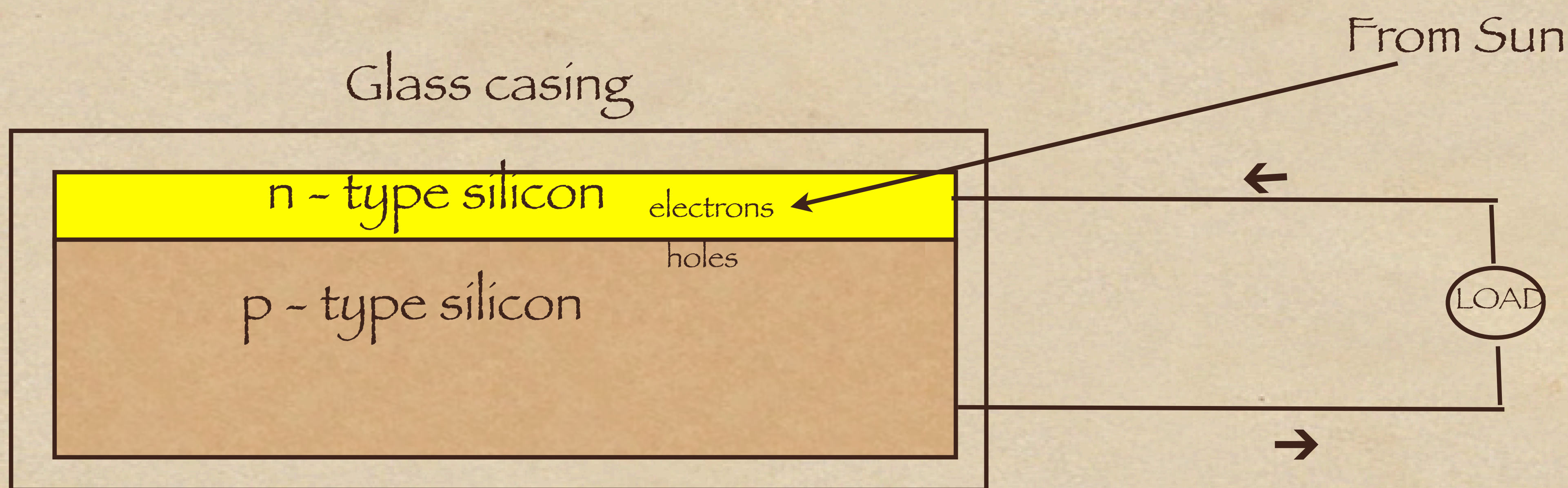
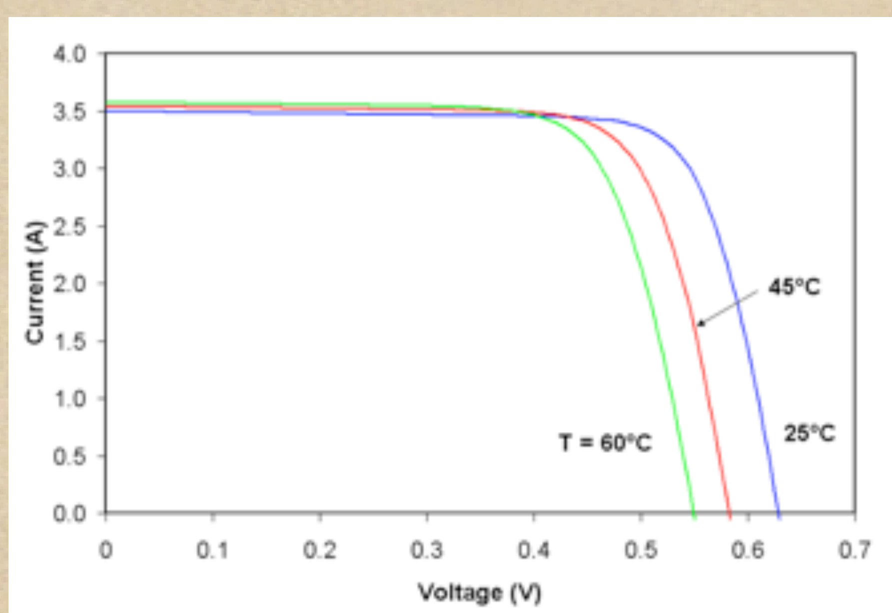
