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Upstream Dashboard Tool Documentation

August 16, 2016

DOE/NETL-2016/1807

U.S. DEPARTMENT OF ENERGY | National Energy Technology Laboratory

OFFICE OF FOSSIL ENERGY

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This report was prepared by Energy Sector Planning and Analysis (ESPA) and Mission Execution and Strategic Analysis (MESA) for the United States Department of Energy (DOE), National Energy Technology Laboratory (NETL). This work was completed under DOE NETL Contract Numbers DE-FE0004001 and DE-FE0005388. This work was performed under ESPA Task 150.08 and MESA 2300.203.

The authors wish to acknowledge the excellent guidance, contributions, and cooperation of the NETL staff, particularly:

Robert James III, Ph.D., NETL Technical Monitor

DOE Contract Numbers DE-FE0004001 and DE-FE0005388

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Acronyms and Abbreviations

BTL	Biomass-to-liquid
CBTL	Coal- and biomass-to-liquid
CCS	Carbon capture and sequestration
CTL	Coal-to-liquid
EC	Energy Conversion
ECF	Energy Conversion Facility
FT	Fischer-Tropsch
GHG	Greenhouse gases
GWP	Global warming potential
IPCC	Intergovernmental Panel on Climate Change
LCA	Life cycle analysis
NMVOC	Non-methane volatile organic compound
NETL	National Energy Technology Laboratory
NREL	National Renewable Energy Laboratory
RMA	Raw Material Acquisition
RMT	Raw Material Transportation

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1 Introduction

In recent years, the National Energy Technology Laboratory (NETL) has been using life cycle analysis (LCA) as a new and innovative way to analyze and compare different power production and transportation fuel production pathways. By using LCA, NETL has integrated a holistic approach to comparing energy production pathways instead of solely considering combustion emissions at energy conversion facilities (i.e., power plant or fuels refinery).

To perform NETL's LCAs, the steps in energy production are broken down into stages (i.e., extraction, transportation, combustion) and even smaller pieces called unit processes (i.e., the operation or construction of each process within a stage). When possible, unit processes incorporate parameter variables that can be adjusted in order to render the unit process applicable to multiple scenarios or functions. For example, a train transport unit process would include adjustable parameters for transport distance, in order to ensure its suitability to a range of transport routes, locations, or products. NETL has built a library of over 400 of these unit processes. They are used as building blocks to create a comprehensive system in support of LCA modeling.

Each of NETL's unit processes functions as a discrete building block. Therefore, the unit processes can be grouped or utilized in different ways for different applications. For example, the group of unit processes needed to represent a coal mine can be connected and used as a group in many different applications: the coal could be routed into numerous different types of power production facilities or into a Fischer-Tropsch (FT) facility for the production of synthetic diesel. The Upstream Tool capitalizes on this flexibility, allowing the user to quickly evaluate a variety of feedstock supply systems or profiles. The goal of the Upstream Tool is to allow the user to customize key parameters specific to their case study or desired scenario, and generate customized results quickly and simply. The results calculated can be allocated, as upstream emissions, to a conversion facility or system of the user's choice. The combination of the upstream and combustion emissions provide a quick estimate of the overall emissions from an entire energy conversion system.

With Version 2.4 of the Upstream Tool, Monte Carlo functionality has been added to provide additional flexibility for users. Monte Carlo simulation uses probability distributions to generate random values for parameters such as transport distance to provide uncertainty for the upstream emissions. See **Section 2.3.4** for a detailed discussion.

2 Model Use Instructions

The following sections guide the user in preparing and using the model, in either Excel 2007 or Excel 2010 and later.

2.1 Macro Enabling

To use the model, Excel Macros must be enabled.

Excel 2007

- When opening Excel, a security warning message should appear just below the tool bars. The general instruction can be activated through clicking the "How to enable" link in the Input sheet, as shown in **Figure 1**.
- If no button appears in the security message, click on the Office button in the top left corner of the screen (**Figure 2**). Select the Excel Options button at the bottom of the menu (**Figure 3**). Within the Excel Options dialog, select the Trust Center on the left menu and

then the Trust Center Settings button at the bottom right of the window (**Figure 4**). To enable the Macros, select the Macro Settings from the left menu and then the bottom option marked "Enable all macros" (**Figure 5**).

Figure 1: General Macro-Enabling Instructions

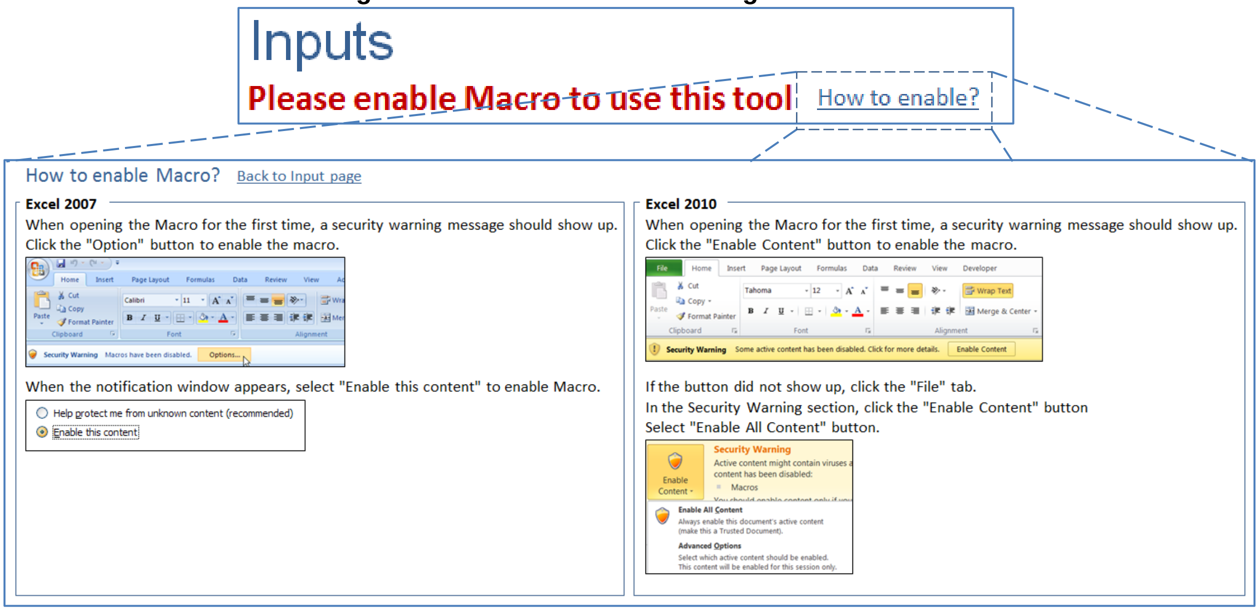


Figure 2: Office Button Location

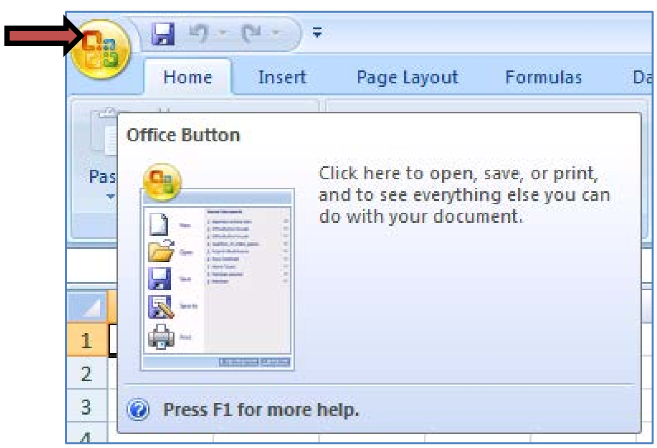


Figure 3: Excel Options Location

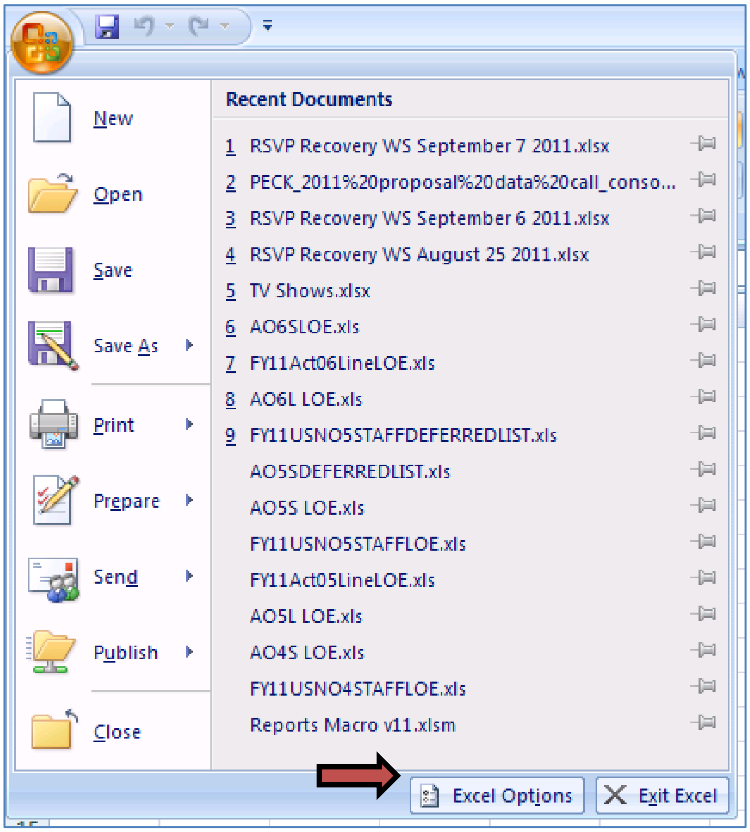


Figure 4: Opening the Trust Center

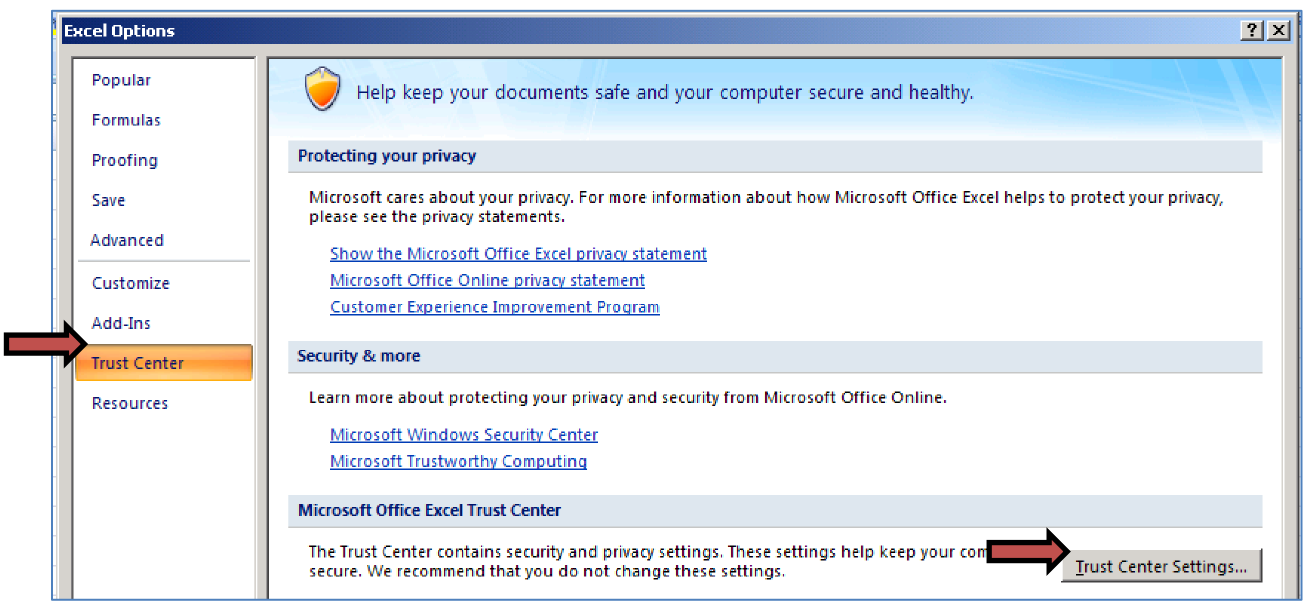
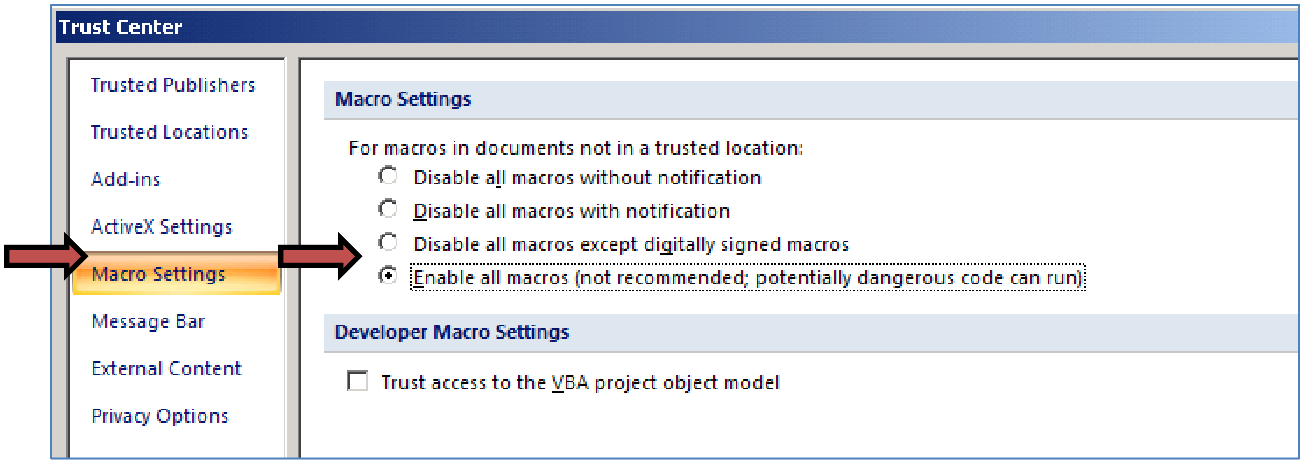


