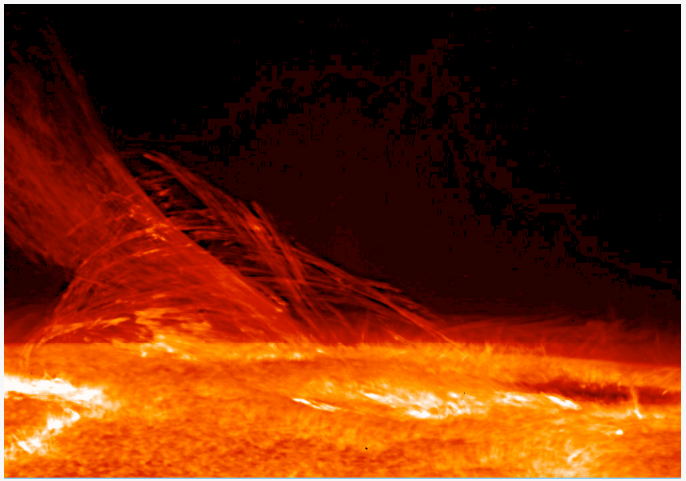
Introduction to Solar Energy

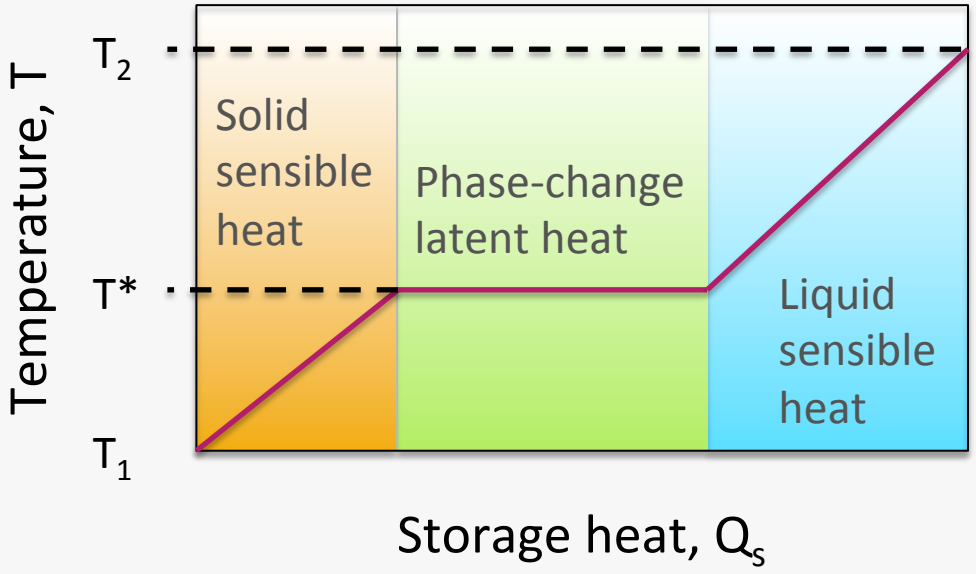
Solar thermal energy I: Basics principles

Week 6.2

Arno Smets

Heat





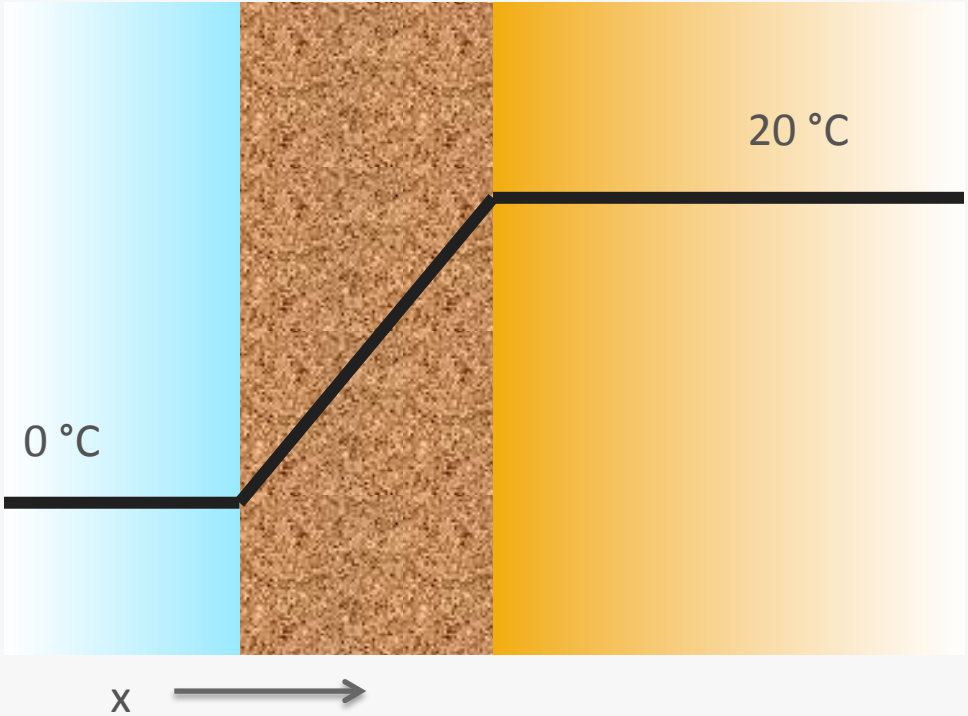
Sensible heat:

$$Q = mC_p (T_2 - T_1)$$

Latent heat:

