CORRECTIONS ATTACHED ON BACK

look at his comments online

PSc-320 Midterm Name_____ A

1) What portion of the world's people live in US? 5 %

2) What portion of US population live in California? 35 mill / 325 mill 6 %

3) The United States consumes about what portion of the world's energy? 15 %

4) What is the power output of your body working hard for 10 seconds? 1000 W

* renewables means wind, solar, geothermal, small hydro…. *ALSO* because we don't list all possible generation forms below, they don't need to add to 100%

5) What portion of *US* electricity is generated by: Coal: 40% NG 20% Renewables* 5%

coal = 30%, NG = 33%, renew = 13%

6) What portion of *Cal* electricity is generated by: Coal: 0% NG 25% Renewables* 11%

NG = 50%, coal ≈ 3%, renew ≈ 25%

↳ technically we import some elec generated by coal

7) State total amount annual energy production/consumption for all USA 4.7×10²² J

$$\frac{15\times10^{19}\,J}{s}\left|\frac{3600\,sec}{1\,hr}\right|\frac{24\,hr}{day}\left|\frac{365\,days}{yr}\right. = 4.7\times10^{22}\ J/yr$$

1W = 1 J/s

1500 GW = 1500 × 10⁹ W

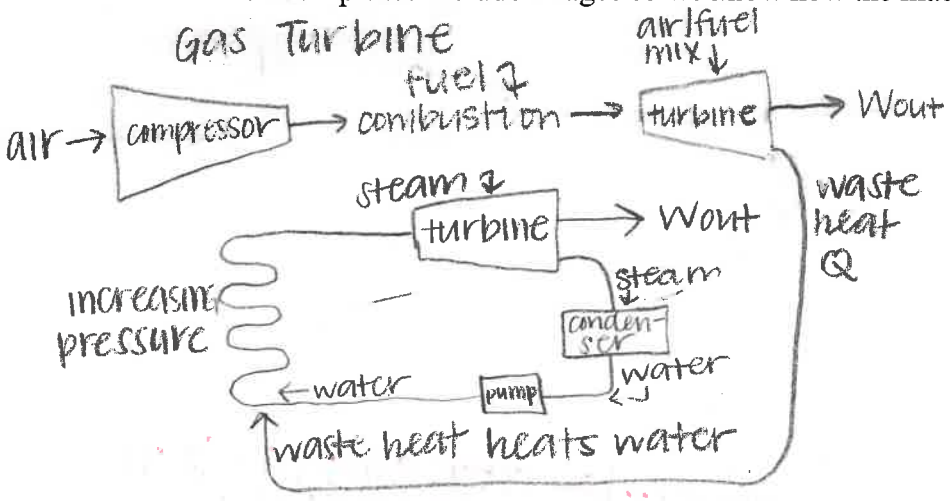
10²⁰ J/yr

Please put any relevant calculations for this on last sheet.

US uses abt 1/5 of world's energy

Some Longer Endeavors

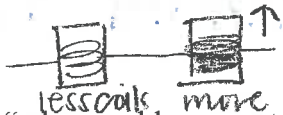
1) Please *explain and show* how a combined cycle electrical facility works with a drawing – not just a flow chart – please include images so we know how the machines actually work.



a combined cycle works by using the waste heat from a gas turbine to help create the steam for a steam turbine, which increases the efficiency of the system

☺

In a gas turbine, air is sent into a compressor which heats/pressurizes the air. Then it is sent to a combustion chamber where fuel is mixed in w/ the hot air, creating a highly pressurized gas. This gas spins a turbine to generate elec. The waste heat is then used to make steam in the steam turbine. Water is pumped & heated w/ this waste heat to make pressurized steam that turns a turbine to produce more electricity. The steam is condensed to water again to be used through the cycle again.

transformer  ↑ voltage ↓ current

less coils more coils

2) Your friend is curious about AC… "why would we want to have alternating current?" You explain to them that we need alternating current to have inexpensive, reliable electricity.
   a) Please explain why AC is necessary for us to have inexpensive, reliable electricity. Please include in your discussion economies of scale, transmission efficiency and transformers. Again, why do we need to have AC? Certainly, draw pictures to help explain anything you like.
   b) Now that you've convinced them that we *do need* AC, explain why we *actually* don't need AC anymore.

a) AC allows us to produce high voltage electricity. Since we require so much electricity, we have designed our infrastructure so that we have LARGE plants that produce a large amt of electricity. But this then requires us to transport this electricity long distances so it can reach everyone. In order to decrease power loss over long distances, we use transformers. These allow us to take the elec. from the power plants & ramp up the voltage so the current decreases (& thus decreases resistive losses since $I^2R = P$ lost). Then when it reaches the needed area, a transformer decreases the voltage so it can be used in a building. The US's transmission system is ≃ 93% efficient, much higher than it used to be. At the time, we did not have the technology to easily change the voltage of DC, so we created our infrastructure based on AC.

b) However, now we do have the technology to transport DC long distances & convert it to usable electricity in homes. DC has a much smaller power loss over extremely long distances so in these cases, it is better than AC. Also, with our increased use of renewables (which create DC electricity), we would be able to incorporate their usage w/ much more ease (since now we have to convert it)

wow!

