ARB CA-GREET 1.8b Interface Version 1.2 Tool
User Manual
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(Developed by Life Cycle Associates, LLC for the Air Resources Board)

1 GREET User Interface Introduction

1.1 Purpose

The ARB CA-GREET 1.8b User Interface Tool provides a means to conduct Well-to-Wheel (WTW) analysis of transportation fuels using the GREET model developed by Argonne National Laboratory. The interface tool organizes input values and assumptions for each fuel pathway on a single, user-friendly worksheet and then inputs them into the CA-GREET 1.8b model to calculate fuel cycle energy and emission results..

1.2 Tool Features

The CA-GREET 1.8b Interface Tool was developed to make the CA-GREET 1.8b model accessible to interested stakeholders in an easy-to-use, transparent format. The Interface Tool enables the user to:

- Externally control CA-GREET 1.8b quickly and easily even with limited familiarity with the CA-GREET 1.8b model.
- Modify CA-GREET 1.8b with confidence that the user will insert parameters in the appropriate cells in the Excel spreadsheet.
- Review fuel pathway inputs in an organized format.
- Model different feedstock and fuel production electricity mixes (The original CA-GREET 1.8b alone allows only one electricity mix to be input for an entire fuel pathway).
- Specify biofuel blending more accurately (The original CA-GREET 1.8b model applied the same process and transport assumptions to ethanol denaturant and gasoline)
- Specify feedstock and fuel transport modes with greater detail and accuracy then in the original CA-GREET 1.8b.
- Determine model sensitivity to key inputs quickly and easily.
- Determine WTW results for blended fuels in a transparent manner for all blending levels.
- Use the Interface Tool with future versions of CA-GREET 1.8b with limited effort to update the tool.

1.3 Tool Function

An Excel workbook with macros operates externally to the CA-GREET 1.8b model workbook and controls the CA-GREET 1.8b model. The interface is currently configured to run the CA-GREET 1.8b model for the following blendstocks and finished fuels:

- California Reformulated Gasoline Blendstock for Oxygenate Blending (CARBOB);
- Corn ethanol (anhydrous and denatured), denatured with (CARBOB or conventional gasoline);
- California Reformulated Gasoline (CaRFG);
- Ultra-Low Sulfur Diesel (ULSD);
- Biodiesel and Renewable Diesel;
- Compressed natural gas (CNG) and;
- Electricity.

Additional pathways will be added in the future. Each fuel/energy input sheet organizes the key fuel pathway input parameters chronologically along the pathway, from the start of the fuel pathway at the top (fossil fuel extraction, crop farming, etc.) to the fueling station and tailpipe emissions at the bottom. The sheets include inputs for both the Well-to-Tank (WTT) and the Tank-to-Wheel (TTW) components of a fuel pathway. In the TTW section, the user can input the vehicle energy consumption and methane (CH_4) and nitrous oxide (N_2O) vehicle emission rates. The fossil carbon in fuel is considered separately (see Section 2.6), assuming all carbon in fuel is oxidized; the fraction of vehicle methane emissions (in g CO_2/mmBtu fuel) associated with fossil carbon in the fuel are subtracted from fossil carbon in fuel to avoid double counting of these carbon emissions. WTW energy use is reported as Btu/mmBtu of finished fuel. WTW emissions are presented in gCO_2e/mmBtu and gCO_2e/MJ.

For pathways such as CaRFG which utilizes as blendstocks, CARBOB and denatured ethanol, the tool allows the user to first start with CARBOB, next by modeling corn ethanol, then utilizing either CARBOB or default gasoline as the denaturant (in a specific amount). The CaRFG sheet allows the user to define a mix based on either a volume based denatured ethanol or an oxygenate percent based denatured ethanol mix. A similar approach is used for biodiesel when blended with ULSD to generate various levels of BD finished fuels.

The interface tool also allows for more detailed specification of regional specific inputs than the CA-GREET 1.8b model alone. For example, parameters such as electricity resource mixes can be varied for the feedstock production and fuel refining steps.

2 Getting Started

2.1 Opening the Excel Files and Enabling Macros

First open the GREET 1.8b Excel file named “CA_GREET 1.8b_07152008.xls”, click “Enable Macros” and then click “Yes,” when it asks if you wish to continue. Next, double click (or open) the CA-GREET 1.8b interface tool and click “Enable Macros”. It is important that you open up the CA-GREET 1.8b model prior to opening the Interface Tool. You are now ready to begin running GREET simulations.

2.2 Overview of Interface Tabs

The workbook is organized as separate input sheets for fuel pathways (sheets “CARBOB, “Corn EtOH”, “Denaturant”, “ULSD”, “BD”, “CNG” and “Electricity”) and two sheets that calculate blended fuel results (“RFG” and “BD Blends”). A “Settings” sheet correctly formats user inputs and contains instructions for macros to insert the parameters throughout the GREET model and the “Defaults” sheet contains the average default inputs to restore input sheets to their original values.

