Lecture 14

May 17 2011

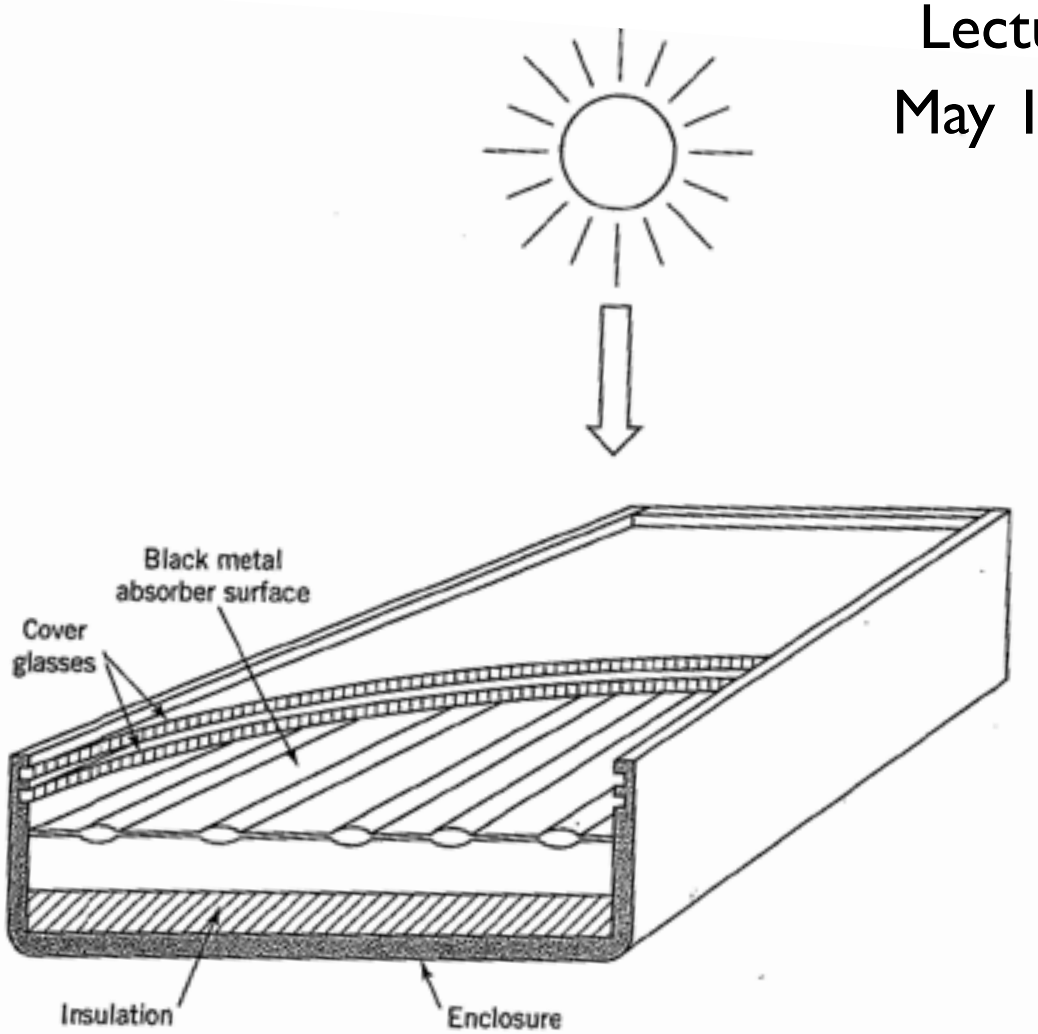


Figure 4.5 A cutaway view of a flat-plate solar collector with two cover glasses. A heat-transfer fluid is circulated through the tubular passages integrally formed into the metal absorber surface. (Not drawn to scale.)

Active & 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.

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).