$$Q = m\lambda$$

Conduction

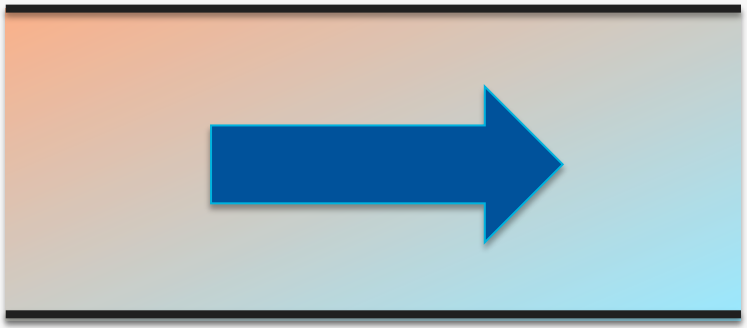


Fourier's law

$$Q\downarrow cond = -kAdT/dx$$

Convection

Forced convection



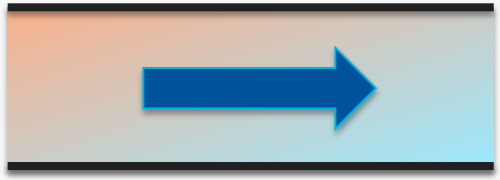
Natural convection

Convection

Newton's law

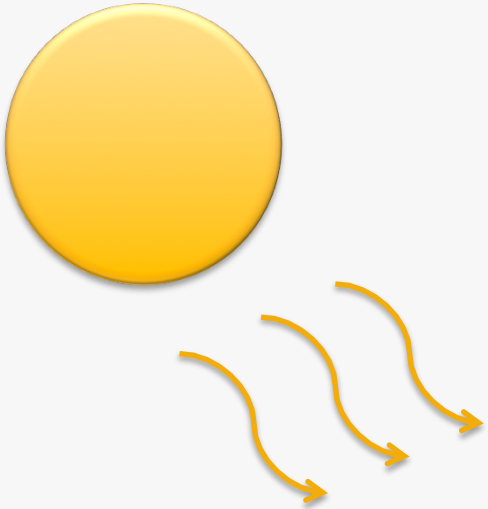
$$Q\downarrow conv = -hA\Delta T$$

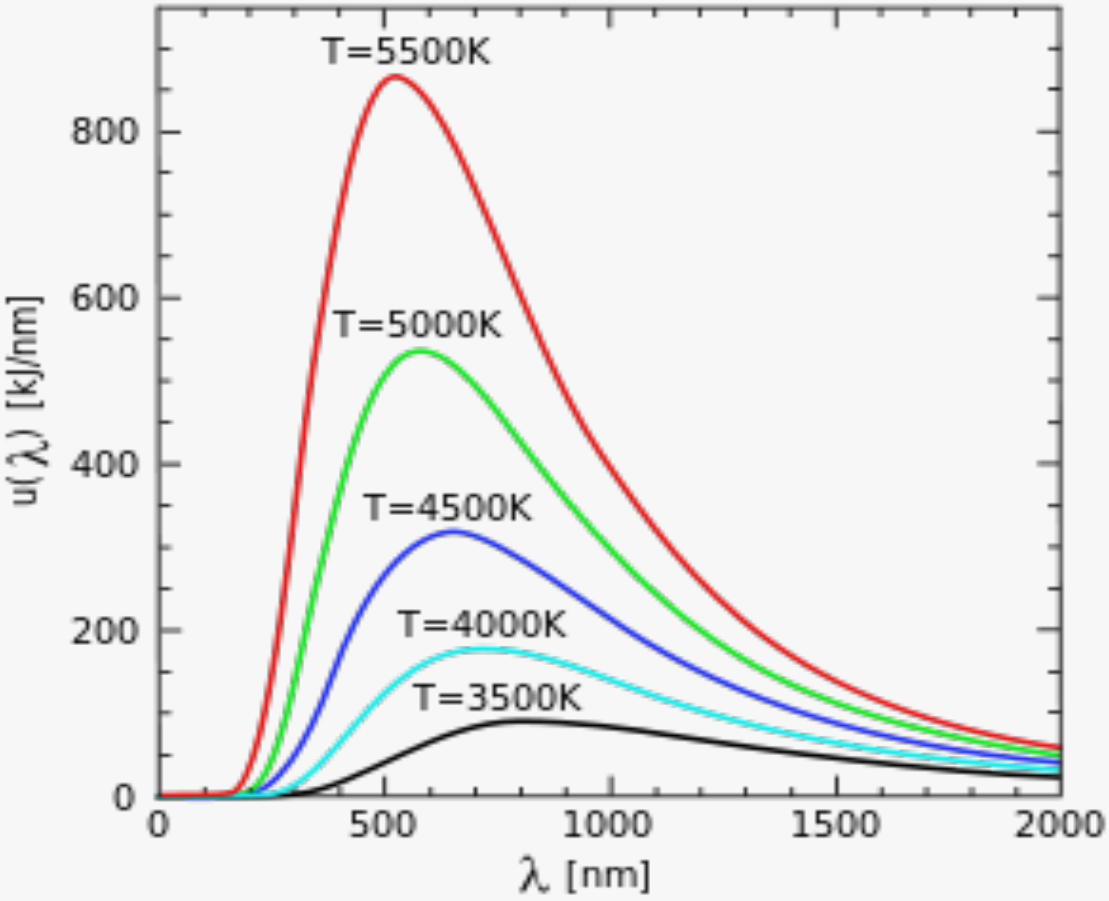
Forced convection



Natural convection

Radiation





http://en.wikipedia.org/wiki/Thermal_radiation

Radiation

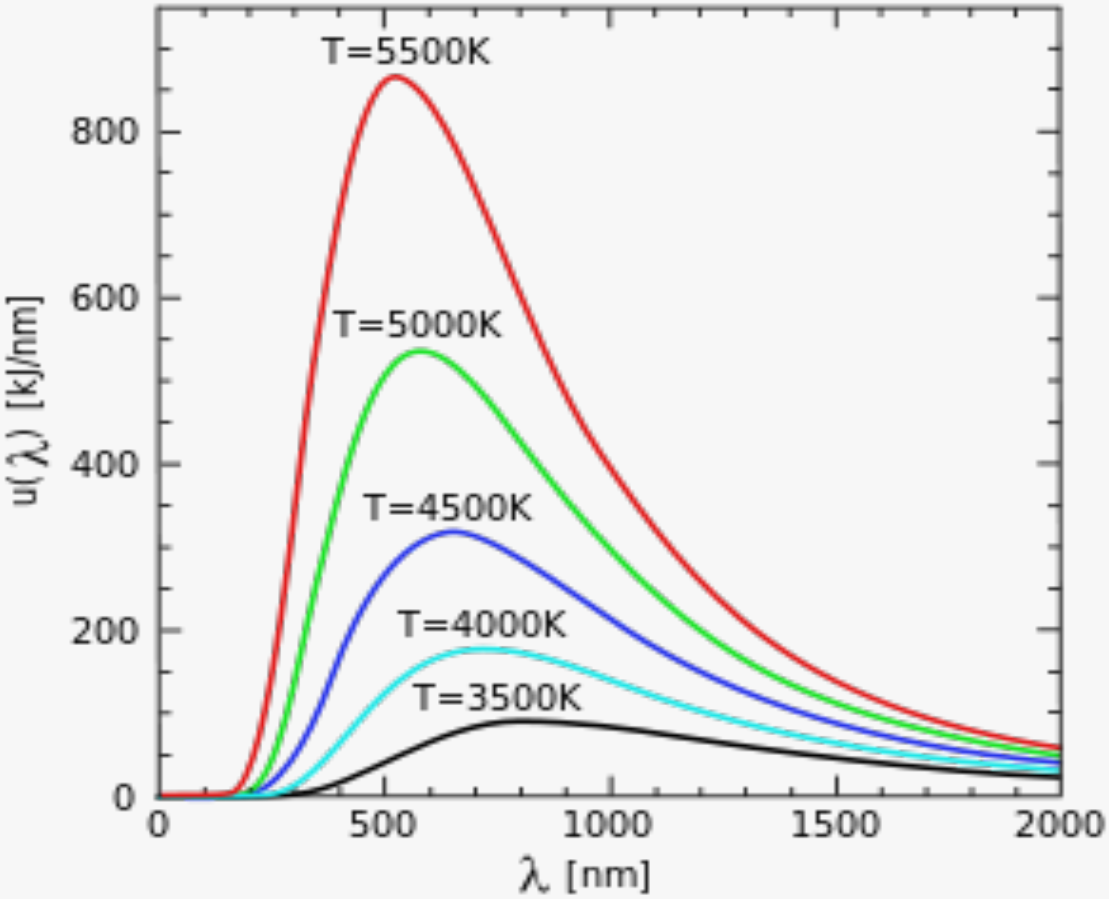
Black body:

$$E\downarrow b = \sigma T\uparrow 4$$

Grey body:

$$Q = \varepsilon A \sigma (T\downarrow 2 \uparrow 4 - T\downarrow 1 \uparrow 4)$$

$\sigma = 5.6697 \times 10^{-8}$ W/m^{2}K^4



http://en.wikipedia.org/wiki/Thermal_radiation

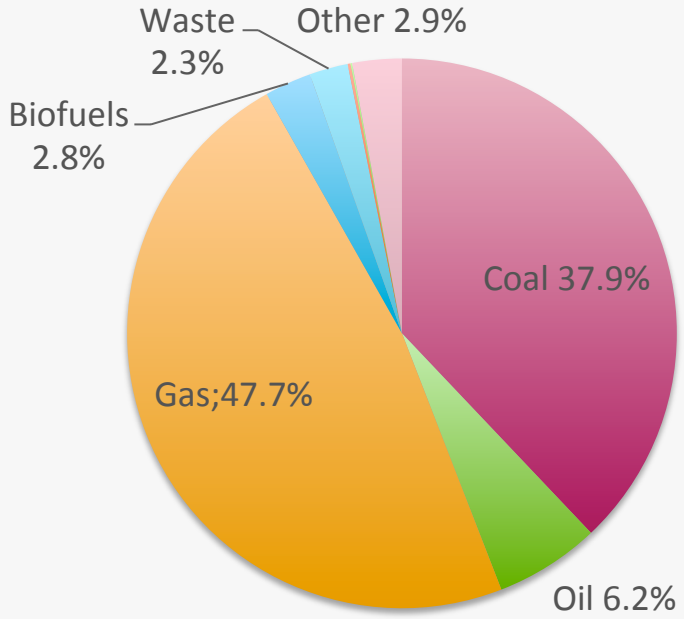
Introduction to Solar Energy

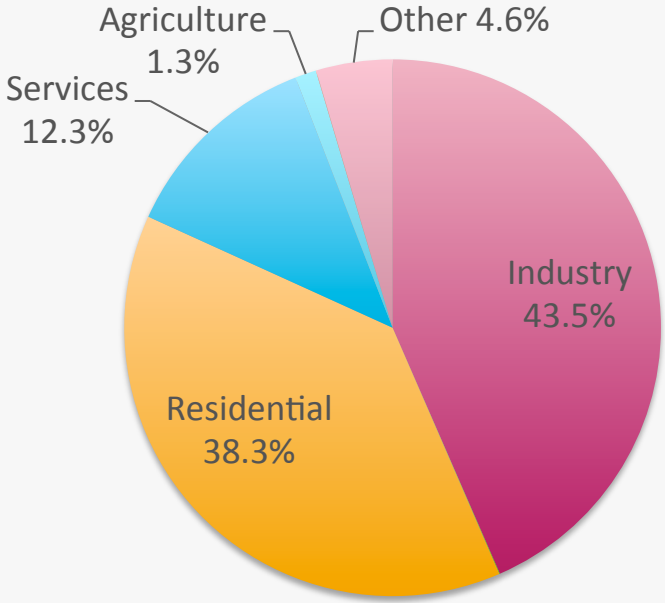
Solar thermal energy II: Solar thermal heating