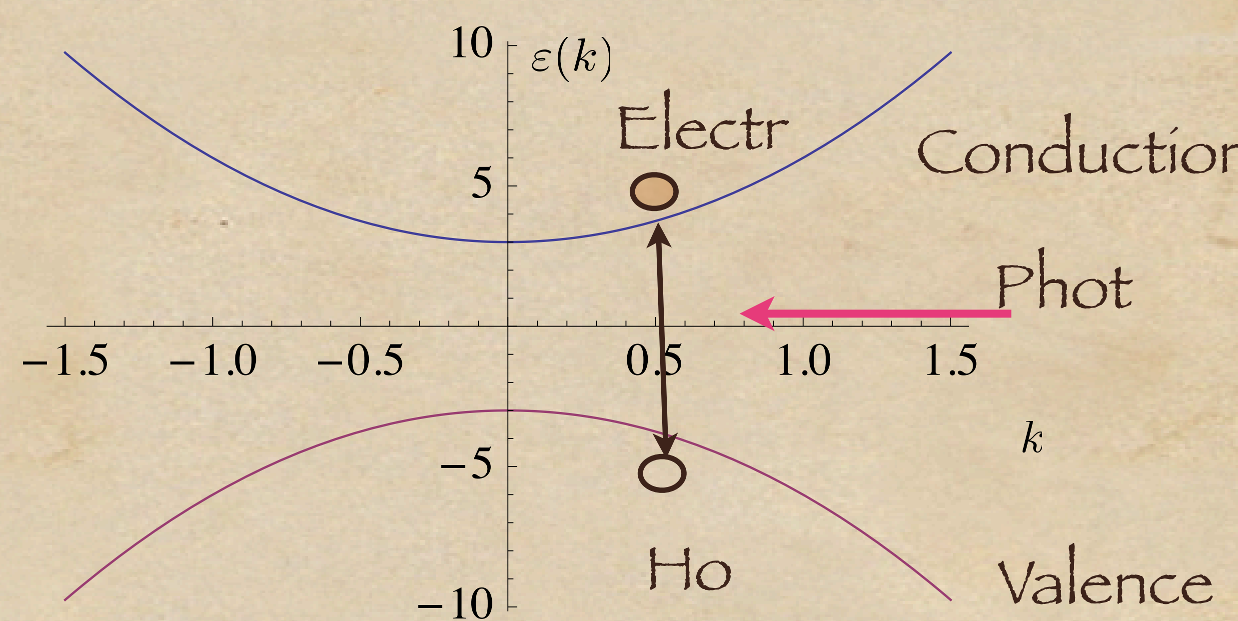
Lecture 21

