GHGenius 5.02b User Guide: Carbon Intensity of Ethanol

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Executive Summary

This guide is intended to assist both ethanol producers and suppliers in determining the carbon intensity (CI) of fuel delivered to British Columbia (BC) using GHGenius 5.02b. It applies to cellulosic and non-cellulosic ethanol feedstocks.

The guide covers the steps that a GHGenius user must use to model a specific ethanol plant. This includes ensuring that Microsoft Excel can properly run the model, setting up the model with correct region, year and using the Global Warming Potentials (GWPs) specified in the BC regulations, and inputting the plant specific data. The guide also covers running the model more than once for activities that occur in multiple regions and describes where the results are found.

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Glossary

Ag. residues	Agricultural residues, plant matter left over after crops are harvested or processed, such as corn stover and wheat straw, which can be a source of biomass.
BC	British Columbia
CCS	Carbon Capture and Storage
CCU	Carbon Capture and Utilization
CCUS	Carbon Capture, Utilization and Storage
CKF	Corn kernel fibre is the shell or bran around each corn kernel, which is mainly composed of cellulose. Corn kernel fibre is considered a component of corn feedstock under the BC Low Carbon Fuels Standard and not a separate feedstock.
DDG	Dried Distillers Grains
DDGS	Dried Distillers Grains with Solubles
GWP	Global Warming Potential
ICM	The developer (ICM Inc.) of the ethanol production process used in about half of the North American ethanol plants
IPCC	Intergovernmental Panel on Climate Change
Kg	Kilogram
kWh	Kilowatt-hour
LCA	Lifecycle Assessment
LCFS	Low Carbon Fuel Standard
MJ	Mega Joule
NaOH	Sodium hydroxide, also know as caustic soda.
PADD	Petroleum Administration for Defense Districts
SRF	Short Rotation Forestry

Introduction

This guidance is for fuel producers who plan to supply ethanol to British Columbia under the *Low Carbon Fuels Act* (LCFA). It provides instructions for setting up and using the approved life cycle assessment (LCA) model – GHGenius 5.02b – to determine the fuel's carbon intensity (CI). Fuel producers must follow the procedures and requirements outlined in this document and incorporate all relevant information into their application form and supplemental report, as applicable.

This document is divided into the following sections:

- Section 1: Ethanol Overview and GHGenius Pathways
- Section 2: GHGenius Model Overview
- Section 3: Feedstock Production and Transportation
- Section 4: Ethanol Production and Transportation
- Section 5: Distribution, Dispensing, and Use in BC
- Section 6: Material Balance Calculation
- Section 7: Appendix 1: Corn Ethanol Example
- Section 8: Appendix 2: Wheat Ethanol Example with CCS
- Section 9: Appendix 3: Cellulosic Hay Ethanol Example with CCU
- Section 10: Appendix 4: Cellulosic Forest Residue Ethanol Example

1 Ethanol Overview and GHGenius Pathways

Ethanol is produced from starch-based and cellulosic crops grown throughout the world and processed in more than 200 facilities in North America. Table 1-1 below outlines the various ethanol feedstock pathways available in the GHGenius model.

Table 1-1 Ethanol Feedstock Categories in GHGenius

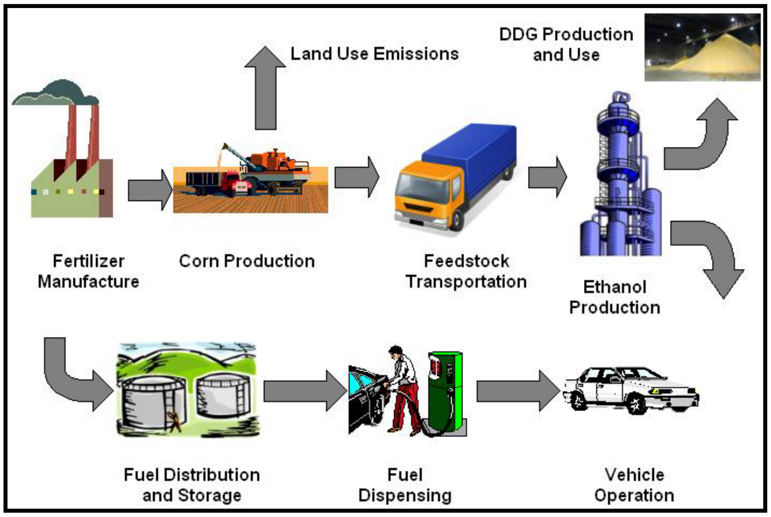
Starch Based	Cellulosic
Barley	Corn Stover
Corn[1]	Hay
Peas	Short Rotation Forestry
Sorghum	Standing Timber
Sugarcane	Sugarcane Bagasse
Sugar Beet	Switchgrass
Wheat	Wheat straw
	Wood Residue
	Sugarcane Bagasse
	Switchgrass

1.1 Ethanol Production System Boundary

Figure 1-1 below illustrates a sample life cycle system boundary for corn ethanol. Other feedstock crops will have similar system boundaries for life cycle assessment.

[1] Corn kernel fibre (CKF) is considered a component of corn feedstock under the BC Low Carbon Fuels Standard.

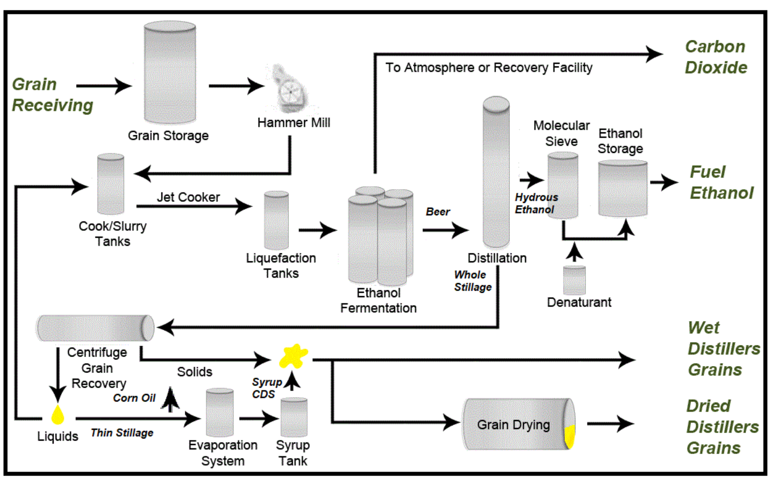
Figure 1-1 Corn Ethanol System Boundary



1.2 Process Flow Diagram

North American ethanol plants are generally similar in concept, with some variation between facilities. Figure 1-2 below outlines a typical process flow diagram for ethanol production.

Figure 1-2 Basic Ethanol Process Diagram



2 GHGenius Model Overview

This section outlines how to obtain the model and the steps that need to be taken to initialize it prior to inputting values for LCA modelling.

GHGenius is a Microsoft Excel-based LCA model. Features of GHGenius that users should be aware of include:

- The use of time-based data series rather than static data:
  - This means the selection of the Target year will alter the CI value of fuels modelled in GHGenius. Users must ensure that they select the appropriate Target year for their modelling (see sections 2.2.2 and 4.1)
- The inclusion of region and country specific datasets:
  - This means that the selection of the region will alter the CI value of fuel modelled in GHGenius. Users must ensure that they select the appropriate region for their modelling. If different life cycle stages occur in different regions, multiple runs of the model may be required (see section 2.2.1)

2.1 Downloading the Model

GHGenius 5.02b is available to download at: https://GHGenius.ca/index.php/downloads/74-GHGenius-5-02b. Registration is required to download the model. There is no cost to users.

The downloaded file is provided as a zipped [.xls] Excel file. After unzipping the file, do not save as a [.xlsx] file as this will deactivate the macros that the model requires to operate correctly.

Although the file can be saved as a macro enabled [.xlsm] format, this may result in loss of functionality. More specifically, some macro buttons may stop working unless manually reassigned. To ensure full functionality it is strongly recommended to save and run the model in its original [.xls] format.

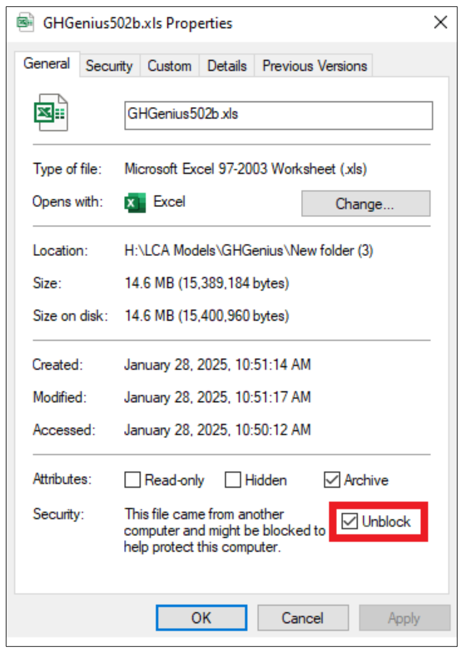
2.1.1 Unblocking Macros

GHGenius relies on macros to set up appropriate Excel settings, calculate output values, and provide additional tools for users. The model will only function properly with macros enabled.

To make Microsoft Office more secure, macros are now blocked by default on files downloaded from the internet. To unblock macros:

1. Navigate to the file in File Explorer
2. Right-click on the file's icon and select [Properties]
3. Select [Unblock] at the bottom of the General tab in the Properties window

Figure 2-1 Unblocking Macros



For more information about this change and alternative ways to unblock macros please visit: https://learn.microsoft.com/en-us/deployoffice/security/internet-macros-blocked.

2.2 Initializing the Model

Before entering any facility specific data to model a fuel pathway, users must first initialize the model as outlined in the sections below.

2.2.1 Model Region

To install the correct model region users must:

1. Select the appropriate modelling region from the dropdown list in cell B4 on the Input sheet,
2. Click the "Install Regional Defaults" button located to the right of the dropdown list (near cell C4)

- This action will run macros to populate region-specific data for the current modelling run.

3. Verify that the correct region has been applied in the model by checking that cell B10 on the Input sheet, which displays the currently active region, shows the correct region.