Week 6.2

Arno Smets

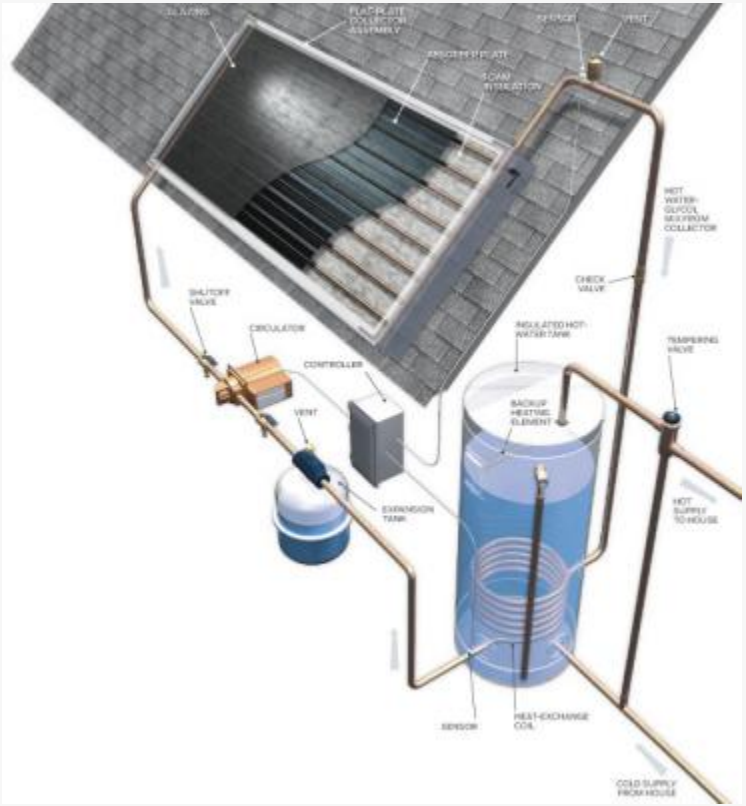
Heat demand



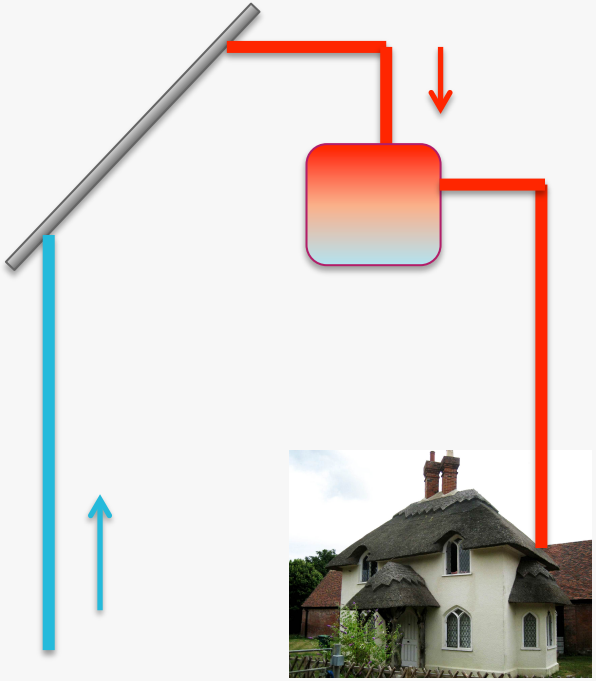


Source: IEA Electricity/Heat in World in 2009

Solar water heating systems



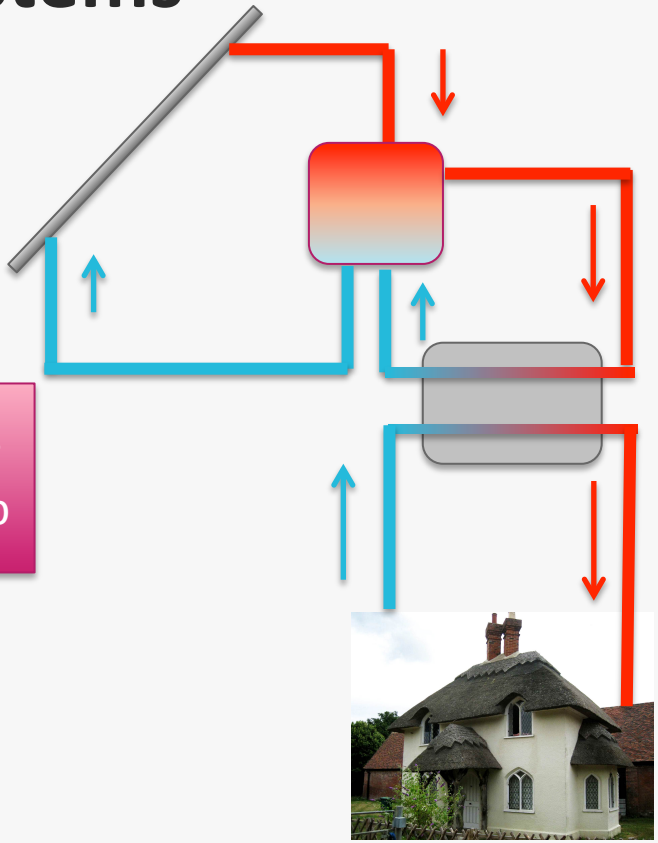
Types of solar water heating systems



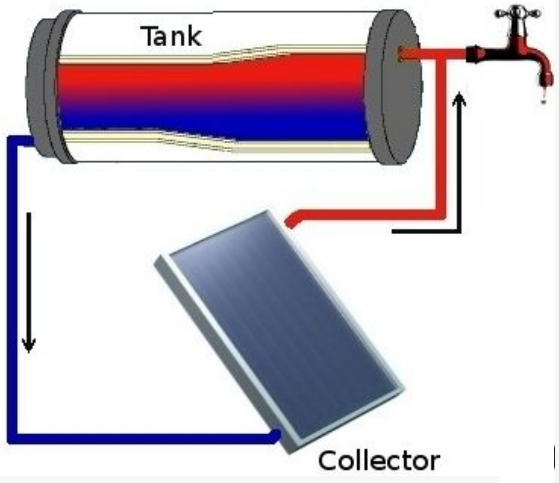
Fluid loop

Direct or open loop

Indirect or closed loop

