Problem Set #4: PHYS-310 Due in class, Friday, April 26

1) Please repeat any questions from the past two assessments that you didn't get totally right.

2) 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.

2| rate of petroleum use → $101.38 \frac{\text{million barrels}}{\text{day}}$ * from EIA

$101.38 \frac{\text{million barrels}}{\text{day}} \times 365 \text{ days} = 37{,}003.7$ million barrels

1700 kWh / barrel

37 billion barrels of oil $\left(\frac{1700 \text{ kwh}}{\text{barrel}}\right) = 62900$ billion kwh $\left(\frac{1 \text{ year}}{8760 \text{ hrs}}\right)$

7.18 billion kW → 7 TW / ~~year~~ on ~~avg~~ average !!

careful of units!

Global Primary energy consumption (2017): 153,595 TWh

$153{,}595 \text{ TWh} \left(\frac{1 \text{ year}}{8760 \text{ hr}}\right) \approx 18$ TW nice!

$\frac{7 \text{ TW}}{18 \text{ TW}} = .388 \approx 1/3$ ✓

3) 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. *The student below did a great job, but left out the consideration that we don't get 1000 W all the time. If we were to find the total energy collected on a solar panel for a year, we'd have to multiply by the duty cycle… or about 1/4, yielding a daily average of about 250 W/m^2. Variable could cover (as noted below) would further reduce this average solar intensity.*

3| $1000 \frac{\text{W}}{\text{m}^2}$ ← equator value from PS#1 but does not take into consideration cloud cover × duty cycle!

$\frac{1700 \text{ kwh}}{\text{barrel}} \times \left(\frac{1 \text{ year}}{8760 \text{ hr}}\right) = 194 \frac{\text{W}}{\text{barrel/year}} \approx 200$ W

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 ~ 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.

4) If I have a Prius that gets about 50 mpg, but my partner drives a 10 mpg hummer, and drives 15,000 miles per year. We drive roughly equal distances. What is our CAFE (Corporate Average Fuel Economy)?.

a) Please prove to yourself that averaging the two to get 32 mpg 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?

b) Recognizing that average fuel efficiency is total miles / total gallons, find the CAFE of my household. If it helps… imagine driving each of them 100 miles.

c) Let's say we agree that we should increase the CAFE of our household, but we will only buy one new vehicle… a more efficient beastly SUV (for her), or a more efficient super-efficient vehicle for me. Which would change would more effectively improve our CAFE? For instance, let's say she was willing to buy a large SUV that gets 12 mpg. If instead, I wanted a new super-efficient car, what would the mileage have to be to get the same increase in CAFE as my partner getting the 12 mpg SUV? With this answer, who should get the new car?

4| 50 mpg 10mpg $15{,}000 \frac{\text{miles}}{\text{year}}$

a. $\text{CAFE} = \frac{\text{miles}}{\text{petroleum}}$

$15{,}000 \frac{\text{mi}}{\text{year}} \left(\frac{\text{gallon}}{50\text{ mi}}\right) = 300 \frac{\text{gallons}}{\text{year}}$

$15000\text{mi} \left(\frac{\text{gallon}}{50\text{ mi}}\right) = 1500 \frac{\text{gallons}}{\text{year}}$ ← Hummer contributes more petroleum

b. $\frac{15{,}000 + 15{,}000}{300 + 1500} = \boxed{16.67\text{ mpg}}$

c. $15{,}000\text{mi} \left(\frac{\text{gallon}}{12\text{ mi}}\right) = 1250 \text{ gallons}$

$\frac{30000\text{ mi}}{1250+300} = 19.355\text{ mpg}$

wife should get new car

$19.355\text{mpg} = \frac{30{,}000\text{mi}}{x + 1500} \Rightarrow 50 \frac{\text{gallons}}{\text{year}}$

$15{,}000\text{mi} \left(\frac{\text{gallon}}{x\text{ mi}}\right) = 50 \text{ gallons} \rightarrow \boxed{300\text{mpg}}$

5) 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?

Please see student answers below. I think it's important to note that while we can recognize some external costs that we do pay like increased health care and bad air that we have to breath, we pay much less than hurricane-prone areas or people that have lost land (and lives) due to flooding. So there is an environmental justice issue here as well. Please see answers below.

5] a. I have never heard the full cost of a gallon of gas to be $15 before. According to fuelfreedom.org the cost is closer to $6 / gallon but many other resources say $15-16 / gallon.

b. External costs in healthcare due to environmental / air pollution, natural disasters due to rapid climate change, and disasters due to political instability since oil is a commodity.