May 21, 2012

Solar Cell Summary and an interesting problem







Question:

Assuming a solar insolation of 1000 W/sq meter and ideal conditions calculate the photon flux, i.e. the number of photons per square meter per second.

Calculate the total electrical current this can generate under ideal conditions.

We assume wavelength to be 5500 Angstroms,

Let ε be the photon energy

Let N_p be the photon flux, i.e. number of photons per square meter per second

Let N_t be the total number of photons per square meter in the day

$$\varepsilon = \frac{hc}{\lambda} = 3.6 \times 10^{-19} J$$

$$N_t = N_p \times 8 \times 3600 = 28800 \times N_p$$

$$Insolation = \varepsilon \times N_t$$

$$N_p = 10^{17}\ photons/sec\ sq\ meter$$

$$I = 2 \times N_p \times q_e = .032 Amp/sq/meter$$

Active & Passive solar power

Solar tech wrap up:
1) Active, i.e. we supply some kind of energy to extract more energy
2) Passive, i.e. we supply very little energy to harvest energy.

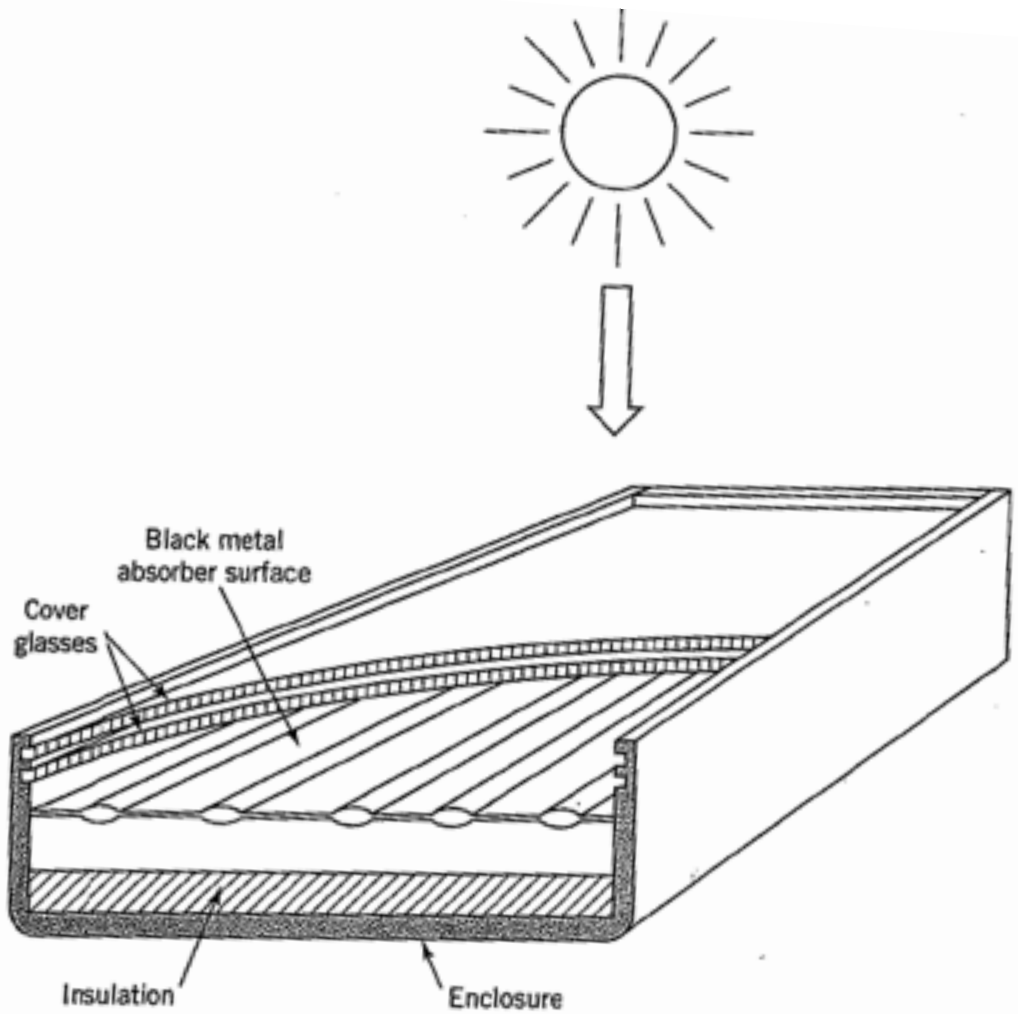


Figure 4.5 A cutaway view of a flat-plate solar collector with two cover glasses. A heat-transfer fluid is circulated through the tubular passages integrally formed into the metal absorber surface. (Not drawn to scale.)

Active: Flat plate Collector system with circulating liquid

- Water+ Antifreeze circulated through pipes
- Black metal absorbs heat
- Two glass panes inhibit loss to outside.
- Here "greenhouse" type physics helps since the black plate re-radiates at longer wavelength and is trapped by the glass.