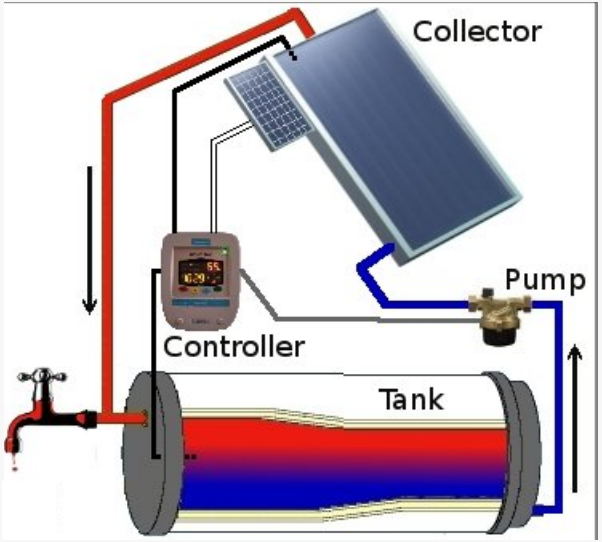


Types of solar water heating systems

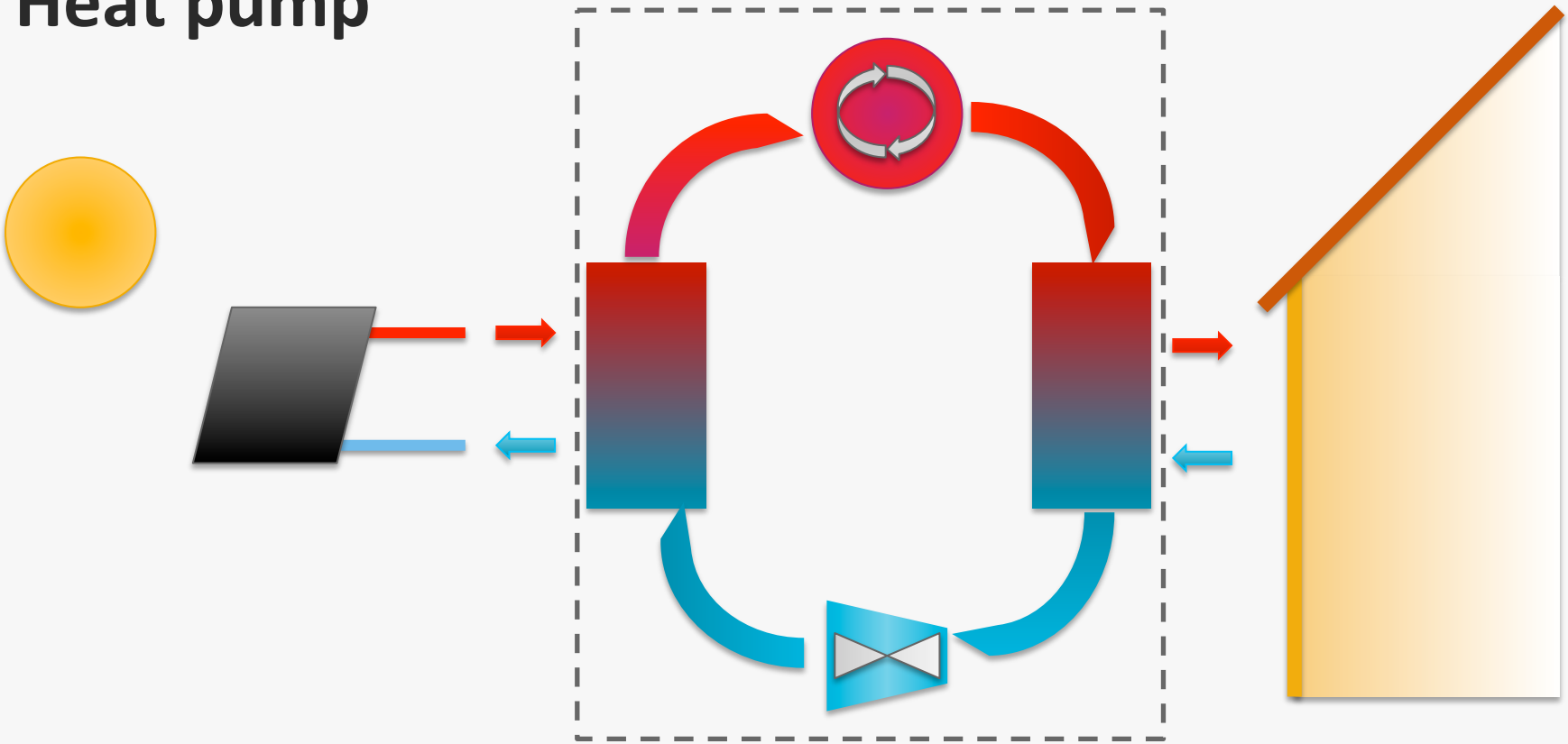


Fluid movement

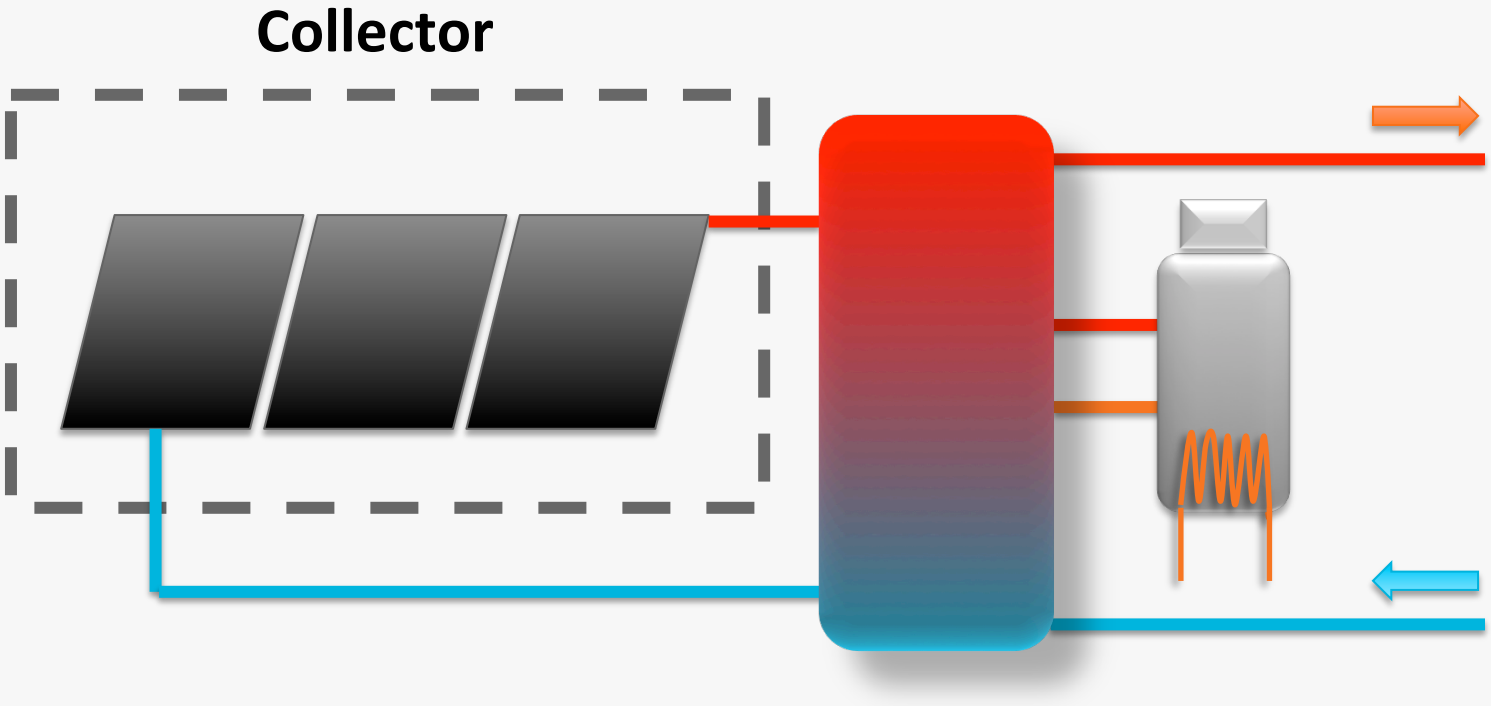
- Passive systems
- Active systems



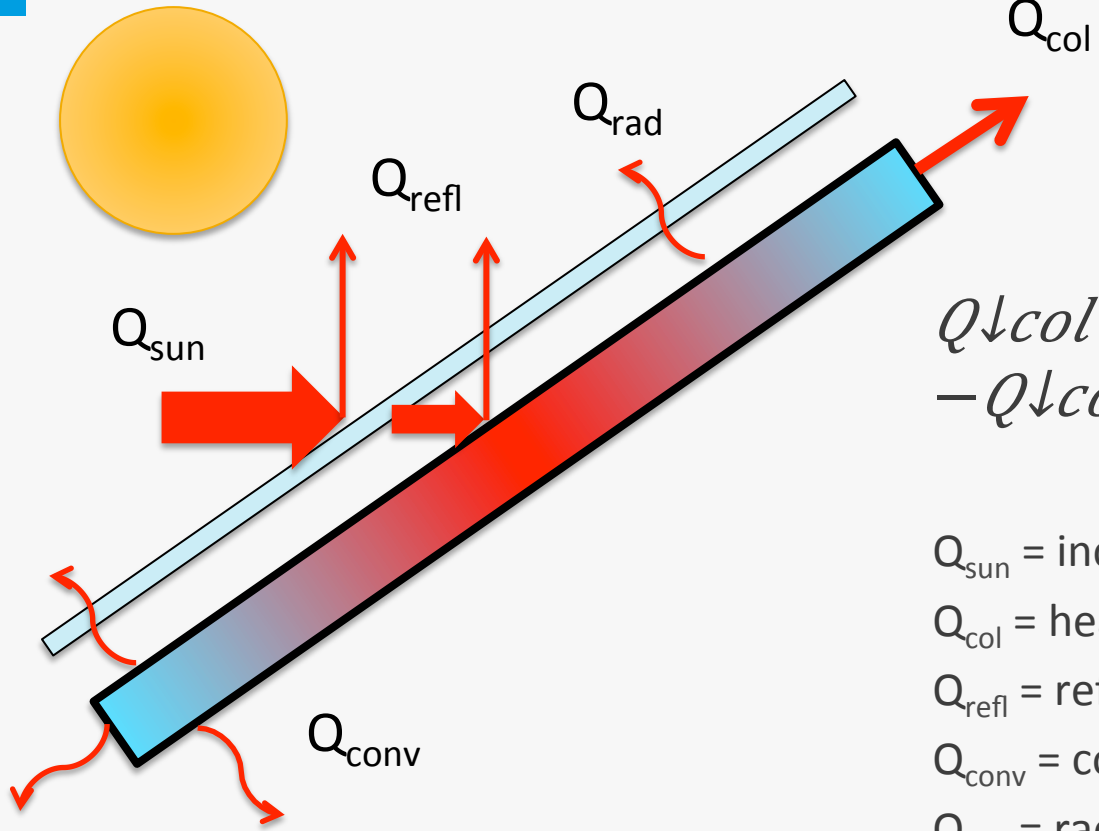
Heat pump



System components



Collector



$$Q\downarrow col = Q\downarrow sun - Q\downarrow refl - Q\downarrow rad - Q\downarrow conv$$

