

Name:

Date:

Class:

## Alternative fuel: Ethanol – Answer Key

**Instructions:** Read this webpage ([https://afdc.energy.gov/vehicles/flexible\\_fuel\\_emissions.html](https://afdc.energy.gov/vehicles/flexible_fuel_emissions.html)) and then answer the questions below.

### Ethanol Vehicle Emissions:

How is ethanol used? By itself or mixed with other substances?

It is blended with gasoline.

### Life Cycle Emissions:

What is a life cycle analysis?

Life cycle analysis is used to assess the environmental impacts of all stages of a product's life, including raw material extraction, processing, manufacturing, distribution, use, and disposal or recycling. When comparing fuels, a life cycle analysis may focus on particular portions of a fuel's life cycle, such as from extraction-to-use, also referred to as well-to-wheels, to determine the merits or problems associated with each fuel.

What are the greenhouse gas (GHG) emissions?

Carbon dioxide (CO<sub>2</sub>)

How can the carbon dioxide emission be offset?

Carbon dioxide (CO<sub>2</sub>) released when ethanol is used in vehicles is offset by the CO<sub>2</sub> captured when crops used to make the ethanol are grown. A 2020 analysis by Argonne National Laboratory(PDF) found that using corn-based ethanol in place of gasoline reduces life cycle GHG emissions on average by 40%.

How does the emission with ethanol compare to the emission with gasoline?

A 2012 study by Argonne National Laboratory found that when fuel life cycles are considered, average emissions reductions of cellulosic ethanol compared to conventional gasoline range from 88% to 108% depending on feedstocks used.

### Evaporative and Tailpipe Emissions:

What are the emissions of primary concern?

E85 decreases the emissions of CO<sub>2</sub>, as well as the emissions of many harmful toxics, such as benzene—a known carcinogen. However, it increases acetaldehyde emissions, which the National Institutes of Health describe as "reasonably anticipated to be a human carcinogen" and is moderately reactive for ground level ozone formation.

Use the GREET excel database to complete the chart below:

1. Open this link: [https://greet.es.anl.gov/greet\\_1\\_series](https://greet.es.anl.gov/greet_1_series)

Name:

Date:

Class:

2. Click the link underneath “GREET 1 Series (Fuel-Cycle Model) or this link [GREET\\_2020rev1.zip](#)
3. Open the GREET folder
4. Select “GREET1-2020”

The screenshot displays the GREET software interface. On the left, there is a text area containing copyright and license information. On the right, there is a navigation menu with various options. A red circle highlights the 'Electric' tab in the bottom navigation bar, and a red arrow points to it from the text below.

**COPYRIGHT NOTIFICATION**

**GREET® SOFTWARE**

**GREET1 MODEL**

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1. Redistributions of the GREET software must retain the above copyright notice, this list of conditions and the following disclaimer. Modification or reverse compilation of the source code is not permitted.

Navigation menu options: Inputs, Results, Petroleum, Ethanol, Natural Gas, MeOH & FTD, RNG, Electric, Hydrogen, BioOil, Pyrolysis & IDL, Integrated Biorefinery, Fuel Production Time Series, Emission Factors Time Series, Agricultural and Mining Machineries Emission Factors Time Series, Water Consumption Factors, Passenger Car Time Series, Light Duty Truck 1 Time Series, Light Duty Truck 2 Time Series, Fuel Specifications, Vehicles, Ag Inputs.

Bottom navigation bar: Inputs, Results, Petroleum, NG, MeOH\_FTD, EtOH, Electric, Hydrogen, BioOil, Algae, RNG, Pyrolysis\_IDL, IBR, PTF, E\_fuel, Fuel\_Prod\_TS

5. To use the GREET database, you have to click on the tab at the bottom of the screen. Ethanol is abbreviated EtOH, so click the “EtOH” tab. The red arrow above is pointing to it.
6. There is a lot of information on this database. Scroll all the way down to 4) Summary of Energy Consumption, Water Consumption, and Emissions. The data you are looking for is listed in table 4.1. This table tells you the energy consumption, water consumption, and total emissions for the use of ethanol fuel.
7. Because we are interested in reducing carbon emissions and climate change, you will be looking at the values for methane (CH<sub>4</sub>), carbon dioxide (CO<sub>2</sub>), and nitrous oxide (N<sub>2</sub>O). There are other variables in this chart, but we will focus just on these three. There is a red box around them in the table below.