Figure 5: Enabling of Macros



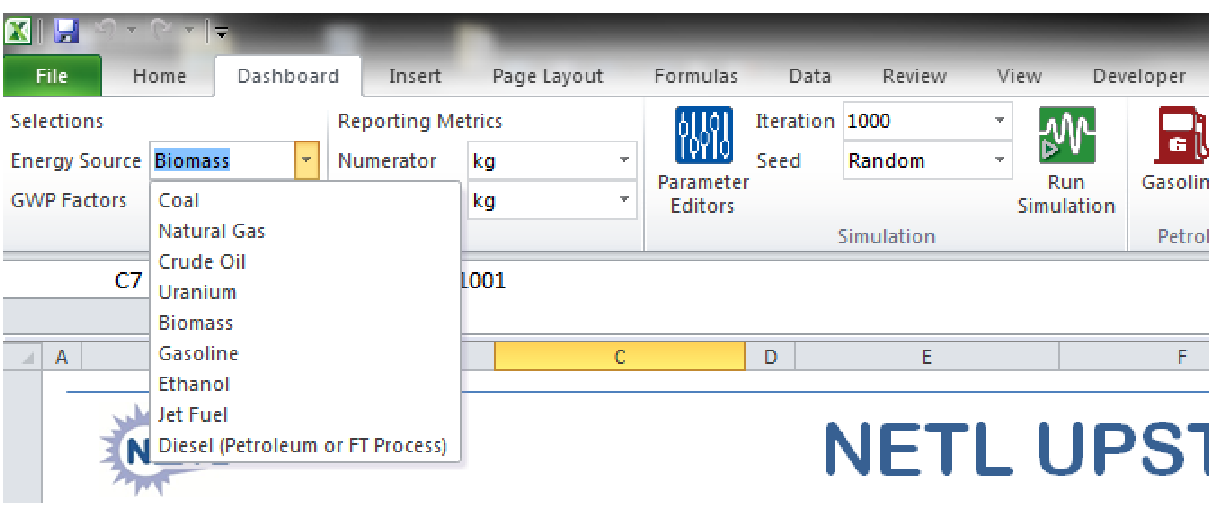
Excel 2010 and Later

- When opening Excel, a security warning message should appear just below the tool bars. The general instruction can be activated through clicking the “How to enable” link in the Input sheet, as shown in **Figure 1**.
- If there is no security warning message or the wrong option is selected, switch to the File tab. In the Security Warning section, clicking on the Enable Content button will open a drop-down menu. Select the option “Enable content for this session only.”

2.2 Inputs

After enabling Macros and selecting to agree to the license usage prompt, switch to the “Dashboard” tab in the ribbon. On that tab, there is an “Energy Source” drop-down menu to choose the desired energy source.

Figure 6: Feedstock Options



The drop-down menus in the "Reporting Metric" section of the "Dashboard" tab select how the results will be displayed (**Figure 7**). The numerator (kg or lb) determines how the emissions should be measured. The denominator (kg, lb, tonne, short ton, MMBtu, or MJ) determines the units for the reference flow. The model will allow for any combination of units the user desires between the English and SI options. The denominator will, however, determine what the acreage changed and water quantity units are. Additionally, depending on the energy source chosen, the model will determine which of the reference flow units are available, based on the units and components used in the selected modeling sequence. For example, coal will not have a volume unit available because it is traditionally discussed or measured based on mass, not volume.

The final option for units selects the International Panel on Climate Change (IPCC) weighting factors for global warming potential to convert all greenhouse gas emissions to carbon-dioxide equivalents. For example, in the IPCC 2007-100 year factors, methane is expected to trap heat as effectively as 25 kg of carbon dioxide, and for the 20 year, is effective as 72 kg of carbon dioxide. The IPCC released the weighting factors in 2001 and revised them in 2007 and 2013, so all versions are provided. The IPCC GWP factors can be found in **Table 1**.

The results are shown on the "Dashboard" worksheet.

Figure 7: Displayed Unit Options

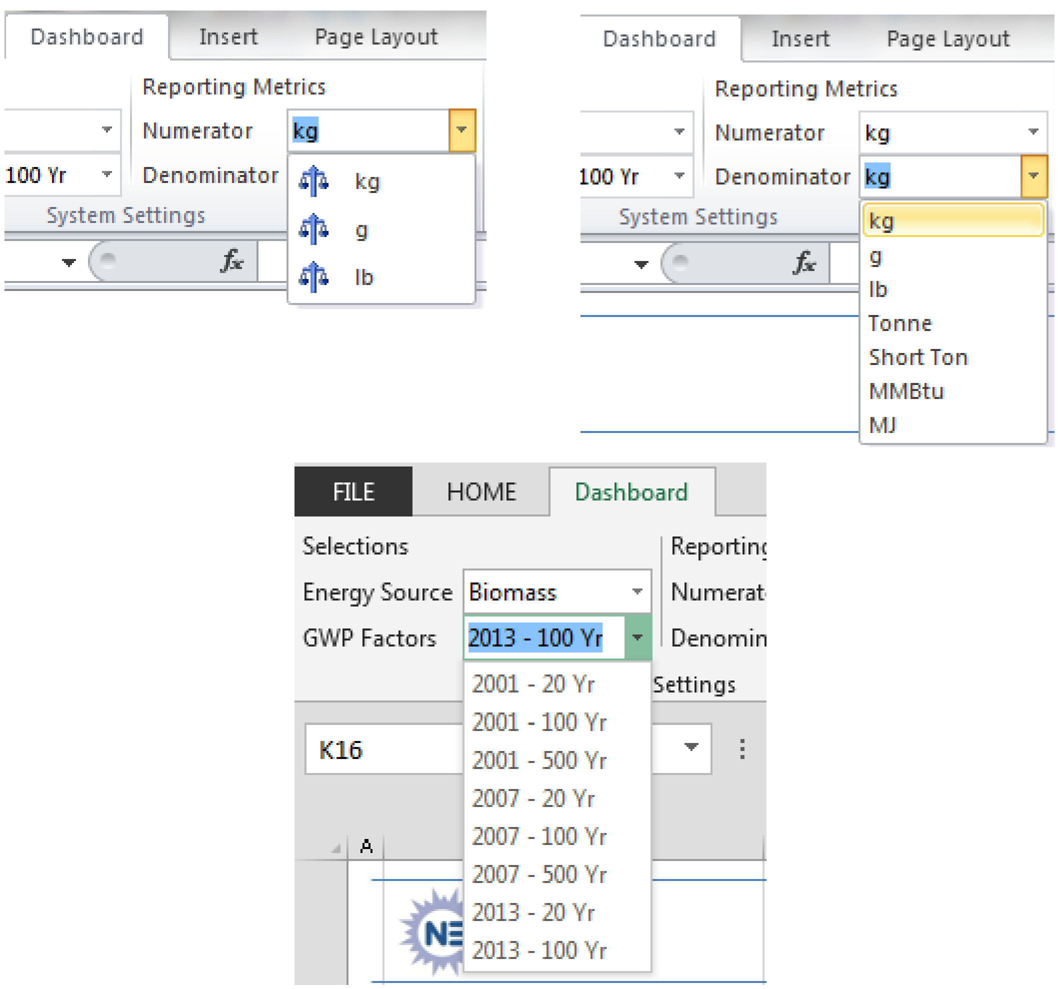
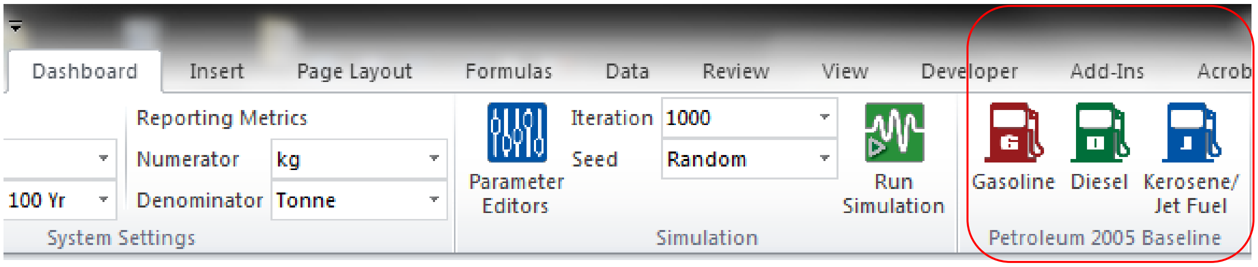


Table 1: IPCC Global Warming Potentials (Ramaswamy et all, 2001; Forster et al., 2007; Myhre et al., 2013)

IPCC GWP Factor	Vintage	20 Year	100 Year	500 Year
CO_2	2013	1	1	N/A
CH_4	2013	87	36	N/A
N_2O	2013	268	298	N/A
CO_2	2007	1	1	1
CH_4	2007	72	25	7.6
N_2O	2007	289	298	153
CO_2	2001	1	1	1
CH_4	2001	62	23	7
N_2O	2001	275	296	156

In addition to the energy sources available in the *"Energy Source" drop-down* , the user also has the ability to select one of three petroleum products from the NETL Petroleum Baseline, which is representative of year 2005 data (NETL, 2008). **Figure 8** indicates the fuel options available to the user: gasoline, diesel, and kerosene/jet fuel. Prior to selecting the desired petroleum product, the user should select the desired units for reporting metrics. The Petroleum Baseline selection does not allow for any user customization of parameters on the dashboard of the tool since the results are recognized as published reference results. If the user desires additional customization for these petroleum products, the desired product should be selected in the *"Energy Source" drop-down menu*.

Figure 8: 2005 Petroleum Baseline Selections



2.3 Dashboard

Results are provided on the "Dashboard" worksheet, which should be the default worksheet on startup. The "Dashboard" worksheet is set up in three sections: across the top are the stages of the life cycle (Raw Material Acquisition, Raw Material Transport, and Energy Conversion Facility), where the user can choose from and vary available parameters. On the lower left is a bar graph that shows global warming contributions from each of the emissions, separated by stage, and the box-andwhisker plot for the Monte Carlo simulation, discussed later. On the lower right is a table showing all the emissions tracked by the NETL Guidelines document.[1]

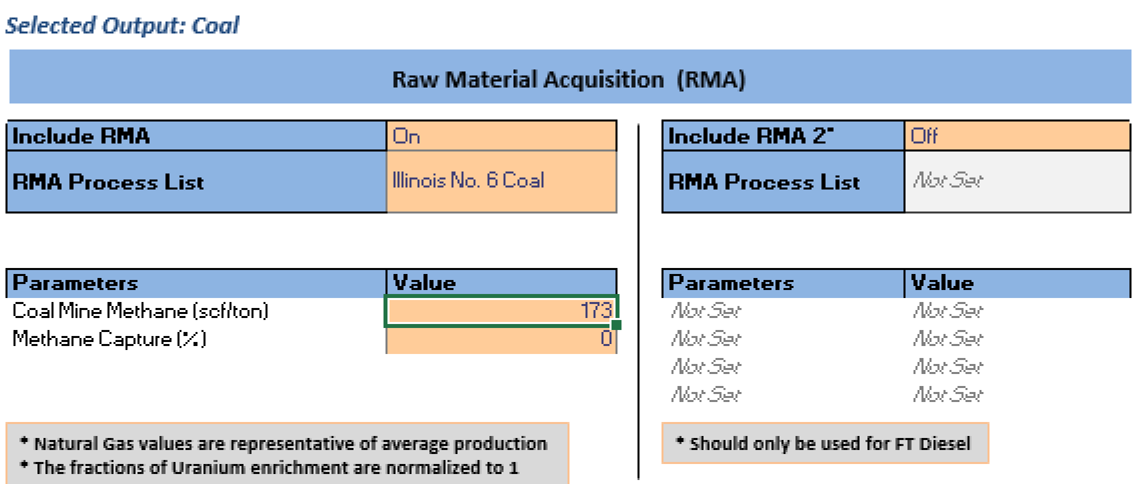
2.3.1 Raw Material Acquisition

Raw Material Acquisition (RMA) boundaries are defined:

> [RMA] starts when material or energy has been drawn from the environment without previous human transformation and includes the extraction of raw feedstocks from the earth and any partial processing of the raw materials that may occur before transport to the energy conversion facility.