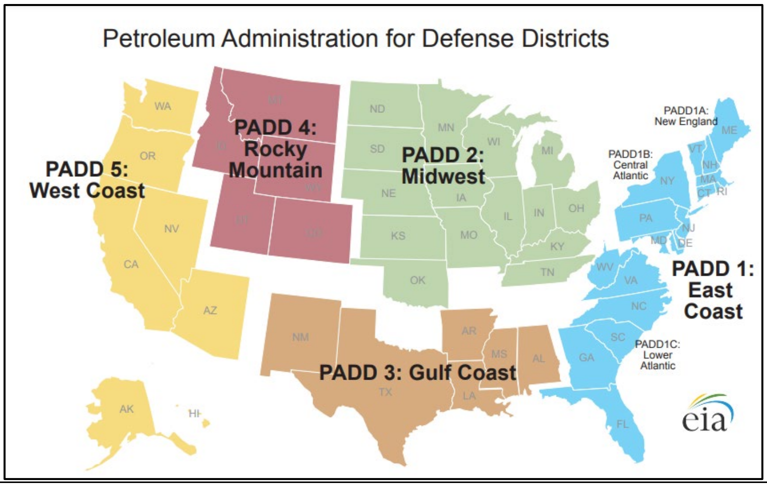
The selected region must correspond to where the relevant process of the fuel life cycle stage(s) occurred. Because fuel pathways often span multiple regions, most carbon intensity assessments will require two or three model runs to reflect the geographic locations of each life cycle stage. For example, if the feedstock originates from one region and the fuel is produced in another (outside British Columbia), the user must complete the following three modelling runs to determine the CI of the fuel:

1. Feedstock production and transportation – use the region where the feedstock originates.
2. Fuel production, transportation, storage and distribution – use the region where the production facility is located.
3. Fuel distribution, storage, dispensing and end use – use the region where the fuel is used (British Columbia).

For processes occurring within Canada, although the model allows selection of broader regions (e.g. Canada West/Central/East), users must select the specific province to accurately determine the fuel's carbon intensity. For cases where the feedstock comes from multiple provinces in one region, users may select the broader Canadian region that the feedstock comes from (e.g. Canada West, if the wheat comes from Manitoba and Saskatchewan).

The United States regions in GHGenius align with the US Energy Information Administration's Petroleum Administration for Defense Districts (PADDs) as shown in Figure 2-2 .

Figure 2-2 US Model Regions – PADDs



Source: https://www.eia.gov/petroleum/marketing/monthly/pdf/paddmap.pdf			
PADD	4 & 5	2 & 3	1
GHGenius Region	US West	US Central	US East

If a process occurs outside of Canada or the USA, users must select the appropriate country from the dropdown list. If the country is not available in the model, users must select the most appropriate proximate region within the model and provide a clear rationale for their selection. If unsure on which region to select please contact the BC Low Carbon Fuels Branch at lcfs@gov.bc.ca to determine which region to use, before submitting a CI application.

2.2.2 Model Year

The model year must be set to match the year the input data was collected or which the data represents. If the supporting data was collected over multiple years, set the model for the latest year in the dataset. For example, if data is from 2023 and 2024, set the year to 2024.

Users must enter the modelling year in two locations in the model, both on the Input sheet:

- Target Year: cell B7
- Base year for Alt Fuel Production: row 241
    - Column will vary depending on feedstock type (see Table 4-2 below).

2.2.3 Global Warming Potentials (GWPs)

By default, the model uses GWP values from the International Panel on Climate Change (IPCC) 5th Assessment Report (2013 100 years) and sets the treatment of short-lived gases as "Carbon Weighted".

The carbon weights for short-lived gases are shown in Table 2-1.

Table 2-1 Carbon Weights of Short-Lived Gases

Short-Lived Gas	Carbon Weight
Non-Methane Organic Compounds (NMOC)	2.99
Methane (CH4)	2.00
Carbon monoxide (CO)	1.57

To change the GWP settings, users can select different values in cells B11 and D11 on the Input sheet. However, for the purposes of fuel CI modelling under the BC LCFS, the selected GWP settings must align with those provided in Information Bulletin RLCF-011: Approved Version of GHGenius and Global Warming Potentials.

3 Feedstock Production and Transportation

Since the model incorporates region-specific data, users must model each feedstock type and its correlating region separately to calculate an accurate fuel CI.

For example, an ethanol plant in US Central that uses corn from US Central and US East and wheat from Saskatchewan would need to complete three separate feedstock transportation and production modelling runs which will then produce three separate fuel CI values when combined with the modelling results for fuel production.

Table 3-2 details the ethanol pathways available in the model along with which column to get the results from in the BC LCFS sheet. All results are found in rows 8-18 of the BC LCFS sheet.

Table 3-1 Ethanol Pathways, Included Feedstocks and Results Location

Ethanol Pathways	Included Feedstocks	GHGenius BC LCFS Sheet Results Column (rows 8-18)
Barley	Barley	R
Corn	Corn[1]	N
Cellulosic Ethanol (WX/GY) X: wood percentage Y: grass and agricultural residues percentage	Corn Stover Hay Short Rotation Forestry Standing Timber Switchgrass Wheat Straw Wood Residue	O
Peas	Peas	S
Sorghum	Sorghum	V
Sugarcane	Sugarcane Sugarcane Bagasse	P
Sugar Beet	Sugar Beet	U
Wet Stover	Wet Stover	P
Wheat	Wheat	Q

3.1 Corn Kernel Fibre

Corn kernel fibre (CKF) is treated as a component of the corn feedstock under the BC LCFS. CKF feedstock used to produce ethanol must be included in the corn feedstock input located in cell AE248 of GHGenius 5.02b. All energy and material inputs associated with the use of CKF (e.g. additional enzyme use) must be included in the corn ethanol pathway.

3.2 Cellulosic Feedstocks

The model uses one pathway to model all cellulosic ethanol feedstocks, except for sugarcane bagasse which is modelled using the sugarcane pathway along with the sugarcane. The cellulosic feedstocks are separated into the following subcategories:

- Grass and agricultural residues (ag. residues), and
- Wood

The pathways and their subcategories are shown in Table 3-2.

Table 3-2 Cellulosic Ethanol Feedstocks

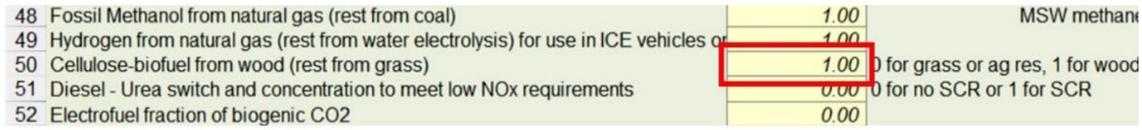
Cellulosic Feedstocks	Cellulosic Subcategory
Corn Stover	Grass and ag. residues
Hay	
Switchgrass	
Wheat Straw	
Short Rotation Forestry	Wood
Standing Timber	
Wood Residue	

The entry in cell B50 of the Input sheet is determined as follows:

- If the feedstock is wood, or
  - Cell B50 of the Input sheet must be set to 1.
- If the feedstock is a grass or agricultural residue.
  - Cell B50 of the Input sheet must be set to 0.

Figure 3-1 shows where to set the cellulosic ethanol subcategory using cell B50 of the Input sheet.

Figure 3-1 Selecting Cellulosic Subcategory



48	Fossil Methanol from natural gas (rest from coal)	1.00	MSW methane
49	Hydrogen from natural gas (rest from water electrolysis) for use in ICE vehicles or	1.00	
50	Cellulose-biofuel from wood (rest from grass)	1.00	0 for grass or ag res, 1 for wood
51	Diesel - Urea switch and concentration to meet low NOx requirements	0.00	0 for no SCR or 1 for SCR
52	Electrofuel fraction of biogenic CO2	0.00	

3.2.1 Grass and Agricultural Residues

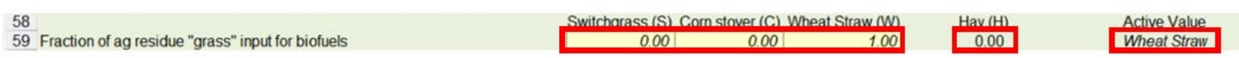
Cells B59-D59 of the Input sheet allows the applicant to select the type of grass or agricultural residue to be modelled.

To model switchgrass, corn stover or wheat straw:

- Set the feedstock's corresponding Input sheet cell to 1,
  - B59 for switchgrass,
  - C59 for corn stover, or
  - D59 for wheat straw.
- Set the other cells set to zero, and
- Run the model and check that cell G59 of the Input sheet contains the correct feedstock.

Figure 3-2 shows how to select wheat straw as the grass or agricultural residue feedstock.

Figure 3-2 Selecting Grass or Agricultural Residue



		Switchgrass (S)	Corn stover (C)	Wheat Straw (W)	Hay (H)	Active Value
58						
59	Fraction of ag residue "grass" input for biofuels	0.00	0.00	1.00	0.00	Wheat Straw

To set the feedstock to hay:

- Set cells in B59-D59 of the Input sheet to 0, and
- Run the model and check that cell G59 of the Input sheet value is "Hay".

3.2.2 Wood

To model wood feedstocks:

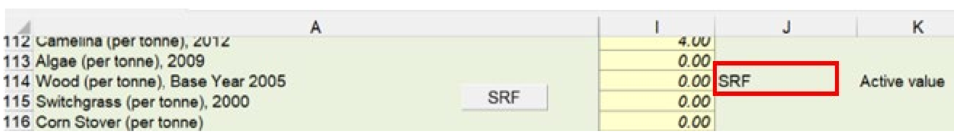
- Cell B50 of the Input sheet must be set to 1,
- Press the corresponding button in cells A14-A122 of the Input sheet as shown in Figure 3-3, and
  - SRF stands for Short Rotation Forestry,

- Wood Residue represent wood wastes from mills, and
- Standing Timber represents wood that comes from trees that were alive and still standing in a forest when they were harvested. Standing Timber can include Forest Residues that is left over after harvesting activities.

Figure 3-3 Selecting Wood Feedstock

- Ensure that cell J114 of the Input sheet contains the correct wood feedstock.
  - Figure 3-4 shows SRF selected as the wood feedstock

Figure 3-4 SRF Selected as Wood Feedstock



3.3 Feedstock Transportation

The transportation distances and modes of transportation for the feedstocks used in ethanol production must be entered in the Input sheet of the model, in Rows 76 to 86, under the column corresponding to the specific feedstock type, as outlined below in Table 3-3 below.

Table 3-3 Ethanol Input Sheet Columns for Feedstock Transportation

Ethanol Feedstock	GHGenius Feedstock Transportation Input Sheet Column
Barley	AJ
Corn	F (single stage), or G/H (two stage)
Corn Stover	I
Hay	I
Peas	AK
Short Rotation Forestry	J

Ethanol Feedstock	GHGenius Feedstock Transportation Input Sheet Column
Standing Timber	J
Sugarcane	AL
Sugarcane Bagasse	AL
Sugar Beet	AM
Sorghum	AN
Switchgrass	I
Wet Stover	G/H
Wheat	AI
Wheat Straw	I
Wood Residue	J

3.3.1 Single stage transportation

To model single stage transportation of a feedstock the steps are as follows:

- Find the column that corresponds to the feedstock,
- Enter the one-way transportation distance in kilometers in rows 76 to 80 on the Input sheet, and
- In rows 82 to 86, enter the tonnes-shipped/tonnes-produced for each mode of transport,
    - This number represents the fraction of total feedstock used in fuel production that was transported by that mode of transport.

