1. Light absorption in materials and excess carrier generation

Absorption is due to interactions with material particles (electrons and nucleus).
If particle energy before interaction was W_1, after photon absorption is $W_1 + h\nu$

- **interactions with the lattice – low energy photons, results in an increase of temperature**
- **interactions with free electrons - important when the carrier concentration is high, results also in temperature increase**
- **interactions with bonded electrons- the incident light may generate some excess carriers (electron/hole pairs)**

Solar Energy Conversion to Thermal Energy

From incident light of an intensity Φ_{in} a power *P* is absorbed by the material. If the material thickness is higher than 3 absorption lengths

$$P = (1 - R)\Phi_{in} = a_s \Phi_{in}$$

a_s is the solar absorptance

The highest power absorbed is for the black body (*R = 0, a_s=1).*

The energy absorption results in a surface temperature increase and consequently, in **heat (energy) transfer due to temperature gradient**

Heat *conduction*

The power density

$$\frac{P}{S} = \kappa \; gradT \qquad \frac{P}{S} = \kappa \frac{\Delta T}{\Delta x}$$

κ is the thermal conductivity

Heat *convection*

Heat transfer from the material into the surrounding ambient

h is the coefficient of heat transfer

$$\frac{P}{S} = h\Delta T$$

Black body radiation

ε_k is the surface emissivity

$$\frac{P}{S} = 5.67\varepsilon_k \left(\frac{T}{100}\right)^4$$

The power density radiated into the surrounding of temperature T_a

$$\frac{P}{S} = 5.67\left[\varepsilon_k \left(\frac{T}{100}\right)^4 - \varepsilon_{ka}\left(\frac{T_a}{100}\right)^4\right]$$

The absorber material should have

- high solar absorptance and low thermal emittance
- high thermal conductiviy

Cu and Al are often used, the solar absorptance can be increased by covering the surface with oxides

Solar absorptance (α_S) and thermal emittance (ε_T) of absorbers deposited on Al and Cu substrates

Absorber	Sample	α_S	ε_T	Surface roughness, [nm]
$Al/Al_2O_3/NiO/TiO_2$ (1)	Al/Al_2O_3	0.94	0.12	330.4
	$Al/Al_2O_3/NiO$	0.92	0.09	28.5
	$Al/Al_2O_3/NiO/TiO_2$	**0.92**	**0.08**	**3.6**
$Cu/CuO_x/NiO/TiO_2$ (2)	Cu/CuO_x	0.94	0.08	303.5
	$Cu/CuO_x/NiO$	0.96	0.06	8.8
	$Cu/CuO_x/NiO/TiO_2$	**0.95**	**0.05**	**1.9**

The heat transfer medium may be gas (air) or liquid (water or oil).

Important parameters of these materials are set out in Table

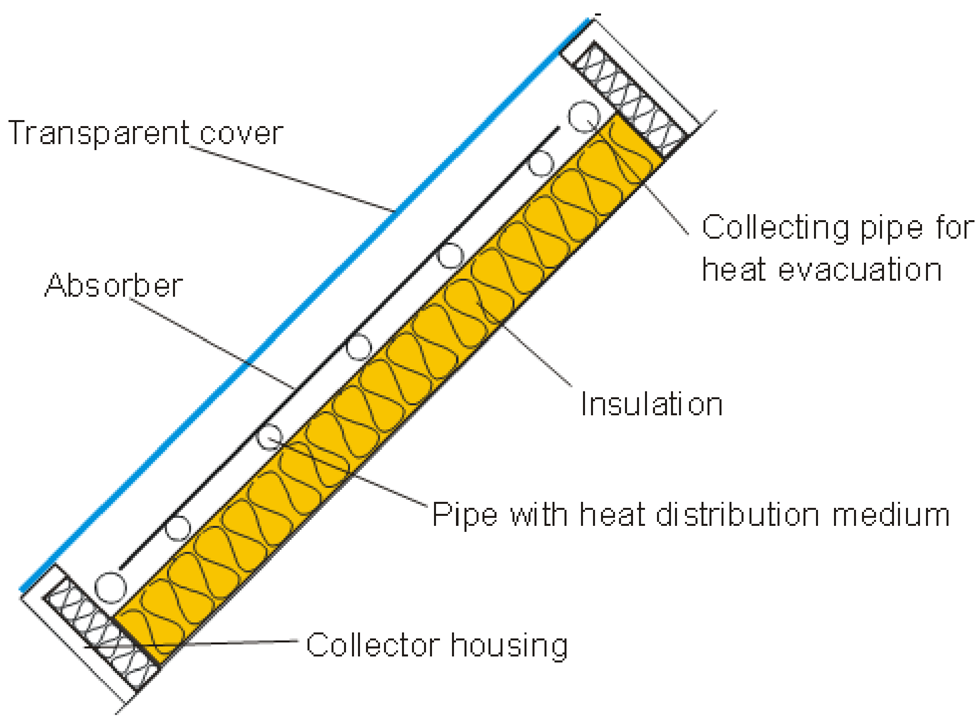
Cooling Medium	**Mass Thermal Capacity** C_m/Jkg^{-1}K^{-1}	**Thermal Conductivity** κ/Wm^{-1}K^{-1}	**Density** ρ/kg m^{-3}	**Kinematic Viscosity** ν/kg m^{-1}s^{-1}	**Heat Transfer Coefficient** h/Wm^{-2}K^{-1}
Air	1006	0.027	1.09	1.7×10^{-5}	8 - 20
Oil	2130	0.181	850	0.98	540
Water	4180	0.600	995	8×10^{-3}	6500

