NETL Life Cycle Inventory Data
Process Documentation File

Process Name: Corn Stover Harvesting & Storage, Operation

Reference Flow: 1 kg Corn Stover Harvesting & Storage

Brief Description: This unit process includes operations for harvesting and storage of corn stover including diesel use, dust emissions, and a yield calculation. Co-product allocation is used to assign inputs and outputs between corn grain and corn stover.

Section I: Meta Data

Geographical Coverage: US **Region:** Midwest

Year Data Best Represents: 2008

Process Type: Extraction Process (EP)

Process Scope: Cradle-to-Gate Process (CG)

Allocation Applied: Yes

Completeness: All Relevant Flows Recorded

Flows Aggregated in Data Set:

☒ Process ☒ Energy Use ☐ Energy P&D ☐ Material P&D

Relevant Output Flows Included in Data Set:

Releases to Air:	☒ Greenhouse Gases	☒ Criteria Air Pollutants	☒ Other
Releases to Water:	☒ Inorganic Emissions	☒ Organic Emissions	☐ Other
Water Usage:	☒ Water Consumption	☒ Water Demand (throughput)	
Releases to Soil:	☐ Inorganic Releases	☐ Organic Releases	☐ Other

Adjustable Process Parameters:

Stover yield (STOVER_YIELD_Y)	*The yield of corn stover, in kg/acre-yr*
Corn yield (CORN_YIELD_Y)	*The yield of corn grain, in kg/acre-yr*
Allocation (ALLOCATE_ENERGY)	*If using energy allocation, use value = 1 else use value = 0.*

Tracked Input Flows:

Biomass Operation [Installation]	*Flow from cultivation of biomass, unit process is assembled, in series, with cultivation process*
Diesel [Crude oil products]	*Diesel (from crude oil) usage for biomass harvesting operations*

Tracked Output Flows:

Corn stover [Biomass Fuels]	*This reference flow represents mass of corn stover that is harvested*

Section II: Process Description

Associated Documentation

This unit process is composed of this document and the data sheet (DS) *DS_Stage1_O_CS_Harvesting_&_Storage_2010.02.xls*, which provides additional details regarding calculations, data quality, and references as relevant.

Goal and Scope

The scope of this unit process covers the operations of farming activities used for the harvesting of corn and stover biomass in life cycle (LC) Stage #1. This unit process is based on the reference flow of 1 kg of corn grain or corn stover biomass production, as described below, and in **Figure 1.** The inputs to the unit process include diesel consumption. Diesel is used as fuel for crop harvesting equipment (a combine with corn header); the energy and material flows for the upstream production and delivery of diesel as well as life cycle emissions of diesel production are not included in the boundary of this process. The air emissions from diesel combustion and fugitive dust from harvesting equipment are included in this unit process boundary. Fugitive dust is categorized as PM (particulate matter) emissions to air. Water use and emissions to water are not characterized in this process, because they are assumed to comprise a negligible contribution to the direct operations of harvesting crops.

Boundary and Description

This unit process is the third unit process in a sequence of four operations processes required for the acquisition of corn stover. The two unit processes that occur upstream of this unit process are corn stover land preparation and corn stover cultivation, and the unit processes that occurs immediately downstream of this unit process is corn stover collection and baling.

The boundaries of this unit process include the harvesting operations that separate corn grain from corn stover. After separation from corn grain, corn stover is left on the ground. The collection of corn stover from the ground and subsequent baling is not included in this unit process, but is accounted for in a downstream unit process. The harvesting operations that occur within the boundaries of this unit process are based on the estimated diesel

consumption of farming equipment, the direct emissions from diesel combustion, fugitive dust emissions caused by surface dust that is disturbed by harvesting equipment, and the annual yield rate of corn stover. **Figure 1** provides an overview of the boundary of this unit process. Rectangular boxes represent relevant sub-processes, while trapezoidal boxes indicate upstream data that are outside of the boundary of this unit process. As shown, upstream emissions associated with the production and delivery of diesel fuel are accounted for outside of the boundary of this unit process. The methods for calculating these operating activities are described below.