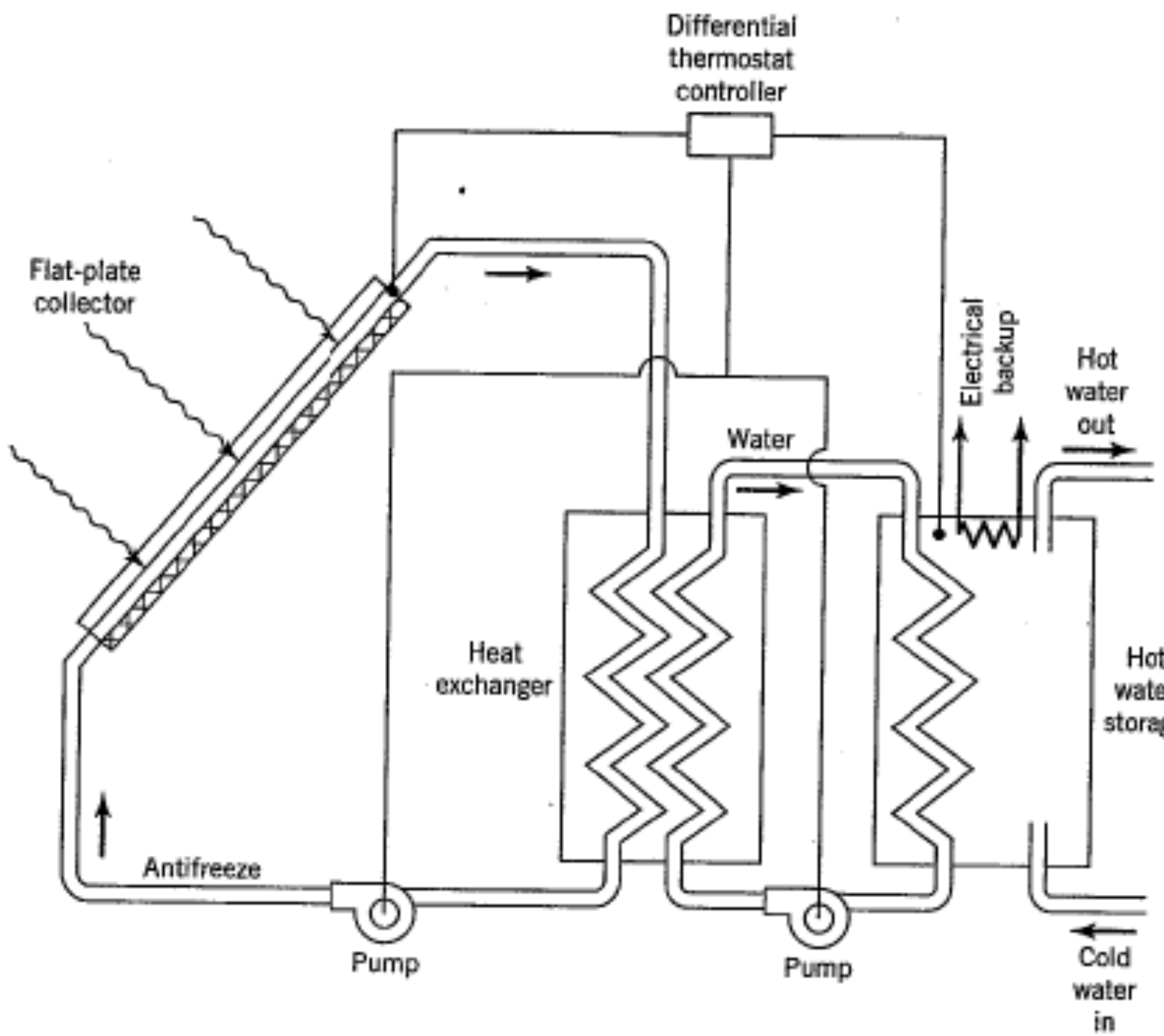


Figure 4.6 A circulating-liquid solar collector system that provides hot water for space heating and domestic use. In a typical installation the collector will be on the roof of a building with the other components in an inside utility area.

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."