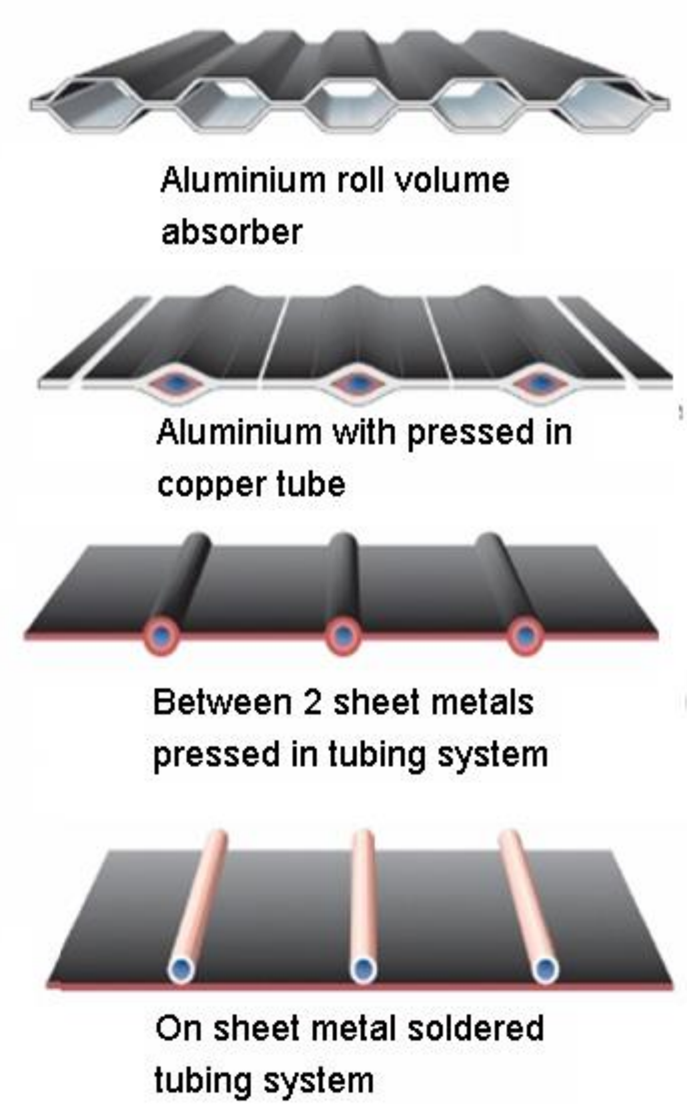
The heat can be used for:

- hot water preparing
  - supply hot water
  - hot water heating of buildings
- hot air preparing

  Heating of buildings
- cooling of buildings (residential air conditioning)
- steam generation (in connection with electrical energy generation)

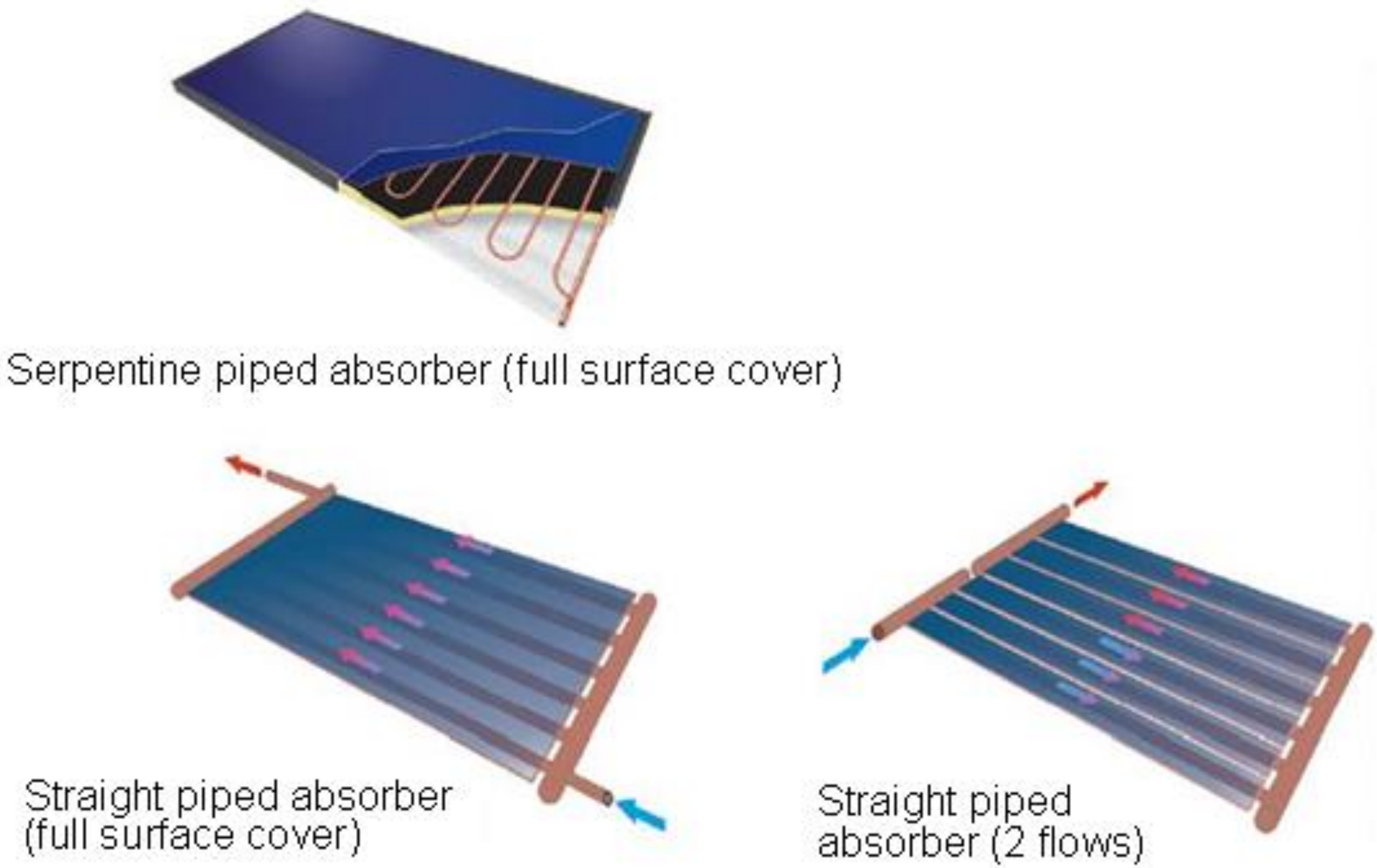
Solar water heating





$$\frac{P}{S} = 5.67\left[\varepsilon_k\left(\frac{T}{100}\right)^4 - \varepsilon_{ka}\left(\frac{T_a}{100}\right)^4\right]$$

