Homework #2 - due Thursday, 9/17 by class time
bonus problems - due Tuesday, 9/22 by class time
5290 problems - due Thursday, 9/24 by class time

Readings for this homework assignment and upcoming lectures
1. Read lecture notes:
   • Part 1. Introduction to Energy
   • Part 2. Energy Perspectives
   • Part 3. Growth Rate and Hubbert’s Peak
   • Weston Chapter 1. Fundamentals of Energy Conversion

2. Watch the sequence of videos on Prof. Bartlett’s lecture on Arithmetic, Population, and Energy; the link to the videos is on the course website and on Canvas.
   [link to Prof. Bartlett’s Lectures]

3. Readings for the 5290 assignment (note the extended due date):
   • Part 4. Energy Economics

Homework Submission
• For this assignment, the homework is to be worked and submitted individually either in class or by dropping off at my office (room 831).

• If you use EES or Matlab for this assignment, then print out your file and solution and include this with your solution set.

• At the end of each problem, rank your confidence in the answer from 1 to 5; 5 being very confident and 1 being ‘a guess’.

Correspondence
• PLEASE include the course number (MEEM4200 -or- MEEM5290) in the subject line of any email correspondence.

Office Hours
• M 3-4, W 4-5, F 9:30-11:30, room 831; or by appointment

References
Homework #2 – Thursday, 9/17 by class time

1. Estimate the power required in the United States during the year 1050, in GW_e, and the energy consumed, in GJ, from the year 2010 to 2050 if the average consumption rate increases at an average rate of 3.2 percent/year. Start with the 1980 annual consumption.

2. Determine the average rate of increase for the total annual energy consumption in the United States from 1963 to 1983 and from 1983 to 2013.

3. If the world’s supply of fossil fuels is uniformly consumed over a 10-year period, find the ratio of the fossil-fuel energy release to the amount of solar energy absorbed by the earth for the same time period. In the determination of the amount of solar energy received by the earth, use the “solar constant” of 1395 W_m/m^2 as the incident energy flux at the earth’s orbital position. Assume that the earth receives solar energy as a disk and that 30% of the incident energy is reflected. Also determine the rate at which the sun is converting mass into energy. The diameter of the earth is 12,756,000 m and the distances from the sun to the earth is $1.49 \times 10^{11}$ m. [cite your sources of information]

4. The total solar insolation on the continental United States is estimated to be $1.87 \times 10^{15}$ W. A typical solar cell has a conversion efficiency of 10 percent. Using the 1990 consumption rate of electricity per year, determine how long it would be before the entire surface of the continental United States were covered with solar cells if all of the electricity were produced this way. Assume a constant electrical energy consumption growth rate of 3 percent per year.

5. Based on the data presented by M. K. Hubbert in his 1956 paper, the 1920 estimate of Texas crude oil production is 100 million barrels per year. The 1951 estimate is 1000 million barrels of oil per year.
   (a) What is the annual growth rate and doubling time for this period?
   (b) If this production had continued to grow at this rate, what would the rate of oil production been in 1980? How does this compare to the actual production rate in 1980?

   ![Figure 7 - Texas production of crude oil.](image)

bonus problems – Tuesday, 9/22 by class time

6. Estimate the power required in the United States during the year 2050, in GW_e, and the energy consumed, in GJ, from the year 2010 to 2050 if the average consumption rate increases at an average rate of 3.2 percent/year. Start with the 1980 annual consumption.

7. A 2007 magazine article states that consumption of fossil fuels will increase by 48% by 2030 due to increasing demand by China and India. What is the assumed annual growth rate from 2005 to 2030 used to generate this percentage increase? How does this compare to the Department of Energy projection?
8. The current heating bill for a large house is $1,600 per year. Determine the maximum price that could be paid for a solar heating system which will pay for itself in 10 years. Assume that the system supplies 80 percent of the space heating requirement and the final salvage value of the system is 50 percent of the initial investment. The available interest for the initial investment and energy payments is 7%, compounded daily, and that the annual heating costs escalate because of inflation at an annual rate of 2%/year. Also, evaluate the total annual heating costs during the tenth year if the solar system is not installed.

9. A replacement residential natural gas hot water heater is $700 while an equivalent solar hot water heater is $7000. Last year’s heating costs were $1200. Using a rate of inflation of 2% for a discount rate with a fuel cost escalation of 4%, what tax incentive value is required to make the present values of the two systems equal after 5 years of use?

10. Your neighbor lives in a 1500-square-foot older home heated by natural gas. The current gas heater was installed in the early 1970’s and has an efficiency (Annual Fuel Utilization Efficiency, or AFUE) of 65%. It is time to replace the furnace, and your neighbor is trying to decide between a conventional furnace with an AFUE of 80% which costs $2,200 and a high-efficiency furnace with an AFUE of 95% which costs $3,600. Your neighbor has offered to pay you $100 if you assist in making the appropriate decision. Considering the weather data, typical heating loads, and the price of natural gas in your area, make a recommendation to your neighbor based on convincing economic analysis.

11. If the capital cost of a 70-MW$_e$ gas-turbine power system is $200/kW$_e$, determine the total cost of energy (capital cost plus fuel costs) in $/kWh. The plant has a capacity factor of 25 percent and a plant life of 15 years with a salvage value of 35 percent of the original cost. The annual percentage rate for investment and payments is 8 percent per year, compounded daily. The plant efficiency is 35% and the fuel costs are $5.50 per million kJ.

12. A person pays $8000 for a solar heating system instead of investing the money in money-market certificates that pay an average of 6 percent/year, compounded semi-annually. The system is designed to operate for 20 years with an estimated salvage value of $3000 at that time. Determine the annual fuel savings required during the first, tenth and twentieth years that must be achieved in order for the system to break even over the twenty year period. Assume that the annual fuel cost savings will increase at a rate of 2% per year. Also, assume that the fuel cost savings realized each year could be invested at an annual interest rate of 7%, compounded daily.

13. A power plant has a nominal construction cost of $1,000 per kW$_e$ and a construction period of 9 years. Payments for the construction are made monthly and escalate at 6 percent per year. The anticipated capacity factor is 70 percent and the price for selling power will not escalate. The discount rate on construction funds and power payments is 9% APR, compounded daily. The operational life of the plant is 40 years and the salvage value negligible.

(a) Determine the future value/kWh at the end of construction.
(b) Determine the future value/kWh at the end of life.
(c) Determine the levelized capital cost in $/kWh.

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1There are 8766 hours in a year.