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Alternative fuel: Hydrogen Answer Key

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?

Hydrogen can be made with near-zero greenhouse gas emissions.

Energy security:
How does hydrogen increase our country's energy security?

Hydrogen can be produced in the U.S.

Public Health and Environment:
What are the environmental and health benefits of using hydrogen as an energy source?

Vehicles powered by hydrogen do not produce any harmful substances, only water and warm air.

Fuel Storage:
What makes storing hydrogen a challenge?

Hydrogen's energy content by volume is low so high pressure and low temperatures are required to store it.

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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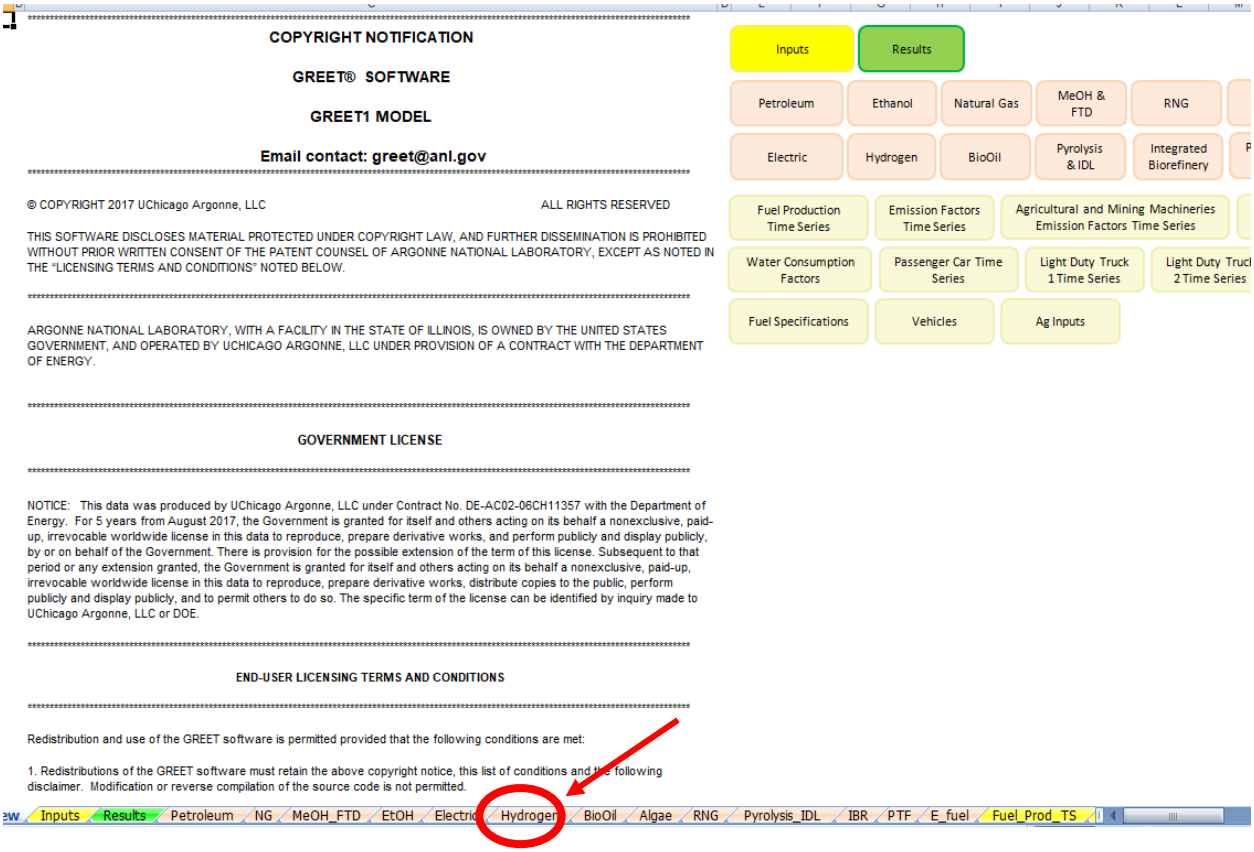

