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Renewable and Low Carbon Fuel Requirements Regulation

Using GHGenius in B.C.

Information Bulletin RLCF-010

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1. Who should read this guide?

This guide is intended for a transportation fuel producer or supplier operating in the British Columbia marketplace who intends to use the approved version of GHGenius to apply for an approval of the carbon intensity of a low carbon fuel under section 6 (6) of the *Greenhouse Gas Reduction (Renewable and Low Carbon Fuel Requirements) Act* (the Act), or who will be relying on section 6 (5) (d) (ii) (A) of the Act to determine the carbon intensity of a Part 3 fuel for the purposes of creating a carbon intensity record (see *RLCF-006 – Carbon Intensity Records*).

GHGenius is a Microsoft Excel-based model that analyzes greenhouse gas (GHG) emissions created in transportation fuel production and use. Many of the sheets in the model contain values for key process-specific variables related to the lifecycle of the fuel.

GHGenius is a mature modelling approach that can be used to develop ISO compliant lifecycle assessments (LCAs). There are specific steps that must be taken to ensure the consistency of the GHGenius results. The instruction manual for using version 4.03 is available on the GHGenius website located at www.GHGenius.ca.

This guide supplements the GHGenius instruction manual to assist the user in ensuring that their results are consistent with the requirements of the Regulation.

2. Collection of data

In order to ensure that an accurate carbon intensity is calculated for a fuel, the producer or supplier will need to collect the best possible data as well as estimates of the uncertainty in that data. To ensure that data is the best quality possible, suppliers may wish to establish a data management process; there are often a number of sources for the same data and these may need to be screened for quality.

ISO 14067 and the draft *Product Accounting and Reporting Standard* (World Business Council for Sustainable Development & World Resource Institute, 2010) outline a number of different types of data that might be used in conducting an LCA. Some data is of higher quality than others, but it is difficult to be sure which data type is the highest quality without analysis. It is expected that site-specific process data will be the maximum achievable quality. The following lists types of data as stated in ISO 14067 and the draft *Product Accounting and Reporting Standard*:

- Primary Data – Data obtained from a direct measurement or a calculation based on direct measurements at its original source
- Secondary Data – Data obtained from sources other than a direct measurement or a calculation based on direct measurements at the original source
- Activity Data – The quantified measure of a level of activity that results in GHG emissions or removals
- Emission Factors – GHG emissions per unit of activity data
- Direct Emissions Data – Emissions released from a process (or removals absorbed from the atmosphere) determined by direct measurement or similar procedure

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- Financial Data – Monetary measures of a process that result in GHG emissions or removals

ISO 14044:2006 defines “data quality” as “relating to data that meets stated requirements”. The following data quality requirements are defined by ISO 14044, and should be considered when assessing the data. Comments speak to what would be considered best practices for those aspects of the data.

Time-related coverage – Best practice would be to use data for the most recent period possible, and whenever possible the data should represent a full compliance year.

Geographic coverage – Best practice would be to use data for the geographical region in which a process occurs, and the data should be for the smallest relevant geographical region for which data is available.

Technological coverage – The data should adequately describe the specific technologies used.

Representativeness – The data should be assessed qualitatively to determine the degree to which the data set reflects the true population of interest.

Precision – If there is variance in values, a large enough set of data should be collected to derive a representative average value.

Completeness – Data for a full year is preferable to data for a shorter period.

Consistency – Data and the methodology used to compile it should be consistent with other data and methodologies in the model.

Reproducibility – The supplier should ensure that the results are reproducible by an independent practitioner, where appropriate.

Uncertainty – Data uncertainty should be minimized, and documented wherever possible. Any assumptions should be explained, with evidence of their validity.

In most cases, GHGenius users should only change GHGenius values when they have Primary Data for the fuel pathway.

3. Identifying the data to be collected

GHGenius allows the user to provide primary data that is specific to the fuel produced, creating a more accurate determination of the carbon intensity of that fuel. In order to determine an accurate carbon intensity, the supplier will need to collect high quality data, as poor data will not create a true representation of the fuel.

A number of the input cells on the sheets are marked with a yellow background colour and can be altered without creating inconsistency in the model. The yellow cells include variables such as transportation distances for the fuel and feedstock, energy use at the fuel production facility and – in the case of biofuels – the volume of feedstock per litre of fuel produced, and the quantity of chemicals used in the process. LCA modelling is based on a systems approach, and parameters should not be changed without consideration of other factors. For instance, when considered in isolation, higher-yielding crop years would decrease carbon intensity, but if the increase in crop yield is a result of an increased use of high greenhouse gas emission fertilizer, the carbon intensity may actually increase. Only a full analysis of the agricultural practices would determine the actual carbon intensity.



Normal use of GHGenius permits changing the values of any of the yellow cells in the model, provided that ISO practices are followed. Fuel suppliers are expected to make best efforts to collect data directly related to the fuel production pathway wherever possible.

While most data fields may be modified if supporting evidence is available, producers and suppliers should generally modify only data relevant to their specific fuel. Some yellow cell fields relate only to single fuels, while others affect multiple fuels. Producers and suppliers should refrain from modifying data that impacts multiple fuels unless sufficient evidence to support their claims can be provided. To provide general guidance on determining which fields may be modified, the factors that influence a fuel production pathway are provided below.

3.1. Factors related to fuel production and distribution.

These are likely under direct control or influence of the fuel manufacturer:

- Amount of energy used at the fuel production facility, for each type of energy (e.g. natural gas, electricity, coal, diesel, biofuels, etc.).
- Mass balance data regarding the quantities of key input chemicals and feedstock in the fuel production facility.
- Fuel storage and distribution distance fuel is transported by each mode (rail, domestic water, international marine, pipeline, tram, conveyor, truck).
- If electricity is produced as a co-product, the amount of electricity sold back to the grid, and the generation profile of the grid into which the electricity is sold.
- Fuel production yield.

3.2. Factors related to feedstock production

These are not likely to be directly influenced by the fuel supplier:

- The distance the feedstock is transported by each mode (rail, domestic water, international marine, pipeline, tram, conveyor, truck).
- For biofuels, quantities of nitrogen fertilizer, phosphorus, potassium, lime, sulphur, pesticide and seed types used.
- The fraction of feedstock grown on land released due to reduced summer fallow, fraction of crop grown with no-till or reduced till management, fraction of total residue (including roots) left in the field.
- Agricultural yield, when considered in the full context of agricultural practices for feedstock production.
- Energy consumed in producing the feedstock (diesel, residual fuel, natural gas, coal, electricity, LPG, biofuel).

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3.3. Factors which may influence all fuels of the same type

These factors should not be changed in a carbon intensity determination:

- Carbon from air incorporated in fuel. This value would affect all fuels based on the same feedstock, and is based on unvarying chemical composition of the feedstock.
- Direct land use change. This value is based on regional data, not specific operations.
- Fertilizer and pesticide manufacture.
- Vehicle or vessel operation fuel consumption data. (Note: if the fuel was supplied to a fleet of known vehicles, vehicle consumption data could be included.).
- U.S. EPA AP-42 emission factors for criteria pollutants.
- Population-wide ultimate emission factors.
- Relative drive train efficiencies.

4. Dealing with data gaps

Fuel producers and suppliers may encounter difficulty collecting data. The default values in GHGenius should be regarded as the best quality data available if no better source is available.

For example, a fuel supplier may be the importer of the fuel into British Columbia, but they may not know the distance the fuel will be transported within the province. Therefore, the supplier may use a default value for the fuel transportation distance.

5. Deciding what GHGenius option choices to make

In order to accurately determine the carbon intensity of a specific transportation fuel, data input options will need to be determined. For instance, the “Input” sheet in GHGenius has options that include the following instructions:

- Set the geographic regions for fuel production, vehicle use, transportation of feedstock and fuel, and electricity generation.
- For hydrogenation-derived renewable diesel, set the feedstock.
- For natural gas, set whether the gas is compressed or liquefied.
- For hydrogen, set whether it is compressed or liquefied.
- For ethanol, identify the possible use of carbon sequestration.

A single set of input options may not accurately reflect all of the pathway components of a fuel. Factors such as production facility energy use, fuel storage and distribution distance, co-product generation and fuel production yield affect the final carbon intensity of the fuel. In some cases, the model may need to be run a number of times with different inputs in order to produce results for specific components of the life cycle as GHGenius uses a single region for a full pathway. Further details will be provided below.



6. Determining the number of times to run the model

If a fuel pathway is entirely within B.C., GHGenius will likely need to be run only once. In the majority of cases, however, a single set of data and option inputs does not represent the fuel pathway, such as the case when feedstock and fuel production processes occur in different locations. In these cases, more than one run of the model will be necessary. For example, feedstock production could occur in Canada, using Canadian agricultural practices, while fuel production could occur in the U.S. Midwest. In this case, multiple runs will be necessary to calculate respective components of the life cycle emissions of the fuel pathway.

Producers and suppliers need to determine the required number of model runs to calculate the total fuel pathway component emissions. If more than one run is needed, it will be necessary to execute a final run to determine the emissions that were accounted for twice from electricity use in Fuel Distribution and Storage. When all runs have been completed, the carbon intensity of the fuel is determined by summing the emissions from the relevant model runs for each of the twelve components.

