG vehicle sales fractions are half the national averages, but that encouraged by the value available to fleet operators from CFP credits sales fractions increase by 2030 to the national average predicted by EIA (2018). It is possible that the added value from CFP credits could further increase interest in heavy duty renewable natural gas vehicles in Washington. The *Accelerated Progress* scenario involves NG vehicle sales rates higher than the EIA (2018) predictions, achieving 0.6% of sales in medium duty by 2030 and 2.1% in heavy duty. This grows the medium and heavy duty NG fleet to 3,000 vehicles by 2030, and remains modest compared to NG fleet deployment assumptions for California in Malins (2018b).

The credits generated by natural gas vehicles are highly dependent on the type of natural gas used. Under the California LCFS system 'book and claim' accounting is allowed to demonstrate the renewability of natural gas fuel consumed. Under book and claim accounting, renewable natural gas injected into the gas pipeline network elsewhere in the country may be counted as supplied for transport in California even though the physical molecules of the supplied natural gas are different. Under this system, CARB expect that all natural gas for transportation in California will be reportable as renewable. In the scenario analysis, it is assumed that a Washington CFP implements the same system, and therefore that it is viable for all natural gas for transportation to be treated as renewable.

Within renewable natural gas, the largest credit generator is the use of captured dairy gas. This is because capturing dairy gas avoids methane emissions and therefore is allocated a negative carbon intensity under the CA-LCFS. We allow for up to 13 million diesel gallons equivalent to be supplied from dairy gas from anaerobic digesters in 2030, based on dairy gas potential reported by Washington State University Energy Program (2017). We also assume that expansion of dairy gas capture capacity follows a trajectory comparable to that assumed by California Air Resources Board (2018a). On this basis, all natural gas consumed by

26 Classes 7 & 8 in VISION.

27 Classes 3-6 in VISION.

transportation in the *Steady Progress* scenario is treated as renewable and allocated the dairy gas carbon intensity.

3.3. Electric drive vehicles

Currently, Washington has one of the highest rates in the U.S. for electric drive passenger vehicle sales (PHEV and BEV), at 2.5% in 2017 and 3.5% for the year to August 2018.[28] For 2017 that gave Washington the second highest ZEV market share by state in the U.S. This remains, however, below the sales share of 5% for 2017 reported in California. As of 2017 no hydrogen fuel cell vehicle sales have been reported in Washington.[29]

Future sales fraction assumptions for passenger electric drive vehicles in the modeling are derived from current sales rates, state targets and from scenarios for sales fractions in California developed for Malins (2018b). Washington State has a target of 50,000 electric drive vehicles on the road by 2020, and in the modeling it is assumed this target is met. Analysis of potential CFP credit generation for the Pacific region by Malins et al. (2015) assumed that ZEV sales rates in Washington and Oregon would lag California sales rates by five years. Based on strong current performance on ZEV sales in Washington, and a firm commitment from the State to develop the ZEV fleet[30], for this analysis we have assumed that sales fractions in Washington will not lag California rates by so many years. By 2030, we assume that overall ZEV sales rates in Washington lag the rate in California by two years, and that California is on track to meet the California Governor's target of five million ZEVs by 2030 following the trajectory developed by Malins (2018b). This turns out to give the same 2030 sales share for ZEVs in Washington modeled in the 'Half the Oil' scenario by ICF (2016), 26.4%, and a similar 2025 ZEV sales share to that modeled in the 'Advanced vehicles' scenario by Pont et al. (2014). For the *High EV* scenario it is modeled that by 2030 Washington State EV sales fractions match the California sales fractions to meet California's 5 million ZEV target for 2030.

While Washington's electric vehicle market is developing well, it does not have the same level of hydrogen infrastructure in place as California[31], and in the model it is assumed that fuel cell vehicle sales only account for a quarter of the share within the ZEV market that they achieve in California.

3.3.1. Electricity beyond light duty vehicles

In the modeling in this paper, only carbon savings associated from the use of electricity in light duty vehicles have been included. There are additional opportunities to generate carbon savings and CFP credits by using electricity for other transport applications, including heavy duty vehicles, onshore electricity in ports, non-road electric vehicles, and electricity for rail transit. In illustrative compliance modeling for the California LCFS, these other electricity pathways account for about 3% of 2030 credit generation. ICF (2016) identified a significant opportunity for electrified drayage at Washington ports (including Tacoma and Seattle) to

28 http://evadoption.com/ev-market-share/ev-market-share-state/

29 https://autoalliance.org/energy-environment/advanced-technology-vehicle-sales-dashboard/

30 See e.g. (Inslee, 2018); https://www.theclimategroup.org/project/zev-challenge

31 See for example https://hydrogen.wsu.edu/2016/05/02/the-potential-for-hydrogen-fueled-cars-in-washington-state/

reduce fossil fuel consumption by 100 million gallons by 2030. West Coast ports are in the vanguard taking action to reduce emissions from drayage fleets[32].

