Problem Set #4: PHYS-310 Due in class, Monday, May 1

1) Please repeat any question from the midterm that needs improvement, with excellent insight and consideration.

2) Dan Kammen at Berkeley says, "we're not running out of petroleum, we're running on of atmosphere. Please investigate this statement.
   a) In the global stocks and flow energy diagram (this is provided for April 3 class on the class website), please estimate how many years our oil will last if we continue using it at the present rate. Assume that we can use every last drop (impossible – most of it is presently considered not accessible). But our rate of use is increasing.
   110 ZJ = ~ 10^{23}J. At about 46 MJ/kg, this gives us 2 x 10^{15} kg of petroleum or 13 trillion barrels… about 13 times what is presently accepted as total accessible oil reserves. Petroleum is essentially a chain of CH_2 groups, so a mass of 14 grams/mole yields about 1.4 x 10^{17} moles of CO_2 into the atmosphere.
   b) Estimate the mass of CO_2 emitted into the atmosphere for every gallon of gas you burn, a gallon is about 4 liters, which is a little less than 4 kg of petroleum (because oil spills float) yielding 3+ kg / gallon. Then each methyl group grabs two oxygen atoms and becomes CO_2 so you have to multiply by 44/14 yielding about 10 kg. then
   c) estimate the mass of CO_2 in the atmosphere if (when) we did use every last drop of petroleum.
   d) Calculate the total mass of the atmosphere knowing that atmospheric pressure times the surface area of the earth is the force of gravity acting on the entire atmosphere (right?) Air pressure is the collective weight of the atmosphere. F = P*A. The atmosphere is about 100 kPa, times the surface area of the earth, yields about 5x10^{19} N assuming gravitational acceleration, 5x10^{18} kg, or about 1.8 x 10^{20} moles of air molecules.
   e) Knowing that the molecular mass of the atmosphere is about 29 g/mole, estimate the PPM increase in CO_2 in the atmosphere from burning all the petroleum. I'm getting about 800 ppm (parts per million)
   f) Estimate the increase in the Radiative Forcing from this increase in CO_2. This would be about 6 times the total anthropogenic GHG so far emitted… that correspond to a radiative forcing of about 2 W/m^2. If we assume linearity, then we might expect an increase of 10 W/m^2. However, the effect may be more logarithmic.
   g) Estimate the increase in global temperature from this increase in CO_2. You may find it helpful to consider the layer model that DH and I published a few years back: http://www.aps.org/units/fps/newsletters/200807/hafemeister.cfm We might again assume linearity here, which would be a simplification. But if present anthropogenic GHG yield about 1 C temperature increase, burning this 13 trillion barrels would increase the earth's temperature by 6 degrees Celsius. There are several reasons this is incorrect. We can talk about it more later if you like… but read the paper first.

3) Look up the rate of petroleum use in gallons or barrels and see if the global use constitutes about 1/3 of humanity's primary energy use.

Checking the EIA website we see about 100 million barrels per day. Check out the break down between rich and poor countries at right! If you extrapolate to 2017, you get about 100 million total, no? That's about 36 billion barrels per year (or about 3.6% of what's left). If a barrel is 8 GJ (see next question) and a year has 3.14×10^7 s, this rate of oil use corresponds to about 7 TW. This is slightly more than 1/3 of 18 TW, which we learned at the beginning of the class is global primary energy use… however, that number is ~ 10 years old, and likely the present rate of global energy use is probably more than 18 TW.

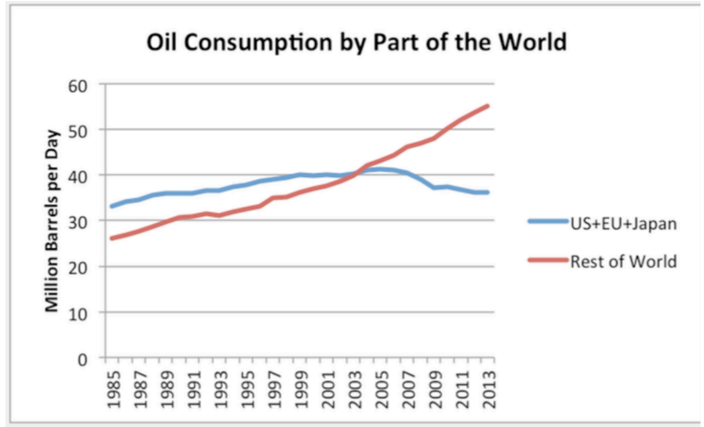


Figure 5. Oil consumption by part of the world updated through 2013, based on BP Statistica Review of World Energy 2014 data.

