# NETL Life Cycle Inventory Data
# Process Documentation File

**Process Name:** Corn Grain Harvesting & Storage, Operation

**Reference Flow:** 1 kg of Corn Grain Biomass

**Brief Description:** This unit process includes operations for harvesting and storage of corn grain including diesel use, dust emissions, and criteria air pollutants. Corn stover is left on the field and is thus not a coproduct in this case.

## 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:** No

**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:**

| | |
|---|---|
| Corn yield (Corn_yield_y) | *Represents the weight of corn grain per acre year.* |

**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 Grain Biomass (15% Moisture) [Biomass Fuels] *This reference flow represents mass of corn and corn stover.*

## Section II: Process Description

### Associated Documentation

This unit process is composed of this document and the data sheet (DS) *DS_Stage1_O_CG_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 grain biomass in life cycle (LC) Stage #1. This unit process is based on the reference flow of 1 kg of corn grain 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

The LC boundary of this unit process begins with the harvesting of corn grain and ends with corn grain biomass ready for delivery to the fuel production facility, and leaves stover biomass on the ground. The harvesting operations for corn grain biomass production 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 grain. **Figure 1** provides an overview of the boundary of this unit process including a schematic of operations considered within 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 is one major adjustable parameter in this unit process: the annual yield of corn grain. This adjustable parameter is designed to allow modeling flexibility to enable the modeler to update the unit process to meet specific assumptions and study criteria, as relevant. Additionally, adjustable values may be updated as needed to incorporate newer or revised data sources. Corn grain yield per year indicates the annual yield of corn grain per acre and is 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 2,980 kg/acre-yr for this parameter.

Diesel is consumed by the combine to rotate the corn header. This calculation assumes that the combine makes a single pass over the site. 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.

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 non-road 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 stoichiometrically 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 $2.52677 \times 10^{-5}$ kg $SO_2$/L.

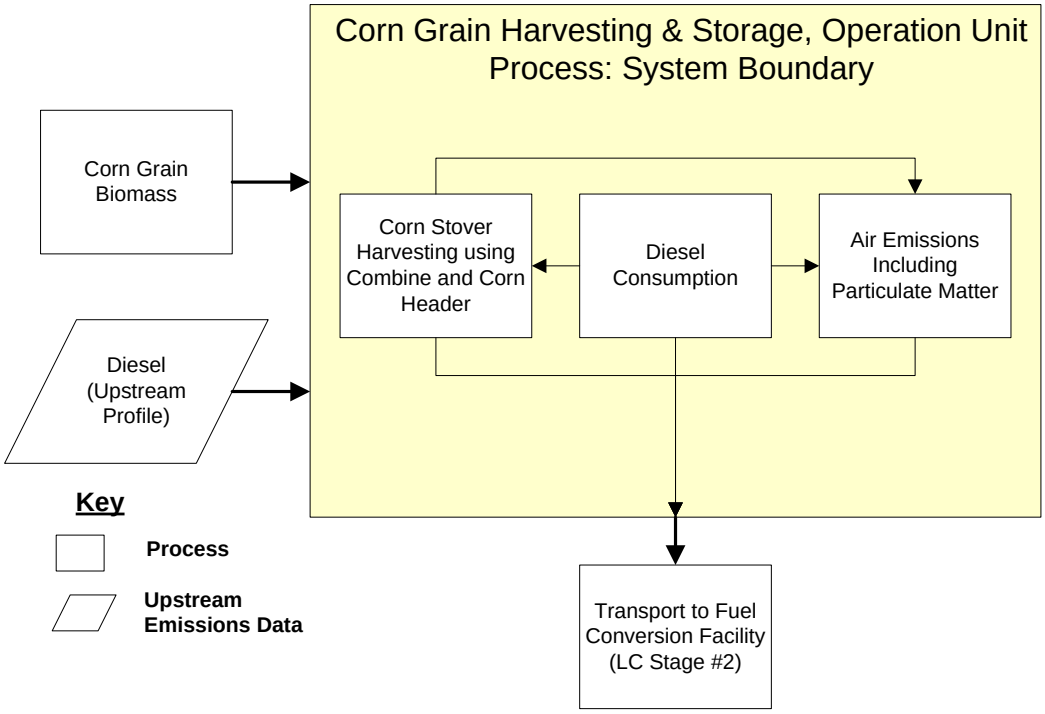
The emissions factors for CO (carbon monoxide) are based on Tier 4 emissions standards, which specify an array of CO emissions factors across a range of engine sizes (DieselNet 2009b). This unit process assumes that the engine of the tractor is greater than 175 horsepower, and the calculated emissions 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 (2.630 kg/kg biomass).

There is one major adjustable parameter in this unit process: the annual yield of corn grain. This adjustable parameter is designed to allow modeling flexibility, enabling the modeler to update the unit process to meet specific assumptions and study criteria, as relevant. Additionally, adjustable values may be updated as needed to incorporate newer or revised data sources. Corn grain yield per year indicates the annual yield of corn grain per acre and it is 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 kilogram of biomass production. NETL currently recommends a default value of 3,829 kg/acre-yr for this parameter based on a survey of national data from 2004 to 2009 (Iowa State 2009, USDA 2010).

**Figure 1: Unit Process Scope and Boundary**




Properties of corn grain biomass cultivation operation activities relevant to this unit process are illustrated 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 Grain (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 grain yield | 3829 | kg/acre-yr |
| HHV corn grain | 6970 | Btu/lb |
| LHV corn grain | 6545 | 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** | **kg** |
| **Diesel [Crude oil products]** | **2.75E-03** | **kg** |
| Corn Grain Biomass [Renewable Resource] | 1 | kg |
| **Outputs** | | |
| Corn Grain Biomass (15% Moisture) [Biomass Fuels] | 1 | kg |
| Carbon dioxide [Inorganic emissions to air] | 8.65E-03 | kg |
| Carbon monoxide [Inorganic emissions to air] | 3.39E-05 | kg |
| Methane [Organic emissions to air (group VOC)] | 1.24E-06 | kg |
| Nitrous oxide (laughing gas) [Inorganic emissions to air] | 2.24E-07 | kg |
| Nitrogen dioxide [Inorganic emissions to air] | 3.91E-06 | kg |
| Sulphur dioxide [Inorganic emissions to air] | 8.23E-08 | kg |
| Particulate Matter, unspecified [Other emissions to air] | 6.87E-04 | kg |
| Volatile Organic Carbons [Organic emissions to air] | 1.83E-06 | 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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## Section III: Document Control Information

**Date Created:** February 15, 2010

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**Revision History:**

| | |
|---|---|
| 13JUNE2012 | Updated to revised parameter values. |

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## Section IV: Disclaimer