CARBON INTENSITY OF
BC PROPANE MOTOR FUEL

Prepared For:

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EXECUTIVE SUMMARY

The Government of British Columbia has introduced the Renewable and Low Carbon Fuel Requirements Regulation (RLCFRR) to reduce British Columbia's reliance on non-renewable fuels, help reduce the environmental impact of transportation fuels and contribute to a new, low-carbon economy.

The RLCFRR provides a regulatory framework that enables the Province to set benchmarks for the amount of renewable fuel in B.C.'s transportation fuel blends, reduce the carbon intensity (CI) of transportation fuels, and meet its commitment to adopt a low-carbon fuel standard.

The RLCFRR is designed to reduce the carbon intensity of transportation fuels through two major requirements:

- The Renewable Fuel Requirement (RFR) (5 percent renewable content in gasoline beginning in 2010 and 3 percent renewable content in diesel in 2010, 4 percent in 2011, and 5 percent for 2012 onward); and
- The Low Carbon Fuel Requirement (LCFR) (30 percent reduction in carbon intensity by 2020).

The RFR requirement has no direct GHG emission performance requirement but the LCFR does require the obligated parties to determine the carbon intensity of the pool of products that they produce or import into BC. In order to do this, the carbon intensity of each unique fuel used in BC must be determined and reported on annually. Over time, the regulation will require a reduction in the GHG emissions of each primary supplier's pool of transportation fuels. The period up to July 1, 2013 was a reporting only period but as noted above the reduction expected in 2020 is 10% below the established baseline.

For propane the province has established a default value of 75.35 g CO_2eq/MJ. This is close to the value in GHGenius for propane produced in an oil refinery and much higher than the GHGenius value of 64.88 g CO_2eq/MJ for propane produced by gas plants.

The supply and demand data for British Columbia does not support the current position of using propane from refineries for the determination of the default carbon intensity for the product. The BC refineries produce about 1.1% of the propane that is produced in the province. Furthermore, the current demand for propane as a transportation fuel in BC exceeds the available supply from BC refineries by a significant margin.

The propane market in British Columbia is relatively large and complex with two distinct types of supplies, many suppliers, inter-provincial movements, and users in essentially every sector of the economy. In spite of this complexity, it is apparent from the available data that is available that the supply is dominated by the gas plant supply, with the two oil refineries in the province having a very minor share of the markets.

The estimated maximum share of the propane energy demand in the province that could be supplied by the oil refineries is 5%. Using this value will produce a conservative carbon intensity of LPG under the BC regulations. If fuel producers can demonstrate that all of their production is from gas plants then using the gas plant value may be appropriate.

The modelling of GHG emissions for propane motor fuel in British Columbia has been undertaken using the version of the GHGenius model (4.03a) that has been specified in the BC LCFS regulations.

The lifecycle emissions for the propane motor fuel in BC are shown in the following table. All of the emissions are from running the model for the BC region.

If fuel suppliers can demonstrate that all of the propane sold in BC is from gas plants then the appropriate CI would be 64.63 g/MJ.

Table ES- 1 CI BC Propane

	Oil Refinery Propane	Gas Plant Propane	93% Gas Plant/7% Refinery
	g CO_2eq/GJ		
Fuel dispensing	34	34	34
Fuel distribution and storage	524	524	524
Fuel production	2,022	2,412	2,390
Feedstock transmission	85	0	5
Feedstock recovery	5,457	2,780	2,927
Feedstock upgrading	5,973	0	327
Land-use changes, cultivation	263	0	14
Fertilizer manufacture	0	0	0
Gas leaks and flares	2,215	625	712
CO_2, H_2S removed from NG	0	994	939
Emissions displaced	-173	0	-9
Sub-Total	16,400	7,368	7,863
Fuel Combustion	57,261	57,261	57,261
Grand Total	72,661	64,629	65,124
CI, g CO_2eq/MJ	72.66	64.63	65.12

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1. INTRODUCTION

The Government of British Columbia has introduced the Renewable and Low Carbon Fuel Requirements Regulation (RLCFRR) to reduce British Columbia's reliance on non-renewable fuels, help reduce the environmental impact of transportation fuels and contribute to a new, low-carbon economy.

The RLCFRR provides a regulatory framework that enables the Province to set benchmarks for the amount of renewable fuel in B.C.'s transportation fuel blends, reduce the carbon intensity (CI) of transportation fuels, and meet its commitment to adopt a low-carbon fuel standard.