3.3.2 Corn Ethanol Two Stage Feedstock Transportation

If whole corn is first transported to a preprocessing facility, where the kernels are separated from the stalks and cobs, before being transported to an ethanol production plant at a different location, users must do the following:

- Record the whole corn transportation distance and tonnes-shipped/tonnes-produced in columns G rows 76- 80 and rows 82-86 respectively, and
- Record the kernel transportation distance and tonnes-shipped/tonnes-produced in columns H rows 76- 80 and rows 82-86 respectively.

Please note: the model only supports this two-step transportation – with mid-way processing/separation – for corn. It is not applicable for wheat or other feedstocks.

3.3.3 Feedstock Transportation Example Scenarios

The three scenarios below outline how to correctly input transportation distances and modes for typical ethanol feedstock transportation scenarios. Users may combine elements from these examples as required to accurately represent their specific transport scenarios.

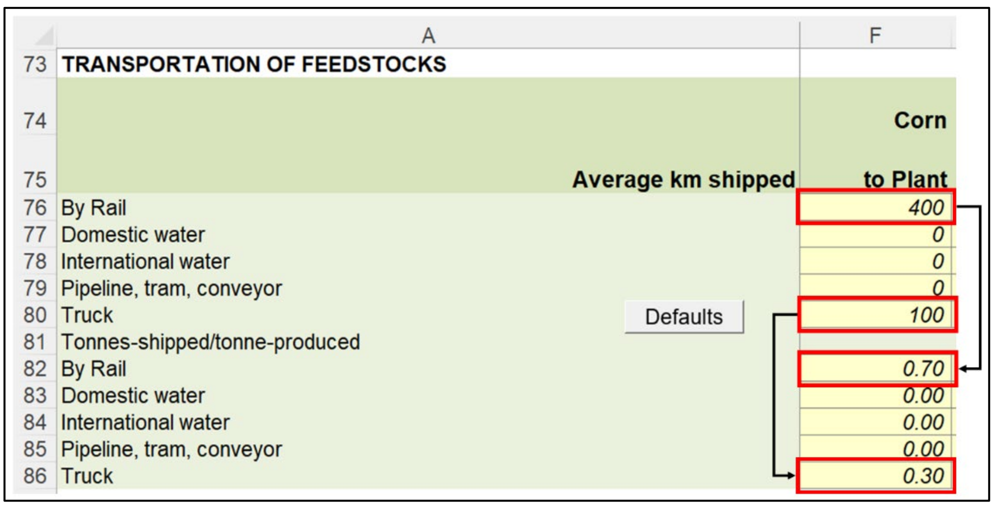
3.3.3.1 Scenario 1: Corn Trucked and Railed

An ethanol plant receives corn both locally via truck and from farther away via rail. For each tonne of corn used in fuel production:

- 300 kg is transported 100 km by truck, and
- 700 kg is transported 400 km by rail.

Figure 3-5 outlines the model inputs for this scenario below.

Figure 3-5 Feedstock Transport Scenario 1 Inputs



	A	F
73	TRANSPORTATION OF FEEDSTOCKS	
74		Corn
75	Average km shipped	to Plant
76	By Rail	400
77	Domestic water	0
78	International water	0
79	Pipeline, tram, conveyor	0
80	Truck	100
81	Tonnes-shipped/tonne-produced	
82	By Rail	0.70
83	Domestic water	0.00
84	International water	0.00
85	Pipeline, tram, conveyor	0.00
86	Truck	0.30

Scenario 2: Wheat Trucked and Railed

A wheat ethanol plant is not located on a railway, requiring trucks to complete the final leg of transportation. This scenario also reflects if the wheat must first be transported by truck to a rail terminal, or if trucking is needed on both ends.

In this scenario, each mode transports the entire tonne of feedstock used in fuel production. Therefore, users must enter

- 1 for the tonnes-shipped/tonnes-produced in rows 82 and 86 for rail and truck respectively,
- 340 km rail distance, and

- 50 km trucking distance.

Figure 3-6 below outlines the modelling inputs for this scenario.

Figure 3-6 Feedstock Transport Scenario 2 Input

	A	AI
73	**TRANSPORTATION OF FEEDSTOCKS**	
74		**Wheat**
75	**Average km shipped**	**to plant**
76	By Rail	*340*
77	Domestic water	*0*
78	International water	*0*
79	Pipeline, tram, conveyor	*0*
80	Truck (Defaults)	*50*
81	Tonnes-shipped/tonne-produced	
82	By Rail	*1.00*
83	Domestic water	*0.00*
84	International water	*0.00*
85	Pipeline, tram, conveyor	*0.00*
86	Truck	*1.00*

Scenario 3: Corn Trucked or Railed, Kernels Railed and Trucked

In this scenario whole corn is first processed into kernels, cobs and stalks in an intermediate facility the details are as follows:

- Half of the corn is transported 100 km by truck, and
- The other half is transported 300 km by rail.

After preprocessing, the kernels are sent to the ethanol plant as follow:

- Sent 200 km by rail, and
- Trucked 50 km from the railway to the ethanol plant.

This scenario combines elements of both scenario 1 and 2 and requires inputs into columns G and H of the Input sheet to reflect the two-stage transportation process. Figure 3-7 outlines the inputs for this scenario below.

Figure 3-7 Feedstock Transport Scenario 3 Inputs

	A	G	H
73	**TRANSPORTATION OF FEEDSTOCKS**		
74		**Whole Corn**	**Elevator**
75	**Average km shipped**	**to Elevator**	**to plant**
76	By Rail	300	200
77	Domestic water	0	0
78	International water	0	0
79	Pipeline, tram, conveyor	0	0
80	Truck (Defaults)	100	50
81	Tonnes-shipped/tonne-produced		
82	By Rail	0.50	1.00
83	Domestic water	0.00	0.00
84	International water	0.00	0.00
85	Pipeline, tram, conveyor	0.00	0.00
86	Truck	0.50	1.00

3.4 Feedstock Production

Users are not required to provide modelling inputs related to growing (or other agricultural processes) feedstocks for ethanol production. The model automatically applies aggregate regional data that is not designed to be customized by users.

However, if available, users should include the energy inputs related to preprocessing the raw feedstock into the form required for fuel production. Users must add these preprocessing energy inputs to the fuel production energy inputs outlined in Section 4.2.

3.5 Avoided Emissions

Waste materials often produce GHG emissions. By repurposing these materials for other uses, such as producing ethanol, you can avoid emissions from conventional disposal methods. GHGenius calculates these avoided emissions and applies an emissions credit to the waste materials used in ethanol production. In some cases, this credit results in negative emissions for the ethanol system.

3.5.1 Forest Residue

Forest Residue is the fibre left behind on a site after primary harvesting operations of Standing Timber have been completed. Forest Residues includes smaller or poor-quality logs and pieces of logs, branches and other woody biomass. This waste is often left in a cut block and piled into large slash piles by machinery.

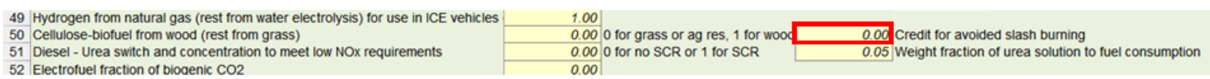
In some jurisdictions, Forest Residues are burned in the forest, leading to suboptimal combustion conditions that produce methane and nitrous oxide emissions. However, using the Forest Residues to produce cellulosic ethanol avoids these emissions.

To select the slash burning avoided emission credit enter one of the following in cell E50 of the Input sheet:

- Entering 0 in this cell provides no avoided emission credit, and
- Entering 1 provides a 100% credit, and
- If the plant processes a combination of Forest Residues and other materials enter a value between 0 and 1 to reflect the proportion of Standing Timber used on a dry mass basis.

Setting a 0% slash burning avoided emission credit is shown in Figure 3-8.

Figure 3-8 Setting Slash Burning Credit



49	Hydrogen from natural gas (rest from water electrolysis) for use in ICE vehicles	1.00			
50	Cellulose-biofuel from wood (rest from grass)	0.00	0 for grass or ag res, 1 for wood	0.00	Credit for avoided slash burning
51	Diesel - Urea switch and concentration to meet low NOx requirements	0.00	0 for no SCR or 1 for SCR	0.05	Weight fraction of urea solution to fuel consumption
52	Electrofuel fraction of biogenic CO2	0.00			

4 Ethanol Production and Transportation

Ethanol production data must be normalized using the volume of undenatured ethanol before it is entered into GHGenius (i.e. the volume of denaturant should be excluded).

Each feedstock pathway must have its own fuel code. However, production facility operating data using mixed feedstocks may be used for modelling in the fuel production stage. For example, if an ethanol plant processes corn and wheat and the facility does not have operating data for each feedstock, the same operating data for the plant can be used for both the corn and wheat feedstocks.

Feedstock and fuel consumption data is entered on the Input sheet, while material consumption data is entered on the Alt Fuel Prod sheet.

Table 4-1 details the columns of the Input and Alt Fuel Prod sheets that energy, material and feedstock consumption data are entered for each ethanol feedstock.

Table 4-1 Ethanol Pathway Input and Alt Fuel Prod Sheet Locations

Ethanol Feedstock	Input Sheet Column	Alt Fuel Prod Sheet Column
Barley	AG	AO
Corn	AE	AM
Peas	AH	AT
Sorghum	AQ	AV
Sugarcane	AI	AP
Sugar Beet	AP	AX
Wheat	AF	AZ
Corn Stover	AK	AX
Hay	AM	AQ
Short Rotation Forestry	AO	AQ
Standing Timber	AO	AY
Sugarcane Bagasse	AI	AS
Switchgrass	AJ	AW
Wheat Straw	AL	AN
Whole Corn	AN	AU
Wood Residue	AO	AX

4.1 Year

The Target Year and the fuel production base year must reflect the year that data used to generate the modelling inputs was collected. If the supporting data was collected over multiple years, set the model for the latest year in the dataset.

- Set the Target year in cell B7 of the Input sheet.
- Set the fuel production year in row 241 of the Input sheet under the column that corresponds to the feedstock type (see Table 4-2 below).

4.2 Feedstock Consumption

Feedstock consumption is entered in rows 247 and 248 of the Input sheet under the column that corresponds to the feedstock type (see Table 4-1). Feedstock consumption in GHGenius should be entered in $kg/L_{ethanol}$

Feedstock consumption is entered in the row corresponding with the feedstock category as detailed in Table 4-2. The feedstock consumption is either entered on a dry mass or a as-received basis.

- For starch-based feedstocks, enter the mass on an "as received" basis (do not convert to "dry mass").
- For cellulosic feedstocks, enter the mass on a "dry mass" basis.