4) I've heard that the thermal solar energy falling on a square meter of surface area is roughly equivalent to a barrel of oil per year. Please check that. Estimate 250 W / m^2, which is an overstatement for the global average because it doesn't consider cloud cover, but it's good for tropical regions because at the equator, the geometric factors alone yield 500 W / m^2. $E = P*t \sim pi*250x10^7$ J, or about 8 GJ. A barrel of oil is 42 gallons, The number I always remember is that the energy density of petroleum is about 46 MJ/kg. There's about 4 kg in a gallon (slightly less because petroleum spills float), so about 160 kg in a barrel yielding about 8GJ.

5) If I have a Prius that gets about 55 mpg and I drive 10,000 miles per year, but my partner has a hummer averaging 9.5 mpg, and drives 15,000 miles per year, what is our CAFE (Corporate Average Fuel Economy?). And if you think you average these two numbers together, think again – which number more strongly influences the answer – the higher mileage or lower mileage? The average fuel efficiency is total miles / total gallons. Please prove to yourself that weighted averages don't work… consider if you had a car that got infinite mileage and another that got zero and you drove them both 10 miles, what would be the average mileage of your household transportation? No you can't average these two numbers together. The CAFE = total miles / total petroleum. You find that the lower mileage vehicles make a larger contribution. For instance you see from our extreme example that the average fuel economy of infinity mpg and 0 mpg is 0 mpg. The Prius consumes in a year 10,000 mi/(55 mi/gal) = 182 gallons, and the Hummer consumes about 1580 gallons. CAFE = (15,000 mi + 10,000 mi)/(182 mi + 1580 mi) = ~ 14 mpg.

6) In my video, I quote the full cost of a gallon of gas to be $15.
   a) have you ever heard this before? What costs do you come up with when you research the full cost of a gallon of gas.
   b) Where do you see yourself paying the external costs so that others to use petroleum cheaply?

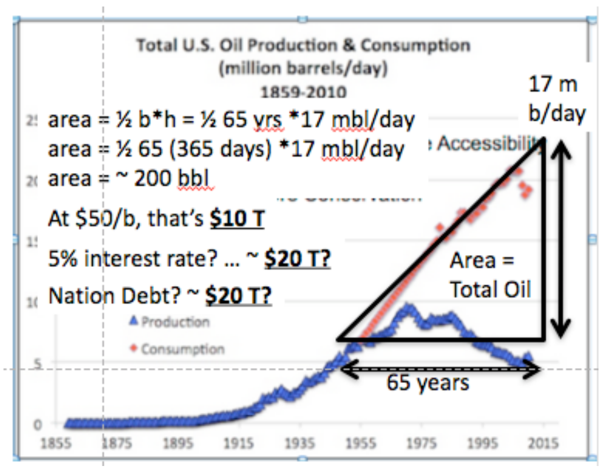
c) Where do you see yourself benefiting from others paying your petroleum external costs?

d) In your opinion, is it OK the way it is, or it should be changed? If your answer is "no it's OK as it is" then please state why it's OK. If your answer is "yes", then what would you propose? If you answered "no" you might propose market mechanisms such as an environmental impact tax that would fund environmental and health remediation as well as research better renewable energy and support for social restructuring of the transportation system. You might also propose command and control mechanisms such as CAFE standards or banning certain vehicles, or requiring electric vehicles for government services such as mail delivery. If your answer is "yes" you might lift policies, but then please quantify the costs to society caused by the significant external costs in the publically subsidized petroleum.

Interesting related readings could include below… but you could look up some yourself if you like:
http://www.washingtonpost.com/wp-dyn/content/article/2010/06/12/AR2010061200167.html
http://www.spur.org/publications/library/article/estimatingtheexternalcostsofdrivinginsf09012005
http://www.hybridcars.com/news/real-cost-gallon-gas-835.html

7) You're at a party and someone screams, "we're running out of oil and when we empty the wells, ***BAM*,** no more oil!" The economists despair, the environmentalists rejoice. Please nicely explain that it's a little more complicated than what the person screamed, and describe what it means to "run out of oil", and describe what it will be like. Please include all following considerations:
   a) technological
   b) Upstream energy use, and emissions
   c) environmental,
   d) economic
   e) political, and
   f) Environmental Justice. Are any groups disproportionately harmed?