The RLCFRR is designed to help diversify B.C.'s transportation fuel supply, decrease GHG emissions and establish a market for low-carbon fuels by:

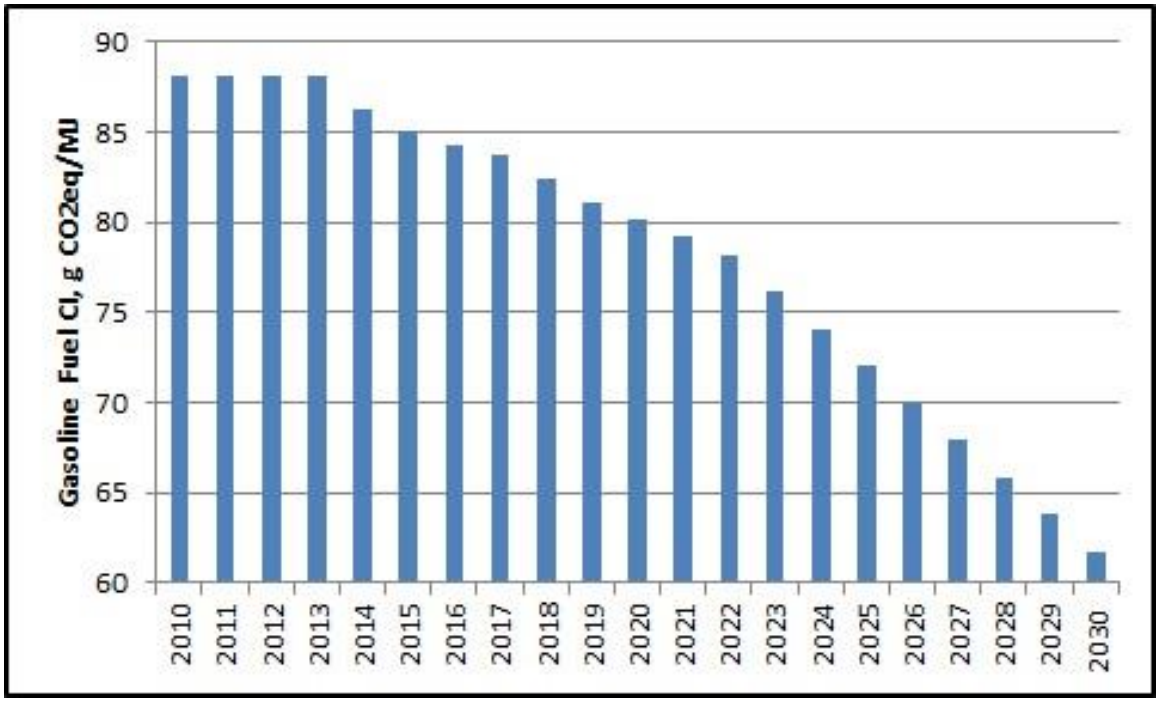
- Encouraging suppliers to determine how best to meet the requirements in accordance with consumer demand and market forces;
- Reducing reliance on non-renewable fuels; and
- Enabling requirements that encourage emerging cleaner fuel technologies.

The RLCFRR is designed to reduce the carbon intensity of transportation fuels through two major requirements:

- The Renewable Fuel Requirement (RFR) (5 percent renewable content in gasoline beginning in 2010 and 3 percent renewable content in diesel in 2010, 4 percent in 2011, and 5 percent for 2012 onward); and
- The Low Carbon Fuel Requirement (LCFR) (30 percent reduction in carbon intensity by 2030).

The RFR requirement has no direct GHG emission performance requirement but the LCFR does require the obligated parties to determine the carbon intensity of the pool of products that they produce or import into BC. In order to do this, the carbon intensity of each unique fuel used in BC must be determined and reported on annually. Over time, the regulation will require a reduction in the GHG emissions of each primary supplier's pool of transportation fuels. The period up to July 1, 2013 was a reporting only period but as noted above the reduction expected in 2030 is 30% below the established baseline.

Figure 1-1 BC LCFS Carbon Intensity Profile - Gasoline



Under the regulations, this CI must currently be calculated using version 4.03a of GHGenius. GHGenius is a spreadsheet tool that implements lifecycle assessment for transportation fuels. It is used to calculate the amount of greenhouse gases generated from the time a fuel is extracted or grown to the time that it is combusted in a motive energy vehicle to produce power. GHGenius has been developed by (S&T)^2 Consultants Inc. and was supported by Natural Resources Canada.

For propane, the Province has established a default value of 75.35 g CO_2eq/MJ (Renewable and Low Carbon Fuel Requirements Regulation). The default value is based on propane imported from US oil refiners as that is the most conservative case. However, most propane is produced by natural gas processing facilities and this supply chain has a lower carbon intensity than the product supplied by refineries.

1.1 SCOPE OF WORK

The work has reviewed the supply and demand situation for propane in the Province of BC to determine the appropriate GHGenius value that should be used for the carbon intensity of propane used for transportation purposes in British Columbia for the 2023 compliance year.

