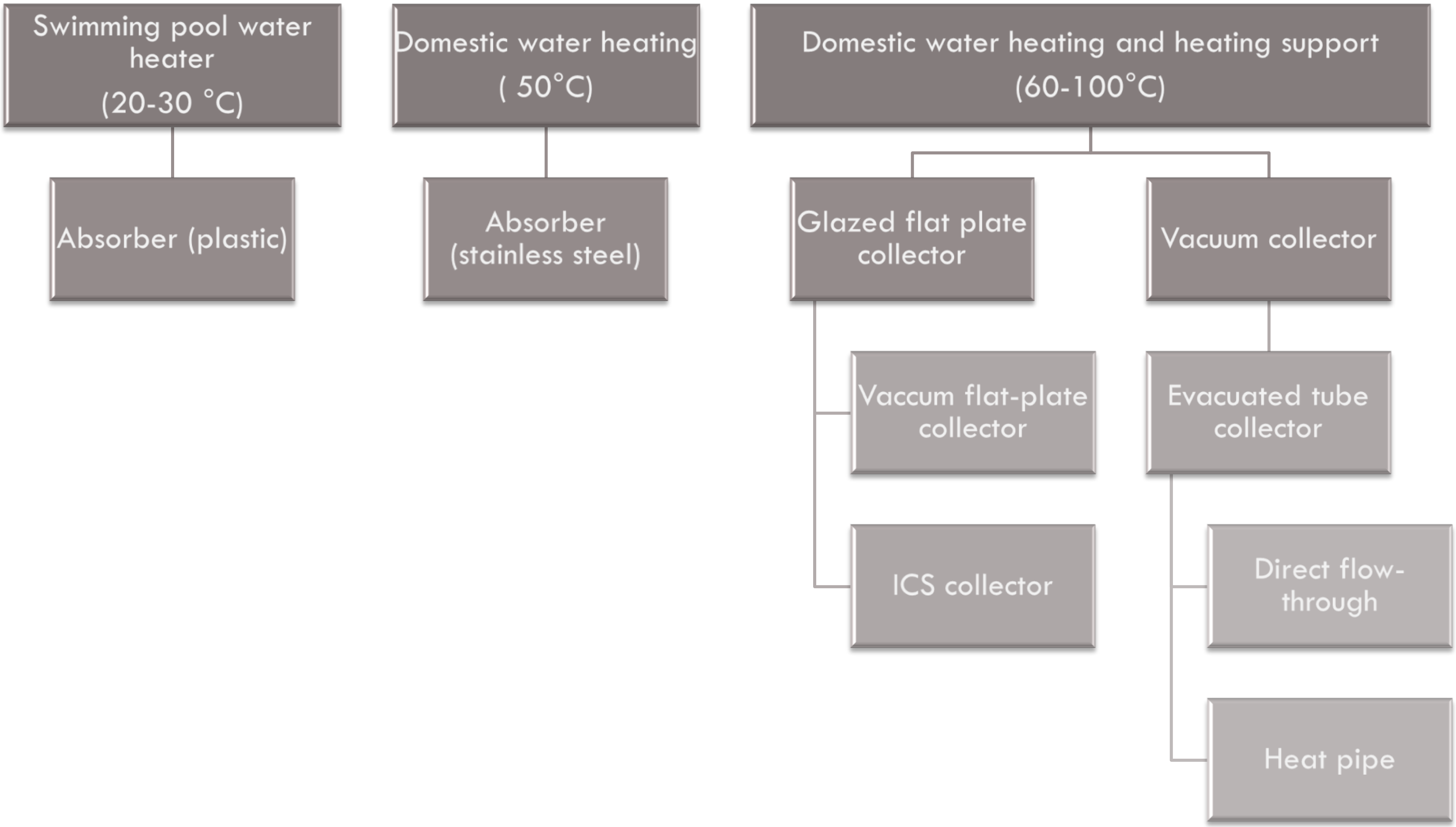
SOLAR THERMAL COLLECTORS

Dr. Osama Ayadi

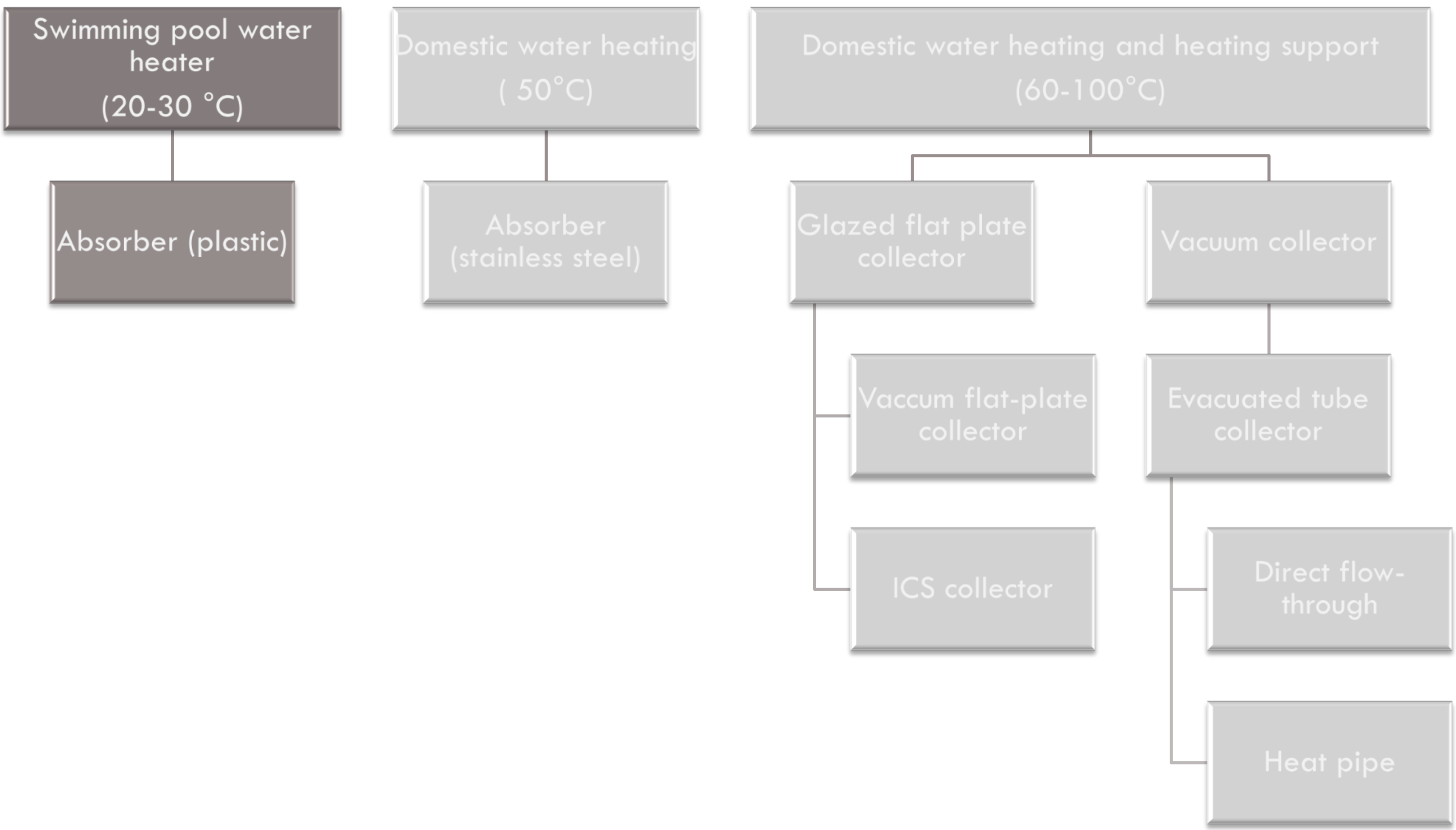
Solar thermal collectors

- Manufacturing and working principle
- Typologies
- Efficiency curve
- Test standards

