TAKE-HOME MIDTERM EXAM

Energy and the built environment CRP 570.004/470.004

Total Points: 50 pts
Due Date: 3/18, 12 pm, in class. Late exams will NOT be accepted.

- *This exam is open book, open notes.*
- *It is a violation of UNM's code of academic honesty if you receive help or discuss the exam with other individuals, whether classmates or otherwise.*
- *Show all of your work. You will be given credit for intermediate steps and answers, as well as final answers.*
- *Be aware of correct units and significant digits Mark your answers clearly by circling/boxing them.*
- *Clearly state any assumptions (e.g., the price of gasoline, the energy content used for a fuel).*
- *Cite all of your data sources.*
- *Show all your work so that I can figure out where you went wrong, and award partial credit where applicable.*
- *Use scientific notation for writing very small or very large numbers.*
- *Your name must appear at the top of each sheet you turn in (and all must be stapled).*
- GOOD LUCK!

Short Answers (16 pts total)

1. List 2 aspects of the US's challenge of energy security, with respect to oil. (2 pts)
   - A large portion of oil reserves are in politically unstable countries
   - Large portion of energy imports are in the form of oil
   - Transportation industry is highly dependent on oil

2. A thermal power plant has a thermal efficiency of 0.35. If the plant is operating at its nameplate rating of 100MW, what is the rate (in MW) that heat is being rejected to the environment? (2 pts)
   - $\frac{100MW}{0.35} = 286MW$
   - Qin = Qwaste + W, Qwaste = Qin - W
   - 286MW – 100 MW = 186 MW

3. If a single wind turbine with a nameplate rate of 2 MW generated 4.95x10^6 kWh per year, then what is its capacity factor? (2 pts)

   CF = $\frac{Annual\ average\ energy\ (\frac{kWh}{yr})}{Nameplate\ x\ 8760\ hrs/yr} = \frac{4.95e6\ (\frac{kWh}{yr})}{2000kW\ x\ 8760\ hrs/yr} = 0.28$

4. Large hydroelectric power is sometimes thought of as an environmentally friendly energy source, but this is not quite true. Name **3** ways in which hydroelectric power generation results in negative environmental impacts. (3 pts)
    - Lifetime GHG emissions from the construction materials
    - Ecological (and social) damage from flooding of valleys to create reservoir
    - Lifetime emissions from decay of submerged biomass
    - Impact to wildlife/communities downstream due altered flow

5. Write the balanced equation for the combustion of propane (C_3H_8) in pure oxygen (2 pts). Give 2 reasons ways in which this equation is simplified from the more complex reaction that would take place in a boiler (2pts).
   $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$
    - In combustion in real conditions, the reaction occurs in air, which is 78% nitrogen gas. The high temperatures result in nitrogen oxides being formed
    - The fuel may not be pure with other reactants that combust
    - There may be insufficient oxygen, resulting in incomplete combustion

6. PNM's residential billing consists of two charges: a monthly fixed charge of $5.00 per bill, and an energy use charge of 0.09 $/kWh for the first 450 kWh, 0.11 $/kWh for each kWh between 450 – 900 kWh, and 0.16 $/kWh for every kWh over 900 kWh.
    a. The average American household consumes 11,000 kWh/year. How much would a such a household expect to pay PNM each month? Show your calculation. (2 pts)
       11,000 kWh/yr x 1 yr/12 months = 917 kWh/month
       $5 + 450 kWh x 0.09 $/kWh + 450 kWh x 0.11 $/kWh + 17 kWh x 0.16 $/kWh = 98 $/mo
    b. What is the purpose for having the price of electricity consumption increase as a household consumes more? (1 pt)
       It creates a dis-incentive for a household to consume more, which encourages energy savings, as well to compensate for the cost of more expensive peaking power plants needed to meet increased demand.

Long Answers

7. The information below is from a rural village in Africa that has 130 houses, with a population of about 1000 people. The table below shows the number of houses which utilize different fuel sources for cooking: (4 pts total)

	wood	charcoal	gas
# of houses	25	85	69
% of total	19%	65%	53%

a) List two advantages that there might be from cooking with wood instead of natural gas.(2pts)
   - *The villagers can gather it for free, so the only cost is the opportunity cost of their time.*
   - *There might also be cultural factors, such as the taste the smoke gives, or the greater power output from the woodfire*
   - *you don't need a special oven to burn it.*

b) List two advantages that there might be from cooking with natural gas instead of wood. (2 pts)
   - *It may be more convenient for cooking some foods*
   - *it is clean burning, so the health impacts of smoke are eliminated*