Q_{sun} = incident energy from the sun

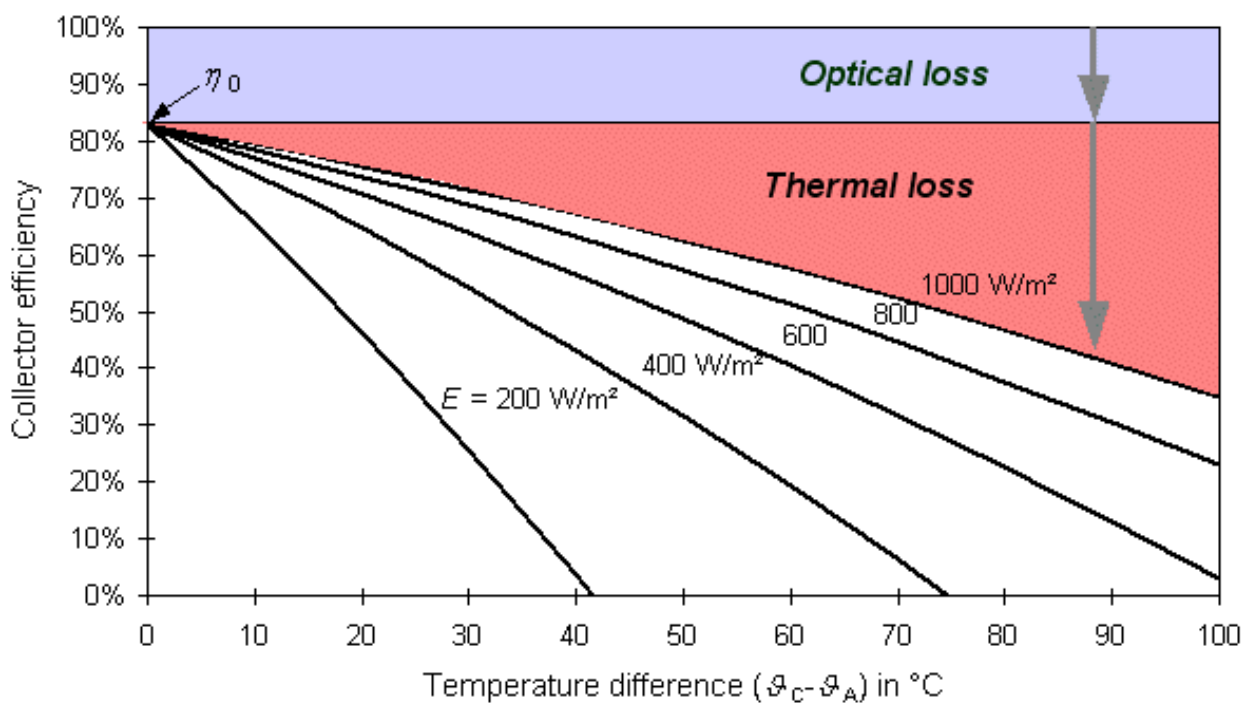
Q_{col} = heat output of the collector

Q_{refl} = reflection losses

Q_{conv} = convection losses

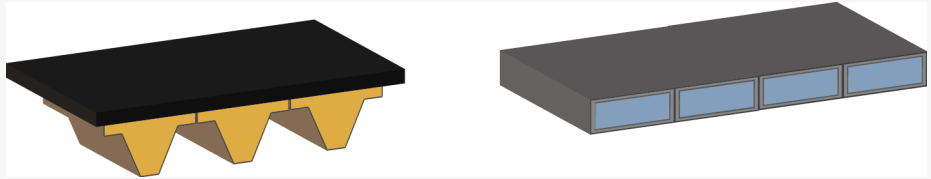
Q_{rad} = radiation losses

Collector efficiency

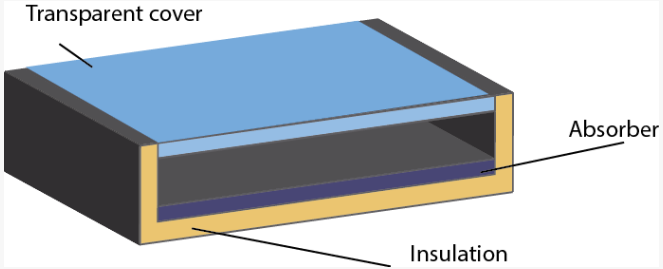


Collector

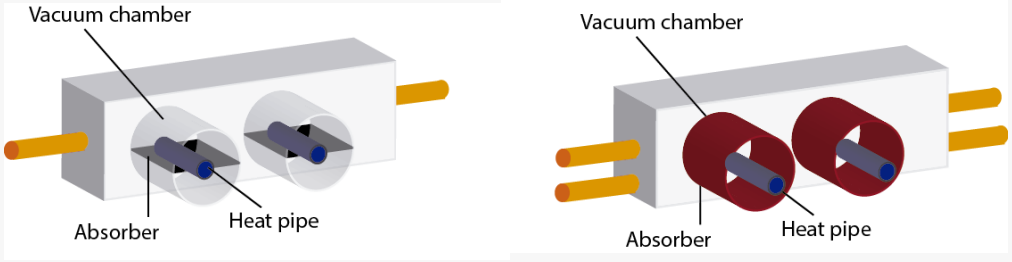
Uncovered



Covered

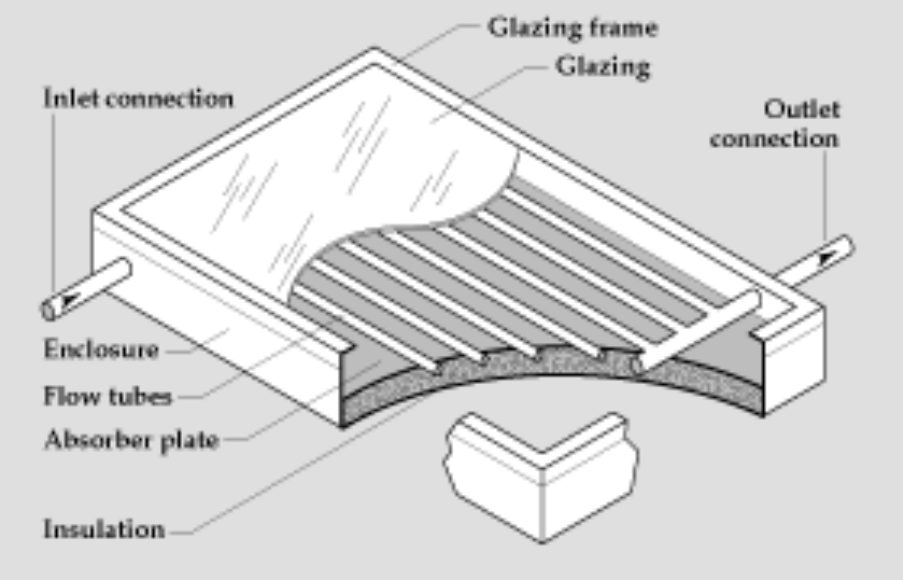


Vacuum

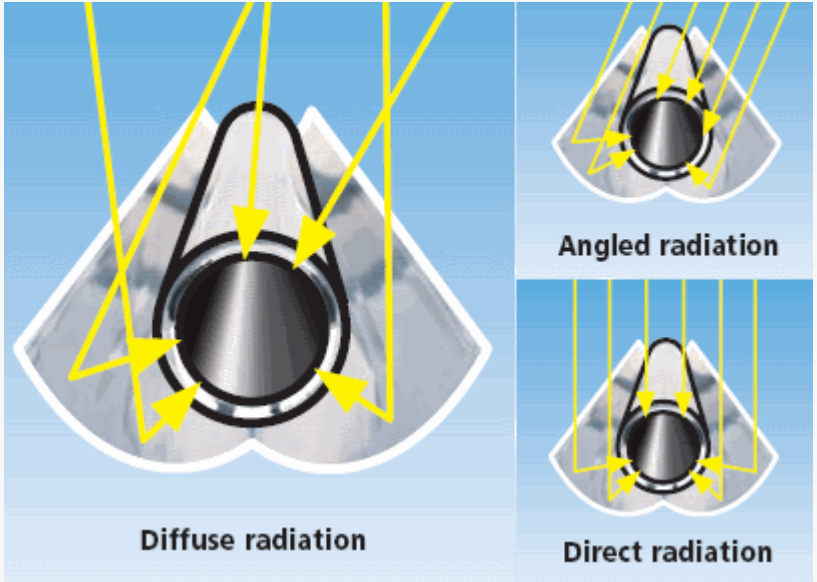


