PROBLEM SET 1: ENERGY, POWER, UNIT CONVERSIONS

Energy and the built environment CRP 570.004/470.004

Total Points: 50 pts
Due Date: 1/28, 12 pm, in class.

Instructions for completing problem sets:

1. *Mark your answers clearly by circling/boxing them.*
2. *Clearly state any assumptions (e.g., the price of gasoline, the energy content used for a fuel).*
3. *Cite all of your data sources.*
4. *Show all your work so that I can figure out where you went wrong, and award partial credit where applicable.*
5. *Use scientific notation for writing very small or very large numbers.*
6. *Use the correct number of significant figures (points will be deducted if you keep to many digits!)*
7. *Your name must appear at the top of each sheet you turn in (and all must be stapled).*
8. *Late assignments should be scanned and emailed to me, and will be penalized 10% for each day late, up to 7 days, after which solutions will be posted and problem sets no longer accepted.*
9. *You will get the most out of the problem sets if you make an initial effort to work through all of the problems on your own. After attempting to solve the problems on your own, you may then work with other students to discuss different approaches. Even then, you should work out each problem yourself. It is encouraged to compare answers with classmates upon completion of the problem set. Remember that it is a violation of UNM's Academic Honesty to copy answers from anyone.*

1. Conversions and energy density. (25 pts)

From EIA "Energy sources are commonly measured in different physical units to include barrels of oil, cubic feet of natural gas, tons of coal, and kilowatthours of electricity. In the United States, British thermal units (Btu), a measure of heat energy, is commonly used for comparing different types of energy. In 2013, total U.S. primary energy use was about 97.5 quadrillion (10^{15}, or one thousand trillion) Btu." The energy density of a fuel is the amount of energy it contains on a per unit (mass or volume) basis.

Show your work for each conversion (don't just use an online converter) and keep only significant digits.

a. Wood: 16 MJ/kg (3)
   - (kWh/kg)
   - ($/kWh)
b. Coal: 24 MJ/kg (3)
   - (kWh/kg)
   - ($/kWh)
c. Gasoline: 112 BTU/gal (you will have to find the density of gasoline) (3)
   - (kWh/kg)
   - ($/kWh)
d. Crude oil: 6.1 GJ/bbl (3)
   - (kWh/kg)
   - ($/kWh)
e. Butter: 717 kcal/100g (3)
   - (kWh/kg)

- ($/kWh)

f. Natural gas: 20,160 BTU/lb (3)
   - (kWh/kg)
   - ($/kWh)

g. The US consumed 12.4 Quads of electricity in 2013.
   - How much primary energy was this, in kWh? Assume that conversion of primary energy into end use electricity is typically 32% efficient. (2)
   - How many kg of primary energy, in the form of gasoline would be needed to meet this demand? (2)
   - How many kg of primary energy, in the form of wood, would be needed to meet this demand? (2)
   - Which fuel from the list would be best to use as a transportation fuel? Why? (1)

2. Electricity generation (15 pts)

a. In 2013 416 MToe of primary energy of coal was used to generate electricity.
   - Using the same average efficiency of 32%, how many TWh of electricity was this? (3)
   - If total electricity generation was 12.5 Quads, what percent was generated from coal? (3)

b. Use the value above of electrical energy generated in a year from coal to calculate the average annual power of the coal generating stations (remember that Power = Energy/time) if you assume that they operated continuously. (3)

c. On the EIA website, find how many coal power plants were operating in 2012. Now, using the average power you calculated above, estimate the average power per coal plant. (2)

d. A generating plant will have a nameplate rating, or rated capacity, which is the maximum power that it can sustain. The capacity factor is the average amount of time that a plant would operate at its nameplate rating. If the average capacity factor for the fleet of coal plants is 65%, estimate the average nameplate rating of the coal plants. (2)

e. The average US home used 11,300 kWh/year in 2011. How many coal plants (using the average size calculated above) would be needed to supply electricity to a city the size of Albuquerque? (2)

f. A 1 kW solar array has a capacity factor of about 25%. What would be the total installed capacity of solar needed to meet the demand of the same city? (2)

3. Energy use patterns (10 pts)

- Visit the EIA and look up the amount of electricity that was consumed in the US in 2013. Look up on the UN the total population of the US. Calculate the average annual consumption per person in the US in 2013. (2)
- Do you think this is a reasonable estimation for annual consumption in the typical home? How does it compare to the number you used for residential consumption in the calculation above? (2)
- Now look at the electricity bill where you live. Divide this number by the total number of people living in your house or apartment. How does this number compare? Given an explanation if it is lower or higher than the US average. (2)
- Now look up the most recent energy production of electricity in India in 2013 available on the International Energy Administration website (www.iea.org) , as well as the current population. Calculate the average consumption per person. Repeat the same calculation for Malawi. Give an explanation why both of these numbers may be bigger or smaller than in the US. (4)