3.4. Petroleum industry

Under the California Low Carbon Fuel Standard, several options are available for the generation of credits by the petroleum industry, both upstream (through innovative crude extraction) and downstream (through refinery investment, carbon capture and storage, renewable hydrogen use, and for low complexity and low energy use refineries). Washington is not an oil producer[33] but has over 600,000 barrels per day of oil refining capacity. It is our understanding that carbon capture and storage has less favorable geological prospects for refineries in Washington than in California, and thus no credit generation from carbon capture and storage is assumed.

A more promising option for Washington may be the utilization of renewable natural gas for process energy as a natural gas alternative. Based on EIA data for PADD 5 refineries[34], about 40 petajoules of natural gas is consumed annually in Washington refineries, not including still gas produced on site. If this could be entirely substituted with renewable natural gas at 40 gCO_2e/MJ[35], this would generate about 1.4 million metric tons of credits per year. These credits are not included in the Steady Progress scenario. In the *Accelerated Progress* scenario it is assumed that renewable natural gas use at refineries increases linearly from 2020 until 25% of refinery natural gas use is renewable in 2030, delivering 0.35 million metric tons of carbon savings[36]. This is less than half of the Washington State potential for renewable natural gas production detailed by Washington State University Energy Program (2017), but delivering local renewable natural gas to refineries at this level would nevertheless require a significant ramp up of production and collection. It is likely that a refinery investment program similar to California's could yield significant emissions reduction and credit generation through efficiency improvements at oil refineries, but analysis of the magnitude of this opportunity is beyond the scope of this analysis, and no other refinery credits are included in any of the scenarios presented here.

32 https://www.trucks.com/2018/09/18/ports-la-long-beach-clean-truck-testing/

33 https://www.dnr.wa.gov/programs-and-services/geology/energy-mining-and-minerals/oil-and-gas-resources

34 The 'PADD 5' fuel supply region includes California, Arizona, Nevada, Oregon, Washington, Alaska, and Hawaii.

35 We assume here that available dairy gas at a lower CI will preferentially be supplied for natural gas vehicles. There may be potential for additional dairy gas capture, which would increase total credit generation if supplied for use in refineries.

36 In order to be conservative it is assumed that none of this gas is dairy gas, and therefore that it does not receive the dairy gas credit for avoided methane emissions.

4. Modeling framework

The modeling presented in this report is based on an updated version of the low carbon fuel supply model documented by Malins et al. (2015) and updated as in Malins (2018b). The model, originally used to assess the potential to comply with a Pacific Coast low carbon fuel standard, couples vehicle stock turnover and energy demand modeling with low carbon fuel supply modeling. The vehicle stock and energy demand model is based on VISION 2014, with some elements updated using data from VISION 2017, including population and GDP assumptions and VMT and vehicle efficiency assumptions for light duty vehicles.[37]
The underlying model is documented extensively in Malins et al. (2015) and Malins (2018b), and the reader is advised to refer to those reports to obtain a more detailed description of the model and elements updated. For this report, the model has been rescaled to the Washington market, with the size of the gasoline and diesel pools respectively adjusted to reflect EIA SEDS reported energy consumption, and adjustments throughout the low carbon fuel supply assumptions.

It must be emphasized that the model used in this report is not a 'compliance model' – there are no internal feedback mechanisms by which the model can respond to credit supply shortages or surpluses, and no attempt is made to model CFP credit prices. Rather, it is a credit supply model, detailing the number of LCFS credits (and hence the level of emissions reduction) that can be generated given certain assumptions about vehicle sales and the availability of various fuel options and carbon intensity reduction technologies. These rates of credit generation are then compared to the requirements of an illustrative compliance trajectory to provide an indication of whether a given target trajectory is achievable with a given fuel supply scenario. In the real world, it is intrinsic to the design of the CFP that suppliers are expected to take measures to increase the supply of CFP credits if confronted with a shortfall against compliance targets, or to reduce the supply of CFP credits if confronted with an over-supplied market. The model's strength in demonstrating the credit generation and compliance outcomes of given combinations of potential fuel and technology availability assumptions.

4.1. Carbon intensities

The CI values in the model are largely based on the regulatory values under the California LCFS – this is consistent with the proposal in House Bill 2338 that Washington should seek to be consistent with rules in place in low carbon fuel standards in other states, and may "consider and rely on carbon intensity calculations for transportation fuels used by similar programs in other states." The gasoline and diesel baseline CI values, however, have been taken from Pont et al. (2014), where Washington-specific values are presented. We assume that the CI of fossil gasoline blendstock[38] and low sulfur diesel will remain constant through the period to 2030, and do not currently model any incremental crude deficits. Where the model assumes changes to CI values over time, it is included above in descriptions of fuels that can generate credits in Section 2.

37 https://www.anl.gov/es/vision-model

38 RBOB, reformulated gasoline blend-stock for oxygen blending, which is blended with ethanol for sale.

For electricity, the CI values have been updated to reflect the Washington State electricity generation mix, which has a large contribution from hydroelectric power and is therefore very low CI.