3) Peaker plants:
   a) Why are they dirty and expensive?
   b) Why do we have them at all?

duty cycle? – how often a machine is on continuously

cycle

a) Peaker plants are usually single combustion systems. These are much less efficient & thus require a lot more fuel to produce the same amount of elec. As a base load plant with an increase fuel usage, these plants pollute more & cost more – because of low duty cycle.

b) At times, our demand for electricity exceeds what base load (coal, nuclear) plants can provide, so we need to rely on these peaker plants to provide the extra electricity.

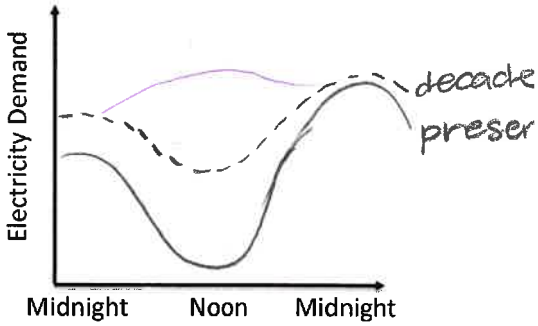
4) Explain how "the duck has landed".

a) At right, please draw the present load curve as well as one from a decade ago. Label each curve.

b) Presently, when (season and time of day) do we have peak load?

c) Why has the curve changed in the past decade, and what kind of problems do we foresee in the near future?

d) Explain what might happen to make this work… to make the "problems" mentioned above actually opportunities?



b) we have peak load in the evening during weekdays (not weekend) (after 530pm) daily
The summer has a high peak load due to air conditioning

c) With our increase renewable use, the curve approaches, more so during the daytime to be times where we have negative load, so the demand is less than what is being produced. This is unfortunate because we will then have these plants running & producing elec (& thus wasting resources) when they don't need to be. But since these are base load plants, they can't really be shut down & turned back on after a few hours. We also can't then use this renewable elec at other times of the day when our elec. need increases.

d) To help fix this problem, or shift load. we need to find a better way to store renewable energy, such as the one Pete & his students made to heat water. This will avoid the issue of negative load while overall decreasing reliance on conventional fuel sources.

5) You hear someone complain that we now have a "smart grid" and that we have to pay different prices for electricity at different times – very confusing.

a) Please explain to them what a smart grid is.

b) Please explain why it's better to have many different time-dependent prices for electricity.

A smart grid helps encourage consumers to either shift or shed their load. By making electricity more expensive during peak hours, the goal is that consumers will use less at these times. Then, during the day or late at night, electricity will be less expensive. The overall goal is to even out the daily load instead of having these rapid inclines and declines throughout the day. making load match supply
This also helps shift the reliance on power plants. With a more even load, peaker plants will have to be turned on less. Also, when renewable energy is more available, then less conventional plants will be needed.

24.4 → 100 hrs

6) I left my lights on during a long weekend. I was gone 4 days and 4 hours and left all the lights on. They were the old incandescent kind because we find those new LED lights weird: 5 bulbs at 100 W each.

a) How much electrical energy was consumed by my mistake?

500W = .5kW

$.5\text{kW} \times (24 \cdot 4 + 4)\text{hrs} = 50\text{ kWh}$

a) About how much money did this oversight cost me if it happened in California?

$\frac{\$0.15}{1\text{ kWh}} \mid \frac{50\text{ kWh}}{} = \$7.50$

b) How much heat was rejected into the environment during the generation of this electricity?

60% - 65%

- If it happened in California: 33% efficient = NGCC

$Q_{in} = Q_{out} + W$

$\text{efficiency} = \frac{W_{out}}{Q_{in}}$

$W = 50\text{kWh}$

$.33 = \frac{50\text{kWh}}{x}$, $x = 151\text{ kWh}$

$Q_{out} = 101\text{ kWh}$

$151\text{ kWh} = Q_{out} + 50\text{kWh}$

$W_{out} = 60\%$ of Win

Heat = 40% of Win

$50\text{kWh} \cdot \frac{2}{3}$

$50 \cdot \frac{40}{60}$

30%-35%

- If it happened in West Virginia, the heart of coal country: 20% efficient

$W = 50\text{kWh}$

$.2 = \frac{50\text{kWh}}{x}$, $x = 250\text{kWh}$

$250\text{ kWh} = Q_{out} + 50\text{kWh}$

$Q_{out} = 200\text{ kWh}$

$W_{out} = 30\%$ of Win

$\text{Heat}_{out} = 70\%$ of Win

$50\text{ kWh} \cdot \frac{70}{30}$

c) How much CO_2 is this student's mistake responsible for emitting into the atmosphere?

