PS#7 Due Monday, March 12

1) Draw and explain the famous California Wealth/Energy use decoupling graph. What is the very very important socio-economic-political message behind that graph regarding GHG reductions? Help?: it shows the per capita electricity use as a function of the year for California and the USA versus the other states and USA as a whole.
2) You hear some people talking, "Heat pump, Heat engine, refrigerator... are they just all the same thing?" Please distinguish these two things or explain how they are the same.
3) Old freezers didn't have defrost, so they would accumulate ice on the evaporator coils. We can clean off the ice by using a screw driver!
   a) Will removing ice improve the efficiency of the freezer? Why or why not?
   b) Why should you ***NEVER*** clean the ice off this way?
4) OTEC What's the best thing about it? What's the greatest challenge?
5) You have a wind farm and notice that when the wind blows at about 3 m/s, it generates 20 MW. About what will be the power you generate when the wind blows at 6 m/s? Why?
6) Incandescent, fluorescent, and LED lighting technologies
   a) Explain with a drawing how these three light-producing technologies work
   b) Why do incandescent lights get such bad efficiency?

Solar, Transportation

Schwartz Problem Set #8

Due Monday, March 12, with PS#7

1. Why do ICE (Internal Combustion Engines) suck (gasoline so much)?
   a) Why is the efficiency so low?
   b) For a hybrid that isn't plug in electric, all the energy still comes from gasoline or diesel. So how does the hybridization of the engine to include an electric motor increase gas mileage?
   c) How does having plug-in capability change the efficiency, cost, etc.?

2. I have a 1996 Subaru Outback, that we drive to the beach about 20 times a year, maybe once to San Francisco or some other far off destination. We've talked about just getting rid of it and renting a car for long trips. However, maybe I should buy an electric car or hydrogen fuel cell vehicle?
   a) How are electric cars and hydrogen fuel cell vehicles the same? How are they different?
   b) What are the advantages/disadvantages of each one over the other? Which one do you recommend for me? Or should I get a hybrid electric?
   c) I have 4 solar panels (about 1600 W total) on my roof that senior project students installed for experiments at home. How would having these solar panels change or not change the situation for me?
   d) Where do you want to be living 5 years from now? Extrapolate into the future and consider at least 3 different transportation strategies for the place you will live. Compare them and state which you will choose.

3. Calculate the surface area of standard PV panels (15% efficiency) necessary for you to live your life. Please include the following consideration:
   a) We live in SLO and can anticipate the corresponding solar incidence.
   b) You continue to use electricity like always, and continue to drive like you always do, but in a (shared?) electric car.

   Please give your answer in square meters.... Does this area seem reasonable to you? Do you feel you are taking too much of the planet's surface area with this?
   c) Indicate what kind of lifestyle changes you would need to make in order to live like this.

4. Concentrated Solar vs PV.
   a) What are the differences between PV, Concentrated Solar Thermal Electric, and Concentrated PV?
   b) What are the relative advantages/disadvantages of each in meeting the electrical demand of society?
   c) Since making this question on CSP (concentrated solar power), there have been some changes. Large solar power towers have been built. Take a look at Ivanpah: https://en.wikipedia.org/wiki/Ivanpah_Solar_Power_Facility What are some advantages of this facility? Some disadvantages/concerns?

5. Taken directly from Monday's Class schedule. Please read the NPR article about infrastructure.
http://www.npr.org/2017/03/09/519500054/engineers-say-tax-increase-needed-to-save-failing-u-s-infrastructure

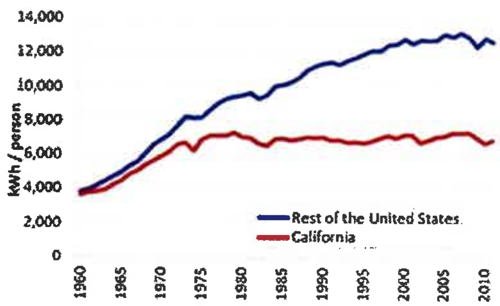
a) $2 trillion... is that a lot? Of course, what this should mean is to find a way to compare it to something that makes sense. For instance, how much is this per US American? Or better yet, per US American family?
b) $0.25 per gallon gasoline tax? How long would it take to bring in $2 trillion at the rate we use petroleum? Use any method you like.
c) Would you consider this a market mechanism? To what degree is this *internalizing* an *external cost*? To what degree is it just raising money and not internalizing an external cost?

