Energy Density of Fossil Fuel

Figure 1. A pump jack in Alberta (by Bill Burris)

Purpose

- Measure the energy density of burning ethanol (alcohol)
- Contextualize the energy density of fossil fuel by making quick comparisons

Introduction and Theory

More than 80% of the world's total energy comes from the burning of fossil fuels. Coal, natural gas, and petroleum (includes oil and gasoline) are all used extensively throughout the world. In fact, these types of fuels have allowed for the massive prosperity brought about by the industrial revolution. Of course, we have since discovered that using fossil fuels extensively result in major consequences for the environment and that these resources are limited; thus efforts are being made to look for alternatives. Fossil fuels remain a competitive energy source, not only because the technology and distribution network are well established, but also because their inherent energy density is fairly high. The energy density of a fuel is an important property. This property helps scientists and engineers determine the usefulness of a fuel. Energy density of a substance is the amount of the useful energy stored (and can be released) per unit volume or per unit mass. In our lab, we define it as the heat produced by the burning of 1 kg of a fuel.

In the lab, you will determine the energy density of ethanol by burning it and capturing the heat released by water. A similar process can be used to determine the energy density of different types of fuels. After that, a series of online research questions will help you contextualize the energy density number.

Name: ____________________________________

Partner(s): _________________________________

Desk #: _______________

1124 section: _______

Date: _________________

Energy Density of Fossil Fuel

Materials

- Computer with LoggerPro
- Temperature probe
- Ring stand with clamp, long rod, right angle clamp
- Soup can
- Stir rod
- Alcohol burner
- 4-beam balance
- 2-pan balance

Procedures

1. Clamp the ring stand to a long rod so that the alcohol burner can be placed below the can with roughly 5 cm of clearance, and that the temperature probe is securely held with the tip close to the middle of the water without touching the can. Plug the temperature probe into Channel 1, and in LoggerPro, open the file "*Earth Science with Computers/30 Fossil Fuels.cmbl*".

2. Using the appropriate balances, determine the initial mass of the filled alcohol burner (with the metal cap) and the mass of the empty can. Then add cold water into the can, making sure that no ice enters the can. (We are using cold water so that the water is colder than the room during roughly half of the trial, in order to cancel out the effect of heat gained or lost to the surroundings.) Measure the mass of the can with water in it. Calculate the mass of the water added.

3. Start collecting temperature data. The temperature should be around 1°C. After 3 or 4 readings, light the burner. **CAUTION:** *Keep hair and clothing away from open flames*.

4. Keep heating the water until the temperature reaches 40 °C and then extinguish the flame.

5. Gently stir the water until the temperature stops rising. Then you can stop the data collection. Click the statistics ("STAT") button to determine the minimum (initial) and maximum (final) temperatures.

6. Measure the final mass of the alcohol burner, again with the metal cap.

7. Allow the setup to cool down and clean up.

Data

Table 1: Mass of the alcohol used and the water in the can

Initial mass of alcohol burner (g)	
Final mass of alcohol burner (g)	
Mass of alcohol burnt (g)	

Mass of empty can (g)	
Mass of can with water (g)	
Mass of water (g)	
Mass of can (g)	

Table 2: Water temperatures

Minimum water temperature (°C)	
Maximum water temperature (°C)	
Change in water temperature (°C)	

Analysis

Q1. Use the equation

$$H = \Delta T \times m \times C_p$$

to calculate the heat energy *H* gained by the water and the can.

where

ΔT = change in temperature (°C)
m = mass of the water or the can (g)
C_p = specific heat capacity (water: 4.18 J/g°C, aluminium: 0.900 J/g°C, iron: 0.450 J/g°C)

Total heat gain by the water and the can is ________________________ J.

Q2. Calculate the energy content of ethanol based on the heat absorbed by the water and the fuel burnt. Express your result in MJ/kg.

Q3. A reference value for the energy density of ethanol is 26.8 MJ/kg. How does your result compare to the reference value? (Calculate the percent difference.) What are some factors that can explain the differences?

For the following questions, you are encouraged to look for appropriate data online. Note down the sources where you got your information from.

Q4. Find the energy density and the price of following materials.

	Energy density (MJ/kg)	Unit price ($/kg)	Unit price ($/MJ)
Crude oil			
Gasoline			
Natural gas			
Liquid hydrogen			
Wood			
Wax			

Q5. If BC Hydro charges 6.80 cents for 1 kWh, and Terasen Gas charges $2.98/GJ, which one is a cheaper energy source for your home (cents/MJ)? Terasen in fact charges $9.38/GJ due to surcharges.

Q6. Compare the electric car and the gasoline car, find (1) the average energy used per 100 km; (2) the average cost per 100 km; (3) the range of the car with one full tank of gasoline or with one fully charged battery. We assume:

- The energy density of gasoline is __________ MJ/L.
- An electric car uses 20 kWh per 100 km.
- A gasoline car has a mileage of 10 km/L.
- A full tank of gasoline is 50 L.
- A full charging period is 4 hours, on a 110 V outlet with 50 A current. Assuming the battery has 100% efficiency (which it has not).

Show your calculations and summarize the results in the table below.

	Electric car	Gasoline car
Energy consumption (MJ/100km)		
Cost ($/100km)		
Range		

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