

Name:

Date:

Class:

Alternative fuel: Hydrogen

Instructions: Read this webpage (https://afdc.energy.gov/fuels/hydrogen_benefits.html) and then answer the questions below.

Hydrogen Benefits and Considerations:

Why is hydrogen a good choice for alternative fuel?

Energy security:

How does hydrogen increase our country's energy security?

Public Health and Environment:

What are the environmental and health benefits of using hydrogen as an energy source?

Fuel Storage:

What makes storing hydrogen a challenge?

Use the GREET excel database to complete the chart below:

1. Open this link: https://greet.es.anl.gov/greet_1_series
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"

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COPYRIGHT NOTIFICATION

GREET® SOFTWARE

GREET1 MODEL

Email contact: greet@anl.gov

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Navigation tabs: 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

- To use the GREET database, you have to click on the “Hydrogen” tab at the bottom of the screen. The red arrow above is pointing to it.
- 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 **what are the units? Each gallon of ethanol? (it says Btu or Gallons or Grams per mmBtu of fuel)**
- Because we are interested in reducing carbon emissions and climate change, you will be looking at the values for methane (CH₄), carbon dioxide (CO₂), and nitrous oxide (N₂O). 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.

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4) Summary of Energy Consumption, Water Consumption, and Emissions: Btu or Gallons or Grams per mmBtu of H2 Throughput at Each Stage

4.1) Energy Use, Water Consumption, and Total Emissions

| | Central Plants: NG or FG to Gaseous Hydrogen | | Central Plants: Solar Energy to Gaseous Hydrogen | | Central Plants: Nuclear to Gaseous Hydrogen | | Central Plants: Electrolysis (HTGR) to Gaseous Hydrogen | | Central Plants: Coal to Gaseous Hydrogen | |
|------------------------|--|---------|--|---------|---|---------|---|---------|--|-------|
| | Feedstock | Fuel | Feedstock | Fuel | Feedstock | Fuel | Feedstock | Fuel | Feedstock | Fuel |
| Loss factor | | 0.827 | | 1.000 | | 1.000 | | 1.000 | | 1.000 |
| Total energy | 72,763 | 517,183 | 1,388,889 | 278,955 | 1,031,282 | 278,955 | 1,289,102 | 278,955 | 20,110 | 90 |
| Fossil fuels | 72,240 | 459,167 | 0 | 221,140 | 26,245 | 221,140 | 32,806 | 221,140 | 19,244 | 84 |
| Coal | 910 | 100,915 | 0 | 100,566 | 8,781 | 100,566 | 10,951 | 100,566 | 2,138 | 71 |
| Natural gas | 67,403 | 352,823 | 0 | 116,652 | 14,933 | 116,652 | 18,666 | 116,652 | 3,240 | 12 |
| Petroleum | 3,927 | 5,429 | 0 | 3,922 | 2,551 | 3,922 | 3,189 | 3,922 | 13,866 | 1 |
| Water consumption | 3.034 | 48.186 | 25.500 | 25.919 | 169.005 | 25.919 | 202.243 | 25.919 | 3.891 | 10 |
| VOC | 7.001 | 6.485 | 0.000 | 2.045 | 0.814 | 2.045 | 1.018 | 2.045 | 7.427 | |
| CO | 15.027 | 11.138 | 0.000 | 6.897 | 3.355 | 6.897 | 4.194 | 6.897 | 2.676 | 1 |
| NOx | 19.936 | 21.069 | 0.000 | 12.641 | 4.430 | 12.641 | 5.537 | 12.641 | 12.033 | 2 |
| PM10 | 0.430 | 4.521 | 0.000 | 2.060 | 0.278 | 2.060 | 0.348 | 2.060 | 8.745 | |
| PM2.5 | 0.386 | 3.317 | 0.000 | 0.917 | 0.167 | 0.917 | 0.209 | 0.917 | 1.407 | |
| SOx | 11.106 | 31.870 | 0.000 | 27.577 | 2.461 | 27.577 | 3.077 | 27.577 | 6.851 | 4 |
| BC | 0.130 | 0.353 | 0.000 | 0.081 | 0.038 | 0.081 | 0.048 | 0.081 | 0.085 | |
| OC | 0.135 | 0.819 | 0.000 | 0.191 | 0.042 | 0.191 | 0.053 | 0.191 | 0.234 | |
| CH4 | 103.358 | 68.951 | 0.000 | 28.884 | 4.178 | 28.884 | 5.223 | 28.884 | 147.503 | 11 |
| N2O | 0.234 | 0.647 | 0.000 | 0.270 | 0.032 | 0.270 | 0.040 | 0.270 | 0.029 | |
| CO2 | 4,700 | 91,052 | 0 | 17,346 | 1,962 | 17,346 | 2,452 | 17,346 | 1,504 | 16 |
| CO2 (w/ C in VOC & CO) | 4,745 | 91,090 | 0 | 17,363 | 1,970 | 17,363 | 2,462 | 17,363 | 1,531 | 16 |
| GHGs | 7,908 | 93,330 | 0 | 18,301 | 2,103 | 18,301 | 2,629 | 18,301 | 5,964 | 16 |