- If it happened in California NGCC

$\frac{333\text{g } CO_2}{1\text{kWh}} \mid \frac{50\text{ kWh}}{} = 16650\text{g} \approx 17\text{ kg } CO_2$

- If it happened in West Virginia coal

$\frac{1\text{ kg } CO_2}{1\text{kWh}} \mid \frac{50\text{kWh}}{} = 50\text{ kg } CO_2$

100% Win → NGCC → 60% W_{out}

NGCC → 40% heat waste

d) What else was emitted into the atmosphere that we should be concerned about?

- If it happened in California

methane

NO_x

- If it happened in West Virginia

sulfure dioxide, particulate matter, mercury, nitrous oxides

$\frac{50}{x} = \frac{60}{40}$

$x = 50 \frac{40}{60}$

7) Hopefully in the above problem you held me accountable for the *marginal electricity* in California and West Virginia. What is marginal electricity, and why should I be accountable for it?

When our renewables cover our electricity needs, then everything is perfect. But when we as consumers turn on appliances & exceed the amt of elec. renewables can produce, then, for example, CAISO has to turn on more plants. This is our marginal electricity. We should be accountable for it so we are aware of the total (including external) costs, instead of ignorantly using elec. whenever we want.

8) The economist says, "In order for the market to work, the decision maker must bare the full cost."

a) In electricity use, who is the "decision maker"?

the consumer

externalities included

b) In our use of electricity, please give 2 examples of "external cost".

1 CO_2 emissions increase

2 opportunity costs of building more transmissions/power plants instead of having something else in those areas

c) How is electricity use subsidized?

Mining, processing fossil fuels are subsidized and since we use fossil fuels to generate electricity, it is also subsidized.

Renewables are also subsidized, just less so than fossil fuels.

nuclear subsidized by GOVT

d) How do these external costs and subsidies prevent the electrical "market from working"?

We as the consumers are not aware of the true cost of electricity. Thus we keep wastefully using it, and pressuring power plants to keep producing to meet our load, with almost no awareness of the environmental and economic consequences of our use.

For example, in question 6, if electricity cost more than $0.15/km the consumer would almost NEVER forget to turn off the lights

9) I have an idea that we can cool the environment by just turning heat in the air into electrical energy, thus "producing cold" as a by-product! How do you think this would work? Explain.

This wouldn't work. according to $Q_{in} + W_{in} = Q_{out} + W_{out}$, there is always waste heat produced - but

Also, by the 2nd Law of thermodynamics (entropy), this process is impossible. because $Q_c \Rightarrow$ colder

wouldn't work b/c of 2nd law of thermo

10) We are closing Diablo Canyon!

a) How much power is this taking off the grid? What portion of Cal's electricity is that?

↳ ≈ 2GW ↳ ≈ 6%.

b) Someone says, "That doesn't matter, we have all kinds of power sources on the grid. We'll do fine." Please explain how this may affect our state:

① - What affect will this have for the other facilities over the course of the year? What effect (if any) will this have on our state's emissions?

② - What affect could this have for peak electricity use?

① 6% of our electricity consumption is a large amount. With the removal of this, we will have to rely on the existing power plants even more. During the summer, there may even be times where we cannot supply enough elec. to meet demand, causing black or brown outs. Unless, by some magic, renewables become our main source of electricity, we will have to increase our reliance on fossil fuel plants or imported electricity. This increases CO_2 emissions in the use & transport of these fossil fuels.

② Our use of peaker plants will also increase since we will be removing a base load power plant. Peaker plants are much less efficient & thus pollute more & cost more, hurting both the economy & environment a little more.

*Please use this sheet for extra calculations and/or room to explain. **PLEASE** put a note by each related question so I know to look here for the extra work!*

PSC 320 Midterm 1 Corrections

Fill in the Blank

5% of the worlds population is in the US (325 million/7.5 billion)

11% of the US population lives in CA (35 million/325 million)

