PS#5 PHYS 310 Due Monday, May 8 in class

#1. Cal Poly recently had an assembly celebrating the largest gift to a CSU school *ever* by Cal Poly graduate William Frost, who in 2013, sold the Paso Robles company he founded, Chemlogics, for $1.3 Billion. The company produces chemicals dedicated to Enhanced Oil Recovery, especially fracking. Please describe the impact that these technologies have on our society.

a) Please discuss the benefits and include reference to financial, environmental and geopolitical.
b) Please discuss the concerns we have about fracking and include reference to financial, environmental and geopolitical.

#2. I was at a party (true story), and someone said, "Hey when we burn some coal, which warms the earth more: the heat of combustion, or the greenhouse gases emitted?" I responded, "damn we should ask a physicist."… we were all physicists. The question isn't really properly placed: The heat of combustion happens immediately, emitting some thermal ***Energy***. The resulting GHGs provide a constant heating effect which would be considered a constant ***power*** that continues to heat the earth through increased *radiative forcing*. So the *real* question to ask is *how much time needs to pass* for the GHG warming from the coal to equal the heat of combustion. We need to answer this question! How much time? Maybe you can do this now, but if not, you can at least set up the question.

a) How is it that the GHG emissions provide a constant heating power to the earth? What is the mechanism?
b) About how long could this 1 kg of coal supply your electricity needs if the heat was used to boil water in a Rankine cycle electricity generating facility?
c) Approximately what is the total anthropogenic GHG emissions since the dawn of the industrial age? Please put your answer in tons of $CO_2$ equivalent.
d) Approximately what is the global temperature increase from these emissions?
e) Approximately what part of these emissions are still in the atmosphere?
f) Approximately what is the radiative forcing from all the historical emissions in $W/m^2$?
g) Approximately what is the heat and $CO_2$ given off when I burn a kg of coal?
h) Using any/all the above numbers, please estimate the amount of time it will take for the GHG warming of the earth from burning the coal to equal the heat of combustion from the coal. No calculators, just estimate within 50%.

You can see my solutions for this on the video for Friday as well as immediately below. I estimated the rise of temperature to be 1 Celsius and the total emissions so far to be 460 GT of $CO_2$. I also estimate the associated radiative forcing to be 5.4 $W/m^2$, which is about twice that we see in the literature. I think that my value is over estimated because it assumes that the radiation comes from the warm surface of the planet, but by the very nature of the greenhouse effect, some of the radiation comes from the upper atmosphere, which is at a lower temperature. At lower temperatures, the 1 degree difference will have a smaller effect. As we see with the linearization of the radiative heat equation, the "constant" is $T^3$. Using my higher radiative forcing, I calculate it would take about 2 months, but with the lower (accepted) number of ~2, it would take 4-5 months.

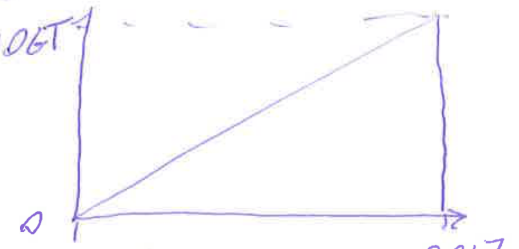
What is the radiative forcing that would be responsible for a 1°C shift in the earth's 16°C average Temp.

$T_E$ : 15°C ⇒ 16°C  $P = A\sigma T^4$

$T_E$ : 288k ⇒ 289k  $\frac{\Delta P}{A} = 5.67\times10^{-8}\ \frac{W}{m^2K^4}\left[(289K)^4-(288K)^4\right]$

Estimated Anthropogenic Climate Radiative Forcing $= 5.4\ W/m^2$

more than, or about twice what is normally given... maybe because they take baseline as ~1970, so $\Delta T \sim \frac{1}{2}$°C .... 10GT




Total carbon emissions (anthropogenic):

$\frac{1}{2}BH = \frac{1}{2}(2017-1925)10GT$

$= \frac{1}{2}(92)10GT \approx 460GT = 4.6\times10^{14}kg$ but 1 kg of C

$10^2\ 10^9\ 10^3 kg$

let's say 1kg Coal produces 30MJ of heat + 3 kg of $CO_2$

This increases the GHG by $\left(\frac{1}{4.6\times10^{14}}\right) \approx 10^{-14}$

so it increases radiative Forcing by $\frac{5.4}{4.6}10^{-14}\ W/m^2$

Total global warming $= PA_e = \sim 1\times10^{-14}\ W/m^2 \cdot \frac{4\pi(6.4\times10^6 m)^2}{\sim 10\ (\sim 40\times10^{12}\ m^2)}$

wow, the 3kg add this much average heating power to the earth! $\approx$ 4W

$P = \frac{\Delta E}{\Delta t}$  $\Delta t = \frac{\Delta E}{\Delta t} = \frac{30MJ}{4W} = 7.5\times10^6 s \approx \frac{1}{5}$ of a year

$\approx$ 2 months @ 2 W/m²

But it's more like 4-5 months if you use accepted RF.

#3 Calculating your carbon footprint: Please estimate your carbon footprint in Tons of $CO_2$ per year. Do this by doing rough calculations on your use of:

a) Car transport – calculate gallons used by you. So if you and your room mate need 200 gallons for the year to commute to Cal Poly from Los Osos, you are responsible for 100 Gallons.

b) Air transport. What is the mileage of the planes you travel in? How far do you fly? How many people share this fuel? You can say that the planes use kerosene… but it is like gasoline.

c) Use of Natural Gas and Electricity

d) Food see below for a paper that will help you.

e) Clothing and other goods

For the last two categories: The embedded carbon in the things you buy, there is a nice publication with some good graphs for you to look at (in particular Fig #2): http://escholarship.org/uc/item/55b3r1qj

**#4 Climate Change and You:** Chris Jones, at Berkeley has created a spreadsheet-based tool for individuals to estimate all direct and indirect emissions of GHGs in $CO_2$ equivalent units resulting from their primary energy related choices: transportation, food, housing (including energy use), goods and services, and waste. Go to Chris' website: http://consumerfootprint.org/ and spend some time exploring to understand the basic logic of what the site. Go to the calculators and fill out the widget that pertains to you, most likely the household widget at the bottom of the calculator page. Fill out the carbon calculator with your individual information for each sector. Please be as honest as possible (I won't publish your names). Go to the Summary tab and save your answers.

a) What is the ratio of the highest category (e.g. housing, food, etc.) of your emissions to the lowest? What is the ratio of your total emissions to the national average of 20 tons $CO_2$ per person per year? What is the ratio of your total emissions to the global average of 4.5 tons $CO_2$ per person per year?

b) What do you find most surprising about your results? Please explain in a short paragraph.

c) What lifestyle changes would you have to make in order to emit no more than the global per capita average of 4.5 tons of $CO_2$? To do this, change the values you entered in the spreadsheet until your total emissions are below 4.5 tons $CO_2$. Try to make realistic choices. What do the results say about how your lifestyle compares to the lifestyles of the majority of people on the planet? Could you live at or below the global average? Please explain in one short paragraph.

d) (10 points) What if, starting June 1, 2012, everyone suddenly started living like the average American (American per capita $CO_2$ emissions: http://en.wikipedia.org/wiki/List_of_countries_by_carbon_dioxide_emissions_per_capita )? How quickly would we reach what many climate scientists consider to be the dangerous level of 500 ppm (parts per million) of carbon dioxide in the atmosphere? State any assumptions you make.

e) (5 pts) How did your estimate from #3 differ from the output of the calculator above? Can you comment on reasons for the difference?