Absorber plate and fluid passageways

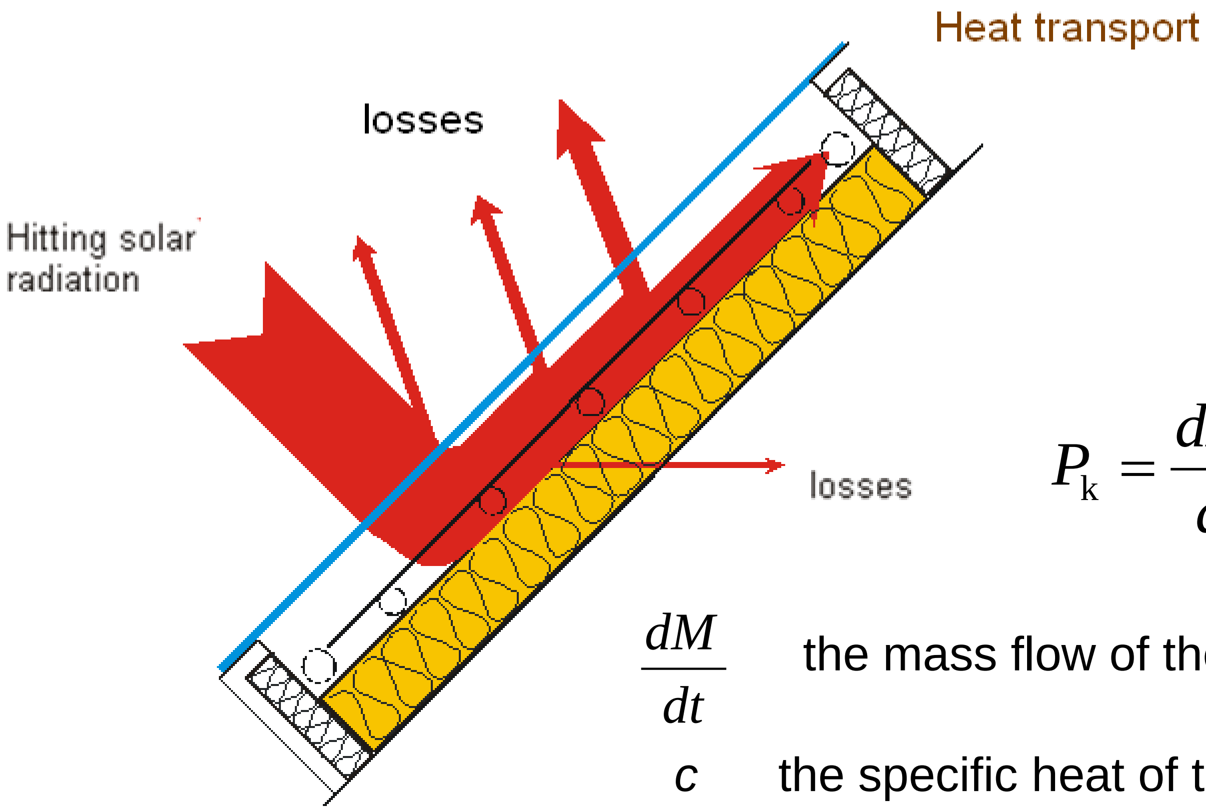


Serpentine piped absorber (full surface cover)

Straight piped absorber (full surface cover)

Straight piped absorber (2 flows)

Thermal power of a solar converter



$$P_k = \frac{dM}{dt} \cdot c \cdot (T_{k2} - T_{k1})$$

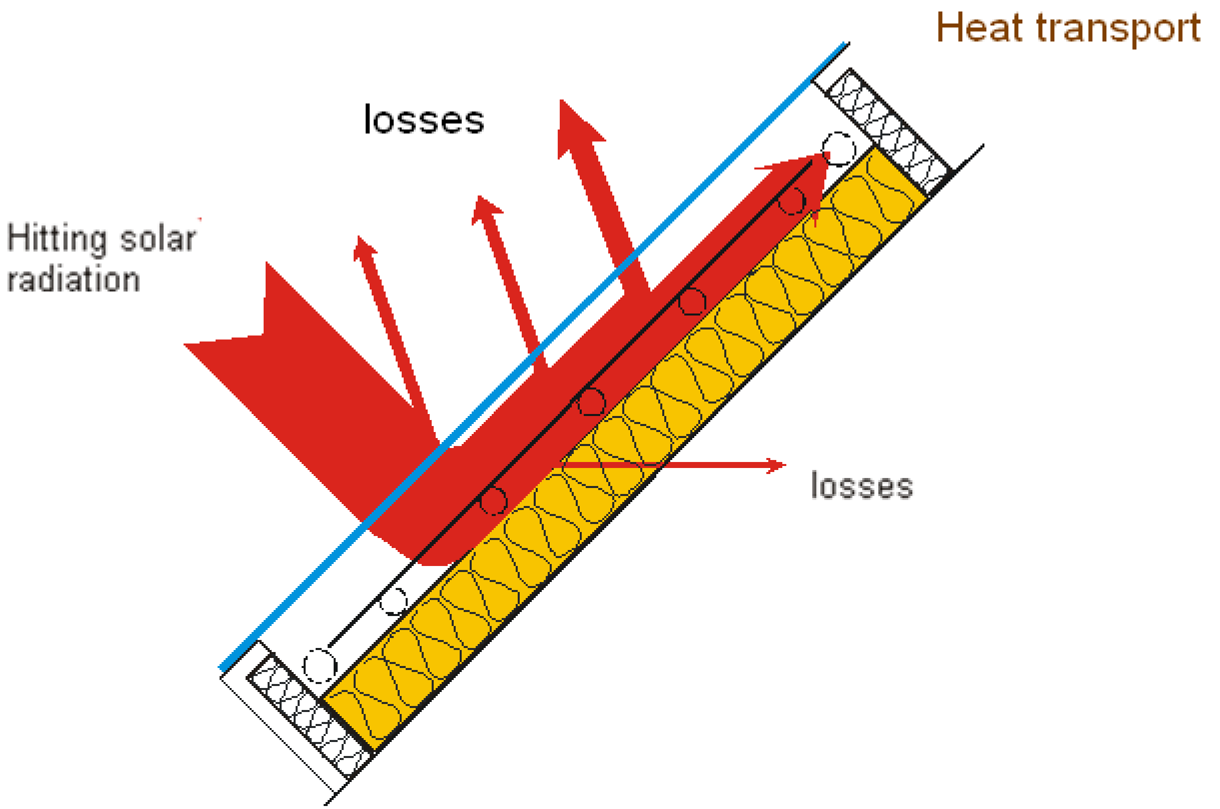
$\frac{dM}{dt}$ the mass flow of the liquid

c the specific heat of the liquid

T_{k1} the input liquid temperature

T_{k2} the output liquid temperature

Thermal losses in a solar collector



$$\frac{P}{S} = \kappa \frac{\Delta T}{\Delta x}$$

$$\frac{P}{S} = 5.67\left[\varepsilon_k \left(\frac{T}{100}\right)^4 - \varepsilon_{ka}\left(\frac{T_a}{100}\right)^4\right]$$