Table 4-2 Ethanol Feedstock Consumption

Ethanol Feedstock	Feedstock Type	Feedstock Consumption Input Row	Feedstock Consumption Mass Basis
Corn Stover	Cellulosic	247	Dry mass
Hay			
Short Rotation Forestry			
Standing Timber			
Sugarcane Bagasse			
Switchgrass			
Wheat Straw			
Whole Corn			
Wood Residue			
Barley	Starch	248	As received
Corn			
Peas			

Ethanol Feedstock	Feedstock Type	Feedstock Consumption Input Row	Feedstock Consumption Mass Basis
Sorghum			
Sugarcane			
Sugar Beet			
Wheat			

4.3 Energy Consumption

Energy consumption is entered in rows 243 to 247 of the Input sheet under the column that corresponds to the feedstock type (see Table 4-1).

4.3.1 Electricity

Enter net electricity purchased in row 243 of the Input sheet in $kWh/L_{Ethanol}$

If a production facility generates electricity internally, such as from a steam pressure let-down turbine, do not include this electricity in the model input. The model only accounts for net electricity used, meaning electricity that crosses the life cycle analysis system boundary outlined in Section 1.1 above. Only include electricity that is purchased or imported into the system boundary. Exclude all internally generated electricity, unless excess electricity is sold to the grid.

4.3.1.1 Combined Heat and Power Systems

Some fuel production facilities include a combined heat and power (CHP) system that generates thermal energy and electricity. The thermal energy is used in the fuel production facility, and the electricity is either used in the fuel production process or sold to the local grid.

Typically, the electricity generated by the CHP system is sold to the grid, with electricity used in fuel production purchased from the grid. As the thermal heat of the CHP system is used in fuel production, the electricity generated by the CHP system is considered inside the system boundary.

Electricity consumption in GHGenius is looked at on a net-basis using the equation below:

$$E_{Net} = E_{purchased -} E_{sold}$$

- If $E_{Net} > 0$
  - E_{Net} is entered as a fuel production input in row 243 of the Input sheet

- If $E_{Net} < 0$:
  - Fuel production electricity in row 243 of the Input sheet is set to 0
  - E_{Net} is entered as a co-product in row 274 of the Input sheet

CHP systems can use fossil (e.g. natural gas) and/or biogenic feedstocks (e.g. sugarcane bagasse and agricultural residues), for instructions on how to model biogenic feedstock used in a CHP systems see Section 4.3.5. Fossil feedstocks used in a CHP system are entered in the following rows of the Input sheet:

- Diesel: row 244
  - Proxy for light fuel oil.
- Natural gas: row 245
- Coal: row 246

4.3.1.2 Other On-Site Electricity Generation

Other on-site electricity generation (e.g. solar panels) is considered outside of the system boundary of the fuel production facility and excess electricity sold to the grid is ineligible for a co-product credit. Other on-site electricity generation can be used to reduce the amount of electricity purchased if the fuel production facility consumes more electricity than it sells to the grid.

Example:

An ethanol production facility has a CHP system and on-site solar panels with the following electricity generation and consumption:

- Ethanol plant electricity consumption: 0.2 kWh/$L_{ethanol}$
- CHP system generation: 0.3 kWh/ $L_{ethanol}$
- Solar generation: 0.06 kWh/ $L_{ethanol}$

As this facility produces more electricity through the CHP system than is consumed by the plant, the solar generation is excluded, and the net electricity is entered as 0.1 kWh/ $L_{ethanol}$ as a co-product in row 274 of the Input sheet.

If instead the ethanol production facility had the following characteristics:

- Ethanol plant electricity consumption: 0.2 kWh/ $L_{ethanol}$
- CHP system generation: 0.12 kWh/ $L_{ethanol}$
- Solar generation: 0.06 kWh/ $L_{ethanol}$

The solar generation can be included as the ethanol production facility consumes more electricity than the fuel production facility and solar panels produce. The net electricity is entered as 0.02 kWh/ $L_{ethanol}$ as a fuel production input in row 243 of the Input sheet.

4.3.2 Diesel Fuel

Enter diesel fuel consumption into row 244 of the Input sheet in $L_{DieselL/LEthanol}$.

Users must include all diesel used at the ethanol production facility, such as fuel for rail car shuttles, front-end loaders, or any other diesel-powered equipment.

4.3.3 Natural Gas

Enter the natural gas use into row 245 on a higher heating value basis in $MJ_{Natural\ gas}/L_{ethanol}$.

4.3.4 Coal

Enter the coal consumption into row 246 in kg_{coal} /$L_{ethanol}$

4.3.5 Biomass

Some fuel production facilities utilize biomass (e.g. agricultural residues, wood and sugarcane bagasse) for use as a fuel source for a CHP system. Biogenic CHP system feedstock consumption is added to row 247 of the Input sheet on a dry mass-basis.

Transportation emissions for biogenic CHP system feedstock are not modifiable as GHGenius assumes the same transportation distances as the main feedstock.

Example:

A corn ethanol facility utilizes the following biogenic feedstocks in a CHP system:

- Agricultural residues:
  - Wet mass: 1 $kg_{agricultural\ residues}/L_{ethanol}$
  - Moisture content: 60%
  - Dry mass: 0.4 $kg_{agricultural\ residues}/L_{ethanol}$
- Wood:
  - Wet mass: 0.4 $kg_{wood}/L_{ethanol}$
  - Moisture content: 50%

  - Dry mass: 0.2 kg/$L_{ethanol}$

The total dry mass of biomass consumed in the CHP system is entered as 0.6 $kg_{biomass}/L_{ethanol}$ in cell AE247 of the Input sheet in GHGenius.

4.3.6 Steam

Some fuel production facilities use steam produced outside of the fuel production system boundary (e.g. an adjacent CHP facility). GHGenius does not include a steam input and requires the user to convert the steam to the equivalent energy input used to produce the steam. For example, if the steam is produced in a natural gas fired boiler, the applicant must convert the quantity of steam used to an equivalent natural gas consumption rate.

Note: It is assumed that steam is generated with 80% efficiency. If applicants can demonstrate data that steam generation is more efficient, they can use their specific conversion efficiency.

The steps to convert steam to an equivalent energy input are as follows:

1 Determine the specific enthalpy of saturated steam consumed in MJ, based on the steam pressure and temperature.
  - Link: Thermodynamic Properties of Saturated Steam: Data & Charts in Bar

2 Divide the energy content by the boiler efficiency (80%) to determine the energy required into the boiler.

3 Convert the energy required to the equivalent energy input in GHGenius by dividing by the energy input's higher heating value (HHV) shown in

4 Table 4-3

Table 4-3 Energy Input HHV

Energy Input		HHV	Unit	Reference
Electricity		3.6	MJ/kWh	N/A
Diesel		38.65	MJ/L	Fuel Char sheet cell B85
Natural gas		1	MJ/MJ	N/A
Coal		21.9	MJ/kg	Fuel Char sheet cell K85 (GHGenius set to BC and 2025)
Biomass	Wood	20.0	MJ/kg	Fuel Char sheet cell K133
	Generic Grass	20.00	MJ/kg	Fuel Char sheet cell K134
	Switch Grass	17.40	MJ/kg	Fuel Char sheet cell K135
	Corn stover (field residue)	18.06	MJ/kg	Fuel Char sheet cell K136

Energy Input		HHV	Unit	Reference
	Wheat Straw	18.30	MJ/kg	Fuel Char sheet cell K137
	Hay	17.40	MJ/kg	Fuel Char sheet cell K138
	Wet Corn stover	17.10	MJ/kg	Fuel Char sheet cell K139
	Sugar cane trash	12.30	MJ/kg	Fuel Char sheet cell K140
	Sugar cane bagasse	18.30	MJ/kg	Fuel Char sheet cell K141
	Manure	18.90	MJ/kg	Fuel Char sheet cell K142
	Organic Waste	16.20	MJ/kg	Fuel Char sheet cell K144

5 Add the equivalent energy input to GHGenius into the following rows of the Input sheet of GHGenius:

- Electricity: 243
- Diesel (light fuel oil): 244
- Natural gas: 245
- Coal: 246
- Biomass: 247

4.3.6.1 Steam Energy Example

An ethanol facility consumes steam from an adjacent boiler facility the steam has the following characteristics:

- Steam properties:
  - Consumption: 2.62 $kg_{steam}/L_{ethanol}$
  - Pressure: 10 bar
  - Temperature: 184 °C
  - Specific enthalpy: 2.78 MJ/kg_{steam}

The amount of steam is converted to an equivalent energy required for the boiler assuming an 80% boiler efficiency as follows:

1) Calculate the total steam energy consumed:

$$2.62\ kg_{steam}\ /L_{ethanol} *\ 2.78\ \mathrm{MJ}/kg_{steam} =\ 7.28\ MJ_{steam}/L_{ethanol}$$

2) Calculate the total equivalent energy required for the boiler:

$$\frac{\text{Total Steam Energy Consumed } (\frac{MJ_{steam}}{L_{ethanol}})}{\text{Boiler Efficiency}} = \frac{7.28}{80\%} = 9.1\ \frac{MJ_{Input}}{L_{ethanol}}$$

3) The total boiler input is converted to an equivalent energy input as follows:
   a) If the boiler consumes light fuel oil (LFO)
      i) Convert the total LFO energy consumed into L:

$$\frac{\text{Total LFO Energy Content }(\frac{MJ_{LFO}}{L_{ethanol}})}{\text{LFO Energy Density }(\frac{\text{MJ}}{L_{LFO}})} = \frac{9.1}{38.65} = 0.24\ \frac{L_{LFO}}{L_{ethanol}}$$

      ii) Add 0.24 $L_{LFO}/L_{ethanol}$ to row 244 of the Input sheet.
   b) If the boiler consumes natural gas (NG)
      i) Add 9.1 $MJ_{NG}/L_{ethanol}$ to row 245 of the Input sheet.
   c) If the boiler consumes coal
      i) Convert the total coal energy consumed into kg:

$$\frac{\text{Total Coal Energy Content }(\frac{MJ_{coal}}{L_{ethanol}})}{\text{Coal Energy Density }(\frac{\text{MJ}}{kg_{coal}})} = \frac{9.1}{21.9} = 0.42\ \frac{kg_{coal}}{L_{ethanol}}$$

      ii) Add 0.42 $kg_{coaL/Lethanol}$ to row 246 of the Input sheet.
   d) If the boiler consumes wood biomass:
      i) Convert the total biomass energy consumed into kg:

$$\frac{\text{Total Wood Energy Content }\left(\frac{MJ_{wood}}{L_{ethanol}}\right)}{\text{Wood Energy Density }\left(\frac{\text{MJ}}{kg_{ethanol}}\right)} = \frac{9.1}{20.0} = 0.46\ \frac{kg_{wood}}{L_{ethanol}}$$

      i) Add 0.46 $kg_{wood}/L_{ethanol}$ to cell AF247 of the Input sheet.

4.3.7 Material Inputs

To model the chemicals additives used for ethanol production, the user must use the Alt Fuel Prod sheet of GHGenius. Enter the values in rows 29-78 that corresponds to the chemical used and under the column that corresponds to the ethanol feedstock (See Table 4-1 above).