Example

In order to illustrate the process of determining the carbon intensity of a fuel, working examples with explanations are presented in the appendices of this document. One of these examples determines the carbon intensity of ethanol made from corn in 2015. In order to perform the analysis, the following information is used:

- a. The corn is grown in U.S. Central and transported 1,750 km by rail from the field to the ethanol production facility in Lethbridge, Alberta.
- b. The finished ethanol fuel is transported 1,800 km by rail to Vancouver, B.C. and then distributed 80 km by truck within Vancouver.

In this example, four model runs are needed to determine the value of each of the lifecycle components for the fuel:

1. One for U.S. Central where the corn is grown,
2. One for Alberta where the ethanol is produced,
3. One for B.C. where the fuel is consumed, and
4. One to account for electricity-related emissions that are double-counted by the multiple runs.

7. Key steps for calculating a carbon intensity

The model can be downloaded from the GHGenius website, <http://www.GHGenius.ca>. The user will need to register on the GHGenius forum to be able to download the model. The model is located in the Resources section under Forums and the sub-forum BC LCFS GHGenius Model on the GHGenius website.

The approved model version for British Columbia is 4.03; see *RLCF-011 – Approved Version of GHGenius* for more information. Under the Regulation, 4.03 is required when calculating the carbon intensity of all fuels supplied starting January 1, 2015 and onwards.

There are specific steps that must be taken to ensure the consistency of the GHGenius results. The order in which buttons are selected in GHGenius has an impact on the data calculated in the model. For every model run, the region must be selected first as this will also input some default transportation distances that may not be correct for the actual fuel pathway being modelled.

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To assist the reader, the following section describes the steps for calculating the carbon intensity of a fuel, with the final section of this document being worked examples that are presented in Appendix A.

7.1. Initializing the model for use

To use GHGenius the user will need to enable macros and agree to the user agreement as follows:

1. To enable macros in GHGenius, open the model in excel and click the “enable content” button on the yellow message bar just above the spreadsheet. Alternatively, macros can be enabled by clicking “File” > “Options” > “Trust Center” > “Trust Center Settings” > “Macro Settings” and enabling all macros. The model will automatically move to the “Index” page.
2. To agree to the user agreement, scroll down on the Index page (row 123) and click “I Agree”. The model will now set itself up for use and take the user directly to the “Input” sheet.
3. The IPCC value is 2007 (cell B6 on the “Input” sheet). This sets the global warming potential for emissions as developed by the Intergovernmental Panel on Climate Change (IPCC).

It is recommended to turn off “automatic calculations” in Excel before using GHGenius. This can be accomplished by selecting the formula tab at the top, selecting calculation options and then selecting “manual”.

7.2. Feedstock supply and fuel production data

First, select the appropriate regional default (row 2). GHGenius includes three Canadian regional defaults along with several Provinces. Canada East is the Atlantic Provinces, Canada Central is Ontario and Quebec, and Canada West is Manitoba, Saskatchewan, Alberta, and British Columbia. The model also includes three American regional defaults: U.S. West, U.S. Central and U.S. East.

Next, select the target year (cell B3). When selecting the target year, careful consideration is required to ensure that the correct year is chosen. When the carbon intensity of a fuel pathway is approved by the Ministry, it is given a unique fuel code with an effective date and an expiry date. In most cases, the effective period begins on the day the carbon intensity application was submitted to the Ministry. Therefore, the target should be the year in which the application was submitted. However, there are certain situations in which the target year will differ from the year of the application, as explained in the example below.

Example

A fuel producer is planning on submitting a carbon intensity application to the Ministry on March 1, 2016. The fuel producer is requesting that the fuel’s effective date be made retroactive to December 1, 2015. The reason for the request is because the fuel producer is aware that their fuel was imported into B.C. in early December 2015. Assuming the request is approved, the fuel pathway’s effective date will be December 1, 2015. Therefore, the target year in the GHGenius analyses must also be set to 2015.

Once the regional default and target year have been selected, input all of the data collected regarding the life cycle analysis of the fuel produced. The model can then be run and values for that fuel will be calculated. This step might require the model to be run several times if the feedstock is produced and processed in another location with significantly different agricultural processes. If feedstock supply and fuel production are in the same region, the model would likely only need to be run once for this step.

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7.3. Transportation mode fractions

The GHGenius model allows the user to enter the fraction for each mode of transport for a fuel or feedstock in the “Transportation of Feedstocks, Fuels, Vehicles, Etc.” area (starting in cell A68) on the “Input” page. For example, if 100% of the feedstock is moved by truck, the fraction is 1.0 in the corresponding cells. If the feedstock was moved by 80% truck and 20% rail, the corresponding values would be 0.8 for truck and 0.2 for rail.

There are factors in the model for the energy requirements to move the feedstock on a KJ/tonne-km basis. This method allows an estimate of the annual rate of improvement through increased efficiency over time to be included. The model calculates the energy consumed per tonne-km of product. The sum of the transportation modes must total at least 1.0, but can be higher due to some feedstocks and finished fuels moving by multiple modes.

7.4. Alternative fuel production base year

The GHGenius model allows the user to enter site-specific alternative fuel production data in the “Alternative Fuel Production” section (starting in cell A231) on the “Input” sheet. Data on electricity usage, natural gas / coal consumption, and feedstock input (per litre of finished fuel) can be entered in this section.

In row 234, the base year is set for the available alternative fuels. Each base year represents a specific set of conditions and default values within the GHGenius model. In order to accurately model the carbon intensity of a fuel, the base year must match the year represented by the data. For example, if the fuel production data is from 2015, then the base year (row 234) must also be set to 2015.

7.5. British Columbia values

This step creates the British Columbia values for fuel dispensing, fuel distribution and storage, and emissions from fuel use that will be created when the fuel is consumed in the province. On the “Input” sheet the regional default is B.C. (B.C. button in the Regional Defaults Box in row 2 and approximately column E). This sets the model to use the B.C. region values for transportation. To get the B.C. emissions for a fuel, the finished fuel transportation distance for alternative fuels needs to be set to 80 km by truck, the same as petroleum-based gasoline and petroleum-based diesel.

7.6. Electricity emissions double counting

The model is unable to avoid an overlap of electricity emissions from fuel distribution and storage when two jurisdictions are modeled. Therefore, the model will need to be run a final time to calculate the electricity that was counted twice. To do this, the model should be set to the fuel producing region and the transportation values of the finished fuel need to be removed and the model run again.

This will calculate the emissions that overlap between the two jurisdictions for fuel distribution and storage. The electricity overlap will be subtracted from the fuel distribution and storage values calculated for both jurisdictions. If the fuel is trans-loaded (moved from truck to rail) between B.C. and the production facility, this step does not need to be done.



7.7. Results

When GHGenius has completed calculations (“Ready” will be displayed in the lower left corner of the screen when complete) for each run, results are found in Table 54 on the “Upstream Results HHV” (High Heat Values) sheet on the bottom of the workbook. To find the fuel and feedstock combination you are analyzing, scroll right until the fuel you are calculating is listed. The High Heat Values represent the maximum heat that may be extracted from the combustion of a fuel when the water vapour from the product condenses; almost all commercial energy sales in North America are done on a HHV basis.

Copy and paste the correct column of values into a new excel workbook, ensuring you use paste special and select values and numbers formatting to ensure the values will replicate.

8. Documenting the process and reporting

As part of creating a carbon intensity record or when applying for the approval of a carbon intensity, fuel producers and suppliers are required to provide all of the information necessary for Ministry staff to verify and reproduce the carbon intensity calculations within the GHGenius model.

A carbon intensity record or carbon intensity approval application must also provide sufficient supporting information to enable the reader to understand how the data was gathered, how the carbon intensity was determined, and any assumptions that were made in the process.

Fuel producers and suppliers should ensure that the carbon intensity record or approval application, and the work done in preparing it, adheres to ISO standards for LCA as well as the requirements of the Ministry. Documentation that supports the LCA must be kept by suppliers and produced when required for inspection.

Need more information?

Please see the Renewable and Low Carbon Fuel website at <http://gov.bc.ca/lowcarbonfuels> or email us at lcfr@gov.bc.ca.

Or the GHGenius website at: <http://www.GHGenius.ca/>

This information is for your convenience and guidance only, and does not replace or constitute legal advice. The *Greenhouse Gas Reduction (Renewable and Low Carbon Fuel Requirements) Act* and the Renewable and Low Carbon Fuel Requirements Regulation can be found on the internet at: <http://www.bclaws.ca>.



Appendix A. Ethanol production example

The following information is used to determine the carbon intensity of ethanol made from corn in 2015:

- a. The corn is grown in U.S. Central and transported 1,750 km by rail from the field to the ethanol production facility in Lethbridge, Alberta.
- b. The finished ethanol fuel is transported 1,800 km by rail to Vancouver, B.C. and then distributed 80 km by truck within Vancouver.

In this example, four model runs are needed to determine the value of each of the lifecycle components for the fuel:

1. One for U.S. Central where the corn is grown,
2. One for Alberta where the ethanol is produced,
3. One for B.C. where the fuel is consumed, and
4. One to account for electricity-related emissions that are double-counted by the multiple runs.

Data used in this example is loosely based on an ethanol production process. Actual production processes data would be different, and could include more inputs or outputs than used in this example depending on the production process used by the plant. Any additional inputs would be included in the Production of Alternative Fuels (“Alt Fuel Prod”) and additional outputs would be included in the Co-Products Produced (“Coprods”) sheets.

The values for Plant Operation Data and Production of Alternative Fuels are for each litre of fuel produced at the plant.