8. The village also has an isolated power system (not connected to the national grid) which is powered by a diesel engine generator. The generator operates at an efficiency of 22 %, and burns 7 gallons of diesel each day. (10 pts total)

a) If diesel has an energy density of 42 kWh/gal, how many kWh of electricity are generated each day? (2 pts)
   7 gallons/day x 42 kWh/gal x 0.22 = 65 kWh/day

b) If 45% of this generation goes to households (the rest goes to public lighting, schools, etc.) what is the annual electricity consumption per household in the village (kWh/household/yr) (2 pts)
   0.45 x 65 kWh/day / 130 hh * 365 day/yr = 82 kWh/year

c) Practical Action's *Poor People's Energy* suggest that a MINIMUM lighting standard for a household is 300 lumens, for 4 hours per day. How many hours/day could each household utilize a CFL (rated at 11W, 800 lumens) bulb? How about an incandescent bulb rated at 60W, 800 lumens? (4 pts)
   - *81.7 kWh/yr x 1yr/365 days = 0.22 kWh/day*
   - $\frac{0.22\ (\frac{kWh}{day})}{0.011kW} = 20hr/day$ *for the CFL (or 5 CFLs for 4 hrs/day)*
   - $\frac{0.22\ (\frac{kWh}{day})}{0.06kW} = 3.7hr/day$ *for the incandescent*

d) What might be 2 reasons why a household might choose to utilize a 60W incandescent instead of an 11W CFL? (2 pts)
   - *The incandescent has a much cheaper upfront cost. A person with limited income will probably value greater upfront savings, rather than long run savings*
   - *Maybe CFL's are not locally available or they are of low quality and burn out quickly due to voltage fluctuations*

- *Maybe the energy bill is a fixed rate, so electricity savings don't save the household money.*
- *Maybe the person isn't aware for the electricity savings.*

2. PNM currently has a pending proposal at the NM Public Regulatory Commission to retire 836 MW of coal capacity, due to haze-causing emission regulations. They have proposed to replace some of this coal with a new 177 MW natural gas plant, 40 MW of solar PV, and 134 MW of imported nuclear.

a) What is meant by a baseload power plant? (1 pt). Which of the power plants (coal, natural gas, solar, nuclear) serve as a base load? (1 pt). What aspects make them appropriate for base load plants? (1 pt).
   - A baseload power plant can operate at a high capacity factor (0.6-0.9) usually at a low variable cost in order to meet the portion of the demand curve that has little variability.
   - Coal, nuclear, and hydro tend to serve as base load plants, although hydro can have a fast ramp rate (rate in which it can increase output) and can also meet intermediate or peak demands.
   - High capacity factor and low variable cost

b) PNM proposed to install a 177 MW simple cycle gas turbine. If it has a capital cost of 917 $/kW, fixed O&M of 13 $/kW per year, and fuel cost of 3.60 $/MWh, what would the *annualized* costs be if it operates with a capacity factor of 0.4? Assume that PNM would borrow money from the bank at a rate of 7% annual interest, and the project has an estimated 20 year lifetime. (6 pts)
   - Capital = 917,000 $/MW x 177MW = $ 162e6. (1pt)
   - Putting this into the formula for uniform payments (annualized payments)
     U = $ 162e6 x [0.07 / (1- (1+0.07)^-20)] = 15,320,821 $/yr (1 pt)
   - Fixed O&M = 13,000$/MW per year x 177 MW = 2,301,000 $/yr (1pt)
   - Annual energy = 177MW x 0.4 x 8760 hrs/yr = 620208 MWh/yr (1pt)
     Fuel cost = 3.6 $/MWh x 620208 MWh/yr = 2,232,749 $/yr (1 pt)
   - Total annualized cost = annualized capital + fixed O&M + variable O&M
     Total annualized cost = 15,320,821 $/yr +2,301,000 $/yr +2,232,749 $/yr
     = 19,854,570 $/yr (1 pt)

c) What would the lifetime cost of energy be ($/kWh). (2 pts)
   LCE = annualized cost / annual energy = 19,854,570 $/yr / 620208000 kWh/yr = 0.03 $/kWh

d) Is there uncertainty in the prices used to estimate the lifetime costs? What could cause actual costs to change drastically over the life of the project? (1 pt)
   - Large variability in the price of natural gas
   - There may be a carbon tax within the next 20 years

e) How many MW of solar capacity would be needed to produce the same amount of annual energy as the 177MW gas turbine? Assume a capacity factor of 0.25 for solar in NM. (2 pts)

- CF = $\frac{Annual\ average\ energy\ \left(\frac{MWh}{yr}\right)}{Nameplate\ x\ 8760\frac{hrs}{yr}}$, $0.25 = \frac{620208\ \text{MWh/yr}}{y\ MW\ x\ 8760\ hrs/yr}$
- 620208 MWh/yr = *y* MW x 8760 hrs/yr x 0.25
- *y* = 283 MW

f) Explain why you think PNM isn't including more renewable energy capacity in their proposal? (2 pts)
   - Too expensive compared to price they are paying for natural gas/nuclear
   - Difficulty planning, due to intermittent nature of renewable – they would probably need greater capacity of intermediate plants that have high ramp rates that could ramp up/down quickly when wind/solar comes/goes.

g) In no more than 250 words, explain whether or not you would describe PNM's proposal as a hard or soft energy path. In your response, define hard vs soft path, and the pros/cons of PNM's plan. (5 pts)
   - Hard path uses high technology (e.g., nuclear) and large, centralized infrastructure (1 pt)
   - Soft path uses more accessible, modular and distributed technology (e.g., solar) (1 pt)
   - PNM's plan will likely have a higher return on investment for its shareholders due to cheap upfront for natural gas and current fuel prices. Nuclear will provide a cheap baseload to replace the coal.
   - PNM is locking itself in to continued dependence on carbon fuels, which will leave it vulnerable if/when carbon regulation is implemented.