Collector

Flat-plate collector

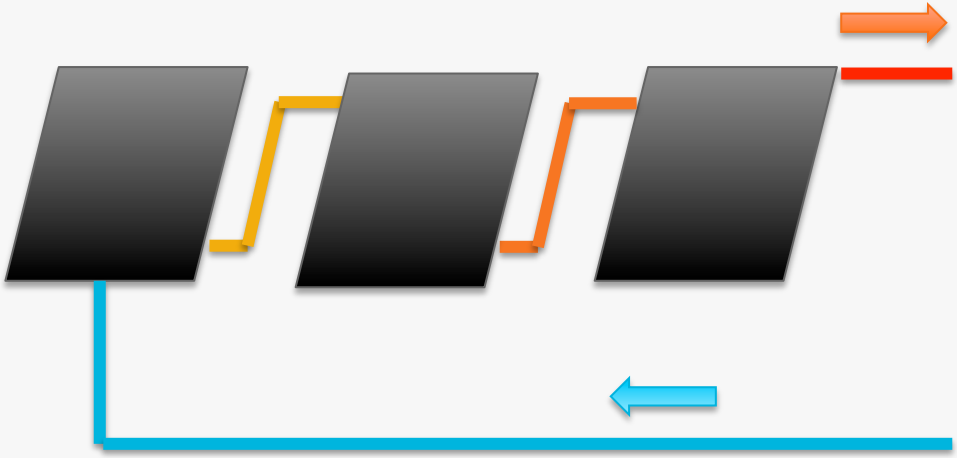


Concentrating collector

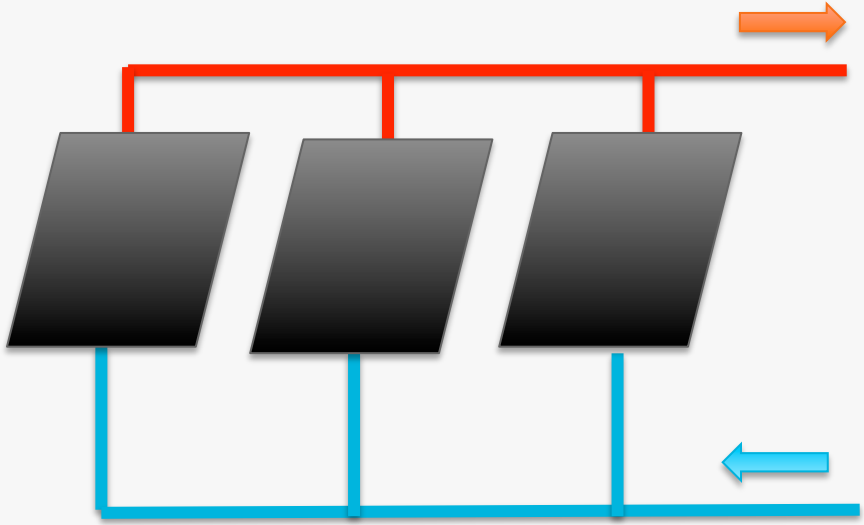


Solar system arrays

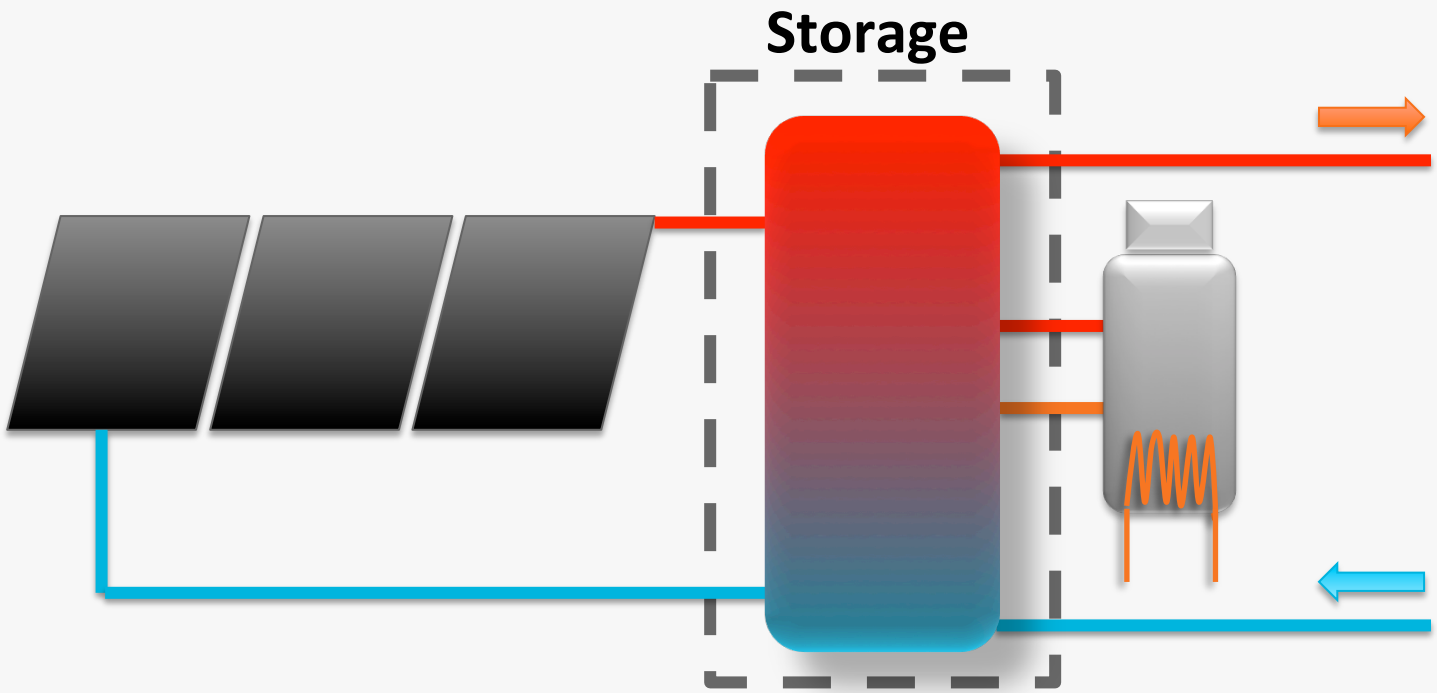
Series connected



Parallel connected



System components



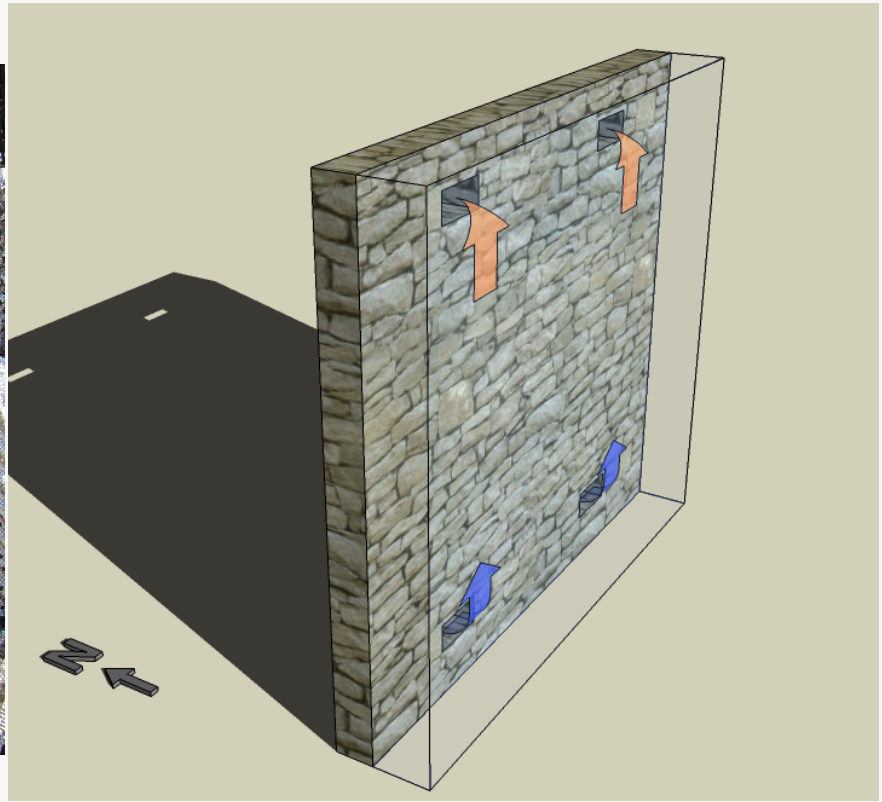
Energy storage

Energy storage: Water

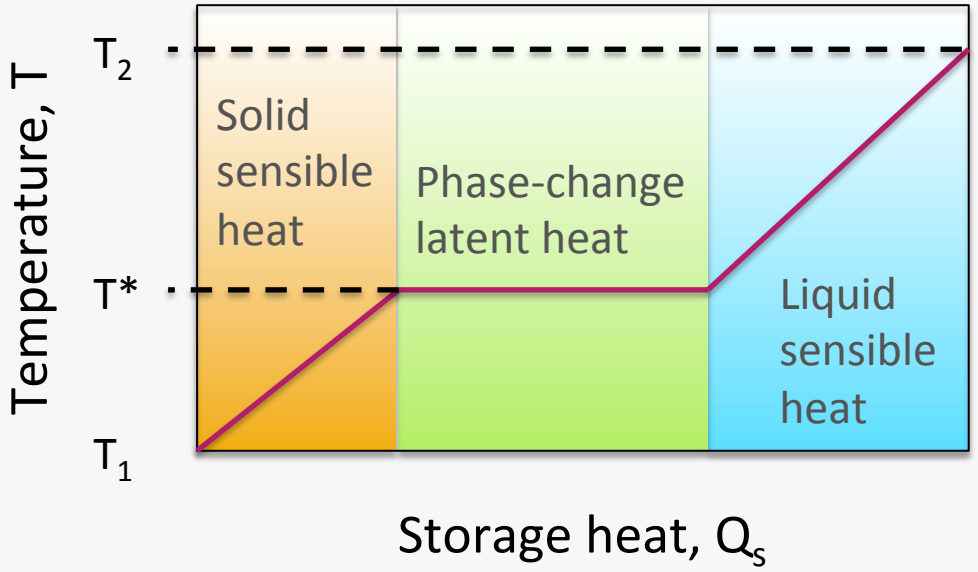
$$Q\downarrow s = V\rho C\downarrow p\,\Delta T$$