PS 7 and 8

PS #7

1. California Wealth/Energy Decoupling use graph

Per Capita Electricity Consumption: California vs. Rest of Nation



This graph shows the leveling off of CA electricity consumption since around the early 1980s, when decoupling was introduced. Decoupling is a technique in which utilities send their revenue requirements and estimated sales to regulators. The California Public Utilities Commission (CPUC), then set rates to make sure utilities collect no more or less than is necessary to run the business and provide a fair return to investors. Excess revenue is credited back to the customers and any shortfall is later recovered from the customers. This process no longer ties revenue to the amount of energy sold. With this connection broke, utility companies can focus on finding more efficient ways to provide energy to customers, without any worry that this increased efficiency (and thus decreased energy sale) will affect their income. With plateauing energy consumption, GHG emissions have decreased immensely. It also shows the ability of a program to tie both customer and shareholder interests in providing decisions. *Shows econ growth doesn't need increased emissions!*

2. Heat Pump vs Heat Engine

In the summer, a heat pump takes the hot air from inside your house and "moves" it outside. First, the very cold refrigerant enters the evaporator coil inside the house. This comes in contact with the hot air inside the house, and thus the hot air warms the refrigerant up. This causes the air to lose its heat and thus cool down. Since the refrigerant has now been heated, it becomes a gas, and enters the compressor. This heats the gas up even more so that it leaves the compressor as a hotter gas. Then the refrigerant moves to the condenser coil outside of the house. Now, since the gas is so hot, the outside air is actually cooler than the gas, and thus the gas is cooled down, and therefore becomes liquid once more. Lastly, it enters a device which de-pressurizes the liquid even more, and can be used again in the process. Depending on the temperature differences involved, for some amount of work put in, you can actually move a lot more heat out, hence why the coefficient of performance for these processes is much greater than 1. This process is essentially reversed in the winter. *And refrigerators?*

A heat engine requires you to put x amount of work in, and through this you get <x work or electricity out along with some waste heat. Therefore, the efficiency is always less than 100%. ✓ *(clarify that x ≠ x)* *(mention why its the same as)*

3. Old freezers

   a. Removing the ice off of the evaporator coils will increase the efficiency of the system. As can be noted from my above answer, when the refrigerant is in the evaporator coils, its purpose is to come in contact with warmer air outside to heat up the refrigerant. If there is ice covering the coil, the ice will absorb some of the heat from outside, thus allowing less heat to be absorbed by the refrigerant. Then, more work will be needed in the compressor in order for the refrigerant to become a hot gas, decreasing the system's efficiency. ✓

   b. You should never clean ice off with a screwdriver because you risk poking holes in the insulation, which will really damage the efficiency of the system. *and release CFCs*

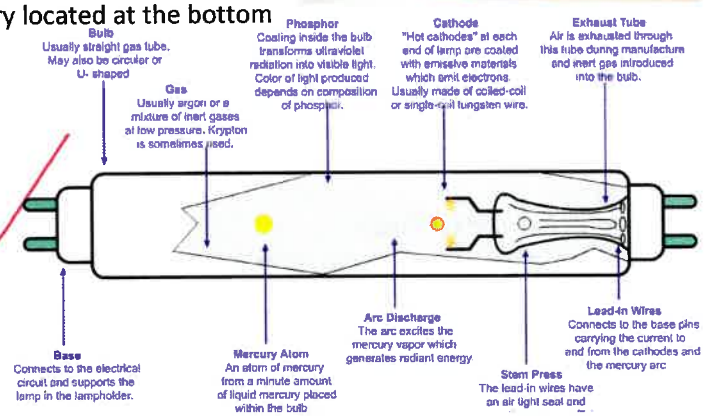
4. OTEC

OTEC is ocean thermal energy conversion. It works by producing electricity using the temperature difference between deep cold ocean water and warm tropical surface waters. The best part about this process is that it is a clean, renewable, and has the ability to produce a lot of electricity per year without harming the thermal structure of the ocean. However, it is very inefficient thermally speaking, since the temperature difference between the ocean layers is not extremely drastic. It is also currently a more expensive form of energy production than some other sources. There are also worries of the effects it could have on nearby oceanic ecosystems.