1.2 GHGENIUS

The GHGenius 4.03a model was developed for Natural Resources Canada between 2003 and 2015. It is based on the 1998 version of Dr. Mark Delucchi's Lifecycle Emissions Model (LEM). GHGenius is capable of analyzing the energy balance and emissions of many contaminants associated with the production and use of traditional and alternative transportation fuels.

GHGenius is capable of estimating life cycle emissions of the primary greenhouse gases and the criteria pollutants from combustion and process sources. The specific gases that are included in the model include:

- Carbon dioxide (CO_2),
- Methane (CH_4),
- Nitrous oxide (N_2O),
- Chlorofluorocarbons (CFC-12),
- Hydro fluorocarbons (HFC-134a),
- The CO_2-equivalent of all of the contaminants above.
- Carbon monoxide (CO),
- Nitrogen oxides (NOx),
- Non-methane organic compounds (NMOCs), weighted by their ozone forming potential,
- Sulphur dioxide (SO_2),
- Total particulate matter.

The model is capable of analyzing the emissions from conventional and alternative fuelled internal combustion engines or fuel cells for light duty vehicles, for class 3-7 medium-duty trucks, for class 8 heavy-duty trucks, for urban buses and for a combination of buses and trucks, for light duty battery powered electric vehicles, and for marine vessels. There are over 200 vehicle and fuel combinations possible with the model.

GHGenius can predict emissions for past, present and future years through to 2050 using historical data or correlations for changes in energy and process parameters with time that are stored in the model. The fuel cycle segments considered in the model are as follows:

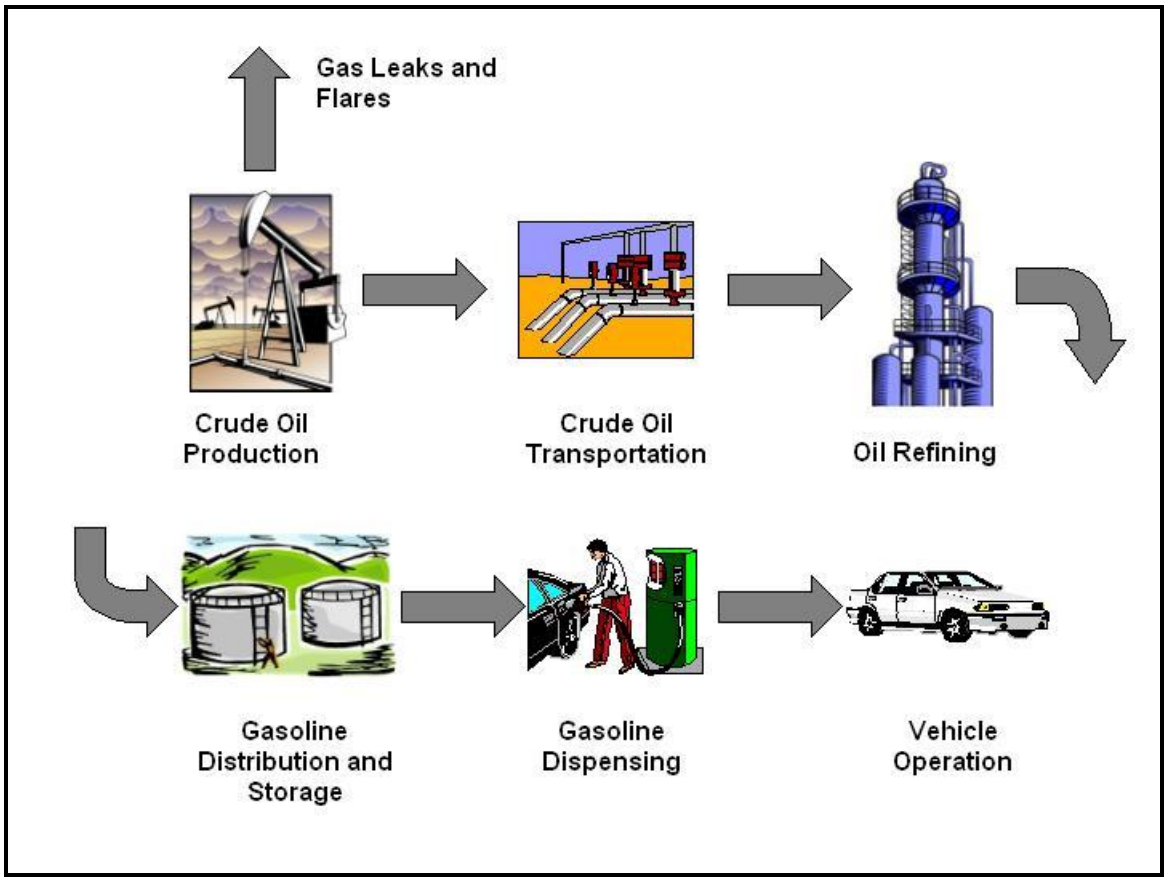
- Vehicle Operation
  Emissions associated with the use of the fuel in the vehicle. Includes all greenhouse gases.
- Fuel Dispensing at the Retail Level
  Emissions associated with the transfer of the fuel at a service station from storage into the vehicles. Includes electricity for pumping, fugitive emissions and spills.
- Fuel Storage and Distribution at all Stages
  Emissions associated with storage and handling of fuel products at terminals, bulk plants and service stations. Includes storage emissions, electricity for pumping, space heating and lighting.
- Fuel Production (as in production from raw materials)
  Direct and indirect emissions associated with conversion of the feedstock into a saleable fuel product. Includes process emissions, combustion emissions for process heat/steam, electricity generation, fugitive emissions and emissions from the life cycle of chemicals used for fuel production cycles.
- Feedstock Transport
  Direct and indirect emissions from transport of feedstock, including pumping, compression, leaks, fugitive emissions, and transportation from point of origin to the fuel refining plant. Import/export, transport distances and the modes of transport are considered. Includes energy and emissions associated with the transportation infrastructure construction and maintenance (trucks, trains, ships, pipelines, etc.)
- Feedstock Production and Recovery

