British Columbia Low Carbon Fuels Compliance Pathway Assessment

No single fuel is expected to provide a complete solution to achieve compliance. In order to provide incentives to change and to include new alternative fuels such as natural gas, hydrogen and electricity, no single petroleum supplier is expected to achieve compliance independently without the purchase of credits. Compliance pathways apply province-wide as well as across the full spectrum of transportation energy.

This document is intended to provide a basis for discussion with fuel suppliers regarding actions to achieve compliance with the Renewable and Low Carbon Fuel Requirements Regulation. This document is explicitly not intended to be, nor should it be relied upon as, advice with respect to compliance with the *Greenhouse Gas Reduction (Renewable and Low Carbon Fuel Requirements) Act* or the regulations enacted under that Act. Part 3 fuel suppliers are advised to seek their own advice in this regard.

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2. Introduction

The purpose of this document is to maintain a common baseline of information to support technical consultations regarding the actions fuel suppliers can take to achieve and maintain compliance with British Columbia's Low Carbon Fuel Standard (BC-LCFS). This document reflects ongoing discussions with fuel suppliers and other stakeholders regarding these actions and provides a summary of the B.C. Ministry of Energy, Mines and Petroleum Resources' (the Ministry) understanding of the issues raised by both petroleum and renewable fuel suppliers. It is an updated version of the document prepared for the 2014 consultations, and is intended to provide the starting point for the consultations taking place in 2017.

The Ministry has committed to a three-year consultation cycle to ensure that the BC-LCFS continues to be informed by the best available science. Following consultations in 2014 to understand the issues facing fuel suppliers and the feasibility of the 2020 reduction target of 10 percent, a report was prepared and presented to the Minister, who confirmed Government's intent to continue the implementation of the BC-LCFS as planned. Section 1.1, below, provides a summary of the report presented to the Minister in 2014.

Framing any discussions regarding the potential for various fuels are a number of common issues that have become apparent. Following the summary of the 2014 consultation findings, the remainder of this section discusses those common issues.

In later sections, individual fuels are discussed with the intent to highlight the current status of issues and opportunities, and to provide the Ministry's assessment of the potential of each fuel to provide compliance credits.

2.1. 2014 Consultation Summary

The findings of the 2014 consultation process were that overall compliance with the BC-LCFS until 2020 would be possible but challenging. In describing their concerns, the petroleum fuel suppliers had ignored the role of credits banked from over-compliance in the early years of the Regulation, credits created by suppliers of low carbon fuels, and credits created through Part 3 Agreements. There were plausible scenarios that showed that sufficient credits could be created to enable the transportation energy sector as a whole to comply until at least 2020. However, given the slow rate of preparation towards meeting the carbon intensity requirements, it was apparent that petroleum suppliers were in a situation where compliance would be harder to achieve than if they had begun their efforts when the Regulation came into effect in 2010.

The BC-LCFS was developed to provide a market-based mechanism that provides fuel suppliers with a wide range of options for generating compliance credits. It was apparent that suppliers were foregoing opportunities because of the uncertainty regarding the cost of alternative compliance mechanisms as well as the possibility that Government might delay the requirements and significantly reduce the value of their actions and the resulting credits.

Given the diverse and sometimes complex opportunities to generate credits, there are many pathways to success. No single pathway is guaranteed to succeed, but relaxing the requirements significantly will cause further inaction by suppliers, which may result in failure for pathways that could achieve significant incremental reductions in greenhouse gas emissions.

The report's recommendations included:

- staying the course;
- reviewing the carbon intensity reduction targets every three years, with the next review in 2017, in order to assess the achievability of the target levels, using principles developed during this review; and
- facilitating the establishment of a functioning credit market as soon as possible.

On May 19, 2015, the Minister of Energy and Mines sent an open letter to stakeholders, stating:

> *Government believes that there are paths to compliance with the Renewable and Low Carbon Fuel Requirements Regulation (Regulation) and; therefore, British Columbia's carbon intensity targets will remain unchanged at this time. Achieving a carbon intensity reduction of 10 percent by 2020 requires early and substantive action by all transportation fuel suppliers, including the petroleum industry, renewable and alternative fuel producers, and suppliers of natural gas, hydrogen and electricity. Where fuel suppliers are unable to achieve carbon intensity reduction targets through individual initiatives, they will be expected to acquire the necessary compliance credits from the market. The availability of compliance credits is expected to be sufficient until after 2020.*
>
> *One of the means to achieve compliance will include supplying increasing volumes of low carbon, renewable content in the gasoline and diesel pools. The Ministry believes that this is achievable through the use of emerging fuels; for example, gasoline made from natural gas, lower carbon diesel produced through advanced bitumen refining, and renewable diesel made from vegetable oils or tallow. As well, the stakeholder consultations established that a significant portion of the fleet is compatible with higher-level blends of renewable fuels such as E85 FlexFuel (85 percent ethanol, 15 percent gasoline) and B20 (20 percent biodiesel, 80 percent diesel), and that this presents opportunities for fuel suppliers that have not been explored.*
>
> *A fundamental component for success of the Regulation is a functioning market for the exchange of compliance credits. This market is essential for enabling fuel suppliers to comply by acquiring credits when necessary. During consultations, stakeholders made it clear that the price of these credits will send an important signal to all suppliers and producers and, accordingly, is a critical performance indicator regarding the results achieved by the Regulation. The Ministry believes that it is essential for the market for credit exchange to function before any further reassessment of compliance opportunities is warranted. Consequently, Ministry staff will be working with fuel suppliers in the coming months to establish transaction protocols that enable credit trading.*
>
> *In order to ensure that the Regulation remains flexible, responsive, and based on the best available science, the Ministry will conduct another review of the Regulation every three years, with the next review to be conducted in 2017. By 2017, a market price for credits will have been established and can be used as an indicator for assessing future carbon intensity reduction targets within the Regulation. There may need to be adjustments to*

> *the short-term targets at that time, but the Ministry will also be considering long-term policy recommendations for Government that align with low carbon fuels policy in other jurisdictions of the Pacific Coast Collaborative and elsewhere.*

Further, in June 2016, the Minister sent open letters to the Canadian Fuels Association, the Canadian Renewable Fuels Association, the Advanced Biofuels Canada Association, and the Canadian Independent Petroleum Marketers Association, establishing the expectations of the Province with regard to the transportation industry meeting their low carbon fuels obligations.

These letters stated that in the Ministry's consultation with the fuel industry in 2014, Ministry staff was made aware of a number of jurisdictions in the United States where fuel suppliers have successfully responded to local and national fuel requirements in a diversity of ways:

- Biodiesel has been successfully supplied at annual average concentrations well above 5 percent year-round in climate conditions that match northern British Columbia through the implementation of strict quality control and the use of commercially available additives;
- Biodiesel at a minimum 2 percent concentration has been shown to be feasible under all conditions, even without additives;
- E85 (FlexFuel) has been supplied in significant quantities when the fuel has been priced attractively;
- Infrastructure development has included rack blending and blender pumps to supply a diversity of products in both the diesel and gasoline pools; and
- Hydrogenation-Derived Renewable Diesel and other forms of renewable diesel are drop-in replacements for petroleum-based diesel and are available in significant quantities in the North American market.

These examples convinced the Ministry that the petroleum industry had not yet taken advantage of significant opportunities to generate compliance credits under the Regulation. Many of these actions were implemented by independent marketers and combined with actions to increase the adoption of other low carbon fuels, such as natural gas, hydrogen, and electricity, these actions can generate sufficient credits to enable the petroleum fuel industry to comply with a 10 percent reduction in carbon intensity by 2020, and possibly even the 20 percent by 2030 target that was recommended by the Climate Leadership Team.

The Canadian Fuels Association has asserted that petroleum fuel suppliers will likely be unable to remain in compliance by 2018. The Ministry's view is that this assertion applies only within the pool of petroleum-based fuels managed by petroleum suppliers and under self-imposed constraints. If petroleum fuel suppliers continue to insist on those constraints, they will indeed need to acquire significant quantities of compliance credits from other sources.

Many independent marketers who operate in British Columbia are either not subject to the Regulation or legitimately choose to claim exemption from the Part 3 low carbon fuel requirements. However, by not participating in the Regulation, they forego the opportunity to accrue compliance credits for profit by increasing the supply of low carbon content in gasoline and diesel fuel blends. This is unfortunate, as the experience in California is that low carbon fuel credits build market value over time, and independent fuel suppliers who recognized this opportunity early are now able to leverage the compliance credit market to transform and grow their businesses.

While some suppliers are directly impacted because they supply fuels with carbon intensities above the target levels, the Regulation applies to all suppliers, including renewable fuel producers and importers. The Regulation implements a form of carbon pricing and will not achieve its goals unless all opportunities to generate credits are used. If some suppliers are unwilling to take action, others must do so.

Any Part 3 fuel supplier can generate credits by supplying low carbon fuel or entering into Part 3 agreements, and many renewable fuel producers and marketers are Part 3 fuel suppliers or could become suppliers. The Ministry believes that this creates an opportunity for low carbon fuel producers and importers to work with independent marketers to provide resources and expertise to diversify the products offered and to demonstrate the feasibility of solutions that are currently being overlooked. Where those efforts increase the quantity of Part 3 fuel supplied, independent marketers may qualify for additional credits under a Part 3 agreement. The Ministry believes that the price of compliance credits provides a clear incentive for everyone to increase their efforts to generate credits for sale to those who will need them.

2.2. Warranty statements

A common concern about the transition to gasoline and diesel with higher biofuel content is the performance of these fuels in vehicle engines and fuel systems. This concern is commonly articulated as a statement that the use of higher biofuel blends will void a given vehicle's engine warranty.

It is important to understand that Original Equipment Manufacturers (OEMs) do not warranty fuels; they warranty the equipment they manufacture. This confusion regarding the role of warranties in determining what fuels should not be used results in precautionary behaviour by suppliers and some customers.

OEMs provide warranties that identify fuels that have been tested to be compatible with their engines. Typically OEMs and Tier 1 suppliers have a set of test fuels that are intended to cover a wide range of expected fuel qualities. The choice and formulations of the test fuels are based upon experience and a desire to ensure compatibility with the range of fuels that a vehicle might use. In some cases, OEMs will include warnings about certain fuels that are known to cause issues. Other fuels may not have been tested, and the effects of those fuels on the engines are not known.

Usually, a fuel that is not mentioned simply has not been tested, or is obviously incompatible (e.g. gasoline engines are incompatible with diesel fuel, but the warranty does not always state this, as it is assumed that the consumer is aware of this fact). Warranties are not statements regarding when engines are expected to experience problems.

OEMs do not warranty fuel – any fuel. They warrant only the materials and workmanship of their product and, in the United States, are precluded by the *Magnuson-Moss Warranty Act* from voiding manufacturer warranties on the basis of fuels used [1]. OEM statements about the use of biodiesel in their equipment are recommendations. Use of biodiesel at any concentration in and of itself does not void an OEM warranty; in reality, OEMs do not cover any proven, fuel-related issues in their warranty, no matter what fuel.

Regulatory agencies typically require on-spec fuel that has been shown to meet the necessary performance objectives for today's engines (e.g. ASTM or CGSB specifications). When there are issues for a vehicle that can be traced to an off-spec fuel, those issues would not be covered by the engine manufacturer regardless of the fuel. All manufacturers adhere to the principle that warranties will not be voided simply for the use of biofuel outside of the recommended concentrations, but that there must be proof that the fuel caused the problem.

OEMs do not perform testing on legacy models, so many older vehicles in use today do not have manufacturer's statements on biodiesel use due to the relatively recent adoption of biodiesel fuels and renewable fuels standards.

Customers should always understand the requirements of their equipment. The Regulation ensures that they will have new choices in meeting their needs for suitable fuels.

2.1. Misfueling

One strategy for increasing the supply of low carbon fuels is for fuel suppliers to sell higher biofuel blends such as B20 and E85. In response to this idea, some fuel suppliers have stated that misfueling is a significant risk that they are unwilling to manage.

Of the multiple combinations of potential engine/fuel mismatches, the most significant one is the potential for putting gasoline in a diesel vehicle, and vice-versa. It is difficult to understand a reluctance to deal with misfueling risk for B20 and E85, considering the routine acceptance of this risk at every outlet that sells gasoline and diesel, often from adjacent nozzles. This is a current risk that is satisfactorily managed at virtually all fuel retail outlets in B.C. today.