Increase of temperature

$$P_{th} = \rho_m c V \frac{dT}{dt} = C_{Th} \frac{dT}{dt}$$

Losses

Black body radiation

ε_k is the surface emissivity

$$\frac{P}{S} = 5.67\,\varepsilon_k \left(\frac{T}{100}\right)^4$$

The power density radiated into the surrounding of temperature T_a

$$\frac{P}{S} = 5.67\left[\varepsilon_k \left(\frac{T}{100}\right)^4 - \varepsilon_{ka}\left(\frac{T_a}{100}\right)^4\right]$$

Heat transfer from the material into the surrounding ambient
h is the coefficient of heat transfer

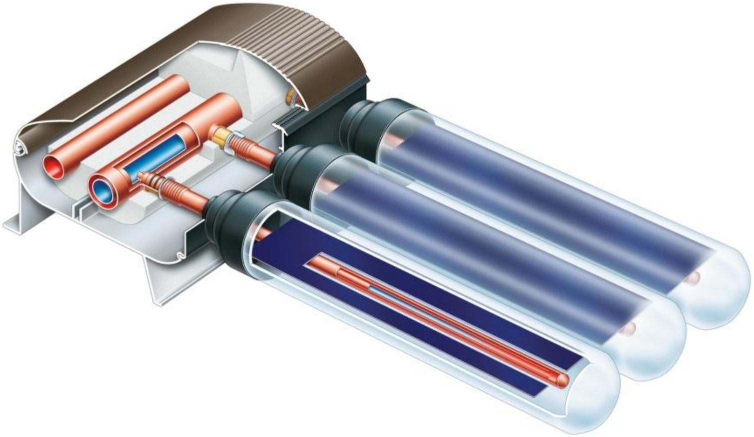
$$\frac{P}{S} = h \Delta T$$

The convective heat transfer coefficient for the heat lost to the cooling medium depends on the ambient (air) speed ***v*** and the ambient viscosity ***ν***

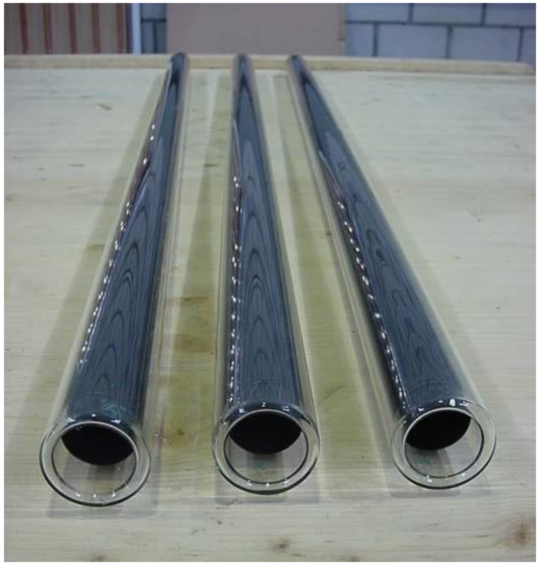
$$h_k = A_k \left(\frac{v}{\nu}\right)^{3/4}$$

