Midterm #3.

1. Wind power. I'm considering buying a wind turbine. Turbine A is bigger than Turbine B but costs way more. So, I could buy lots of Turbine B or just one Turbine A. Turbine A has three times the radius of turbine B and it is also taller, so the effective wind speed for A is twice that of turbine B.

a) If I decide to go with Turbine B, how many will I need to buy in order to get as much power as one Turbine A?

2. Lighting. Consider each of the three lighting technologies: Incandescent, Fluorescent, LED. Light Emitting Diodes work by the magic of solid state semiconductors. Briefly describe the mechanisms for fluorescent and incandescent lights and compare their efficiency to that of the LED along with the supporting underlying principle.

a) Incandescent
- How does it produce light?
- How does the efficiency compare to an LED and why?

As upper division technical students, I expect that you understand much about the physical world and can express it in words correctly. This didn't come out in many of your descriptions. In your discussion, and descriptions, please remember that words matter. Voltage is *applied across* a filament, *driving* current *through* the filament. Radiated heat *is* light, only a small fraction of which is visible. Energetic particles are actually *ionized atoms* from and *electron collision* after the *electron* is *accelerated* across an *electric potential* or *by an electric field*.

b) Fluorescent
- How does it produce light?
- How does the efficiency compare to an LED… you don't have to state why.

I found this on Wikipedia and liked it…. Although it is not the answer to the question. "Fluorescent lamps are negative differential resistance devices, so as more current flows through them, the electrical resistance of the fluorescent lamp drops, allowing for even more current to flow. Connected directly to a constant-voltage power supply, a fluorescent lamp would rapidly self-destruct due to the uncontrolled current flow. To prevent this, fluorescent lamps must use an auxiliary device, a ballast, to regulate the current flow through the lamp." From reading the Wikipedia article, it seems that the discharge in a fluorescent tube can run in either AC or DC mode. Really, there is a fascinating amount of interesting physics in the article and the process is way more complicated than I realized before. Read it if you get a chance.

3. I live in Alaska by a lake and keep my house at 30 ^oC. Only the top 1m freezes in the winter, so I have year-round access to water at the freezing point! I decide to heat my house with heat from the lake.
   a) With a quick drawing, *briefly* explain how I could use a heat pump to heat my house with water from the lake.
   b) If I buy a 200 W_E (electrical wattage) heat pump, estimate the maximum possible rate of thermal heat delivery to my house at 30 ^oC.
   c) I worry that the coils in the water may accumulate ice. Is this something I should be concerned about? Why or why not?

   In a heat pump, it is not the water or air that is moved. Heat is moved. The fluid in the system *could* be a gas because the compression would heat it, but it is a refrigerant that condenses when it is put under higher pressure… this increases its temperature *a lot* because the heat of vaporization is released as it compresses.

4. Efficiency: A closed in parking lot is lit with a hundred 200W fluorescent light fixtures 24-7 even though most of the time, there's no one there. I recommend a $30,000 sensor system whereby only the immediate lights are turned on when motion is sensed. We estimate this will cut the electricity use in half.

a) Calculate the annual cost savings and the simple payback time. Many folks calculated the energy use in Joules and converted to kWh… this is a lot of math. There are about 8760 hr/yr… multiplying by power in kW yields energy use nicely in kWh/yr.

b) We take out a 7% loan annual interest loan for over the 30-year expected lifetime of the parking structure. Please estimate the cost of conserved energy. CRF (Yes this is "CRF" for "Capital Recovery Factor", rather than "CRP" for "City and Regional Planning") for 7% 30 year is about 8%.

c) Please make a financially based recommendation to the company – should they make this $30,000 investment. Support your answer.

5. The company is also environmentally motivated, and are also concerned about potential forthcoming carbon taxes.

d) We want to calculate the reduction in CO_2 emissions. Please identify the carbon(dioxide) intensity (in kg_{CO2}/kWh_E) that we should use for marginal electricity in California. You should be able to calculate the carbon intensity for different technologies by using known primary carbon intensity or energy density of different primary energy sources. However, for this it would suffice to know that single cycle coal is about 1 kg / kWh_E, NGCC is three times better (and be able to explain why it's three times better), and single cycle NG is about 30% better than coal. You should have some idea that using a hairdryer for an hour would result in about 1/3 kg of CO_2 not several tons or a microgram. Think about how much gasoline (for instance) you'd burn to make the same amount of heat as kWh of electricity. That gasoline would turn into how much CO_2? It just grabs 2 oxygen atoms.

e) Please describe what it means to be marginal electricity, and why don't you just use all the electricity generating technologies on the California Grid weighted by how much they are used. I consider this an important question. We won't talk about marginal electricity again, but please understand that I expect you'll know for the last midterm what it is and why it's relevant. I looked it up and it seems few people use the term like I do. It comes from economics I think – you can find the marginal electricity *cost* or the marginal electricity *emissions*. But you rarely find "cost of marginal electricity". However, "marginal electricity" is used among energy economists,** and please understand that I'll expect that you will too. Discuss it with your group if you like.

f) Calculate the annual reduction of CO_2 from the investment.

g) Please estimate the cost of abated carbon. Will there need to be a carbon tax in order to motivate this efficiency upgrade? If not why? If so, how much of a carbon tax will be necessary? There were different ways to solve this. Some people calculated the total costs and emissions with and without the technology over the lifetime of the parking garage, or for a single year, or for just a kWh of electrical "service" with and without the investment: If we pay $0.15/$kWh_E$ in California and it results in 1/3 of a kg of CO_2, and the cost *not* to buy this electricity through efficiency investments is about $0.03/kWh of electricity *not* consumed with no CO_2 emissions, then investing in the efficiency measure will cost about a *negative* $0.36/kg of CO_2 *not* emitted, or about $360 / ton of abated CO_2. Thus, they could *pay us to emit CO_2* and this investment would still be profitable for us unless they were paying us more than $360 per ton of CO_2. So, no we don't need a carbon tax to make this investment profitable.

** for example please see:
https://energyathaas.wordpress.com/2012/04/17/marginal-vs-average-generation-the-case-of-the-electric-car/

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