4.2. Fuel consumption and VMT

Fuel demand in the model is calibrated independently for the gasoline and diesel pool to match reported 2016 transportation demand for gasoline and diesel type fuels as documented by EIA SEDS[39]. From 2016, fuel demand evolves based on assumed VMT, fleet size and fleet composition. For 2020, the model estimates total demand of 2.8 billion gallons of gasoline and substitutes, and 1 billion gallons of diesel and substitutes. By 2030 in the *Steady Progress* scenario total gasoline and substitutes demand reduces to 2.6 billion gallons, while total diesel and substitutes demand remains around 1 billion gallons.

The vehicle efficiency assumptions are the same as the values used in the previous modeling by Malins (2018b). For vehicle miles traveled (VMT), while Malins (2018b) assumed that various measures taken in California[40] would reduce average VMT over time, for Washington we have currently assumed the slight VMT increase that is the default national assumption in VISION.

39 https://www.eia.gov/state/seds/

40 Such as those documented by (ICF, 2016).

5. Scenario results

Below we provide results from four fuel supply scenarios:

- *Steady Progress*, using the central assumptions described above. This scenario assumes increases in supply of diesel substitutes, gradual reductions in the CI of ethanol and significant deployment of electric vehicles.
- *Accelerated Progress*, which is like *Steady Progress* but with higher assumed blends of biodiesel and ethanol (B10 and E15 by 2030), more use of imported low CI sugarcane ethanol, a modest increase in the heavy duty natural gas vehicle fleet, and crediting assumed for renewable natural gas use in local refineries.
- *Accelerated EVs,* which is like *Steady Progress* but in which EV sales fractions match anticipated California levels by 2030.
- *Delayed EV*, which is like *Steady Progress* but in which EV sales fractions have an additional anticipated lag behind California levels, running five years behind by 2030.

5.1. Steady Progress scenario

The outcomes for the *Steady Progress* scenario are shown in Figure 3 for the period 2022 to 2030. In 2028, an 11.2% carbon saving is delivered compared to the baseline, above the compliance requirement. This rises to 14.3% by 2030. Under this scenario, early credit generation is led by the supply of corn ethanol as E10, but as the program goes on the contribution of biodiesel and renewable diesel/jet becomes comparable to that of ethanol. The largest overall contribution to credit generation, especially later in the period, is the use of electricity in BEVs and PHEVs. In the *Steady Progress* scenario The ZEV fleet grows from 50,000 in 2020 to 610,000 by 2030.

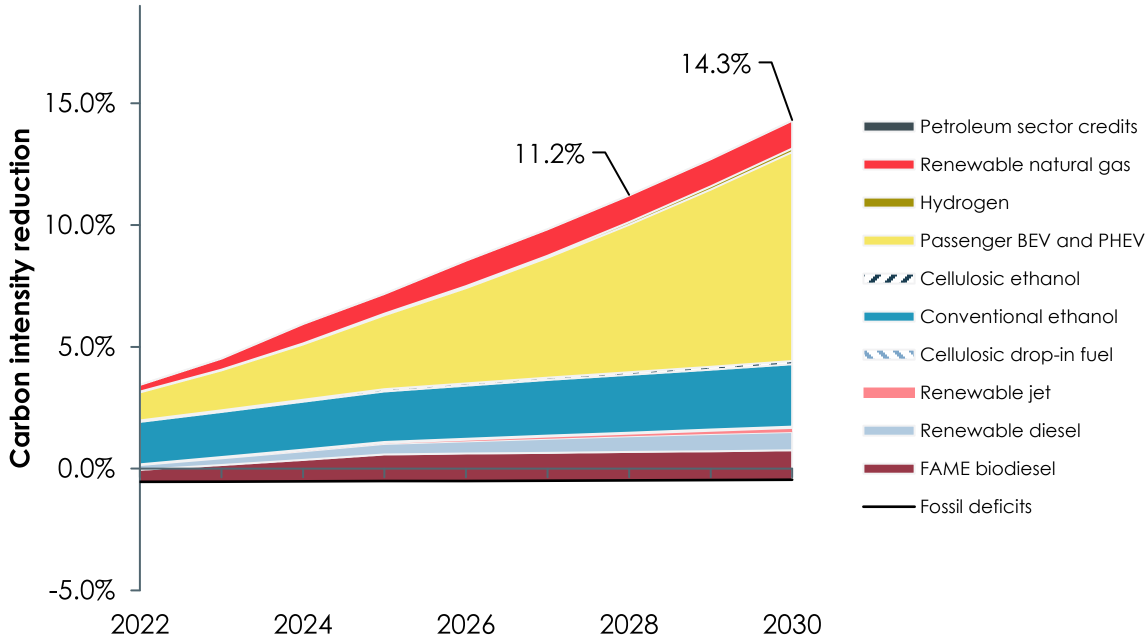

Figure 3. Carbon savings against baseline delivered in *Steady Progress* scenario

Figure 4 compares the carbon savings delivered in this scenario to the requirements from 2020 to 2028 under the illustrative compliance trajectory explained above. The fuel supply achieved under the *Steady Progress* scenario would generate a significant credit bank between 2022 and 2028 growing to 8 million metric tons of CO_2e by 2028.

