Assessment #2 PHYS-310. Please do all the problems. I only have to recognize that you know what you're doing.

1) Step #1: get rid of coal. There are at least 3 reasons that coal is the very very worst way to generate electricity. Please describe at least two environmental/health disasters associated with coal. Include both what happens when we use coal, and what it is about coal that causes this particular problem.

Coal is a solid with lots of impurities… some toxic, and some ash. Coal also has a rather low heat of combustion for the amount of CO_2 produced… or it has a "high thermal carbon intensity". Consequently, it doesn't work in a Brayton Cycle, so you can't get CC efficiency, resulting in electricity with three times the carbon intensity as NGCC, it produces lots of soot and criteria pollutants including mercury and sulfur with awful health/environment consequences it is estimated that for every person working in a coal mine, another person dies of respiratory disease every year. The mining of coal causes considerable health damage to the miners themselves. Lastly, the prolific amount of coal ash left over after burning coal is environmentally damaging, with a considerable number of associated disasters. For example: https://en.wikipedia.org/wiki/2014_Dan_River_coal_ash_spill

Some folks wrote that coal is full of mercury, NO_x and SO_x. Is this true? Coal is full of Mercury and Sulfur, releasing mercury and SO_2 or SO_3, making sulfurous or sulfuric acid (respectively). Where do NO_X come from? They are the result of nonequilibrium products from the extra hot combustion temperatures. Normally Nitrogen and Oxygen exist in diatomic molecules (their lowest energy state). However, when combustion is super super hot, these molecules break apart and produce NO_x compounds, which are a higher energy state, but they get cooled right away and so do not return to diatomic elemental states. So, NO_x are produced just when combustion is very hot – super high compression… SS jets, and suped-up race cars.

1. coal facilities (rankine) are very inefficient (~35%) so there is a lot of wasted energy

2. coal emits ~1kg of CO_2 per kWh whereas other methods, like NGCC are 1/3 of this.

health disaster → black lungs for miners. Their lungs are coated in toxins from mining for coal.

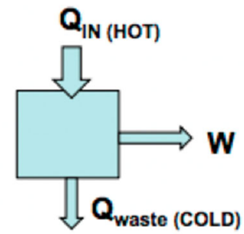
environmental disaster → huge amounts of CO_2 emitted.

Basically, coals chemical makeup alongside low efficiency of facilities makes for a lot of CO_2 emissions. It isn't actually "cheap" production when externalities (environmental disaster, deaths) are considered

2) You’re at an Earth Day event, and overhear someone ask, “we need AC electricity so everyone has cheap electricity!”

a) Please thoroughly explain and support this statement in the context of the last century.

b) Please describe why this may not be the case for many of the earth’s people, and/or for much longer.



   a) In order to win economies of scale, we ramp up the size of production facilities, so we need to transmit the electricity long distances, requiring HV (lowering current and resistive losses), requiring the ability to change voltages, requiring transformers, which require a changing magnetic field (Faraday’s Law), requiring AC.

   b) None of the above is universally pertinent any more. We have the capacity to change DC voltage, and actually HVDC is more efficient in transmitting power than AC is. However, we also don’t benefit from economies of scale as we once did. Solar electricity and other kinds of distributed generation is very cheap. Many places, especially the rural poor are opting to not have grid electricity because transmission and distribution is more expensive than generation now. Just check you electricity bill.

a) AC allows us to use an electrical grid to supply power to everyone. AC can be transmitted long distances b/c transformers use AC, as AC allows for induced voltage from change in flux. Transformers step up voltage to transmit over long distances and reduce power losses b/c higher V = lower I & power loss is I^2R. Basically, AC lets us transmit electricity over long distances w/ the use of transformers.

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b) DC has potential to take over b/c at shorter distances the power losses can be less than AC, so smaller areas can run on their own DC "grid." AC has more losses & introduces capacitive/inductive line losses, so DC is a potential for small grids in the future. lots of devices we use are DC as well, so a straight DC source could be better than using an AC → DC converter.

3) My daughter left her 1500 W turbo power hair dryer on over the weekend! 2 full days! Oh, the house was toasty warm when we got back to SLO (and so were the wires)! Estimate the amount of CO_2 this mistake emitted.

In California, the marginal electricity is almost always NGCC with carbon intensity about 1/3 $kg_{(CO2)}$/kWh:

I get about 1.5 kW * 50 hours * (1/3) $kg_{(CO2)}$/kWhr = 25 $kg_{(CO2)}$

It seems very few people read through the solutions to the second question on PS #3. This was a very easy problem if you just left answer in kWh.

toasty warm when we got back to SLO (and so were the wires)! Estimate the amount of CO_2 this mistake emitted.

1500 × 50 = 75000

48 ≈ 50

$1500\,W \times 2\,days \times \frac{24\,hrs}{1\,day} \approx 75\,kWhrs$

in CA, we use NGCC which emits 1/3 kg of CO_2 per kWh

$75\,kWhrs \times \frac{1/3\,kg(CO_2)}{1\,kWhr} = \boxed{25\,kg\,CO_2}$

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4) You find a hot springs of boiling water next to a glacier! You immediately set out to build a Sterling Engine to generate electricity from this thermal resource. The glacier cools the engine by melting, absorbing thermal energy at 9 kW, producing 1 kW of electricity!

a) Estimate the efficiency of your electricity production.

Conserving energy, we see the input power from the hot source must be 10 kW, Efficiency = 10%

b) A person publicly challenges you that his way-better-device is the opposite of yours: producing 9 kW of electricity while kicking out waste heat at only 1 kW. With a drawing and/or calculation, professionally, and politely explain to the people why they might dismiss his trash-talk.

Using the above math, we would calculate an efficiency of 90%. However, this is way more than the thermodynamic limit, or Carnot efficiency given these temperatures, or about 25%.

energy at 9 kW, producing 1 kW of electricity!

a) Estimate the efficiency of your electricity production.

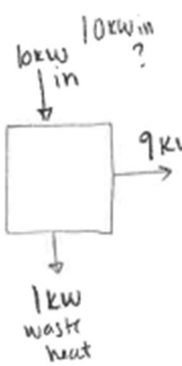
boiling water → $T_H = 100°C = 373K$ Carnot efficiency (2nd law)

freezing outside → $T_c = 0°C = 273K$

theoretical max thermal efficiency: $\eta_{th} = \frac{T_H - T_c}{T_H} = \frac{373-273}{373} = \frac{100}{373} \approx 37\%$

1st law efficiency → $\frac{W_{net}}{Q_{in}} \approx \frac{P_{out}}{P_{in}} = \frac{1kW}{9kW} = \frac{1}{9} \approx \boxed{10\%}$

b) A person publicly challenges you that his way-better-device is the opposite of yours: producing 9 kW of electricity while kicking out waste heat at only 1 kW. With a drawing and/or calculation, professionally, and politely explain to the people why they might dismiss his trash-talk.



→ output of 9kW

waste heat of 1kW

$\eta = \frac{9}{10} = 90\%$

however, as shown above the max carnot efficiency is 37%. 90% is above this, so already it is impossible to achieve.

· This doesn't follow the fundamental energy laws, specifically 2nd law

1. energy is conserved

2. heat flows from hot → cold

The efficiency he is proposing (1st law) violates what is actually possible to achieve when compared to carnot efficiency

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