- Report input units in kilogram of chemical per litre of undenatured ethanol ($kg_{ChemicaL/LEthanol}$).
- All chemical inputs must reflect 100% purity. If the chemical is less than 100% pure, adjust the input value before entering it into the model.

- For example, if using a 93% pure sulphuric acid additive, multiply by 0.93 before inputting into the model to account for the actual active chemical content.

4.4 Coproducts

GHGenius automatically calculates the quantity of coproducts from ethanol production based on a mass balance approach, using the ethanol yield as the determining factor. The model accounts for the stoichiometric production of carbon dioxide and allocates the remaining non-fermentable components, such as corn oil, dried distillers' grains, wet distillers' grains, condensed syrup and other fractions of fiber, protein and minerals as coproducts.

No user inputs are required for modelling the primary coproducts of ethanol.

The model's default settings assign a displacement credit to ethanol coproducts. These coproducts displace the original grain and a protein meal. For corn ethanol, distillers' grains displace both corn and soybean meal.

4.4.1 Carbon Capture and Utilization Coproduct Credit

Some ethanol plants capture a portion of the CO_2 produced during fermentation for utilization in industrial applications, such as beverage carbonation, or flash freezing. Because this CO_2 is eventually released into the atmosphere, it cannot be treated as sequestration. This method is called Carbon Capture and Utilization (CCU) and can be eligible for a coproduct credit.

Capturing CO_2 from an ethanol plant usually requires less energy than capturing it from other sources due to the relative purity of CO_2 produced in the fermentation process. The coproduct credit is based off the difference of energy used to capture CO_2 at an ethanol plant and the energy required to capture the same CO_2 at a natural gas power plant.

Many ethanol plants sell the captured CO_2 to industrial gas companies, which are responsible for the electricity used for compression.

Plants that claim the CCU coproduct credit, cannot claim the fuel production credit for either:

- Carbon capture and storage (CCS see Section 4.5), or
- Carbon capture, utilization and storage (CCUS see Section 4.5.1).

Claiming the CCU credit and one of the CCS or CCUS fuel production credit would result in double counting of captured CO_2 .

The CCU coproduct credit is smaller than the fuel production credit for CCS and CCUS as it does not include negative CO_2 emissions associated with permanent storage.

To model CCU in GHGenius the steps are as follows:

1. Enter the amount of CO_2 captured for utilization in cell B261 on the Input sheet as shown in Figure 4-1.
    a. The amount entered in B261 should be the amount utilized or sold for utilization and should not include any losses within the system boundary as detailed in Section 1.

Figure 4-1 Entering CO_2 Captured for Utilization Coproduct Credit

260	EMISSIONS DISPLACED BY CO PRODUCTS OF FUEL PRODUCTION PROCESSES (Sheet: Coproducts)	
261	Carbon Dioxide Capture With Ethanol Plant (kg CO2 captured/litre ethanol)	0.00
262	Fraction of DDGS that displaces existing soy meal or corn feed (rest adds to ne	1.00
263	Kilograms of algae meal produced per litre of algae oil produced and used as fe	2.05

2. Include the electricity used for the CO_2 purification and compression in the ethanol plant's electricity input in row 243 of the Input sheet under the column that corresponds to the feedstock type (see Table 4-2).

The model then includes the avoided emissions in the Fuel Coproducts Production result in row 15 of the BC LCFS sheet for the column corresponding to the feedstock (see Table 3-1).

4.4.2 Excess Electricity Coproduct Credit

Section 4.3.1.1 details how to determine the net electricity consumed or generated at an ethanol plant. For cases where the fuel production facility produces more electricity than it consumes (excluding other on-site electricity generation, see section 4.3.1.2), a coproduct credit can be claimed for the net excess electricity generated.

The excess electricity coproduct credit is entered in row 274 of the feedstock's corresponding column in the Input sheet of GHGenius. The excess electricity coproduct credit uses energy allocation by default which is entered in cell B268 of the Input sheet.

4.5 Carbon Capture and Sequestration

Some ethanol plants capture the fermentation CO_2 and sequester that material permanently in underground storage.

Figure 4-2 Ethanol Fermentation Equation

$$C_6H_{12}O_6\ (\boldsymbol{Glucose}\ 180\frac{g}{mol}) \rightarrow 2C_2H_5OH\ \left(\boldsymbol{Ethanol}\ 2*46\frac{g}{mol}\right) + 2CO_2(\boldsymbol{CO_2}\ 2*\ 44\frac{g}{mol})$$

The ethanol fermentation process, as shown in Figure 4-2, produces 44 kg of CO_2 per 46 kg of ethanol, which is the equivalent of 0.755 kg CO_2 per litre of ethanol. A sequestration rate of 100% would be the equivalent of sequestering 0.755 kg CO_2 per litre of ethanol, actual sequestration rates can be significantly lower than this once losses such as fugitives and venting are accounted for.

To model carbon capture and storage (CCS) in GHGenius, complete the following steps:

1. On the Input sheet, enter 1 in cell B69 to activate the CCS calculation as shown in Figure 4-3.

Figure 4-3 Activating CCS Calculation

67	MISCELLANEOUS FUEL, FEEDSTOCK, AND FUELCYCLE INPUT DATA/CARBON SEQUESTRATION (Sheet: Sequestration)			
68	Carbon Sequestration for power generation		0.00	Enter 1 to account for carbon sequestration for the electricity generation
69	Carbon Sequestration for fuel production	Go to Sequestration	1.00	Enter 1 to account for carbon sequestration for alternative fuel production
70	Carbon Sequestration for refineries		0.00	Enter 1 to account for carbon sequestration for crude oil refineries

In the Sequestration sheet under the column that corresponds to the feedstock type (see Table 4-2), enter the fraction of CO_2 sequestered in row 19, then enter the energy used in the sequestration process in rows 22–26. The corn ethanol sequestration cells are shown in Figure 4-4.

- The fraction sequestered should only include the CO_2 permanently sequestered and should exclude any losses to the atmosphere such as fugitive emissions and venting at the injection site.

Figure 4-4 Entering CCS Sequestration Rate and Energy Inputs

15	Fuel	M100	M100	Ammonia	E100	E100	E100
16	Feedstock	Coal	Wood	Natural Gas	Corn	Wheat	Barley
17	Inputs (below) per output	litre	litre	kg	litre	litre	litre
18							
19	Fraction emissions sequestered	0.85	0.85	0.85	0.85	0.85	0.85
20	Dollars per tonne sequestered	50.00	50.00	50.00	50.00	50.00	50.00
21							
22	Electricity (kWh)	0.13	0.15	0.13	0.09	0.09	0.09
23	Diesel (L)	0.00	0.00	0.00	0.00	0.00	0.00
24	Natural gas (MJ)	0.00	3.14	2.40	0.00	0.00	0.00
25	Coal (kg)	0.12	0.00	0.00	0.00	0.00	0.00
26	Wood (kg)	0.00	0.00	0.00	0.00	0.00	0.00

4.5.1 Carbon Capture, Utilization and Storage

Carbon capture, utilization and storage (CCUS) is when captured CO_2 is utilized before being permanently stored underground, through processes such as enhanced oil recovery (EOR). CCUS is considered a form of CCS and is modelled using the same steps detailed in Section 4.5

4.6 Ethanol Transportation

To model the transportation of ethanol from the production facility to BC enter the transportation distances and modes of transportation for the ethanol in the Input sheet in rows 91 to 102, under the column that corresponds to the feedstock type, (see Table 4-4 below).

Table 4-4 Ethanol Input Sheet Columns for Finished Ethanol Transportation

Ethanol Feedstock	GHGenius Ethanol Transportation Input Sheet Column
Barley	AG
Corn	AD
Peas	AH
Sugarcane	AI
Sugarcane Bagasse	AI
Sugar Beet	AJ
Sorghum	AK
Wheat	AF
Corn Stover	AE
Hay	
Short Rotation Forestry	
Standing Timber	
Switchgrass	
Wet Stover	
Wheat Straw	
Wood Residue	

Users must use the same modelling region for this stage as used for fuel production stage (see Section 2.3.1) and should be completed in the same model run.

4.6.1 Transloading

Transloading refers to the process of transferring the product from one mode of transportation to another (i.e. from truck to rail or vise versa). Within the GHGenius model, transloading is used to account for electricity consumption associated with fuel transferring, blending and/or storage.

- If any transloading, blending, or storage of fuel occurs between the production facility and its delivery to a location within BC, then set Transloading to “Yes” in row

91 and under the column that corresponds to the feedstock type (see Table 4-4 above).

- If there is a single mode of transportation used between the production facility and delivery to a location in BC and no blending or storage occurs, then set Transloading to "No" in row 91 and under the column that corresponds to the feedstock type (see Table 4-4 above).

5 Distribution, Dispensing, and Use in BC

Users must model the fuel pathway to include the emissions associated with distribution, dispensing, and use within BC.

- Set the model region to BC to accurately capture these emissions (see 2.2.1 above).
- If fuel production occurs outside of BC, run a separate model to capture the related emissions.
- If fuel production occurs within BC, include these emissions in the same modelling run as fuel production and finished fuel transportation.

Enter the following information in the Input sheet column that represents the ethanol feedstock (see Table 4-4 above):

- Row 91 – Transloading: Yes
- Row 96 – Truck Distance: 80 km
- Row 102 – Truck Mode: 1

6 Material Balance Calculation

The material balance calculation requirements are detailed in RLCF-008. Ethanol CI applications submitted under the BC LCFS must include a material balance calculation for the fuel production stage.

6.1 Wheat Ethanol Material Balance Example

Wheat ethanol is produced in a facility with the input data shown in Table 6-1. Other material inputs (e.g. enzymes and yeast) are deemed immaterial as they contribute <1% to the total input mass.

Table 6-1 Material Balance Example Inputs

Input Stream	GHGenius Location	GHGenius Input	Input ($g/L_{ethanol}$)	Function	Notes
Wheat	Input AF248	2.61 kg/L	2610	Feedstock	
Water	N/A	N/A	154	Hydrolysis	Measured
Other Inputs	N/A	N/A	N/A	Other	Excluded due to immateriality
Total Input			**2764**		

The output data for the facility is shown in Table 6-2. The facility captures and sequesters CO_2 which is measured. The mass of waste is calculated as the difference between the total input mass and the total of the other outputs' masses.

