NETL Life Cycle Inventory Data
Process Documentation File

Process Name: Switchgrass Harvesting & Storage, Operation

Reference Flow: 1 kg of Biomass Operation

Brief Description: This unit process includes operation of farming activities for harvesting & storage of switchgrass including an input of combusted diesel and fugitive dust emissions.

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:

Switchgrass yield (Biomass_yield_y)	*The annual yield rate of switchgrass production.*

Tracked Input Flows:

Biomass Operation [Installation]	*This unit process is assembled with cultivation unit process in series.*
Diesel Combustion, Mobile Sources, Truck [Refinery products]	*Amount of diesel combusted within the mobile source.*
Equipment Assembly per kg Biomass [Valuable substances]	*Amount of farm equipment required for 1 kg of biomass.*

Tracked Output Flows:

Switchgrass Biomass [Biomass Fuels] *This reference flow represents mass of switchgrass biomass product.*

Section II: Process Description

Associated Documentation

This unit process is composed of this document and the data sheet (DS) *DS_Stage1_O_SG_Harvesting_&_Storage_2010.03.xlsx*, 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 harvesting and storage of switchgrass biomass in Life Cycle (LC) Stage #1. The unit process is based on the reference flow of 1 kg of biomass operation, as described below, and in **Figure 1.** The inputs to this unit process include diesel consumption and biomass resource. Diesel is used as fuel for crop harvesting and baling equipment (a harvester, tractor and baler). 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. Diesel combustion is handled in a linked upstream unit process which accounts for the associated combustion emissions. The input biomass resource is assumed to be completely converted into biomass material without any loss in harvesting operations. The air emissions from fugitive dust from harvesting equipment are included in this unit process boundary. Fugitive dust is categorized as particulate matter (PM10 and pm 2.5) emissions to air. Water use and emissions to water are not characterized in this process, because they are assumed to be negligible to the direct operations of harvesting crops.

Boundary and Description

The boundary of this unit process starts with the harvesting of switchgrass and ends with switchgrass biomass ready for delivery to the fuel production facility. The harvesting operations for switchgrass biomass production are based on the estimated diesel consumption of farming equipment (a harvester, a tractor and a baler), fugitive dust emissions caused by surface dust that is disturbed by harvesting equipment, and the annual yield rate of switchgrass.

Figure 1 provides an overview of the boundary of this unit process. The figure includes operation directly related to the harvesting and storage of switchgrass, as well as upstream processes that account for diesel production and other agricultural inputs. Upstream processes may require energy or other ancillary substances, which are not shown here. Rectangular boxes represent relevant upstream 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.

One adjustable process parameter is included in this unit process. This 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, this value may be updated as needed to incorporate newer or revised data sources. The annual yield rate represents the annual yield of switchgrass per acre area in a year. NETL currently recommends a default value of 3,569 kg/acre–year for this parameter based on the Calculating Uncertainty in Biomass Emissions (CUBE) model (NETL 2011).

Diesel is consumed in harvester and tractor equipment. The diesel consumption of the harvester was calculated based on specifications of a 595 hp harvester consuming 0.154 kg diesel/hp-hour (0.34 lb/hp-hour) operating a 4.58 m (15 ft) wide header (John 2008, John 2009a). Assuming that the harvester combine operates at 6 miles per hour (mph), an average operating speed, and by multiplying the width of the header by the operating speed of the harvester, the land harvesting coverage rate is estimated at 10.92 acres per hour. Dividing this land harvesting coverage rate by the fuel consumption rate, the estimated diesel consumption is 9.96 L/acre-pass cultivated. This calculation assumes that the harvester makes a single pass over the site.