5. To use the GREET database, you have to click on the "Hydrogen" tab at the bottom of the screen. The red arrow above is pointing to it.
6. There is a lot of information on this database. Scroll all the way down to 4) Summary of Energy Consumption, Water Consumption, and Emissions. The data you are looking for is listed in table 4.1. This table tells you the energy consumption, water consumption, and total emissions for what are the units? Each gallon of ethanol? (it says Btu or Gallons or Grams per mmBtu of fuel)
7. Because we are interested in reducing carbon emissions and climate change, you will be looking at the values for methane (CH_4), carbon dioxide (CO_2), and nitrous oxide (N_2O). 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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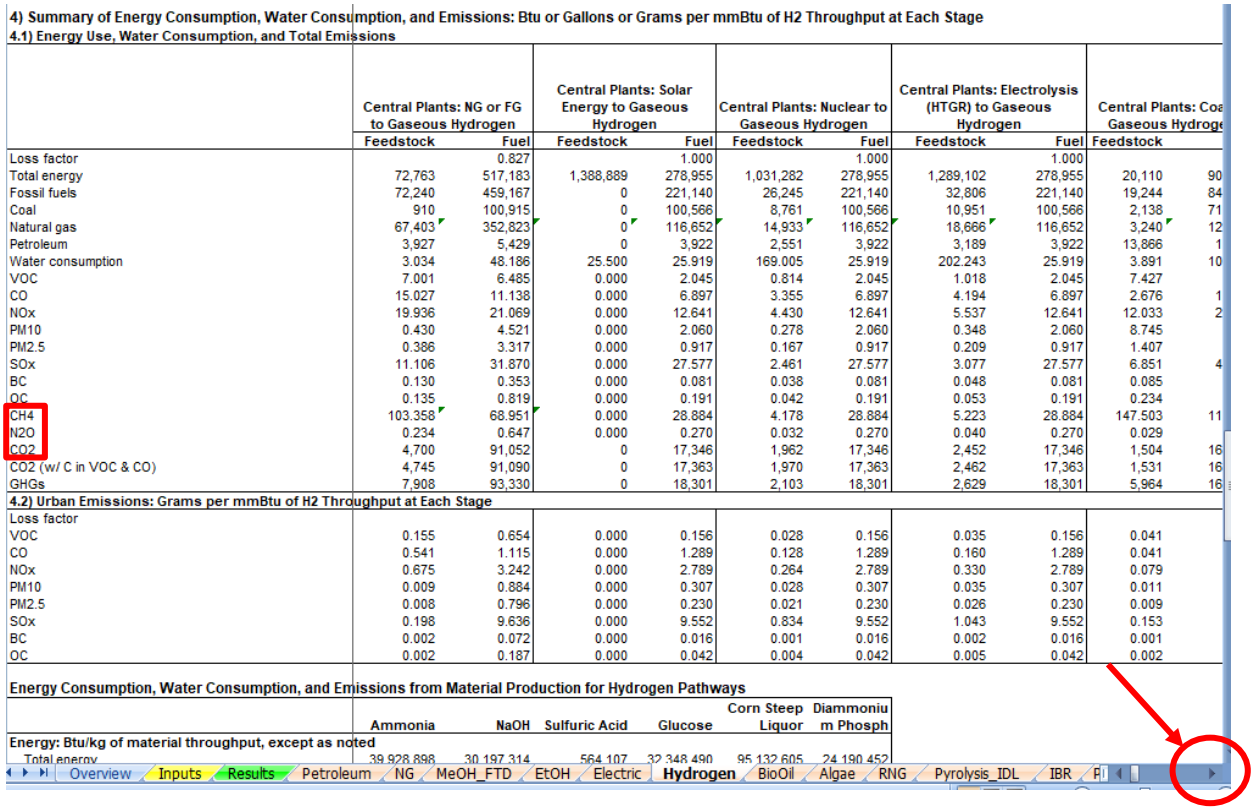

4) Summary of Energy Consumption, Water Consumption, and Emissions: Btu or Gallons or Grams per mmBtu of H2 Throughput at Each Stage

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: Coa Gaseous Hydroge	
	Feedstock	Fuel	Feedstock	Fuel	Feedstock	Fuel	Feedstock	Fuel	Feedstock	
Loss factor		0.827		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	8,761	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										
VOC	0.155	0.654	0.000	0.156	0.028	0.156	0.035	0.156	0.041	
CO	0.541	1.115	0.000	1.289	0.128	1.289	0.160	1.289	0.041	
NOx	0.675	3.242	0.000	2.789	0.264	2.789	0.330	2.789	0.079	
PM10	0.009	0.884	0.000	0.307	0.028	0.307	0.035	0.307	0.011	
PM2.5	0.008	0.796	0.000	0.230	0.021	0.230	0.026	0.230	0.009	
SOx	0.198	9.636	0.000	9.552	0.834	9.552	1.043	9.552	0.153	
BC	0.002	0.072	0.000	0.016	0.001	0.016	0.002	0.016	0.001	
OC	0.002	0.187	0.000	0.042	0.004	0.042	0.005	0.042	0.002	

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

	Ammonia	NaOH	Sulfuric Acid	Glucose	Corn Steep Liquor	Diammoniu m Phosph
Energy: Btu/kg of material throughput, except as noted						
Total energy	39,928,898	30,197,314	564,107	32,348,490	95,132,605	24,190,452

Overview | Inputs | Results | Petroleum | NG | MeOH_FTD | EtOH | Electric | **Hydrogen** | BioOil | Algae | RNG | Pyrolysis_IDL | IBR

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: Solar to Gaseous Hydrogen Nuclear to Gaseous Hydrogen Electrolysis to Gaseous Hydrogen	
Type of emission	Total amount of emission for LPG
CH_4	28.9
N_2O	.3
CO_2	17,346

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

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NO_X = 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
SO_X = sulfur oxides
BC = black carbon (particulate matter/ soot & contributes to climate change)
OC = organic carbon (respiratory effects)
CH_4 = methane
N_2O = nitrous oxide
CO_2 = 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.

Answers will vary based in student presentations

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:

The expectation is that they will choose hydrogen, but it does depend on students' presentations.

Evidence and reasoning for this recommendation:

Evidence used would be the low greenhouse gas emissions.

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