PHYS-310 Heat Transfer, Efficiency, Electricity, Problem Set #3:

1) We learned this week about carbon intensity: 15, 20, 25, (MJ/g_{carbon}) for NG, Petroleum, and coal. We also learned about efficiency of energy conversion. On the street, you're not going to be able to use these values for many relevant calculations because it takes too much time and the people you're talking to will get bored. I want you to become comfortable using the following estimations:
   a) Burning a gallon of gas emits about 10 kg of CO_2 into the atmosphere.
   b) Using electricity emits about 1 $kg_{(CO2)}$/kWh for coal, and a third as much for NGCC.

   Please prove that these estimates are pretty good.

2) Using the above estimations like you will on the street talking with folks about energy, please estimate:
   a) Your driving-related CO_2 emissions for the road trip to SF and back, in your friend's F-150.
   b) The extra CO_2 emissions for your mistake for leaving the 100 W bulb for the 4 days you were gone (refer to first assessment).

3) <u>Running a Natural Gas Combined Cycle</u>

   Let's say you're in charge of a NGCC for Southern LA. You control the flow of NG to the Brayton Cycle turbine and you can monitor the (a) electrical current, (b) the torque (how hard the turbine has to push the generator to keep it going), (c) the spinning frequency of the turbine, and the (d) output voltage. At 5:30 PM, everyone gets home and turns on their electrical appliances – especially air conditioners..
   a) When this happens, what do you notice about measurements in (a) – (d) above?
   b) How do you respond with the flow of NG to the Brayton Cycle Turbine? What does this do?
   c) After your action, how do measurements (a) – (b) compare to how they were before everyone came home?

4) <u>Transmission</u>

   Why do we need Transformers?
   a) Please explain how transformers reduce transmission losses, and include consideration of High Voltage, AC/DC, and resistive heat losses in a wire.

   Let's say you're on a task force to address the power loss to Bakersfield from Diablo. The power lines were made a long time ago and since then, Bakersfield's demand for electricity during peak hours has doubled.
   b) If the power use has doubled, by what factor will the amount of heat loss in the cables increase?
   c) On extra hot days, there will be an extra thermal load on the wires because of t he heat. What problem occurs when the wires heat up? How would this change the transmission losses?
   d) Long wires have considerable inductance and capacitance. How does this affect heating loses?
   e) You find a way to increase the transmission voltage by a factor of 5. By what factor will this change the transmission losses?

   Please read more about what transmission lines are made of at
   http://en.wikipedia.org/wiki/Electric_power_transmission

5) A few years ago, the fastest, most expensive production car in the world was the Bugatti Veyron. Here's the video: http://www.youtube.com/watch?v=LO0PgyPWE3o Then you can read about it in Wikipedia, or any place else you can find that interests you. You can skip down to the statistics if you like. At its maximum speed we can presume that it puts out its maximum power, find the efficiency:

a) Look up the maximum power that the engine puts out (please give answer in HP and Watts). What form of energy is this?
b) How does this power compare to a regular car? What is the max power (in HP and Watts) of your car?
c) What is the rate of consumption of petroleum at maximum power output?
d) What is the (chemical potential) energy consumption rate? Please put answer in Watts.
e) What is the efficiency of the gasoline engine at maximum power?
f) What rate (in Watts) does the engine dissipate heat? How many 100W light bulbs would this be? Why would this car need 10 radiators?
g) How much CO_2 does the car put into the atmosphere in the 12 minutes it can drive at top speed before running out of gas? Please put answers in kg of CO_2.

Demographics: You may not be able to find the exact information you are looking for below. Don't sweat it… Please innovate an answer that makes sense to you.

h) If a group of people in the following countries wanted to buy a Veyron, and saved half of their salary for a year, how many people would they have to get together?: USA, Guatemala, DR Congo.
i) In e) above, you calculated the *first law efficiency*, the *actual* efficiency: energy in (gasoline) vs physical work out. Please look up the engine temperature and estimate the maximum possible efficiency given these temperature extremes (Carnot Efficiency). I wasn't able to find it for a Veyron. You could look it up for the general Otto Cycle.)
j) What portion of this maximum theoretical efficiency did you achieve? This portion is called the "second law efficiency" because the Carnot Efficiency comes from adhering the second law of thermal physics.
    a) Even a perfect, frictionless Otto Cycle doesn't achieve the Carnot Efficiency. Please see: http://web.mit.edu/16.unified/www/SPRING/propulsion/notes/node25.html and investigate the efficiency of the Otto Cycle – what is the key factor? Why are diesel engines a little more efficient than the Otto Cycle? Well, there are a few reasons we will touch on later, but please find one of them now.
    b) What is the second law efficiency for a perfect Otto Cycle (achieving perfect Otto Cycle efficiency for the temperatures and compression ratios you find)?
    c) What portion of the maximum possible Otto Cycle efficiency does your Veyron actually achieve?