In contrast with the consequences for misfueling between gasoline and diesel, the consequences for misfueling between different blend concentrations within the options based on a similar fuel (gasoline or diesel) are significantly lower, because the vehicle will not be damaged by occasional misfueling with higher-level blends. Operability or performance problems will signal the error, which can be corrected in most cases by returning to the recommended fuel for the vehicle.

CAN/CGSB-3.512 *Automotive ethanol fuel (E50-E85)* applies to automotive fuel composed of 50-85% by volume denatured fuel ethanol, for use in flex-fuel vehicles over a wide range of climatic conditions, and includes the statement that "[f]uel produced to this standard is <u>not for use</u> in conventional vehicles…" and is intended "strictly for use in flexible fuel vehicles." The Ministry does not agree that this prevents fuel suppliers from offering E85 at retail outlets; it is a warning that the fuel does not have universal applicability and implies the need for labelling and consumer education.

Misfueling mitigation has been extensively addressed in the US market, and the US Department of Energy states that, "a single misfueling event will not permanently damage a non-E85 vehicle" [2].

Petroleum suppliers argue that B5 is the maximum biodiesel concentration that can be supplied at retail outlets because retail customers are not sufficiently informed regarding mid-level blends of biodiesel. There has been no demonstrated harm to legacy model vehicles from widespread biodiesel adoption in North America.

CAN/CGSB-3.522 *Diesel Fuel Containing Biodiesel (B6-B20)* includes the statement that "The blends of biodiesel covered by this standard are more appropriate for fleets and users who understand and can manage the potential risks." The Ministry's position is that users should understand and manage the potential risks of any fuel, and that retail consumers can be provided with enough information through labelling and the posting of product information.

For all of these blends, misfueling risks can be adequately managed through misfueling mitigation strategies that include customer education by both fuel suppliers and OEMs, and clear fuel labelling.

2.2. Fuel delivery infrastructure

The petroleum industry has over a century of experience delivering transportation fuels safely and reliably. The delivery network has developed over time to become able to withstand the effects of a wide diversity of circumstances and operator competencies. Introducing a diversity of renewable fuels, each with its own unique issues, is testing the ability of the delivery network to learn and adapt while avoiding any incident that damages the reputation for delivering reliable high-quality fuels safely.

Change is possible and it is happening, but it takes time as well as strong drivers such as the low carbon fuel requirements.

2.3. Blend Walls

"Blend wall" is a term coined to describe a combination of circumstances that limit the amount of a particular biofuel blend fuel that can be sold. These circumstances may include:

- technical limitations
- climate conditions
- lack of infrastructure
- lack of market demand
- OEM support

Fuel suppliers also use the term "blend wall" to refer to the upper limit of renewable fuel specified in a vehicle warranty statement.

Unfortunately, the concept of a "blend wall" implies that there are limits to any opportunities without considering whether these limits can be overcome. In fact, a blend wall only applies for specific combinations of vehicles and fuels. For example, an E10 blend wall exists only for vehicles designed to use no more than 10% ethanol. For FlexFuel vehicles, the 10% blend wall does not exist. Also, the United States Environmental Protection Agency (U.S. EPA) has registered E15 as a fuel for use in light-duty vehicles with a model year of 2001 or newer [3], and the majority of auto manufacturers in the U.S., comprising 81% of the new vehicle market, have now approved the use of E15 in their warranty statements [4].

For renewable gasoline and diesel, where the product fully meets current petroleum fuel specifications, no blend wall exists.

There are significant opportunities for bypassing the E10 and B5 “blend walls” by making higher blend levels available for suitable vehicles. It appears that petroleum suppliers are extremely reluctant to market these fuels, and the renewable fuel industry does not supply fuel at retail outlets in British Columbia.

2.4. Pricing fuel

Some Canadian provinces have chosen to regulate the pricing of transportation fuels within their jurisdictions. British Columbia has chosen not to regulate the price of fuel, and this paper will not discuss the behaviour of fuel suppliers in setting prices, nor will it discuss cost factors such as:

- fuel transportation costs
- infrastructure costs
- fuel component pricing
- production costs

This is not to say that the Ministry considers these factors to be unimportant. Rather, the Ministry views these factors to be the purview of suppliers, and the market will determine appropriate pricing in the context of the BC-LCFS. However, the BC-LCFS is fundamentally an economic instrument that is intended to influence fuel supplier and consumer behaviour through pricing. In order for a fuel such as E85 or B20 to gain a share of the market there must be a tangible perceived benefit to the user, such as reduced cost or increased performance. This section sets out some facts related to pricing that the Ministry feels are relevant to the BC-LCFS.

In order to influence consumers to choose low carbon fuels instead of high carbon alternatives, fuel suppliers need to set prices appropriately. The BC-LCFS is structured to create a cross-subsidy, where low carbon fuels are discounted at a cost to high carbon fuels. In order to develop sufficient demand to generate the necessary compliance, suppliers will need to price their products to ensure that low carbon fuels are sold in sufficient quantities to generate the credits needed to balance the debits generated by the sale of high carbon fuels.

There have been discussions indicating that some suppliers feel that blends such as B20 should be priced according to the cost of the components, including any cost premium for the 20% biodiesel. However, in the case of HDRD, which is more expensive than both diesel and biodiesel, suppliers have indicated that at various times in the year there may be as much as 20% HDRD in some customer’s fuel. Yet, there is no indication that the customer has been required to pay for the more expensive content.

Given that fuel suppliers incur debits for the petroleum diesel they sell anywhere in the province, it seems counter-intuitive to charge the premium to the customer who is facilitating a solution. It is also counter-intuitive that the value of avoiding the need to purchase compliance credits at market price is not being factored into the fuel price.

In Minnesota, when E85 was priced an average of 18% below regular unleaded gasoline in 2013, the demand increased significantly. A recent series of detailed economic analyses conducted by the Center for Agricultural and Rural Development (CARD) and Iowa State University found that demand for E85—and, in turn, investment in E85 infrastructure—expands dramatically when the fuel is priced attractively at retail, indicating that pricing is the dominant consideration when consumers are buying fuel [5]. Data from the Minnesota Department of Commerce show that consumption of E85 is highly responsive to price, and that demand increases significantly as the discount to regular unleaded gasoline widens [6],[7].

In the U.S., RFS compliance credits values are applied in such a way as to improve the blending economics so that independent retailers are motivated to invest in blending at wholesale and retail levels. BC-LCFS credits are expected to play an analogous role in motivating the market to adjust pricing so as to motivate the purchase of low carbon fuels.

Credit trading under the Regulation began on November 5, 2015. As of September 30, 2017, there have been 36 credit transfers totalling 389,500 credits at an average price of $168.36 per credit. In the first three quarters of 2017, there have been 19 credit transfers totalling 176,441 credits at an average price of $165.33 per credit, with a minimum price of $60 per credit and a maximum of $185 per credit.

To date, it is not clear whether suppliers have considered the benefits of fuels that generate compliance when setting prices for these fuels. To illustrate the value of a BC-LCFS credit, Table 1 provides some estimates of the compliance value of a quantity of fuel if the resulting credit is considered to have a market value of $150.

Table 1: Credit Values

Fuel	Carbon Intensity (g CO_2e/MJ)	Quantity	Units	Price	Credit value
Gasoline	88.14	1	Litre	$1.20	-$0.05*
Ethanol	40.00	1	Litre	$1.20	$0.14
Ethanol	25.00	1	Litre	$1.20	$0.19
Ethanol	10.00	1	Litre	$1.20	$0.25
Electricity (Gasoline class)	20.04	1	kWh	$0.11	$0.13
Hydrogen	33.00	1	kg	-	$3.50
Diesel	94.76	1	Litre	$1.10	-$0.05*
Biodiesel	15.00	1	Litre	$1.10	$0.37
HDRD	15.00	1	Litre	$1.10	$0.38
CNG (diesel class)	63.64	1	GJ	$3.70	$1.97
CNG (diesel class)	8.00	1	GJ	$14.50	$10.32

*A negative credit value indicates that a debit is generated. The value indicates the cost of credits needed to offset the debit.

2.5. Market control

One concern that the RFA has identified in the past is that in the U.S., independent retailers can be prevented from offering mid- and high-level biofuel blends by contracts with their fuel suppliers [9]. The reported result is that these branded stations are roughly four to six times less likely to offer E85 and 40 times less likely to offer E15 than stations not affiliated with a major refiner brand. Concerns have been expressed that this may be happening in B.C, but the extent to which retailers in B.C. are constrained from offering blends beyond the current offerings is unknown.

Kent Group Ltd has reported [8] that, as of December 31, 2015, 11,916 retail gasoline stations in Canada, and that there were 71 companies involved in marketing fuels (owning more than two stations). In B.C., there were 1,368 retail gasoline stations and 22 companies involved in marketing fuels. At individual stations, either the marketer sets the price of fuel (a controlled site) or the site operator sets the price of fuel (an uncontrolled site). In B.C. in 2015, 54% of retail fuelling stations were controlled and 46% were uncontrolled. Table 2 illustrates the B.C. and Canadian situation in 2015.

Table 2: Who determines pricing (2015)?

British Columbia		Controlled (Price set by Marketer)	Uncontrolled (Price set by Retailer)
		(54%)	(46%)
Integrated Refiner-Marketer	(52%)	503 (37%)	202 (15%)
Non-Refiner-Marketer	(48%)	233 (17%)	430 (31%)

Canada		Controlled (Price set by Marketer)	Uncontrolled (Price set by Retailer)
		(51%)	(49%)
Integrated Refiner-Marketer	(32%)	2212 (19%)	1615 (14%)
Non-Refiner-Marketer	(68%)	3827 (32%)	4262 (36%)

With the acquisition of Chevron Canada R&M ULC by Parkland Industries Ltd., the B.C. market shifts significantly towards fuel being supplied by integrated refiner marketers. The Ministry anticipates that relationships between Parkland and its customers would not shift significantly, so the entity setting fuel prices at retail outlets is not expected to change. The resulting market composition (based on 2015 data) is illustrated in Table 3.

Table 3: Who determines pricing in B.C. (2017)?

British Columbia		Controlled (Price set by Marketer)	Uncontrolled (Price set by Retailer)
		54%	46%
Integrated Refiner-Marketer	61%	549 (40%)	284 (21%)
Non-Refiner-Marketer	39%	187 (14%)	348 (25%)

2.6. Concerns regarding availability of fuel

Concerns have been expressed regarding the availability of sufficient fuels to meet the combined mandates of jurisdictions implementing low carbon fuel requirements. In addition, questions have been raised about whether the carbon intensity of available ethanol will be low enough to substantially contribute to the GHG reduction requirements under the Act.

While these may be current concerns, the market is expected to respond to the increased demand for low carbon fuels by increasing production and by reducing the carbon intensity of the fuels being produced. It is important that carbon intensity is included as a factor that is considered by the market when it determines how to meet any increased demand.

The RFA estimated that in 2014, approximately 159 ethanol plants in Canada and the U.S. (representing 39.9 billion litres of capacity) *had not* applied for unique carbon intensity under the BC-LCFS, California LCFS, or U.S. RFS. As well, they argued that there are dormant facilities that could be reactivated to produce another 13 billion litres. As the value of carbon credits under these programs increase in value it is likely that additional facilities will register their carbon intensity.

The U.S. production capacity of biodiesel in 2017 is 8,700 million litres/year [10]. The Canadian production capacity of biodiesel in 2017 was forecast to be 600 million litres/year from 10 facilities [11]. Thus, in 2013 the North American production capacity of biodiesel was 9,300 million litres/year. As of September 2017, 2,508 million litres of biodiesel, or less than one quarter of that production capacity is registered in B.C. In addition, 2,055 million litres/year of HDRD was registered in B.C.

The January 2015 report "Potential Low-Carbon Fuel Supply to the Pacific Coast Region of North America" [12] argues that there will be enough low carbon fuel to fulfil demand even with Washington and Oregon implementing their low carbon fuel measures. This study found that although various fuel pathways each have unique deployment constraints that affect certain aspects of near-term fuel deployment, all (eight) scenarios analyzed deliver 14-21% carbon intensity reduction by 2030, from 2010 levels. For context, the scenarios are compared against an estimated Pacific Coast region-wide composite policy target for all jurisdictions included in the study (B.C., California, Washington, and Oregon). Since the results are region-wide, greater or lesser emission reduction would be possible in any of the four jurisdictions depending on the varying mix of policy, market, and fiscal incentives within each area.