RMA is broken into two subsections. Based on the "Energy Source" selection, the RMA section will auto-populate with appropriate options. For all products other than diesel, there will only be one RMA section available; for diesel, the user may desire to model Fischer-Tropsch (FT) diesel with a combination of coal and biomass feedstocks, and therefore both RMA sections will be available. **Figure 9** shows both RMA sections when Coal is selected and therefore the second RMA is not being used.

Figure 9: Raw Material Acquisition Selection



If RMA is the only stage selected, the results will be normalized to the reference flow units determined in "Denominator" drop-down. If additional stages are selected, the quantity processed in RMA will be adjusted to produce the final product at the last stage per the reference units. For example, the transport of natural gas via pipeline results in fugitive losses of the natural gas, so to provide 1 kg of delivered natural gas, the RMA stage must provide 1.02 kg of natural gas.

[1] The NETL Guidelines is an internal document that describes life cycle analysis as whole and specifically discusses the scoping of a project. It is meant to assist in the creation and performance of an LCA. All stage descriptions are taken from it.

For all energy sources except FT Diesel

Select the desired feedstock type from the drop-down in cell C3. After selection, the available parameters will appear starting in Row 7. The orange cells in Column C allow the user to enter values based a desired configuration. The table and graph will automatically update based on the changes.

For FT Diesel

To model FT diesel using combined coal and biomass feedstocks, turn "on" the second RMA portion in cell F2. The second RMA section will be activated and will operate the same as the first RMA section. Illinois No. 6 coal should be the chosen feedstock for the first RMA and the biomass type used should be selected in the second RMA.

Please note: for any case in which feedstocks may be mixed other than FT diesel (i.e., a co-fired power plant), use the dashboard to determine the emissions for each feedstock separately, and then apply the ratio of the feedstocks based on their feed rates into a facility.

2.3.2 Raw Material Transportation

Raw Material Transportation (RMT) boundaries are defined by NETL as:

> [RMT] starts when raw material is ready for shipment to the energy conversion facility. RMT includes fuel use and transport vehicle construction burdens as well as fugitive emissions during transport.

Based on the selected "Energy Source", the logical options for transportation modes will be available in the RMT section. Up to four modes of transportation may be selected for use in series as shown in **Figure 10**. The top mode in Row 7 is the first mode in the series; the increase in rows shows sequentially the order of transportation.

Figure 10: Raw Material Transport Selection

Raw Material Transport (RMT)

Include RMT	On
Num of Transp. Mode	4
RMA Suggested RMT	

Transportation Mode**	Unit	Value
Petroleum Pipeline	mi	394.6
Petroleum Water Carrier	mi, one way	4309
Petroleum Tanker Truck	mi, one way	2.7
Petroleum Rail	mi, one way	1.2

**Add sequential modes with the first at the top
**For FT Diesel, coal should be above the biomass transport

For FT Diesel

The FT Diesel calculations are set up differently than the rest of the calculations. For the FT Diesel calculations to be completed correctly, add the coal train in Row 7 and biomass transportation in Row 8.

2.3.3 Energy Conversion

Energy Conversion (EC) boundaries are defined:

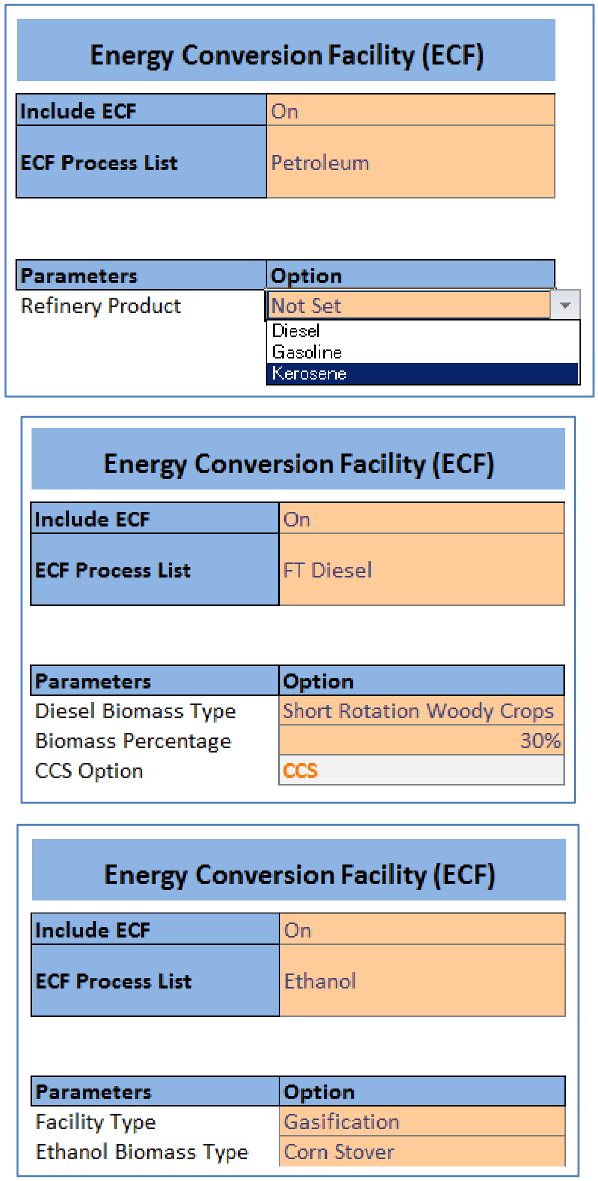
> [EC] starts with the primary transformation of a raw material into a product. Physical boundary is defined by the acceptance of ownership of the raw material by the transformation entity.

The EC stage is different from the other stages and always thought of in terms of the facility. It is often referred to as the Energy Conversion Facility (ECF). Based on the way the facilities are modeled, no parameter variations are allowed. Instead, there is a predefined set of scenarios which the user may choose from. The type of facility selected determines how specific the model gets. For petroleum, the user may only choose the product. For an FT facility, the user can choose whether or not it is a combined input of coal and biomass, the concentration of the biomass input (0 percent,[1] 15 percent, 30 percent, or 100 percent), the type of biomass, and whether there is a carbon capture and sequestration unit (CCS).[2] Ethanol has the option of using corn grain into dry mill processes or advanced combustion and gasification processes based on switchgrass or corn stover.

There are no valid energy conversion facilities defined for the following energy sources: Powder River Basin coal, all types of natural gas, and uranium. Setting the option to "Include ECF" is on with these sources selected may cause errors and any dashboard output will be invalid.

[1] To have a coal-to-liquids facility, switch the "Diesel Biomass Type" to "None."
[2] For a coal and biomass-to-liquids facility, it is required to have CCS and the model will force the decision.

Figure 11: Energy Conversion Options



When evaluating petroleum and FT facilities, it is possible to manually select RMA processes that are not applicable for a particular facility, which result in erroneous results. For example, if "Petroleum" is selected in the "ECF Process List", the user can select Illinois No. 6 Coal or one of the biomass options in the "RMA Process List". It is recommended that all liquid fuels feedstock options be set in the ECF section to reduce the possibility of erroneous output.

Many of the fuel production facilities also produce co-products that have been modeled through system expansion. System expansion is performed by giving a credit to what the co-product replaces by its production. Each applicable energy conversion facility is explained below:

- Lignocellulosic Gasification: electricity production displacing power from the Midwest Reliability Organization West

- Lignocellulosic Combustion: electricity production displacing power from the Midwest Reliability Organization West
- Advanced Dry Mill, with and without CCS: corn oil produced displacing soybean oil
- Coal- and Biomass-/Biomass-to-Liquids: synthetic naphtha created displacing petroleum-based kerosene
- Coal-to-Liquids: electricity production displacing the North American average mix and synthetic naphtha to displace petroleum-based kerosene
- Petroleum Refinery: steam from hydrogen production displacing steam from natural gas

2.3.4 Monte Carlo Simulation

Monte Carlo simulation generically uses random sampling to generate model results based on a given algorithm. In this case, Excel is used to randomly generate values for parameters available to the user based on a given probability distribution, and the resulting emissions data is collected for statistical analysis. This process allows the user to generate uncertainty using random values for available parameters with defined distributions.

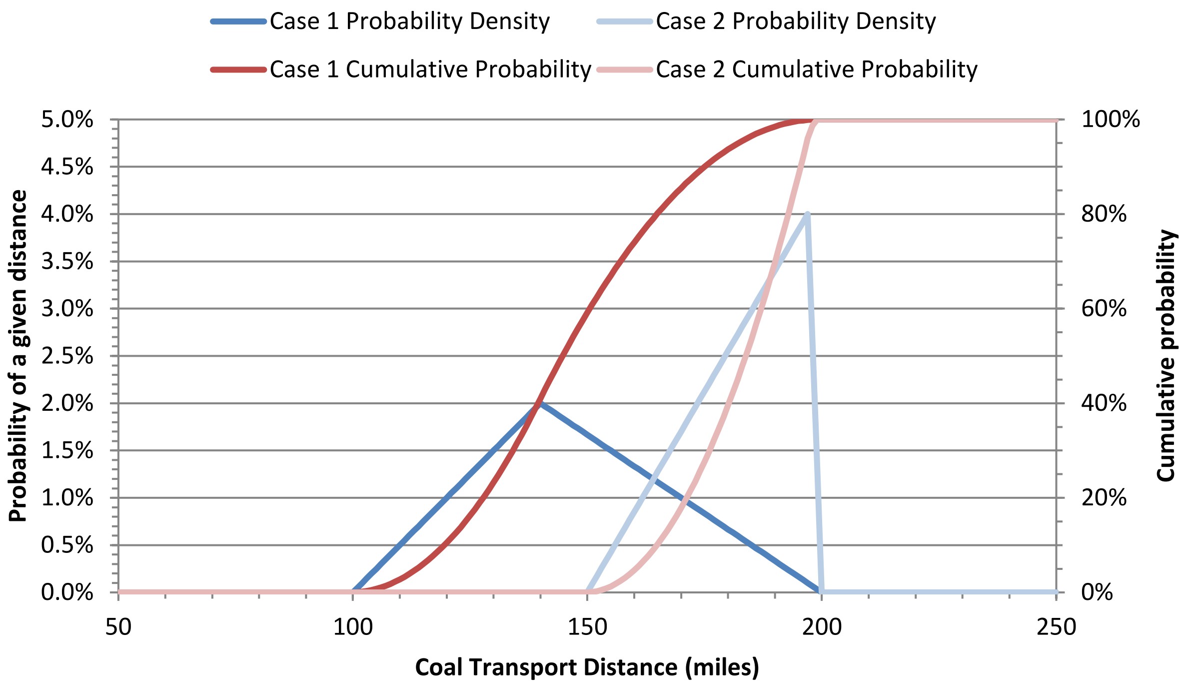
For example, a user may be uncertain of the transport distance that is required to deliver coal from the mine to their facility, in the RMT stage, but the user knows that the round-trip distance is between 100 and 200 miles, with an expected distance of 120 miles. This information is entered into the upstream dashboard as a triangular probability distribution with a minimum of 100 miles, expected value of 140 miles, and maximum value of 200 miles. This triangular distribution is shown in Figure 12 as Case 1, along with an alternate distribution (Case 2) for low, expected, and high values of 150, 197, and 200 miles. There are several things to note on this graph:

1. The probability of the expected value is a function of difference between the low and high values. The expected value of Case 1, defined by the range of 139.5-140.5, only has a 2% chance of being selected versus 4% for Case 2, defined by the range of 196.5-197.5.

2. The effect of the expected value is somewhat muted for the triangle distribution but does force the majority of the values to be weighted towards the expected value. For Case 1, 59 percent of randomly generated values would be expected to be less than 150 miles, the midpoint of the distribution. For Case 2, 72 percent of the values are expected to be greater than the midpoint of 175 miles despite the expected value being so close to the high value.

3. The low and high distribution values cannot be randomly generated because the distribution defines the probability at these values as 0.