There are three adjustable parameters in this unit process: the annual yield of corn stover ("STOVER_YIELD_Y"), the annual yield of corn grain ("CORN_YIELD_Y"),and the calculation of co-product allocation based on energy ("ALLOCATE_ENERGY") basis. The annual yields of corn grain and stover(kg/acre-year) are used to translate the values for diesel consumption, diesel combustion and fugitive dust emissions from a basis of quantity per acre to a basis of quantity per kg of biomass production. NETL currently recommends a default value of 3,829 kg/acre-yr for corn yield based on a survey of national data from 2004 to 2009 (Iowa State 2009, USDA 2010). The recommendation for stover yield is 1,001 kg/acre year (NETL 2011, Petrolia 2009).

The parameter for energy-based co-product allocation allows the unit process to allocate inputs and outputs between co-products on an energy or mass basis. If the value for "ALLOCATE_ENERGY" is 1, then energy-based co-product allocation is used; if the value for "ALLOCATE_ENERGY" is 0, then mass-based co-product allocation is used and a ratio of the yield rates is used to apportion emissions.

Diesel is consumed by the combine to rotate the corn header. The diesel consumption of the harvesting combine was calculated based on specifications of a 360 horsepower (hp) combine consuming 0.154 kg diesel/hp-hour (0.34 lb/hp-hour) rotating a corn header of 2.40 m (7.91 ft) width (John 2008a, John 2009h). Assuming that the combine operates at 5.5 miles per hour (mph), an average operating speed, and by multiplying the width of the corn header by the operating speed of the combine, the land coverage rate is estimated at 5.27 acres per hour. Dividing this land coverage rate by the fuel consumption rate, the estimated diesel consumption is 12.47 L/acre-pass calculated. This calculation assumes that the combine makes a single pass over the site.

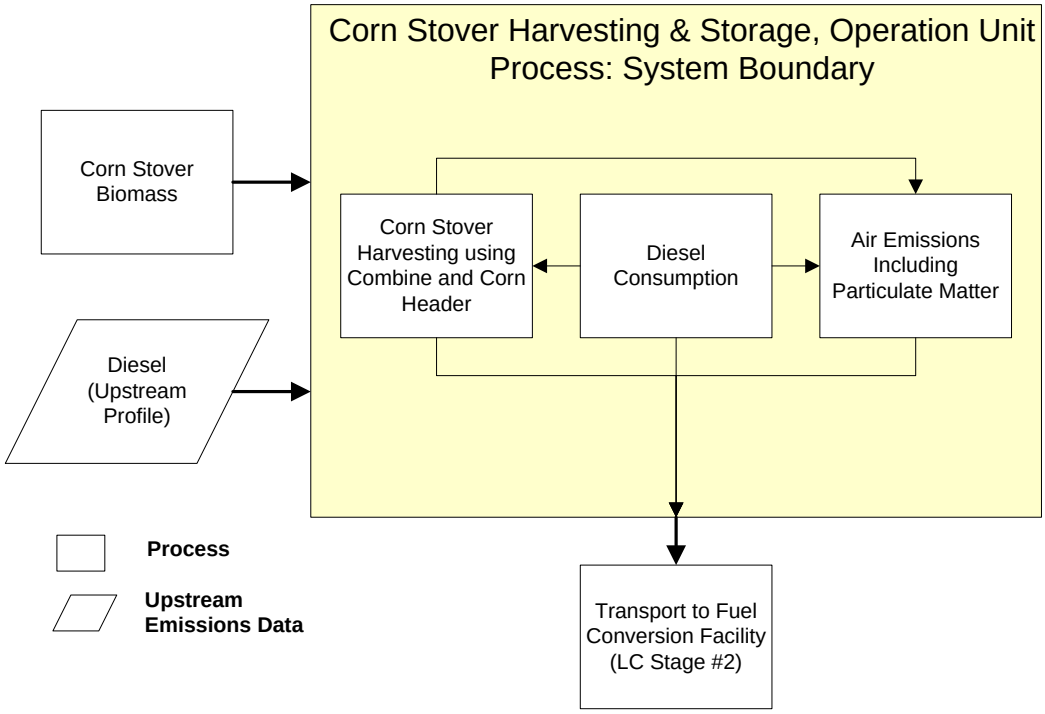
The combustion of diesel results in the direct emission of GHGs (greenhouse gases) and CAPs (criteria air pollutants). The emissions factors for GHGs are based on DOE instructions for the voluntary reporting of GHGs (DOE 2007). Emissions factors for PM (particulate matter), NO_x (nitrogen oxides), and VOCs (volatile organic compounds) are based on EPA documentation on air emissions from nonroad diesel engines. These emissions factors are expressed in terms of the mass of emissions per bhp (brake horsepower-hour), which requires a determination of the bhp of the combine. This unit process uses a conversion factor of 0.066 gal/bhp-hr (SCAQMD 2005) to apply the emissions factors for PM, NO_x, and VOC to a basis of gallons of diesel combusted in non-road heavy equipment.