From Wein's displacement law (microns):

$$\lambda_{max} = \frac{2898}{T(K)}$$

$$\lambda_{Solar} = 0.5\ microns = \ 5000\ A^0$$

$$\lambda_{Re-Radiant} = 8.5\ microns = \ 85000\ A^0$$

A more elaborate design with electrical back up and two heat exchangers (to avoid antifreeze in the potable water).

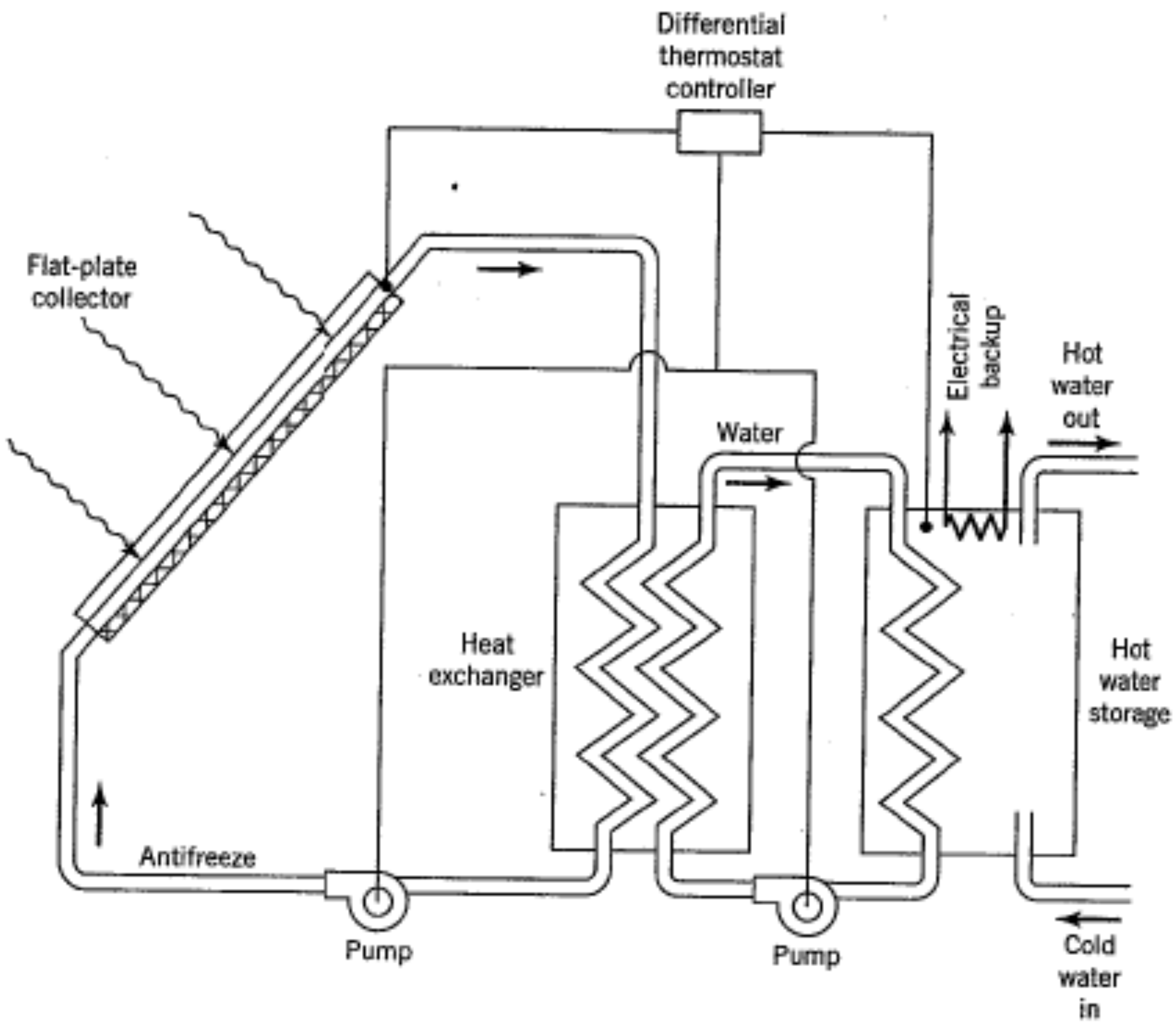


Figure 4.6 A circulating-liquid solar collector system that provides hot water for space heating and domestic use. In a typical installation the collector will be on the roof of a building with the other components in an inside utility area.

Passive:

South facing glass windows in homes.

A Sample Example:
Given that the daily insolation is 1000 Btu/ft^2, how much area do we need of solar panel to heat up 100 gallons water by 70^0 F?

Recall: 1 Btu heats one pound of water by 1^0 Farenheit, and one gallon weighs 8 pounds hence heat needed is

$$100\frac{gallon}{day} \times \frac{8\ lb}{1\ gallon} \times 1\frac{Btu}{^0F \cdot lb} \times 70^0F = 56,000\ \frac{Btu}{day}$$

Need 56 Sq ft. Usually efficiency is 50% so need 112 Sq ft.

Further ideas involve

- Tracking the sun to maximize input
- Focussing light on pipes that carry liquids rather than flat panels. This way we utilize all the light.
- Converting solar energy to electricity.
- Converting solar energy to produce H_2, O and CO using catalysis.

BARSTOW •

Retired Brig. Gen. Steven Anderson — who used to work for Gen. David Petraeus in Afghanistan — said the Barstow area could be at the forefront of a push to get renewable energy into the armed forces.

According to Anderson, Barstow has a climate that is very similar to Afghanistan's, with an abundance of both solar power and wind energy at its disposal. Anderson said that $20 billion a year in fuel was spent to air conditioning structures in Afghanistan and Iraq and technologies developed in the desert could reduce both the cost of fuel and the number of casualties of soldiers who protect the fuel shipments on their way to bases in Afghanistan.

He added that renewables developed in the Mojave Desert could be used in Afghanistan. "There are some profound natural gifts here."