Direct and indirect emissions from recovery and processing of the raw feedstock, including fugitive emissions from storage, handling, upstream processing prior to transmission, and mining.

- Feedstock Upgrading
  Direct and indirect emissions from the upgrading of bitumen to synthetic crude oil at a standalone facility, including fugitive emissions.
- Fertilizer Manufacture
  Direct and indirect life cycle emissions from fertilizers, and pesticides used for feedstock production, including raw material recovery, transport and manufacturing of chemicals. This is not included if there is no fertilizer associated with the fuel pathway.
- Land use changes and cultivation associated with biomass derived fuels
  Emissions associated with the change in the land use in cultivation of crops, including N_2O from application of fertilizer, changes in soil carbon and biomass, methane emissions from soil and energy used for land cultivation.
- Carbon in Fuel from Air
  Carbon dioxide emissions credit arising from use of a renewable carbon source that obtains carbon from the air.
- Leaks and flaring of greenhouse gases associated with production of oil and gas
  Fugitive hydrocarbon emissions and flaring emissions associated with oil and gas production.
- Emissions displaced by co-products of alternative fuels
  Emissions displaced by co-products of various pathways. System expansion is used to determine displacement ratios for co-products from biomass pathways.
- Vehicle assembly and transport
  Emissions associated with the manufacture and transport of the vehicle to the point of sale, amortized over the life of the vehicle.
- Materials used in the vehicles
  Emissions from the manufacture of the materials used to manufacture the vehicle, amortized over the life of the vehicle. Includes lube oil production and losses from air conditioning systems.

The main lifecycle stages for gasoline are shown in the following figure.

Figure 1-2 Lifecycle Stages – Gasoline



For this work, the GHGenius model version 4.03a has been set to 2023 and the 2007 IPCC GWPs in accordance with the BC Regulations.

2. PROPANE DEMAND

Propane is used in a variety of applications in the Province of BC from fuel for outdoor barbeques to fuel for light and medium duty vehicles in the Province. It has been used as a transportation fuel for more than 40 years in British Columbia.

Some information on propane use in British Columbia is available from Statistics Canada (2023) data on energy supply and demand, but some data is redacted (producer consumption and non-energy use). The available information is summarized in the following table.

Table 2-1 Propane Demand in BC

	2019	2020	2021	2022
	Litres			
Energy use, final demand	378,600,000	298,600,000	327,900,000	337,700,000
Total industrial	81,500,000	70,100,000	74,300,000	73,300,000
Total transportation	153,900,000	118,400,000	131,400,000	134,900,000
Agriculture	7,200,000	5,500,000	6,100,000	10,800,000
Residential	46,500,000	35,800,000	39,700,000	40,100,000
Commercial and other institutional	89,500,000	68,800,000	76,400,000	78.600,000

Statistics Canada. Table 25-10-0026-01 Supply and demand of natural gas liquids, annual

In 2022, the last year that this data is available, transportation demand was 135 million litres and represented about 40% of final demand for energy use. This value of 40% has been quite stable over the years.

3. PROPANE SUPPLY IN BC

Propane supply in BC is derived from three sources, refineries, gas plants that process natural gas before it enters the pipeline system to remove the gas liquids to ensure that the gas entering the pipeline meets specifications, and imports. Each of these sources produces similar products but the carbon intensities of the different production systems and supply chains are different.