Name:

Date:

Class:

4) Summary of Energy Consumption, Water Consumption, and Total Emissions  
 4.1) Energy Consumption, Water Consumption, and Total Emissions

	Combined		Poplar Ethanol: Fermentation		Poplar Ethanol: Gasification		Poplar Ethanol: Combined		Switchgrass Ethanol: Fermentation		Switchgrass Ethanol: Gasification
	Ethanol	Poplar	Ethanol	Poplar	Ethanol	Poplar	Ethanol	Poplar	Ethanol	Poplar	Switchgrass
Loss factor	1.001		1.001		1.001		1.001		1.001		1.001
Total energy	1,438,540	99,541	1,520,732	102,063	1,550,085	99,541	1,520,732	673,685	1,406,994		62
Fossil fuels	-42,891	98,539	-42,891	101,035	29,174	98,539	-42,891	95,281	1,471		8
Coal	-58,941	1,741	-58,941	1,785	2,753	1,741	-58,941	3,991	-53,309		5
Natural gas	-7,767	26,365	-7,767	27,033	9,263	26,365	-7,767	54,730	29,396		3
Petroleum	23,817	70,432	23,817	72,216	17,158	70,432	23,817	36,560	25,384		1
Water consumption	117,779	4,475	117,779	4,588	35,952	4,475	117,779	9,882	150,380		1
VOC	34,368	4,925	34,390	5,050	21,449	4,925	34,390	6,439	35,934		1
CO	155,480	20,892	155,820	21,421	19,829	20,892	155,820	12,316	157,046		1
NOx	232,113	51,924	234,347	53,239	123,650	51,924	234,347	34,448	225,493		1
PM10	12,946	2,904	12,996	2,978	3,090	2,904	12,996	2,283	13,051		1
PM2.5	3,948	2,631	3,993	2,698	2,621	2,631	3,993	1,873	3,990		1
SOx	212,699	12,104	174,928	12,410	41,433	12,104	174,928	37,915	278,209		1
BC	0.364	1.618	0.370	1.659	0.402	1.618	0.370	0.467	0.360		1
CH4	0.768	0.514	0.783	0.527	0.950	0.514	0.783	0.316	0.766		1
N2O	4.309	10.084	4.674	10.340	20.044	10.084	4.674	11.941	8.551		1
CO2	10.805	7.026	11.031	7.204	10.538	7.026	11.031	19.882	11.928		1
CO2 (w/ C in VOC & CO)	-3,779	8,152	-3,781	8,358	2,090	8,152	-3,781	3,699	-808		1
GHG	-3,428	8,200	-3,429	8,408	2,188	8,200	-3,429	3,738	-449		1
GHG	-435	10,364	-365	10,627	5,582	10,364	-365	9,365	2,969		1
<b>4.2) Urban Emissions</b>											
Urban VOC	13.312	0.227	13.312	0.233	13.348	0.227	13.312	0.154	13.349		1
Urban CO	-0.352	0.275	-0.352	0.262	0.310	0.275	-0.352	0.318	-0.194		1
Urban NOx	-0.152	0.599	-0.152	0.615	1.269	0.599	-0.152	0.779	0.144		1
Urban PM10	-0.133	0.051	-0.133	0.052	0.051	0.051	-0.133	0.053	-0.112		1
Urban PM2.5	-0.092	0.041	-0.092	0.042	0.043	0.041	-0.092	0.043	0.077		1
Urban SOx	-5.931	0.261	-5.931	0.267	0.262	0.261	-5.931	0.535	-5.399		1
Urban BC	-0.004	0.005	-0.004	0.005	0.004	0.005	-0.004	0.005	-0.003		1
Urban OC	0.002	0.009	0.002	0.009	0.023	0.009	0.002	0.012	0.006		1

Navigation: Overview | Inputs | Results | Petroleum | NG | MeOH\_FTD | **EtOH** | Electric | Hydrogen | BioOil | Algae | RNG | Pyrolysis\_IDL | IBR | FI

8. There are many different plants that are used to make ethanol. Look through the data table and find the type of ethanol that you think is best in regards to the amount of CO<sub>2</sub>, N<sub>2</sub>O, CH<sub>4</sub> in the emissions. To move through the data table, use the arrow that has the red circle around it in the picture above. Record the data in the table below. This is what you will share when the group comes back together. (there are extra lines in the data table, you can use them if it is helpful to record information while trying to determine which version of ethanol you want to use - circle the one that you will share)

Gas emission	Ethanol type					
CH <sub>4</sub>						
N <sub>2</sub> O						
CO <sub>2</sub>						

The abbreviations in GREET are defined below:

VOC = volatile organic compounds

CO = carbon monoxide

NO<sub>x</sub> = nitric oxide

PM10 = particulate matter with a diameter of 10 micrometers or less

PM2.5 = particulate matter with a diameter of 2.3 micrometers or less

Name:

Date:

Class:

SO<sub>x</sub> = sulfur oxides

BC = black carbon (particulate matter/ soot & contributes to climate change)

OC = organic carbon (respiratory effects)

CH<sub>4</sub> = methane

N<sub>2</sub>O = nitrous oxide

CO<sub>2</sub> = carbon dioxide

9. Fill in the row below for ethanol.
10. When everyone is finished learning about the energy sources, share what you have learned with the group. Each individual should summarize the questions they answered and share the GREET emissions that were calculated. Notes should be taken in the table below so that the information can be shared with your poster group.
11. Highlight the energy source you will use to heat your building (remember that we are assuming that the technology for this will be in place) and complete the information below the table.

Energy Source	Information about energy source	GREET values
Ethanol		
Electric		
Biodiesel		
Natural Gas		
Propane		
Hydrogen		

Type of fuel that will be recommended for use in heating your building structure:

Evidence and reasoning for this recommendation:

12. Return to the "Energy Source" document and continue to step 2.