This potential credit bank is smaller in absolute terms than that which was accumulated under the CA-LCFS by 2018 (about 10 million metric tons), but given that the California transportation fuel market is several times larger than that in Washington, this would be a very large credit accumulation in a Washington CFP. In practice, a large credit bank accumulation could result in reduced credit values, which would weaken the value signal to deliver clean fuels.

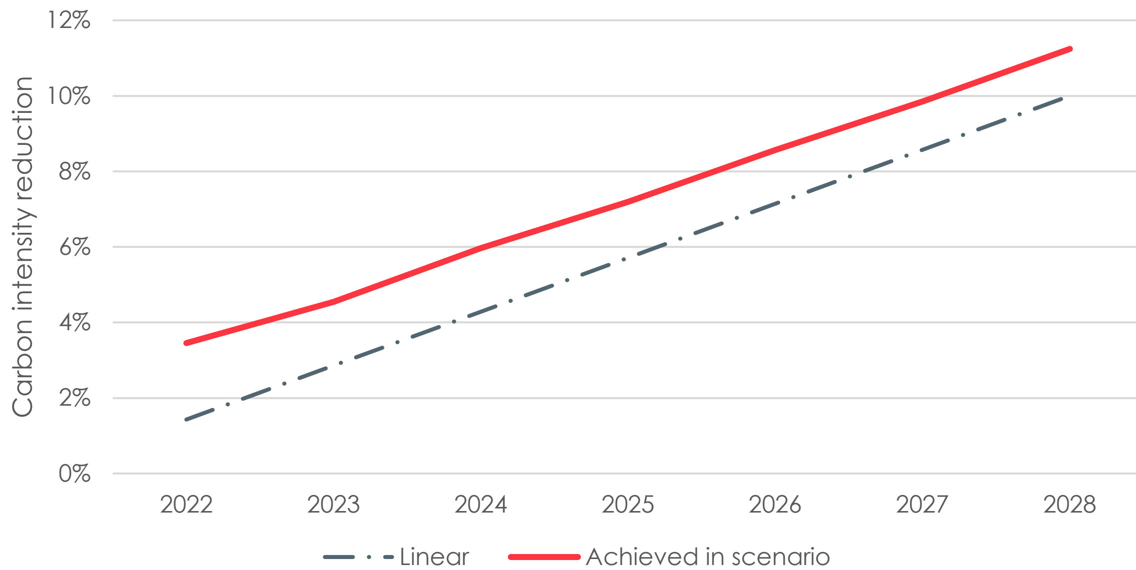

Figure 4. Comparison of savings delivered under *Steady Progress* against illustrative compliance trajectory

Table 4 provides additional detail of the vehicle pool, fuel supply and credit generation under the *Steady Progress* scenario, assuming the illustrative linear compliance trajectory.

Table 3. Additional results from *Steady Progress* scenario

	2022	2025	2028	2030
No. ZEVS (thousand)	91	219	430	612
BEVs	*42*	*116*	*240*	*347*
PHEVs	*47*	*98*	*181*	*253*
FCVs	*2*	*5*	*9*	*12*
Credit generation by light duty ZEVs (million tCO_2e)	0.51	1.26	2.37	3.38
% NG for HDVs	0.7%	0.7%	0.8%	0.8%
Credit generation by renewable natural gas (million tCO_2e)	0.1	0.3	0.5	0.5
Credit generation by first generation ethanol (million tCO_2e)	0.7	0.8	0.8	0.9
Credit generation by HVO and biodiesel (million tCO_2e)	0.3	0.6	0.7	0.8
Credit generation by cellulosic biofuels (million tCO_2e)	0.04	0.05	0.06	0.07
Annual credit generation (million tCO_2e)	1.7	3.1	4.4	5.7
Banked credits at year end (million tCO_2e)	0.9	3.0	4.7	7.8
% CI reduction	**3.5%**	**7.2%**	**11.2%**	**14.3%**

5.1.1. Comparison of Steady Progress to Pont et al. (2014) Scenario A

It is interesting to compare some of the fuel supply and credit generation results in the *Steady Progress* scenario here against the scenarios laid out in Pont et al. (2014), which considers scenarios for compliance with a 10% CFP carbon intensity reduction requirement by 2026. For the comparison we consider only the results from Pont et al. (2014) corresponding to their "advanced vehicles scenario with banking and trading" (referred to as Scenario A with B&T in that report), as this is the most similar to the *Steady Progress* scenario here, in particular in terms of having the largest ZEV population of the Pont et al. (2014) scenarios. Figure 5 shows the sources of credit generation in 2026 for these scenarios from the two studies.