Emissions of SO_2 (sulfur dioxide) are calculated by assuming that diesel has a sulfur content of 15 ppm (DieselNet 2009a) and that all sulfur in diesel is converted to SO_2 upon combustion. The calculated emissions factor for diesel is 2.53×10^{-5} kg SO_2/L.

The emissions factors for CO (carbon monoxide) are based on Tier 4 emissions standards, which specify an array of CO emissions factors across a range of engine sizes (DieselNet 2009b). This unit process assumes that the engine of the tractor is greater than 175 horsepower and the calculated emissions factor for diesel is 0.0104 kg CO/L.

Fugitive dust emissions are generated by the disturbance of surface soil during harvesting. Fugitive dust emissions from harvesting activities are estimated using an emissions factor specified by WRAP (Western Regional Air Program) (Countess Environmental 2004), which conducted air sampling studies on ripping and sub-soiling practices used for breaking up soil compaction. The emissions factor for fugitive dust is 5.8 lb PM/acre-pass (Gaffney, P. and Yu, H. 2003). The total emissions of fugitive dust are 0.000384 kg PM/acre (2.63 kg/kg biomass).

Figure 1: Unit Process Scope and Boundary



Properties of corn stover and corn grain relevant to this unit process are indicated in **Table 1**. **Table 2** provides a summary of modeled input and output flows. Additional details regarding input and output flows, including calculation methods, are contained in the associated DS sheet.

Table 1: Properties of Corn & Stover (NETL, 2009)

Physical Component/Property	Value	Units
Ash	9.82 – 13.51	%
Carbon	44.7 - 48.02	%
Hydrogen	5.41 – 6.14	%
Nitrogen	0.59 – 0.74	%
Oxygen	36.99 – 41.42	%
Sulfur	0.06 – 0.10	%
HHV Moisture Free	7,697 – 7,967	Btu/lb
LHV Moisture Free	7,197 – 7,467	Btu/lb
Na_2O	1.47	% composition of ash
Corn stover yield, (kg/acre-year)	1001	kg/acre-yr
Corn grain yield, (kg/acre-year)	3829	kg/acre-yr
HHV corn stover, (Btu/lb) at 15% moisture	6399	Btu/lb
HHV corn grain, (Btu/lb) at 15% moisture	6970	Btu/lb
K_2O	20.22	% composition of ash
Ash Fusion Temperature	884 (reducing atmosphere), 1054 (oxidizing atmosphere)	°C

Table 2: Unit Process Input and Output Flows

Flow Name*	Value	Units (Per Reference Flow)
Inputs		
Biomass Operation [Installation]	**1.00**	**kg**
Diesel [Crude oil products]	**4.22E-04**	**kg**
Corn Stover Biomass [Renewable Resource]	**1.00**	**kg/kg biomass**
Outputs		
Corn Stover Biomass [Biomass Fuels]	1.00	kg
Carbon dioxide [Inorganic emissions to air]	1.33E-03	kg
Carbon monoxide [Inorganic emissions to air]	5.20E-06	kg
Methane [Organic emissions to air (group VOC)]	1.90E-07	kg
Nitrous oxide (laughing gas) [Inorganic emissions to air]	3.43E-08	kg
Nitrogen dioxide [Inorganic emissions to air]	6.00E-07	kg
Sulfur dioxide [Inorganic emissions to air]	1.26E-08	kg
Particulate Matter, unspecified [Other emissions to air]	2.07E-08	kg
Volatile Organic Carbons [Organic emissions to air]	2.80E-07	kg

* **Bold face** clarifies that the value shown *does not* include upstream environmental flows. Upstream environmental flows were added during the modeling process using GaBi modeling software, as shown in Figure 1.

Embedded Unit Processes

None.