2.3 Determine the Order for Fuel Pathway Simulations

Click on the “Intro Tab”, decide which fuel pathway you want to model and consult the table on this sheet to determine the order to simulate pathways. The order for simulating fuel pathways is important because fuel pathways rely on other fuel inputs; for example, nearly all fuels use diesel for transport or production. It is therefore desirable to execute the diesel pathway prior to executing any of the other pathways, if diesel is used as a fuel in that pathway. The table shown in the “Intro” tab indicates which pathways to run and the order to simulate them (1 = first). Note that the order of simulations shown in this table is only a suggestion if the user wishes to modify several fuel pathways and/or parameterize pathways with regional specific parameters; if only one pathway is simulated, the process fuel inputs in that pathway will be based on CA-GREET 1.8b default values. The “Defaults” tab lists all the default values.

The Interface Tool can be used to determine the sensitivity of fuel pathway results to changes in the key inputs values of other fuel pathways. For example, a user might vary transportation distances to see the impact on the final emissions for a given fuel pathway. Electricity mixes can be set to user-defined and changed to reflect a marginal mix to calculate the impact of marginal electricity mix on the emissions for any given fuel pathway.

2.4 Input User Parameters in Fuel Input Sheet

There are three types of cells in the Interface Tool: input cells (yellow), pull-down menus of scenario options (light blue) and calculation cells (see Figure 1 below). *Only the yellow and light blue cells should be changed*; the calculation cells consist of percentage shares determined by difference of yellow input shares and unit transformations necessary to transform certain user inputs into CA-GREET 1.8b-appropriate units. This latter category of white cells is organized in a column to the right of the results table (discussed below) labeled "Inputs into CA-GREET 1.8b", and shows the actual inputs into the CA-GREET 1.8b model for user inputs with different units than CA-GREET 1.8b. The interface tool allows several more transportation mode options for crude oil transport (which impacts CARBOB, denaturant and ULSD) than the standard CA-GREET 1.8b model and these input sheets have two columns of direct input parameters to combine crude transport inputs into a single input for use in CA-GREET 1.8b. The Interface tool was designed to use units familiar to model users and unit transformations are necessary when the choice of units differs from the CA-GREET 1.8b methodology.

Review the default inputs and make the necessary changes in input values by entering values in the yellow input cells and selecting the desired scenarios in the light blue input cells (pull-down menus) using your mouse.

Color-coding for input cells

Dry mill	Option selection (click in cell for pulldown menu)
33,500	User input
1.00	Calculated value

Figure 1. The three types of cells in the CA-GREET 1.8b Interface Tool. The light blue cells are pull-down menus of scenario options, the yellow cells are direct inputs where the user types values and the white cells are calculation cells, not to be modified by the user.

2.5 Calculating Fuel Cycle Energy and Emissions

After you have reviewed the fuel pathway inputs, click on the button labeled "Insert User Inputs in GREET." This button triggers a macro that inserts the user inputs into CA-GREET 1.8b, runs the model and extracts the appropriate results. The results are presented in the same input sheet, to the right of the inputs at the top.

2.5.1 CARBOB, Corn Ethanol, Denaturant and RFG

When running CARBOB, corn ethanol, or denaturant, the macro invoked by clicking “Insert User Inputs in GREET” will also copy the results for the active blendstock into the “RFG” sheet. Once all three have been calculated, the RFG sheet acts as a “fuel blender” by calculating the energy and emission results for any user input blending level, using the energy shares of the three RFG components. The “Corn EtOH” sheet blends the anhydrous corn ethanol result from CA-GREET 1.8b with the denaturant results from the “Denaturant” input sheet to yield denatured ethanol results in addition to the anhydrous results (see Figure 2).

2.5.2 ULSD, BD and BD Blends

Similarly, the Interface tool copies the results for ULSD and BD/RD into the BD/RD blends sheet when the user runs these fuel pathways. The BD Blends sheet blends ULSD energy and emission results with BD/RD results on an energy basis for the user input blending level.

2.5.3 CNG and Electricity

CNG and electricity are modeled as finished fuels and the results are shown in the input sheets. The CNG input sheet allows the user to input one electricity mix for Natural Gas (NG) recovery and processing and a different mix for NG compression. The electricity input sheet contains fuel shares and generation technology share inputs for electricity generated from residual oil, natural gas, coal, biomass and renewables and energy intensity and electricity use inputs for nuclear generation technologies.