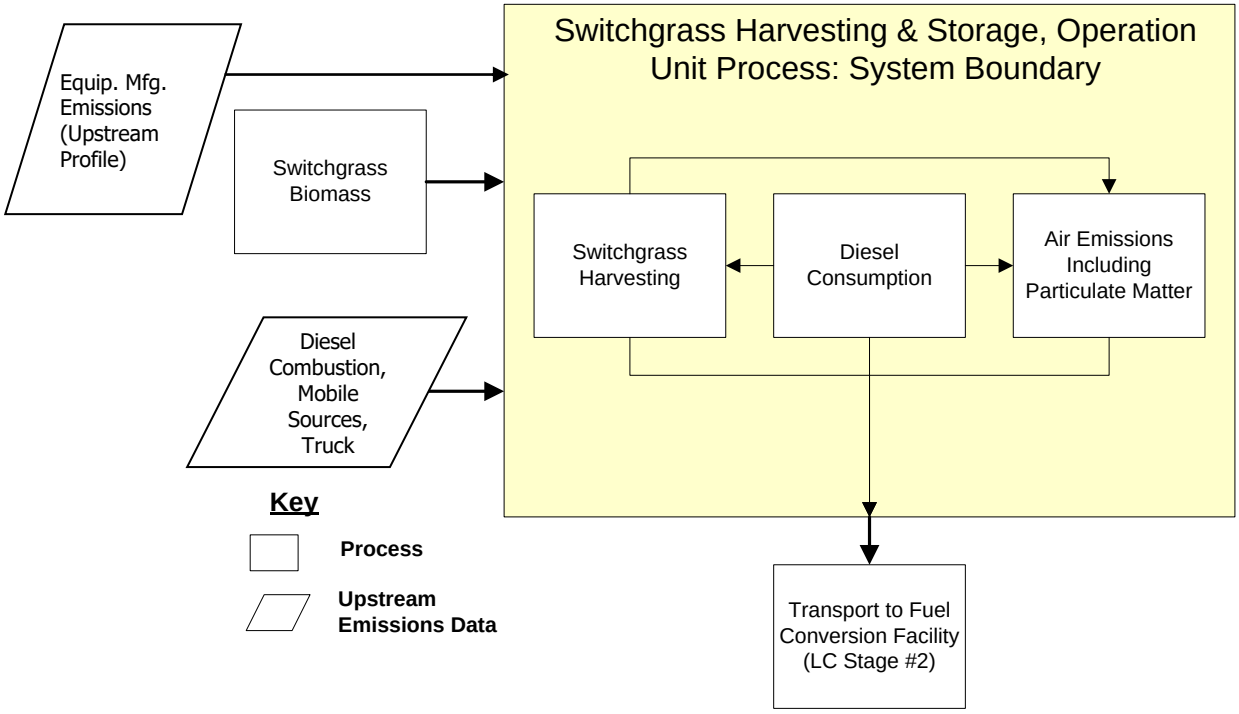
The tractor baler makes a single pass to bale biomass of the land site. Similarly, the tractor baler consumes an average of 10.26 gallons per hour (John 2009d). The width of the baler is 2.74 m (9 feet) wide (John 2009c). Assuming that the harvester combine operates at 5 miles per hour (mph), an average operating speed, and by multiplying the width of the baler by the operating speed of the tractor, area of baler coverage for baling biomass is estimated at 5.45 acres per hour, which, when factored with the fuel consumption rate, results in a diesel consumption rate of 7.120 L/acre-pass. The impacts associated with the manufacturing of the tractor and harvester are accounted for in a separate unit process. This process scales the manufacturing processes based on the amount of biomass demanded.

The combined diesel consumption of the harvester and tractor-baler is the sum of 9.96 L/acre and 7.120 L/acre, which equals 17.083 L/acre. The engine of harvester and tractor baler is greater than 175 horsepower. The emissions for the required amount of diesel combusted for this process are accounted for in an upstream diesel combustion process. That process is pulled as an input to this process.

Fugitive dust emissions are generated by the disturbance of surface soil during harvesting activities. Fugitive dust emissions from harvesting activities are estimated using an emissions factor specified by Western Regional Air Program (WRAP) (WRAP 2004), which conducted air sampling studies on ripping and sub-soiling practices used for breaking up soil compaction. Assuming that fugitive dust emissions for wheat harvest are similar to switchgrass harvest, the emissions factor for fugitive dust using a switchgrass harvester is 2.63 kg PM10/acre-pass (5.8 lb PM10/acre-pass). Assuming emissions factor for fugitive dust using tractor-baler is similar to tractor-tiller, the emissions factor for fugitive dust is 0.54 kg PM10/acre-pass (1.2 lb PM10/acre-pass) (WRAP. 2004). The harvester makes one pass of the site per harvest and thus has a fugitive dust emissions factor of 2.63 kg PM10/acre-year and tractor-baler also makes one pass of the site and thus has a fugitive dust emissions factor of 0.54 kg PM10/acre-

year (1.2 lbs PM10/acre-year). The total emissions of fugitive dust are 3.18 kg PM10/acre-year. The ratio of PM2.5 to PM10 utilized for this study is 0.15 kg PM2.5/kg PM10.

Figure 1: Unit Process Scope and Boundary



Properties of switchgrass 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 Switchgrass Biomass (NETL, 2012)

Physical Component/Property	Value (as received)
Ash (%)	6.33
Carbon (%)	36.21
Hydrogen (%)	5.57
Nitrogen (%)	1.11
Oxygen (%)	35.77
Sulfur (%)	0.01
Moisture (%)	15.00
HHV at 15% moisture (Btu/lb)	6,619
LHV at 15% moisture (Btu/lb)	5,935

Table 2: Unit Process Input and Output Flows

Flow Name*	Value	Units (Per Reference Flow)	DQI
Inputs			
Diesel Combustion, Mobile Sources, Truck [Refinery products]	4.04E-03	**kg**	**2,2**
Equipment Assembly per kg Biomass [Valuable substances]	**1.00E+00**	**Pieces**	**2,2**
Biomass Operation [Installation]	**1**	**kg**	**2,2**
Switchgrass Biomass [Renewable Resource]	1	kg	2,2
Outputs			
Switchgrass Biomass [Biomass Fuels]	1	kg	2,2
Dust (PM10) [Particles to air]	8.90E-04	kg	1,2
Dust (PM2.5) [Particles to air]	1.33E-04	kg	1,2

* **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.

Inventory items not included are assumed to be zero based on best engineering judgment or assumed to be zero because no data was available to categorize them for this unit process at the time of its creation.

Embedded Unit Processes

None.

References

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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.
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Section III: Document Control Information

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Revision History:

13JUNE2012	Updated to revised parameter values.
29DECEMBER2014	Updated to reflect combustion removal. Diesel combustion is now an input.

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