Figure 12: Example triangular distribution for transport distance

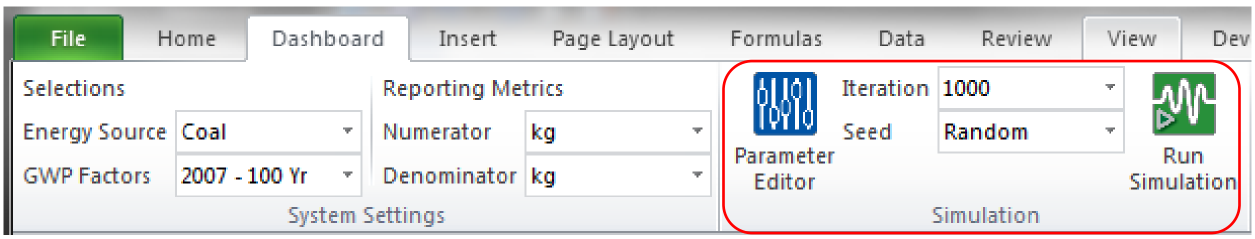


A uniform distribution is also available, which means that all values between low and high have an equal probability of being generated.

2.3.4.2 Setting the Distributions

The distributions for the parameters are set using the "Parameter Editor" button in the "Dashboard" ribbon tab. The "Parameter Editor" button is shown within the "Dashboard" ribbon tab in **Figure 13**. The "Parameter Editor" is shown in **Figure 14**, using the example of Illinois No. 6 coal. The available parameters are dependent on the chosen feedstock.

Figure 13: Monte Carlo Simulation Section of Dashboard Ribbon Tab



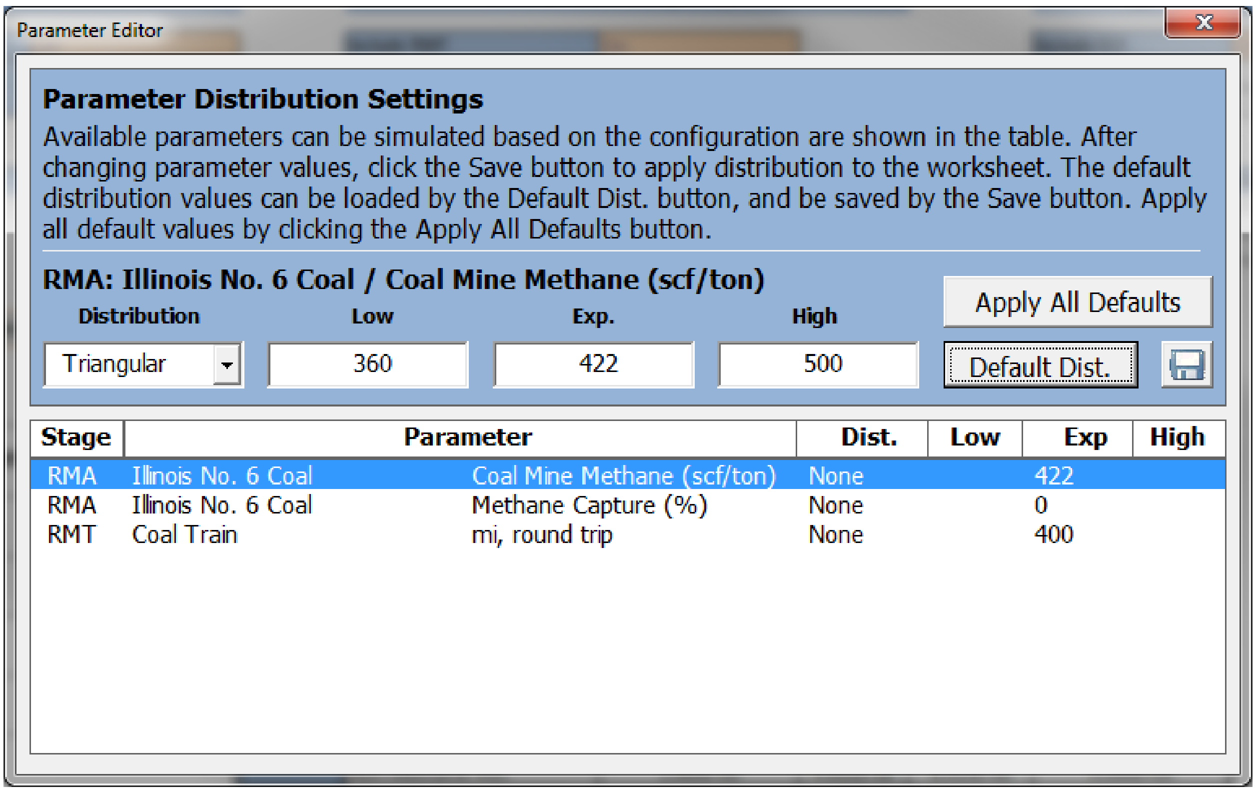
Distribution parameters are set as follows:

1. Select the desired parameter in the lower section of the window. In **Figure 14**, RMA – Illinois No. 6 Coal – Coal Mine Methane (scf/ton) is selected). The background color of the upper section of the window will change based on the life cycle stage (blue for RMA and red for RMT).
2. Default distributions are available for all parameters. The dashboard will automatically populate all fields with the default parameters when the "Apply All Defaults" button is

pressed. The default distribution can be set for individual parameters by pressing the "Default Dist." button after an individual parameter is selected.

3. Select the distribution type (uniform, triangular, or none).
4. Enter the low, expected (applicable for triangular or none only), and high values. For a triangular distribution, all three values cannot be the same (i.e., low – 1, expected – 1, and high – 1).
5. Click the "Save" button, the button with the floppy disk icon.
6. Set the other available parameters as needed. The simulation will run so long as one parameter has a distribution. The other parameters will remain fixed for the simulation.

Figure 14: Parameter Editor



2.3.4.3 Running the Simulation

Once the distributions are set, the simulation is ready to run. Choose the number of simulation iterations to run (1,000 and 1,500 iterations are available) using the "Iteration" dropdown menu in the "Dashboard" ribbon tab (see **Figure 13**).

If desired, the user can insert a seed value in the "Seed" dropdown menu by simply replacing "Random" with the seed value (any integer between -32,768 to 32,767). Setting a specific seed value will result in the generation of the same 1,000 or 1,500 random results every time that specific seed value is used.

Next, click the "Run Simulation" button. You will be prompted to close other open Excel files to speed up the simulation.

Once the simulation is completed, the results are available in a graph on the "Dashboard" worksheet and in a table in the "Stats" worksheet.

2.4 Results

After the user has selected and adjusted the appropriate feedstocks and options, the model calculates the impacts of the created system. The model takes into account any losses during the transport stage, and the feedstock requirements for the energy conversion stage. **Table 2** shows the inventory table of the emissions from a sample model run. The values shown are direct emissions to the atmosphere or water, emissions of solid waste, land use change area, or energy return on investment (EROI), as shown. Impacts at each stage are shown so that the user can see relative contribution of each stage to the entire system.

Table 2: Inventory Results Table

Emission Inventory (Unit = kg / kg)

Life Cycle Inventory		Total	RMA	RMT	ECF
Air Emissions	Carbon Dioxide	9.863E-02	8.541E-02	1.322E-02	0.000E+00
	Methane	6.601E-03	6.584E-03	1.689E-05	0.000E+00
	Nitrous Oxide	1.601E-05	1.583E-05	1.766E-07	0.000E+00
	Nitrogen Oxides	5.746E-04	2.895E-04	2.851E-04	0.000E+00
	Sulfur Dioxide	1.744E-04	1.660E-04	8.376E-06	0.000E+00
	Carbon Monoxide	2.012E-04	1.366E-04	6.468E-05	0.000E+00
	Particulate Matter	6.911E-05	4.867E-05	2.044E-05	0.000E+00
	Lead	1.293E-08	1.283E-08	1.027E-10	0.000E+00
	Mercury	1.521E-09	1.511E-09	1.057E-11	0.000E+00
	Ammonia	1.451E-06	1.426E-06	2.484E-08	0.000E+00
	Radiation	3.415E-11	1.786E-11	1.629E-11	0.000E+00
	Non Methane VOC	3.449E-05	2.076E-05	1.373E-05	0.000E+00
Solid Waste	Heavy Metals to Soil	1.080E-03	1.080E-03	3.273E-08	0.000E+00
	Solid Waste	3.918E-06	3.480E-06	4.383E-07	0.000E+00
Water Emissions	Aluminum	6.017E-08	5.090E-08	9.269E-09	0.000E+00
	Ammonium/ammonia (as N)	4.731E-06	4.707E-06	2.396E-08	0.000E+00
	Heavy Metals	5.415E-05	5.406E-05	9.428E-08	0.000E+00
	Nitrate	6.840E-06	6.828E-06	1.184E-08	0.000E+00
	Nitrogen	3.386E-07	3.313E-07	7.309E-09	0.000E+00
	Phosphate	5.239E-08	5.227E-08	1.202E-10	0.000E+00
	Phosphorus	5.125E-08	4.930E-08	1.956E-09	0.000E+00
Water	Water Withdrawal (L)	3.968E+00	3.793E+00	1.745E-01	0.000E+00
	Water Consumption (L)	6.378E-01	6.309E-01	6.840E-03	0.000E+00
Land Use	Land Transformation (m^2)	2.090E-04	1.863E-04	2.269E-05	0.000E+00

Below the Inventory Table, is a second table with the greenhouse gas (GHG) equivalents from each stage, shown in CO_2 equivalents. GHG values are calculated based on the selections made on the GWP factors drop-down menu for the IPCC vintage (2001, 2007, or 2013) and GWP time horizon (20-year, 100-year, or 500-year). The values from the Inventory Table are converted into CO_2e as shown in **Table 3**.

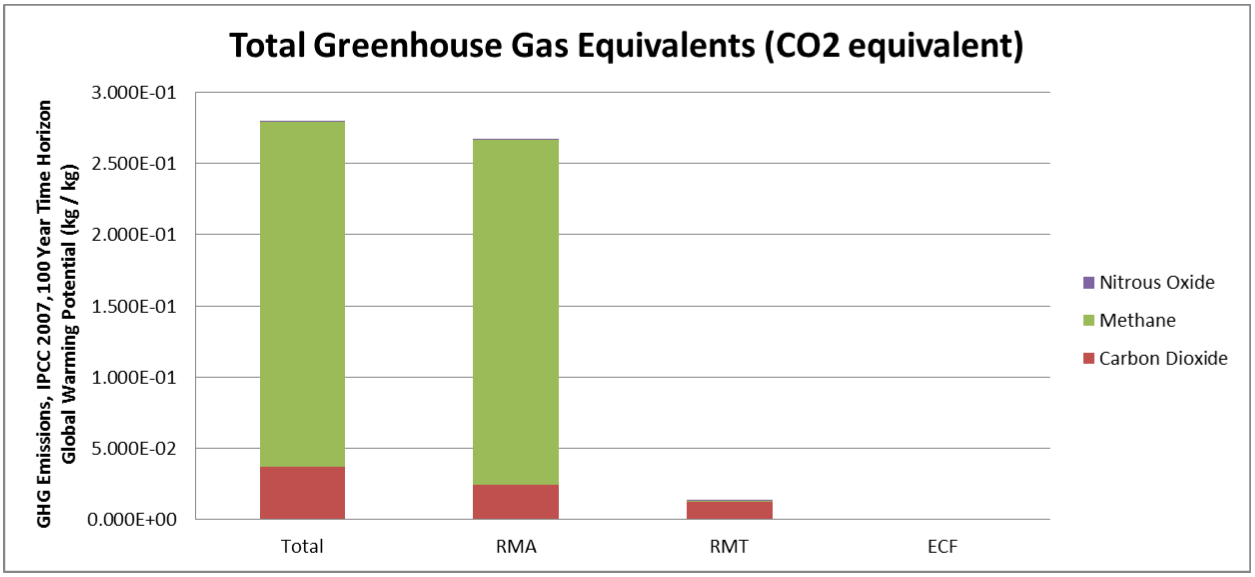
Table 3: Global Warming Potential Results Table

Greenhouse Gas Equivalents (Unit = kg CO_2 equivalent / kg)   Based on IPCC 2013, 100 Year

GHG Inventory		Total	RMA	RMT	ECF
Air Emissions	Carbon Dioxide	9.863E-02	8.541E-02	1.322E-02	0.000E+00
	Methane	2.376E-01	2.370E-01	6.080E-04	0.000E+00
	Nitrous Oxide	4.770E-03	4.717E-03	5.263E-05	0.000E+00
	Total	3.410E-01	3.272E-01	1.388E-02	0.000E+00

For a visual representation of the GHG equivalents results, a graph with the stage results is also presented as shown in **Figure 15**. For the biomass feedstocks, carbon is sequestered during biomass growth, and thus a negative carbon dioxide (CO_2) emission value is portrayed for the RMA. The amount of CO_2 uptake will be offset by other CO_2 emissions, so the value shown in the graph will not be the exact amount of uptake.

Figure 15: Global Warming Potential Results Graph



As discussed in **Section 2.3.4.3**, the Monte Carlo results are reported in a graph and a table. An example graph is shown in **Figure 16**. The data for that graph is available in the table on the “Stats” worksheet. See **Table 4** for an example.

