PS#6, Due Tuesday, February 20

1. **What will kill you?:** Please see Meera Subramanian's Nature article *Global health: Deadly dinners* and the statistics on deaths from electricity production.
   a) If you were born in an area where people use the 3-stone fires, what is the probability that it will cost you your life? The WHO (World Health Organization) estimates that 4 million people die globally from HAP (Household Air Pollution) *each year*. There's probably 3 billion people who cook with three stone fires, so this corresponds to 0.13% of their population *per year.* There's a wide range of life expectancies in developing countries, and likely the life expectancy is lower in homes that use three stone fires, because they are poorer. I will estimate 60 years, and thus about 7% of the world's poor die from indoor air pollution.
   b) How does this compare with the probability of being killed in a car accident in the USA? In 2015, about 38,000 of the 320 million USAmericans died in traffic accidents, corresponding to ~0.019%. With a life expectancy of ~ 80 years, about 1% of USAmericans will die in a traffic accident.
   c) Given the amount of electricity the USA will use over your lifetime, what is the probability that it would cost you your life if this electricity was from coal-fired generation? From nuclear generation? For Thursday of week 3, we read "How Deadly is your KiloWatt? We see that in the USA, there are about 10,000 deaths per Trillion (10^{12}) kWhr, for coal electricity, which constitute 44% of our electricity production. I also look up to see that about 4 trillion kWh are generated in the USA each year, or about 1.7 Trillion kWhr from coal per year, corresponding to about 17,000 deaths per year in the USA. I plan to live to be 100 years old, corresponding to about 1.7 million deaths over my lifetime, or about 0.5% of the US population. So, I guess there's a ½ % chance that it will be me. This is flawed… I hope because we will stop using coal in the near future. The same consideration for nuclear (at 0.01 deaths per trillion kWh), 20% of USA electricity production, or 0.8 Trillion kWh, corresponding to about 0.008 deaths a year, or about 1 death over my lifetime, corresponding to a one in 300 million chance that it will be me.
   d) How many people have been killed recently in wars? What's the probability of an earthling dying in a war? About 400,000 people die in war each year (or 1/3 of global traffic deaths), or about 32 million over a 80-year life span, corresponding to 1/1000 of the world's people die in war…. WOW the media would have you believe it's much more, no?
   e) How many people have been killed in the past decade as a result of terrorist attacks? From Statista.com, we see an average of about 20,000 per year, or 200,000 a decade. What's the probability of an American being killed by a terrorist? From https://www.start.umd.edu/pubs/START_AmericanTerrorismDeaths_FactSheet_Oct2015.pdf we see that the overwhelming majority of all terror attacks on USAmericans was 9-11. Since then we've averaged about 5 deaths per year in the USA and 10 deaths per year outside of the USA. That's 15 deaths per year, or 1,200 deaths over an 80 life time, or about one in 100,000 people will die in a terrorist attack: 0.001%

2. I've heard that each person is about a 100 W lightbulb… that we put out heat at the rate of about 100 W, on average throughout our lives.

a) Does it seem to you that this is about right if you think about the heat you give off… does it compare to be about the same as a 100 W lightbulb? You'd have to do your own estimation about this. A 100 Watt bulb is way hotter than a person, but a person has much greater surface area.

b) Consider if you just lived and didn't exercise too much, how many calories would you consume in a day. Energy in = Energy out. So if you metabolize all the nutrients in your food into heat (a reasonable estimate), calculate the rate at which you dissipate heat into the world. Is this close to 100 W? Remember that a **C**alorie is actually 1000 thermal calories. What if I eat 3000 Calories a day, or 3 million calories (1 cal = ~4.2 J), or about 12 MJ a day. That's ½ MJ/hour, an hour is 3600 seconds, corresponding to 10^6J/7000s, or 140 W.

c) There was one more question we could ask: Estimate your CO_2 emissions for a day knowing the carbon intensity of your fuel. We know that sugar is like wood (30 g(C)/MJ) and fat is oil (20 g(C)/MJ), so we can estimate the carbon intensity of your food as about 25 g(C)/MJ, multiplying by 44/12 to convert to CO_2 we get about 90 g(CO_2)/MJ). Thus, converting 12 MJ of energy at this rate, we get a little over 1 kg of CO_2 emissions daily.

3. Fission – Fusion what is the difference between these two processes?

a) How are these two processes different? Please give an example of each process. Fusion joins small nuclei (like in the sun) while fission breaks apart large nuclei.

b) What is necessary to make each process happen? What do we have to do to make it happen? Fusion, we need to get them to collide, it's all about confinement and heating them up so they collide at high velocity. Fission, you need critical mass so the neutrons collide with a nucleus, so it's about increasing the amount and density of the fuel and controlling the neutrons.

c) What are the major challenges to making each a wide-spread source of clean energy? Fusion, we can't make it work. It's hard to confine the hot plasma. Fission, we have to control the neutrons, and dissipate the heat or risk a meltdown. In particular with Fukushima, the reactors shut down, but there was no power to keep the water pumps running. The delay neutrons from the radioactive isotopes gave off enough heat to cause a meltdown.

4. Nuclear safety, costs, etc. Nuclear power has the promise of wide spread, low carbon electricity for everyone. However, it's not widely adopted.

a) Discuss your take on challenges to widespread nuclear adoption. Making them safe and inexpensive.

b) Do you think that the challenges to nuclear acceptance is more real or more imaginary? They are already way safer than other electrical generation means – however, this imaginary threat is real because people are still scared. Additionally, the extreme oversight to make them way way way safe makes them expensive to build and take a long time, which further increases the price as the debt increases with the interest.

c) Compared to last week, are you more pro-nuke or anti-nuke? Why do you think? Me, Pete? I guess I'm a little more pro-nuclear. But they are so central station and supply side management. I'll spend my time and energy working on looking at distributed generation solutions, such as PV, and how we can manage our consumption with efficiency measures and be aware of how we use electricity so we can use it when it's available. Of course, your view might be very different from mine.

5. As you watch the videos for cost of energy use and carbon abatement, please consider the following questions:

a) What is the difference between cost of conserved energy and cost of abated carbon? CCE is $/kWh(not used), and CAC is $/kg($CO_2$ not emitted). The other difference is that the CCE does NOT consider the savings you make by not consuming electricity. Thus, you can have a positive CCE and still be saving money in the investment – as long as the CCE is less than the cost of actually buying the electricity (or about 15 cents in California).

b) If cost of conserved energy is positive, does this mean that you will lose money if you conserve this energy? No, see above. How about the cost of abated carbon: if this is positive, will you lose money if you don't emit this carbon? Yes, it is a positive cost.

c) How does cost of abated carbon compare with capital intensity of abated carbon? When/why is the latter important? If the capital cost of abated carbon is very high, it could appear as a risk to make the investment.