In this example we are not modifying all of the potential inputs that are available on each sheet. The data that is left unchanged is default data saved in GHGenius and therefore is acceptable for this example. Each fuel pathway is unique; the methodology used in this example may not accurately represent the carbon intensity of all corn-based ethanol.

A.1. Collect the necessary data

Feedstock Production	Growing Corn	U.S. Central
Transportation	Corn from field to fuel production facility	1,750 km by rail
	Ethanol from fuel production facility to Vancouver, B.C.	1,800 km by rail
	Ethanol from Vancouver, B.C. to market	80 km by truck
Plant Operation Data (Energy and feedstock use)	Location	Alberta
	Target (Production) year	2015
	Base year	2015
	Electricity (kWh/litre)	0.203
	Energy (Natural Gas & Coal) (MJ/litre)	7.166
	Natural Gas share	1.0
	Coal share	0.0



	Feedstock yield (Kg/litre)	2.376
Production Chemicals (Used in production)	Ammonia (NH ₃) (Kg/litre)	0.01001
	Enzymes (Kg/litre)	0.00353
	NaOH (Kg/litre)	0.00472
	Sulphuric Acid (Kg/litre)	0.00876
	Yeast (Kg/litre)	0.00191

A.2. Create a workbook for model run results

To ease the calculation of the carbon intensity of a given fuel, we recommend setting up an additional Excel workbook, separate from the GHGenius model, to organize the results of your model runs.

1. Copy the following table into A1 of the new workbook:

Row	Source of Emissions
-	Region
7	Fuel/Fuel Precursor
8	Feedstock
9	Fuel dispensing
10	Fuel distribution and storage
11	Fuel production
12	Feedstock transmission
13	Feedstock recovery
14	Feedstock upgrading
15	Land-use changes, cultivation
16	Fertilizer manufacture
17	Gas leaks and flares
18	CO ₂ , H ₂ S removed from NG
19	Emissions displaced

- **Row** – Refers to location of the data for a given aspect of the lifecycle within the GHGenius output table (“Upstream Results HHV” sheet)
 - **Source of Emissions** – Refers to the various stages of a fuel’s lifecycle where emissions occur
2. Add a new column to the right for each region involved in the lifecycle of the fuel:
 - a. In the case of our example, there are three regions where stages of the fuel lifecycle take place: U.S. Central (feedstock production), Alberta (fuel production) and B.C. (fuel distribution, storage and use).
 - b. Since the lifecycle analysis in our example takes place across more than one region, we need to add a fourth column for the final model run that will calculate the electricity emissions that are double-counted.
 - c. Add a row directly below the table and label it “Emissions from fuel use” in Column B.

3. To complete the lifecycle analysis, we will need to compile the results from the various model runs.
 - a. For the region where the feedstock is grown and/or produced, include: Feedstock transmission and recovery as well as emissions from Land-use changes, and Fertilizer manufacture. These stages are highlighted in Blue on the table below.
 - b. For the region where fuel production occurs, include: Fuel distribution and storage, Fuel production and Emissions displaced. These are highlighted in Green.
 - c. For the region where the fuel is consumed, include: Fuel dispensing, Fuel distribution and storage and Emissions from fuel use. These cells are highlighted in Yellow.
 - d. Finally, to account for the overlap in electricity emissions from multiple regions, highlight the Fuel distribution and storage cell in Orange.

4. The finished results table should look like this:

Row	Source of Emissions	Feedstock Production	Ethanol Production	Fuel Use	Electricity usage
-	Region	U.S. Central	Alberta	B.C.	
7	Fuel				
8	Feedstock				
9	Fuel dispensing				
10	Fuel distribution and storage				
11	Fuel production				
12	Feedstock transmission				
13	Feedstock recovery				
14	Feedstock upgrading				
15	Land-use changes, cultivation				
16	Fertilizer manufacture				
17	Gas leaks and flares				
18	CO2, H2S removed from NG				
19	Emissions displaced				
	Emissions from fuel use				

A.3. Run 1: Components for feedstock production in “U.S. Central”

The first model run will calculate the values associated with growing corn in U.S. Central.

1. Open the model, enable macros and agree to the user agreement.
2. On the “Input” sheet:
 - a. Select U.S. Central as the regional default in the Regional Defaults Box in row 2 and approximately column H. The result will be displayed in cell G3.
 - b. Set the year of analysis (target year) to 2015, cell B3.
 - c. Verify that the IPCC value is set to 2007, cell B6 (value 2).



- d. Navigate to the transportation of feedstock and fuels section, starting at row 68 of the “Input” sheet. Enter the corn transportation component in column F “corn to plant” for the distance the feedstock travels to the fuel production facility.

In this example, corn is shipped via rail 1,750 km to the fuel production facility. Enter:

- i. “Average km shipped by rail” cell F78 = 1750
- ii. “Tonnes-shipped/tonnes-produced by rail” cell F84 = 1.0
- iii. Ensure that all other cells in that column = 0 (F79 – F82; F85 – F88 = 0)

- e. Scroll down to the Alternative Fuel Production section starting at row 231. This section allows the user to input the feedstock yield from the ethanol plant. In this model run, GHGenius uses this value in calculating emissions from producing and transporting the feedstock.

In this example, the feedstock yield is 2.376 kg / litre. In column S “E100 corn”, enter:

- i. “Base year ” cell S234 = 2015
- ii. “Corn/soybean/canola/wheat (feedstock yield)” cell S241 = 2.376

3. Scroll to cell A1 at the top of the “Input” sheet and click “Run Program”.
4. Navigate to the “Upstream Results HHV” sheet; find column S, “Ethanol Corn”.
 - a. Copy rows 7 to 19, and paste into the Results Table.

Remember to use “paste special → values and number formatting”.

With the U.S. Central feedstock values added, your Results Table should look like this:

Row	Source of Emissions	Feedstock Production	Ethanol Production	Fuel Use	Electricity usage
-	Region	U.S. Central	Alberta	B.C.	
7	Fuel	Ethanol			
8	Feedstock	Corn			
9	Fuel dispensing				
10	Fuel distribution and storage				
11	Fuel production				
12	Feedstock transmission	3,569			
13	Feedstock recovery	5,730			
14	Feedstock upgrading				
15	Land-use changes, cultivation	17,215			
16	Fertilizer manufacture	7,598			
17	Gas leaks and flares				
18	CO2, H2S removed from NG				
19	Emissions displaced				
	Emissions from fuel use				

A.4. Run 2: Fuel production in “Alberta”

The second model run will calculate the values associated with the fuel production in Alberta.

1. On the “Input” sheet in the same GHGenius workbook:
 - a. Set the model to Alberta (near cell E2). The result will be displayed in cell G3.



- b. Set the year of analysis (target year) to 2015, cell B3.
- c. Verify that the IPCC value is set to 2007, cell B6 (value 2).
- d. Locate the Finished Fuels transportation area on the “Input” sheet starting at row 90.

In this example, the ethanol is shipped 1,800 km by rail from Lethbridge, Alberta to Vancouver, B.C. In column S “ethanol corn”, enter:

- i. “Average km shipped by rail” cell S92 = 1800
- ii. “Tonnes-shipped/tonnes-produced by rail” cell S98 = 1.0
- iii. Ensure that all other cells in that column = 0 (S93 – S96; S99 – S102 = 0)

- e. Scroll down to the Alternative Fuel Production section starting at row 231 column A. The Alternative Fuel Production section allows inputs for fuel production from plant operation data.

This example will use general ethanol plant operation data from 2015. In column S “E100 corn”, enter:

- i. “Base year” cell S234 = 2015
- ii. “Corn/soybean/canola/wheat” (feedstock) cell S241 = 2.376

The ethanol production facility is located in Western Canada; in column D “Canada West”, enter:

- i. “Net electricity purchased” cell D246 = 0.203
- ii. “Total coal+NG” cell D247 = 7.166
- iii. “Natural gas share” cell D248 = 1.0
- iv. “Coal share” cell D249 = 0.0

- f. Scroll to the Fertilizer Manufacture, Application; Nutrient Loss; Land Use section starting at row 150 column A. In this model run, this section is used (1) to indicate the region in which the corn ethanol is produced, and (2) to indicate the region in which the products displaced by the ethanol co-products (i.e. corn meal and soybean meal displaced by distillers grains) are produced. See below for more information.

In this example, the corn ethanol is produced in Alberta. In column D “Canada West”, enter:

- i. “Corn Producing Region” cell D155 = 1.00
- ii. Ensure that all other cells in that row = 0 (B155 – C155; E155 – M155 = 0)

Note: When calculating fuel production emissions for corn ethanol production in GHGenius, the “Corn Producing Region” must be set to the same region as the fuel production facility. This is because the programming structure of GHGenius is such that it uses the ethanol plant electricity data from the region indicated within the “Corn Producing Region”. Recall in the previous section that the corn ethanol electricity usage data was entered into the “Canada West” column. In order for GHGenius to use that data in its calculation of fuel production emissions, the “Corn Producing Region” must also be set to “Canada West”. This interconnection only applies to corn-based ethanol production (and not other feedstocks used to produce ethanol).

The co-product (i.e. distillers grains) are produced at the ethanol facility in Alberta and then sold to local farmers as livestock feed. Since the distillers grains displace the need for local farmers to acquire livestock feed from another source (i.e. corn meal and soybean meal), this process can be credited in the lifecycle analysis of the ethanol. In this example, both corn meal and soybean meal are produced in Western Canada; we therefore indicate “Canada West” as the “Corn and Soybean Producing Regions” in GHGenius. The selection of the corn meal and soybean meal producing

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regions affects the Emissions displaced lifecycle stage calculation.