References

Countess Environmental 2004	Countess Environmental. 2004. *WRAP Fugitive Dust Handbook.* WGA Contract No. 30204-83. Western Regional Air Partnership.
DieselNet 2009a	DieselNet. 2009. *Emission Standards >> United States Stationary Diesel Engines*. Ecopoint Inc. http://www.dieselnet.com/standards/us/stationary.php (Accessed February 4, 2010).
DieselNet 2009b	DieselNet. 2009. *Nonroad Diesel Engines*. Ecopoint Inc. www.dieselnet.com/standards/us/nonroad.php (Accessed February 4, 2010).
DOE 2007	DOE. 2007. *Instructions for Form EIA-1605, Voluntary Reporting of Greenhouse Gases*. OMB No. 1905-0194. U.S. Department of Energy.
Gaffney, P. and Yu, H. 2003	Gaffney, P. and Yu, H. 2003. *Computing Agricultural PM10 Fugitive Dust Emissions Using Process Specific Emissions Rates and GIS*. US EPA Annual Emission Inventory Conference. April, 2003.
Iowa State 2009	Iowa State. 2009. *Iowa Farm Outlook Chartbook.* Iowa State University. http://www2.econ.iastate.edu/outreach/agriculture/periodicals/chartbook/Chartbook2/Tables/Table10.pdf (Accessed June 13, 2012)
John 2008a	John Deere. 2008a. *PowerTech 6090H Diesel Engine Specifications*. Deere & Company. www.deere.com/en_US/rg/ESC/SpecSheet/Ind/6125HF070_U_S0_R0.html (Accessed February 4, 2010).
John 2009b	John Deere. 2009h. *John Deere 9770 STS (Manufacturer Specifications)*. Deere & Company.
NETL 2009	NETL. 2009. *Personal Communication with NETL OSAP*. May 2009.
NETL 2011	NETL. (2011). *Calculating Uncertainty in Biomass Emissions Model, Version 2.0 (CUBE 2.0): Model and Documentation.* (DOE/NETL-2012/1538). Pittsburgh, PA: National Energy Technology Laboratory http://www.netl.doe.gov/energy-

	analyses/refshelf/PubDetails.aspx?Action=View&PubIP=409 (Accessed June 13, 2012).
Petrolia 2009	D. R. Petrolia. (2009). Economics of Crop Residues: Corn Stover. Little Rock, Arkansas. http://www.farmfoundation.org/news/articlefiles/1712-PetroliaTWO%20hndout.pdf (Accessed June 13, 2012).
SCAQMD 2005	South Coast Air Quality Management District. 2005. *Final Environmental Assessment: Proposed Rule 1469.1 - Spraying Operations Using Coatings Containing Chromium*. SCAQMD. February, 2005.
SunGrant Initiative 2007	SunGrant Initiative. 2007*. Management Guide for Biomass Feedstock Production From Switchgrass in the Northern Great Plains.* South Dakota State University.
USDA 2009	USDA. 2009. *Fact Sheet: Management and Lifecycle Assessment of Bio-energy Crop Production*. U.S. Department of Agriculture.
USDA 2010	USDA. 2010. *2009 Crop Year is One for the Record Books, USDA Reports.* U.S. Department of Agriculture. Washington D.C.

Section III: Document Control Information

Date Created: February 04, 2010

Point of Contact: Timothy Skone (NETL), Timothy.Skone@NETL.DOE.GOV

Revision History:

13JUNE2012	Updated to revised parameter values.

How to Cite This Document: This document should be cited as:

NETL (2010). *NETL Life Cycle Inventory Data – Unit Process: Corn Stover Harvesting & Storage, Operation.* U.S. Department of Energy, National Energy Technology Laboratory. Last Updated: June 2012 (version 02). www.netl.doe.gov/energy-analyses (http://www.netl.doe.gov/energy-analyses)

Section IV: Disclaimer

Neither the U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL) nor any person acting on behalf of these organizations:

A. Makes any warranty or representation, express or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this document, or that the use of any information, apparatus, method, or process disclosed in this document may not infringe on privately owned rights; or

B. Assumes any liability with this report as to its use, or damages resulting from the use of any information, apparatus, method, or process disclosed in this document.

Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by NETL. The views and opinions of the authors expressed herein do not necessarily state or reflect those of NETL.