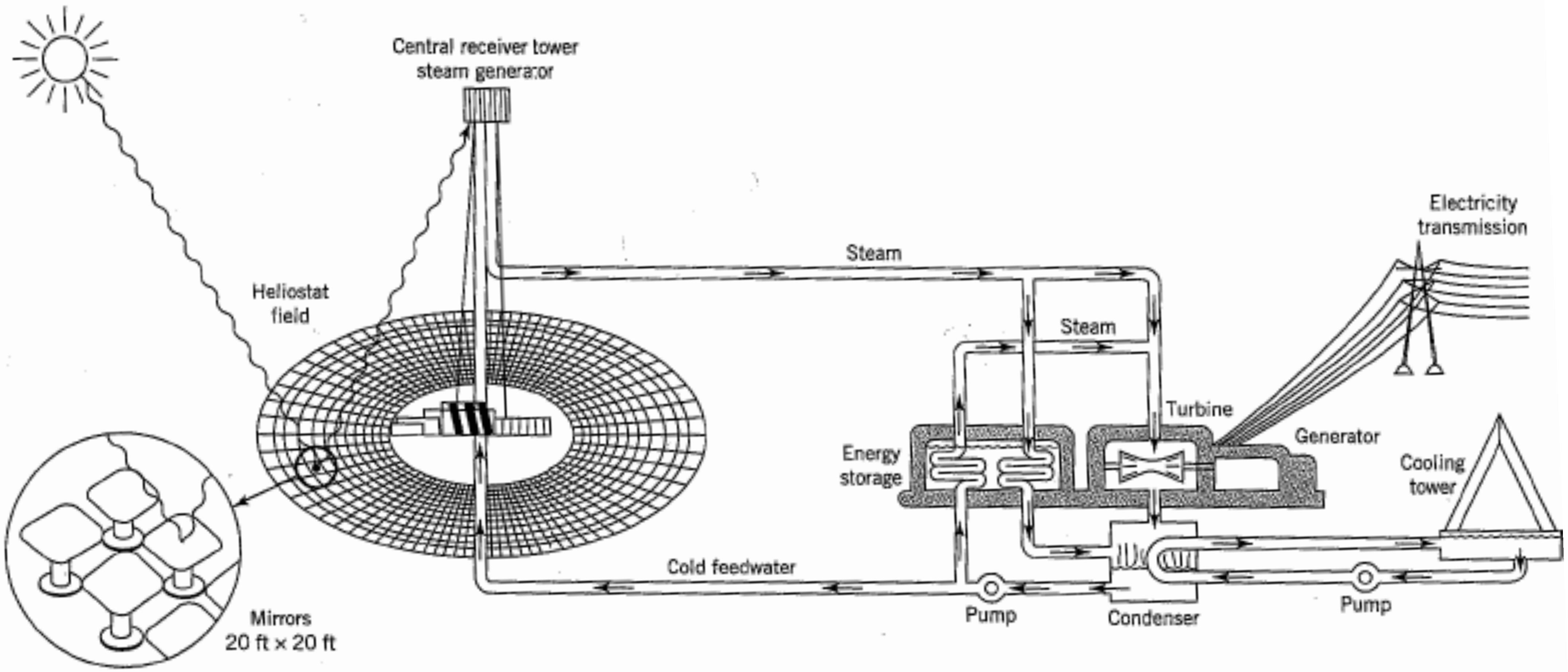


Figure 4.11 A schematic view of a 10 MW_e solar-thermal power plant near Barstow, California. The receiver and boiler that absorb the sunlight reflected from 1900 heliostats are at the top of a 90 meter tower. The heliostats are each steered by computer control to reflect the sunlight onto the receiver. 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

Thousand MHW= 10^9 WH

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**

10^{12} watthour= TWH

where T=Tera

1 Quad= 293 TWH

100 Q= 29700 TWh

Total Generation = 3950 TWH

Coal = 1755 TWH

Solar Thermal + PV = .891 THW

Fusion ideas 2010 Livermore Labs

Could This Lump Power the Planet? Newsweek Nov 2009 and last tear
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.

More prosaic but very useful applications for airconditioning airports in sunny cities

Heliodynamics @ Albequerque, NM

The Albuquerque International Sunport is a world-renowned, full-service airport facility that welcomes more than six million travellers per year. The Sunport Car Rental Center houses a number of major car rental companies which service the majority of the Sunport users.

We were commissioned to design and install a solar air-conditioning system which would provide both cooling and heating to the facility. With no available ground area for solar collection we placed our collectors on top of carports in the parking lot area. The system we designed and installed consisted of eighteen HD16 solar collectors. These feed heat to either an absorption chiller providing cooling or provide space heating to the facility.