Solar thermal collectors



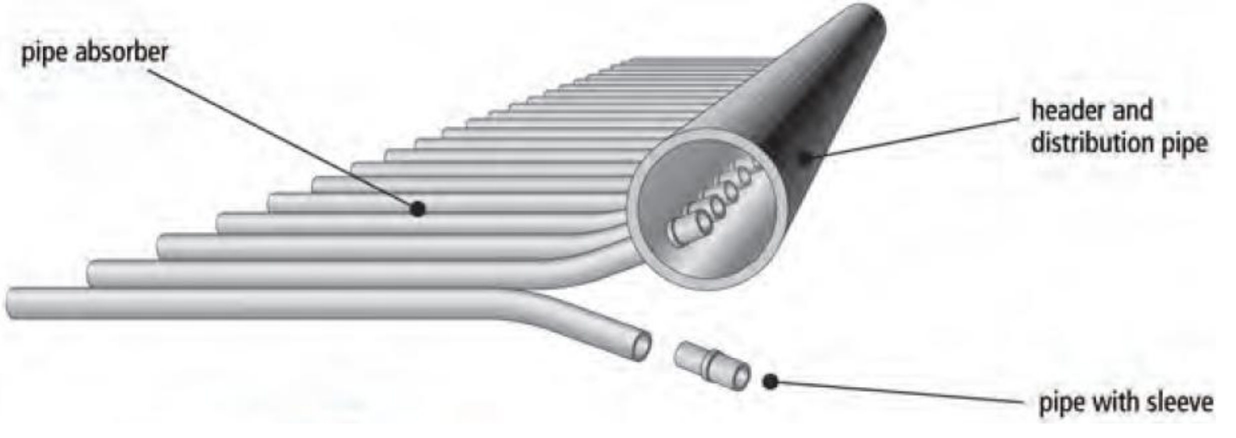
Solar thermal collectors



Collectors without cover

Advantages:

1. The required temperature level is comparatively low, at 18–25°C.
2. The swimming season coincides with the time of the highest solar radiation.
3. Simple system design. The pool water flows directly through the absorber.