It can be seen immediately that Pont et al. (2014) anticipated a much more rapid deployment of cellulosic ethanol than modelled here, or indeed than has been observed in the past five years. There are therefore more credits from those ethanol overall due to the lower CI. There is also a much larger contribution in Pont et al. (2014) from biodiesel, due to a combination of a high assumed biodiesel blend of B15 by 2023 in Pont et al. (2014), as well as a larger assumed fraction of lower CI waste based biodiesel. In contrast, Pont et al. (2014) assume that there is no hydrotreated fuel available to Washington, and therefore no credits are generated from HVO or other drop-in renewable fuels. The *Steady Progress* scenario here also involves more credit generation by natural gas vehicles than is seen in Pont et al. (2014).

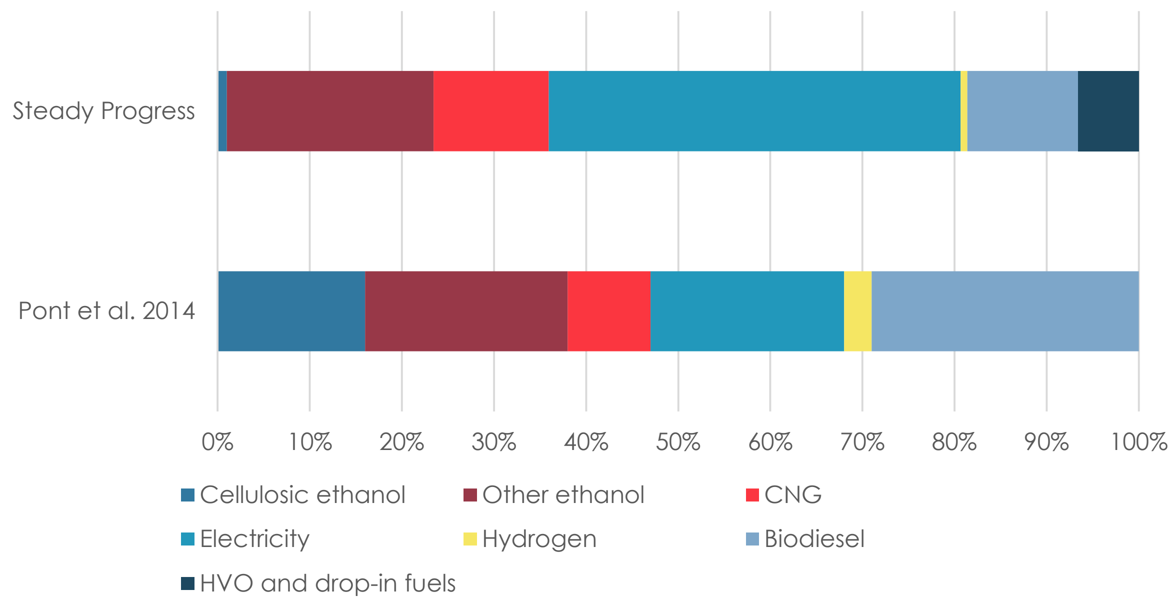

Figure 5. Sources of credit generation in 2026

The higher rate of EV and natural gas vehicle deployment in our scenarios as compared to Pont et al. (2014) imply that a more rapid development of relevant infrastructure would be required for these scenarios to be realized, but there is no fundamental barrier to achieving this deployment.

5.2. *Accelerated Progress* scenario

The *Accelerated Progress* scenario illustrates the additional carbon savings that could be delivered under a Washington CFP if additional action could be taken to more quickly overcome infrastructural limits on the supply of low carbon fuels, and if additional credits could be generated from a switch to renewable natural gas in the refining sector.

This scenario assumes higher blends of both ethanol and biodiesel than the *Steady Progress* scenario, with an average ethanol blend of E15 and average biodiesel blend of B10 from 2025 onward. Credit generation from first generation ethanol is further increased by importing a larger amount of low-CI sugarcane ethanol, for instance from Brazil, and by reducing the carbon intensity of corn ethanol through either CCS or use of biogas for process energy. It also assumes that natural gas vehicle sales increase modestly so that renewable natural gas meets one per cent of heavy duty fuel demand by 2030, with the benefit of this maximized by the use of captured dairy gas under a book and claim reporting system. In 2028, a 13.1% carbon saving is delivered by this scenario.

The *Accelerated Progress* scenario comfortably exceeds both illustrative compliance trajectories in all years, with a 2028 credit bank of 13 million metric tons CO_2e against the linear trajectory. Achieving these rates of fuel deployment would likely require the adoption of more stringent targets to support credit prices. Achieving the fuel supply in this scenario would also be dependent on complementary measures to boost fuel blending and increase the availability of natural gas refueling infrastructure.