3. Compliance scenario

Transportation energy use in B.C. was modelled in 2015 by B.C.'s Climate Action Secretariat to produce the forecast curves used for 2016 to 2030 as illustrated in Figure 1. Light duty vehicle energy is expected to decline from 2025 to 2030, largely due to increasing fuel economy associated with Canada's Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations. For heavy duty vehicles, the gradual increase in energy use is driven by expected growth in goods-producing industries. Heavy-duty energy use is expected to increase at a slower rate than it did from 1990 to 2013 as a result of expected fuel economy gains from Canada's Heavy Duty Vehicle and Engine Greenhouse Gas Emission Regulations [13].

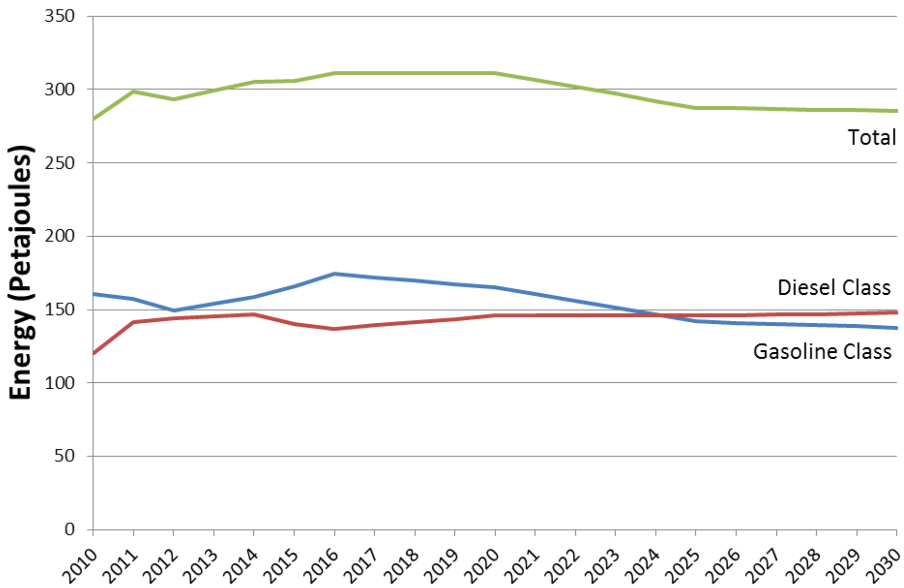

Figure 1: Transportation Energy Use Forecasts

Figure 2 illustrates a compliance scenario based on a simple spreadsheet model. Credits from electricity, hydrogen and natural gas are determined from forecasts of vehicle populations and typical energy use per vehicle. Credits from liquid biofuels are based on fuel quantities and simple assumptions that quantities will increase while carbon intensity will decrease. The model then adjusts the quantities of gasoline and diesel fuel to match the forecast total energy use. Note that the 10% reduction is achieved without the use of banked credits or Part 3 Agreements beginning in 2023-2024.

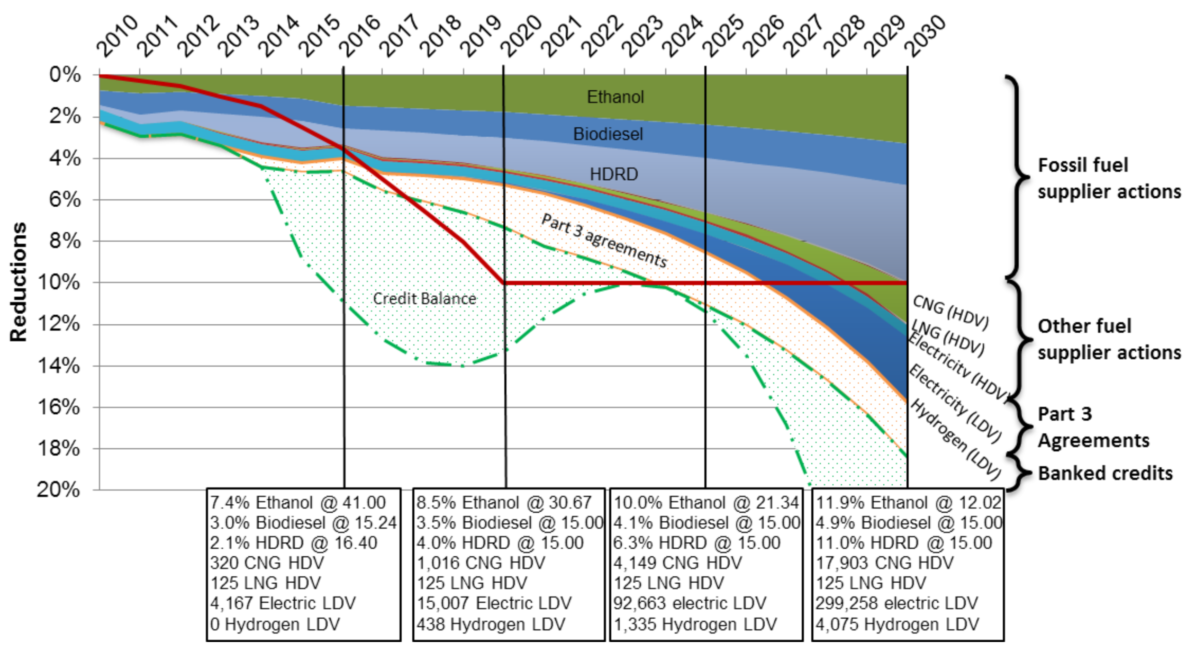

Figure 2: Compliance Scenario

The scenario illustrates minimum efforts required to achieve compliance. There are clear challenges for all industry participants, and these will be discussed in the individual fuel discussions that follow. The scenario assumes the following:

- Only the volume and carbon intensity were varied for liquid fuels after 2016.
- For the gasoline blends from 2017 to 2030,
  - the quantity of fossil gasoline decreases 28%,
  - the average carbon intensity of ethanol decreases 61%, and
  - the quantity of ethanol increases 19%.
- For the diesel fuel blends from 2017 to 2030,
  - the quantity of fossil diesel fuel decreases 16%,
  - the quantity of biodiesel increases 46%,
  - the average carbon intensity of biodiesel and HDRD drops to 15.00 g CO_2e/MJ in 2016 and remains at that level, and
  - the quantity of HDRD doubles.
- Gasoline class use of electricity increases as the light-duty electric vehicle population increases, while diesel class use of electricity remains at the 2015 level.
- Propane and CNG use in the gasoline pool are a constant fraction of the total energy use in the gasoline pool.
- CNG in the diesel pool is forecast to grow at a rate predicted by FortisBC.
- LNG vehicles in the diesel pool are set to 125 to reflect the number of vehicles currently in service and the lack of any OEM option for new Class 8 truck engines.
- Hydrogen in the gasoline pool increases as hydrogen vehicle population increases.

Table 4 provides specific data for the compliance scenario illustrated in Figure 2. Data for 2010 to 2016 reflect actual compliance data, while data for 2020, 2025 and 2030 are based on the assumptions described above.

Table 4: Compliance Scenario Data

Fuel		Units	Actual							Scenario		
			2010	2011	2012	2013	2014	2015	2016	2020	2025	2030
Gasoline	Quantity (millions)	Litres	4,459	4,311	4,079	4,200	4,320	4,501	4,718	4,426	3,689	3,358
	Avg. Carbon Intensity	g CO_2e/MJ	87.30	87.30	87.30	87.30	87.30	87.30	87.30	88.14	88.14	88.14
Ethanol	Quantity (millions)	Litres	235	263	251	275	299	343	375	409	412	455
	Avg. Carbon Intensity	g CO_2e/MJ	55.51	51.66	53.11	51.27	49.74	49.47	41.00	30.67	21.34	14.84
Hydrogen (Gasoline class)	Quantity (millions)	Kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.33	1.02
	Avg. Carbon Intensity	g CO_2e/MJ	92.06	92.06	92.06	92.06	92.06	92.06	95.64	34.00	34.00	34.00
Electricity (Gasoline class)	Quantity (millions)	KWh	0.00	0.00	0.00	0.14	0.28	0.86	1.32	35.91	221.74	716.12
	Avg. Carbon Intensity	g CO_2e/MJ	11.94	11.94	11.94	11.48	11.00	11.00	11.00	20.04	20.04	20.04
CNG (Gasoline class)	Quantity (millions)	m^3	0.25	1.19	1.42	1.35	1.28	1.45	2.03	1.92	1.65	1.60
	Avg. Carbon Intensity	g CO_2e/MJ	59.74	59.74	59.74	61.21	62.14	62.14	62.14	62.14	62.14	62.14
Propane	Quantity (millions)	Litres	1.49	76.83	70.72	66.78	62.84	70.48	70.31	66.70	57.26	55.55
	Avg. Carbon Intensity	g CO_2e/MJ	78.29	78.29	78.29	73.66	68.44	68.15	68.02	68.02	68.02	68.02
Diesel	Quantity (millions)	Litres	2,977	3,459	3,531	3,526	3,521	3,349	3,306	3,604	3,410	2,940
	Avg. Carbon Intensity	g CO_2e/MJ	93.56	93.56	93.56	93.56	93.56	93.56	93.56	94.76	94.76	94.76
Biodiesel	Quantity (millions)	Litres	61	96	89	95	101	101	105	135	157	171
	Avg. Carbon Intensity	g CO_2e/MJ	15.23	16.20	21.84	21.06	20.37	15.98	15.24	15.00	15.00	15.00
HDRD	Quantity (millions)	Litres	31	59	70	98	126	121	73	155	241	383
	Avg. Carbon Intensity	g CO_2e/MJ	48.04	40.30	45.42	32.11	24.72	16.37	16.40	15.00	15.00	15.00
Hydrogen (Diesel class)	Quantity (millions)	Kg	0.18	0.26	0.28	0.19	0.10	0.00	0.00	0.00	0.00	0.00
	Avg. Carbon Intensity	g CO_2e/MJ	92.06	92.06	92.06	92.95	95.51	95.51	95.51	34.00	34.00	34.00
Electricity (Diesel class)	Quantity (millions)	KWh	167	169	178	173	169	171	171	171	171	171
	Avg. Carbon Intensity	g CO_2e/MJ	11.68	11.68	11.68	11.68	11.68	11.68	11.68	20.04	20.04	20.04
CNG (Diesel class)	Quantity (millions)	m^3	0.00	0.11	4.40	6.17	7.94	13.57	14.88	26.56	108.44	467.93
	Avg. Carbon Intensity	g CO_2e/MJ	59.74	59.74	59.74	61.21	62.14	62.14	62.14	62.14	62.14	62.14
LNG	Quantity (millions)	Kg	0.00	0.15	2.41	4.28	6.16	8.63	9.01	21.40	21.40	21.40
	Avg. Carbon Intensity	g CO_2e/MJ	69.48	66.54	66.54	64.18	63.26	63.26	63.26	63.26	63.26	63.26

4. Hydrogen

4.1. Current Situation

From 2010 to 2013, a fleet of hydrogen fuel cell buses was operated by BC Transit in Whistler, using hydrogen trucked from Quebec. This fleet is no longer operating.

British Columbia's clean energy vehicle program, CEVforBC, provides a purchase incentive of $6,000 for a qualifying hydrogen fuel cell vehicle. The Hyundai Tucson is the only hydrogen fuel cell vehicle available in B.C., and there are currently ten of them on the road. At least four additional vehicles are expected to be operating in 2018.

Hydrogen Technology & Energy Corporation (HTEC) has entered into Part 3 Agreements for the construction and operation of six hydrogen fuelling stations, with one being located in Victoria and the rest in Metro Vancouver. These stations will be supplied from local facilities producing low carbon hydrogen from electrolysis.

4.2. Market Outlook, Challenges and Opportunities

OEMs are beginning to supply fuel cell vehicles to the retail market. While the Hyundai Tucson is available to residents of the Greater Vancouver Area, the Toyota Mirai is expected to be available by early 2018, and Honda and Mercedes are both expected to bring a hydrogen fuel cell vehicle to market in the next one to three years. The Canadian Hydrogen Infrastructure Initiative, with the support of OEMs, governments, and industry, has set a goal of 2,000 hydrogen fuel cell vehicles in Canadian markets by the end of 2020.