3.1 GAS PLANTS

There are several data sources for propane production in BC and Canada and each source has slightly different coverage of the data.

3.1.1 BC Gas Plants

The total propane supply from BC gas plants is no longer available from Statistics Canada as the data is now redacted. However, the information on exports, imports, and availability is still available and that should allow a calculation of the BC production. that information is shown in the following table.

Table 3-1 BC Gas Plant Propane Production

	2019	2020	2021	2022
	Million Litres			
Production (calculated)	3,414.70	4,320.60	5,253.00	5,546.10
Exports	2,864.30	3,798.90	4,712.90	4,937.40
Imports	22.4	23.9	26.4	5.9
Availability	572.8	545.6	566.5	614.6

Statistics Canada. Table 25-10-0026-01 Supply and demand of natural gas liquids, annual

Propane imports in 2022 were about 2% of the BC demand. Propane imports declined significantly in 2022.

Some gas plant production information is available from the BC Ministry of Energy Mines and Petroleum Resources. Gas plant propane production continues to increase as shown in the following table.

Table 3-2 BC Gas Plant Propane Production

	2019	2020	2021	2023
	1,000 Litres			
Production	2,221,834	2,089,866	2,360,521	2,745,462

Source: BC Energy Mines and Low Carbon Innovation

The supply of propane from BC gas plants is more than 8 times the BC demand for propane using the BC data and 16 times higher using the StatsCan data.

3.1.2 Canadian Gas Plants

The production and disposition data for Canada is available from Statistics Canada and that data is shown in the following table. As with BC gas plant production, the production in all of Canada is also increasing.

Table 3-3 Canada Gas Plant Propane Production

	2019	2020	2021	2022
	Million Litres			
Production	15,832.0	14,953.9	15,804.6	16,887.9
Exports	10,834.1	9,293.7	11,838.4	11,245.9
Imports	281.9	345.3	300.4	87.7
Availability	6,722.0	6,728.0	6,909.7	7,362.8

Statistics Canada. Table 25-10-0026-01 Supply and demand of natural gas liquids, annual

Propane imports into Canada in 2022 also shown a sharp decline in 2022 compared to previous years.

3.2 REFINERIES

With only two BC refineries the propane supply data is redacted in all of the available data sources.

The refinery supply of propane at the Canada level is redacted in the NGL supply and demand file from Statistics Canada (2023) but it is not fully redacted in the refinery production data from Statistics Canada (2023b). This information is available monthly and the sum of the available monthly data is used to generate an annual value. That information is shown in the following table.

Table 3-4 Canada Refinery Propane Production

	2019	2020	2021	2022
	1000 Litres			
Production	1,247,655	1,196,169	1,233,726	1,179,770
% of Total domestic production	8.0%	8.0%	7.9%	7.0%

Statistics Canada. Table 25-10-0081-01 Petroleum products by supply and disposition, monthly

The two BC refineries account for only 2.5% of the Canadian refinery throughput. Assuming that the production rate is similar at all refineries, then the BC refinery propane production rate will be about 29 million litres per year, or about 1.1% of the BC propane production.

