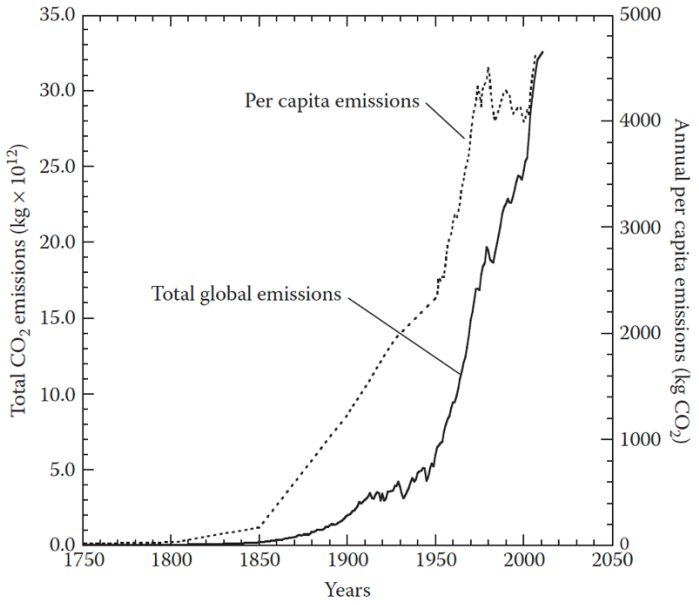
GRD – Weeks 1, 2, 3 – Exercises

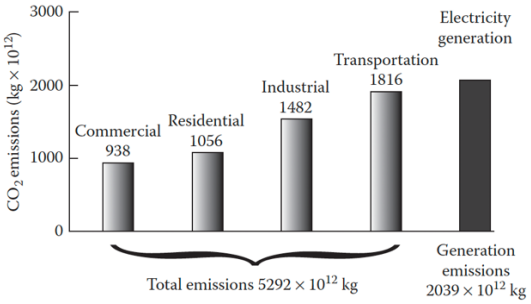
Due October 2, 2024, beginning of class.

1. From an environmental perspective, how does geothermal energy use differ from that of fossil-fuel systems? What are the benefits? What are the disadvantages?

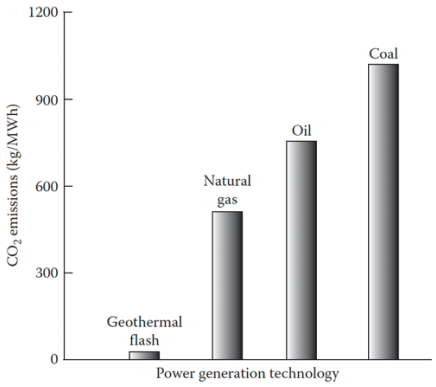
2. Assume that protocols are put in place to reduce global CO2 emissions to the levels in 1980. Using the data in the three figures below, suggest, ***quantitatively***, how this might be achieved. What assumption must you make to do these calculations?



Total global emission of CO_2 per year from 1750 to 2011 and per capita CO_2 emissions for the same period. (from Glassley)



The amount of CO_2 emissions from commercial, residential, industrial, and transportation sectors of the US economy in 2012. Also shown is the total amount of CO_2 emitted through electricity generation, which contributed to all of those sectors. (from Glassley)



CO_2 emissions (in kg of CO2/MWh) for different power generating technologies. Note that binary geothermal power generation produces no emissions. (from Glassley)

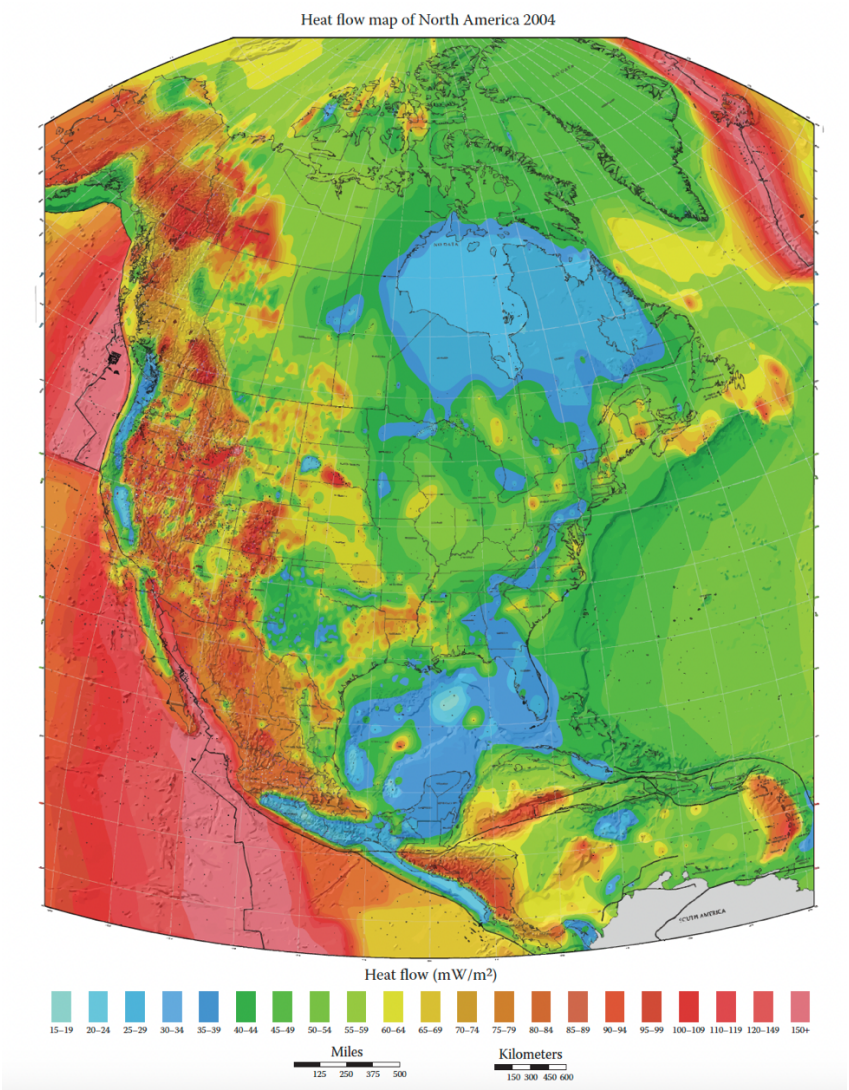
3. Assume a well is drilled in dry sand to a depth of 2800 m and the temperature at the bottom of the well is measured to be 200°C. Assume, too, that the thermal conductivity of dry sand is constant between 10°C and 250°C. Is there likely to be a geothermal resource in the area?