Vacuum collectors

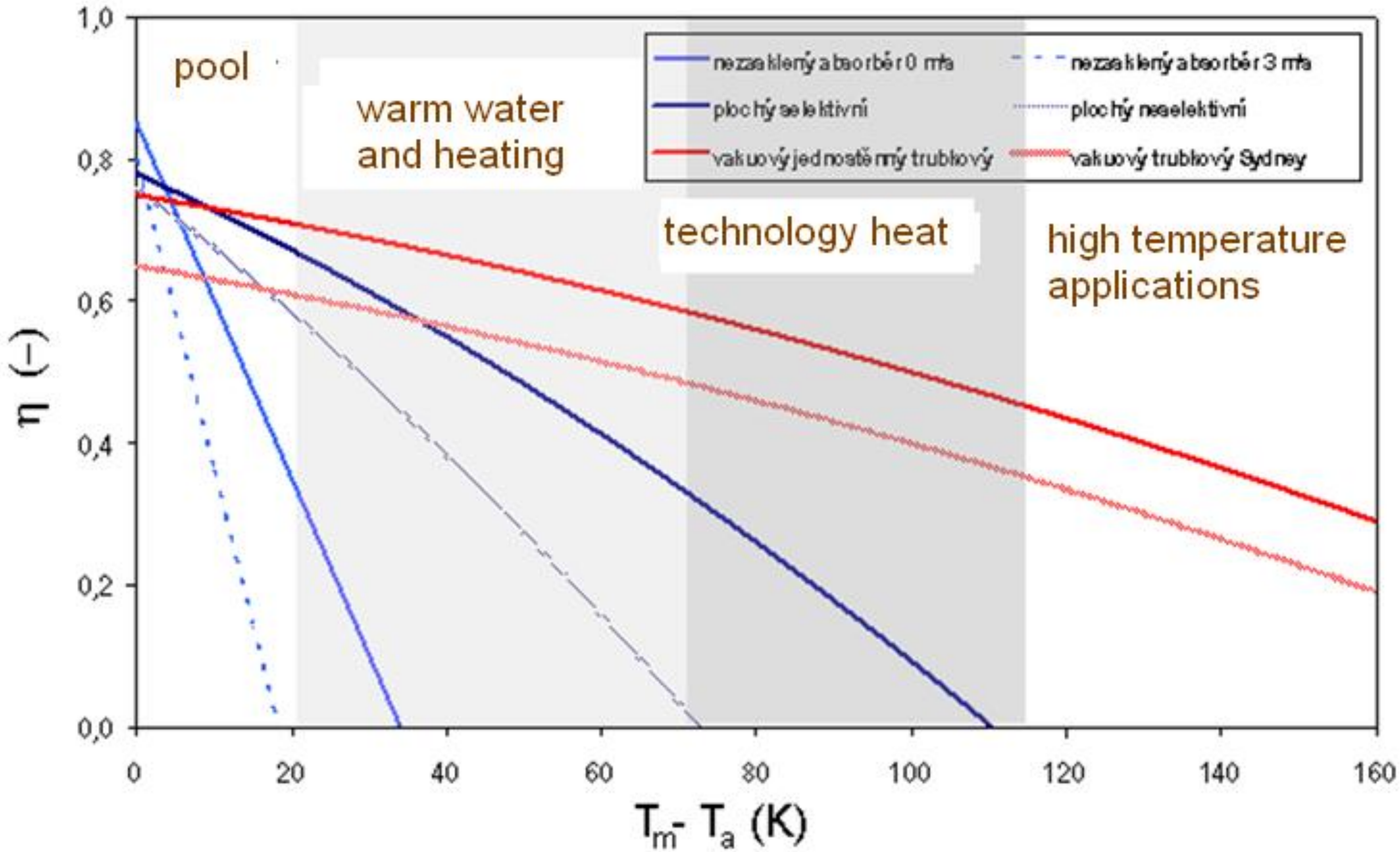
Flat vacuum collector



Tube one-wall vacuum collector



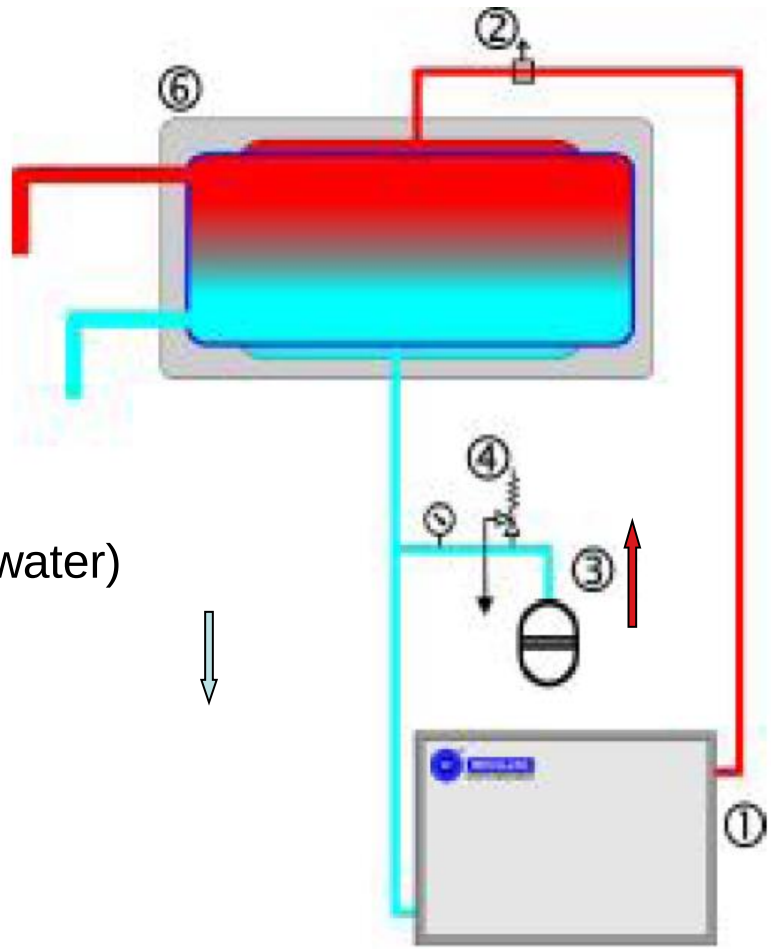
Dewar tube collectors

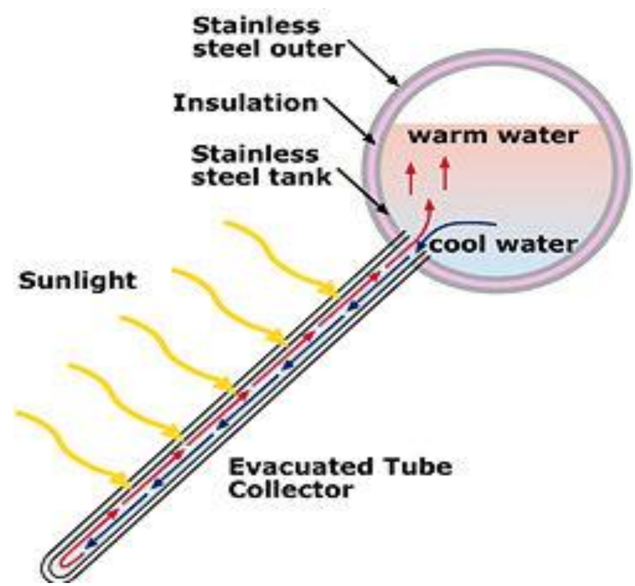

1,0
0,8
0,6
0,4
0,2
0,0
0
20
40
60
80
100
120
140
160
pool
warm water and heating
technology heat
high temperature applications
nezasklený absorbér 0 m/s
nezasklený absorbér 3 m/s
plochý selektivní
plochý neselektivní
vakuový jednostěnný trubkový
vakuový trubkový Sydney
η (–)
$T_m - T_a$ (K)

Thermosyphon systems

Output
(warm water)

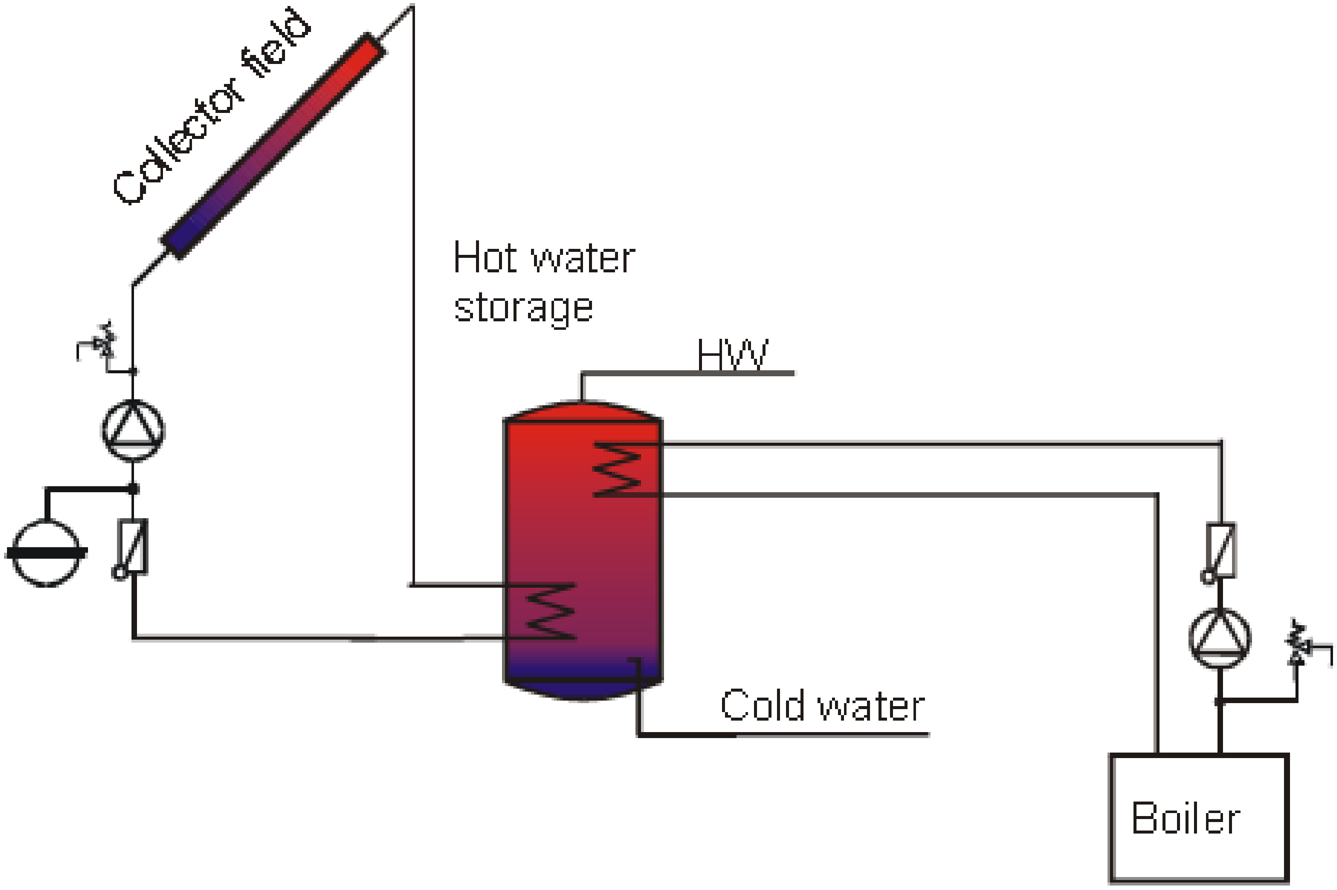
Input (cold water)