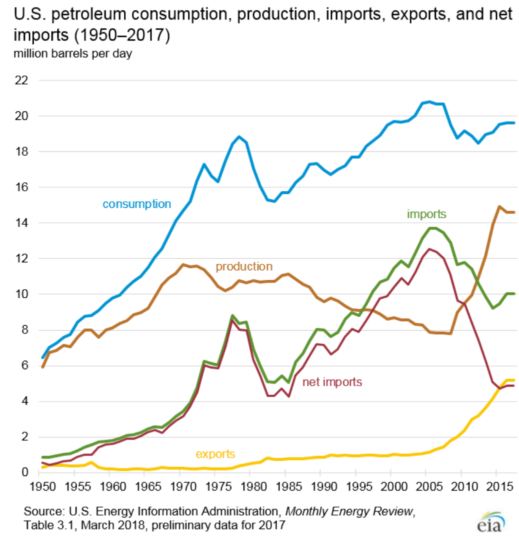
c. I get to use this natural resource for a "small price" without experiencing the cons.

d. I don't think our system is okay the way it is and I think oil drilling companies should have to pay for some of the environmental impact they cause.

6) 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?

6] If were to run out of oil it would mean we have exhausted all of our technological advancements in drilling / fracking. We don't actually run out of oil it is just harder for us to reach but given how great the demand is, we will just keep inventing new methods to get to the oil which can wreck our environment. The uprising of the environmental community can also cause political tension between countries (like U.S & Canada). Groups that live ~~off~~ of their land (like many indigenous groups) are disproportionately harmed b/c they likely do not have the means to fight back while their land is vulnerable to environmental disaster. It is also not economically viable to keep drilling deeper and deeper for oil.



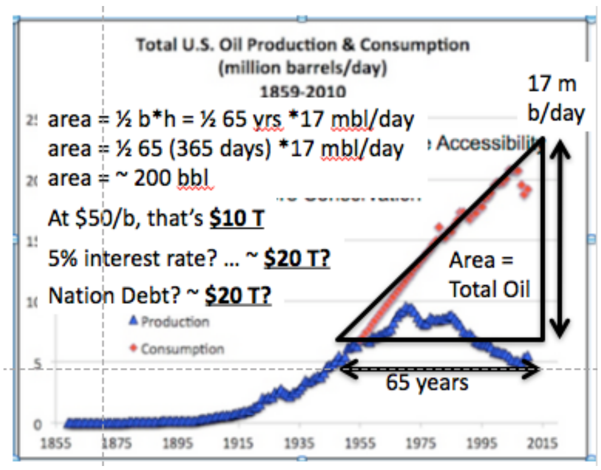
7) Please look at the graph from the video. Comment on a few things:

a) Starting around 1955, what started to happen and what effect did it have on USA security? *We started exporting our money. We also became insecure because our well-being depended on the cooperation of oil-producing countries. We were suddenly vulnerable to them.*

b) Note very recently, there has been an abrupt shift in the consumption and the production of petroleum in the USA. What caused that? *The scarcity caused price increase pushed technology… in particular fracking. This increased the available reserves.*

c) Has the trend (in b above) continued, increased, decreased? Please do some internet research (careful about which websites you believe). I refer you to a website for Friday's class that will provide an update. *In class, we looked at the website I referred you to (at right) we see that our oil production has increased incredibly. How long will it last? Maybe the better question is "how long will our atmosphere last?" Dan Kammen at Berkeley often says, "we're not running out of oil, we're running out of atmosphere."*

8) I've said to my class once (or twice, or more) that 100% of our national debt can be attributed to importing oil over the years. Let's see if it's true. Please look up a graph of US oil production and consumption. I refer you to one for Friday's preparation.
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?



I mentioned this in class today. If we look at the approximate area of the triangular debt, we can calculate about $10 T, maybe now $12 T two years later. How can we consider interest rate? Because out debt puts us more in debt. The correct thing to do is integrate it properly, year by year. Or you could do it on Excel. However, I could just get a basic idea… what is the interest rate on debt? I look up mortgages. How about 5%? Then maybe the center of mass of that triangle falls around 1995?... ~ 24 years ago? Thus it might be reasonable to estimate that the debt is great by a factor of about $(1.05)^{24}$*, with out using a calculator, we can make a lowest guess at* $(1+E)^n > 1+En$ *+ higher order terms… so the debt would certainly be more than double, more than $20 Trillion. Using a computer, I get* $(1.05)^{2\,4}$*~ 3.2. But again, there were several estimates here.*