In column D “Canada West”, enter:

- i. “Soybean Producing Region” cell D171 = 1.00
- ii. Ensure that all other cells in that row = 0 (B171 – C171; E171 – M171 = 0)

Note: When calculating the carbon intensity of corn ethanol, the “Soybean Producing Region” should not be changed to a different region without having credible supporting evidence that the distillers grains are in fact displacing soybean meal produced within that other region.

2. Locate the “Alt Fuel Prod” sheet (to the right of the Input sheet).
 - a. Find column Z “E100 corn” and enter the remaining alternative fuel production inputs.
 - i. Ensure that all cells in that column = 0 (Z29 – Z51), then enter:
 - ii. “Ammonia” cell Z30 = 0.01001
 - iii. “Enzymes” cell Z33 = 0.00353
 - iv. “NaOH” cell Z40 = 0.00472
 - v. “Sulphuric Acid” cell Z50 = 0.00876
 - vi. “Yeast” cell Z51 = 0.00191

Note: We recommend entering zero into cells Z29 to Z51 before entering data to ensure that no small default values (smaller than three decimal places) get included in the carbon intensity calculation.

3. Navigate back to the “Input” sheet. Click “Run Program” in cell A1.
4. Locate the “Upstream Results HHV” sheet; find column S, “Ethanol Corn”.
 - a. Copy rows 7 to 19 and paste into the Results Table.
Again, remember to use “paste special → values and number formatting”.

With the Alberta values for corn ethanol added, your Results Table should look like this:

Row	Source of Emissions	Feedstock Production	Ethanol Production	Fuel Use	Electricity usage
-	Region	U.S. Central	Alberta	B.C.	
7	Fuel	Ethanol	Ethanol		
8	Feedstock	Corn	Corn		
9	Fuel dispensing				
10	Fuel distribution and storage		1,444		
11	Fuel production		27,813		
12	Feedstock transmission	3,569			
13	Feedstock recovery	5,730			
14	Feedstock upgrading				
15	Land-use changes, cultivation	17,215			
16	Fertilizer manufacture	7,598			
17	Gas leaks and flares				
18	CO2, H2S removed from NG				
19	Emissions displaced		-7,469		
	Emissions from fuel use				

A.5. Run 3: Distribution and consumption in B.C.

The third model run will calculate the values associated with the fuel storage, dispensing and use in B.C.

1. On the “Input” sheet in the same GHGenius workbook:
 - a. Set the regional default to B.C. by clicking the B.C. button in the Regional Defaults Box in row 2 and approximately column E. The result will be displayed in cell G3.
 - b. Set the year of analysis (target year) to 2015, cell B3.
 - c. Verify that the IPCC value is set to 2007, cell B6 (value 2).
 - d. Locate the Finished Fuels section (starting row 90); find column S.

The distance for the B.C. default for any fuel calculated will be 80 km by truck.

- i. “Average km shipped by truck” cell S96 = 80
 - ii. “Tonnes-shipped/ tonnes-produced by truck” Cell S102 = 1.0
 - iii. Ensure that all other cells in that column = 0 (S92 – S95; S98 – S101 = 0)
 2. Scroll to cell A1 at the top of the “Input” sheet and click “Run Program”.
 3. Locate the “Upstream Results HHV” sheet; find column S, “Ethanol Corn”.
 - a. Copy rows 7 to 19 and paste into the Results Table.
- Remember to use “paste special → values and number formatting”.**

With the British Columbia values for corn ethanol added, your Results Table should look like this:

Row	Source of Emissions	Feedstock Production	Ethanol Production	Fuel Use	Electricity usage
-	Region	U.S. Central	Alberta	B.C.	
7	Fuel	Ethanol	Ethanol	Ethanol	
8	Feedstock	Corn	Corn	Corn	
9	Fuel dispensing			56	
10	Fuel distribution and storage		1,444	482	
11	Fuel production		27,813		
12	Feedstock transmission	3,569			
13	Feedstock recovery	5,730			
14	Feedstock upgrading				
15	Land-use changes, cultivation	17,215			
16	Fertilizer manufacture	7,598			
17	Gas leaks and flares				
18	CO ₂ , H ₂ S removed from NG				
19	Emissions displaced		-7,469		
	Emissions from fuel use				

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Determining the British Columbia emissions from fuel use values

The emissions released when the fuel is burnt in an engine will need to be included in the carbon intensity calculation. This information is found on the “Exhaust Emissions” sheet in GHGenius.

4. Locate the “Exhaust Emissions” sheet (it is near the end).

Depending on which fuel class (gasoline or diesel) the fuel being produced qualifies for, either the light-duty vehicle exhaust emissions (gasoline) or the heavy-duty vehicle exhaust emissions (diesel) value will be needed.

In this example, ethanol is used as a replacement for gasoline in light-duty vehicles.

5. Find the “Light-Duty Vehicles: Calculated Emissions” section (Table 50d, row 66).
6. Copy the Net CO₂+non CO₂ (g/GJ) value from row 97 column I “Ethanol E100” and paste into the Results Table in the B.C. column.

Remember to use “paste special → values and number formatting”.

With the emissions from fuel use in B.C. added, your Results Table should look like this:

Row	Source of Emissions	Feedstock Production	Ethanol Production	Fuel Use	Electricity usage
-	Region	U.S. Central	Alberta	B.C.	
7	Fuel	Ethanol	Ethanol	Ethanol	
8	Feedstock	Corn	Corn	Corn	
9	Fuel dispensing			56	
10	Fuel distribution and storage		1,444	482	
11	Fuel production		27,813		
12	Feedstock transmission	3,569			
13	Feedstock recovery	5,730			
14	Feedstock upgrading				
15	Land-use changes, cultivation	17,215			
16	Fertilizer manufacture	7,598			
17	Gas leaks and flares				
18	CO ₂ , H ₂ S removed from NG				
19	Emissions displaced		-7,469		
	Emissions from fuel use			2,144	

A.6. Run 4: Determining electricity usage

The fourth model run will calculate the values associated with the overlap of electricity use between regions.

1. On the “Input” sheet in the same GHGenius workbook:
 - a. Set the model to Alberta (near cell E2). The result will be displayed in cell G3.
 - b. Set the year of analysis (target year) to 2015, cell B3.



- c. Verify that the IPCC value is set to 2007, cell B6 (value 2).
- 2. Locate the Finished Fuels section (starting row 90); find column S.
 - i. “Average km shipped by truck” cell S96 = 0.01
 - ii. “Tonnes-shipped/ tonnes-produced by truck” cell S102 = 1.0
 - iii. Ensure that all other cells in that column = 0 (S92 – S95; S98 – S101 = 0)

Note: The small value in cell S96 is necessary for the transportation distance or the model will not run correctly; the effect of this practice on final emissions is negligible.

- 3. Scroll up and select “Run Program” in cell A1.
 - 4. Locate the “Upstream Results HHV” sheet; find column S, “Ethanol Corn”.
 - a. Copy rows 7 to 19 and paste into the Results Table.
- Remember to use “paste special → values and number formatting”.**

With the overlap of electricity value added, your Results Table should look like this:

Row	Source of Emissions	Feedstock Production	Ethanol Production	Fuel Use	Electricity usage
-	Region	U.S. Central	Alberta	B.C.	
7	Fuel	Ethanol	Ethanol	Ethanol	Ethanol
8	Feedstock	Corn	Corn	Corn	Corn
9	Fuel dispensing			56	
10	Fuel distribution and storage		1,444	482	224
11	Fuel production		27,813		
12	Feedstock transmission	3,569			
13	Feedstock recovery	5,730			
14	Feedstock upgrading				
15	Land-use changes, cultivation	17,215			
16	Fertilizer manufacture	7,598			
17	Gas leaks and flares				
18	CO ₂ , H ₂ S removed from NG				
19	Emissions displaced		-7,469		
	Emissions from fuel use			2,144	

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A.7. Calculating the final fuel carbon intensity

To calculate the carbon intensity of a fuel, specific values from each run (region) are required to create a full lifecycle analysis of the carbon intensity of the fuel.

Line Number	Source	Values Explanation	Calculation Formula
9	Fuel dispensing	Occurs entirely within B.C.	= (B.C. value)
10	Fuel distribution and storage	Occurs in every region from fuel production onward. Must be corrected for double counting.	= (B.C. value) + (Alberta value) – (Electricity Usage value)
11	Fuel production	Occurs entirely within “Alberta”	= (Alberta value)
12	Feedstock transmission	Occurs entirely within “U.S. Central”	= (U.S. Central value)
13	Feedstock recovery	Occurs entirely within “U.S. Central”	= (U.S. Central value)
14	Feedstock upgrading	This occurs in the fuel production run.	No value in example
15	Land-use changes, cultivation	Occurs entirely within “U.S. Central”	= (U.S. Central value)
16	Fertilizer manufacture	Occurs entirely within “U.S. Central”	= (U.S. Central value)
17	Gas leaks and flares	This occurs in the fuel production run.	No value in example
18	CO ₂ , H ₂ S removed from NG	This occurs in the fuel production run.	No value in example
19	Emissions displaced	Occurs entirely within “Alberta”	= (Alberta value)
	Emissions from fuel use	Occurs entirely within B.C.	= (B.C. value)



To calculate the fuel’s final carbon intensity:

1. Add a column to your Results Table; label it “Final”.
2. Use the formulas provided on the previous page to determine the final values for each emissions source.
3. Sum all of the values in the Final column to get the total (i.e. 58,358)
4. Divide the sum of the Final column by 1000 to determine the carbon intensity of the fuel.