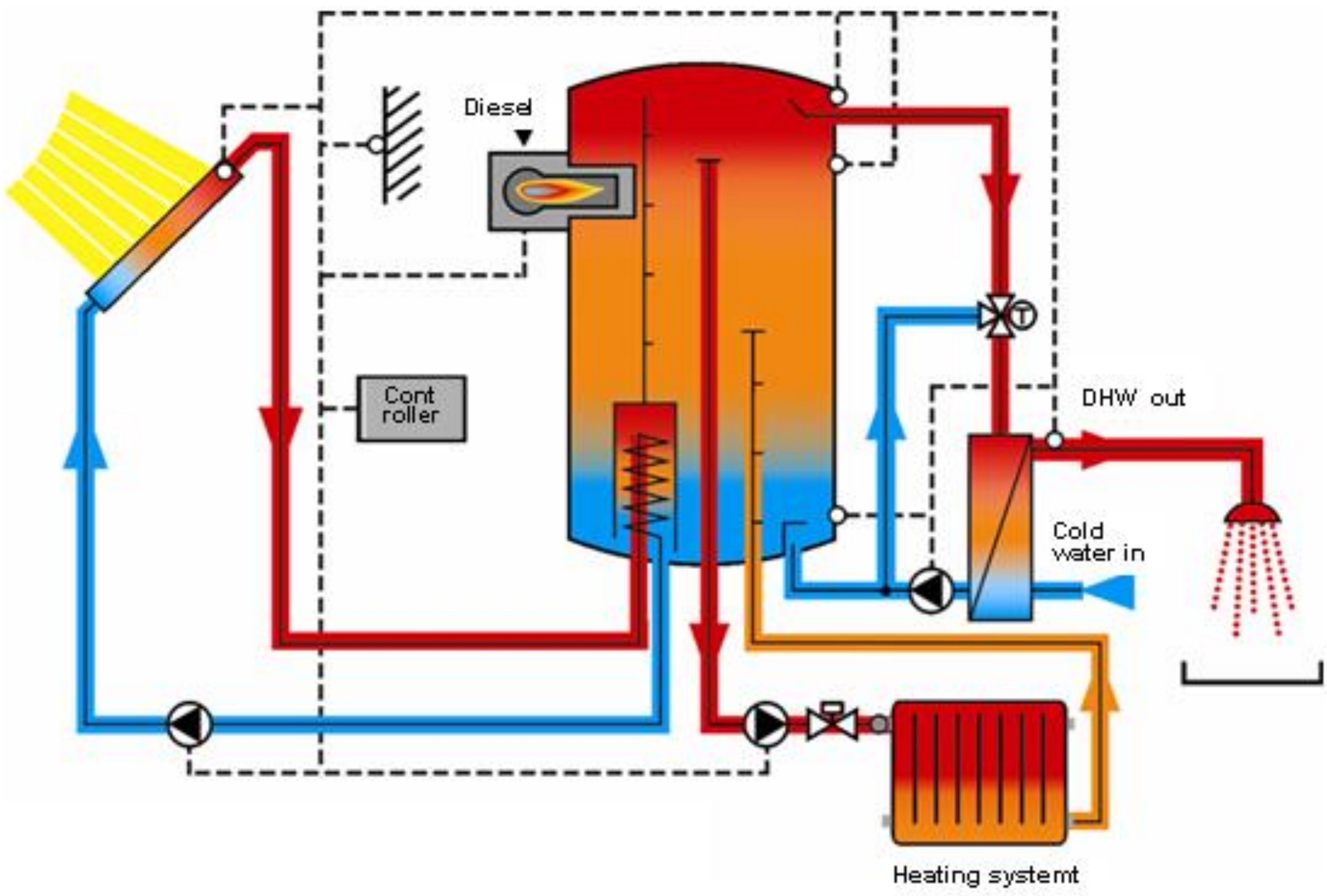



10
BLOK

Solar water heating (active systems)