The US consumes about **20%** of the world's energy

The power output of my body for 10 seconds is between 500 and 700 W

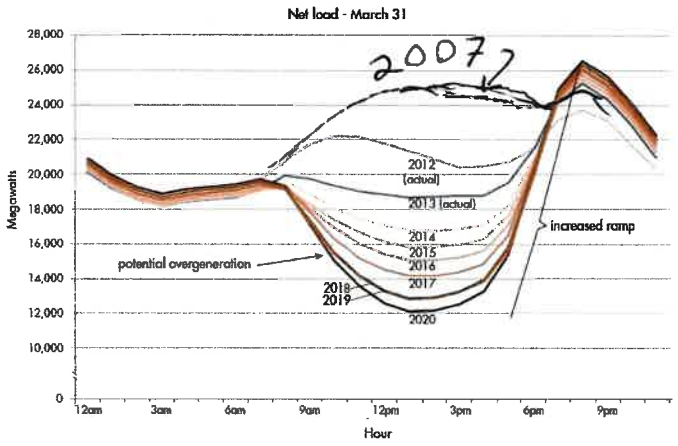
US electricity generated by **30% coal, 33% NG, 13% renewables**

CA electricity generated by **50% NG, 3% coal (imports), 25% renewables**

The total annual energy production/consumption for the US is about **10^{20} J (1/5 of the global production of $5*10^{20}$ J)**

Short Answer

1. See original midterm
2. See original midterm
3. See original midterm
   - Also note that peaker plants have a low duty cycle which means they are not on continuously for long periods of time which increases their price.
4. Duck Curve



   - A decade ago renewables were not implemented in many large scale energy production systems. Therefore, for example, in 2012, the curve is not minimized during the daytime because solar wasn't prominent.
   - To fix this situation, we could find a better way to store renewable energy OR we could also shift the load so that there is less of an intense "ramp" during the evening.
5. Smart Grid
   - The smart grid is a network that involves constant communication between the suppliers and consumers of energy. Pricing can be updated constantly, giving consumers real time pricing that is based on the current demand for electricity. The main goal of this smart grid is that groups such as CAISO are able to match load to supply as accurately as possible. Not only does this prevent black or brown outs, but also reduces wasted electricity since the controllers are able to adjust electricity flow based on the time of day (instead of having a constant flow always). Using this new grid could allow for increased pricing during peak hours in order to make consumers aware of their electricity usage and encourage evening out of the load throughout the day, instead of having evening spikes.

6. Lights left on
    a. See original midterm
    b. NGCC is 60-65% efficient. Therefore the 50kWh produced is only 60% of the total energy that went into the system. Thus 40% of the energy that went in is dispensed as waste heat. (see image on original midterm) → $\frac{P_{out}}{Q_{cold}} = \frac{60}{40} = 1.5$ $Q_{cold} = \frac{P_{out}}{1.5} \approx \frac{50kW}{1.5} \approx 33kW$

    Coal plants are 30-35% efficient. Therefore, the 50 kWh produced is only 30% of the total energy that went into the system. Thus 70% of the energy that went in is dispensed as waste heat. → $\frac{P_{out}}{Q_{cold}} = \frac{35}{65} \approx \frac{1}{2}$ $Q_{cold} \approx 2P_{out} \approx 100kW$
    c. See original midterm
    d. Burning natural gas releases nitrous oxides (NO_x) into the atmosphere.
7. Marginal Electricity
    - Whenever consumers use electricity, the controller (ex. CAISO in CA) has to turn on more plants. At lower load times, the base load plants can usually cover the needed electricity. These plants are more efficient and cheaper. However, during the evening or summer, when load increases a lot, the controller must get electricity from other plants, usually know as peaker plants. These plants are less efficient and more expensive. However, when this happens, the base load plants also get paid the same as the peaker plants. The cost of electricity then increases.

    because of the 100% Duty Cycle
    - Essentially, the marginal electricity is the ~~amount of~~ electricity ~~that needs to be~~ added to the grid as consumers demand more electricity.
    - Consumers should be held accountable for this because then it allows them to become more aware of the impacts of their usage. We cannot ignorantly use as much electricity as we want but instead need to be aware when our electricity usage is burdening the grid.
8. The decision maker must bare the full costs
    a. See original midterm
    b. See original midterm
    c. See original midterm
        - Also note that in this new administration, subsidizing fossil fuels will most likely increase
        - Nuclear is also subsidized by the government.
        - As renewables become increasingly competitive, their subsidies have been decreasing.
        - All forms of energy are subsidized in some way to make them economically viable in the market. Otherwise electricity would be incredibly expensive.
    d. See original midterm

9. Producing cold as a by product
    - This product would NOT work. By the 2nd law of thermodynamics (entropy), heat must be a by product of any product that produces work, but this is producing cold as a byproduct.
    - Note: the definition of entropy is - a thermodynamic quantity representing the *unavailability of a system's thermal energy for conversion into mechanical work*.
10. Diablo Canyon
    a. Nuclear is actually closer to 9% of CA's electricity production
    b. See original midterm

This is the electricity generated because of the last consumer to turn something on... which means ~~it is~~ every consumer is responsible for this generation, because if any one of them shed load, that (marginal) electricity generator would be turned off.