Homework Eight

Physics & Mathematics of Sustainable Energy

College of the Atlantic

Due Friday, May 20, 2016

Please print out this cover sheet and attach it to your problem solutions. Completed assignments should go in my mailbox or be handed in during class. Please don't hand them to me other times, as I might end up losing them and that would make us both sad.

Your Name: _____

Please list all the students you collaborated with on this assignment:

_____ _____

_____ _____

_____ _____

Did you get help from Aura or Morgan?

Did you consult any resources other than our textbook or class notes? (If yes, please include citations in your solutions.)

Were you able to get enough help so you could complete this assignment to your satisfaction?

Approximately how many hours did you spend on this assignment?

Anything else of note about this assignment? (It was too hard, too easy, lots of fun, too repetitious...)

The work I am turning in for this assignment is an accurate reflection of my own understanding of the material.

Signature: _____ Date: _____

Assignment is on the next page....

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This problem concerns Cottage House on the campus of College of the Atlantic. We will use this as a case study for residential heating. Here are some relevant facts and assumptions.

- The average fuel consumption of Cottage House from 2010 to 2014 was 875 gallons. However, the house is unoccupied during December, which is a cold month that would require a lot of heating. So let's say that the average fuel use is 950, so that its consumption is closer to that of a "normal" house and not a dorm.[1]
- I believe that up to six people live in Cottage. But let's say that the occupancy is four, which again makes is closer to a "normal" house and not a dorm.
- The furnace in Cottage uses #2 Fuel Oil. Burning one liter of fuel oil releases 37.3 MJ of heat. The carbon intensity of fuel oil is 260 grams of CO_2 per kWh.
- The furnace in Cottage is a Milwaukee Thermoflo purchased in 1997. Its nameplate efficiency is 83%. Let's assume that because it is old it isn't operating at full efficiency. Use an efficiency of 80%.
- The average number of degree days per year was 7211 (using a base of 65 degrees). This means that the average difference between the inside and outside temperature was a ΔT of around 20 degrees Fahrenheit, assuming an inside temperature of 65 degrees Fahrenheit. Note that these temperatures are in Fahrenheit because America and that you'll need to convert these to Celsius because Science.

The goal of these exercises is to get a general feel for the numbers. We're working with approximations and averages. So at most two significant digits are called for.

1. How much does it cost per year to heat Cottage per year, assuming a cost of \$3/gallon for heating oil?
2. How much chemical energy from the heating oil is released when Cottage burns 950 gallons of fuel? Answer in kWh and both kWh per day per person. Is this a little or a lot?
3. How much CO_2 is released into the atmosphere as a result of burning the 950 gallons of fuel oil needed to heat Cottage? Answer in tons of CO_2 per year per person. Is this a little or a lot?
4. Let's say that the Cottage residents had been keeping their thermostat at 65 degrees. Suppose that for one year they donned sweater and hats and turned the thermostat down to 61 degrees. If they did so how much less energy would the house use in one year? How much less CO_2 would be emitted into the atmosphere as a result.
5. Given the furnace's 80% efficiency, how much heat (in kWh) was delivered to the inside of Cottage? Answer in kWh per year and kWh per person per day. This quantity is the *heating load* of Cottage—the amount of heat we need to add to Cottage so it is a comfortable temperature.

[1] The State of Maine claims that an average, well-insulated, home of 1500 square feet will use approximately 540 gallons of fuel oil per year. `http://www.maine.gov/energy/fuel_prices/heating-calculator.php`.

6. Suppose that you wanted to generate the heat for Cottage using traditional electric resistive heating.

   (a) How much would this cost?

   (b) How much CO_2 would be released into the atmosphere? Assume that we're using average US electricity, that released about 600 grams per kWh of electricity generated. Express your answer in tonnes of CO_2 per person per year.

7. Now suppose that you want to generate heat for Cottage by using an electric heat pump with a COP of 4.

   (a) How much electricity would you need to use in one year to meet the heating load of Cottage? Express your answer in kWh and kWh per person per day.

   (b) How much would this electricity cost?

   (c) How much CO_2 would be released into the atmosphere as a result of generating this electricity?

8. Comment briefly on the three options: Using an oil furnace, using traditional resistive heating, and using an electric heat pump. Which is the best financially? Which produces the least CO_2?