With the final calculations added, your Results Table should look like this:

Row	Source of Emissions	Feedstock Production	Ethanol Production	Fuel Use	Electricity usage	
-	Region	U.S. Central	Alberta	B.C.		Final
7	Fuel	Ethanol	Ethanol	Ethanol	Ethanol	Ethanol
8	Feedstock	Corn	Corn	Corn	Corn	Corn
9	Fuel dispensing			56		56
10	Fuel distribution and storage		1,444	482	224	1,701
11	Fuel production		27,813			27,813
12	Feedstock transmission	3,569				3,569
13	Feedstock recovery	5,730				5,730
14	Feedstock upgrading					
15	Land-use changes, cultivation	17,215				17,215
16	Fertilizer manufacture	7,598				7,598
17	Gas leaks and flares					
18	CO ₂ , H ₂ S removed from NG					
19	Emissions displaced		-7,469			-7,469
	Emissions from fuel use			2,144		2,144
	Total					58,358

Dividing the sum of the Final column by 1000 (i.e. 58,358 / 1000) results in a value of 58.36.

Therefore, the Carbon Intensity of this fuel is 58.36 gCO₂e/MJ.

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Appendix B. Biodiesel production example

This example determines the carbon intensity of biodiesel made from soybean oil in 2015. In order to perform the analysis, the following information is used:

- The soybean is grown in the Ontario region and transported 50 km to the crushing facility.
- The soybean oil is then transported 25 km to the biodiesel production facility in Thunder Bay, Ontario.
- The finished biodiesel fuel is transported 3,200 km by rail to Vancouver, B.C. and then distributed 80 km by truck within Vancouver.

In this example, three model runs are needed to determine the value of each of the lifecycle components for the fuel:

- One for the soybean production and biodiesel production in Ontario,
- One for fuel consumption in B.C., and
- One to account for electricity-related emissions that are double-counted by the multiple runs

Data used in this example is loosely based on a biodiesel production process. Actual production processes data would be different, and could include more inputs or outputs than used in this example depending on the production process used by the plant. Any additional inputs would be included in the Production of Alternative Fuels (“Alt Fuel Prod”) and additional outputs would be included in the Co-Products Produced (“Coprods”) sheets.

The values for Plant Operation Data, Production of Alternative Fuels and Co-Products produced are for each litre of fuel produced at the plant.

In this example we are not modifying all of the potential inputs that are available on each sheet. The data that is left unchanged is default data saved in GHGenius and therefore is acceptable for this example. Each fuel pathway is unique; the methodology used in this example may not accurately represent the carbon intensity of all soybean-based biodiesel.

B.1. Collect the necessary data

Feedstock Production	Growing soybean	Ontario
Transportation	Soybean from field to crushing facility	50 km by truck
	Soybean oil from crushing facility to fuel production facility	25 km by truck
	Biodiesel from fuel production facility to Vancouver, B.C.	3,200 km by rail
	Biodiesel from Vancouver, B.C. to market	80 km by truck
Plant Operation Data (Energy and feedstock use)	Location	Ontario
	Target (Production) year	2015
	Base year	2015
	Electricity (kWh/litre)	0.042
	Diesel (L/litre)	0.0

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	Natural Gas (L/litre)	42.0
	Coal (Kg/litre)	0.0
	Feedstock yield (Kg/litre)	0.877
Production Chemicals (Used in production)	Methanol (L/litre)	0.123
	Nitrogen (Kg/litre)	0.24
	Sodium Methylate (Kg/litre)	0.009
	Sulphuric Acid (Kg/litre)	0.012
Co-products Produced	Glycerine feed (Kg/litre)	0.032
	Glycerine crude (Kg/litre)	0.022

B.2. Create a workbook for model run results

To ease the calculation of the carbon intensity of a given fuel, we recommend setting up an additional Excel workbook, separate from the GHGenius model, to organize the results of your model runs.

1. Copy the following table into A1 of the new workbook:

Row	Source of Emissions
-	Region
7	Fuel/Fuel Precursor
8	Feedstock
9	Fuel dispensing
10	Fuel distribution and storage
11	Fuel production
12	Feedstock transmission
13	Feedstock recovery
14	Feedstock upgrading
15	Land-use changes, cultivation
16	Fertilizer manufacture
17	Gas leaks and flares
18	CO ₂ , H ₂ S removed from NG
19	Emissions displaced

- **Row** – Refers to location of the data for a given aspect of the lifecycle within the GHGenius output table (“Upstream Results HHV” sheet)
 - **Source of Emissions** – Refers to the various stages of a fuel’s lifecycle where emissions occur
2. Add a new column to the right for each region involved in the lifecycle of the fuel:
 - a. In our example, there are two regions where stages of the fuel lifecycle take place: Ontario (feedstock and fuel production) and B.C. (fuel distribution, storage and use).
 - b. Since the lifecycle analysis in our example takes place across multiple regions, we need to add a third column for the model run that will calculate the electricity emissions that are double-counted.



- c. Add a row directly below the table and label it “Emissions from fuel use” in Column B.
3. To complete the lifecycle analysis, we will need to compile the results from the various model runs.
 - a. For the region where the feedstock is grown and the fuel is produced, include: Fuel distribution and storage, Fuel production, Feedstock transmission, Feedstock recovery, Land-use changes, Fertilizer manufacture and Emissions displaced. These stages are highlighted in Blue on the table below.
 - b. For the region where the fuel is consumed, include: Fuel dispensing, Fuel distribution and storage and Emissions from fuel use. These cells are highlighted in Yellow.
 - c. To account for the overlap in electricity emissions from multiple regions, highlight the Fuel distribution and storage cell in Orange.
4. The finished results table should look like this:

Row	Source of Emissions	Feedstock & Fuel Production	Fuel Use	Electricity usage
-	Region	Ontario	B.C.	
7	Fuel	Biodiesel	Biodiesel	Biodiesel
8	Feedstock	Soybean Oil	Soybean Oil	Soybean Oil
9	Fuel dispensing			
10	Fuel distribution and storage			
11	Fuel production			
12	Feedstock transmission			
13	Feedstock recovery			
14	Feedstock upgrading			
15	Land-use changes, cultivation			
16	Fertilizer manufacture			
17	Gas leaks and flares			
18	CO ₂ , H ₂ S removed from NG			
19	Emissions displaced			
	Emissions from fuel use			

B.3. Run 1: Components for feedstock and fuel production in “Ontario”

The first model run will calculate the emission values associated with growing soybean and producing biodiesel in Ontario.

1. Open the model, enable macros and agree to the user agreement.
2. On the “Input” sheet:
 - a. Select Ontario as the regional default in the Regional Defaults Box in row 2 and approximately column D. The result will be displayed in cell G3.
 - b. Set the year of analysis (target year) to 2015, cell B3.
 - c. Verify that the IPCC value is set to 2007, cell B6 (value 2).



- d. Navigate to the transportation of feedstock and fuels section, starting at row 68 of the “Input” sheet, and enter the soybean transportation distance in column M (“soybean to plant”) for the soybean from the field to the crushing facility.

In this example, the distance of the feedstock to the crushing facility is 50 km by truck. Enter:

- i. “Average km shipped by truck” cell M82 = 50
- ii. “Tonnes-shipped/tonnes-produced by truck” cell M88 = 1.0
- iii. Ensure that all other cells in that column = 0 (M78 – M81; M84 – M87 = 0)

- e. Next, enter the transportation distance in column N (“soybean oil to plant”) for the soybean oil to the biodiesel production facility.

In this example, the distance between the crushing facility and biodiesel production facility is 25 km by truck. Enter:

- i. “Average km shipped by truck” cell N82 = 25
- ii. “Tonnes-shipped/tonnes-produced by truck” cell N88 = 1.0
- iii. Ensure that all other cells in that column = 0 (N78 – N81; N84 – N87 = 0)

- f. Locate the Finished Fuels transportation area on the “Input” sheet starting at row 90.

In this example, the biodiesel is shipped 3,200 km from Ontario to B.C. by rail.

In column AB “biodiesel soybean”, enter:

- i. “Average km shipped by rail” cell AB92 = 3200
- ii. “Tonnes-shipped/tonnes-produced by rail” cell AB98 = 1.0
- iii. Ensure that all other cells in that column = 0 (AB93 – AB96; AB99 – AB102 = 0)

- g. Scroll down to the Alternative Fuel Production section starting at row 231 column A. The Alternative Fuel Production section allows inputs for fuel production from plant operation data. Since the biodiesel producer likely does not have access to the operating data of the crushing facility, the default values in GHGenius are acceptable. However, if access to this data is possible, it can be inputted into the GHGenius model in lieu of the default values.

For biodiesel production, this example will use general plant operation data from 2015. In column AL “Vegetable Oil Esterification”, enter:

- i. “Base year” cell AL234 = 2015
- ii. “Net electricity purchased” cell AL236 = 0.042
- iii. “Diesel” cell AL237 = 0.0
- iv. “Natural gas” AL238 = 42.0
- v. “Coal” AL239 = 0.0
- vi. “Corn/soybeans/canola/wheat” (feedstock yield) cell AL241 = 0.877

3. Locate the “Alt Fuel Prod” sheet (to the right of the Input sheet).

- a. Find column AQ “SoyD100” and enter the remaining alternative fuel production inputs.
- i. Ensure that all cells in that column = 0 (AQ29 – AQ51), then enter:
 - ii. “Methanol” cell AQ39 = 0.123
 - iii. “Nitrogen” cell AQ42 = 0.24
 - iv. “Sodium Methylate” cell AQ48 = 0.009
 - v. “Sulphuric Acid” cell AQ50 = 0.012

Note: We recommend entering zero into cells AQ29 to AQ51 before entering data to ensure that no small default values (smaller than three decimal places) get included in the carbon intensity calculation.