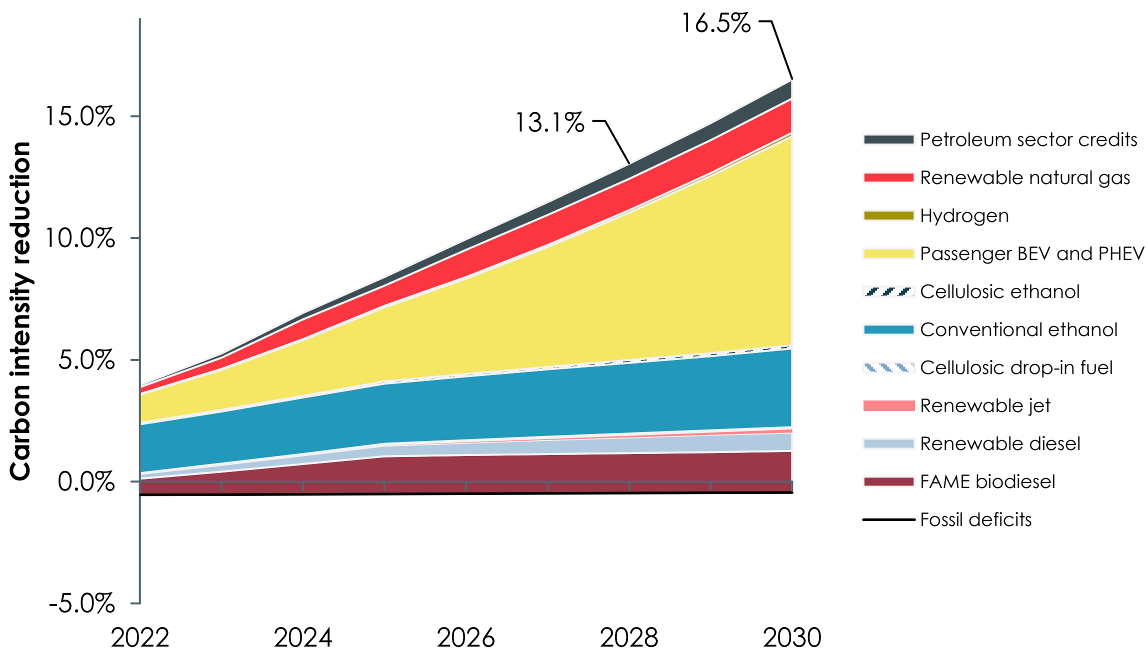

Figure 6. Carbon savings against baseline delivered in *Accelerated Progress* scenario

Table 5 provides additional detail of the vehicle pool, fuel supply and credit generation under the *Steady Progress* scenario, assuming the illustrative linear compliance trajectory.

Table 4. Additional results from *Accelerated Progress* scenario

	2022	2025	2028	2030
No. ZEVS (thousand)	91	219	430	612
BEVs	*42*	*116*	*240*	*347*
PHEVs	*47*	*98*	*181*	*253*
FCVs	*2*	*5*	*9*	*12*
Credit generation by light duty ZEVs (million tCO_2e)	0.51	1.26	2.37	3.38
% NG for HDVs	0.7%	0.8%	0.9%	1.0%
Credit generation by renewable natural gas (million tCO_2e)	0.1	0.4	0.5	0.6
Credit generation by first generation ethanol (million tCO_2e)	0.8	1.0	1.0	1.1
Credit generation by HVO and biodiesel (million tCO_2e)	0.4	0.8	0.9	1.0
Credit generation by cellulosic biofuels (million tCO_2e)	0.04	0.05	0.06	0.07
Annual credit generation (million tCO_2e)	2.0	3.6	5.2	6.6
Banked credits at year end (million tCO_2e)	1.1	4.6	8.4	13.3
% CI reduction	**4.0%**	**8.4%**	**13.1%**	**16.5%**

5.3. *High EV* scenario

In the *Steady Progress* scenario we assume that the rate of EV sales in Washington lags expected California sales by two years – for the *High EV* scenario it is instead assumed that by 2030 Washington sales reach the same level as a fraction of total light duty sales as California sales. This more rapid increase in EV sales would put an additional 120,000 electric vehicles on the road by 2030, and deliver proportionately higher carbon savings (Figure 7). As for the other scenarios, credit generation exceeds the compliance requirement under both illustrative compliance trajectories in all years.

The *High EV* scenario highlights that credit generation under a Washington CFP will be quite sensitive to rates of EV deployment. Rapid increase in ZEV market share could drive the accumulation of large credit banks, whereas delayed deployment of ZEVs could result in a tighter credit market than anticipated. It might therefore be appropriate in designing a CFP for Washington to allow for some administrative flexibility to adjust annual compliance requirements to reflect realized rates of electric vehicle sales.