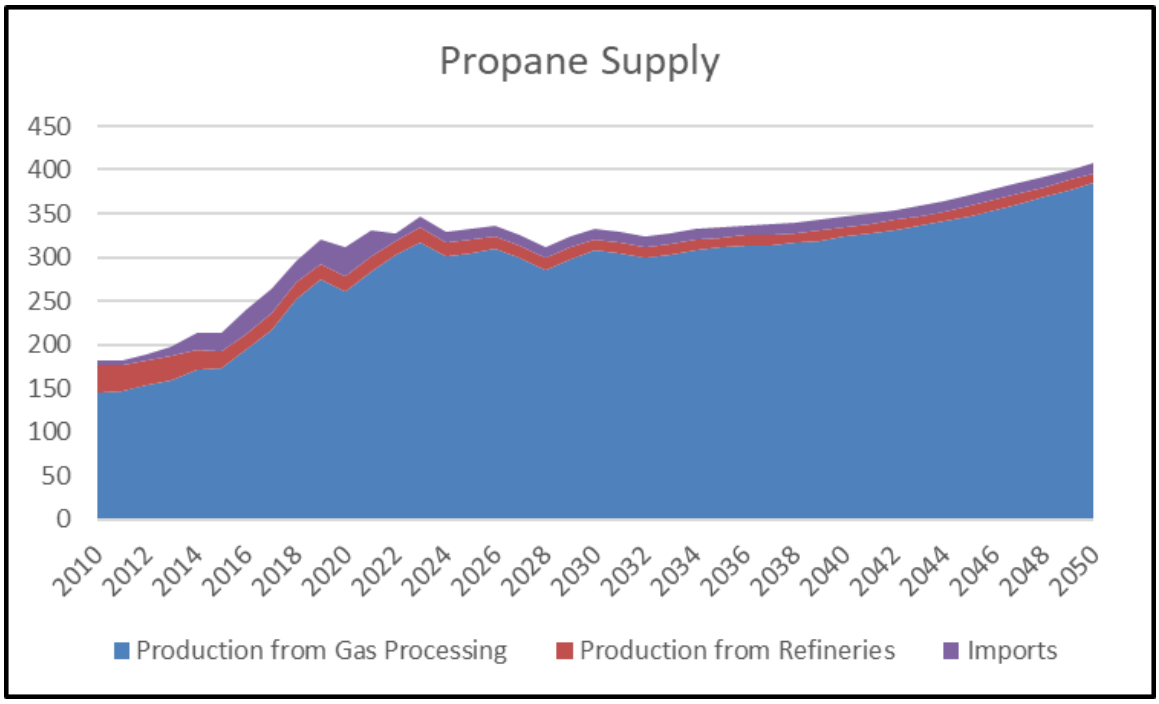
3.3 PROPANE IMPORTS

Propane imports into BC (Table 3-1) and Canada (Table 3.2) declined significantly in 2022 compared to previous years. BC imports represent less than 1% of the propane availability according to the StatsCan data and at the national level the value is 1.2%.

4. PROPANE SUPPLY IN CANADA

The historical propane supply data for all of Canada is also available from the Canada Energy Regulator (Canada's Energy Future, 2023). The historical data and the 2023 projection (Current Measures scenario) are shown in the following figure. Similar to the other data sets there has been a large increase in production from gas plants over the past five years. At the same time the production from refineries has declined.

Figure 4-1 Canada Propane Production

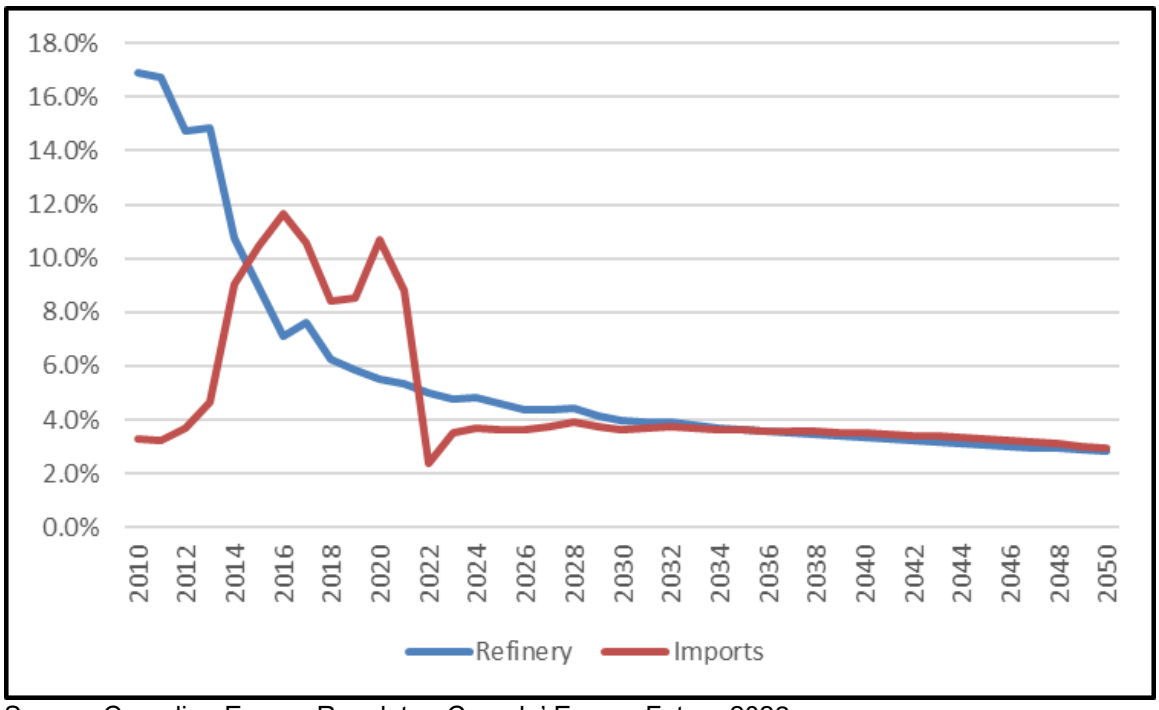


Source: Canadian Energy Regulator. Canada' Energy Future 2023.