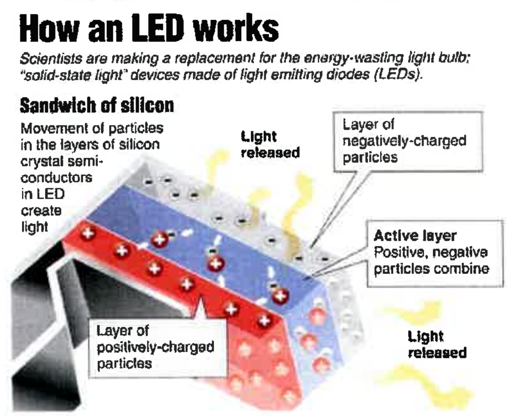
5. Wind Power
P α v^3r^2 so if you have 20MW α $(3m/s)^3r^2$, then doubling the velocity will increase the power output by a factor of 2^3=8. Therefore, 6m/s will cause a power output of 20*8 = 160 MW.
6. Lighting Tech

a. Incandescent bulbs work by heating a tungsten filament to the point that it produces light. These have such bad efficiency because they produce mostly non-visible light, which results in a lot of heat, but a very low luminous efficacy.

b. Fluorescent lights work by heating mercury located at the bottom off the tube, which forms vapor electrons. When there is voltage on both sides, a force is places on the electrons, and they strikes atoms. The electron will bounce off the atom and maybe split it or it may produce UV light. Since we cannot see UV light well, there are phosphors on the glass which absorb UV and radiates visible light.



c. LED lights work by moving electrons. In the p-junction, there are holes where electrons can fill, and in the n-junction there are free electrons that want to move. As you run a current through this, electrons move from the n-junction to the p-junction, and the "holes" to move from the p-junction to the n-junction (with no voltage you only have free electrons moving to the holes). When the electrons move to fill in the holes, they release energy, which produces photons. By using silicon diodes, the photons released have low frequency, and thus can be seen by the human eye.



PS #8

1. Internal Combustion Engines
a. Their efficiency is so low because of all of the parts that go into an ICE. You have to pump air in and out of the engine, the numerous moving parts cause energy loss to friction, and a lot is removed as waste heat.
engine power levels?
b. Non-plug in hybrids increases gas mileage for a few reasons. First, when you are idling, a hybrid allows the conventional engine to turn off, and instead uses the battery to keep all of the accessories (A/C, radio...) running. Regenerative braking also works to capture the heat energy formed by friction braking, and use that energy to be converted to electricity to charge the battery to be used later. At low speeds, hybrid cars

can also switch to run solely on battery, which decreases fuel use. When the battery is low, the gas motor can work to charge it back up (batteries are much more efficient at running cars than ICE's).

c. Having a plug in capability can essentially remove any need for an ICE. Batteries operate cars at about a 95% efficiency. If you are using electricity produced from a renewable source or natural gas, you are decreasing GHG emissions. Since ICE's have a much lower efficiency, removing its use improves the overall fuel economy of the car. Since non-plug in hybrids still rely on ICE's to charge the battery at times, their fuel economy decreases. But plugging in your car to an outlet allows for the use of electricity which is produced much more efficiently than energy produced by an ICE. Electricity is also often much cheaper than gas, reducing your costs.

2. Electric vs hydrogen fuel

a. Both use electric motors. However, electric vehicles use energy stored in a battery while fuel cell cars have stored fuel that is used to create energy through a reaction. Electric vehicles are much more popular than fuel cell cars. Fuel cell cars don't have the same range limitation that electric cars have, since you can simply get more hydrogen fuel. But on the same note, the infrastructure for hydrogen refueling is not very good, making it fairly similar to electric vehicle charge stations. It also has a much lower efficiency than electric cars.

b. Advantages of fuel cell vehicles: more efficient than ICE, fairly quiet, only byproduct is water, longer range than most electric vehicles, very little maintenance needed

Disadvantages of fuel cell vehicles: efficiency is about 50%, platinum is very expensive, there are impurity issues with the fuel, hydrogen transport and storage are still not perfected

Advantages of electric vehicles: decreased emissions if in a state that has good renewable mix in electricity generation, government incentives for buying the car, low maintenance, fairly quiet, savings from less fuel purchasing

Disadvantages of electric vehicles: if you are in a state that produces electricity mainly using coal you will not be decreasing your CO2 emissions much and in some cases you may even be increasing them, limited driving range based on charging stations, long recharge time, battery replacement is expensive and batteries can have environmental harm.