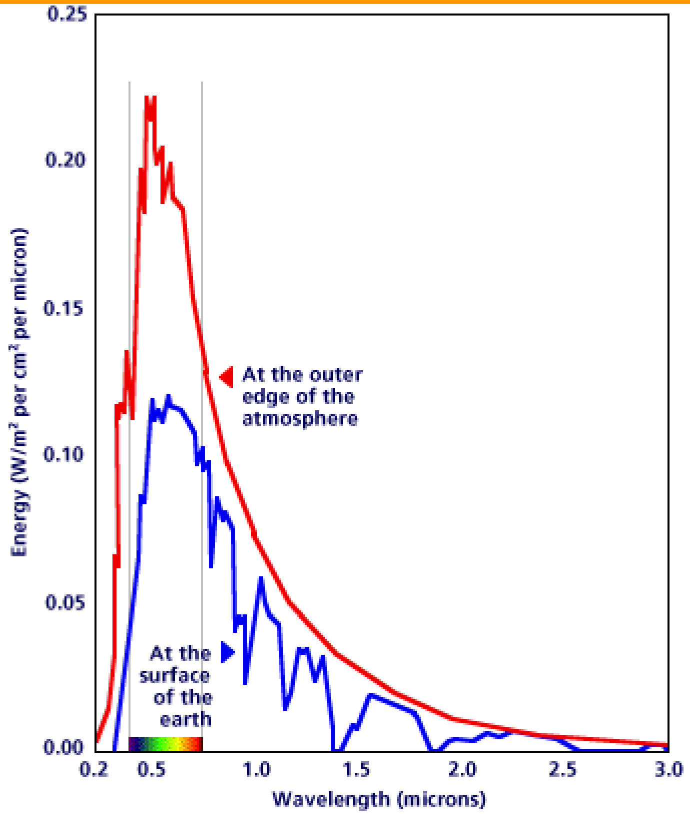


Collectors without cover

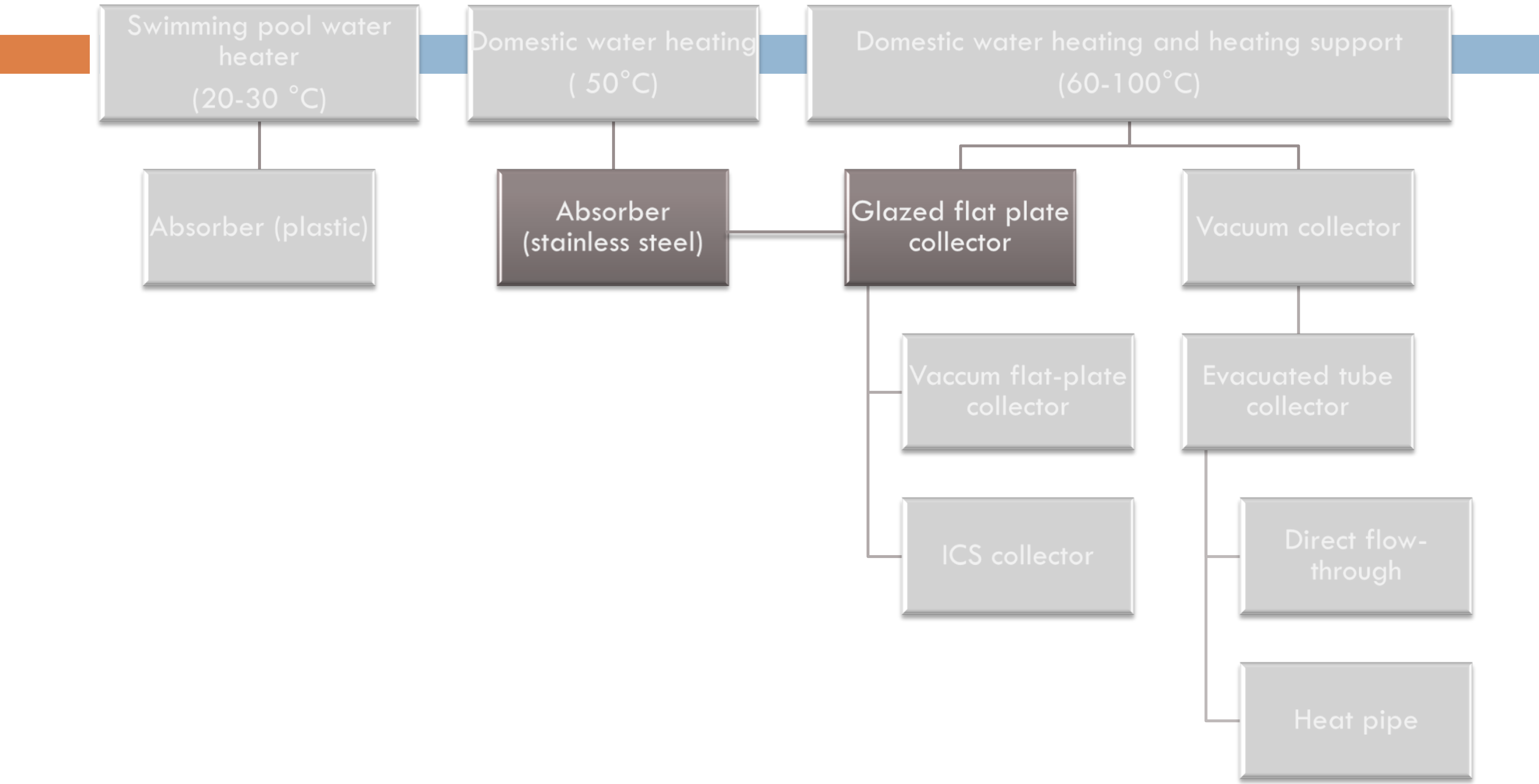
- No box, no cover, no insulation
- ***Absorber*** is made of black plastic material, resistant to UV radiation:
    - **Polypropylene**
    - **Neoprene**
    - **PVC**
    - **Synthetic rubber (EPDM)**