Figure 16: Monte Carlo Simulation Global Warming Potential Graph

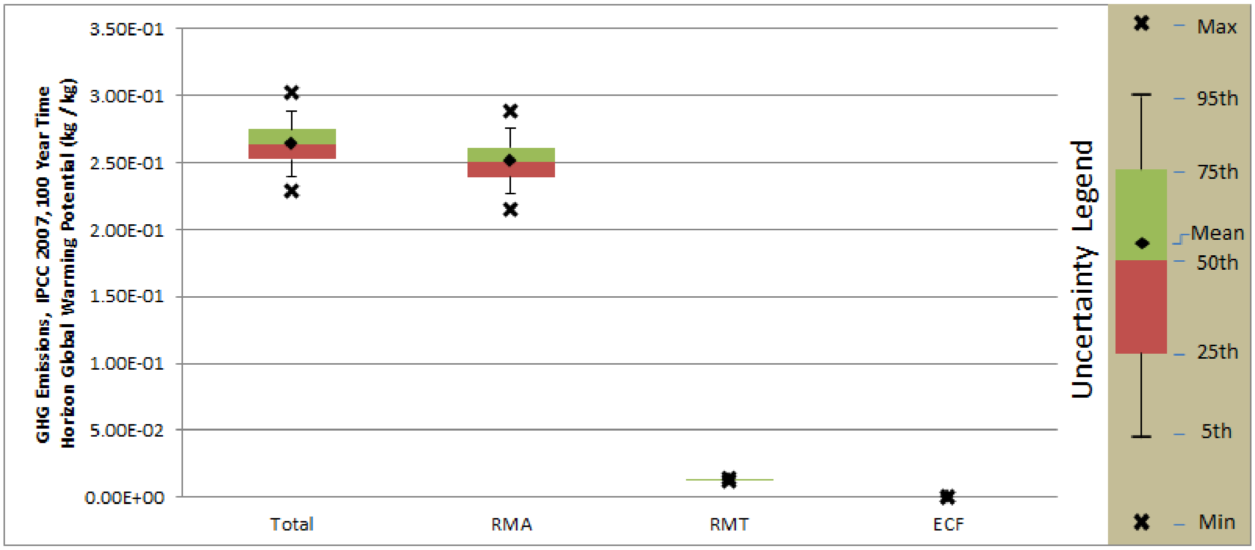


Table 4: Monte Carlo Simulation Global Warming Potential Results Table

Stage	Air Emission	Mean	Min	Max	StdDev	5%	25%	50%	75%	95%
Total	Total	2.64E-01	2.28E-01	3.02E-01	1.51E-02	2.39E-01	2.52E-01	2.63E-01	2.75E-01	2.89E-01
RMA	Total	2.51E-01	2.15E-01	2.88E-01	1.51E-02	2.26E-01	2.39E-01	2.50E-01	2.61E-01	2.76E-01
RMT	Total	1.31E-02	1.19E-02	1.44E-02	5.30E-04	1.22E-02	1.27E-02	1.31E-02	1.35E-02	1.40E-02
ECF	Total	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Stage	Air Emission	Mean	Min	Max	StdDev	5%	25%	50%	75%	95%
Total	Carbon Dioxide	3.71E-02	3.59E-02	3.83E-02	5.11E-04	3.63E-02	3.67E-02	3.71E-02	3.75E-02	3.80E-02
Total	Methane	2.26E-01	1.91E-01	2.64E-01	1.51E-02	2.02E-01	2.15E-01	2.26E-01	2.37E-01	2.52E-01
Total	Nitrous Oxide	2.29E-04	2.20E-04	2.39E-04	3.89E-06	2.23E-04	2.26E-04	2.29E-04	2.32E-04	2.36E-04
RMA	Carbon Dioxide	2.45E-02	2.45E-02	2.45E-02	2.49E-08	2.45E-02	2.45E-02	2.45E-02	2.45E-02	2.45E-02
RMA	Methane	2.26E-01	1.91E-01	2.64E-01	1.51E-02	2.02E-01	2.15E-01	2.26E-01	2.37E-01	2.51E-01
RMA	Nitrous Oxide	1.34E-04	1.34E-04	1.34E-04	1.37E-10	1.34E-04	1.34E-04	1.34E-04	1.34E-04	1.34E-04
RMT	Carbon Dioxide	1.26E-02	1.14E-02	1.39E-02	5.11E-04	1.18E-02	1.22E-02	1.26E-02	1.30E-02	1.35E-02
RMT	Methane	3.87E-04	3.50E-04	4.24E-04	1.55E-05	3.61E-04	3.75E-04	3.87E-04	3.98E-04	4.13E-04
RMT	Nitrous Oxide	9.48E-05	8.56E-05	1.04E-04	3.89E-06	8.85E-05	9.18E-05	9.48E-05	9.76E-05	1.01E-04
ECF	Carbon Dioxide	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ECF	Methane	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ECF	Nitrous Oxide	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

3 Data Tables

The following pages contain the data sets as extracted from NETL models with default parameter values used for the dashboard.

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Table 5: Raw Material Acquisition Inventory

Life Cycle Inventory (kg/kg)		Coal		Uranium		Biomass			
		I6	PRB	100% US Enrichment	100% EU Enrichment	Corn Grain	Corn Stover	SRWC	Switch-grass
Air Emissions	Carbon Dioxide	8.54E-02	8.72E-03	9.08E+02	7.32E+02	-1.37E+00	-1.12E-01	-4.76E-01	-8.97E-01
	Methane	6.58E-03	1.62E-04	7.57E+00	6.67E+00	1.54E-04	2.19E-04	1.47E-04	1.08E-04
	Nitrous Oxide	1.58E-05	6.40E-06	3.49E-02	3.03E-02	5.51E-04	6.16E-04	4.09E-04	3.77E-04
	Total GWP	3.27E-01	1.64E-02	1.19E+03	9.81E+02	-1.20E+00	7.90E-02	-3.49E-01	-7.81E-01
	Nitrogen Oxides	2.90E-04	1.12E-04	3.75E+00	3.22E+00	4.54E-05	5.33E-06	2.26E-04	1.79E-04
	Sulfur Dioxide	1.66E-04	8.75E-06	1.94E+00	1.68E+00	1.45E-04	1.82E-04	1.23E-04	8.00E-05
	Carbon Monoxide	1.37E-04	1.79E-05	2.65E+00	2.35E+00	1.47E-04	9.28E-05	3.34E-04	1.20E-04
	Particulate Matter	4.87E-05	8.09E-06	2.09E-01	1.27E-01	1.36E-06	2.08E-06	8.43E-05	7.27E-05
	Lead	1.28E-08	1.28E-09	6.15E-05	6.89E-05	7.42E-09	3.74E-09	2.14E-08	8.11E-09
	Mercury	1.51E-09	8.99E-11	8.86E-06	7.00E-06	3.73E-10	3.69E-10	6.90E-10	3.16E-10
	Ammonia	1.43E-06	2.72E-07	7.12E-01	6.54E-01	1.02E-04	1.57E-04	7.59E-05	7.02E-05
	Radiation	1.79E-11	4.42E-12	6.18E-05	6.18E-05	4.83E-13	7.50E-13	3.82E-13	2.23E-13
	Non Methane VOC	2.08E-05	4.15E-06	4.99E-01	4.44E-01	1.43E-05	2.11E-05	1.22E-05	9.29E-06
Solid Waste	Heavy Metals to Soil	1.08E-03	6.73E-05	6.46E+03	1.43E+04	6.16E-05	9.55E-05	4.87E-05	2.84E-05
	Solid Waste	3.48E-06	2.04E-07	2.86E+00	2.11E+00	9.03E-08	1.40E-07	7.13E-08	4.16E-08
Water Emissions	Aluminum	5.09E-08	4.29E-09	5.02E-04	2.52E-03	2.73E-08	4.09E-08	2.02E-08	1.75E-08
	Ammonium/ammonia	4.71E-06	1.95E-06	7.12E-01	6.54E-01	1.02E-04	1.37E-04	1.66E-05	1.53E-05
	Heavy Metals	5.41E-05	3.32E-06	2.73E+02	6.05E+02	8.11E-06	1.18E-05	6.08E-06	4.48E-06
	Nitrate	6.83E-06	4.95E-07	7.09E-01	7.06E-01	1.76E-06	2.65E-06	1.30E-06	1.17E-06
	Nitrogen	3.31E-07	3.39E-08	9.42E-01	4.26E-01	6.71E-05	1.03E-05	8.07E-06	8.46E-06
	Phosphate	5.23E-08	4.55E-10	0.00E+00	0.00E+00	6.10E-08	8.73E-08	4.46E-08	3.78E-08
	Phosphorus	4.93E-08	5.12E-09	1.66E-03	1.41E-03	1.06E-04	1.03E-04	6.90E-05	3.29E-05
Water	Water Withdrawal (L)	3.79E+00	3.21E-01	1.31E+05	6.27E+05	6.02E+02	1.15E+02	4.45E+02	4.76E+02
	Water Consumption (L)	6.31E-01	5.77E-02	1.47E+04	1.33E+04	5.86E+02	-6.85E+01	4.33E+02	4.65E+02
Land Use	Land Transformation (m^2)	1.86E-04	5.67E-08	6.96E+00	7.64E+00	7.23E-04	1.02E-03	5.21E-04	4.35E-04

Table 5: Raw Material Acquisition Inventory (Continued)

Life Cycle Inventory (kg/kg)		Natural Gas						
		Coalbed Methane			Offshore Conventional			
		Appalachian	Black Warrior	Central	Rocky Mountains	Alaska	Gulf of Mexico	Pacific
Air Emissions	Carbon Dioxide	2.18E-01	2.41E-01	2.10E-01	2.09E-01	1.22E-01	1.22E-01	1.22E-01
	Methane	3.14E-03	1.49E-03	2.39E-03	2.79E-03	3.34E-03	3.34E-03	3.34E-03
	Nitrous Oxide	1.12E-06	1.52E-06	1.25E-06	1.42E-06	3.27E-07	3.44E-07	3.23E-07
	Total GWP	3.32E-01	2.95E-01	2.96E-01	3.10E-01	2.42E-01	2.42E-01	2.42E-01
	Nitrogen Oxides	4.15E-03	4.30E-03	4.18E-03	4.19E-03	3.84E-03	3.84E-03	3.83E-03
	Sulfur Dioxide	6.14E-03	5.92E-03	5.47E-03	5.34E-03	3.58E-03	3.35E-03	3.58E-03
	Carbon Monoxide	6.63E-04	8.28E-04	6.96E-04	7.02E-04	3.18E-04	3.16E-04	3.16E-04
	Particulate Matter	3.31E-05	4.86E-05	3.68E-05	3.77E-05	2.12E-06	2.15E-06	1.96E-06
	Lead	2.61E-08	3.89E-08	2.89E-08	2.95E-08	4.28E-10	3.60E-10	2.97E-10
	Mercury	1.09E-09	1.56E-09	1.21E-09	1.25E-09	1.29E-10	1.35E-10	1.24E-10
	Ammonia	1.11E-07	1.19E-07	1.32E-07	1.42E-07	9.51E-08	1.02E-07	9.50E-08
	Radiation	8.42E-13	9.20E-13	9.94E-13	1.07E-12	6.86E-13	7.35E-13	6.85E-13
	Non Methane VOC	1.03E-03	3.29E-04	4.59E-04	3.78E-04	1.22E-03	9.65E-04	1.22E-03
Solid Waste	Heavy Metals to Soil	1.10E-04	1.12E-04	1.31E-04	1.43E-04	1.06E-04	1.14E-04	1.06E-04
	Solid Waste	3.41E-04	5.08E-04	3.77E-04	3.84E-04	3.86E-06	2.84E-06	2.14E-06
Water Emissions	Aluminum	2.57E-08	3.60E-08	2.89E-08	2.98E-08	5.00E-09	5.28E-09	4.89E-09
	Ammonium/ammonia (as N)	6.46E-08	6.89E-08	7.64E-08	8.27E-08	5.59E-08	5.99E-08	5.59E-08
	Heavy Metals	1.02E-03	1.02E-03	1.02E-03	1.02E-03	4.90E-06	5.26E-06	4.90E-06
	Nitrate	1.39E-08	1.49E-08	1.64E-08	1.77E-08	1.18E-08	1.27E-08	1.18E-08
	Nitrogen	3.99E-08	4.10E-08	4.77E-08	5.19E-08	4.46E-05	4.46E-05	4.46E-05
	Phosphate	1.26E-09	1.83E-09	1.41E-09	1.44E-09	1.31E-10	1.36E-10	1.26E-10
	Phosphorus	4.43E-09	4.53E-09	5.28E-09	5.75E-09	5.94E-07	5.94E-07	5.94E-07
Water	Water Withdrawal (L)	3.96E+00	5.75E+00	4.41E+00	4.52E+00	3.61E-01	3.73E-01	3.42E-01
	Water Consumption (L)	-2.06E+00	-2.81E-01	-1.66E+00	-1.58E+00	-5.75E-01	-5.81E-01	-5.94E-01
Land Use	Land Transformation (m^2)	5.28E-04	2.91E-04	4.56E-04	2.59E-04	5.14E-07	5.48E-07	5.14E-07