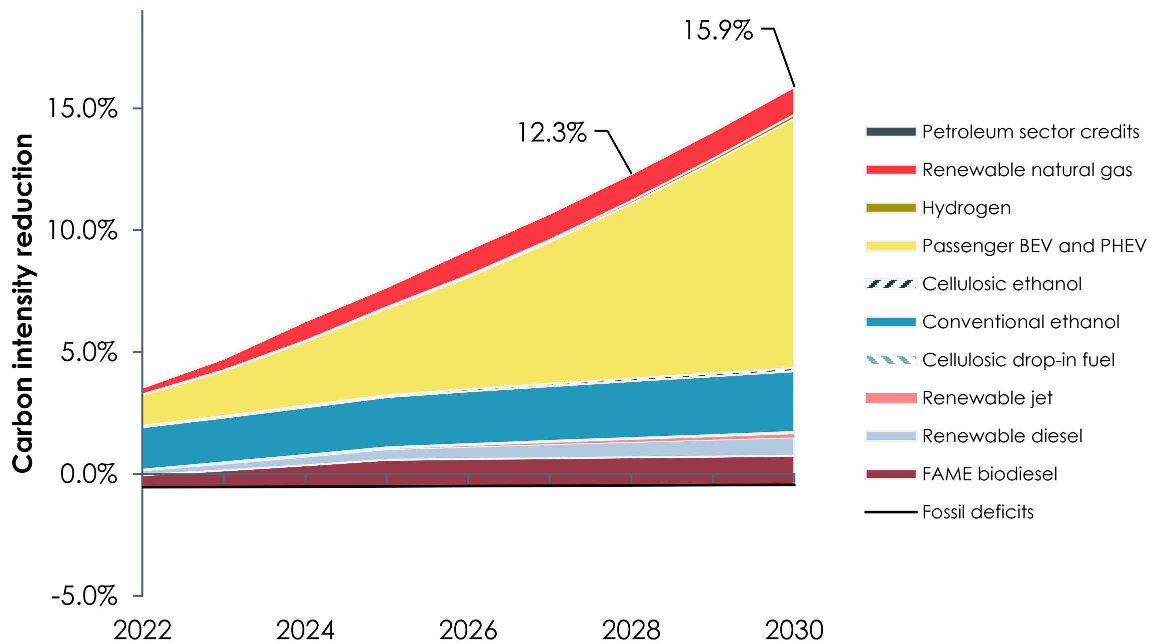

Figure 7. Carbon savings against baseline delivered in *High EV* scenario

Table 6 provides additional detail of the vehicle pool, fuel supply and credit generation under the *Steady Progress* scenario, assuming the illustrative linear compliance trajectory.

Table 5. Additional results from *High EV* scenario

	2022	2025	2028	2030
No. ZEVS (thousand)	98	253	510	732
BEVs	*46*	*136*	*286*	*417*
PHEVs	*49*	*111*	*213*	*301*
FCVs	*3*	*5*	*10*	*14*
Credit generation by light duty ZEVs (million tCO_2e)	0.56	1.47	2.83	4.07
% NG for HDVs	0.7%	0.7%	0.8%	0.8%
Credit generation by renewable natural gas (million tCO_2e)	0.1	0.3	0.5	0.5
Credit generation by first generation ethanol (million tCO_2e)	0.7	0.8	0.8	0.9
Credit generation by HVO and biodiesel (million tCO_2e)	0.3	0.6	0.7	0.8
Credit generation by cellulosic biofuels (million tCO_2e)	0.04	0.05	0.06	0.07
Annual credit generation (million tCO_2e)	1.8	3.3	4.9	6.4
Banked credits at year end (million tCO_2e)	0.9	3.5	6.4	10.8
% CI reduction	**3.6%**	**7.7%**	**12.3%**	**15.9%**

5.4. *Delayed EV* scenario

In contrast to the *High EV* scenario, the *Delayed EV* scenario presents a case where rather than catching up with expected California sales fractions for ZEVs, Washington State is lagging five years behind by 2030. Figure 8 shows that there is a significant reduction in carbon savings compared to *Steady Progress* due to the reduced ZEV fleet. In 2028, the carbon intensity reduction delivered is only 9%. This is short of the 2028 compliance schedule (Figure 9), but because of credit banking in the early years of the program compliance would still be achieved in each year modeled, with a remaining 0.6 million metric tons of CO_2e reductions in the credit bank at the end of 2028.