The increase in the availability of hydrogen fuel cell vehicles offered by auto manufacturers and the efforts by HTEC to provide refuelling infrastructure are expected to encourage both demand and supply for hydrogen fuel cell vehicles in B.C.

The hydrogen industry feels that there will be thousands of fuel cell vehicles by 2020 in North America. They have not provided estimates of vehicle adoption rates for British Columbia, but without strong incentives and increased fuelling infrastructure, the number is expected to be small. Given the early stages of market development, the OEMs do not wish to share their business plans and/or adoption forecasts. The Ministry estimates that fewer than 1,000 hydrogen fuel cell vehicles will be on the road in B.C. by 2020. Early uptake is expected to be slow due to the relative short time the vehicles have been available to the public, the higher purchase price, and the small scale of the emerging refuelling infrastructure.

4.3. Outlook for Carbon Intensity

The majority of hydrogen is currently produced by natural gas reformation, which has a default carbon intensity of 96.82 g CO_2e/MJ under the Regulation. The hydrogen used to fuel the fleet of fuel cell buses in Whistler was trucked from Quebec and had a carbon intensity of 51.99 g CO_2e/MJ. While HTEC is pursuing hydrogen a carbon intensity of about 34 g CO_2e/MJ from electrolysis, other hydrogen proponents are looking at the potential for waste capture at electrochemical production facilities. These proponents believe that such a facility would be able to produce hydrogen with a carbon intensity of approximately 11.00 g CO_2e/MJ.

4.4. Pathway Assessment

In 2014 the Canadian Hydrogen Fuel Cell Association the estimated hydrogen use would be approximately 250 Kg of hydrogen per year per vehicle.

Based on confidential estimates from a number of sources, the vehicle population estimates used for the compliance scenario are:

Year	2016	2017	2018	2019	2020	2025	2030
Number of vehicles	7	10	150	350	438	1,335	4,075

5. Propane

5.1. Current Situation

Propane is a fossil fuel with a carbon intensity between 66.36 and 75.3 g CO_2e/MJ. Total GHG reductions from propane use are minimal at this time, but could become significant if large quantities are consumed. New retrofit technologies are available that would allow a significant fraction of the current fleet of gasoline vehicles to become dual-fuel capable.

The supply of propane has been relatively constant since reporting began in 2011. In 2015, approximately 70 million litres of propane were supplied for transportation in B.C. The propane industry has indicated that they do not have plans to expand propane use in transportation.

CAN/CGSB 3.14 *Propane for Fuel Purposes* specifies an upper limit for sulphur (including odorants) of 123 mg/kg. The current limit on sulphur content for gasoline sold in Canada is 80 mg/kg maximum, with an annual pool average limit that has been 30 mg/kg since 2005, and will be 10 mg/kg beginning in 2020. The low sulphur limit in gasoline is to enable catalytic conversion of air contaminants. Levels above the design concentration will poison the catalyst and cause a dual-fuel vehicle to be out of compliance with emission standards when operating on gasoline. All vehicle conversions should be certified to conform with the applicable emissions standards.

5.2. Market Outlook, Challenges and Opportunities

Light duty gasoline engines can be converted to dual-fuel with propane using conversion kits. These kits and the cost of installation are exempt from Provincial Sales Tax [14] in order to provide an incentive to have them installed. Dedicated motor fuel taxes that support transit do not apply to the sale of propane [15].

Propane is expected to become increasingly available as the production of natural gas in B.C. increases, but it is expected that much of this increased propane volume will be exported from B.C.

5.3. Outlook for Carbon Intensity

The default carbon intensity value of propane in the Regulation is 75.35 g CO_2e/MJ because propane can either be sourced from natural gas plants or oil refineries. The default value reflects B.C. propane sourced entirely from an oil refinery. The carbon intensity of propane derived solely from natural gas production is 66.36 g CO_2e/MJ (from GHGenius version 4.03). The average blend of propane in B.C. in 2012 was a 90/10 mix of natural gas plant vs. oil refinery production [16]. The carbon intensity for propane of this average blend is 67.30 g CO_2e/MJ.

5.4. Pathway Assessment

Propane retrofit technologies are available that would allow a significant proportion of the current gasoline-fuelled fleet to become dual-fuel vehicles. Evidence shows that this can be done cost-effectively and result in significant cost savings to the vehicle owner over the life of vehicles that are on the road today.

Propane could serve as a near-term transition solution that can result in immediate reductions in carbon intensity in the current gasoline fleet, but as there are no known industry plans to increase propane use, we have assumed that propane consumption will vary by the same percentage each year as the overall gasoline pool (see section 2).

6. Natural Gas

6.1. Current Situation

FortisBC is the largest regulated natural gas provider in B.C. They have a five-year natural gas vehicle incentive program ending in 2018 that includes vehicles, fuelling stations and maintenance facilities for both compressed natural gas (CNG) and liquefied natural gas (LNG).

Cummins Westport Inc. manufacturers 6 to 12L spark ignited natural gas engines that are suitable for a wide variety of transportation applications [17]. However, the absence of a suitable factory-built 15L on-road heavy-duty LNG engine, such as the Cummins ISX15 G, has hampered the development of a natural gas transportation sector.

BC Ferries has purchased three new dual-fuel LNG ferries with the intention of fuelling them only with LNG; these ferries are now in service [18]. BC Ferries is also planning to convert two of their Spirit Class vessels to dual-fuel. The two Spirit Class vessels service the Vancouver to Victoria route and consume approximately 15% of the diesel fuel used by BC Ferries each year [19].

It is the Ministry's policy that the supplier of CNG is usually the owner of the gas when it is compressed for transportation use [20]. Under the rate schedules governing the sale of natural gas for transportation, this means that fleet operators are often considered to be suppliers. In 2017, 14 suppliers of CNG for transportation have been identified, including waste disposal services, public school buses, forklifts, parcel delivery services, municipalities, and a commercial refuelling station. Both BC Transit and Translink have natural gas compression facilities that are used for CNG buses. BC Transit has been expanding the number of CNG buses in its fleet due in part to the FortisBC natural gas vehicle program. CNG has proven popular in return-to-base vehicle fleets, particularly in waste hauling fleets.

There are approximately 500 CNG vehicles and 140 LNG vehicles in use in B.C. today, as well as roughly half a dozen LNG mine haul trucks and marine vessels.

6.2. Market Outlook, Challenges and Opportunities

Liquefied natural gas production is expected to increase in B.C. due to the expansion of natural gas development locally and in other parts of North America. Large capital intensive facilities are needed to liquefy natural gas. It is anticipated that significant increases in the use of natural gas as a transportation fuel will occur in B.C.

Liquefied natural gas vehicle options have increased in the past several years and now include off-road and marine applications. However, the Cummins ISX15 G LNG engine is out of production and its replacement has been delayed indefinitely.

Compressed natural gas usage is expected to continue to increase due to increasing vehicle availability, favourable fuel costs, and the relative simplicity of compression facility installation. The Greenhouse Gas Reduction Regulation now allows utilities to recover in rates the cost to acquire RNG at a cost of up to $30/GJ for up to the equivalent of 5% of the utility's total volume sold to non-bypass customers in 2015.

FortisBC has approval from the BC Utilities Commission to source renewable natural gas from several suppliers in the near future.

6.3. Outlook for Carbon Intensity

The carbon intensity of natural gas may change if gas extraction techniques show different GHG performance for fracking than the current methods of natural gas extraction.

Currently, FortisBC purchases renewable natural gas from three suppliers. However, this is a more expensive product. FortisBC has approval from the B.C. Utilities Commission to purchase renewable natural gas from four additional suppliers in the near future. The carbon intensity for conventional CNG is 63.64 g CO_2e/MJ. The carbon intensity of CNG produced from renewable sources – landfill gas or anaerobic digestion – is expected to be around 5 to 10 g CO_2e/MJ (GHGenius 5.0 beta).

The carbon intensity for LNG is dependent on the methods used to liquefy the natural gas, and can be as low as 63.04 g CO_2e/MJ for large electric drive mixed coolant facilities operated in B.C. Smaller facilities or other cooling methods are less efficient, resulting in higher carbon intensity. If the production methods use a gas drive and a high carbon intensity electricity supply such as coal, the resulting carbon intensity of the LNG can be as high as 112.65 g CO_2e/MJ.

6.4. Pathway Assessment

The estimated numbers of vehicles are given in the following table. These numbers reflect information submitted to the Ministry of Energy, Mines and Petroleum Resources by FortisBC.

Table 5: Natural gas vehicle population forecasts

Consumption (GJ/year/vehicle)	**3,500**	**1,000**	**18,000**	**110,000**
Year	**# LNG Class 7/8**	**# CNG Class 4,5,6**	**# Mine Trucks**	**# Marine Vessels**
2013	50	125	0	0
2014	125	130	0	0
2015	125	250	0	0
2016	125	320	0	0
2017	125	400	4	5
2018	125	505	8	5
2019	125	730	8+	5+
2020	125	1016	8+	5+
2021	125	1265	8+	5+
2022	125	1711	8+	5+
2023	125	2334	8+	5+
2024	125	3155	8+	5+
2025	125	4149	8+	5+
2026	125	5529	8+	5+
2027	125	7516	8+	5+
2028	125	10041	8+	5+
2029	125	13385	8+	5+
2030	125	17903	8+	5+

7. Electricity

7.1. Current Situation

B.C's electricity is supplied primarily from hydroelectric dams, and 98% comes from clean or renewable sources [21]. This results in electricity with a carbon intensity of 19.73 g CO_2e/MJ.

In 2016, 1% of new passenger vehicles sold in B.C. were zero-emission vehicles (ZEVs). In Q1 2017 in B.C., there were approximately 5,400 light-duty electric vehicles on the road, and it is expected that vehicle numbers will continue to increase. Electricity used in light duty electric vehicles is considered to be gasoline class fuel.

British Columbia provides financial incentives up to $5,000 for the purchase of an electric car under the 2017 Clean Energy Vehicle (CEVforBC) program. Under the Part 3 Agreement program, Scrap-It offers an additional $6,000 if an older petroleum fuel vehicle is scrapped. There are currently no incentives for the public to install residential charging stations.

As a result of the previous Clean Energy Vehicle program, there are at least 550 public Level 2 charging stations across B.C., 142 Level 2 charging stations in multi-unit buildings, 306 residential Level 2 charging stations, and 30 DC fast charging stations [22].

In diesel class, transportation use of electricity includes the use by Translink and SkyTrain for the trolley buses and the light rail system in Metro Vancouver, as well as shore power at some B.C. Ferries terminals. We assume no increase in this sector.

7.2. Market Outlook, Challenges and Opportunities

The CEVforBC program has a goal of 5% of new passenger vehicle sales as ZEVs by 2020. The program expects the ZEV population to be 48,000 vehicles by 2020.

There is no issue regarding the availability of sufficient electricity, but charging infrastructure is still needed because of the impact that charging infrastructure has on vehicle adoption rates. The CEV Charging Program plans to support the construction of up to 300 more Level 2 charging stations in sectors or geographic regions where there are gaps in charging infrastructure [22]. Purchase incentives can also play an important role in the market penetration of electric vehicles.

There are still several areas of opportunity for shifting from petroleum-based fuels to electricity. These opportunities include: rail; port terminals; dredging; material handling; airport ground support equipment; and truck stop electrification.

The gasoline class EER listed in the Regulation is 3.4, while the diesel class EER is 2.7. These will be monitored and may be adjusted in the future to reflect improved information regarding the efficiency of electric vehicles.

7.3. Outlook for Carbon Intensity

Prior to 2017, the carbon intensity of electricity was 11.00 g CO_2e/MJ in the Regulation. This has increased to 19.73 g CO_2e/MJ (beginning January 1, 2017) to reflect an improved understanding of methane emissions from hydroelectric operations, which dominate the B.C. mix of electricity production.

Given that 98% of B.C.'s electricity supply already comes from clean or renewable sources, no significant change in carbon intensity is anticipated. Electric vehicles benefit from high efficiency, reflected by an EER of 3.4 relative to gasoline, which leads to an effective carbon intensity of 19.73/3.40 = 5.80 g CO_2e/MJ.