Life Cycle Inventory (kg/kg)		Natural Gas								
		Conventional Onshore								
		Alaska	Appalachian	Central	Gulf Coast	Illinois-Michigan	North-Central	Rocky Mountains	TX-LA-MS Salt	West Coast
Air Emissions	Carbon Dioxide	1.37E-01	1.23E-01	1.31E-01	1.37E-01	1.33E-01	7.20E-01	1.29E-01	1.39E-01	1.33E-01
	Methane	7.92E-03	5.94E-03	1.99E-03	8.63E-03	6.00E-03	6.36E-03	8.76E-03	8.60E-03	7.28E-03
	Nitrous Oxide	3.85E-06	3.41E-06	6.15E-06	4.00E-06	3.72E-06	8.33E-06	3.59E-06	1.07E-05	4.22E-06
	Total GWP	3.36E-01	2.73E-01	1.82E-01	3.54E-01	2.84E-01	8.81E-01	3.49E-01	3.57E-01	3.16E-01
	Nitrogen Oxides	3.95E-03	3.91E-03	1.17E-04	3.00E-03	3.97E-03	1.59E-03	3.93E-03	3.94E-03	3.28E-03
	Sulfur Dioxide	2.49E-05	1.06E-05	3.87E-06	1.16E-04	3.12E-05	1.01E-04	1.90E-05	2.95E-05	3.97E-05
	Carbon Monoxide	3.62E-04	3.27E-04	2.88E-05	2.62E-04	3.78E-04	6.35E-04	3.47E-04	3.44E-04	2.96E-04
	Particulate Matter	2.09E-05	1.42E-05	6.20E-06	1.38E-05	2.38E-05	1.13E-05	1.81E-05	1.72E-05	1.66E-05
	Lead	1.89E-08	7.77E-09	6.02E-10	9.31E-09	2.37E-08	7.25E-09	1.43E-08	1.20E-08	1.30E-08
	Mercury	5.18E-10	2.13E-10	1.65E-11	8.47E-10	6.52E-10	3.59E-10	3.91E-10	3.99E-10	4.83E-10
	Ammonia	3.20E-09	1.35E-09	4.74E-10	2.60E-08	4.01E-09	6.59E-04	2.43E-09	6.49E-09	7.50E-09
	Radiation	2.83E-12	1.16E-12	4.03E-13	7.82E-12	3.56E-12	2.11E-12	2.13E-12	4.30E-12	3.40E-12
	Non Methane VOC	1.43E-03	9.91E-04	2.23E-04	1.61E-03	1.01E-03	2.76E-04	1.63E-03	1.59E-03	1.31E-03
Solid Waste	Heavy Metals to Soil	6.46E-06	2.65E-06	2.05E-07	2.16E-04	8.12E-06	3.12E-05	4.87E-06	2.89E-05	4.98E-05
	Solid Waste	4.86E-08	4.86E-08	4.87E-08	4.82E-08	4.86E-08	1.05E-04	4.86E-08	4.86E-08	4.85E-08
Water Emissions	Aluminum	7.23E-10	3.01E-10	5.69E-11	1.63E-08	9.07E-10	9.71E-09	5.47E-10	2.47E-09	3.90E-09
	Ammonium/ammonia (as N)	4.62E-06	1.90E-06	7.01E-07	7.72E-06	5.81E-06	2.71E-06	3.49E-06	1.33E-05	2.81E+01
	Heavy Metals	2.94E-06	0.00E+00	3.77E-07	1.23E-05	1.05E-03	3.80E-06	2.25E-06	4.63E-06	1.03E-04
	Nitrate	2.78E-09	0.00E+00	7.29E-10	3.61E-08	3.37E-09	4.00E-06	2.22E-09	6.78E-09	9.46E-09
	Nitrogen	5.56E-09	0.00E+00	4.65E-05	1.86E-07	6.99E-09	5.39E-05	4.20E-09	9.33E-06	5.88E-06
	Phosphate	1.60E-11	0.00E+00	3.19E-12	1.92E-10	1.97E-11	1.15E-07	1.25E-11	3.80E-11	5.09E-11
	Phosphorus	3.92E-07	0.00E+00	6.76E-07	2.22E-07	4.92E-07	8.86E-07	2.95E-07	6.35E-07	3.65E-07
Water	Water Withdrawal (L)	7.73E-01	0.00E+00	6.41E-03	2.62E+00	1.36E-01	6.30E+00	1.53E+00	9.46E-01	1.21E+00
	Water Consumption (L)	-5.05E-01	-5.49E-01	-7.13E-01	1.20E+00	-5.88E+00	-4.24E-01	1.14E+00	8.02E-01	-2.05E-01
Land Use	Land Transformation (m^2)	1.13E-06	1.13E-06	0.00E+00	2.32E-06	6.78E-08	2.20E-06	1.16E-05	4.81E-07	1.16E-05

Life Cycle Inventory (kg/kg)		Natural Gas							
		Shale							
		Appalachian	Central	Fort Worth	Illinois-Michigan	North-Central	Rocky Mountains	West Coast	West Texas-Permian
Air Emissions	Carbon Dioxide	1.79E-01	1.96E-01	1.81E-01	1.81E-01	2.36E-01	1.90E-01	2.02E-01	1.81E-01
	Methane	7.35E-03	6.84E-03	4.88E-03	1.21E-02	1.33E-02	9.05E-03	5.73E-03	5.22E-03
	Nitrous Oxide	8.13E-07	4.74E-07	4.31E-07	3.76E-07	7.73E-07	2.30E-06	4.52E-07	4.46E-07
	Total GWP	4.44E-01	4.42E-01	3.57E-01	6.15E-01	7.16E-01	5.17E-01	4.08E-01	3.69E-01
	Nitrogen Oxides	3.88E-03	3.88E-03	3.88E-03	3.86E-03	4.02E-03	3.93E-03	3.89E-03	3.88E-03
	Sulfur Dioxide	1.38E-02	1.86E-02	1.87E-02	1.37E-02	1.37E-02	1.37E-02	1.89E-02	1.87E-02
	Carbon Monoxide	3.87E-04	4.24E-04	4.16E-04	3.81E-04	5.49E-04	4.51E-04	4.33E-04	4.21E-04
	Particulate Matter	4.91E-06	5.82E-06	5.09E-06	3.94E-06	1.94E-05	1.05E-05	6.55E-06	5.68E-06
	Lead	2.12E-09	3.39E-09	2.79E-09	1.91E-09	1.48E-08	7.35E-09	4.10E-09	3.28E-09
	Mercury	2.45E-10	2.48E-10	2.26E-10	1.87E-10	6.62E-10	3.93E-10	2.66E-10	2.44E-10
	Ammonia	1.40E-07	1.04E-07	1.04E-07	9.80E-08	1.03E-07	1.04E-07	9.74E-08	1.04E-07
	Radiation	1.01E-12	7.56E-13	7.50E-13	7.09E-13	7.62E-13	7.61E-13	7.08E-13	7.53E-13
	Non Methane VOC	2.74E-03	2.05E-03	1.41E-03	4.35E-03	5.47E-03	2.92E-03	2.12E-03	1.56E-03
Solid Waste	Heavy Metals to Soil	1.55E-04	1.14E-04	1.14E-04	1.08E-04	1.06E-04	1.12E-04	1.06E-04	1.14E-04
	Solid Waste	2.52E-05	4.25E-05	3.47E-05	2.32E-05	1.92E-04	9.44E-05	5.20E-05	4.11E-05
Water Emissions	Aluminum	8.52E-09	7.74E-09	7.24E-09	6.29E-09	1.65E-08	1.08E-08	7.95E-09	7.63E-09
	Ammonium/ammonia (as N)	6.65E-06	6.11E-08	6.08E-08	5.76E-08	5.99E-08	6.09E-08	5.71E-08	6.09E-08
	Heavy Metals	7.23E-06	6.05E-06	6.01E-06	5.73E-06	5.99E-06	6.05E-06	5.70E-06	6.03E-06
	Nitrate	1.73E-08	1.29E-08	1.29E-08	1.22E-08	1.28E-08	1.29E-08	1.21E-08	1.29E-08
	Nitrogen	9.00E-06	4.10E-08	4.08E-08	3.88E-08	3.84E-08	4.02E-08	3.82E-08	4.09E-08
	Phosphate	2.56E-10	2.70E-10	2.43E-10	1.99E-10	7.61E-10	4.41E-10	2.93E-10	2.65E-10
	Phosphorus	1.24E-07	4.57E-09	4.56E-09	4.33E-09	4.28E-09	4.49E-09	4.26E-09	4.56E-09
Water	Water Withdrawal (L)	1.55E+00	1.64E+00	1.56E+00	1.42E+00	3.21E+00	2.19E+00	1.72E+00	1.63E+00
	Water Consumption (L)	1.18E+00	1.16E+00	1.08E+00	9.52E-01	2.74E+00	1.71E+00	1.26E+00	1.15E+00
Land Use	Land Transformation (m^2)	2.47E-04	9.46E-04	7.05E-04	7.99E-04	3.92E-03	1.41E-03	7.47E-04	7.06E-04

Life Cycle Inventory (kg/kg)		Natural Gas								
		Tight Gas							Associated	National Mix
		Appalachian	Central	Gulf Coast	Illinois-Michigan	North-Central	Rocky Mountains	TX-LA-MS Salt		
Air Emissions	Carbon Dioxide	1.84E-01	1.64E-01	1.41E-01	1.78E-01	1.99E-01	1.58E-01	1.92E-01	1.39E-01	1.33E-01
	Methane	3.38E-03	5.38E-03	2.55E-03	8.33E-03	9.64E-03	5.22E-03	3.54E-03	8.60E-03	7.28E-03
	Nitrous Oxide	5.53E-07	4.63E-07	4.65E-07	5.61E-07	9.12E-07	2.31E-06	5.07E-07	1.07E-05	4.22E-06
	Total GWP	3.06E-01	3.57E-01	2.33E-01	4.78E-01	5.46E-01	3.47E-01	3.20E-01	3.57E-01	3.16E-01
	Nitrogen Oxides	3.93E-03	3.88E-03	3.89E-03	3.93E-03	4.07E-03	3.93E-03	3.91E-03	3.94E-03	3.28E-03
	Sulfur Dioxide	6.42E-03	9.85E-03	5.31E-03	7.82E-03	7.51E-03	7.62E-03	1.21E-02	2.95E-05	3.97E-05
	Carbon Monoxide	4.31E-04	3.88E-04	3.83E-04	4.37E-04	5.85E-04	4.32E-04	4.23E-04	3.44E-04	2.96E-04
	Particulate Matter	1.15E-05	6.22E-06	7.63E-06	1.16E-05	2.53E-05	1.13E-05	8.54E-06	1.72E-05	1.66E-05
	Lead	8.22E-09	3.72E-09	4.90E-09	8.23E-09	1.96E-08	7.95E-09	5.62E-09	1.20E-08	1.30E-08
	Mercury	4.20E-10	2.61E-10	3.04E-10	4.22E-10	8.43E-10	4.15E-10	3.34E-10	3.99E-10	4.83E-10
	Ammonia	1.00E-07	1.04E-07	1.05E-07	1.02E-07	1.06E-07	1.04E-07	1.08E-07	6.49E-09	7.50E-09
	Radiation	7.33E-13	7.58E-13	7.63E-13	7.48E-13	7.92E-13	7.64E-13	7.84E-13	4.30E-12	3.40E-12
	Non Methane VOC	1.14E-03	1.61E-03	6.78E-04	2.96E-03	3.90E-03	1.63E-03	9.09E-04	1.59E-03	1.31E-03
Solid Waste	Heavy Metals to Soil	1.07E-04	1.14E-04	1.14E-04	1.09E-04	1.07E-04	1.12E-04	1.17E-04	2.89E-05	4.98E-05
	Solid Waste	1.06E-04	4.69E-05	6.23E-05	1.06E-04	2.55E-04	1.02E-04	7.17E-05	4.86E-08	4.85E-08
Water Emissions	Aluminum	1.13E-08	8.00E-09	8.94E-09	1.14E-08	2.04E-08	1.13E-08	9.63E-09	2.47E-09	3.90E-09
	Ammonium/ammonia (as N)	5.85E-08	6.12E-08	6.15E-08	5.97E-08	6.15E-08	6.11E-08	6.31E-08	1.33E-05	2.81E+01
	Heavy Metals	5.17E-06	5.39E-06	5.42E-06	5.27E-06	5.48E-06	5.40E-06	5.56E-06	4.63E-06	1.03E-04
	Nitrate	1.25E-08	1.30E-08	1.30E-08	1.27E-08	1.32E-08	1.30E-08	1.34E-08	6.78E-09	9.46E-09
	Nitrogen	3.85E-08	4.10E-08	4.10E-08	3.93E-08	3.88E-08	4.03E-08	4.20E-08	9.33E-06	5.88E-06
	Phosphate	4.75E-10	2.85E-10	3.36E-10	4.77E-10	9.75E-10	4.67E-10	3.71E-10	3.80E-11	5.09E-11
	Phosphorus	4.29E-09	4.58E-09	4.57E-09	4.38E-09	4.32E-09	4.49E-09	4.68E-09	6.35E-07	3.65E-07
Water	Water Withdrawal (L)	1.45E+00	8.45E-01	1.01E+00	1.46E+00	3.04E+00	1.43E+00	1.12E+00	9.46E-01	1.21E+00
	Water Consumption (L)	1.20E+00	5.73E-01	7.37E-01	1.20E+00	2.78E+00	1.16E+00	8.38E-01	8.02E-01	-2.05E-01
Land Use	Land Transformation (m^2)	8.21E-04	1.10E-03	1.95E-04	1.07E-03	1.26E-03	3.43E-04	8.90E-04	4.81E-07	1.16E-05