Installed Capacity: 216 kW
Application: Air conditioning
Completion Date: Dec, 2009

Case Study - 2009

Albuquerque, USA

- 216kW
- Solar Air Conditioning
- Heating
- HD16 (18 modules)
- Roof mounted

HelioDynamics

ENERGYMIXX

HD16 Solar collector…

POWERFUL

• 16 suns concentration into the receiver.

• Generates up to 170°C steam at 8 bar pressure.

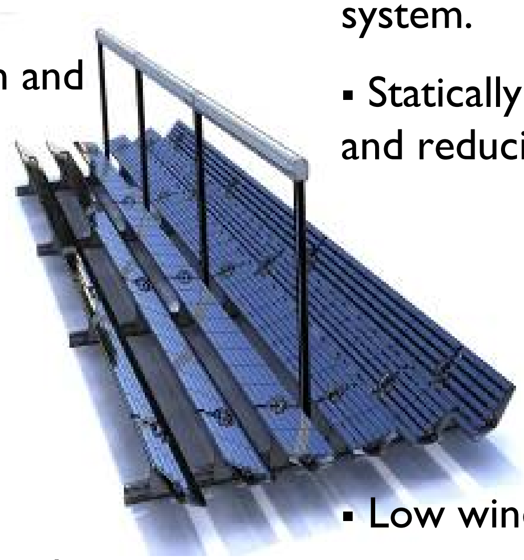
• High mirror accuracy thanks to design and structure.

SMART

▪ Mirrors inversion during night, cloud, hail or high wind.

▪ Higher energy output over a day due to tracking system.

▪ Statically balanced for low drive torque saving energy and reducing wear.



PRACTICAL

▪ Commodity materials lowers costs of production

▪ High adaptability to location constraints due to modular structures

▪ Light weight due to aluminium structure no need to reinforce roof spaces

SAFE

▪ Low wind profile. Hurricane rated.

▪ Thin tough flat glass for long life plus restricting reflection loss in case of break.

General Idea behind solar cooling

Exploit evaporative cooling cycles
i.e. Desert Coolers

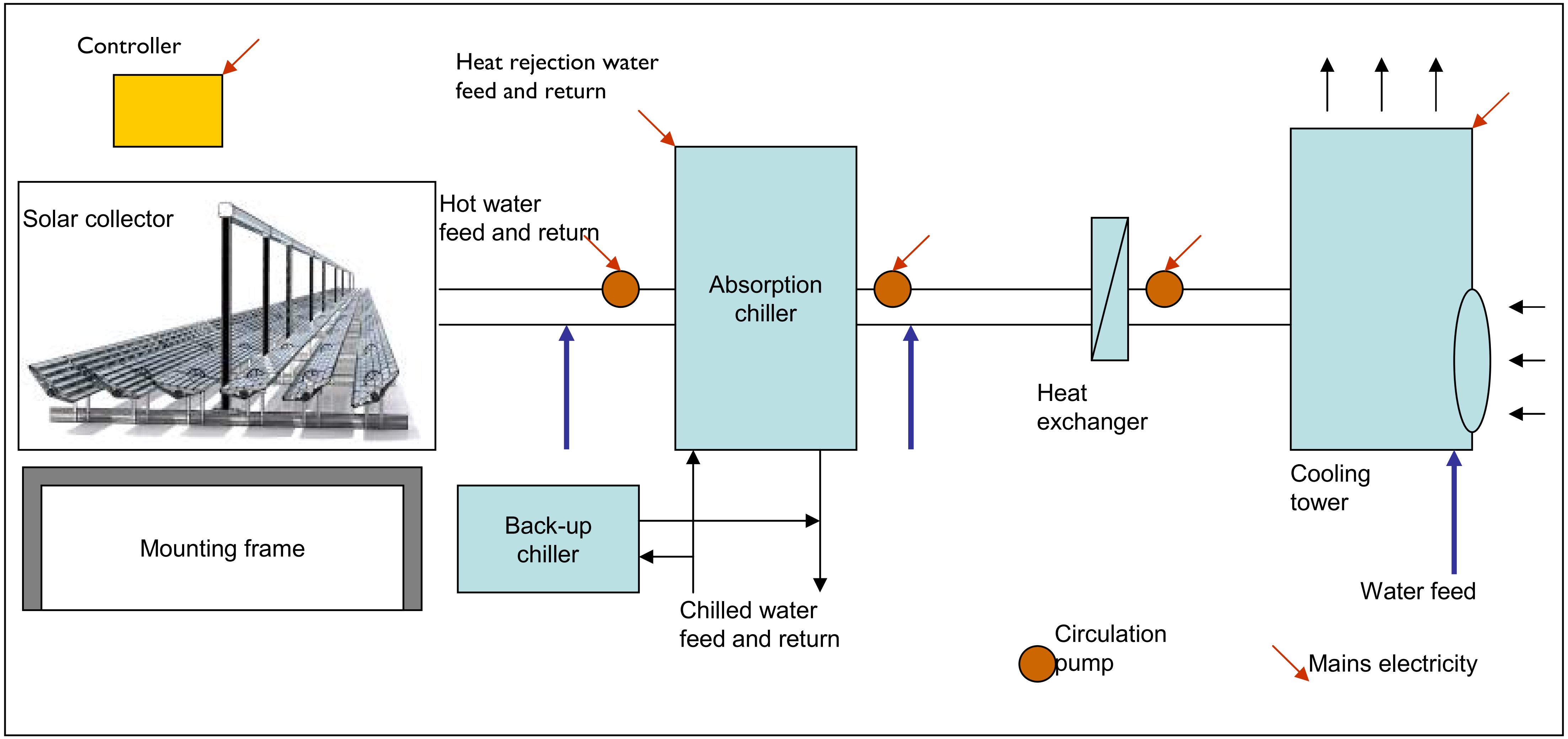
Active solar cooling wherein solar thermal collectors provide input energy for a desiccant cooling system:

