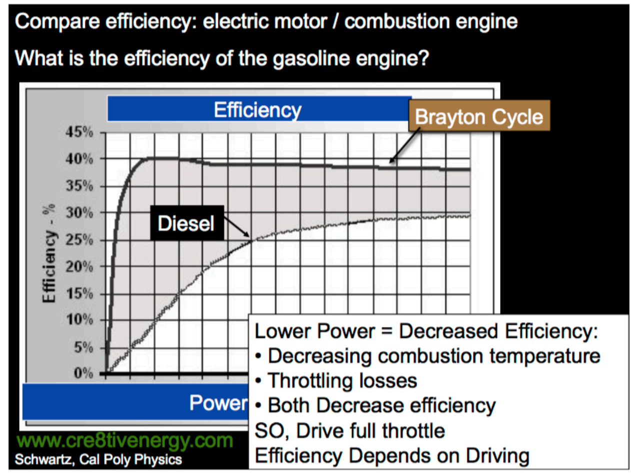
Wind, Transportation

Schwartz Problem Set #7

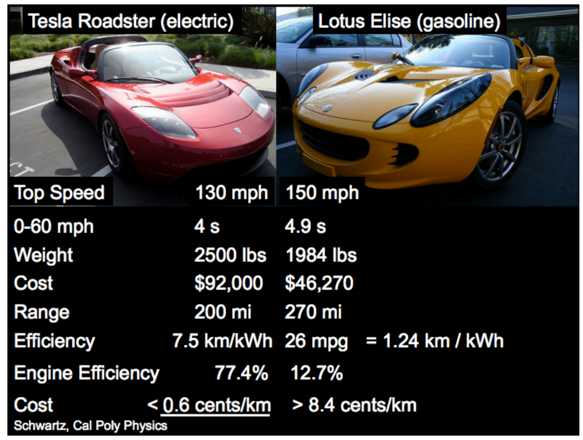
Due Monday, March 11



1. Why do ICE (Internal Combustion Engines) suck (gasoline so much)?
   a) Why is the efficiency so low? As illustrated at right, the reciprocating engine that we use in cars get very poor efficiency when they are idling or being used at a very low portion of their full power… when we choke off the air and most of the energy is just used to keep the engine going. Because we LOVE to have high super high power machines, for most of our use, the engines are just idling. To give some numbers to this, we might want to have a 200+ HP super car, but we only need 10 HP to keep the car driving at highway speeds.
   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? If we have an undersized engine, then
      - it is using a high % of its power just to move us around.
      - The battery can be used with a high efficiency electric motor when power demands are really low,
      - The battery can be used *with the engine* when power depand is high.
      - We can regard the battery with regenerative breaking whereby the electric motor acts as a generator turning the vehicle's kinetic energy back to stored chemical energy in the battery.
   c) How does having plug-in capability change the efficiency, cost, etc.? With PHE (plug in hybrid electric), we can have a larger electric motor and more batteries (increased expense), but we can charge the battery from the grid using electricity from NGCC, Solar (we hope), or Coal. This is much cheaper than gasoline and pollutes less as well (except for Coal, which pollutes about the same as driving with gasoline).

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 these kinds of cars the same? How are they different? Both Hydrogen Fuel Cell (HFC) and Battery Electric Vehicle (BEV) use electric motors. However, HFC creates electricity from hydrogen, where BEV uses batteries.
   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? The major expense in a BEV is the batteries. HFC is much more expensive, but it can drive much further and fuel up much faster than a BEV. However, this doesn't

matter to me because I'm never going to drive very far… additionally, there are no hydrogen refueling stations in SLO. So a BEV with small battery capacity will be inexpensive and provide me with all the range I need. If I need to drive far away, I'll need to rent a car.



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? This is perfect! I'll never have to charge my car from the grid. With 5 hours at 1600 W, I can average 8 kWh each sunny day. At 7.5 km/kWh, this would allow me to drive 60 km every day without using grid electricity. This will more than get me to the beach and back. I can even lend my car to my friend who drives for Uber Monday – Thursday! 60 km for free roughly corresponds to 2 gallons of gas every day, or about $6 and 20 kg of CO_2 if I actually drive the full 60 km. However, probably we won't come close to this full potential, because then we have to drain the batteries every time, risking running out of charge and getting stranded… imagine running up to someone's house with an extension cord asking for a 30 charge to get you home?

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 this place. Compare. Sigh, I'll probably still be here. My daughter will be a senior in HS and want a car. We live next to the HS, so I'll tell her to walk. My son will be 13 and probably logging 20 miles / day on a bicycle. He'll want a Tesla and I'll tell him to build something with the old electric motors kicking around the house. To have sanity, likely we'll have two cars. I'm guessing we'll still have our 1996 Outback (28 miles/gallon) and some electric car we'll get to play with and zip around town. Teenagers behind the wheel. I won't sleep well at night. The cars are helpful when it rains, is cold, when the trip is more than 3 miles away, when riding just isn't fun. The Subaru is financially and environmentally much more expensive, so it will almost never be used. We may get rid of the Subaru if it gives us trouble. We can always use Uber in a pinch. Public transport: I just don't see it in the area… I'd rather get rained on than sit in a bus. However, we take the trains/bus to SF and LA. If California could get reliable trains, it'd be way fun to take the train all the time. Hyperloop? Supertrain? I'm not banking on these.

3. You own a small wind farm and notice that when the wind blows at 3 m/s, you generate 20 MW.

a) About what will be your power generation when the wind blows at 6 m/s? Explain how you know this. This is a doubling of the speed. However, power scales like the speed *cubed*, so we will double the power *three times* yielding an increase of a factor of 2*2*2 = 8, and 8*20 MW = 160 MW… not bad, eh?

b) It seems as though they are always making wind turbines bigger and taller. "Go BIG, or go home." Please explain why we would want to do it rather than making many small, modular wind turbines like we do with roof top solar panels. There are economies of scale… in order to double the amount of power of a PV, you double the number of panels, doubling the cost. However, if you double the length of the blades of a wind turbine, the area (and power) increases by r^2, or a factor of 4. Does the cost increase by a factor of 4? Probably not because you still have a single (but larger) generator and tower. ALSO, when the tower is higher, the turbine is in faster and *more consistent, less turbulent* wind. And power scales like windspeed *cubed*. Thus for wind turbines, bigger is better!

4. 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. I don't agree too much with the student below… 25 cents per gallon will have little effect on consumption, in my opinion.
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? The external cost is that society pays for the roads through taxes that we don't pay for when we drive. If we paid when we gassed up, that would be a way for "the decision maker" (the driver) to pay for their decision. Electric cars?.. they get away tax free… seems unfair.

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. $\$1\times10^{12} \cdot \frac{1\text{ gallon}}{\$0.25} \cdot \frac{1\text{ day}\cdot 1\text{ person}}{1.36\text{ gallons}} \cdot \frac{1}{323.1\times10^{6}\text{ ppl}} = 9103\text{ days} = 25\text{ yrs}$
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. ✓