7.4. Pathway Assessment

In 2017, BC Hydro forecasted the electric vehicle population using a multi-equation economic stock turnover model, which forecasts that the number of EVs will grow according to the table below. Forecast drivers include fuel prices, capital cost differential including charging equipment and purchase incentives, EV fuel efficiency, and driving population. Each vehicle is assumed to consume 3,000 kWh/year.

Table 6: Electric vehicle population forecasts

Year	# of electric light-duty vehicles		
	2010 estimates	**2014 estimates**	**2017 estimates**
2013	1,313	0	0
2014	2,710	950	769
2015	5,537	2,710	2,729
2016	8,681	5,537	4,167
2017	12,242	8,681	5,927
2018	16,345	12,242	8,211
2019	21,155	16,345	11,171
2020	26,889	21,155	15,007
2021	33,838	26,889	20,024
2022	42,400	33,838	29,934
2023	53,116	42,400	45,056
2024	66,743	53,116	66,021
2025	84,338	66,743	92,663
2026	107,210	84,388	125,114
2027	137,403	107,210	163,839
2028	177,860	137,403	208,213
2029	232,883	177,860	253,429
2030	308,814	232,883	299,258

One issue identified by the Ministry is that the electricity reported is only about 10 percent of the expected usage. To date this has been an impact of less than 1,000 credits per year, but in the next few years the discrepancy will increase by a factor of 10, and a factor of 100 by about 2023. The Ministry expects that this is due to unreported home charging, and will be consulting stakeholders regarding modifications to the reporting policies in order to ensure that electricity credits from light duty vehicles are more accurately identified.

The current electricity use in Diesel Class is not forecast to change.

8. Dimethyl Ether (DME)

8.1. Current Situation

DME has potential as a transportation fuel and ASTM D7901 "Standard Specification for Dimethyl Ether for Fuel Purposes" has been established. DME is currently being researched by Volvo [23] and Ford [24] as a fuel that could be suitable for freight and personal transport. Further, California-based Oberon Fuels is currently working with Mack Trucks on the first customer demonstration project – a Pinnacle tractor fuelled by DME for the New York City Department of Sanitation [25]. However, there is currently no DME fuel supply in B.C., and there are no known plans to develop this market.

8.2. Market Outlook, Challenges and Opportunities

No concrete plans regarding DME have been presented to the Ministry. The development of DME in B.C. will depend on initiatives completed by industry.

8.3. Outlook for Carbon Intensity

The carbon intensity will depend on the specifics of the production methods. Using the default assumptions in GHGenius version 4.03, DME produced from natural gas in British Columbia has a carbon intensity of approximately 74 g CO_2e/MJ, representing a 20.5% reduction in carbon intensity relative to petroleum diesel. A lower carbon intensity could be achieved if renewable feedstocks, such as wood residue or other organic wastes, were used to produce the DME. While the energy efficiency and power ratings of DME and diesel engines are virtually identical, DME has approximately half of the energy density of diesel fuel [26].

8.4. Pathway Assessment

Currently the Ministry is not forecasting any use of DME, as there is no commercially available supply expected in B.C.

9. Renewable or Low Carbon Gasoline and Diesel Fuel

9.1. Current situation

There is no production of renewable diesel or gasoline in Canada. Hydrogenation-derived renewable diesel (HDRD) is the only form of renewable gasoline or diesel that is commercially available in the global market. HDRD is discussed further in section 13.

Other technologies capable of producing renewable diesel or gasoline have potential and are being developed, but are not sufficiently advanced to provide commercial quantities.

9.2. Market Outlook, Challenges and Opportunities

9.2.1. Thermal treatment of biomass

Gasification and pyrolization technologies such as Proton Power, Cool Planet, KIOR and others show promise to produce renewable fuels or renewable fuel components, but have not been proven at commercial scale. There is significant potential to produce renewable fuels with low carbon intensity, but until these fuels are made available to the market, they cannot provide guaranteed compliance opportunities.

9.2.2. "Biocrude" refinery co-processing

Renewable feedstock can be combined with petroleum crude oil for processing in conventional refineries. The Regulation does not specifically identify this as a fuel type, as the renewable portion of the refinery output would be considered to be renewable gasoline or renewable diesel fuel, as appropriate.

Technologies capable of producing low carbon crude oil for co-processing are being developed by companies such as Carbon Engineering, Licella/Canfor, Ensyn, Highbury Energy, Metro Vancouver/Genifuel and others. Co-processing offers a significant opportunity to enable fossil fuel refineries to transition to the production of low carbon fuels and chemicals.

Ministry staff understand that co-processing of alternative crude oil has been successfully demonstrated by a number of companies. Petroleum refiners are showing interest in this concept, but no-one is regularly producing co-processed fuels. The Ministry believes that co-processing offers a significant opportunity for fossil fuel refineries to transition to low carbon fuel production.

Under Part 3 Agreements, Chevron has been testing bio-oils for refinery compatibility, and will be continuing to scale up their testing to determine the scope of the opportunity to co-process renewable crude oil with fossil crude oil. Depending on the feedstock, this technology has the potential to produce fuels at commercial scale, where the renewable fraction has a carbon intensity below 20 g CO_2/MJ.

The Province of Alberta's renewable fuel requirement does not recognize co-processing as a means of complying with their requirements, which may limit the potential interest for developing this capacity in Alberta-based refineries that supply B.C. The federal government does recognize co-processing in its renewable fuel requirements.

9.2.3. New refineries

Northwest Redwater Sturgeon Refinery will be coming online in the near future, to produce "Clean Performance Diesel", which Northwest Redwater expects will be lower carbon intensity than the current average for fossil fuels.

The Act does not allow a different carbon intensity to be assigned for petroleum-based fuels, but the Ministry intends to develop a means of recognizing the carbon intensity benefits of processing bitumen in a refinery that has been constructed to minimize the carbon intensity of the final product.

9.2.4. Natural gas-based gasoline

The Regulation was amended in 2015 to recognize natural gas-based gasoline as being distinct from petroleum-based gasoline and to allow the carbon intensity to be assessed for that fuel. The default carbon intensity is set to 90.07 g CO_2e/MJ to reflect the value for natural gas-based gasoline produced from natural gas in British Columbia using known processes. Advocates for natural gas-based gasoline are exploring options to produce a product with a carbon intensity roughly 10 to 12 percent lower than the default.

For more information, see the proponent's websites:

- Blue Fuel Energy – http://bluefuelenergy.com
- Ainsworth Energy – http://ainsworthenergy.com

9.3. Outlook for Carbon Intensity

Fuels made from renewable feedstocks can have very low carbon intensities. The Act recognizes that fuels made from differing feedstocks result in different fuels, so it recognizes that the renewable component of co-processed fuel is a fuel distinct from the fossil fuel component. This means that the carbon intensity of the renewable portion of co-processed fuel can be evaluated and approved.

Petroleum-based fuels made in new facilities may be able to produce significant quantities of fuel with a carbon intensity below the average value currently supplied in B.C., but the Regulation sets single carbon intensities for petroleum-based gasoline and for petroleum-based diesel fuel.

These fuels have not been included in the assessment due to the uncertain nature of the opportunity, but it is expected that they will have a positive impact. The Act and/or Regulation may need amendments in order to recognize the benefits of some of these fuels and/or processes.

9.4. Pathway assessment

While it is expected that standards-compliant gasoline and diesel fuel will soon play an important role in decreasing the carbon intensity of transportation fuel, the compliance scenario does not include any of these fuels. At this time, HDRD serves as a modelling surrogate for all other forms of fungible renewable diesel.

10. Methanol

10.1. Current Situation

Methanol was introduced to the North American market as a potential transportation fuel in the 1990s, and a number of flexible fuel M85 vehicles (methanol blended with gasoline at higher levels, i.e. 85% methanol) were built and sold, including roughly 6,000 in B.C. Since that time, interest in North America has diminished significantly and regulatory requirements governing vehicle and fuel emissions have become more stringent.

The automotive industry associations have clearly stated that the use of methanol in vehicles currently being manufactured for the North American market will cause damage. They have also stated that the low cost estimates of making methanol-compatible vehicles are no longer relevant.

10.2. Market Outlook, Challenges and Opportunities

Current issues that have to be resolved in North America before methanol will be recognized as a transportation fuel under the Renewable and Low Carbon Fuel Requirements Regulation include:

- Co-solvent: Methanol does not require a co-solvent when blended with gasoline at higher levels (i.e. M85), but it does when blended with gasoline at lower levels (i.e. M15). It is not clear what the GHG impact of this co-solvent would be.
- Volatility: Low level methanol blends (i.e. M15) typically have higher volatility than ethanol blends. The B.C. Cleaner Gasoline Regulation restricts the volatility of gasoline and specifies that all gasoline must meet applicable CGSB standards. This issue would also have a significant impact on vehicle evaporative control systems.
- The CGSB draft standard for M85 has been withdrawn due to lack of interest.
- Methanol blends need to be shown to meet the screening assessment requirements under the *Canadian Environmental Protection Act* of 1999.
- Most vehicle manufacturers explicitly warn against the use of methanol at any concentration, and both the Canadian Vehicle Manufacturer's Association and the Association of International Automobile Manufacturers of Canada have categorically stated that methanol would damage modern engines.

Given the situation described above, we are not considering methanol to be a potential transportation fuel for B.C.

10.3. Outlook for Carbon Intensity

This is not relevant given the above situation. However, it should be recognized that the carbon intensity of methanol would likely be quite high unless innovative production methods are developed or a renewable feedstock is identified. Using the default assumptions in GHGenius 4.03, methanol produced from natural gas in British Columbia has a carbon intensity of about 78 g CO_2e/MJ, which translates into a 10.7% reduction in carbon intensity relative to petroleum gasoline. A lower carbon intensity could be achieved if renewable feedstocks, such as organic wastes, were used to produce the methanol.

There is no data available to assess whether engines running on methanol would require a specific EER, which could also impact the benefits of methanol as a transportation fuel.

10.4. Pathway Assessment

Methanol will not be considered as a transportation fuel under the Renewable and Low Carbon Fuel Requirements Regulation until it is demonstrated to be a commercially available transportation fuel capable of delivering significant carbon intensity reductions, and compatible vehicles are available in the market.

11. Ethanol

11.1. Current Situation

Annual gasoline consumption in B.C. was 5.2 billion litres in 2016 [27]. Of this gasoline, 7.2% was denatured fuel ethanol, meaning that 375 million litres of ethanol were consumed. As expected, ethanol blending in B.C. has increased in response to Renewable and Low Carbon Fuel Requirements. Petroleum fuel suppliers have raised some questions and concerns about the feasibility of further expanding ethanol consumption in the province.

Ethanol blends in the B.C. market today contain no more than 10 percent ethanol.

Based on current gasoline consumption levels in B.C., roughly 520 million litres of ethanol would be needed to enable province-wide E10 blending. This represents an increase of 145 million litres over current ethanol consumption. However, the Compliance Scenario shows that gasoline consumption is expected to drop, resulting in a demand for only 455 million litres of ethanol. The 19 ethanol plants operating in Canada in 2017 have the capacity to produce approximately 2.0 billion litres of fuel ethanol annually [28]. Total Canadian production in 2016 was estimated to be 1.75 billion litres [11]. The production capacity represented by suppliers who have an approved carbon intensity in B.C. is about 6.0 billion litres.

In 2016, the Ministry offered up to 30,000 compliance credits to suppliers under the Part 3 Agreements program for the installation of blender pumps and/or the supply of higher-level blends of ethanol. No suppliers applied for these credits, but some indicated that they were interested and needed more time to prepare a proposal. The Ministry has renewed the offer in the 2017 Part 3 Agreements program.

11.2. Market Outlook, Challenges and Opportunities

As can be seen in Figure 3, there is significantly more ethanol available than is needed to fulfil the volumetric needs of the compliance scenario. However, there is a significant lack of ethanol with low enough carbon intensity to meet the needs of B.C. suppliers unless they supply an average concentration that greatly exceeds 10%.

One issue that affects blends with higher ethanol concentration is that ethanol has about two thirds of the energy per litre compared to gasoline. On the surface this implies a decrease in fuel economy that will have a noticeable impact on consumers, but the relationship between energy content and fuel economy is more complex, and has an impact that depends on the ethanol concentration. By offering mid- and high-level ethanol blends at retail locations, retailers would provide additional fuelling options for FlexFuel vehicles and generate additional compliance through increased ethanol use.