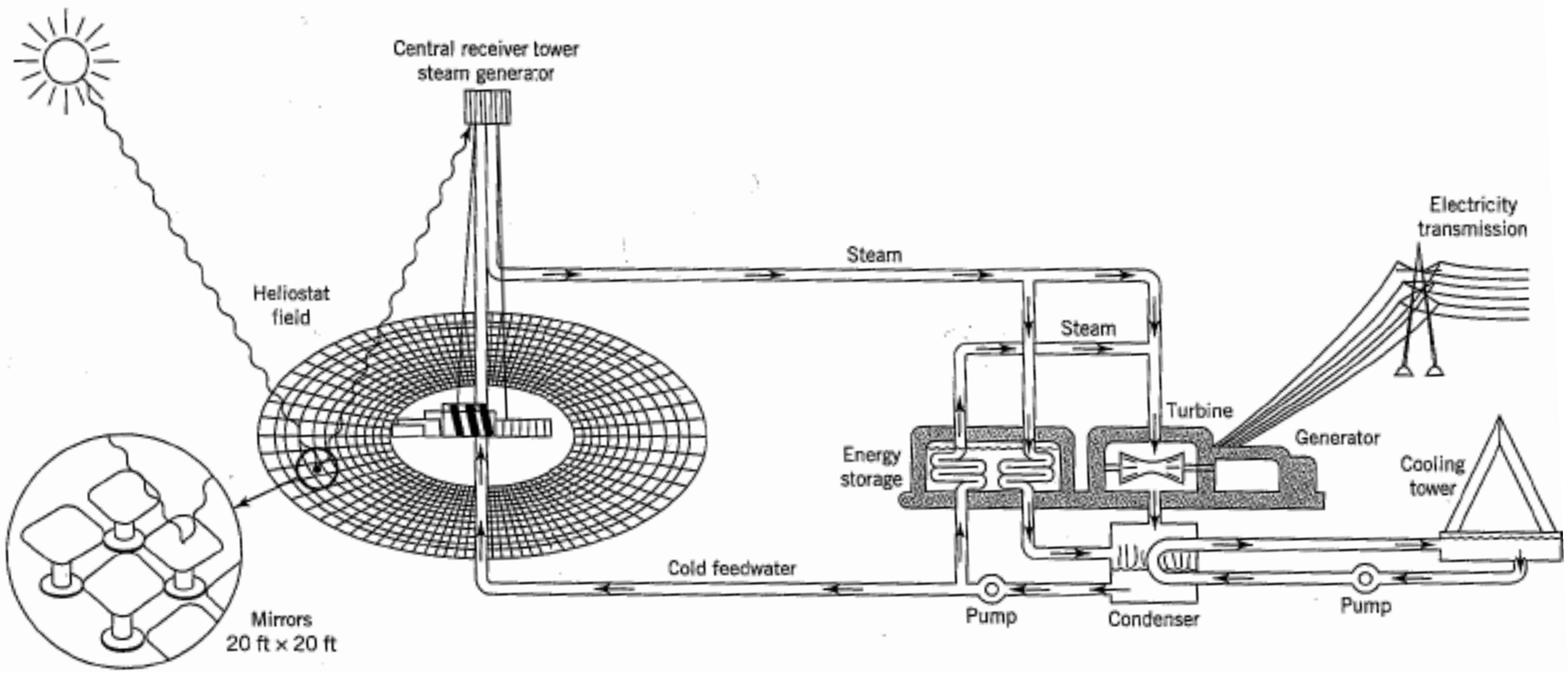


Figure 4.11 A schematic view of a 10 MW_e solar-thermal power plant near Barstow, California. The receiver and boiler that absorb the sunlight reflected from 1900 heliostats are at the top of a 90 meter tower. The heliostats are each steered by computer control to reflect the sunlight onto the receiver. The steam from the boiler can be either delivered directly to the turbine and generator or to storage. The storage system can provide steam for 4 hours of generation at a level of 7 MW_e without sunlight. (*Source*: Solar Energy Research Institute.)

Computer controlled mirrors focussing the sunlight onto one spot is the basic idea here.

10 MW full year around produces 8760 MW = 8.7×10^9 WH
Total Solar + PV in the US is around 1 THW= 10^{12} WH

Important table

Electric power statistics from DOE

Description	2009
Net Generation (thousand megawatthours)	
Coal[1]	1,755,904
Petroleum[2]	38,937
Natural Gas[3]	920,979
Other Gases[4]	10,632
Nuclear	798,855
Hydroelectric Conventional[5]	273,445
Other Renewables[6]	144,279
Wind	73,886
Solar Thermal and Photovoltaic	891
Wood and Wood Derived Fuels[7]	36,050
Geothermal	15,009
Other Biomass[8]	18,443
Pumped Storage[9]	-4,627
Other[10]	11,928
All Energy Sources	**3,950,331**

Thousand MHW= 10^9 WH

Thousand thousand megawatt hr= 10^{12} watthour= TWH where T=Tera

1 Quad= 293 TWH
100 Q= 29700 TWh

Total Generation = 3950 TWH
=134 Quad

Coal = 1755 TWH

Solar Thermal + PV = .891 THW

Fusion ideas 2010 Livermore Labs

Could This Lump Power the Planet?
Newsweek Nov 2009 and last year
Scientists at Lawrence Livermore National Lab are betting $3.5 billion in taxpayer money on a tiny pellet that could produce an endless supply of safe, clean energy.

This target chamber is 10 meters in diameter and weighs 287,000 pounds.
It contains small pellets of radioactive material (deuterium-tritium fuel) that are to undergo fusion.