2.6 Results

The results presented in the input sheets and fuel “blending” sheets are based on the CA-GREET 1.8b calculated feedstock and fuel results. The feedstock numbers include feedstock extraction or production and transport and the fuel results include fuel production and fuel transport and distribution (T&D); energy values are presented as Btu/mmBtu fuel and emission results are in gCO_2e/mmBtu (also presented as gCO2e/MJ). Figure 2 below shows result table on the “Corn EtOH” input sheet, which illustrates the feedstock and fuel (bottom two tables in figure) results from CA-GREET 1.8b. The next paragraph describes the upper table of results in the figure.

Results	Anhydrous EtOH	Denatured EtOH	Denaturant	
	100%	95.24%	4.76%	Volume %
Anhydrous EtOH (E100)	100%	93.09%	6.91%	Energy %
WTT Energy (Btu/mmBtu)	1,538,639	1,447,449	218,254	
CH_4 (g/mmBtu)	130.346	128.644	105.697	
N_2O (g/mmBtu)	49.291	45.907	0.292	
CO_2 (g/mmBtu)	59,766	56,842	17,422	
GHGs (g/mmBtu)	77,713	73,738	20,151	
Fossil Carbon Content of Fuel (g/mmBtu)	0	5,317	76,982	
Total WTT + Carbon in Fuel (g/mmBtu)	77,713	79,055	97,133	
Total WTT + Carbon in Fuel (g/MJ)	**73.7**	**74.9**	**92.1**	

Ethanol

WTT energy (Btu/mmBtu)	1,272,212
CH_4 (g/mmBtu)	96.667
N_2O (g/mmBtu)	0.672
CO_2 (g/mmBtu)	37,639

Feedstock Loss Factor 1.001

WTT energy (Btu/mmBtu)	265,651
CH_4 (g/mmBtu)	33.613
N_2O (g/mmBtu)	48.594
CO_2 (g/mmBtu)	22,096

Figure 2. Results table from the "Corn EtOH" tab, illustrating the feedstock (corn) and fuel (ethanol) results and the combined results in the above table labeled "Anhydrous EtOH". The results labeled "Denatured EtOH" corresponds to anhydrous ethanol blended with the input (4.76% in figure) percentage of denaturant.

2.6.1 Fuel Cycle Calculation

The Interface calculates WTW emissions as follows:
WTW (g/MJ) = WTT results + fossil carbon in fuel (g/MJ) + vehicle CH_4 and N_2O emissions (g/MJ)

Fossil carbon in fuel refers to the portion of the C in fuel that originates from a fossil source, expressed as fully oxidized (CO_2); vehicle CH_4 emissions originating from fossil-derived carbon is subtracted from the fossil carbon in fuel. Fossil carbon in fuel accounts for the vast majority of TTW emissions for conventional fuels; biogenic C in the fuel is ignored (assigned zero) because it originates from the atmosphere so the net effect is neutral. Vehicle emissions of methane and nitrous oxide are expressed as g/mmBtu by dividing the vehicle emission rate of each in g/mi by the vehicle energy use (mmBtu/mi). At the bottom of the results table, the WTW emission results are converted to gCO_2e/MJ, the preferred units for calculating the carbon intensities of the various transportation fuels.

2.7 How to Start Over

To restore an input sheet in the Interface Tool to its default values, simply click "Restore Average Values" button and the input sheet will return to the original default parameter values. If a problem or error does arise, simply close the tool and the GREET model and start over with a fresh version of CA-GREET 1.8b. Do not save any work if you wish to start with the original ARB provided CA-GREET 1.8b model.

3 The Settings Sheet

The user interested in viewing all of the direct CA-GREET 1.8b inputs in one place and where they are inserted in GREET is referred to the Settings sheet in the workbook. The "Settings" Sheet contains the name of the CA-GREET 1.8b file the Interface Tool modifies, a column of all of the direct inputs (in correct units) into CA-GREET 1.8b and the corresponding sheet name and cell address for each input parameter. The sheet lists the corresponding units, fuel pathway category (i.e., feedstock production) and a description of the input parameter. Macros within the workbook insert the selected set of fuel pathway inputs (determined when a user clicks "Insert User Inputs in GREET") in the correct fields in CA-GREET 1.8b, based on the cell addresses in the columns the left of the input parameter column.

4 The Defaults Sheet

The "Defaults" Sheet provides the initial values for the CA-GREET 1.8b model that represent an estimate of average values for California. These values are not intended to represent bounding defaults that would be used in a regulatory context for producer calculations. Regulatory defaults may be adjusted to allow regulated entities to select regulatory defaults without determining all of the process parameters. The user should not make any changes to the "Defaults" sheet, but rather use it as a reference for default parameters. Note that clicking "Restore Average Values" in any input sheet will populate that input sheet with the default parameters from the "Defaults" sheet.