Some questions were raised in the 2014 consultations regarding the compatibility of ethanol with existing fuel storage tanks, piping, pumps and dispensers. All existing equipment that is sold today for the distribution, storage, and dispensing of gasoline is approved by OEMs for the use of E10 at a minimum, and most is compatible with E100. It is not known whether any tanks in use in B.C. have problems.

Some suppliers have suggested that small retailers may be continuing to operate because they cannot afford the costs to decommission their facility, but given the increasing environmental liability of untested fuel tanks it seems that these are a concern for enforcement of pollution laws, and the potential for their existence should not influence the introduction of new fuel blends.

Ethanol and ethanol blended gasoline cannot be shipped in the Kinder Morgan Trans Mountain pipeline because of contamination from other products such as crude oil that are also shipped in the pipeline. However, since 2015 the two off-loading destinations (Kamloops and Vancouver) and Hatch Point on Vancouver Island all have ethanol blending capability.

Low-level Blends (E1 to E15)

In 2014, the Canadian Fuels Association (CFA) reported to the Ministry that its members were preparing to extend the use of E10 throughout B.C., and that they would be able to achieve an annual provincial average of 8% ethanol in the gasoline pool by 2020. In 2016 the average concentration of ethanol in the regulated pool of gasoline in B.C. was 7.4% [27]. Effectively, E10 is the default for Regular grade (87 octane) gasoline in B.C.

All engine manufacturers have been aware of the likelihood of wide-spread adoption of ethanol for over 30 years, and now support the use of ethanol up to E10. E10 has been approved for use in marine and other small engines, and has effectively become the default fuel in most markets. For older engines, or marine applications where ethanol blends may cause problems, the suppliers provide premium grade gasoline as an ethanol-free product in most markets. The E10 ethanol "blend wall" is an infrastructure blend limitation imposed by the fuel suppliers and not a technical limitation for the market as a whole, in that there are FlexFuel vehicles and other vehicles capable of using higher level blends, as will be discussed in the following paragraphs.

The U.S. EPA has approved E15 blends when used in model year 2001 and newer passenger cars, light-duty trucks, and medium-duty vehicles, and the majority of American auto manufacturers, representing approximately 81% of the U.S. market, have explicitly approved the use of E15 in all new vehicle models [4].

The U.S. has updated ASTM D4806 *Standard Specification for Denatured Fuel Ethanol for Blending with Gasolines for Use as Automotive Spark-Ignition Engine Fuel* to provide the specifications for gasoline fuel containing 1-15% ethanol by volume.

The CAN/CGSB-3.511 *Oxygenated Unleaded Automotive Gasoline Containing Ethanol* standard will soon include ethanol concentrations up to 15 percent.

The U.S. National Renewable Energy Laboratory has assessed infrastructure E15 compatibility at retail locations, and confirms that there are UL testing standards available now for all gasoline–ethanol blends from 0% to 85% ethanol, and lists manufacturer-approved equipment for blends above E10 [29]. The cost of upgrading to E15 compatible equipment varies depending on circumstances. In a report to the U.S. Department of Agriculture, the Petroleum Equipment Institute estimated costs for a number of scenarios [30]. Many outlets are already compatible with E15. Where upgrades are necessary, the costs range from US$4,200 per pump for retrofits to an incremental cost of about US$10,000 for new installations.

Mid-level Blends (E16 to E50)

Mid-level blends created from currently available blending components will have octane levels similar to or higher than Premium Grade gasoline. Studies have shown that FlexFuel vehicles operating on E25 can optimize engine efficiency to use the increased octane to achieve volumetric fuel efficiency similar to the efficiency achieved when they operate on E10 [32],[33]. Offering mid- and high-level ethanol blends at retail locations would provide an additional fuelling option for FlexFuel vehicles while generating additional compliance for fuel suppliers.

The technology to dispense mid-level blends (e.g. blender pumps) is readily available, and blends containing 16-50% ethanol are now offered through blender pumps to FlexFuel vehicles at over 570 stations in the U.S. [34].

In the longer term, Tier 3 CAFE requirements to 2025 will lead to high compression engines that will require 100 octane gasoline and achieve increased energy efficiency. While these high octane fuel blends are not currently available, the ASTM D8076 *Standard Specification for 100 Research Octane Number Test Fuel for Automotive Spark-Ignition Engines* is a performance based standard that allows up to 50% ethanol. ASTM D7794 *Standard Practice for Blending Mid-Level Ethanol Fuel Blends for Flexible-Fuel Vehicles with Automotive Spark-Ignition Engines* guides the blending of gasoline fuels containing 11-50% by volume ethanol. This Standard Practice describes how to calculate the volumes of E10 and E85 required in order to make blends in the E11 to E50 range.

While mid-level blends are not currently available in B.C., it is possible that there will be a role for these products in the future. Under the Cleaner Gasoline Regulation, all gasoline in B.C. must conform to an applicable standard. CAN/CGSB-3.512 *Automotive ethanol fuel (E50-E85)* standard is being amended to include E20-E25, which will enable the use of mid-level blends in B.C.

High-level Blends (E50 to E85)

There is a relatively large population of FlexFuel vehicles in Canada. IHS Polk/DesRosiers estimates indicate that about 1.62 million FlexFuel vehicles are in operation, representing approximately 7% of the light duty vehicle fleet [35]. Assuming FlexFuel vehicles are distributed in the same proportion by province, B.C. is home to approximately 189,000 FlexFuel vehicles. An average LDV in Canada is driven 17,916 km per year at an average G100 consumption of 9.8 l/100 km. If the 189,000 FlexFuel vehicles were consistently refuelled with E85, they would consume 488 million litres of E85 on a gasoline equivalent basis. Yet, these vehicles cannot refuel with E85 in B.C. because there are no retail stations offering the fuel.

An emerging concern is that, while production and sales of FlexFuel vehicles in North America have significantly increased in recent years, with FlexFuel vehicles accounting for approximately 20-25% of all new vehicle sales, automaker production of these vehicles is uncertain going forward, as the U.S. EPA has re-opened its midterm evaluation of the 2022-2025 CAFE requirements. Vehicle efficiency standards for the Canadian market have been aligned with CAFE standards to 2025, and it is not clear whether there will be changes to the U.S. CAFE requirements and whether this will impact the number of FlexFuel vehicles being produced for the Canadian market.

The majority of existing fuel storage tanks in North America are approved to store E85 or E100. Tanks previously used for storing other types of fuel may be used for E85 if the tank is properly cleaned first. During storage of conventional gasoline, debris and moisture can build up over time to form sludge or “water bottoms.” There are several acceptable methods for cleaning sludge from storage tanks that are being converted to E85 service [36]. All major dispenser manufacturers sell pumps that are approved for dispensing E85.

11.3. Outlook for Carbon Intensity

To date, the Ministry has approved carbon intensities for 81 ethanol fuel pathways, ranging from -54.80 to 74.91 g CO_2e/MJ. Most registered ethanol is in the 50-60 g CO_2e/MJ range, and the average carbon intensity of ethanol supplied in B.C. has dropped 28%, from 55.51 g CO_2e/MJ in 2010 to 40.00 g CO_2e/MJ in 2016. In California, the average carbon intensity of ethanol has decreased 19% from the first quarter of 2011 to the first quarter of 2017 [37].

It is expected that increased carbon credit values will continue driving investment and technology adoption at existing conventional ethanol facilities to reduce the carbon intensity of their ethanol. Technologies that can significantly reduce the carbon intensity of conventional ethanol include:

- Adoption of combined heat and power,
- raw starch hydrolysis,
- using an anaerobic digester to produce renewable biogas to generate power in lieu of natural gas,
- using biomass or renewable natural gas to generate power in lieu of fossil-based natural gas,
- using waste steam from an adjacent power plant to generate power in lieu of natural gas,
- oil recovery from stillage,
- co-processing grain with waste feedstock, and
- carbon capture and sequestration (CCS).

For example, CCS has the potential to significantly reduce the CI of conventional ethanol. The Archer Daniels Midland Company (ADM) has already safely captured and stored 750,000 tonnes of CO_2 generated by its ethanol facility in Decatur, Illinois, with plans to expand CCS capacity [38]. Similarly, Husky Energy has adopted CCS technology to capture and store 100,000 tonnes of CO_2 annually at its Lloydminster ethanol facility [39]. The captured CO_2 is used in enhanced oil recovery, displacing other sources of CO_2 and resulting in a reduction in the carbon intensity of over 30 gCO_2e/MJ.

As well, adoption of improved agricultural practices – such as no-till, cover crops, nitrogen fertilizer inhibitors – reduces the carbon intensity of feedstock production. Technology adoption and improved practices could conservatively reduce the overall carbon intensity of most conventional ethanol by 10 to 25 g CO_2e/MJ (or even more if several innovative practices are combined). Conventional ethanol has the potential for a carbon intensity of zero g CO_2e/MJ.

The renewable fuel industry has identified a number of potential sources of cellulosic ethanol globally. Lifecycle analyses conducted by U.S. EPA, U.S. DOE, and other entities suggest that the carbon intensity of cellulosic ethanol is likely to be in the range of 0 to 20 g CO_2e/MJ.

Fuel suppliers have expressed concern regarding the timing required to fund, design and build such modifications. Given that the intent of the BC-LCFS has been clear since 2007, with regulations in place since 2010, the Ministry expects that in 2017, fuel producers and suppliers have had time to plan accordingly.

Figure 3 shows historical data for the quantities of ethanol available at various carbon intensities. The bars show the estimated total capacity to produce ethanol within that carbon intensity range, while the lines show the total capacity for all production at or below that carbon intensity. The black line shows the quantity and carbon intensity needed to fulfill the expectations of the compliance model, with arrowheads at 2015, 2020, 2025, and 2030. The figure shows that by about 2020 the quantity of ethanol with low carbon intensity will not be low enough for the scenario. The Ministry expects that either the ethanol industry will respond with lower carbon intensities or suppliers will generate compliance by supplying other lower carbon fuels such as biodiesel or HDRD.

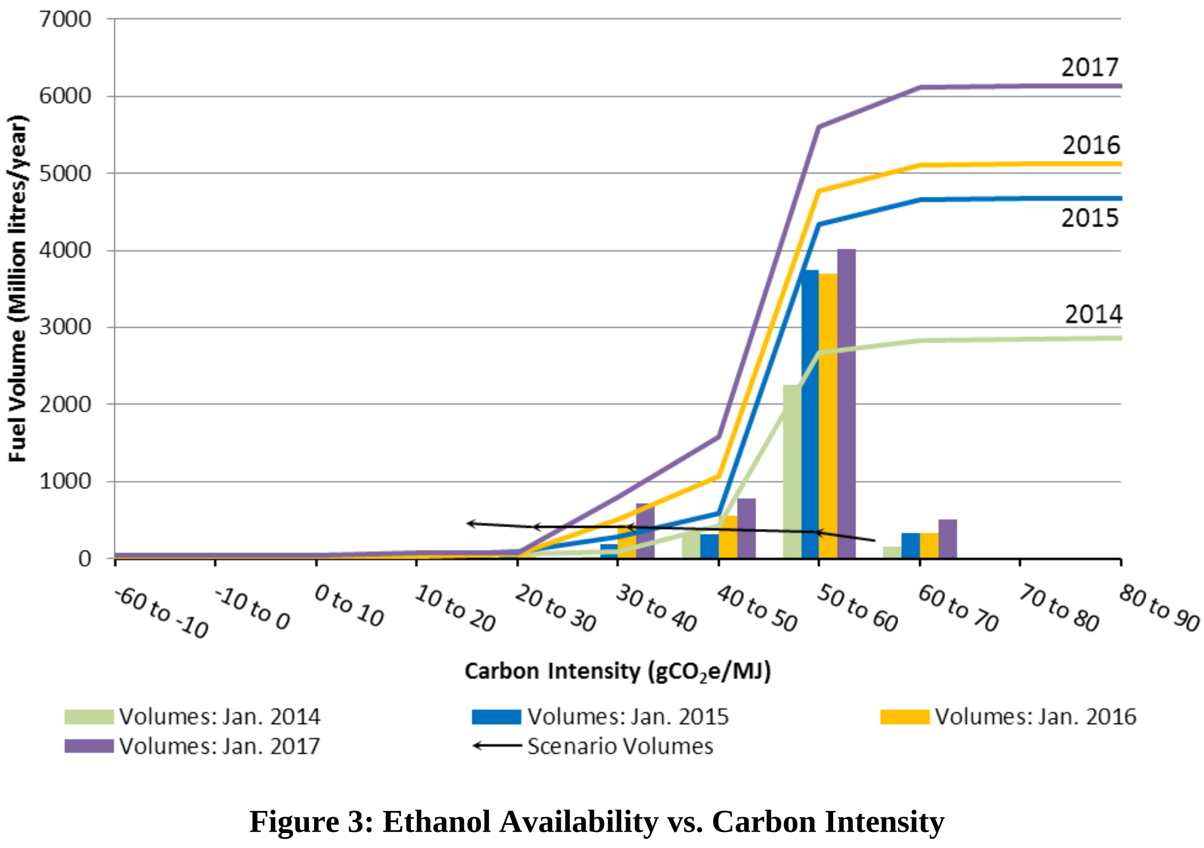

Figure 3: Ethanol Availability vs. Carbon Intensity

11.4. Pathway Assessment

The proportion of ethanol in gasoline in B.C. will not exceed about 8 or 9% unless the market supplies blends above 10%.