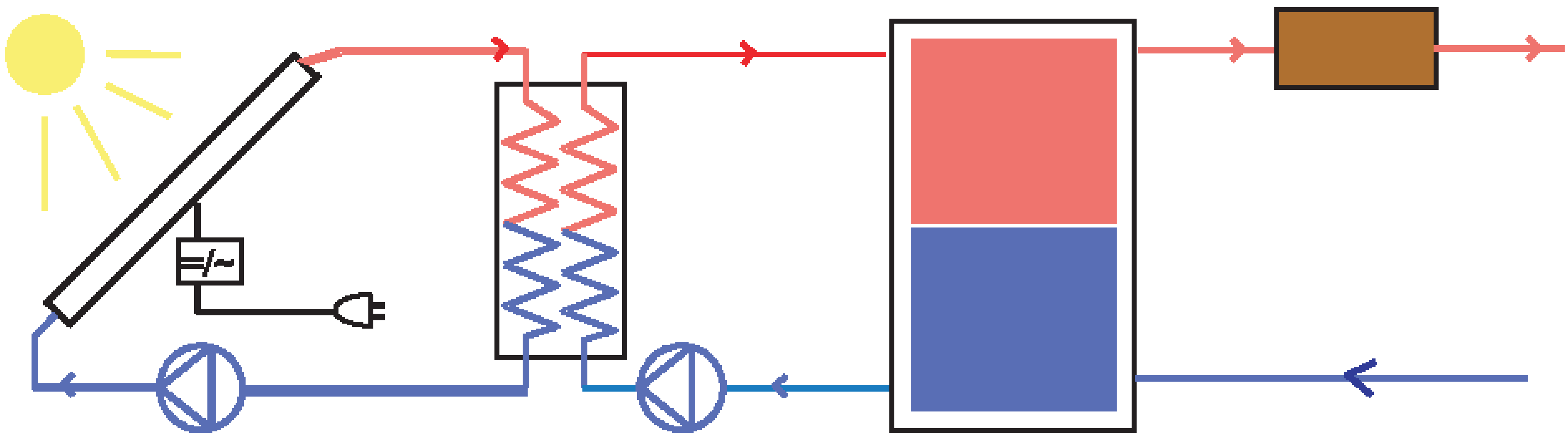


Solar water heating (combined with a gas heating)



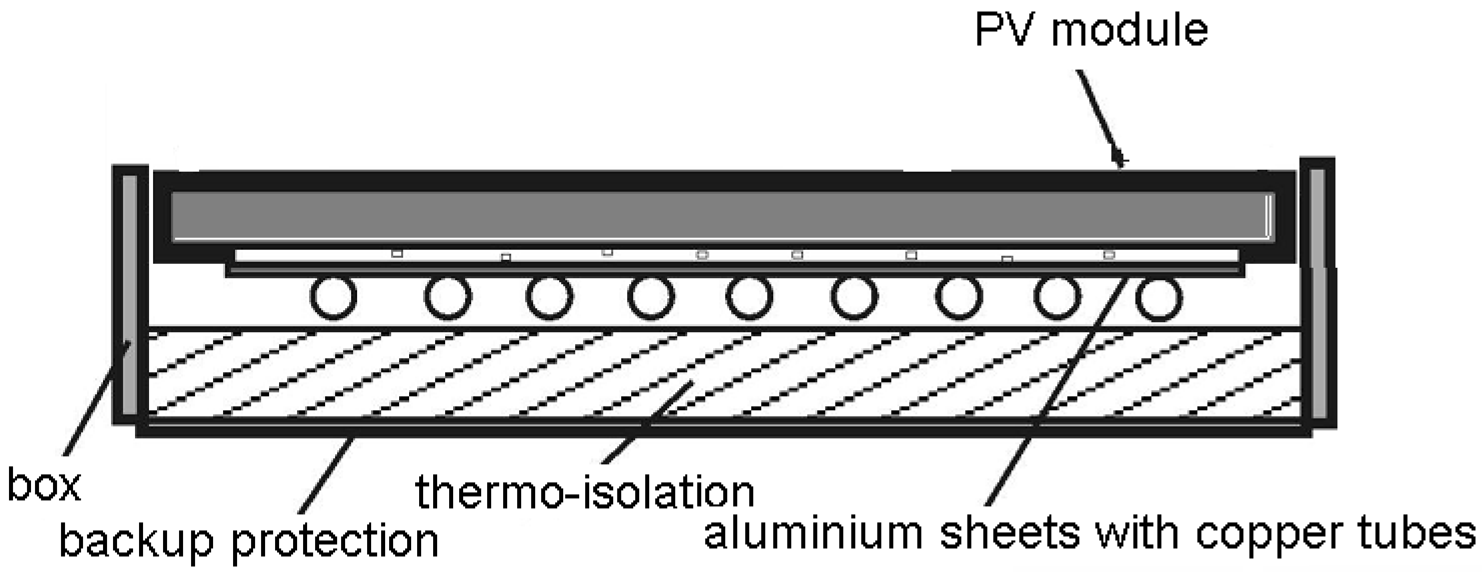

PV-Thermal

The heat from the PV cells are conducted through the metal and absorbed by the working fluid (presuming that the working fluid is cooler than the operating temperature of the cells).



Both electric and thermal energy generation

PV-T module structure



PV-T modules have:

• relatively high parasitic capacitance

• relatively low temperature of the output liquid (high temperature of cooling liquid decreases efficiency of PV module)


alpakot ranch 40kwhd multi solar sys.

PVT liquid collector

unglazed module (ECN)

glazed module (PVTwins)