4. For a material that has a Rayleigh number of 10, what mode of heat transfer will dominate? For a value of 100? For a value of 10,000? Will this behaviour have any influence on heat flow measured at the surface of the earth? If so, what?

5. What are the geological hazards that might influence whether a geothermal resource is developed? Discuss this in terms of the geological environments that host geothermal reservoirs.

6. What would be better as a geological resource – dry sand or fully saturated sand?

7. Consider the figure below. What geological environment makes the Lesser Antilles islands in the Caribbean a promising place for geothermal energy development? What about Nicaragua?



Heat flow map of North America 2004. (from Glassley)

8. a) In a Carnot cycle involving an ideal gas that has a molar volume of 40,000 cm3/mole, assume that the initial pressure of the gas phase is 1 bar and the volume is 1 m3. What is the initial temperature of the Carnot cycle?

b) How much heat must be added to the system to achieve isothermal expansion to a pressure of 0.25 bar and a volume of 3 m^2. Assume that Cp = 1.02 kJ/kg-K and the density of the gas is constant at 1.2 kg/m^3.

9. What volume of water would be required to cool 1 m3 of a rock composed of 100% potassium feldspar from 300°C to 295°C, if the water starts off at 25°C and is allowed to increase in temperature by only 1 degree.

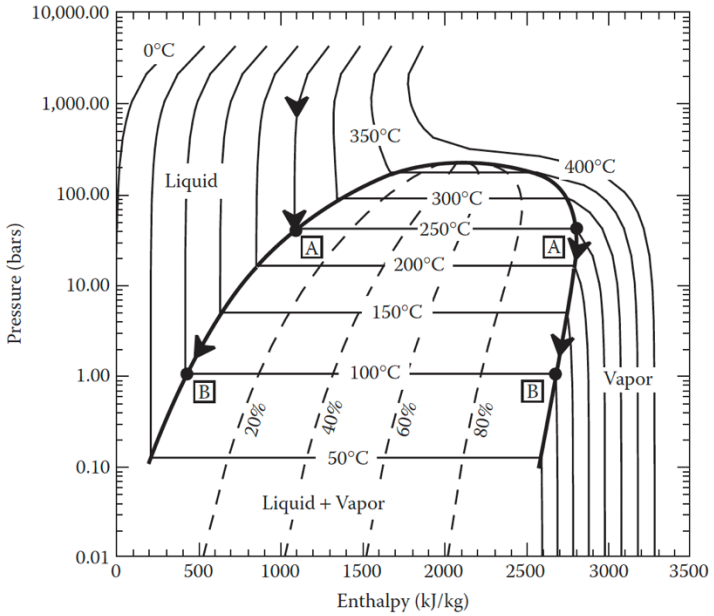
The heat capacity for potassium feldspar at 300°C is 1.05 kJ/kg-K; and the heat capacity of water at 25°C is 4.18 kJ/kg-K.

The gram formula weight for potassium feldspar is 278.337 gm/mole and is 18.0 gm/mole for water. The molar volume for potassium feldspar is 108.87 cc/mole and is 18.0 cc/mole for water.

10. a) If an ideal gas isothermally expands from a volume of 1 m^3 to 2 m^3 against a pressure of 1 MPa, how much work is performed and what is the efficiency?

11. a) If 10 kg of liquid water completely flashes to steam at a pressure of 10 bars, what is the total enthalpy available for work in the steam?

How much of the enthalpy would be used for work if the end point for the cycle is 50°C?



Pressure versus enthalpy diagram, contoured for temperature. The heavy black line encloses the region where steam and liquid coexist. The dashed lines are lines of constant mass percent steam coexisting with liquid water. The arrowed paths indicate the pressure-enthalpy path followed by a liquid at 250°C that ascends from 1000 bars and exits a wellhead at 1 bar and 100°C. (from Glassley)

12. a) What would be the internal exposed surface area in 1 m3 of rock that was cut by planar fractures with an aperture of 10 microns and which had a total fracture porosity of 10%?

b) What is the permeability of this rock?

13. What would be the total volume of water that would move through a conducting fracture over an hour if the aperture were 1 cm and the pressure gradient was 1 kPa per meter?