In 2017, E85 is an established option that fuel suppliers have not taken advantage of, while E15 is an emerging option that has significant potential to offer wide-scale compliance once standards and regulatory support have been established.

FlexFuel vehicles comprise about 7% of the Canadian fleet today, but the fuel has not been marketed in B.C. We have included in the Ministry's modelling contributions from higher level blends such as E15, E25 and E85, all of which are being marketed in the U.S. today. By 2020, the Ministry expects that suppliers will have addressed the infrastructure and marketing issues to enable the sale of ethanol blends above E10. It is unlikely that compliance will be possible in the longer term without supplying these blends in significant quantities.

As of January 2017, there is insufficient low carbon intensity ethanol capacity registered with the Ministry to fulfil the expectations of the model. Quantities of low carbon intensity of ethanol must become increasingly available to the B.C. market. The Ministry expects that ethanol producers will produce, and fuel suppliers will supply, increasing volumes of lower carbon intensity ethanol by 2020.

12. Biodiesel

12.1. Current Situation

Annual diesel consumption in B.C. in 2015 was 3.7 billion litres [27]. Of this, 102 million litres (approximately 2.7%) was biodiesel. In 2017, there were 15 facilities with biodiesel carbon intensities approved for use under the BC-LCFS.

Blends above 5% concentration are not being supplied at any commercial outlets, although one municipality has reported use of B20 blends [40].

Biodiesel blending in B.C. can increase significantly from current levels. Petroleum fuel suppliers have raised concerns about the feasibility of expanding biodiesel consumption in the province, but data from comparable U.S. markets provide a framework for understanding the potential for increased blending in B.C.

In 2017, approximately 70% of the major diesel engine manufacturers that operate in the United States have approved the use of B20 in new engines, while the remaining 30% approve the use of B5 [41].

Concerns regarding biodiesel fall into two general categories; the suitability of biodiesel blends at low temperatures, and the use of blends above 5% biodiesel concentration. Low temperature suitability is addressed in this section, while blends above 5% biodiesel concentration will be addressed in the following section.

There is a considerable body of evidence to show that biodiesel blends of at least 2% can be made to CGSB specification at any temperature experienced in Canada [42]. At most times of the year, there is enough “extra” cloud point room for blends up to B5 to meet the specification without adding any kerosene [43].

Renewable fuel producers, wholesalers, and retailers have shown that B5 is feasible for most of B.C. at all times, based on experience in jurisdictions such as Minnesota, Illinois, and the European Union [44], where some suppliers are providing B11 year-round using a combination of #1 diesel and additives in the coldest weather. Petroleum suppliers have disagreed with these statements, arguing that there have been failures in those jurisdictions, but have not produced any data to support their claims. No documentation has been presented to show that engine problems have been caused by biodiesel blends when the blends have met specifications in effect since 2011, demonstrating that biodiesel standards have evolved to address problems that were encountered with biodiesel produced to meet earlier versions of the standards.

In the 2014 consultations, it was confirmed that cold-flow improvers (additives) had not been used in B.C. to date, and evidence was presented to indicate that additives could significantly improve the ability to create workable biodiesel blends at all temperatures. The need for suppliers to evaluate the usefulness of additives for Canadian blending was identified.

A report by the Coordinating Research Council has evaluated the relevance of existing low temperature operability tests to additized biodiesel blends, enabling testing and operational use of cold flow improvers [low temperature additives] in Canada [45]. However, as of September

2017, the B.C. Ministry of Energy, Mines and Petroleum Resources has not been made aware of any testing or additization in B.C. This is despite the opportunity to enter into Part 3 Agreements for such testing and use stated in the 2016 Part 3 Agreement Program and again in the 2017 Program.

12.2. Market Outlook, Challenges and Opportunities

Petroleum suppliers have expressed concern regarding the amount of low temperature blending component (typically ultra-low sulphur kerosene, or ULSK) needed to create blends with the necessary cloud point temperatures. Biofuel proponents challenged the existing blending model on the basis that it is much more conservative than necessary, and that the petroleum industry has not conducted technical studies of their blending practices to minimise the use of ULSK. In addition, the concern regarding low temperatures could be alleviated by the use of cold-flow additives that are available at significantly lower cost than ULSK blending.

Low-level Blends

CAN/CGSB-3.520 (B1-B5) and ASTM D975 standards exist for biodiesel blends up to 5%.

All major Original Equipment Manufacturers (OEMs) have approved the use of standards-compliant biodiesel blends of up to 5%, and over 70% of those now support blends up to 20% in new vehicles [46]. OEMs reference biodiesel fuel quality standards (e.g. ASTM or CGSB) in their recommendations and often recommend or require fuel production and/or handling QA/QC certification (e.g. under a BQ9000 program).

Two percent biodiesel blends are feasible in all conditions experienced in B.C., but petroleum suppliers have not reported any efforts to use B2 blends in conditions where they feel that B5 is difficult. The Ministry has offered extra compliance credit for the supply of B2 in cold climates through Part 3 Agreements in 2016 and 2017, but no fuel suppliers have entered into agreements to do so.

Mid-level Blends

CAN/CGSB-3.522 and ASTM D7467 standards exist for biodiesel blends up to 20%. CAN/CGSB-3.522 includes the statement “The blends of biodiesel covered by this standard are more appropriate for fleets and users who understand and can manage the potential risk”. Fuel suppliers have stated that they interpret this statement to mean that mid-level blends cannot be sold at cardlocks or retail stations. A more appropriate interpretation would be that a risk mitigation strategy should include education for potential customers about real-world experience using the fuel in vehicles that have not been tested by the manufacturer for compatibility.

The Ministry’s position is that all fuel standards have limited applicability. Precautionary notes are intended to provide guidance, not to prevent the use of the fuel. Biodiesel blends up to B20 can be used at any temperature when they meet the cloud point requirements for that temperature, and the majority of light-duty diesel vehicles can use B20. B20 can be blended to meet cloud point requirements in B.C. in all but a few weeks of the year when B5 is possible.

Today’s growing fleet of light-duty diesel vehicles, such the Chevrolet Cruze, Ford F-250 and Ram trucks support up to B20. Virtually all larger, heavy-duty engines manufactured by companies such as Caterpillar, Cummins, Mack and International also support up to B20. It is these heavy haulers that consume most of the country's diesel fuel. Under certain off-highway applications, such as farming and construction, the approved blend levels are often higher. Many of these heavy-duty engine manufacturers have studied high blends to ensure that the operation would be trouble free. They often work with their consumers, such as for underground mining applications, to ensure that the engines and vehicles are able to operate on B100 in order to meet stringent air quality emissions requirements.

No evidence has been presented to show that if a customer occasionally fills a vehicle with standards-compliant biodiesel blends at a concentration above B5, they will damage the engine, regardless of the manufacturer's recommended levels for that engine. Possible lubricant dilution can be dealt with by following the manufacturer's recommended oil change intervals. Elastomer failure is a possible result of long-term use of mid-level blends of biodiesel, although known issues are limited to seals in older vehicles.

The maximum quantity of biodiesel that the market could consume is unknown, as it depends on demand for B20, which the suppliers are not providing.

High-level Blends

Standards do not exist for supplying blends of biodiesel above 20% concentration, and suppliers are not expected to pursue this option unless they wish to. Strictly speaking, fuel standards do not exist in Canada for B21 to B99, but CAN/CGSB-3.524 exists for pure biodiesel for fuel blending, so any blend can be created using standards-compliant components.

12.3. Outlook for Carbon Intensity

High quality biodiesel with low carbon intensity is readily available for the B.C. market. As of December 2016, there were 38 approved carbon intensities in B.C. for biodiesel. These range from -15.74 g CO_2e/MJ to 98.96 g CO_2e/MJ. The majority of approved biodiesel falls into the 10 to 20 g CO_2e/MJ range (~44% of total approved supply) with an additional 517 million litres below 10 g CO_2e/MJ (~17% of total approved biodiesel supply).

Biodiesel producers have been responding to carbon pricing by improving production efficiency and co-product use to decrease the carbon intensity of biodiesel significantly, resulting in several pathways with carbon intensities below 10 g CO_2e/MJ. It is expected that this trend will continue.

Figure 4 shows the quantities of biodiesel that are available between ten gram increments of carbon intensity for 2014 to 2016. Generally, the quantities have increased due to increased production of biodiesel with a carbon intensity of less than 20 g CO_2e/MJ resulting from new production capacity as well as improved production processes. The small black arrow at about 15 g CO_2e/MJ shows the compliance scenario demand for biodiesel from 2010 to 2030, and illustrates that there is sufficient capacity to supply the anticipated demand and to reduce the average carbon intensity.

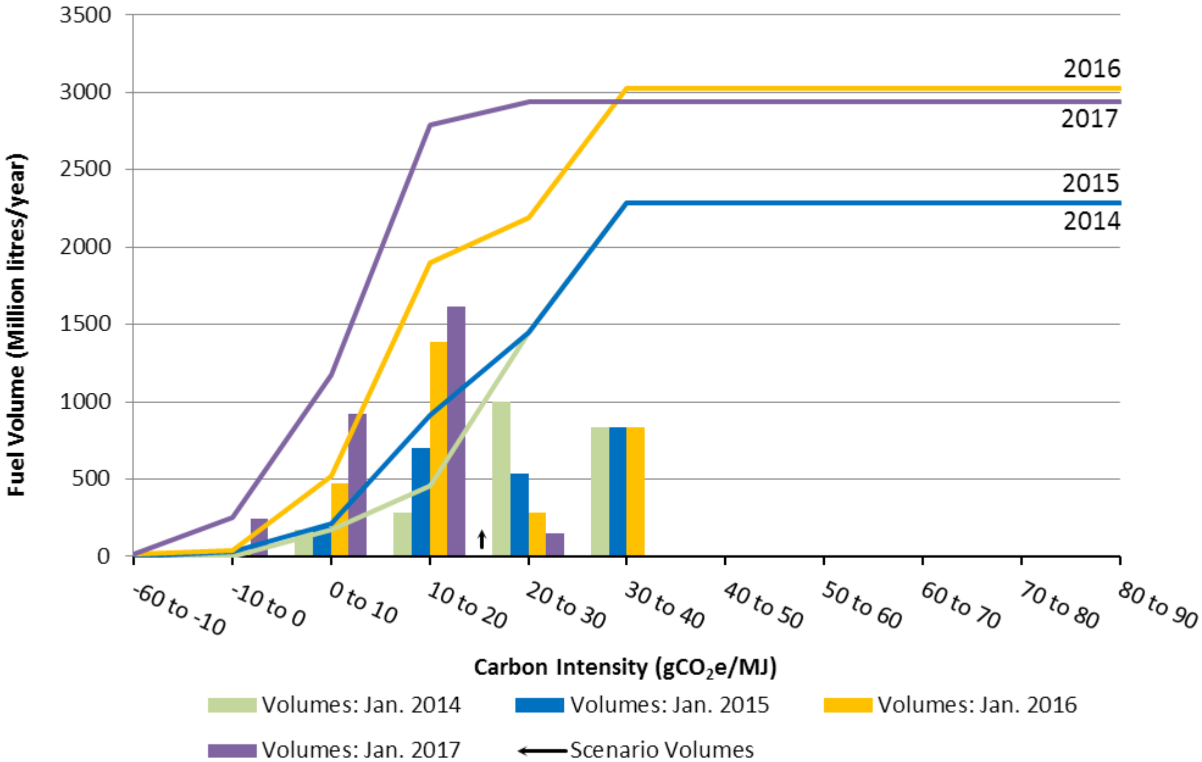

Figure 4: Biodiesel Availability vs. Carbon Intensity

12.4. Pathway Assessment

The CFA has stated that, using B5 blends, they will be able to achieve a 3.5% provincial average biodiesel concentration by 2020. This statement implies that 70% of diesel in the province would be sold as B5 and 30% would be B0. The successful adoption of biodiesel in Minnesota and Illinois shows that it may be possible to use additives to achieve B5 in nearly all of the fuel supplied in B.C. Cold flow additives have not been investigated in the Canadian market. They have been in widespread use in Minnesota, Illinois, and the European Union to successfully market up to B11 in climates that match the extreme temperatures that affect B.C. in winter.