Depending on your patience I recommend either a hybrid plug in or fully electric. I have a plug in hybrid right now which I love to use for driving around SLO, but on longer trips the gas usage can get expensive. If you don't mind taking breaks on road trips, fully electric cars can be a nice excuse to take a break and go walk around for a while as your car charges. The time it takes to charge can be long, unless you have a Tesla and stop at a supercharger, so it really depends on your preferences.

c. Having the solar panels would decrease your emissions from charging your car at home. If you don't have free chargers close to your house (which you do at the hospital!), then it could also help decrease the cost of your charge. Since 1kWh can get you about 3 miles, it might take quite some time charging your car with the solar panels (1.6 kWh). And sadly, when you would want to charge your car overnight when you are sleeping, the solar panels don't provide much help.

d. Ideally I would like to continue living in SLO, teaching at SLO high school. The best case scenario would be living close to the school so I can walk (like I did everyday from 1st-12th grade as a kid). SLO high is also pretty close to downtown, so I could walk or bike most places. There are a lot of free charging stations, so I could use my electric car to get around if I needed to, while avoiding using gas. I could also get better at using the bus system we have here. If I didn't stay in SLO, I would move up north to a town that is fairly similar to SLO, so the circumstances would translate.

3. Average Californian uses 7000 kWh per year in their home, excluding transportation $\frac{10000\,mi}{yr} \cdot \frac{1\,kWh}{3\,mi} = 3333\,kWh/yr$

If I drive about 10,000 miles per year, and 1 kWh gets me 3 miles, I would need about ^ just for driving. Incident solar radiation in SLO is about 5.34 kWh/m2. Solar is 15% efficient $\frac{1m^2 \cdot 1day}{5.34kWh \cdot 0.15} \cdot \frac{10333\,kWh}{365\,days} = 35m^2$

Compared to the land use needed for conventional fuel, I feel like this would be less. It is still a lot of land, but a good portion of this would fit on the roof of my house if I owned one.

a. In order to live fully on solar, I would need to own my own land. Then I would have the power to make my needed changes in order to fit the panels everywhere and potentially get off the grid.

4.

a. PV cells convert sunlight directly into electricity. There are 4 types of PV. The most common type uses silicon as a semiconductor. When sunlight hits this cell, electrons escape from their atoms. If conductors are attached to the positive and negative sides of the cells, an electric current can form.
Concentrated Solar Thermal Electric works by setting up reflectors that capture and focus sunlight onto some type of receiver. Within the receiver is usually a heat transfer fluid, which becomes steam through the heat reflected by the mirrors. The steam then turns a turbine to make electricity.
Concentrated PV works by using lenses and curved mirrors to focus sunlight onto solar cells.
All three have the ability to use solar trackers to maximize sunlight hitting them.

b. All have fairly low efficiency
PV: advantages – clean and silent electricity production, can be put on top of roofs so as to not take up more space, locally available, can be constructed to be almost any size, super cheap/ disadvantages- some of the material used to make the cells is toxic, can only supply electricity during the day (unless you have some type of storage)
Concentrated Solar Thermal Electric: advantages: could be used 24/7 if the mirrors were used to warm a molten salt which could them heat a fluid at night make steam/disadvantages: requires a lot of space, affects habitat it is on, can blind airplanes and fry any birds that fly through it
Concentrated PV: advantages – higher efficiency than other PVs/disadvantages – land use requirement, can only be used during the day, overall performance out of the la is lower than conventional PV

c. Ivanpah
Advantages – could provide 1000 jobs, 86 of which were permanent, $3 billion economic benefit, high electricity output
Disadvantages – environmental impacts on the desert, especially the desert tortoise and some bird species, requires burning of natural gas to commence each morning

5. Infrastructure

a. $2 trillion/126.22 million families = $15,845 per family. This does seem like a lot but if you account for time saved and fuel saved, I feel that over a couple of years this is a manageable amount to account for each family. Per person it is $6190.

b. The average American uses 500 galllons of gas per year, so about 1.36 gallons per day. There are 323.1 million Americans in the US. $\$1 \times 10^{12} \cdot \frac{1\,\text{gallon}}{\$0.25} \cdot \frac{1\,\text{day} \cdot 1\,\text{person}}{1.36\,\text{gallons}} \cdot \frac{1}{323.1 \times 10^{6}\,\text{ppl}} = 9103\,\text{days} = 25\,\text{yrs}$
But you also need to consider that this large of a tax would probably cause a decrease in fuel use so it would most likely take longer.

c. I would consider this a market mechanism, since they are changing the financial ability of people to afford fuel in order to lead to a desired result. I think this pricing would cause people to notice the change, and cause them to question what this change is caused by. In that regard, this does seem to be somewhat holding people accountable for the external costs. However, if the goal is to raise money, then gasoline may not be the best tactic to use, since it could lead to people buying electric cars, which still clog the roads. However, there is also a chance it could lead people to carpool more or take more public transit, which would help with the infrastructure issues, but probably not to the extent needed to avoid having to actually change the infrastructure.