4.2) Urban Emissions: Grams per mmBtu of H2 Throughput at Each Stage

| Loss factor | Central Plants: NG or FG to Gaseous Hydrogen | Central Plants: Solar Energy to Gaseous Hydrogen | Central Plants: Nuclear to Gaseous Hydrogen | Central Plants: Electrolysis (HTGR) to Gaseous Hydrogen | Central Plants: Coal to Gaseous Hydrogen |
|-------------|--|--|---|---|--|
| VOC | 0.155 | 0.654 | 0.000 | 0.156 | 0.041 |
| CO | 0.541 | 1.115 | 0.000 | 1.289 | 0.041 |
| NOx | 0.675 | 3.242 | 0.000 | 2.789 | 0.079 |
| PM10 | 0.009 | 0.884 | 0.000 | 0.307 | 0.011 |
| PM2.5 | 0.008 | 0.796 | 0.000 | 0.230 | 0.009 |
| SOx | 0.198 | 9.636 | 0.000 | 9.552 | 0.153 |
| BC | 0.002 | 0.072 | 0.000 | 0.016 | 0.001 |
| OC | 0.002 | 0.187 | 0.000 | 0.042 | 0.002 |

Energy Consumption, Water Consumption, and Emissions from Material Production for Hydrogen Pathways

| Energy: Btu/kg of material throughput, except as noted | Ammonia | NaOH | Sulfuric Acid | Glucose | Corn Steep Liquor | Diammonium Phosph |
|--|------------|------------|---------------|------------|-------------------|-------------------|
| Total energy | 39,928,888 | 30,197,314 | 564,107 | 32,348,490 | 95,132,605 | 24,190,452 |

8. There are many different ways to make hydrogen. Look at the first 4 columns in the data table (for Fuel, not Feedstock) and find the type of hydrogen formation that you think is best in regards to the amount of CO2, N2O, CH4 in the emissions. Record the type of hydrogen formation in the first row and the emissions data in the rows below. If you would like to move through the data table and investigate other ways of making hydrogen, use the arrow that has the red circle around it in the picture above.

| Central Plants: | |
|------------------|----------------------------------|
| Type of emission | Total amount of emission for LPG |
| CH4 | |
| N2O | |
| CO2 | |

The abbreviations in GREET are defined below. We are focusing on the highlighted gases:
 VOC = volatile organic compounds
 CO = carbon monoxide
 NOx = nitric oxide

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

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

SO_x = sulfur oxides

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

OC = organic carbon (respiratory effects)

CH₄ = methane

N₂O = nitrous oxide

CO₂ = carbon dioxide

9. Fill in the row below for hydrogen.
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. Circle 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.