Air can be passed over common, solid desiccants (like silica gel or zeolite) to draw moisture from the air to allow an efficient evaporative cooling cycle. The desiccant is then regenerated by usin solar thermal energy to dry it out, in a cost-effective, low-energy-consumption, continuously repeating cycle. A PV system can power a low-energy air circulation fan, and a motor to slowly rotate a large disk filled with desiccant.

The potential for near-future exploitation of this type of innovative solar-powered desiccant air conditioning technology is great.

HelioDynamics ENERGYMIXX

Solar chillers…

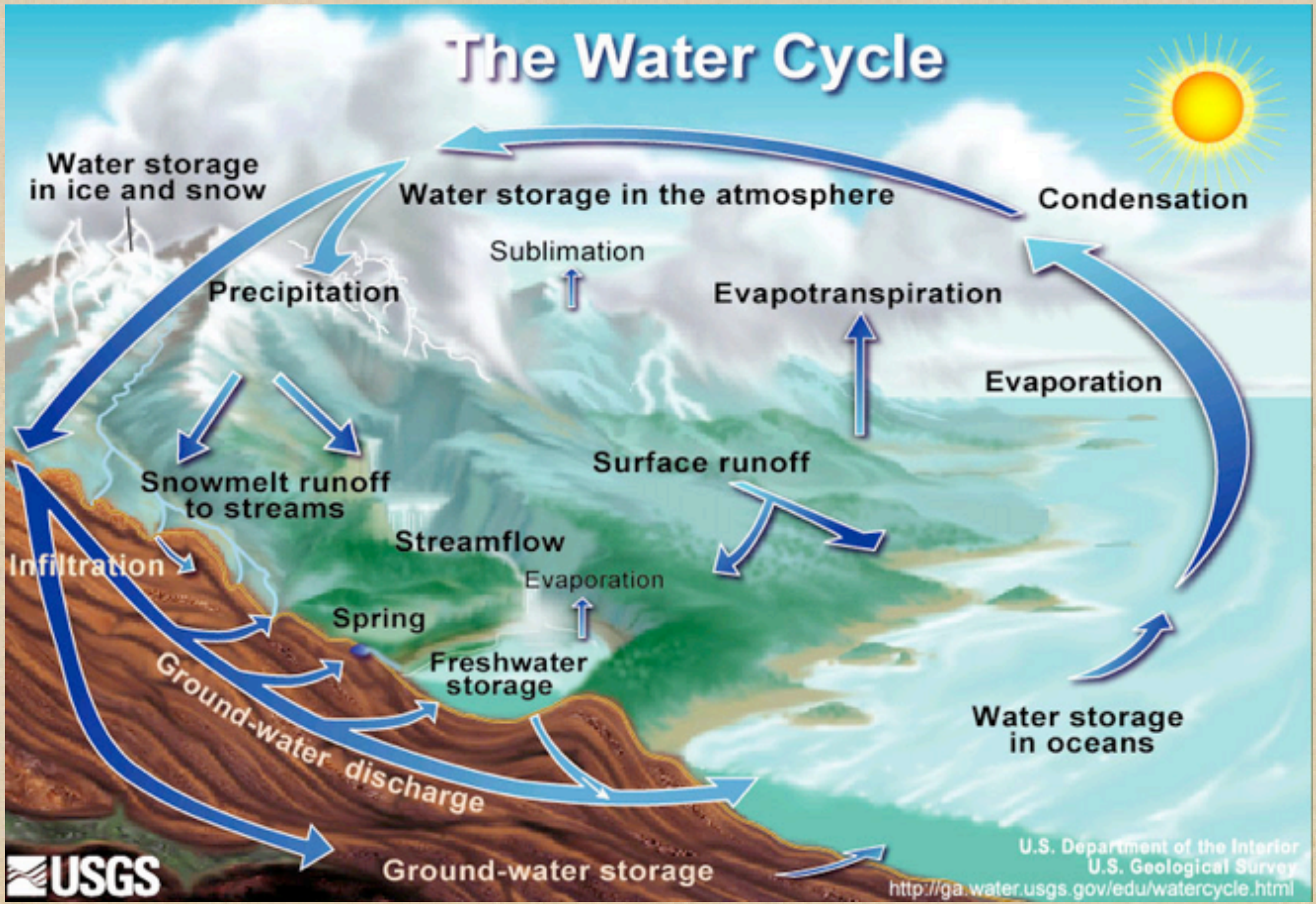


Renewable Energy sources

- Hydroelectric power
- Ocean derived power
- Tidal energy
- Wind power
- Geothermal energy
- Biomass

Hydroelectric power

- Hydel power per se
- Pumped storage systems
- Dead sea project and other examples



Water power is conversion of potential energy of water to electrical energy, e.g. by turning a turbine.

- 80% to 90% efficient
- Cyclical and weather (precipitation) dependent
- In USA currently less than 7% of total usage from 30% in post war years

Head= "h" the height of water

