



NETL Life Cycle Inventory Data

Process Documentation File

Section II: Process Description

Associated Documentation

This unit process is comprised of this document, as well as the data sheet (DS) *DS_Stage1_O_SGLandprep_2011.02.xls*, which provides additional details regarding calculations, data quality, and references as relevant.

Goal and Scope

This unit process accounts for the operating activities for the preparation of land for switchgrass production. The process is based on the reference flow of 1 kg of switchgrass production. The inputs to the process include diesel and land use. Diesel is used as fuel for the land preparation equipment (a motor grader and a track bulldozer); the energy and material flows for the upstream production and delivery of diesel are not included in the boundaries of this process. Land use, expressed in terms of acres per unit production of switchgrass, is considered a resource that involves no upstream operating or construction activities. The air emissions from diesel combustion and fugitive dust from the use of land preparation equipment are included in this unit process. Fugitive dust is categorized as particulate matter (PM) 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 land preparation.

Boundary and Description

Operations for the preparation of land for switchgrass 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 land preparation equipment, and the annual yield rate of switchgrass. **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 electricity and 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 two adjustable parameters in this unit process: the annual yield of switchgrass and the study period. The annual yield of switchgrass (kg/acre-year) is used to translate the values for diesel consumption, land use, and fugitive dust emissions from a basis of quantity per acre to a basis of quantity per kilogram of switchgrass production. 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). The study period is used to determine the amount of land needed to produce one kg of switchgrass.

Diesel is consumed by a track bulldozer and a motor grader. A track bulldozer consumes an average of 12 gallons of diesel per hour (BAH 2005). Based on equipment specifications published by a heavy equipment manufacturer, the width of a bulldozer bucket is 177 inches (14.75 feet) (Caterpillar 2009c). Assuming that the bulldozer operates in second gear, the manufacturer specifications for the bulldozer show an operating speed of 4.2 miles per hour (Caterpillar 2010). By multiplying the width of the blade by the operating speed of the bulldozer, the land coverage rate of the bulldozer is estimated at 7.5 acres per hour. Multiplying this land coverage rate by the fuel consumption rate, the estimated diesel consumption for is 1.60 gal/acre. This calculation assumes that the bulldozer makes a single pass over the site.

Similarly, the motor grader consumes an average of 17.5 gallons per hour (BAH 2005). The scraper blade of the motor grader is 14 feet wide (Caterpillar 2009). Assuming the motor grader operates in third gear, the speed of the motor grader has an average operating speed of 5 miles per hour (Caterpillar 2009). The width and speed of the motor grader translate to a land coverage rate of 8.48 acres per hour, which, when factored with the fuel consumption rate, results in consumption rate of 2.06 gal of diesel per acre. This unit process assumes that the motor grader must make two passes of the land site, which doubles the total fuel consumption of the motor grader to 4.12 gal/acre.

The combined diesel consumption of the track bulldozer and motor grader is the sum of 1.60 gal/acre and 4.12 gal/acre, which equals 5.72 gal/acre (21.7 L/acre).

The combustion of diesel results in the direct emission of greenhouse gases (GHGs) and criteria air pollutants (CAPs). The emission factors for GHGs are based on Department of Energy (DOE) instructions for the voluntary reporting of GHGs (DOE 2007).

Emission factors for PM, nitrogen oxides (NO_x), and volatile organic compounds (VOC) are based on EPA documentation on air emissions from nonroad diesel engines (National Archives and Register Association 2004). These emission factors are expressed in terms the mass of emission per brake horsepower-hour (bhp), which requires a determination of the bhp of the track bulldozer and motor grader. This unit process uses a conversion factor of 0.066 gal/bhp-hr (SCAQMD 2005) to apply the emission factors for PM, NO_x, and VOC to a basis of gallons of diesel combusted in heavy equipment.

Emissions of sulfur dioxide (SO₂) are calculated by assuming that diesel has a sulfur content of 15 ppm (DieselNet 2009) and that all sulfur in diesel is converted to SO₂ upon combustion. The calculated emission factor for diesel is 9.56×10^{-5} kg SO₂/gal.

The emissions factors for carbon monoxide (CO) are based on Tier 4 emission standards, which specify an array of CO emission factors across a range of engine sizes (DieselNet 2009). This unit process assumes that the engines of the track bulldozer and motor grader are greater than 175 horsepower.