B20 blends can be produced to comply with specifications for a significant fraction of the year and a significant number of vehicles are approved to use these blends, but suppliers will need to educate the consumers and make the product available. It is not clear how much more biodiesel can be placed into the market through blends greater than 5%, as that will depend on availability, pricing and vehicle populations.

To create a conservative estimate of the potential for increasing biodiesel usage, we begin with the fact that in 2015, 102 million litres of biodiesel were supplied [27]. If we assume that this was all at a concentration of 5%, the biodiesel would have been sold with 1.94 billion litres of diesel. Given that 3.56 billion litres of petroleum-based diesel fuel were supplied, this leaves 1.61 billion litres of petroleum-based diesel supplied without biodiesel. Assuming that this fuel was supplied in parts of B.C. that experience cold winters, it would be practical to limit the use of B5 to half of the year and supply B2 in the remainder of the year. This would result in the supply of an additional 56.5 million litres of biodiesel. Developing a market for B20 that amounts to 5% of total fuel sales would result in a net further increase of 28.7 million litres (after reducing B5 and B2 blends by 5%). Together, this would imply a total of 187 million litres of biodiesel, or 5% average biodiesel content in B.C. Another scenario that cannot be discounted is that the use of additives would enable the use of B5 year-round in southern regions that do not experience extreme cold in winter, leading to the potential for the supply of significantly more than 187 million litres of biodiesel.

In order to comply with the low carbon fuel requirements in the long term, fuel suppliers will likely need to develop markets for B20. The support for B20 from OEMs implies that the owners of those vehicles should be provided with the choice to purchase this blend.

13. Hydrogenation Derived Renewable Diesel (HDRD)

13.1. Current Situation

Annual diesel consumption in B.C. in 2015 was 3.66 billion litres [27]. Of this, 121 million litres (approximately 3.3%) was HDRD. In 2016, annual diesel consumption was 3.48 million litres of which 73 million litres (approximately 2%) was HDRD.

As of January 2017, the Ministry of Energy, Mines and Petroleum Resources has approved 17 carbon intensity pathways for HDRD, reflecting 2,055 million litres/year of production capacity from three producers.

Currently, there is no HDRD production in Canada.

13.2. Market Outlook, Challenges and Opportunities

HDRD is a mixture of hydrocarbons similar to ULSD and will meet the diesel fuel specification CAN/CGSB-3.517-2013. As long as HDRD meets the local fuel standard, and in some cases additional requirements set by engine manufacturer, there is no restriction to using HDRD with full warranty coverage.

There are more stringent requirements for diesel fuel in the World Wide Fuel Charter [47] created by automotive manufacturers, including limitations on density. In practice, HDRD may have a lower density and some OEM's have specified a lower limit that may not be met unless HDRD is less than 40% of the finished fuel blend. HDRD also has lower aromatics content than typical diesel, as do some fossil diesel fuels. In long-term use, this can cause shrinking or swelling in some equipment seals, leading to leaks, but this can be addressed through the use of commercially available additives.

Canadian suppliers are limiting the concentration of HDRD to no more than 20% as a precautionary measure. No evidence has been presented to show that this specific limit is necessary, but this is not a barrier to delivering more HDRD in the B.C. market at this time. Blends of 15% to 40% HDRD are in use in European markets. With additives, HDRD is also being used at 100% concentration both in North America and Europe.

While the typical cloud point of HDRD supplied in Canada to date is about -10 C, it can be produced to meet seasonal cold flow requirements. Currently the lowest cloud point in production diesel is -34 °C (Ultra-Low Sulphur Kerosene (ULSK)). The HDRD process can be adjusted to produce diesel with a cloud point as low as ULSK, as has been demonstrated in production of renewable aviation fuels using the same process.

HDRD is more expensive than biodiesel, but there are no market indices for pricing and information is not publicly available. The producers recognize that they need to compete with biodiesel as a more affordable alternative, and as the HDRD production processes mature, it is expected that improved efficiencies will result in price reductions.

It is expected that HDRD blending in B.C. will continue to increase in response to the Renewable and Low Carbon Fuel Requirements.

13.3. Outlook for Carbon Intensity

Figure 5 shows the quantities of HDRD that are available between ten gram increments of carbon intensity for 2014 to 2016. The black arrows show the compliance scenario demand for biodiesel from 2010 to 2030, and illustrate that there is sufficient capacity to supply the anticipated demand and to reduce the average carbon intensity.

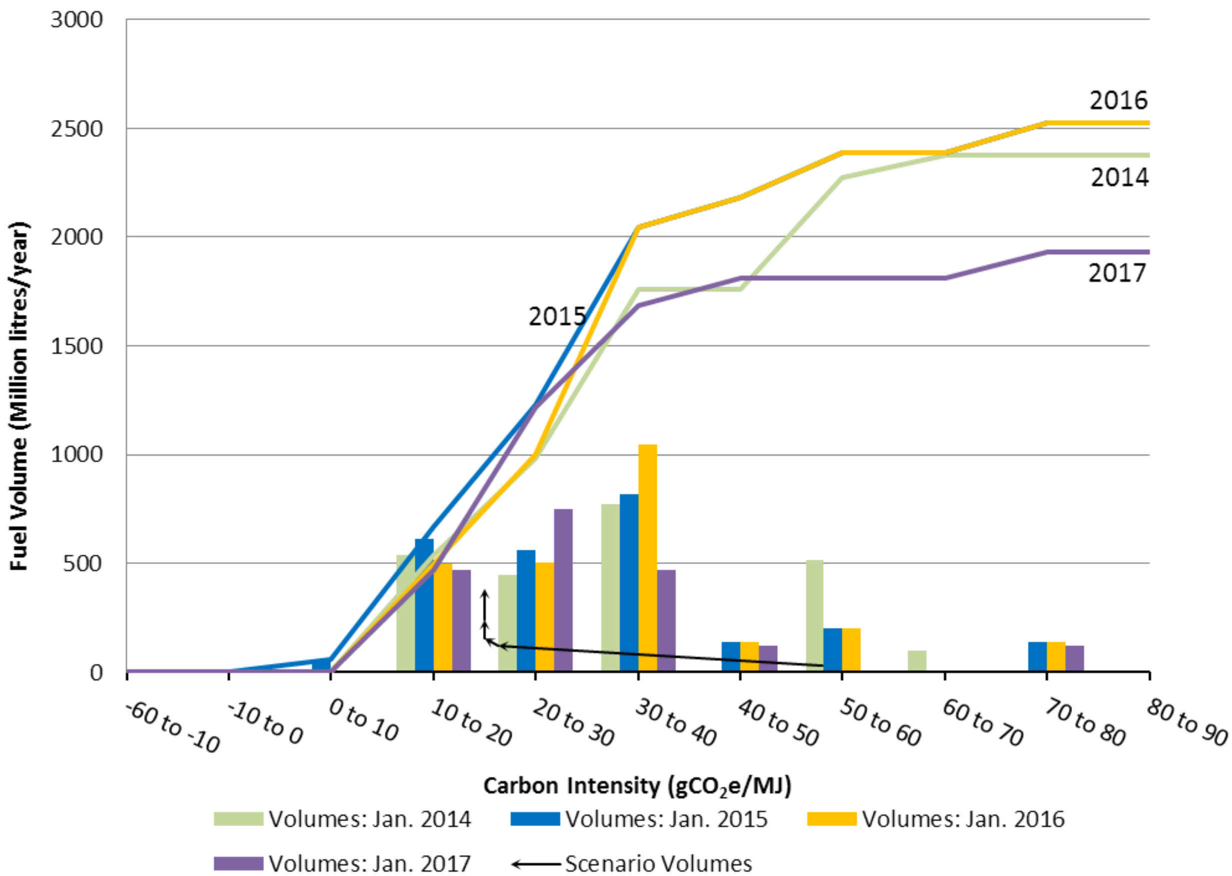

Figure 5: HDRD Availability vs. Carbon Intensity

13.4. Pathway Assessment

In 2014, the CFA stated that the quantity of HDRD that can be delivered to the B.C. market is limited by their ability to store the fuel as it is offloaded from ships and then sent to market at no more than 20% concentration. Given this limitation, the CFA estimates that they will be able to achieve a maximum 4% provincial average concentration by 2020.

The Ministry expects that fuel suppliers will address the limits on HDRD production, storage and handling capacity to enable a significant increase in its availability and use. Without significantly increased volumes of low carbon HDRD, compliance may be difficult after 2020.

14. Conclusions

Compliance with the 10% carbon intensity reduction target by 2020 is possible. Consumption and available quantities of all low carbon fuels must increase. The consumption of some fuels, such as electricity, are limited by the number of vehicles able to consume those fuels. Other fuels are limited by their availability in a market that currently offers a limited number of choices.

Until electric vehicle populations become significant around 2025, compliance with the Regulation is heavily dependent on contributions from ethanol, biodiesel, HDRD, and electricity for transit. Liquid fuels alone will not achieve 10% reductions until renewable content approaches 12 to 15 percent by volume.

Quantities of some biofuels are limited by compatibility with large segments of the fleet population, but there is a complete lack of product offerings suitable for FlexFuel and B20-compatible vehicles. The diversity of product offerings must increase and suppliers will need to educate consumers to select appropriate fuels for their vehicles. This will not happen unless these fuels begin to be offered to the general public at competitive prices.

There is significant potential for ethanol to double the GHG reductions beyond today's use of ethanol if the suppliers increase the quantities supplied and producers innovate and improve their production processes to reduce the carbon intensity. This will only happen if suppliers start differentiating between the carbon intensities of each ethanol, either through pricing according to carbon intensity or through market selection.

Despite the potential to significantly increase the quantity of biodiesel supplied in B.C., some suppliers continue to avoid blending it, and all suppliers are avoiding blending at 2% in winter and 5% in summer for interior and northern regions. B2 has been demonstrated to be feasible under all B.C. operating conditions, even without the use of additives, and B5 has been demonstrated to be feasible in most of B.C. Given the lack of valid technical barriers to a significant increase in biodiesel use, it appears that suppliers who are not blending biodiesel at these levels have chosen to rely on alternative means to achieve compliance.

Lack of the use of additives and/or B2 continues to be a significant oversight, as this could significantly increase the quantity of biodiesel supplied without noticeable impact on the consumers. The lack of availability of B20 in the market is also a concern.

Suppliers have yet to offer the expected diversity of fuels and associated pricing that will allow consumers access to low carbon alternatives. Fuel suppliers must address issues within their control, including supporting retailers and consumers in transitioning to a market with an increased diversity of fuels, including B2, B20, E85, and blender pumps.

Claims of a lack of consumer demand for any low carbon fuels are not consistent with market information from the U.S. When fuels are made available at attractive prices, consumers will buy them. Suppliers need to factor in their need to generate compliance when pricing fuels.

Renewable gasoline and diesel will have significant impact on carbon intensity when they become available, as there are no blend limits. Renewable fuel costs will likely remain higher than their fossil counterparts for several years, and will not be able to compete with cheaper petroleum without mandates. HDRD is a form of renewable diesel that is available in the market today, but there is strong competition for the product that is currently available, and global demand is increasing.

In addition to actions that need to be taken by suppliers to achieve compliance, renewable fuel producers need to take a more active role in reducing the carbon intensity of their fuels and developing markets for their products.

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