Table 6-2 Material Balance Example Outputs

Output Stream	GHGenius Location	GHGenius Input	Output ($g/L_{ethanol}$)	Function	Notes
Animal feed	N/A	N/A	914	Co-product	Not entered in GHGenius
Ethanol	N/A	N/A	790	Main Product	Density from cell E105 of Fuel Char sheet
CO2	Sequestration AJ19	85%	642	CCS	85% of available 755 g_{CO2}/L ethanol

Output Stream	GHGenius Location	GHGenius Input	Output ($g/L_{ethanol}$)	Function	Notes
Other Outputs	N/A	N/A	N/A	Other	Excluded due to immateriality
Waste	N/A	N/A	418	Waste	Unmetered streams. Calculated using material balance.
Total Output			**2764**		

7 Appendix 1: Corn Ethanol Example

Any fuels produced outside of BC require at least two separate model runs to accurately calculate the results. Below is an example where the pathway has the following characteristics:

- The feedstock is corn is from the US Central region,
- The fuel production facility is in Iowa, and
  - Iowa is in the US Central modelling region.
- The ethanol is railed to BC.

Note: For ethanol plants that utilize corn kernel fibre (CKF), the modelling steps are the same, with the CKF included in the feedstock input along with the corn starch.

The first run is for feedstock and fuel production in the US Central region. This is used to generate the emissions for the following life cycle stages:

- Direct land use change emissions,
- Feedstock production or cultivation,
- Feedstock upgrading,
- Feedstock transport,
- Feedstock coproducts production,
- Avoided emissions,
- Fuel production,
- Fuel coproduct production, and
- Fuel distribution and storage.

Be sure to click the Install Regional Defaults button after setting cell B4 to the appropriate region. Table 7-1 shows the values used for this modelling exercise. A GHGenius user would replace these values with their actual values.

Table 7-1 US Central Corn Ethanol: US Central Run Model Inputs

Sheet	Cell	Parameter	Value
Input	B4	Region	US Central
Input	B7	Year	2023
Input	B11	GWP	2013 (100 year)

Sheet	Cell	Parameter	Value
Input	D11	Short lived gases	Carbon Weighted
Input	F80	Feedstock truck distance, km	80
Input	F86	Feedstock truck mode	1
Input	AD91	Transloading	No
Input	AD92	Finished fuel rail distance, km	3000
Input	AD96	Finished fuel truck distance, km	0
Input	AD98	Finished fuel rail mode	1
Input	AD102	Finished fuel truck mode	0
Input	AE241	Year	2023
Input	AE243	Electricity, kWh/L	0.2
Input	AE244	Diesel, L/L	0
Input	AE245	Natural Gas, MJ/L	7.5
Input	AE246	Coal, kg/L	0
Input	AE248	Corn, Kg/Litre	2.35
Alt Fuel Prod	AM30	Ammonia, kg/L	0.005
Alt Fuel Prod	AM41	Enzymes, kg/L	0.002
Alt Fuel Prod	AM53	NaOH, kg/L	0.005
Alt Fuel Prod	AM72	Sulphuric acid, kg/L	0.01
Alt Fuel Prod	AM76	Urea, kg/L	0.0000
Alt Fuel Prod	AM77	Yeast, kg/L	0.0001

The transportation emissions are based on the distance and the mode. Either a zero distance or a zero mode will result in no emissions being calculated.

The chemicals are entered on a 100% basis, caustic soda (NaOH) is often sold and used at a 50% concentration. Similarly, the standard concentration of sulphuric acid is 93%.

The default value for all other chemicals for this ethanol pathway is zero.

The results for the year 2023 are shown in Table 7-2. These values are from the BC LCFS sheet column N, rows 8 to 16.

Table 7-2 US Central Corn Ethanol: US Central Run 2023 Emissions

Stage	Emissions, g CO_2e/GJ (HHV)
Direct land use change	0
Feedstock production or cultivation	23,287
Feedstock upgrading	0
Feedstock transport	1,045

Stage	Emissions, g CO_2e/GJ (HHV)
Feedstock coproducts production	0
Avoided emissions	0
Fuel production	26,524
Fuel coproducts production	-11,679
Fuel distribution and storage	2,022

The second run is in BC and uses a prescribed 80 km of distribution by truck to calculate the following life cycle stages:

- Fuel distribution and storage,
- Fuel dispensing, and
- Vehicle or Vessel operation.

After the BC region is selected in cell B4 the "Install Regional Defaults" button must be pressed. Most of the inputs can be left the same as the first US Central run. Only the changes outlined in Table 7-3 are required to calculate the BC emissions. These changes can be made to the version of the model used for the US Central run or a fresh version of the model.

Table 7-3 US Central Corn Ethanol: BC Final Run Model Inputs

Sheet	Cell	Parameter	Value
Input	B4	Region	BC
Input	AD91	Transloading	Yes
Input	AD92	Finished fuel rail distance, km	0
Input	AD96	Finished fuel truck distance, km	80
Input	AD98	Finished fuel rail mode	0
Input	AD102	Finished fuel truck mode	1

The results for the BC region are in Table 7-4. These are from the BC LCFS sheet, column N rows 16 to 18.

Table 7-4 US Central Corn Ethanol: BC Final Run 2023 Emissions

Stage	Emissions, g CO_2e/GJ (HHV)
Fuel distribution and storage	643
Fuel dispensing	133
Vehicle or Vessel operation	2,397

The results from the two regions are combined to produce a final CI as shown in Table 7-5. The values in the first two columns are summed to produce the values in the right-hand column.

Table 7-5 US Central Corn Ethanol: Total 2023 Emissions

Stage	US Central	BC	Total
	Emissions, g CO_2e/GJ (HHV)		
Direct land use change	0		0
Feedstock production or cultivation	23,287		23,287
Feedstock upgrading	0		0
Feedstock transport	1,045		1,045
Feedstock coproducts production	0		0
Avoided emissions	0		0
Fuel production	26,524		26,524
Fuel coproducts production	-11,679		-11,679
Fuel distribution and storage	2,022	643	2,665
Fuel dispensing		133	133
Vehicle or Vessel operation		2,397	2,397
Total	41,199	3,173	44,372
Total, g CO_2e/MJ	41.20	3.17	44.37

7.1 Corn Ethanol Material Balance

The material balance inputs are shown in Table 7-6 for the corn ethanol pathway. Only the corn feedstock is considered, with the other inputs considered immaterial as they make up less than 1% of the input mass.

Table 7-6 Corn Ethanol Material Balance Inputs

Input Stream	GHGenius Location	GHGenius Input	Input ($g/L_{ethanol}$)	Function	Notes
Corn	Input AE248	2.35 kg/L	2350	Feedstock	
Water	N/A	N/A	160	Hydrolysis	Measured
Other Inputs	N/A	N/A	N/A	Other	Excluded due to immateriality
Total Input			**2510**		

The output data for the facility is shown in Table 7-7. The mass of waste is calculated as the difference between the total input mass and the total of the other outputs' masses and includes CO_2, as the CO_2 is not measured

Table 7-7 Corn Ethanol Material Balance Outputs

Output Stream	GHGenius Location	GHGenius Input	Output (g/L$_{ethanol}$)	Function	Notes
Animal feed	N/A	N/A	682	Coproduct	Not entered in GHGenius
Ethanol	N/A	N/A	790	Main Product	Density from cell E105 of Fuel Char sheet
CO2	N/A	N/A	N/A	N/A	Not measured
Other Outputs	N/A	N/A	N/A	Other	Excluded due to immateriality
Waste	N/A	N/A	1038	Waste	Unmetered streams. Calculated using material balance.
Total Output			**2510**		

8 Appendix 2: Wheat Ethanol Example with CCS

This example represents a pathway with the following characteristics:

- The feedstock is Wheat from Manitoba that is railed to an ethanol plant in Saskatchewan, and
- The ethanol plant has a carbon capture system that trucks the CO_2 to a nearby injection well to be permanently sequestered.

The first run is in the Manitoba region. This is used to generate the emissions for the following life cycle stages:

- Direct land use change emissions,
- Feedstock production or cultivation,
- Feedstock upgrading,
- Feedstock transport,
- Feedstock coproducts production, and
- Avoided emissions.

Be sure to click the Install Regional Defaults button after setting cell B4 to the appropriate region. Table 8-1 shows the values used for this modelling exercise. A GHGenius user must replace these values with their actual values.

Table 8-1 Manitoba Wheat with CCS: Manitoba Run Model Inputs

Sheet	Cell	Parameter	Value
Input	B4	Region	Manitoba
Input	B7	Year	2023
Input	AI76	Feedstock rail distance, km	700
Input	AI80	Feedstock truck distance, km	0
Input	AI82	Feedstock rail mode	1
Input	AI86	Feedstock truck mode	0
Input	AF241	Year	2023
Input	AF243	Electricity, kWh/L	0.2
Input	AF244	Diesel, L/L	0
Input	AF245	Natural Gas, MJ/L	10.0
Input	AF246	Coal, kg/L	0
Input	AF248	Wheat, kg/L	2.50

The energy inputs of AF243 through AF246 are not needed until the second run, but there is no harm in entering them at this point since the adjacent cells with year (AF241) and yield (AF248) are necessary. These two inputs are required to scale the feedstock production to one litre of ethanol produced.

Table 8-2 below are needed from Column Q, rows 8 through 13 of the BC LCFS sheet.

Table 8-2 Manitoba Wheat with CCS: Manitoba Run 2023 Emissions

Stage	Emissions, g CO_2e/GJ (HHV)
Direct land use change	0
Feedstock production or cultivation	-5,338
Feedstock upgrading	0
Feedstock transport	1,328
Feedstock coproducts production	0
Avoided emissions	0

The second run is in the Saskatchewan region and the B7 and AF241 to AF248 values are the same as the first run. This run is used to generate the emissions for the following life cycle stages:

- Fuel production,
- Fuel coproduct production, and
- Fuel distribution and storage.

This run will use urea as an input instead of ammonia, but ammonia has a non-zero default value that must be set to zero.

The captured CO_2 is transported by diesel trucks and injected at a nearby site. Table 8-3 details the data used to model the sequestration system.

Table 8-3 Manitoba Wheat with CCS: Sequestration Data

Description	Value	Unit
CO2 Injected	0.65	$\frac{kg\ CO_2}{L\ ethanol}$
CO2 Vented at Injection Site	0.11	$\frac{kg\ CO_2}{L\ ethanol}$
Fugitive CO2 Emissions at Injection Site	0.01	$\frac{kg\ CO_2}{L\ ethanol}$

Description	Value	Unit
CO2 Sequestered =CO2 Injected - CO2 Vented at Injection Site - Fugitive CO2 Emissions at Injection Site	0.53	$\frac{kg\ CO_2}{L\ ethanol}$
Fraction emissions sequestered =CO2 Sequestered/ CO2 Produced per L ethanol As determined by stoichiometric equation detailed in Section 4.5 =0.53 $\frac{kg\ CO_2}{L\ ethanol}$ / 0.755 $\frac{kg\ CO_2}{L\ ethanol}$	70.2	%
Sequestration Electricity	0.1	$\frac{kWh}{L\ ethanol}$
Sequestration Diesel	0.01	$\frac{L\ diesel}{L\ ethanol}$

The GHGenius inputs used for the Saskatchewan run are detailed in Table 8-4.