Table 5: Raw Material Acquisition Inventory (Continued)

Life Cycle Inventory (kg/kg)		Petroleum					
		Domestic	National Average	African	Middle Eastern	North American	South American
Air Emissions	Carbon Dioxide	1.36E-01	1.92E-01	3.47E-01	9.84E-02	1.95E-01	1.36E-01
	Methane	7.26E-04	3.85E-03	1.72E-02	5.32E-04	2.01E-03	1.61E-03
	Nitrous Oxide	4.09E-06	5.22E-06	8.99E-06	2.29E-06	5.59E-06	3.47E-06
	Total GWP	1.55E-01	2.90E-01	7.79E-01	1.12E-01	2.47E-01	1.77E-01
	Nitrogen Oxides	6.02E-04	6.13E-04	7.25E-04	3.24E-04	7.22E-04	4.09E-04
	Sulfur Dioxide	2.27E-04	9.86E-04	2.98E-03	1.27E-04	8.43E-04	5.75E-04
	Carbon Monoxide	3.63E-04	4.43E-04	8.80E-04	1.79E-04	4.46E-04	3.10E-04
	Particulate Matter	9.71E-06	6.81E-06	2.69E-06	3.10E-06	9.96E-06	2.82E-06
	Lead	1.41E-08	8.35E-09	1.05E-09	1.59E-09	1.35E-08	3.46E-09
	Mercury	4.05E-10	2.94E-10	3.21E-11	1.56E-11	4.97E-10	8.57E-11
	Ammonia	1.81E-07	2.26E-06	1.77E-08	1.27E-08	4.07E-06	2.39E-08
	Radiation	2.84E-10	2.27E-10	9.95E-12	5.09E-12	3.97E-10	3.39E-11
	Non Methane VOC	1.58E-04	8.68E-04	3.83E-03	9.65E-05	4.88E-04	3.07E-04
Solid Waste	Heavy Metals to Soil	6.52E-06	1.08E-05	6.81E-06	2.27E-05	1.06E-05	4.32E-07
	Solid Waste	0.00E+00	1.35E-04	0.00E+00	0.00E+00	2.42E-04	0.00E+00
Water Emissions	Aluminum	2.48E-08	1.94E-08	1.05E-09	9.02E-10	3.37E-08	3.19E-09
	Ammonium/ammonia	4.90E-07	1.01E-06	4.98E-07	1.59E-06	1.19E-06	6.19E-08
	Heavy Metals	3.96E-06	3.52E-06	1.96E-06	4.65E-07	5.42E-06	1.19E-06
	Nitrate	9.20E-08	1.19E-07	2.31E-07	3.18E-08	1.39E-07	2.66E-08
	Nitrogen	0.00E+00	1.95E-09	1.97E-10	3.25E-11	3.25E-09	8.09E-10
	Phosphate	1.16E-08	9.04E-09	5.30E-09	3.60E-09	1.26E-08	5.28E-09
	Phosphorus	5.10E-08	1.10E-07	5.50E-08	1.76E-07	1.28E-07	6.27E-09
Water	Water Withdrawal (L)	1.02E-01	2.31E-01	2.77E-01	1.37E-01	2.89E-01	6.09E-02
	Water Consumption (L)	5.36E-02	1.12E-01	2.35E-01	1.09E-01	9.63E-02	5.36E-02
Land Use	Land Transformation (m^2)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 6: Raw Material Transport Inventory

Life Cycle Inventory		Coal Train	Natural Gas Pipeline	Bale Truck	Container Truck	Petroleum Pipeline	Petroleum Tanker Truck	Petroleum Ocean Tanker	Petroleum Rail
Air Emissions	Carbon Dioxide	1.32E-02	3.13E-02	2.37E-03	2.45E-03	3.49E-02	6.62E-05	2.35E-02	6.53E-05
	Methane	1.69E-05	5.22E-03	7.05E-06	7.20E-06	5.31E-05	1.32E-09	1.72E-06	5.15E-09
	Nitrous Oxide	1.77E-07	3.29E-07	6.30E-08	6.11E-08	6.28E-07	1.70E-09	5.99E-07	1.67E-09
	Total GWP	1.39E-02	1.62E-01	2.56E-03	2.65E-03	3.64E-02	6.67E-05	2.38E-02	6.59E-05
	Nitrogen Oxides	2.85E-04	1.43E-05	2.20E-06	2.54E-06	3.95E-05	4.86E-09	4.25E-05	1.74E-07
	Sulfur Dioxide	8.38E-06	1.83E-05	3.03E-06	3.84E-06	9.13E-05	4.67E-10	0.00E+00	6.15E-10
	Carbon Monoxide	6.47E-05	4.27E-05	5.46E-06	4.86E-06	1.25E-05	1.52E-07	4.53E-06	2.01E-07
	Particulate Matter	2.04E-05	6.55E-06	2.68E-07	5.04E-07	8.00E-06	2.43E-10	4.03E-05	4.02E-09
	Lead	1.03E-10	1.69E-08	6.25E-10	5.39E-10	2.25E-09	0.00E+00	0.00E+00	0.00E+00
	Mercury	1.06E-11	4.61E-10	9.03E-11	1.01E-10	3.26E-10	0.00E+00	0.00E+00	3.21E-15
	Ammonia	2.48E-08	1.33E-08	1.77E-08	1.83E-08	2.72E-07	0.00E+00	7.25E-07	2.68E-09
	Radiation	1.63E-11	4.37E-13	5.33E-12	5.05E-12	2.48E-09	0.00E+00	0.00E+00	0.00E+00
	Non Methane VOC	1.37E-05	2.69E-07	2.63E-06	2.56E-06	8.59E-04	8.52E-04	8.52E-04	8.52E-04
Solid Waste	Heavy Metals to Soil	3.27E-08	4.67E-06	1.48E-08	1.40E-08	6.29E-10	0.00E+00	0.00E+00	0.00E+00
	Solid Waste	4.38E-07	0.00E+00	1.05E-05	5.86E-05	1.13E-04	0.00E+00	0.00E+00	0.00E+00
Water Emissions	Aluminum	9.27E-09	3.76E-10	1.58E-09	2.55E-09	2.00E-07	0.00E+00	0.00E+00	0.00E+00
	Ammonium/ammonia	2.40E-08	6.45E-07	2.99E-08	1.72E-08	1.42E-07	0.00E+00	0.00E+00	0.00E+00
	Heavy Metals	9.43E-08	8.03E-07	5.98E-08	1.25E-07	7.19E-06	0.00E+00	0.00E+00	0.00E+00
	Nitrate	1.18E-08	8.94E-10	1.70E-07	1.70E-07	1.60E-06	0.00E+00	0.00E+00	0.00E+00
	Nitrogen	7.31E-09	4.02E-09	9.03E-09	8.56E-09	4.04E-12	0.00E+00	0.00E+00	0.00E+00
	Phosphate	1.20E-10	5.00E-12	2.60E-10	3.29E-10	4.85E-09	0.00E+00	0.00E+00	0.00E+00
	Phosphorus	1.96E-09	4.48E-08	7.66E-09	7.13E-09	1.71E-10	0.00E+00	0.00E+00	0.00E+00
Water	Water Withdrawal (L)	1.74E-01	6.44E-02	2.86E-03	2.49E+00	1.87E+01	0.00E+00	0.00E+00	0.00E+00
	Water Consumption (L)	6.84E-03	2.29E-02	-5.10E-01	8.15E-01	1.94E-01	0.00E+00	0.00E+00	0.00E+00
Land Use	Land Transformation (m^2)	2.27E-05	5.25E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 6: Raw Material Transport Inventory (Continued)

Life Cycle Inventory		Enclosed Train	Enclosed Truck	Ocean Freighter
Air Emissions	Carbon Dioxide	1.96E-03	6.14E-05	8.30E-06
	Methane	2.28E-06	2.62E-07	9.62E-09
	Nitrous Oxide	4.85E-08	1.36E-09	2.05E-10
	Total GWP	2.04E-03	6.84E-05	8.60E-06
	Nitrogen Oxides	4.88E-06	6.29E-08	2.06E-08
	Sulfur Dioxide	7.17E-07	8.57E-08	3.03E-09
	Carbon Monoxide	5.37E-06	8.95E-08	2.27E-08
	Particulate Matter	1.44E-07	5.27E-09	6.10E-10
	Lead	1.35E-11	1.65E-12	5.70E-14
	Mercury	5.19E-13	6.33E-14	2.19E-15
	Ammonia	7.12E-08	4.44E-10	3.01E-10
	Radiation	1.97E-12	2.41E-13	8.34E-15
	Non Methane VOC	9.18E-07	1.12E-07	3.88E-09
Solid Waste	Heavy Metals to Soil	5.48E-09	6.68E-10	2.31E-11
	Solid Waste	9.34E-08	1.14E-08	3.95E-10
Water Emissions	Aluminum	4.58E-10	5.58E-11	1.93E-12
	Ammonium/ammonia	4.14E-09	5.05E-10	1.75E-11
	Heavy Metals	2.17E-08	2.65E-09	9.18E-11
	Nitrate	1.56E-09	1.90E-10	6.59E-12
	Nitrogen	9.29E-13	1.13E-13	3.92E-15
	Phosphate	1.21E-11	1.48E-12	5.12E-14
	Phosphorus	2.85E-10	3.48E-11	1.21E-12
Water	Water Withdrawal (L)	1.56E-02	1.91E-03	6.60E-05
	Water Consumption (L)	1.46E-02	1.78E-03	6.17E-05
Land Use	Land Transformation (m^2)	0.00E+00	0.00E+00	0.00E+00

Table 7: Energy Conversion Facility Inventory

Life Cycle Inventory (kg/kg)		Ethanol								
		Lignocellulosic Combustion		Lignocellulosic Gasification		Gasification		Dry Milling	Adv. Dry Milling	Adv. Dry Milling with CCS
		Corn Stover	Switch - grass	Corn Stover	Switch - grass	Corn Stover	Switch - grass	Corn Grain	Corn Grain	Corn Grain
Air Emissions	Carbon Dioxide	2.98E+00	2.98E+00	1.37E-01	1.37E-01	4.20E+00	4.20E+00	1.81E+00	2.73E+00	2.15E+00
	Methane	-5.67E-04	-5.67E-04	-1.64E-03	-1.64E-03	1.98E-04	1.98E-04	5.20E-03	2.26E-03	1.46E-03
	Nitrous Oxide	5.44E-05	5.44E-05	4.18E-05	4.18E-05	6.97E-05	6.97E-05	1.23E-05	6.74E-05	6.92E-05
	Total GWP	2.98E+00	2.98E+00	1.09E-01	1.09E-01	4.23E+00	4.23E+00	1.95E+00	2.80E+00	2.21E+00
	Nitrogen Oxides	-2.78E-04	-2.78E-04	-9.36E-04	-9.36E-04	1.34E-04	1.34E-04	2.78E-03	6.44E-04	1.62E-03
	Sulfur Dioxide	5.11E-04	5.11E-04	-1.79E-03	-1.79E-03	1.02E-03	1.02E-03	3.00E-03	3.95E-03	4.45E-03
	Carbon Monoxide	-1.20E-04	-1.20E-04	-8.72E-05	-8.72E-05	9.24E-05	9.24E-05	7.82E-04	1.64E-03	-2.36E-04
	Particulate Matter	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Lead	-1.74E-08	-1.74E-08	-4.80E-08	-4.80E-08	8.10E-09	8.10E-09	1.48E-08	1.50E-07	8.57E-08
	Mercury	-5.60E-09	-5.60E-09	-1.23E-08	-1.23E-08	3.04E-10	3.04E-10	2.48E-09	3.24E-09	5.28E-09
	Ammonia	-3.69E-06	-3.69E-06	-8.99E-06	-8.99E-06	2.63E-05	2.63E-05	2.10E-06	-2.88E-04	-2.88E-04
	Radiation	-2.44E-08	-2.44E-08	-5.06E-08	-5.06E-08	8.56E-12	8.56E-12	9.27E-09	9.94E-09	1.89E-08
	Non Methane VOC	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Solid Waste	Heavy Metals to Soil	4.34E-07	4.34E-07	-1.04E-08	-1.04E-08	2.89E-09	2.89E-09	9.46E-06	6.40E-09	1.33E-08
	Solid Waste	-1.98E-03	-1.98E-03	-4.21E-03	-4.21E-03	8.72E-05	8.72E-05	7.83E-04	9.83E-04	1.68E-03
Water Emissions	Aluminum	-1.98E-06	-1.98E-06	-4.23E-06	-4.23E-06	1.85E-08	1.85E-08	8.20E-07	8.82E-07	1.63E-06
	Ammonium/ammonia	-5.67E-04	-5.67E-04	-1.64E-03	-1.64E-03	1.98E-04	1.98E-04	0.00E+00	0.00E+00	0.00E+00
	Heavy Metals	-3.68E-05	-3.68E-05	-8.49E-05	-8.49E-05	3.41E-06	3.41E-06	2.57E-05	9.08E-01	4.19E-05
	Nitrate	-2.00E-05	-2.00E-05	-5.25E-05	-5.25E-05	9.66E-06	9.66E-06	1.14E-05	1.76E-05	2.63E-05
	Nitrogen	3.03E-10	3.03E-10	1.90E-10	1.90E-10	6.14E-11	6.14E-11	6.21E-06	2.81E-06	4.83E-06
	Phosphate	1.48E-07	1.48E-07	9.18E-08	9.18E-08	1.76E-06	1.76E-06	2.02E-08	8.55E-08	6.93E-08
	Phosphorus	5.26E-08	5.26E-08	2.66E-08	2.66E-08	1.03E-08	1.03E-08	2.93E-06	9.50E-04	2.82E-06
Water	Water Withdrawal (L)	-1.26E+02	-1.26E+02	-3.01E+02	-3.01E+02	8.45E+00	8.45E+00	6.22E+01	-2.62E+02	-2.11E+02
	Water Consumption (L)	-1.55E+00	-1.55E+00	-3.73E+00	-3.73E+00	4.22E+00	4.22E+00	0.00E+00	0.00E+00	0.00E+00
Land Use	Land Transformation (m^2)	2.35E-04	2.35E-04	2.35E-04	2.35E-04	2.35E-04	2.35E-04	2.35E-04	2.35E-04	2.02E-04