PVT air collector

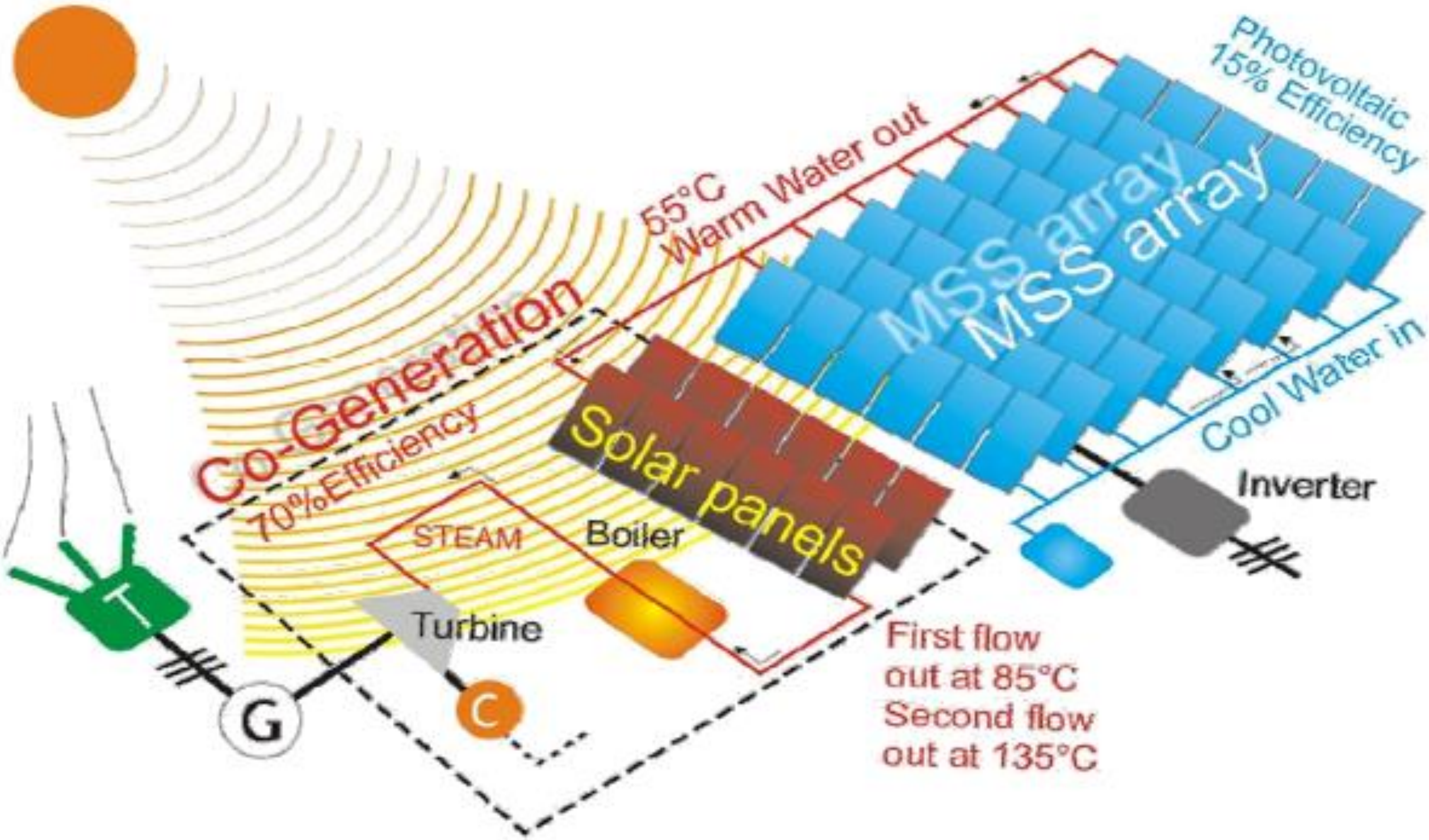
unglazed module (Grammer Solar)

glazed module (Aidt Miljø)

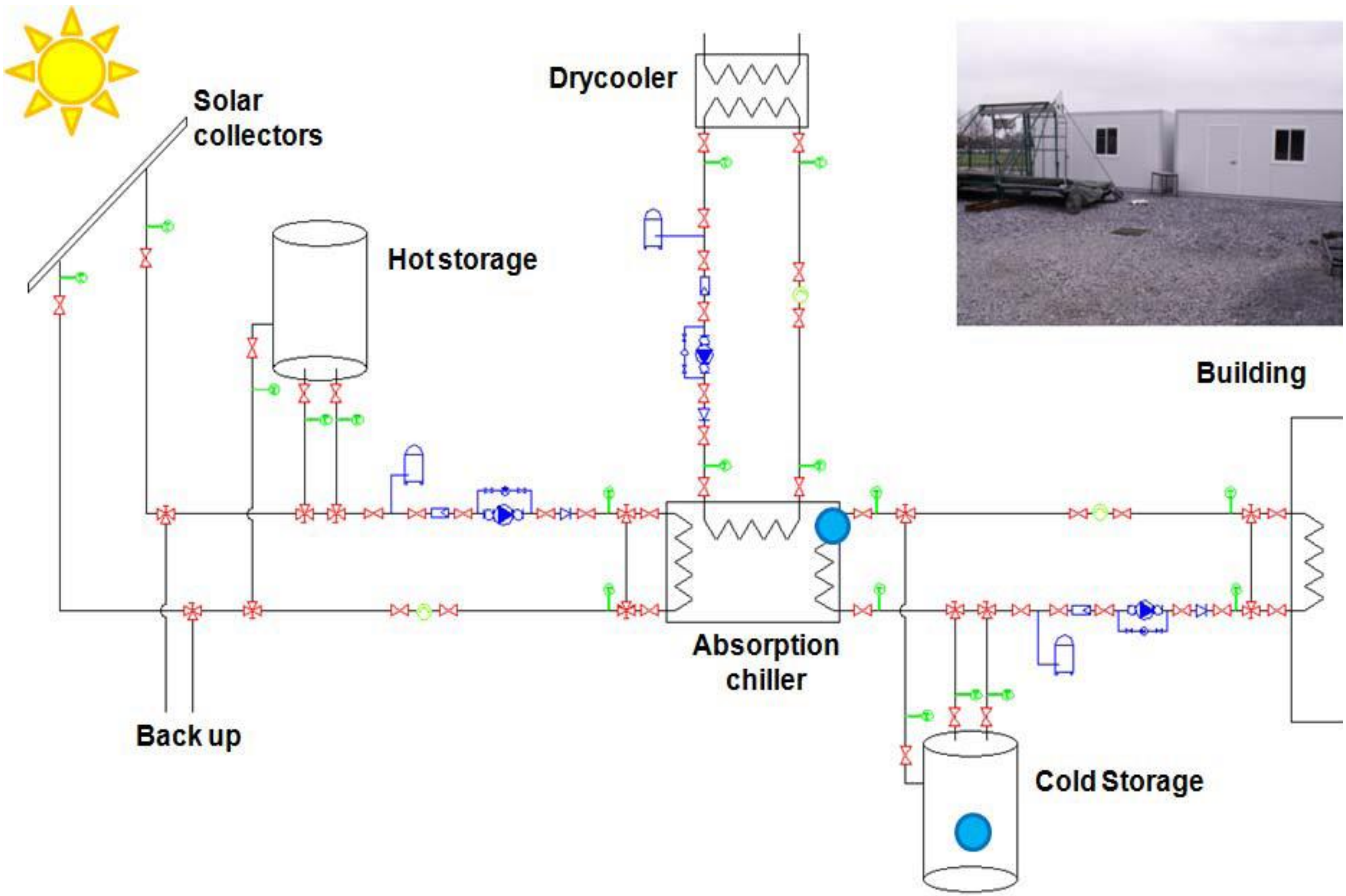
PVT concentrator

stationary module (Vattenfall)

tracking module (ANU)


Photovoltaic
15% Efficiency
MSS array
MSS array
55°C
Warm Water out
Co-Generation
70%Efficiency
Solar panels
Cool Water in
Inverter
STEAM
Boiler
Turbine
T
G
C
First flow
out at 85°C
Second flow
out at 135°C

Solar cooling



http://www.solcoproject.net/docs/SOLCO_TECHNICAL_FINAL.pdf

http://www.youtube.com/watch?v=AtMC2MXc_n8