Table 8-4 Manitoba Wheat with CCS: Saskatchewan Run Model Inputs

Sheet	Cell	Parameter	Value
Input	B4	Region	Saskatchewan
Input	B7	Year	2023
Input	B69	CCS for fuel production toggle (1 is on 0 is off)	1
Input	AF91	Transloading	No
Input	AF92	Finished fuel rail distance, km	1600
Input	AF96	Finished fuel truck distance, km	0
Input	AF98	Finished fuel rail mode	1.00
Input	AF102	Finished fuel truck mode	1.00
Input	AF241	Year	2023
Input	AF243	Electricity, kWh/L	0.2
Input	AF244	Diesel, L/L	0
Input	AF245	Natural Gas, MJ/L	10.0
Input	AF248	Wheat, kg/L	2.50
Alt Fuel Prod	AN30	Ammonia, kg/L	0
Alt Fuel Prod	AN41	Enzymes, kg/L	0.002
Alt Fuel Prod	AN53	NaOH, kg/L	0.005
Alt Fuel Prod	AN72	Sulphuric acid, kg/L	0.01
Alt Fuel Prod	AN76	Urea, kg/L	0.025
Alt Fuel Prod	AN77	Yeast, kg/L	0.0002

Sequestration	AJ19	Fraction emissions sequestered	0.702
Sequestration	AJ22	Electricity, kWh/L	0.1
Sequestration	AJ23	Diesel L/L	0.01

This run includes results only related to producing the ethanol and transporting it to BC, the results are shown in Table 8-5.

Table 8-5 Manitoba Wheat with CCS: Saskatchewan Run 2023 Emissions

Stage	Emissions, g CO_2e/GJ (HHV)
Fuel production	16,190
Fuel coproducts production	-10,452
Fuel distribution and storage	984

The final region is in BC and uses a prescribed 80 km of distribution by truck to calculate the following life cycle stages:

- Fuel distribution and storage,
- Fuel dispensing, and
- Vehicle or Vessel operation.

After the BC region is selected in cell B4 the “Install Regional Defaults” button must be pressed. Most of the inputs can be left the same as the previous run. Only the changes as outlined in the following table are required to calculate the BC emissions. These changes can be made to the version of the model used for the US Central run or a fresh version of the model. The model inputs are shown in Table 8-6.

Table 8-6 Manitoba Wheat with CCS: BC Final Run Model Inputs

Sheet	Cell	Parameter	Value
Input	B4	Region	BC
Input	AF91	Transloading	Yes
Input	AF92	Finished fuel rail distance, km	0
Input	AF96	Finished fuel truck distance, km	80
Input	AF98	Finished fuel rail mode	0
Input	AF102	Finished fuel truck mode	1

The results for the BC region are in Table 8-8. These are again from the BC LCFS sheet, column Q rows 16 to 18.

Table 8-7 Manitoba Wheat with CCS: BC Final Run 2023 Emissions

Stage	**Emissions, g CO_2e/GJ (HHV)**
Fuel distribution and storage	643
Fuel dispensing	133
Vehicle or Vessel operation	2,397

The results from all three regions are combined to get the total CI of this example plant, which is shown in Table 8-8.

Table 8-8 Manitoba Wheat with CCS: Total 2023 Emissions

Stage	**Manitoba**	**Saskatchewan**	**BC**	**Total**
	Emissions, g CO_2e/GJ (HHV)			
Direct land use change	0			0
Feedstock production or cultivation	-5,338			-5,338
Feedstock upgrading	0			0
Feedstock transport	1,328			1,328
Feedstock coproducts production	0			0
Avoided emissions	0			0
Fuel production		16,190		16,190
Fuel coproducts production		-10,452		-10,452
Fuel distribution and storage		984	643	1,627
Fuel dispensing			133	133
Vehicle or Vessel operation			2,397	2,397
Total	-4,010	6,721	3,173	5,884
Total, g CO_2e/MJ	-4.01	6.72	3.17	5.88

8.1 Wheat Ethanol Material Balance

The material balance inputs are shown in Table 8-9 for the wheat ethanol pathway. Only the wheat feedstock is considered, with the other inputs considered immaterial as they make up less than 1% of the input mass.

Table 8-9 Wheat Ethanol Material Balance Inputs

Input Stream	**GHGenius Location**	**GHGenius Input**	**Input ($g/L_{ethanol}$)**	**Function**	**Notes**
Wheat	Input AF248	2.50 kg/L	2500	Feedstock	

Water	N/A	N/A	165	Hydrolysis	Measured
Other Inputs	N/A	N/A	N/A	Other	Excluded due to immateriality
Total Input			**2665**		

The output data for the facility is shown in Table 8-10. The mass of waste is calculated as the difference between the total input mass and the total of the other outputs' masses. The CO_2 sequestered is measured so it is included in the material balance.

Table 8-10 Wheat Ethanol Material Balance Outputs

Output Stream	**GHGenius Location**	**GHGenius Input**	**Output ($g/L_{ethanol}$)**	**Function**	**Notes**
Animal feed	N/A	N/A	875	Coproduct	Not entered in GHGenius
Ethanol	N/A	N/A	790	Main Product	Density from cell E105 of Fuel Char sheet
CO2	Sequestration AJ19	70.2%	470	CCS	70.2% of available 755 g CO_2/L ethanol
Other Outputs	N/A	N/A	N/A	Other	Excluded due to immateriality
Waste	N/A	N/A	470	Waste	Unmetered streams. Calculated using material balance.
Total Output			**2665**		

9 Appendix 3: Cellulosic Hay Ethanol Example with CCU

This example represents a pathway with the following characteristics:

- The feedstock is hay from Alberta that is trucked to an Alberta ethanol plant,
- The ethanol plant has a carbon capture system, with the CO_2 sold to an adjacent industrial gas plant, and
    - 0.5 kg $\frac{kg\ CO_2}{L\ ethanol}$ is sold to the industrial gas plant
    - 0.2 $\frac{kwh\ electricity}{L\ ethanol}$ is needed for the carbon capture system,
        - In addition to the 0.1 kwh $\frac{kg\ CO_2}{l\ ethanol}$ required for the rest of the ethanol facility
- The ethanol is railed to BC.

The first run is in the Alberta region. This is used to generate the emissions for the following life cycle stages:

- Direct land use change emissions,
- Feedstock production or cultivation,
- Feedstock upgrading,
- Feedstock transport,
- Feedstock coproducts production,
- Avoided emissions,
- Fuel production,
- Fuel coproduct production, and
- Fuel distribution and storage.

Be sure to click the Install Regional Defaults button after setting cell B4 to the appropriate region. The following table shows the values used for this modelling exercise. A GHGenius user must replace these values with their actual values.

The GHGenius inputs used for the Alberta run are detailed in Table 8-4.

Table 9-1 Alberta Hay Ethanol with CCU: Alberta Run Model Inputs

Sheet	Cell	Parameter	Value
Input	B4	Region	Alberta

Sheet	Cell	Parameter	Value
Input	B7	Year	2025
Input	B11	GWP	2013 (100 year)
Input	D11	Short lived gases	Carbon Weighted
Input	B50	Cellulose-biofuel from wood toggle (1 is wood, 0 is grass or agricultural residues)	0
Input	B59	Fraction Switchgrass	0
Input	C59	Fraction Corn Stover	0
Input	D59	Fraction Wheat Straw	0
Input	B69	CCS for fuel production toggle (1 is on 0 is off)	0
Input	I76	Feedstock Rail Distance, km	0
Input	I80	Feedstock Truck Distance, km	75
Input	I82	Feedstock Rail Mode	0
Input	I86	Feedstock Truck Mode	1
Input	AE91	Transloading	No
Input	AE92	Finished fuel rail distance, km	750
Input	AE96	Finished fuel truck distance, km	0
Input	AE98	Finished fuel rail mode	1.00
Input	AE102	Finished fuel truck mode	0
Input	AM241	Year	2025
Input	AM243	Electricity, kWh/L	0.3
Input	AM244	Diesel, L/L	0.001
Input	AM245	Natural Gas, MJ/L	9.5
Input	AM246	Coal, kg/L	0
Input	AM247	Hay, kg/L	3.00
Input	B261	Carbon Dioxide capture with Ethanol Plant, kg CO2 captured/litre ethanol	0.5
Input	E274	Net electricity produced (kWh)	0
Alt Fuel Prod	AV30	Ammonia, kg/L	0
Alt Fuel Prod	AV48	Limestone, kg/L	0.03
Alt Fuel Prod	AV53	NaOH, kg/L	0.08
Alt Fuel Prod	AV61	Phosphate nutrients (P2O5), kg/L	0.004
Alt Fuel Prod	AV70	Sugar, kg/L	0.08
Alt Fuel Prod	AV72	Sulphuric acid, kg/L	0.07
Alt Fuel Prod	AN77	Yeast, kg/L	0.004

This Alberta run results are found in cells O8-O16 of the BC LCFS sheet, the results are shown in Table 9-2.

Table 9-2 Alberta Hay Ethanol with CCU: Alberta Run 2025 Emissions

Stage	Emissions, g CO_2e/GJ (HHV)
Direct land use change	10,140
Feedstock production or cultivation	29,994
Feedstock upgrading	0
Feedstock transport	1,419
Feedstock coproducts production	0
Avoided emissions	0
Fuel production	45,405
Fuel coproducts production	-6,794
Fuel distribution and storage	443

The final region for this example is a BC run that is set up very similarly to the previous example. The run is in BC and uses a prescribed 80 km of distribution by truck to calculate the following life cycle stages:

- Fuel distribution and storage,
- Fuel dispensing, and
- Vehicle or Vessel operation.

After the BC region is selected in cell B4 the "Install Regional Defaults" button must be pressed. Most of the inputs can be left the same as the previous run. Only the changes as outlined in the following table are required to calculate the BC emissions. These changes can be made to the version of the model used for the US Central run or a fresh version of the model. The model inputs are shown in Table 9-3.

Table 9-3 Alberta Hay Ethanol with CCU: BC Final Run Model Inputs

Sheet	Cell	Parameter	Value
Input	B4	Region	BC
Input	AE91	Transloading	Yes
Input	AE92	Finished fuel rail distance, km	0
Input	AE96	Finished fuel truck distance, km	80
Input	AE98	Finished fuel rail mode	0
Input	AE102	Finished fuel truck mode	1

The results for the BC region are below. These are again from the BC LCFS sheet, column O rows 16 to 18.

Table 9-4 Alberta Hay Ethanol with CCU: BC Final Run 2025 Emissions

Stage	**Emissions, g CO_2e/GJ (HHV)**
Fuel distribution and storage	639
Fuel dispensing	134
Vehicle or Vessel operation	2,479

The results from all three regions are combined to get the total CI of this example plant, which is shown in Table 9-5.