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4. Locate the “Coprods” sheet (left of “Alt Fuel Prod” sheet).
 - a. Find column Y “biodiesel” in the Emissions Displaced by Net Electricity Production section (starting Row 81) and input the co-product values from the fuel production process:
 - i. “Glycerine feed” cell Y99 = 0.032
 - ii. “Glycerine crude” cell Y101 = 0.022
5. Scroll to cell A1 at the top of the “Input” sheet and click “Run Program”.
6. Navigate to the “Upstream Results HHV” sheet; find column AE (Biodiesel Soybean).
 - a. Copy rows 7 to 19, and paste into the Results Table.
Remember to use “paste special → values and number formatting”.

With the Ontario values added, your Results Table should look like this:

Row	Source of Emissions	Feedstock & Fuel Production	Fuel Use	Electricity usage
-	Region	Ontario	B.C.	
7	Fuel	Biodiesel	Biodiesel	Biodiesel
8	Feedstock	Soybean Oil	Soybean Oil	Soybean Oil
9	Fuel dispensing			
10	Fuel distribution and storage	1,620		
11	Fuel production	18,914		
12	Feedstock transmission	988		
13	Feedstock recovery	9,555		
14	Feedstock upgrading			
15	Land-use changes, cultivation	67,088		
16	Fertilizer manufacture	5,573		
17	Gas leaks and flares			
18	CO ₂ , H ₂ S removed from NG			
19	Emissions displaced	-81,471		
	Emissions from fuel use			

B.4. Run 2: Distribution and consumption in B.C.

The second model run will calculate the values associated with fuel storage, dispensing and use in B.C.

1. On the “Input” sheet in the same GHGenius workbook:
 - a. Set the regional default to B.C. by clicking the B.C. button in the Regional Defaults Box in row 2 and approximately column E. The result will be displayed in cell G3.
 - b. Set the year of analysis (target year) to 2015, cell B3.
 - c. Verify that the IPCC value is set to 2007, cell B6 (value 2).
 - d. Locate the Finished Fuels section (starting row 90); find column AB.

The distance for the B.C. default for any fuel calculated will be 80 km by truck.

- i. “Average km shipped by truck” cell AB96 = 80
- ii. “Tonnes-shipped/ tonnes-produced by truck” Cell AB102 = 1.0

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- iii. Ensure that all other cells in that column = 0 (AB92 – AB95; AB98 – AB101 = 0)
- 2. Scroll to cell A1 at the top of the “Input” sheet and click “Run Program”.
- 3. Locate the “Upstream Results HHV” sheet; find column AE, “Biodiesel Soybean”.
 - a. Copy rows 7 to 19 and paste into the Results Table.

Remember to use “paste special → values and number formatting”.

With the British Columbia values for soybean biodiesel added, your Results Table should look like this:

Row	Source of Emissions	Feedstock & Fuel Production	Fuel Use	Electricity usage
-	Region	Ontario	B.C.	
7	Fuel	Biodiesel	Biodiesel	Biodiesel
8	Feedstock	Soybean Oil	Soybean Oil	Soybean Oil
9	Fuel dispensing		42	
10	Fuel distribution and storage	1,620	359	
11	Fuel production	18,914		
12	Feedstock transmission	988		
13	Feedstock recovery	9,555		
14	Feedstock upgrading			
15	Land-use changes, cultivation	67,088		
16	Fertilizer manufacture	5,573		
17	Gas leaks and flares			
18	CO ₂ , H ₂ S removed from NG			
19	Emissions displaced	-81,471		
	Emissions from fuel use			

Determining the British Columbia emissions from fuel use values

The emissions released when the fuel is burnt in an engine will need to be included in the carbon intensity calculation. This information is found on the “Exhaust Emissions” sheet in GHGenius.

- 4. Locate the “Exhaust Emissions” sheet (it is near the end).

Depending on which fuel class (gasoline or diesel) the fuel being produced qualifies for, either the light-duty vehicle exhaust emissions (gasoline) or the heavy-duty vehicle exhaust emissions (diesel) value will be needed.

In this example biodiesel is used as a replacement for diesel in heavy-duty vehicles.

- 5. Find the “Heavy-Duty Vehicles: Calculated Emissions” section (Table 50e, row 112).
- 6. Copy the Net CO₂+non CO₂ (g/GJ) value from row 143 column G “Biodiesel SoyD100” and paste into the Results Table in the B.C. column.

Remember to use “paste special → values and number formatting”.

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With the emissions from fuel use in B.C. added, your Results Table should look like this:

Row	Source of Emissions	Feedstock & Fuel Production	Fuel Use	Electricity usage
-	Region	Ontario	B.C.	
7	Fuel	Biodiesel	Biodiesel	Biodiesel
8	Feedstock	Soybean Oil	Soybean Oil	Soybean Oil
9	Fuel dispensing		42	
10	Fuel distribution and storage	1,620	359	
11	Fuel production	18,914		
12	Feedstock transmission	988		
13	Feedstock recovery	9,555		
14	Feedstock upgrading			
15	Land-use changes, cultivation	67,088		
16	Fertilizer manufacture	5,573		
17	Gas leaks and flares			
18	CO ₂ , H ₂ S removed from NG			
19	Emissions displaced	-81,471		
	Emissions from fuel use		1,735	

B.5. Run 3: Determining electricity usage

The final model run will calculate the values associated with the overlap of electricity use between regions.

1. On the “Input” sheet in the same GHGenius workbook:
 - a. Set the model to Ontario (near cell D2). The result will be displayed in cell G3.
 - b. Set the year of analysis (target year) to 2015, cell B3.
 - c. Verify that the IPCC value is set to 2007, cell B6 (value 2).
2. Locate the Finished Fuels section (starting row 90); find column AB.
 - i. “Average km shipped by truck” cell AB96 = 0.01
 - ii. “Tonnes-shipped/ tonnes-produced by truck” cell AB102 = 1.0
 - iii. Ensure that all other cells in that column = 0 (AB92 – AB95; AB98 – AB101 = 0)

Note: The small value in cell AB96 is necessary for the transportation distance or the model will not run correctly; the effect of this practice on final emissions is negligible.

3. Scroll up and select “Run Program” in cell A1.
4. Locate the “Upstream Results HHV” sheet; find column AE, “Biodiesel Soybean”.
 - a. Copy rows 7 to 19 and paste into the Results Table.
Remember to use “paste special → values and number formatting”.

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With the overlap of electricity value added, your Results Table should look like this:

Row	Source of Emissions	Feedstock & Fuel Production	Fuel Use	Electricity usage
-	Region	Ontario	B.C.	
7	Fuel	Biodiesel	Biodiesel	Biodiesel
8	Feedstock	Soybean Oil	Soybean Oil	Soybean Oil
9	Fuel dispensing		42	
10	Fuel distribution and storage	1,620	359	92
11	Fuel production	18,914		
12	Feedstock transmission	988		
13	Feedstock recovery	9,555		
14	Feedstock upgrading			
15	Land-use changes, cultivation	67,088		
16	Fertilizer manufacture	5,573		
17	Gas leaks and flares			
18	CO ₂ , H ₂ S removed from NG			
19	Emissions displaced	-81,471		
	Emissions from fuel use		1,735	

B.6. Calculating the final fuel carbon intensity

To calculate the carbon intensity of a fuel, specific values from each run (region) are required to create a full lifecycle analysis of the carbon intensity of the fuel. The calculation formulas may differ depending on the fuel in question's specific lifecycle components and the regions in which those components occur.

Line Number	Source	Values Explanation	Calculation Formula
9	Fuel dispensing	Occurs entirely within B.C.	= (B.C. value)
10	Fuel distribution and storage	Occurs in every region from fuel production onward. Must be corrected for double counting.	= (Ontario value) + (B.C. value) – (Electricity usage value)
11	Fuel production	Occurs entirely within Ontario	= (Ontario value)
12	Feedstock transmission	Occurs entirely within Ontario	= (Ontario value)
13	Feedstock recovery	Occurs entirely within Ontario	= (Ontario value)
14	Feedstock upgrading	This occurs in the fuel production run.	No value in example
15	Land-use changes, cultivation	Occurs entirely within Ontario	= (Ontario value)
16	Fertilizer manufacture	Occurs entirely within Ontario	= (Ontario value)
17	Gas leaks and flares	This occurs in the fuel production run.	No value in example
18	CO ₂ , H ₂ S removed from NG	This occurs in the fuel production run.	No value in example
19	Emissions displaced	Occurs entirely within Ontario	= (Ontario value)
	Emissions from fuel use	Occurs entirely within B.C.	= (B.C. value)



To calculate the fuel’s final carbon intensity:

- Add a column to your Results Table; label it “FINAL”.
- Use the formulas provided on the previous page to determine the final values for each emissions source.
- Sum all of the values in the Final column to get the total (i.e. 24,310)
- Divide the sum of the Final column by 1000 to determine the carbon intensity of the fuel.

