

**HOMEWORK #2**

*Assigned:* Thursday 9 February 2012

*Due:* 10 a.m., Thursday 16 February 2012

1. (10 points) The high capacity of water can be used to smooth the temperature variation over the diurnal cycle (day-time), and it has been suggested that one should try to do the same over the seasonal cycle (summer-winter), albeit with a much bigger tank of water in the basement.

Consider the case of a house with the following monthly heat budgets (in million BTUs for each month):

	Solar supply	Energy demand	Difference
May	3.718	1.643	+2.075
June	3.619	0.425	+3.042
July	3.995	0	+3.995
August	4.326	0	+4.326
September	4.661	0.938	+3.723
October	4.929	3.158	+1.771
November	3.766	5.706	-1.940
December	3.695	8.783	-5.088
January	3.959	9.494	-5.535
February	4.611	8.322	-3.711
March	4.901	7.258	-2.357
April	3.857	4.158	-0.301

First, show that there is just enough energy excess in the gaining months to cover the cumulated need in the losing months. (The house's solar heat gain and insulation were designed such that this would be the case.)

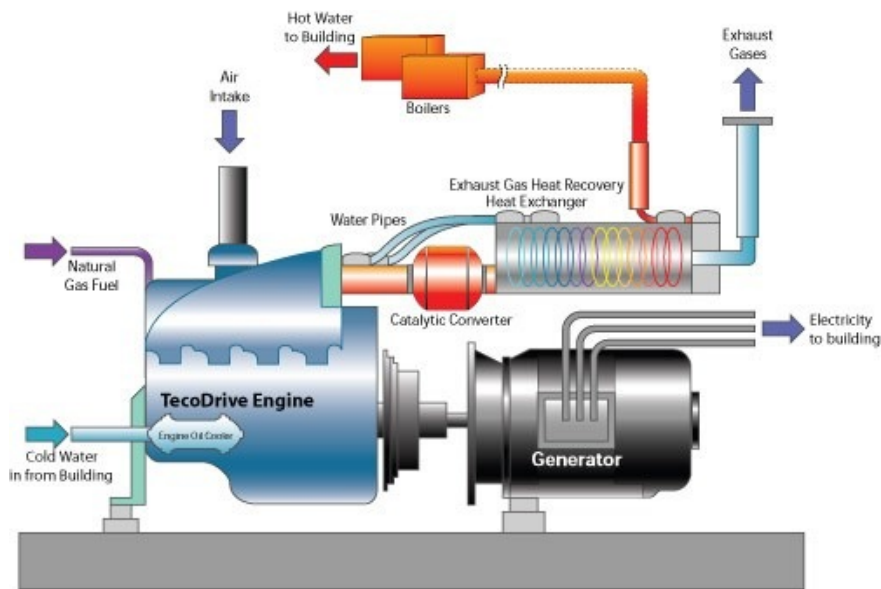
Next, imagine that the cumulated heat of the warm months (May to October) go to raise the temperature  $T$  of a volume  $V$  of water by a few degrees Fahrenheit each month, which add up to a 30°F temperature rise by the end of those months. Then, during the cold months (November to April), heat is gradually extracted from this heat storage so that by the end to the cold months the temperature excess in the water tank has been depleted. Determine the volume of water necessary to accomplish this.

What do you think? Is there enough room in the basement for such volume?



2. (10 points) State the heat budget for a thermal solar collector taking into account two properties of the glass pane: its albedo [fraction of sunlight reflected,  $\alpha = 0.12$ ] and its thermal conductivity [ $U = 1.2$  BTUs/(ft<sup>2</sup>·hr·°F)]. Denote the incident solar radiation as  $I$ . Once the budget is established, define the efficiency  $\eta$  as a function of the temperature difference  $\Delta T$  between the water inside the pipes (average between cold-entering and hot-exiting) and ambient air. Neglect heat losses through the bottom and sides as these are much smaller than the loss through the glass pane. Also neglect the infrared radiation emitted by the components inside the collector.

Plot the efficiency  $\eta$  versus  $\Delta T/I$ . Can it go to zero?



3. (10 points) Co-generation of heat and electricity as done on the campus of Dartmouth College is most often a great idea, but how does it play out at the level of a single house? To explore this possibility, imagine that the salt-box house used as an example in Prof. Cushman-Roisin's lectures has its typical oil furnace replaced by a gasoline generator, which is sized so that the electricity produced meets the demand of the house. The heat generated by the generator is partially captured and used to meeting a portion of the building's heating need.

Determine the fraction of the heating load in December that can be met by this form of co-generation if the residents' electricity consumption is 650 kWh for that month. Assume that gasoline yields 117.2 MJ of energy per gallon, and that the output of the generator is divided as follows: 30% electricity, 40% captured heat, and 30% heat lost to the outdoors by fumes through the chimney.

Compare also the cost of purchasing the electricity from the grid (at 17¢ per kWh) to that of purchasing the gasoline at the pump (at \$3.51 per gallon).



4. (10 points) To provide heat to a significant portion of the Dartmouth campus with geothermal energy, one would have to drill a relatively large number of wells, which is an expensive proposition, and this observation begs the following question: Why not use heat from the water flowing in the Connecticut River, which is free and flows by without any need for pumps? So let us ask: How much of the Connecticut River water would Dartmouth have to divert and then return at a slightly lower temperature, say 3°F colder, to meet half of its building heating need?

For the calculations, assume that Dartmouth has already lowered its building energy needs to an average of 50,000 BTUs per ft<sup>2</sup> per year for its  $5.8 \times 10^6$  ft<sup>2</sup> of buildings. Recall that 1 BTU is the energy that 1 lb of water releases when its temperature drops by 1°F, and that 1 ft<sup>3</sup> of water weighs 62.44 lbs.

Is there enough water in the Connecticut River for this? For flow rates in the Connecticut River, consult:  
[http://waterdata.usgs.gov/nh/nwis/uv/?site\\_no=01144500&PARAMeter\\_cd=00065,00060](http://waterdata.usgs.gov/nh/nwis/uv/?site_no=01144500&PARAMeter_cd=00065,00060)