Table 9-5 Alberta Hay Ethanol with CCU: Total 2025 Emissions

Stage	**Alberta**	**BC**	**Total**
	Emissions, g CO_2e/GJ (HHV)		
Direct land use change	10,140		10,140
Feedstock production or cultivation	29,994		29,994
Feedstock upgrading	0		0
Feedstock transport	1,419		1,419
Feedstock coproducts production	0		0
Avoided emissions	0		0
Fuel production	45,405		45,405
Fuel coproducts production	-6,794		-6,794
Fuel distribution and storage	443	639	1,083
Fuel dispensing		134	134
Vehicle or Vessel operation		2,479	2,479
Total	80,208	3,252	83,459
Total, g CO_2e/MJ	80.21	3.25	83.46

9.1 Cellulosic Hay Ethanol Material Balance

The material balance inputs are shown in Table 9-6 for the hay ethanol pathway. Only the hay feedstock is considered, with the other inputs considered immaterial as they make up less than 1% of the input mass.

Table 9-6 Hay Ethanol Material Balance Inputs

Input Stream	GHGenius Location	GHGenius Input	Input ($g/L_{ethanol}$)	Function	Notes
Hay	Input AM247	3.00 kg/L	3000	Feedstock	
Water	N/A	N/A	190	Hydrolysis	Measured
Other Inputs	N/A	N/A	N/A	Other	Excluded due to immateriality
Total Input			**3190**		

The output data for the facility is shown in Table 9-7. The mass of waste is calculated as the difference between the total input mass and the total of the other outputs' masses. Cellulosic ethanol does not produce animal feed coproduct. The CO_2 mass sold is measured so it is included in the mass balance table.

Table 9-7 Hay Ethanol Material Balance Outputs

Output Stream	GHGenius Location	GHGenius Input	Output ($g/L_{ethanol}$)	Function	Notes
Animal feed	N/A	N/A	N/A	Coproduct	No animal feed coproduct
Ethanol	N/A	N/A	790	Main Product	Density from cell E105 of Fuel Char sheet
CO2	Input B261	0.5 kg	500	Coproduct	Entered in Input sheet
Other Outputs	N/A	N/A	N/A	Other	Excluded due to immateriality
Waste	N/A	N/A	1900	Waste	Unmetered streams. Calculated using material balance.
Total Output			**3190**		

10 Appendix 4: Cellulosic Forest Residue Ethanol Example

This example represents a pathway with the following characteristics:

- The feedstock is forest residue from Standing timber that is all avoiding slash burning and is trucked and railed to an ethanol plant in Alberta, and
- The ethanol is railed to BC.

The first run is in the BC region. This is used to generate the emissions for the following life cycle stages:

- Direct land use change emissions,
- Feedstock production or cultivation,
- Feedstock upgrading,
- Feedstock transport,
- Feedstock coproducts production,
- Avoided emissions,

Be sure to click the Install Regional Defaults button after setting cell B4 to the appropriate region. The following table shows the values used for this modelling exercise. A GHGenius user must replace these values with their actual values.

The GHGenius inputs used for the BC run are detailed in Table 10-1.

Table 10-1 BC Forest Residue Ethanol: BC Feedstock Run Model Inputs

Sheet	Cell	Parameter	Value
Input	B4	Region	BC
Input	B7	Year	2025
Input	B11	GWP	2013 (100 year)
Input	D11	Short lived gases	Carbon Weighted
Input	B50	Cellulose-biofuel from wood toggle (1 is wood, 0 is grass or agricultural residues)	1
Input	E50	Credit for avoided slash burning	1
Input	J76	Feedstock Rail Distance, km	750
Input	J80	Feedstock Truck Distance, km	75
Input	J82	Feedstock Rail Mode	1
Input	J86	Feedstock Truck Mode	1
Input	A120-122	Standing Timber Button	Press Button

Sheet	Cell	Parameter	Value
		(Check that cell J114 says "Standing Timber)	
Input	AO241	Year	2025
Input	AO243	Electricity, kWh/L	0.1
Input	AO244	Diesel, L/L	0.01
Input	AO245	Natural Gas, MJ/L	9
Input	AO246	Coal, kg/L	0
Input	AM247	Standing timber, kg/L	3.1
Input	G274	Net electricity produced, kWh	0

This results for the BC Feedstock run are found in cells O8-O16 of the BC LCFS sheet, the results are shown in Table 10-2.

Table 10-2 BC Forest Residue Ethanol: BC Feedstock Run 2025 Emissions

Stage	Emissions, g CO_2e/GJ (HHV)
Direct land use change	0
Feedstock production or cultivation	5,207
Feedstock upgrading	0
Feedstock transport	3,319
Feedstock coproducts production	0
Avoided emissions	-36,263

The second run is in the Alberta region and the B7 and AO241 to AO248 values are the same as the first run. This run is used to generate the emissions for the following life cycle stages:

- Fuel production,
- Fuel coproduct production, and
- Fuel distribution and storage.

The GHGenius inputs used for the Alberta run are detailed in Table 10-3.

Table 10-3 BC Forest Residue Ethanol: Alberta Run Model Inputs

Sheet	Cell	Parameter	Value
Input	B4	Region	Alberta
Input	B7	Year	2025
Input	B11	GWP	2013 (100 year)

Sheet	Cell	Parameter	Value
Input	D11	Short lived gases	Carbon Weighted
Input	B50	Cellulose-biofuel from wood toggle 1 is wood, 0 is grass or agricultural residues	1
Input	E50	Credit for avoided slash burning	1
Input	AE91	Transloading	No
Input	AE92	Finished fuel rail distance, km	750
Input	AE96	Finished fuel truck distance, km	0
Input	AE98	Finished fuel rail mode	1.00
Input	AE102	Finished fuel truck mode	0
Input	A120-122	Standing Timber Button (Check that cell J114 says "Standing Timber)	Press Button
Input	AO241	Year	2025
Input	AO243	Electricity, kWh/L	0.1
Input	AO244	Diesel, L/L	0.01
Input	AM245	Natural Gas, MJ/L	9.0
Input	AM246	Coal, kg/L	0
Input	AM247	Standing timber, kg/L	3.1
Input	G274	Net electricity produced, kWh	0
Alt Fuel Prod	AX30	Ammonia, kg/L	0.04
Alt Fuel Prod	AX48	Limestone, kg/L	0.035
Alt Fuel Prod	AX53	NaOH, kg/L	0.08
Alt Fuel Prod	AX61	Phosphate nutrients (P2O5), kg/L	0.005
Alt Fuel Prod	AX70	Sugar, kg/L	0.09
Alt Fuel Prod	AX72	Sulphuric acid, kg/L	0.072
Alt Fuel Prod	AX77	Yeast, kg/L	0.004

This run includes results only related to producing the ethanol and transporting it to BC, the results are shown in Table 10-4.

Table 10-4 BC Forest Residue Ethanol: Alberta Run 2025 Emissions

Stage	Emissions, g CO_2e/GJ (HHV)
Fuel production	47,169
Fuel coproducts production	0
Fuel distribution and storage	443

The final run is in BC and uses a prescribed 80 km of distribution by truck to calculate the following life cycle stages:

- Fuel distribution and storage,
- Fuel dispensing, and
- Vehicle or Vessel operation.

After the BC region is selected in cell B4 the “Install Regional Defaults” button must be pressed. Most of the inputs can be left the same as the previous run. Only the changes as outlined in the following table are required to calculate the BC emissions. These changes can be made to the version of the model used for the US Central run or a fresh version of the model. The model inputs are shown in Table 10-5.

Table 10-5 BC Forest Residue Ethanol: BC Final Run Model Inputs

Sheet	Cell	Parameter	Value
Input	B4	Region	BC
Input	AE91	Transloading	Yes
Input	AE92	Finished fuel rail distance, km	0
Input	AE96	Finished fuel truck distance, km	80
Input	AE98	Finished fuel rail mode	0
Input	AE102	Finished fuel truck mode	1

The results for the BC region in Table 10-6. These are again from the BC LCFS sheet, column O rows 16 to 18.

Table 10-6 BC Forest Residue Ethanol: BC Final Run 2025 Emissions

Stage	Emissions, g CO_2e/GJ (HHV)
Fuel distribution and storage	639
Fuel dispensing	134
Vehicle or Vessel operation	2,479

The results from all three regions are combined to get the total CI of this example plant, which is shown in Table 10-7.

Table 10-7 BC Forest Residue Ethanol: Total 2025 Emissions

Stage	BC Feedstock	Alberta	BC	Total
	Emissions, g CO_2e/GJ (HHV)			
Direct land use change	0			0
Feedstock production or cultivation	5,207			5,207
Feedstock upgrading	0			0
Feedstock transport	3,319			3,319
Feedstock coproducts production	0			0
Avoided emissions	-36,263			-36,263
Fuel production		47,169		44,872
Fuel coproducts production		-0		-1,227
Fuel distribution and storage		443	639	1,083
Fuel dispensing			134	134
Vehicle or Vessel operation			2,479	2,479
Total	-27,736	47,613	3,252	23,128
Total, g CO_2e/MJ	-27.74	47.61	3.25	23.13

10.1 Cellulosic Forest Residue Ethanol Material Balance

The material balance inputs are shown in Table 10-8 for the forest residue ethanol pathway. Only the forest residue feedstock is considered, with the other inputs considered immaterial as they make up less than 1% of the input mass.

Table 10-8 Forest Residue Ethanol Material Balance Inputs

Input Stream	GHGenius Location	GHGenius Input	Input ($g/L_{ethanol}$)	Function	Notes
Forest Residue	Input AM247	3.1 kg/L	3100	Feedstock	
Water	N/A	N/A	170	Hydrolysis	Measured
Other Inputs	N/A	N/A	N/A	Other	Excluded due to immateriality
Total Input			**3270**		

The output data for the facility is shown in Table 10-9. The mass of waste is calculated as the difference between the total input mass and the total of the other outputs' masses and includes CO_2.

Table 10-9 Forest Residue Ethanol Material Balance Outputs

Output Stream	GHGenius Location	GHGenius Input	Output (g/L$_{ethanol}$)	Function	Notes
Animal feed	N/A	N/A	N/A	Coproduct	No animal feed coproduct
Ethanol	N/A	N/A	790	Main Product	Density from cell E105 of Fuel Char sheet
CO2	N/A	N/A	N/A	N/A	N/A
Other Outputs	N/A	N/A	N/A	Other	Excluded due to immateriality
Waste	N/A	N/A	2480	Waste	Unmetered streams. Calculated using material balance.
Total Output			**3270**		

Need more information?

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

This information is for your convenience and guidance only and does not replace or constitute a legal interpretation of the legislation. It is recommended that parties who may be a Fuel Supplier review the Low Carbon Fuels Act (Act), the Low Carbon Fuels (General) Regulation and the Low Carbon Fuels (Technical) Regulation, and seek independent legal advice to confirm their status, legal obligations and opportunities. The Act and regulations can be found on the internet at: http://www.bclaws.ca.