There have been significant changes in the supply situation since 2010. The average value for the quantity of propane supplied by Canadian refineries has dropped from 17% in 2010 to 5% in 2022 as the gas plant production has increased and refinery production has decreased. There has been a 42% reduction in refinery propane production between 2010 and 2012.

The following figure shows the refinery production and the imports as a percentage of supply for the historical period of 2010 to 2022 and the forecast from 2023 to 2050. As the other datasets have shown propane imports dropped significantly in 2022 and are forecast to remain below historical levels through to 2050.

Figure 4-2 Refinery Production and Imports



Source: Canadian Energy Regulator. Canada' Energy Future 2023.

5. GHGENIUS VALUES

The supply and demand data for British Columbia does not support the current position of using propane from refineries for the determination of the default carbon intensity for the product. The BC refineries now only produce about 1.1% of the propane that is produced in the province as gas plant production has increased in recent years. Furthermore, the current demand for propane as a transportation fuel in BC exceeds the available supply from BC refineries by a significant margin.

5.1 BRITISH COLUMBIA

The propane market in British Columbia is relatively large and complex with two distinct types of supplies, many suppliers, inter-provincial movements, and users in essentially every sector of the economy. In spite of this complexity, it is apparent from the data that is available that the supply is dominated by the gas plant supply, with the two oil refineries in the province having a very minor share of the total propane markets.

The estimated maximum share of the propane energy demand in the province that could be supplied by the oil refineries is 5% (the estimated refinery production divided the end use energy demand). This could set a conservative value for the propane CI as it is also likely that gas plant propane may be preferable for transportation applications due to quality issues.

To arrive at the values in the following table, the model year has been set to 2023. The mixed supply propane value is determined by setting cells E35 and E36 on the Fuel Char sheet to 0.95 from the default value of 0.86. All of the other values in the model use the default values. The propane results are then found in columns M, N, and O on the Upstream Results HHV sheet.

Table 5-1 CI Values for Propane – BC GHGenius 4.03a

	Oil Refinery Propane	Gas Plant Propane	95% Gas Plant/5% Refinery
	g CO_2eq/GJ		
Fuel dispensing	34	34	34
Fuel distribution and storage	524	524	524
Fuel production	2,022	2,412	2,390
Feedstock transmission	85	0	5
Feedstock recovery	5,457	2,780	2,927
Feedstock upgrading	5,973	0	327
Land-use changes, cultivation	263	0	14
Fertilizer manufacture	0	0	0
Gas leaks and flares	2,215	625	712
CO_2, H_2S removed from NG	0	994	939
Emissions displaced	-173	0	-9
Sub-Total	16,400	7,368	7,863
Fuel Combustion	57,261	57,261	57,261
Grand Total	72,661	64,629	65,124
CI, g CO_2eq/MJ	**72.66**	**64.63**	**65.12**

If fuel suppliers can demonstrate that all of the propane sold in BC is from Gas plants then the appropriate CI would be 64.63 g/MJ.

6. REFERENCES

BC Energy Mines and Low Carbon Innovation. 2023. B.C. By-Products Production. https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/natural-gas-oil/production-statistics/byproducts.xls

Canada Energy Regulator. 2023. Canada's Energy Future Data Appendices. Propane. DOI: https://doi.org/10.35002/zjr8-8x75