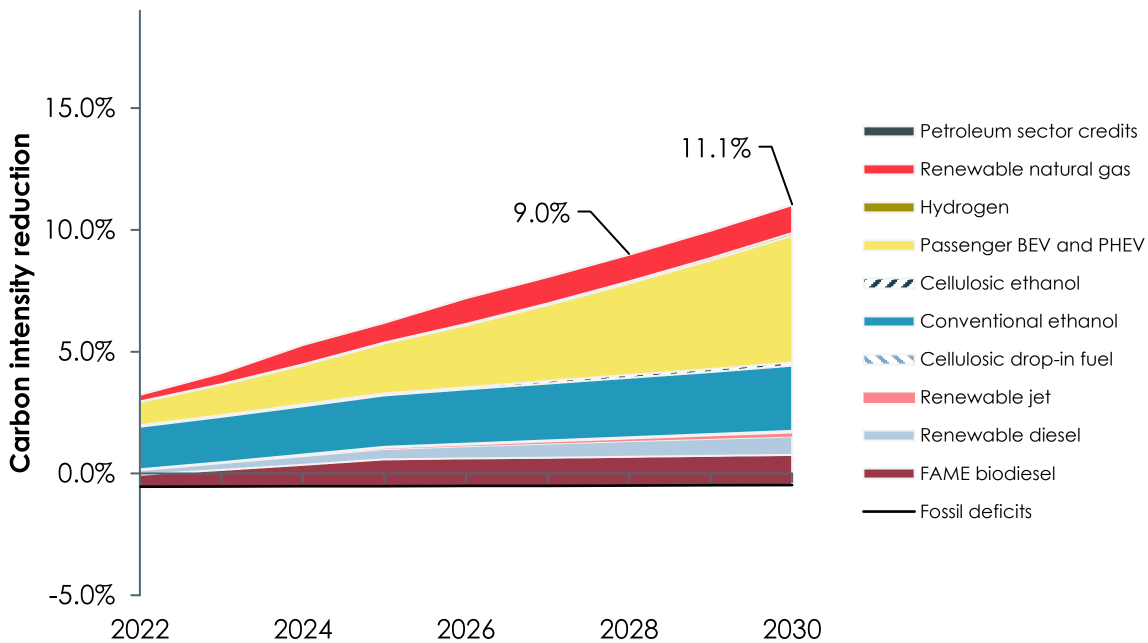

Figure 8. Carbon savings against baseline delivered in *Delayed EV* scenario

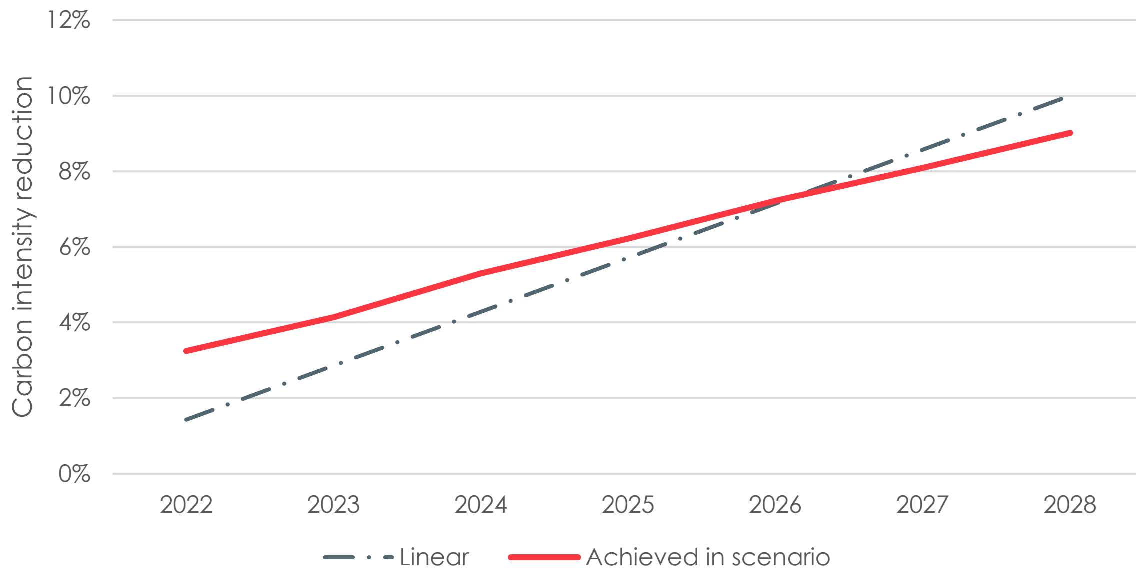

Figure 9. Comparison of savings delivered under *Delayed EV* **against illustrative compliance trajectory**

Table 7 provides additional detail of the vehicle pool, fuel supply and credit generation under the *Delayed EV* scenario, assuming the illustrative linear compliance trajectory. There are two hundred thousand fewer ZEVs than in the *Steady Progress* scenario, and consequently in 2028 0.9 million fewer metric tons of CO_2e reductions delivered from the supply of energy to ZEVs. Nevertheless, by 2030 an 11% carbon saving is achieved.

Table 6. Additional results from *Low EV* scenario

	2022	2025	2028	2030
No. ZEVS (thousand)	78	154	274	376
BEVs	*34*	*77*	*146*	*204*
PHEVs	*42*	*73*	*122*	*163*
FCVs	*2*	*4*	*6*	*8*
Credit generation by light duty ZEVs (million tCO_2e)	0.42	0.85	1.47	2.03
% NG for HDVs	0.7%	0.7%	0.8%	0.8%
Credit generation by renewable natural gas (million tCO_2e)	0.1	0.3	0.5	0.5
Credit generation by first generation ethanol (million tCO_2e)	0.7	0.8	0.8	0.9
Credit generation by HVO and biodiesel (million tCO_2e)	0.3	0.6	0.7	0.8
Credit generation by cellulosic biofuels (million tCO_2e)	0.04	0.05	0.06	0.07
Annual credit generation (million tCO_2e)	1.7	2.7	3.6	4.3
Banked credits at year end (million tCO_2e)	0.8	2.0	1.4	1.8
% CI reduction	**3.2%**	**6.2%**	**9.0%**	**11.1%**

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