With the final calculations added, the Results Table should look like this:

Row	Source of Emissions	Feedstock & Fuel Production	Fuel Use	Electricity usage	FINAL
-	Region	Ontario	B.C.		FINAL
7	Fuel	Biodiesel	Biodiesel	Biodiesel	Biodiesel
8	Feedstock	Soybean Oil	Soybean Oil	Soybean Oil	Soybean Oil
9	Fuel dispensing		42		42
10	Fuel distribution and storage	1,620	359	92	1,887
11	Fuel production	18,914			18,914
12	Feedstock transmission	988			988
13	Feedstock recovery	9,555			9,555
14	Feedstock upgrading				
15	Land-use changes, cultivation	67,088			67,088
16	Fertilizer manufacture	5,573			5,573
17	Gas leaks and flares				
18	CO ₂ , H ₂ S removed from NG				
19	Emissions displaced	-81,471			-81,471
	Emissions from fuel use		1,735		1,735
	TOTAL				24,310

Dividing the sum of the Final column by 1000 (i.e. 24,310 / 1000) results in a value of 24.31.

Therefore, the Carbon Intensity of this fuel is 24.31 gCO₂e/MJ.



Appendix C. Hydrogenation-Derived Renewable Diesel (HDRD) production example

The following information is used to determine the carbon intensity of HDRD made from yellow grease in 2015:

- a. The yellow grease is collected from local restaurants and food production facilities in Boise, Idaho and transported 85 km by truck to the HDRD production facility just outside the city.
- b. The finished HDRD fuel is transported 1,030 km by truck to Vancouver, B.C. and then distributed 80 km by truck within Vancouver.

In this example, three model runs are needed to determine the value of each of the lifecycle components for the fuel:

1. One for feedstock collection and HDRD production in U.S. West,
2. One for fuel consumption in B.C., and
3. One to account for electricity-related emissions that are double-counted by the multiple runs.

Data used in this example is loosely based on a HDRD production process. Actual production processes data would be different, and could include more inputs or outputs than used in this example depending on the production process used by the plant. Any additional inputs would be included in the Production of Alternative Fuels (“Alt Fuel Prod”) and additional outputs would be included in the Co-Products Produced (“Coprods”) sheets.

The values for Plant Operation Data and Production of Alternative Fuels are for each litre of fuel produced at the plant.

In this example we are not modifying all of the potential inputs that are available on each sheet. The data that is left unchanged is default data saved in GHGenius and therefore is acceptable for this example. Each fuel pathway is unique; the methodology used in this example may not accurately represent the carbon intensity of all yellow grease-based HDRD.

C.1. Collect the necessary data

Feedstock Production	Collecting yellow grease	U.S. West
Transportation	Yellow grease distance to fuel production facility	85 km by truck
	HDRD from fuel production facility to Vancouver, B.C.	1,030 km by truck
	HDRD from Vancouver B.C. to market	80 km by truck
Plant Operation Data (Energy and feedstock use)	Location	U.S. West
	Target (Production) year	2015
	Base year	2015
	Electricity (kWh/litre)	0.888
	Diesel (L/litre)	0.0
	Natural gas (L/litre)	6.80



	Coal (Kg/litre)	0.0
	Feedstock yield (Kg/litre)	0.933
Production Chemicals (Used in production)	Hydrogen (Kg/litre)	0.01001
	NaOH (Kg/litre)	0.00353
	Nitrogen (N) (Kg/litre)	0.00472
	Phosphoric Acid	0.00176
Co-products Produced	Gaseous fuel (L/litre)	0.112
	Liquid fuel (L/litre)	0.0045

C.2. Create a workbook for model run results

To ease the calculation of the carbon intensity of a given fuel, we recommend setting up an additional Excel workbook, separate from the GHGenius model, to organize the results of your model runs.

- Copy the following table into A1 of the new workbook:

Row	Source of Emissions
-	Region
7	Fuel/Fuel Precursor
8	Feedstock
9	Fuel dispensing
10	Fuel distribution and storage
11	Fuel production
12	Feedstock transmission
13	Feedstock recovery
14	Feedstock upgrading
15	Land-use changes, cultivation
16	Fertilizer manufacture
17	Gas leaks and flares
18	CO ₂ , H ₂ S removed from NG
19	Emissions displaced

- Row** – Refers to location of the data for a given aspect of the lifecycle within the GHGenius output table (“Upstream Results HHV” sheet)
 - Source of Emissions** – Refers to the various stages of a fuel’s lifecycle where emissions occur
- Add a new column to the right for each region involved in the lifecycle of the fuel:
 - In the case of our example, there are two regions where stages of the fuel lifecycle take place: U.S. West (fuel production) and B.C. (fuel distribution, storage and use).
 - Since the lifecycle analysis in our example takes place across more than one region, we need to add a third column for the final model run that will calculate the electricity emissions that are double-counted.



- c. Add a row directly below the table and label it “Emissions from fuel use” in Column B.
3. To complete the lifecycle analysis, we will need to compile the results from the various model runs. In this example, yellow grease is considered a waste product, so the lifecycle assessment does not include its production (feedstock production) at restaurants and other sources.
 - a. For the region where fuel production occurs, include: Fuel distribution and storage, Fuel production, Feedstock transmission and Emissions displaced. These are highlighted in Green.
 - b. For the region where the fuel is consumed, include: Fuel dispensing, Fuel distribution and storage and Emissions from fuel use. These cells are highlighted in Yellow.
 - c. Finally, to account for the overlap in electricity emissions from multiple regions, highlight the Fuel distribution and storage cell in Orange.
4. The finished results table should look like this:

Row	Source of Emissions	HDRD Production	Fuel Use	Electricity usage
-	Region	U.S. West	B.C.	
7	Fuel			
8	Feedstock			
9	Fuel dispensing			
10	Fuel distribution and storage			
11	Fuel production			
12	Feedstock transmission			
13	Feedstock recovery			
14	Feedstock upgrading			
15	Land-use changes, cultivation			
16	Fertilizer manufacture			
17	Gas leaks and flares			
18	CO2, H2S removed from NG			
19	Emissions displaced			
	Emissions from fuel use			

C.3. Run 1: Fuel production in “U.S. West”

The first model run will calculate the values associated with the fuel production in Boise, Idaho.

1. Open the model, enable macros and agree to the user agreement.
2. On the “Input” sheet:
 - a. Select U.S. West as the regional default in the Regional Defaults Box in row 2 and approximately column H. The result will be displayed in cell G3.
 - b. Set the year of analysis (target year) to 2015, cell B3.
 - c. Verify that the IPCC value is set to 2007, cell B6 (value 2).



- d. Scroll down to the Characteristics of Fuels, Gases, and Feedstocks section, starting at row 32. Click on the “HRD Feedstock” cell in row 50 (cell B50) to bring up a drop-down arrow directly to the right of the cell. Using the drop-down menu, select the feedstock.

In this example, the HDRD feedstock is yellow grease. Select:

- i. “HRD Feedstock” cell B50 = “Yellow Grease”

Note: If you have turned off Excel’s “automatic calculation” feature, it is recommended to click on the calculate button at this time. It is located in the bottom left corner of Excel. Doing so will update the “HRD feedstock” columns with the heading “Yellow Grease”.

- e. Navigate to the Transportation of Feedstocks, Fuels, Vehicles, Etc. section, starting at row 68 of the “Input” sheet. Enter the yellow grease transportation component in column Z “yellow grease to plant” for the distance the feedstock travels to the fuel production facility.

In this example, yellow grease is shipped 85 km by truck to the fuel production facility. Enter:

- i. “Average km shipped by truck” cell Z82 = 85
ii. “Tonnes-shipped/tonnes-produced by truck” cell Z88 = 1.0
iii. Ensure that all other cells in that column = 0 ($Z78 - Z81$; $Z84 - Z87 = 0$)

- f. Next, locate the Finished Fuels transportation area on the “Input” sheet starting at row 90.

In this example, the HDRD is shipped 1,030 km from Boise, Idaho to B.C. by truck.

In column AK “HRD”, enter:

- i. “Average km shipped by truck” cell AK96 = 1030
ii. “Tonnes-shipped/tonnes-produced by truck” cell AK102 = 1.0
iii. Ensure that all other cells in that column = 0 ($AK92 - AK95$; $AK98 - AK101 = 0$)

- g. Scroll down to the Alternative Fuel Production section starting at row 231 column A. The Alternative Fuel Production section allows inputs for fuel production from plant operation data.

This example will use general HDRD plant operation data from 2015. In column BH “HRD yellow grease”, enter:

- i. “Base year” cell BH234 = 2015
ii. “Net electricity purchased” cell BH236 = 0.888
iii. “Diesel” cell BH237 = 0.0
iv. “Natural gas” cell BH238 = 6.80
v. “Coal” BH239 = 0.0
vi. “Corn/soybean/canola/wheat” (feedstock) cell BH241 = 0.933

3. Locate the “Alt Fuel Prod” sheet (to the right of the Input sheet).

- a. Find column BN “HRD yellow grease” and enter the remaining alternative fuel production inputs.

- i. Ensure that cells BN29 to BN51 = 0, then enter:
ii. “Hydrogen” cell BN36 = 0.01001
iii. “NaOH” cell BN40 = 0.00353
iv. “Nitrogen” cell BN42 = 0.00472
v. “Phosphoric Acid” cell BN45 = 0.00176

Note: We recommend entering zero into cells BN29 to BN51 before entering data to ensure that no small default values (smaller than three decimal places) get included in the carbon intensity calculation.