Table 7: Energy Conversion Facility Inventory (Continued)

Life Cycle Inventory (kg/kg)		Fischer - Tropsch Diesel						
		CBTL 15% Corn Stover with CCS	CBTL 15% Switchgrass with CCS	CBTL 15% SRWC with CCS	CBTL 30% Corn Stover with CCS	CBTL 30% Switchgrass with CCS	CBTL 30% SRWC with CCS	BTL Corn Stover
Air Emissions	Carbon Dioxide	1.23E-01	7.09E-02	-9.92E-02	-1.00E-01	7.03E-02	-1.00E-01	2.38E-02
	Methane	-2.96E-03	-2.96E-03	-2.96E-03	-2.96E-03	-2.96E-03	-2.96E-03	-2.75E-03
	Nitrous Oxide	-9.69E-07	-9.76E-07	-9.76E-07	-9.76E-07	-9.76E-07	-9.76E-07	-5.29E-07
	Total GWP	4.83E-02	-3.41E-03	-1.74E-01	-1.74E-01	-3.97E-03	-1.74E-01	-4.52E-02
	Nitrogen Oxides	-5.52E-04	-5.53E-04	-6.18E-04	-6.18E-04	-5.53E-04	-6.18E-04	-5.44E-04
	Sulfur Dioxide	1.56E-04	1.03E-04	1.55E-04	1.55E-04	1.03E-04	1.55E-04	-4.91E-04
	Carbon Monoxide	-1.87E-04	-1.88E-04	-1.88E-04	-1.88E-04	-1.88E-04	-1.88E-04	-1.58E-04
	Particulate Matter	3.68E-04	3.67E-04	3.96E-04	3.96E-04	3.67E-04	3.96E-04	4.38E-04
	Lead	1.08E-07	1.08E-07	1.08E-07	1.08E-07	1.08E-07	1.08E-07	1.36E-07
	Mercury	3.31E-08	3.30E-08	5.52E-08	3.15E-08	3.30E-08	5.52E-08	-2.26E-10
	Ammonia	-1.75E-06	-1.75E-06	-1.75E-06	-1.75E-06	-1.75E-06	-1.75E-06	-1.62E-06
	Radiation	-6.19E-10	-6.19E-10	-6.19E-10	-6.19E-10	-6.19E-10	-6.19E-10	-5.77E-10
	Non Methane VOC	-7.41E-04	-7.41E-04	-7.41E-04	-7.41E-04	-7.41E-04	-7.41E-04	-6.90E-04
Solid Waste	Heavy Metals to Soil	2.65E-05	2.64E-05	2.64E-05	2.64E-05	2.64E-05	2.64E-05	3.41E-05
	Solid Waste	-6.28E-05	-6.28E-05	-6.28E-05	-6.28E-05	-6.28E-05	-6.28E-05	-3.08E-05
Water Emissions	Aluminum	-1.91E-05	-1.91E-05	-1.91E-05	-1.91E-05	-1.91E-05	-1.91E-05	-1.78E-05
	Ammonium/ammonia	-4.92E-05	-4.92E-05	-3.91E-05	-3.96E-05	-4.92E-05	-3.91E-05	-1.48E-05
	Heavy Metals	-9.52E-05	-9.53E-05	-9.48E-05	-9.48E-05	-9.53E-05	-9.48E-05	-8.68E-05
	Nitrate	-4.17E-07	-4.17E-07	-4.17E-07	-4.17E-07	-4.17E-07	-4.17E-07	-3.08E-07
	Nitrogen	1.31E-08	1.31E-08	1.31E-08	1.31E-08	1.31E-08	1.31E-08	1.87E-08
	Phosphate	-1.72E-08	-1.72E-08	-1.72E-08	-1.72E-08	-1.72E-08	-1.72E-08	-1.57E-08
	Phosphorus	-1.86E-05	-1.86E-05	-1.86E-05	-1.86E-05	-1.86E-05	-1.86E-05	-1.73E-05
Water	Water Withdrawal (L)	-8.75E+00	-8.75E+00	-8.75E+00	-8.75E+00	-8.75E+00	-8.75E+00	-7.28E+00
	Water Consumption (L)	-6.27E-01	-6.28E-01	-6.28E-01	-6.29E-01	-6.28E-01	-6.28E-01	-5.70E-01
Land Use	Land Transformation (m^2)	1.44E-04	1.44E-04	1.44E-04	1.44E-04	1.44E-04	1.44E-04	1.44E-04

Table 7: Energy Conversion Facility Inventory (Continued)

Life Cycle Inventory (kg/kg)		Fischer - Tropsch Diesel						
		BTL Corn Stover with CCS	CTL I6 Coal with CCS	CTL I6	BTL Switchgrass	BTL Switchgrass with CCS	BTL SRWC	BTL SRWC with CCS
Air Emissions	Carbon Dioxide	7.17E-03	2.81E-02	4.46E+00	6.75E-03	6.74E-03	8.08E-02	8.08E-02
	Methane	-2.95E-03	-3.28E-03	-3.29E-03	-2.95E-03	-2.95E-03	-2.95E-03	-2.95E-03
	Nitrous Oxide	-9.60E-07	-2.87E-06	-2.87E-06	-9.40E-07	-9.65E-07	-9.56E-07	-9.56E-07
	Total GWP	-6.70E-02	-5.48E-02	4.38E+00	-6.73E-02	-6.74E-02	6.67E-03	6.67E-03
	Nitrogen Oxides	-5.91E-04	-7.40E-04	-7.39E-04	-5.88E-04	-5.92E-04	-5.92E-04	-5.92E-04
	Sulfur Dioxide	-5.40E-04	-2.43E-04	-2.40E-04	-5.36E-04	-5.41E-04	-5.41E-04	-5.41E-04
	Carbon Monoxide	-1.84E-04	-2.05E-04	-1.97E-04	-1.74E-04	-1.87E-04	-1.86E-04	-1.86E-04
	Particulate Matter	4.27E-04	3.70E-04	3.80E-04	4.29E-04	4.27E-04	4.27E-04	4.27E-04
	Lead	1.14E-07	1.06E-07	1.26E-07	1.36E-07	1.08E-07	1.08E-07	1.08E-07
	Mercury	-2.69E-10	3.49E-08	3.58E-08	-2.51E-10	-2.71E-10	-2.57E-10	-2.57E-10
	Ammonia	-1.75E-06	-2.19E-06	-2.19E-06	-1.74E-06	-1.75E-06	-1.75E-06	-1.75E-06
	Radiation	-6.18E-10	-6.32E-10	-6.33E-10	-6.18E-10	-6.18E-10	-6.18E-10	-6.18E-10
	Non Methane VOC	-7.40E-04	-7.65E-04	-7.66E-04	-7.40E-04	-7.40E-04	-7.40E-04	-7.40E-04
Solid Waste	Heavy Metals to Soil	2.81E-05	-1.73E-03	-1.72E-03	3.38E-05	2.64E-05	2.65E-05	2.65E-05
	Solid Waste	-5.77E-05	-7.68E-05	-6.12E-05	-4.10E-05	-6.26E-05	-6.26E-05	-6.26E-05
Water Emissions	Aluminum	-1.91E-05	-1.93E-05	-1.93E-05	-1.90E-05	-1.91E-05	-1.91E-05	-1.91E-05
	Ammonium/ammonia	-2.91E-05	-9.98E-05	-9.70E-05	-2.90E-05	-2.92E-05	-2.92E-05	-2.92E-05
	Heavy Metals	-9.41E-05	-1.78E-04	-1.77E-04	-9.38E-05	-9.42E-05	-9.42E-05	-9.42E-05
	Nitrate	-4.02E-07	-6.18E-07	-5.73E-07	-3.53E-07	-4.16E-07	-4.16E-07	-4.16E-07
	Nitrogen	1.43E-08	-1.18E-06	-1.18E-06	1.81E-08	1.31E-08	1.32E-08	1.32E-08
	Phosphate	-1.71E-08	-1.88E-08	-1.87E-08	-1.69E-08	-1.71E-08	-1.71E-08	-1.71E-08
	Phosphorus	-1.86E-05	-1.88E-05	-1.88E-05	-1.86E-05	-1.86E-05	-1.86E-05	-1.86E-05
Water	Water Withdrawal (L)	-8.58E+00	-1.05E+01	-1.01E+01	-8.05E+00	-8.73E+00	-8.73E+00	-8.73E+00
	Water Consumption (L)	-6.25E-01	-1.93E+00	-1.92E+00	-6.15E-01	-6.27E-01	-6.25E-01	-6.25E-01
Land Use	Land Transformation (m^2)	1.44E-04	3.36E-05	3.36E-05	1.44E-04	1.44E-04	1.44E-04	1.44E-04

Table 7: Energy Conversion Facility Inventory (Continued)

Life Cycle Inventory (kg/kg)		Petroleum		
		Diesel	Gasoline	Kerosene/ Jet Fuel
Air Emissions	Carbon Dioxide	3.75E-01	3.89E-01	2.36E-01
	Methane	4.59E-04	4.74E-04	2.89E-04
	Nitrous Oxide	6.00E-06	6.52E-06	3.79E-06
	Total GWP	3.88E-01	4.03E-01	2.45E-01
	Nitrogen Oxides	2.84E-04	2.91E-04	1.79E-04
	Sulfur Dioxide	3.60E-04	3.95E-04	2.28E-04
	Carbon Monoxide	1.59E-04	1.68E-04	1.00E-04
	Particulate Matter	9.24E-06	9.50E-06	5.83E-06
	Lead	1.59E-08	1.51E-08	9.96E-09
	Mercury	5.37E-10	5.83E-10	3.39E-10
	Ammonia	3.76E-06	4.11E-06	2.37E-06
	Radiation	2.18E-09	2.41E-09	1.38E-09
	Non Methane VOC	1.64E-04	1.77E-04	1.04E-04
Solid Waste	Heavy Metals to Soil	-4.89E-09	4.25E-09	-2.75E-09
	Solid Waste	1.15E-04	1.23E-04	7.23E-05
Water Emissions	Aluminum	6.47E-07	7.34E-07	6.05E-07
	Ammonium/ammonia	0.00E+00	0.00E+00	0.00E+00
	Heavy Metals	9.25E-06	1.03E-05	6.71E-06
	Nitrate	1.77E-06	1.87E-06	1.12E-06
	Nitrogen	9.98E-12	1.43E-11	6.43E-12
	Phosphate	1.15E-08	1.16E-08	7.25E-09
	Phosphorus	4.48E-07	5.14E-07	4.70E-07
Water	Water Withdrawal (L)	1.92E+01	2.09E+01	1.27E+01
	Water Consumption (L)	1.78E+00	1.99E+00	1.74E+00
Land Use	Land Transformation (m^2)	0.00E+00	0.00E+00	0.00E+00

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