$$E = Mgh$$

Potential energy of water

$$g = 9.8 \text{ meter}/\text{sec}^2$$

Example: Water drops in a hydel project with a head of 90 meters. How much water flow is needed to produce 10 kW power, assuming 80% conversion efficiency?

Let x liters of water flow per second.

Hence mass flow is x kg/sec (using density of water - d =1 kg/Liter)

Power = energy /time = M gh/t = (M/t) g h

$$\begin{aligned} Power &= x(kg/sec) \times 9.8(m/sec^2) \times 90m \\ &= x \times 882\ kg\ m^2/sec^3 \\ &= x \times 882\ watts \end{aligned}$$

$$\text{Watt} = \text{kg}\ meter^2/\text{sec}^3$$

Next equate these:

$$0.8 \times x \times 882\ watts = 10^4\ watts \qquad x = 14.17\ Litres\ /sec$$

River discharge rates:

Amazon = 219 Million Litres/sec

= 219,000 m^3 /sec (1 m^3 = 10^3 L)

Ganges = 42 Mil L /sec

St Lawrence = 10 M L/s

Ohio - Missisippi = 8 ML/s

Problem:

If we can drop the Ohio river by 10 meters, what is the generated power?

$$Power = 8 \times 10^6 \ (kg/sec) \ \times 9.8 \times (m/sec^2) \ \times 10(m)$$
$$= 0.8 \times 10^9 \ Watts$$

$$Total\ energy\ per\ year = Power \times 365 \times 24\ Watt\ hour$$

$$Total\ energy\ per\ year = 5.6\ TeraWatt\ hour$$