8) Please look up a graph of US oil production and consumption … here's a pretty good website: http://islandbreath.blogspot.com/2017/02/cheap-profitable-and-abundent.html
Look up the price of crude oil over the years: https://en.wikipedia.org/wiki/Price_of_oil
Please estimate the total debt US might expect to have because of our… "oil problem". If you include consideration of interest paid on debt* – more power to you. What portion of our present debt might this constitute?
* http://3.bp.blogspot.com/-W9I/URrH6UrACXI/AAAAAAAABqs/I6sh



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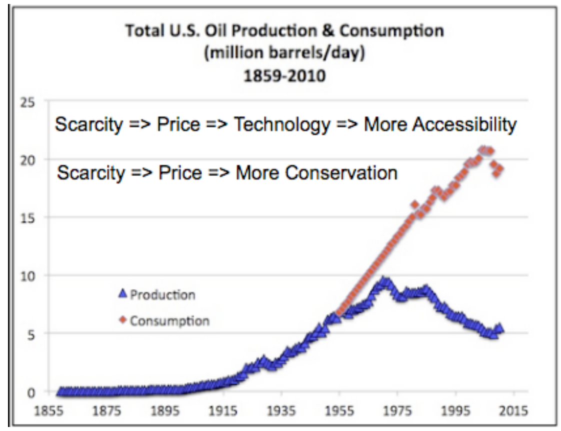
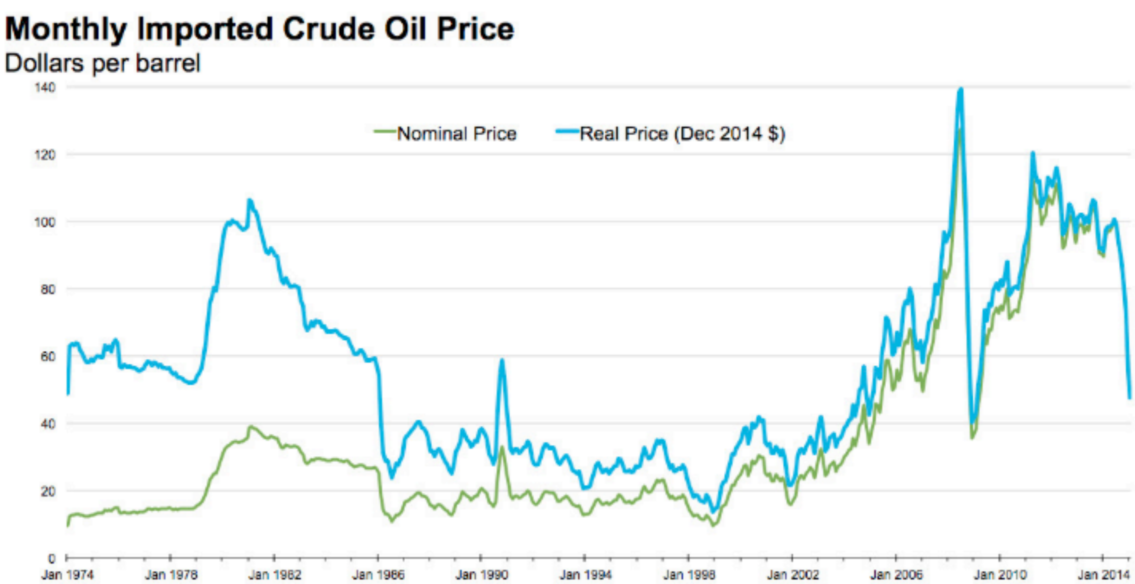
In class, we went over this calculation. If you missed it, we estimated that our shortfall in oil production is responsible for about 100% of our present national debt. Please see the slide at right.

9) Please look at the graph from the video. Comment on a few things:
   a) Starting around 1955, what started to happen and what effect did it have on USA security?
   b) Note very recently, there has been an abrupt shift in the consumption and the production of petroleum in the USA. What caused that?
   c) Has the trend (in b above) continued, increased, decreased? Please do some internet research (careful about which websites you believe).
   d) What do you expect to see happen under the new federal administration?



   Probably the answer to this question and question 7 is that it's all about the price of petroleum. The price increase starting in 2006 pushed both efficiency and conservation measures on the demand side and both risk and technology development on the supply side. Since then, production has greatly increased (almost as high as it was in our heydays of the 1970s) and the consumption has gone up a little. With present reduction in regulations and the price of gas, I predict that exploration will continue to increase (for another decade.. then EIA estimates of our reserves will be used up) and consumption will continue to increase considerably. In 5-10 years, the cycle may repeat itself… but probably not. Electric transportation will likely pick up and there will be other measures that may reduce both demand and production.



10) 10.25 in DH’s book