$$Q\downarrow loss = UA\Delta T$$

Energy storage: Solids

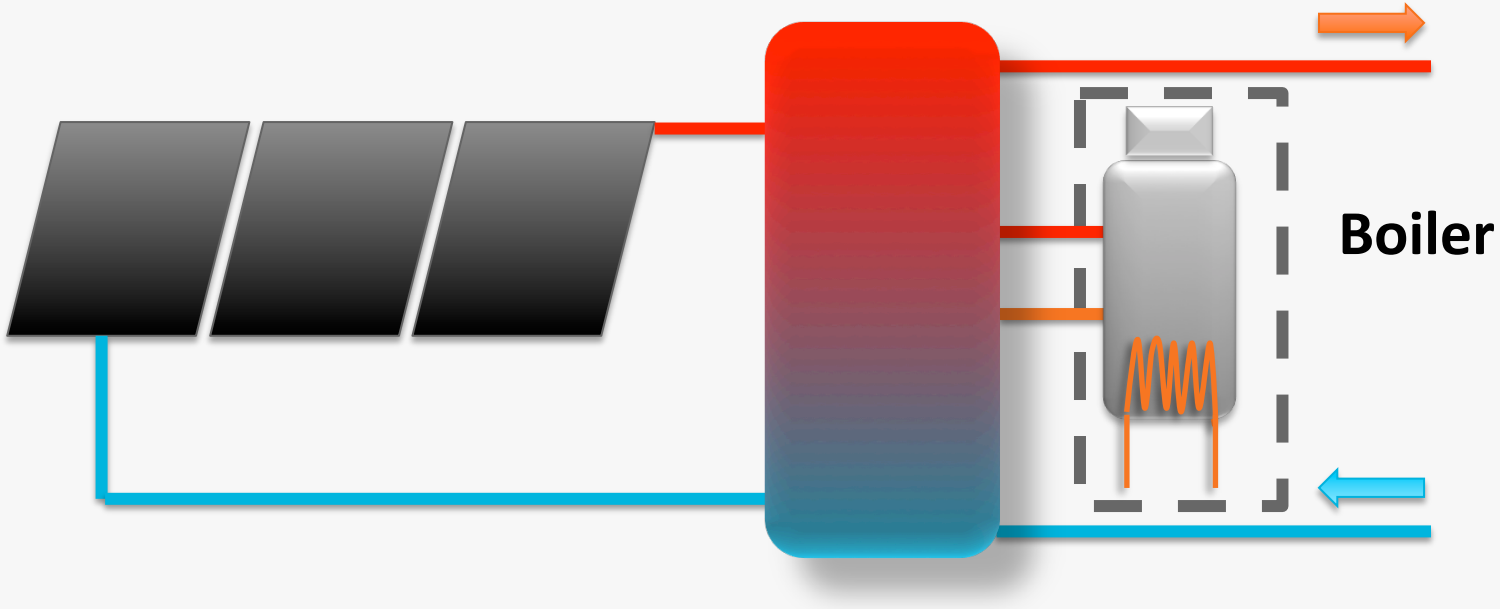


Energy storage: Phase change

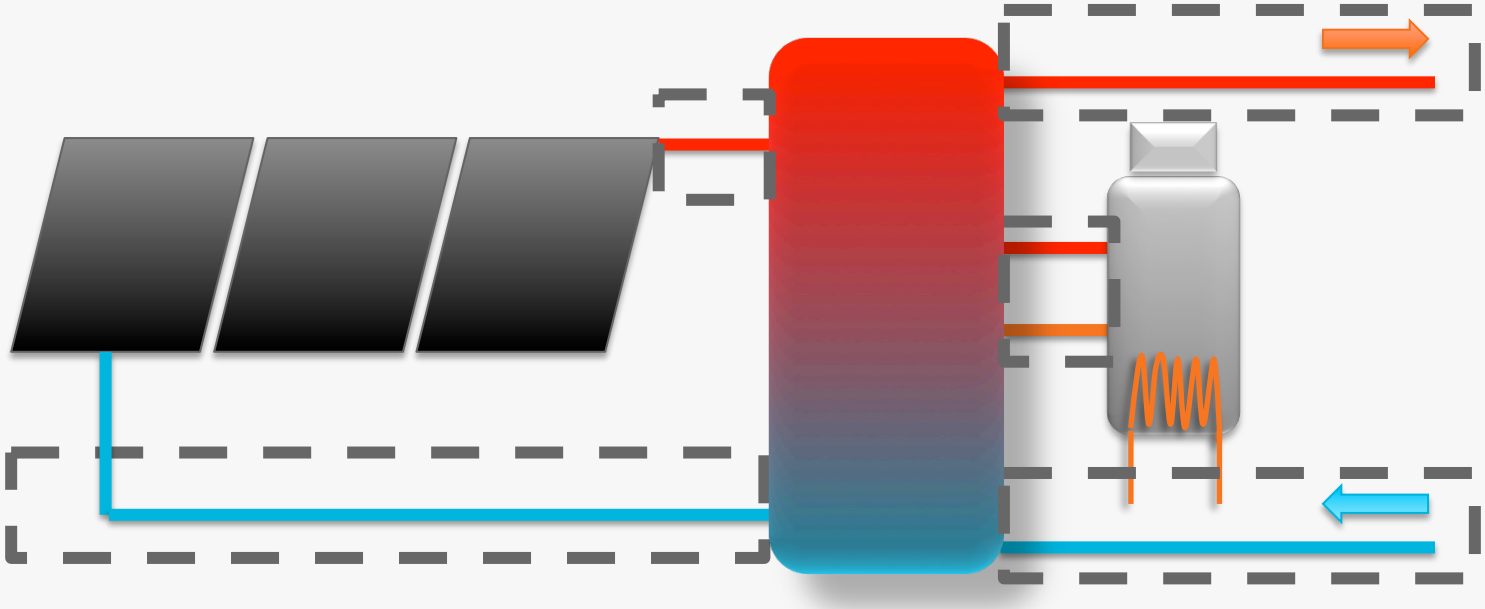


$$Q\downarrow s = m[C\downarrow s\,(T\uparrow * - T\downarrow 1\,) + \lambda + C\downarrow l\,(T\downarrow 2 - T\uparrow *\,)]$$

System components

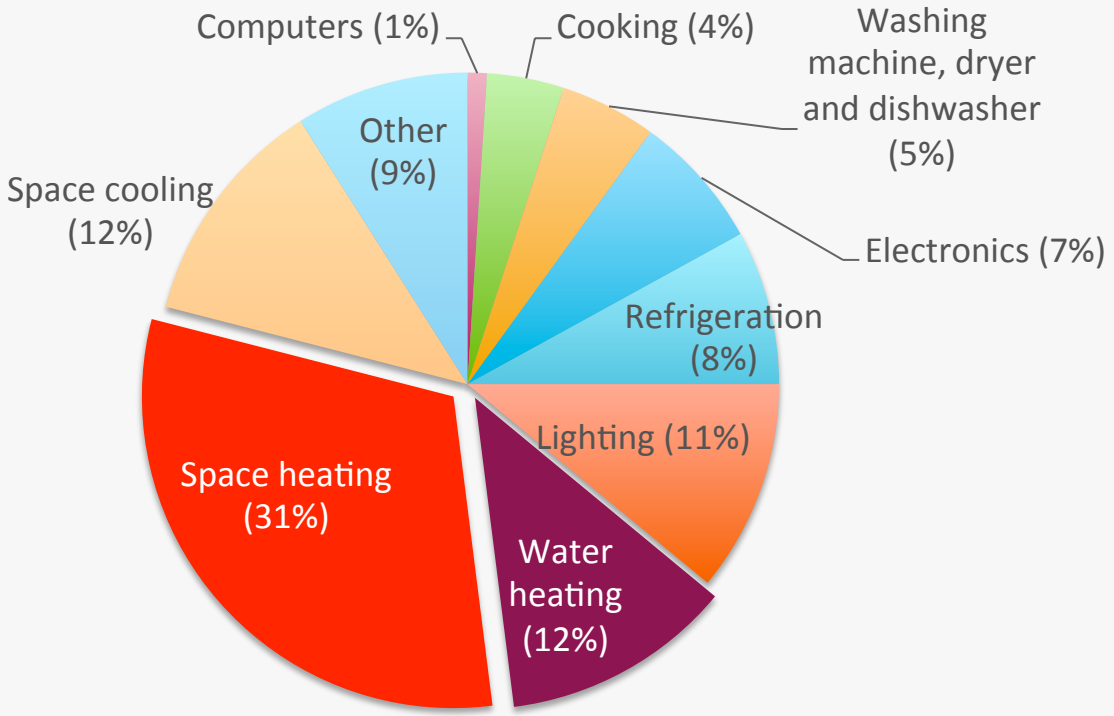


System components



Collector circuit

Household energy demand



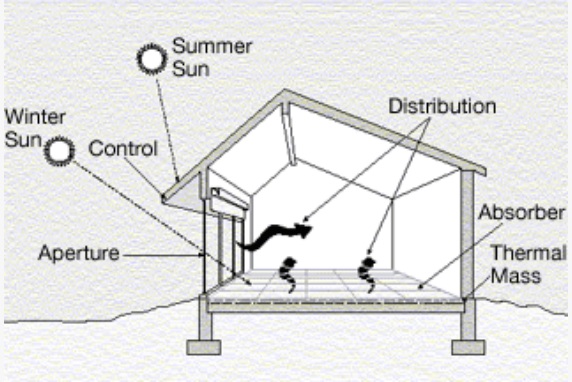
Source: IEA Electricity/Heat in World in 2009

Solar cooling

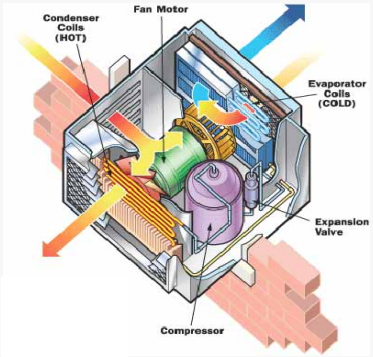
Solar absorption cooling

Solar dessicant cooling

Combined solar heating and cooling



Solar-mechanical cooling



Introduction to Solar Energy

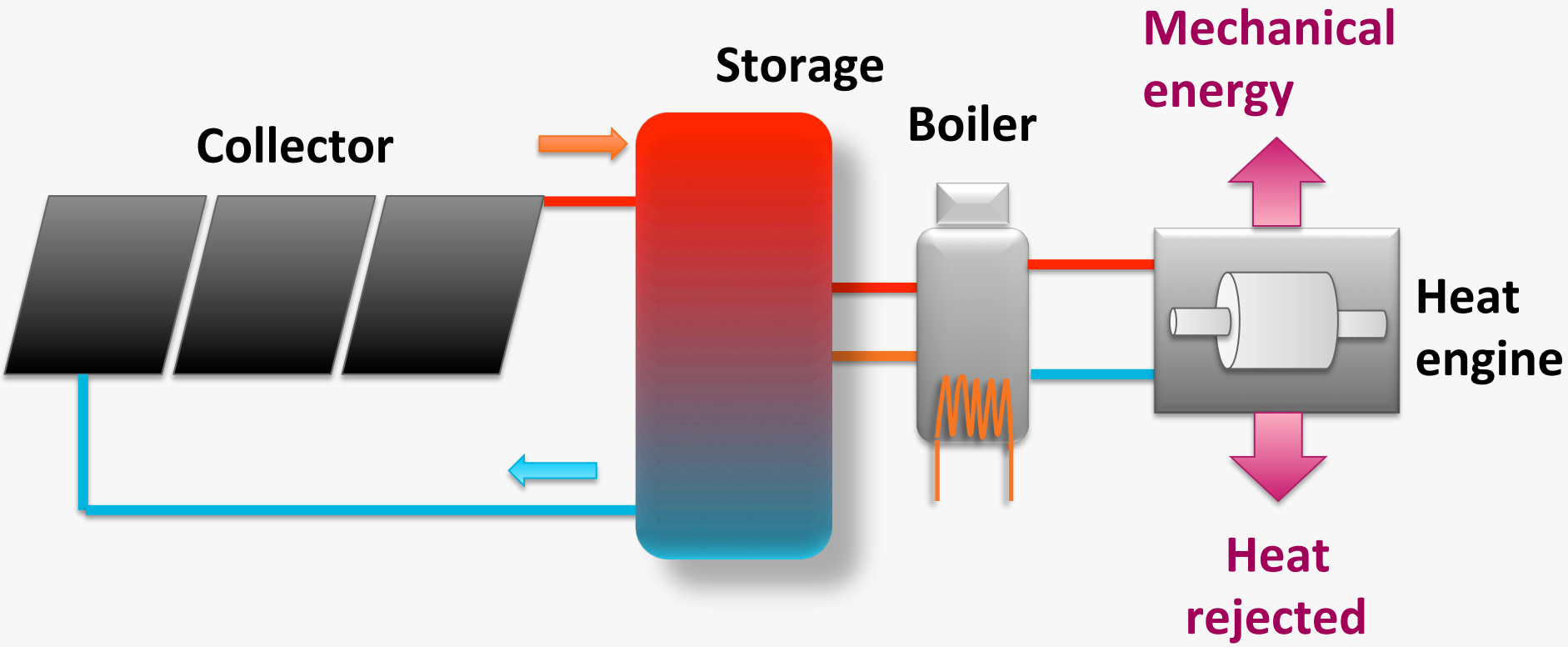
Solar thermal energy III: Solar thermal power