Fugitive dust emissions are generated by the disturbance of surface soil land preparation. Fugitive dust emissions from land preparation are estimated using an emission factor specified by Western Regional Air Program (WRAP) (Countess Environmental 2004), which conducted air sampling studies on ripping and subsoiling practices used for breaking up soil compaction. The emission factor for fugitive dust is 4.6 lb PM/acre-pass. The track bulldozer makes one pass of the site and thus has a fugitive dust emission factor of 4.6 lbs PM/acre; the motor grader makes two passes on the site and thus has a fugitive dust emission factor of 9.2 lbs PM/acre. The total emissions of fugitive dust are 13.8 lbs PM/acre, which is the sum of the emission factors for the track bulldozer and motor grader.

Properties of switchgrass 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 Switchgrass (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)
Inputs		
Diesel [Crude oil products]	1.72E-04	kg
Area of Production Land	9.34E-06	acres
Outputs		
Switchgrass [biomass]	1	kg
Carbon dioxide [Inorganic emissions to air]	5.37E-04	kg
Carbon monoxide [Inorganic emissions to air]	2.11E-06	kg
Methane [Organic emissions to air (group VOC)]	7.70E-08	kg
Nitrous oxide (laughing gas) [Inorganic emissions to air]	1.39E-08	kg
Nitrogen dioxide [Inorganic emissions to air]	2.43E-07	kg
Sulphur dioxide [Inorganic emissions to air]	5.11E-09	kg
Particulate Matter, unspecified [Other emissions to air]	5.85E-05	kg
Volatile Organic Carbons [Organic emissions to air]	1.13E-07	kg

* **Bold face** clarifies that the value shown *does not* include upstream environmental flows.

Embedded Unit Processes

None.

References

BAH 2005

Booz Allen Hamilton, South Coast Air Quality Management District, and California Air Resources Board, 2005. *Demonstration of Particulate Trap Technologies on Existing Off-Road Heavy-Duty Construction Equipment: Final Report*. SCAQMD and CARB. July, 2005.

Caterpillar 2009

Caterpillar, Inc., 2009. *Variable Radius Blades: Overview & Specifications*. Caterpillar, Inc. <http://www.cat.com/cda/layout/cda/layout?m=163632&x=7&f=305446> (accessed December 7, 2009). Caterpillar, Inc. (2009b). 160M Motor Grader: Specifications. Caterpillar, Inc. <http://www.cat.com/cda/layout?m=308645&x=7> (accessed December 7, 2009).

- Caterpillar 2010
Caterpillar, Inc., 2010. *D9T Track-Type Tractor: Overview & Specifications*. Caterpillar, Inc.
<http://www.cat.com/cda/layout?m=null&x=7&id=519361&printerFriendly=true> (Accessed February 2, 2010).
- Countess Environmental 2004
Countess Environmental, 2004. *WRAP Fugitive Dust Handbook*. WGA Contract No. 30204-83. Western Regional Air Partnership.
- DieselNet 2009
DieselNet, 2009. *Emission Standards, United States: Stationary Diesel Engines*. Ecopoint Inc.
<http://www.dieselnet.com/standards/us/stationary.php> (accessed December 7, 2009).
- DOE 2007
DOE, 2007. *Instructions for Form EIA-1605, Voluntary Reporting of Greenhouse Gases*. OMB No. 1905-0194. U.S. Department of Energy.
- 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, from <http://www.netl.doe.gov/energy-analyses/refshelf/PubDetails.aspx?Action=View&PubIP=409>
- NETL 2012
NETL. (2012). *Greenhouse Gas Reductions in the Power Industry Using Domestic Coal and Biomass Volume 2: Pulverized Coal Plants*. (DOE/NETL-2012/1547). Pittsburgh, PA: National Energy Technology Laboratory, from <http://www.netl.doe.gov/energy-analyses/refshelf/PubDetails.aspx?Action=View&SourSo=Main&PubId=426>
- 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 Bioenergy Crop Production*. U.S. Department of Agriculture.

Section III: Document Control Information

Date Created: May 24, 2011

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 (2011). NETL Life Cycle Inventory Data – Process Documentation File: Switchgrass, Land Preparation, 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.