4. Locate the “Coprods” sheet (left of “Alt Fuel Prod” sheet).
 - a. Find column AO “HRD” in the Emissions Displaced by Net Electricity Production section (starting Row 81) and input the co-product values from the fuel production process:
 - i. “Gaseous fuel” cell AO106 = 0.112
 - ii. “Liquid fuel” cell AO108 = 0.0045
5. Navigate back to the “Input” sheet. Click “Run Program” in cell A1.
6. Locate the “Upstream Results HHV” sheet; find column AV, “HRD Yellow Grease”.
 - a. Copy rows 7 to 19 and paste into the Results Table.
Remember to use “paste special → values and number formatting”.

With the U.S. West values for yellow grease HDRD added, your Results Table should look like this:

Row	Source of Emissions	HDRD Production	Fuel Use	Electricity usage
-	Region	U.S. West	B.C.	
7	Fuel	HRD		
8	Feedstock	Yellow Grease		
9	Fuel dispensing			
10	Fuel distribution and storage	3,174		
11	Fuel production	19,960		
12	Feedstock transmission	927		
13	Feedstock recovery			
14	Feedstock upgrading			
15	Land-use changes, cultivation			
16	Fertilizer manufacture			
17	Gas leaks and flares			
18	CO ₂ , H ₂ S removed from NG			
19	Emissions displaced	-6,037		
	Emissions from fuel use			

C.4. Run 2: Distribution and consumption in B.C.

The second model run will calculate the values associated with fuel storage, dispensing and use in B.C.

1. On the “Input” sheet in the same GHGenius workbook:
 - a. Set the regional default to B.C. by clicking the B.C. button in the Regional Defaults Box in row 2 and approximately column E. The result will be displayed in cell G3.
 - b. Set the year of analysis (target year) to 2015, cell B3.
 - c. Verify that the IPCC value is set to 2007, cell B6 (value 2).
 - d. Locate the Finished Fuels section (starting row 90); find column AK.
The distance for the B.C. default for any fuel calculated will be 80 km by truck.
 - i. “Average km shipped by truck” cell AK96 = 80

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- ii. “Tonnes-shipped/ tonnes-produced by truck” Cell AK102 = 1.0
 - iii. Ensure that all other cells in that column = 0 (AK92 – AK95; AK98 – AK101 = 0)
2. Scroll to cell A1 at the top of the “Input” sheet and click “Run Program”.
 3. Locate the “Upstream Results HHV” sheet; find column AV, “HRD Yellow Grease”.
 - a. Copy rows 7 to 19 and paste into the Results Table.
Again, remember to use “paste special → values and number formatting”.

With the British Columbia values for yellow grease added, your Results Table should look like this:

Row	Source of Emissions	HDRD Production	Fuel Use	Electricity usage
-	Region	U.S. West	B.C.	
7	Fuel	HRD	HRD	
8	Feedstock	Yellow Grease	Yellow Grease	
9	Fuel dispensing		35	
10	Fuel distribution and storage	3,174	297	
11	Fuel production	19,960		
12	Feedstock transmission	927		
13	Feedstock recovery			
14	Feedstock upgrading			
15	Land-use changes, cultivation			
16	Fertilizer manufacture			
17	Gas leaks and flares			
18	CO2, H2S removed from NG			
19	Emissions displaced	-6,037		
	Emissions from fuel use			

Determining the British Columbia emissions from fuel use values

The emissions released when the fuel is burnt in an engine will need to be included in the carbon intensity calculation. This information is found on the “Exhaust Emissions” sheet in GHGenius.

4. Locate the “Exhaust Emissions” sheet (it is near the end).

Depending on which fuel class (gasoline or diesel) the fuel being produced qualifies for, either the light-duty vehicle exhaust emissions (gasoline) or the heavy-duty vehicle exhaust emissions (diesel) value will be needed.

In this example HDRD is used as a replacement for diesel in heavy-duty vehicles.

5. Find the “Heavy-Duty Vehicles: Calculated Emissions” section (Table 50e, row 112).
6. Copy the Net CO2+non CO2 (g/GJ) value from row 143 column E “HRD Yellow Grease” and paste into the Results Table in the B.C. column.
Remember to use “paste special → values and number formatting”.

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With the emissions from fuel use in B.C. added, your Results Table should look like this:

Row	Source of Emissions	HDRD Production	Fuel Use	Electricity usage
-	Region	U.S. West	B.C.	
7	Fuel	HRD	HRD	
8	Feedstock	Yellow Grease	Yellow Grease	
9	Fuel dispensing		35	
10	Fuel distribution and storage	3,174	297	
11	Fuel production	19,960		
12	Feedstock transmission	927		
13	Feedstock recovery			
14	Feedstock upgrading			
15	Land-use changes, cultivation			
16	Fertilizer manufacture			
17	Gas leaks and flares			
18	CO ₂ , H ₂ S removed from NG			
19	Emissions displaced	-6,037		
	Emissions from fuel use		1,725	

C.5. Run 3: Determining electricity usage

The third model run will calculate the values associated with the overlap of electricity use between regions.

1. On the “Input” sheet in the same GHGenius workbook:
 - a. Set the model to U.S. West (near cell H2). The result will be displayed in cell G3.
 - b. Set the year of analysis (target year) to 2015, cell B3.
 - c. Verify that the IPCC value is set to 2007, cell B6 (value 2).
2. Locate the Finished Fuels section (starting row 90); find column AK.
 - i. “Average km shipped by truck” cell AK96 = 0.01
 - ii. “Tonnes-shipped/ tonnes-produced by truck” cell AK102 = 1.0
 - iii. Ensure that all other cells in that column = 0 (AK92 – AK95; AK98 – AK101 = 0)

Note: The small value in cell AK96 is necessary for the transportation distance or the model will not run correctly; the effect of this practice on final emissions is negligible.

3. Scroll up and select “Run Program” in cell A1.
4. Locate the “Upstream Results HHV” sheet; find column AV, “HRD Yellow Grease”.
 - a. Copy rows 7 to 19 and paste into the Results Table.
Remember to use “paste special → values and number formatting”.

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With the overlap of electricity value added, your Results Table should look like this:

Row	Source of Emissions	HDRD Production	Fuel Use	Electricity usage
-	Region	U.S. West	B.C.	
7	Fuel	HRD	HRD	HRD
8	Feedstock	Yellow Grease	Yellow Grease	Yellow Grease
9	Fuel dispensing		35	
10	Fuel distribution and storage	3,174	297	117
11	Fuel production	19,960		
12	Feedstock transmission	927		
13	Feedstock recovery			
14	Feedstock upgrading			
15	Land-use changes, cultivation			
16	Fertilizer manufacture			
17	Gas leaks and flares			
18	CO ₂ , H ₂ S removed from NG			
19	Emissions displaced	-6,037		
	Emissions from fuel use		1,725	

C.6. Calculating the final fuel carbon intensity

To calculate the carbon intensity of a fuel, specific values from each run (region) are required to create a full lifecycle analysis of the carbon intensity of the fuel.

Line Number	Source	Values Explanation	Calculation Formula
9	Fuel dispensing	Occurs entirely within B.C.	= (B.C. value)
10	Fuel distribution and storage	Occurs in every region from fuel production onward. Must be corrected for double counting.	= (B.C. value) + (U.S. West value) – (Electricity Usage value)
11	Fuel production	Occurs entirely within “U.S. West”	= (U.S. West value)
12	Feedstock transmission	Occurs entirely within “U.S. West”	= (U.S. West value)
13	Feedstock recovery	Related to feedstock production	No value in example
14	Feedstock upgrading	This occurs in the fuel production run.	No value in example
15	Land-use changes, cultivation	Related to feedstock production	No value in example
16	Fertilizer manufacture	Related to feedstock production	No value in example
17	Gas leaks and flares	This occurs in the fuel production run.	No value in example
18	CO ₂ , H ₂ S removed from NG	This occurs in the fuel production run.	No value in example
19	Emissions displaced	Occurs entirely within “U.S. West”	= (U.S. West value)
	Emissions from fuel use	Occurs entirely within B.C.	= (B.C. value)

To calculate the fuel’s final carbon intensity:

1. Add a column to your Results Table; label it “Final”.
2. Use the formulas provided on the previous page to determine the final values for each emissions source.
3. Sum all of the values in the Final column to get the total (i.e. 19,964)
4. Divide the sum of the Final column by 1000 to determine the carbon intensity of the fuel.

With the final calculations added, your Results Table should look like this:

Row	Source of Emissions	HDRD Production	Fuel Use	Electricity usage	Final
-	Region	U.S. West	B.C.		
7	Fuel	HRD	HRD	HRD	HRD
8	Feedstock	Yellow Grease	Yellow Grease	Yellow Grease	Yellow Grease
9	Fuel dispensing		35		35
10	Fuel distribution and storage	3,174	297	117	3,354
11	Fuel production	19,960			19,960
12	Feedstock transmission	927			927
13	Feedstock recovery				
14	Feedstock upgrading				
15	Land-use changes, cultivation				
16	Fertilizer manufacture				
17	Gas leaks and flares				
18	CO ₂ , H ₂ S removed from NG				
19	Emissions displaced	-6,037			-6,037
	Emissions from fuel use		1,725		1,725
	Total				19,964

Dividing the sum of the Final column by 1000 (i.e. 19,964 / 1000) results in a value of 19.96.

Therefore, the Carbon Intensity of this fuel is 19.96 gCO₂e/MJ.