Week 6.2

Arno Smets

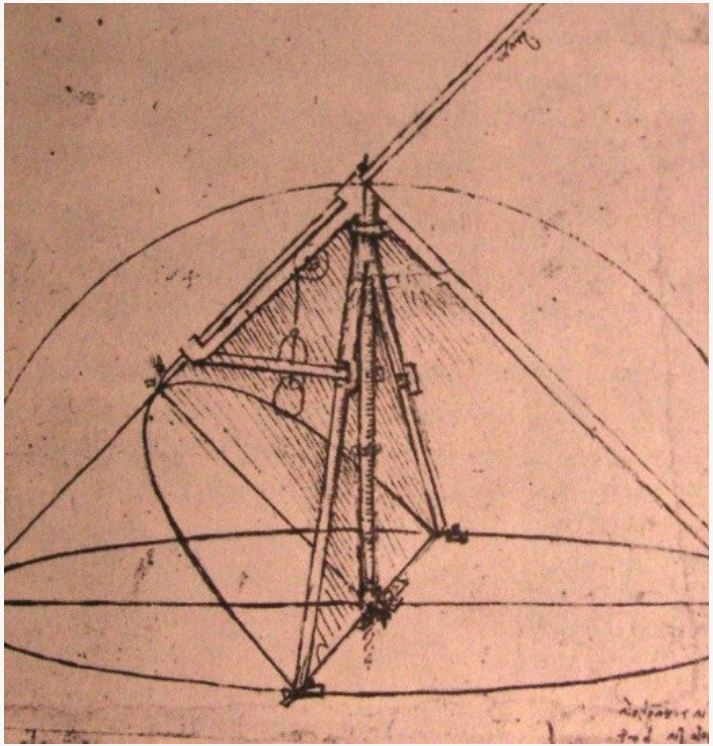
Solar thermal power plant

Solar thermal power system

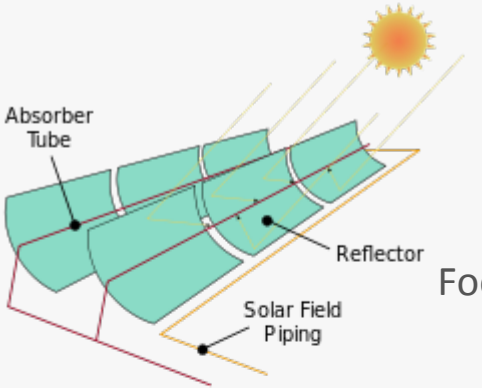


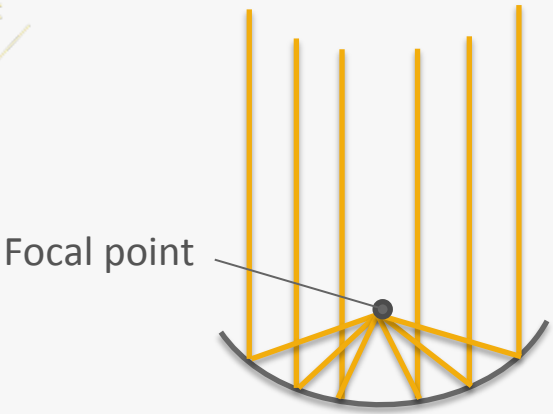
Animation solar thermal power plant

Solar concentrators

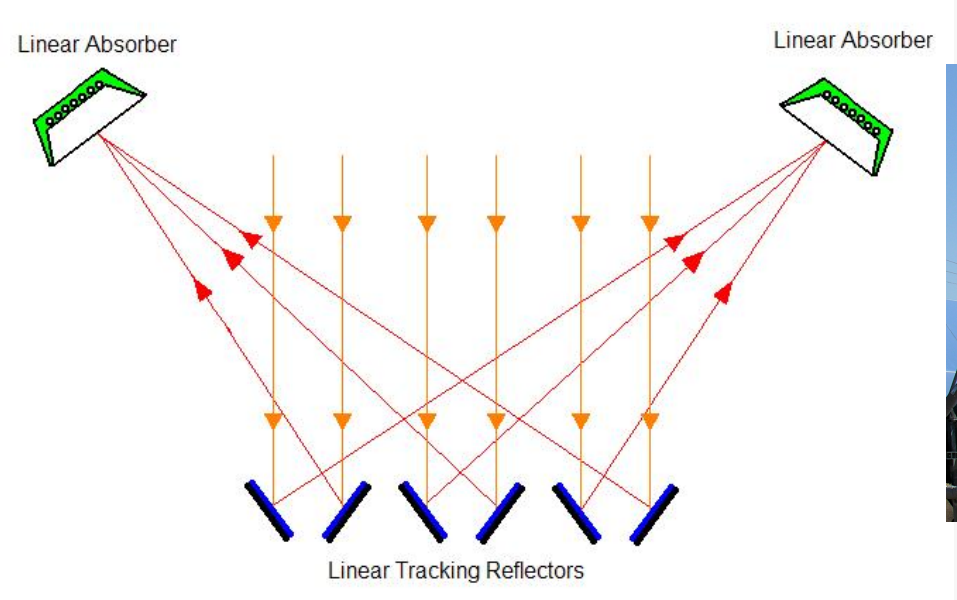


Types of concentrators: Parabolic



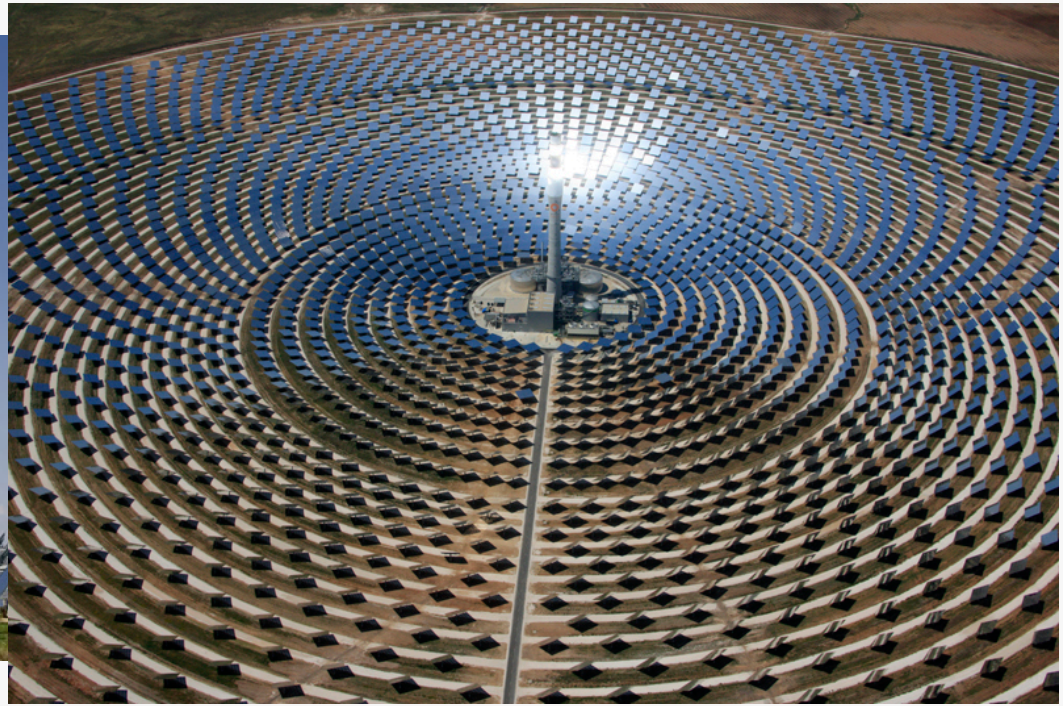


Types of concentrators: Fresnel Reflector



Types of concentrators: Dish stirling

Types of concentrators: Power towers



Thank you for your attention!