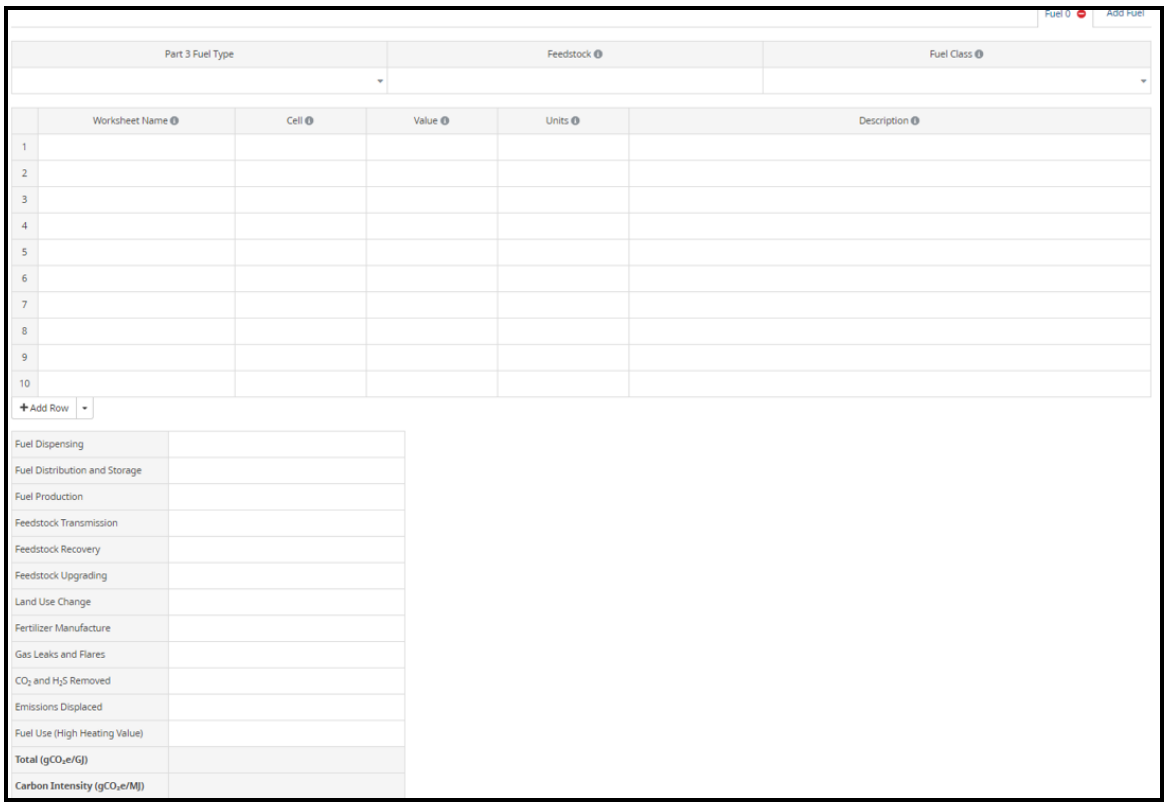
Statistics Canada. 2023b. Table 25-10-0081-01 Petroleum products by supply and disposition, monthly. https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=2510008101

Statistics Canada. 2023. Table 25-10-0026-01 Supply and demand of natural gas liquids, annual. https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=2510002601

7. APPENDIX

There is a schedule D form that must be completed as part of the annual compliance reporting. That is shown in the following figure.

Figure 7-1 Schedule D Compliance Report



The data that must be entered in this form is provided below for the propane from gas plants.

Part 3 Fuel Type: Propane
Feedstock: Natural Gas
Fuel Class: Gasoline

GHGenius Inputs

Worksheet	Cell	Value	Units	Description
Input	~E2	BC	None	Region
Input	B3	2023	None	Year

The results are shown in the following table

Fuel dispensing	34
Fuel distribution and storage	524
Fuel production	2,412
Feedstock transmission	0
Feedstock recovery	2,780
Feedstock upgrading	0
Land-use changes, cultivation	0
Fertilizer manufacture	0
Gas leaks and flares	625
CO_2, H_2S removed from NG	994
Emissions displaced	0
Fuel Combustion	57,261
Grand Total	64,629
CI, g CO_2eq/MJ	**64.63**

The data that must be entered in this form is provided below for the propane from oil refineries.

Part 3 Fuel Type: Propane
Feedstock: Crude Oil
Fuel Class: Gasoline

GHGenius Inputs

Worksheet	Cell	Value	Units	Description
Input	~E2	BC	None	Region
Input	B3	2023	None	Year

The results are shown in the following table

Fuel dispensing	34
Fuel distribution and storage	524
Fuel production	2,022
Feedstock transmission	85
Feedstock recovery	5,457
Feedstock upgrading	5,973
Land-use changes, cultivation	263
Fertilizer manufacture	0
Gas leaks and flares	2,215
CO_2, H_2S removed from NG	0
Emissions displaced	-173
Fuel Combustion	57,261
Grand Total	72,661
CI, g CO_2eq/MJ	**72.66**

The data that must be entered in this form is provided below for the propane from the blend of gas plants and oil refineries.

Part 3 Fuel Type: Propane
Feedstock: 95% Natuiral Gas/5% Crude Oil
Fuel Class: Gasoline

GHGenius Inputs

Worksheet	Cell	Value	Units	Description
Input	~E2	BC	None	Region
Input	B3	2023	None	Year
Fuel Char	E35	0.95	None	Fraction propane from gas plants
Fuel Char	E36	0.95	None	Fraction propane from gas plants

The results are shown in the following table

Fuel dispensing	34
Fuel distribution and storage	524
Fuel production	2,022
Feedstock transmission	85
Feedstock recovery	5,457
Feedstock upgrading	5,973
Land-use changes, cultivation	263
Fertilizer manufacture	0
Gas leaks and flares	2,215
CO_2, H_2S removed from NG	0
Emissions displaced	-173
Fuel Combustion	57,261
Grand Total	72,661
CI, g CO_2eq/MJ	**72.66**