Used only in warm seasons (e.g. open pools):

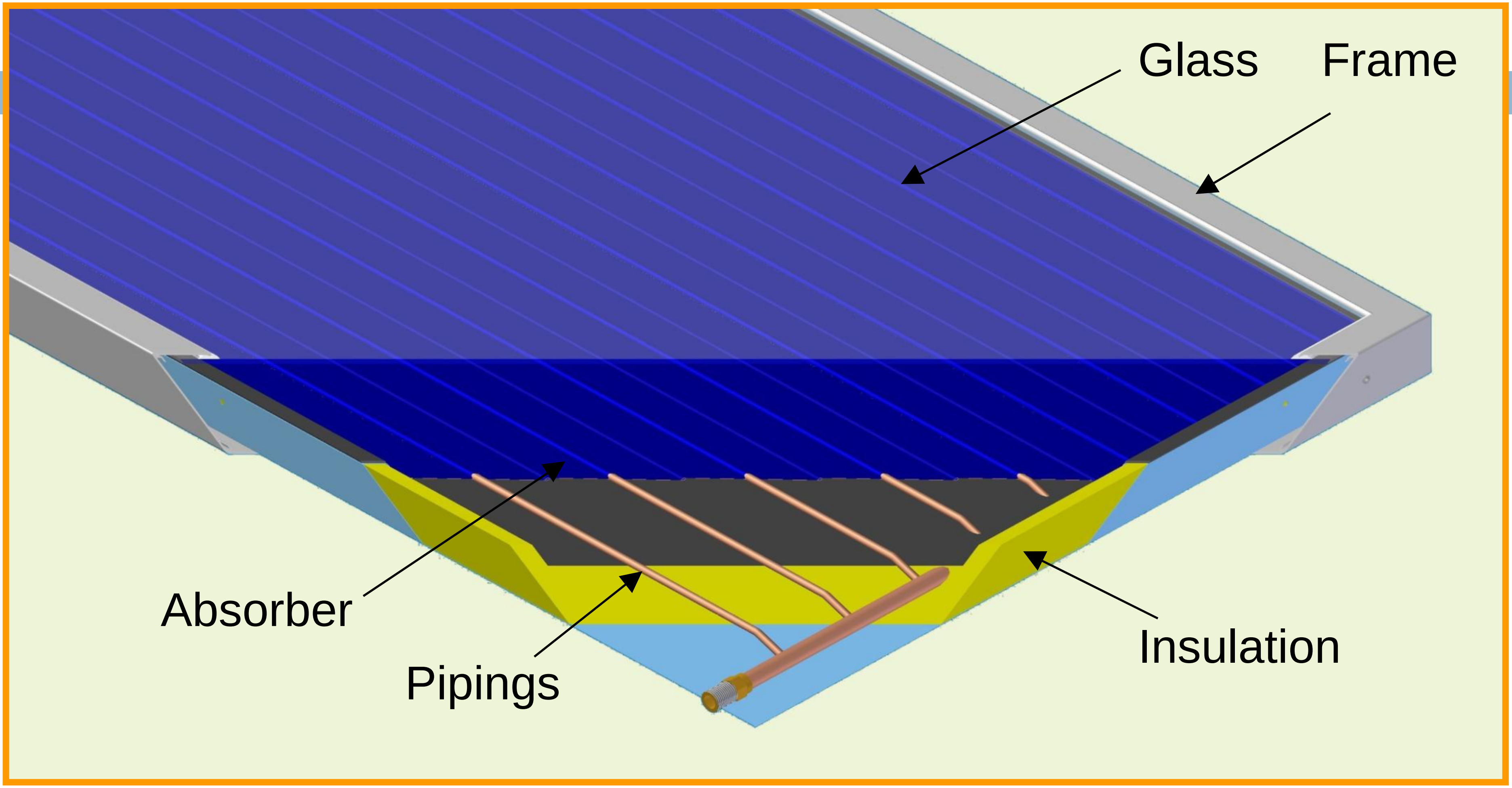
- low required temperature
- low investment costs



Solar thermal collectors

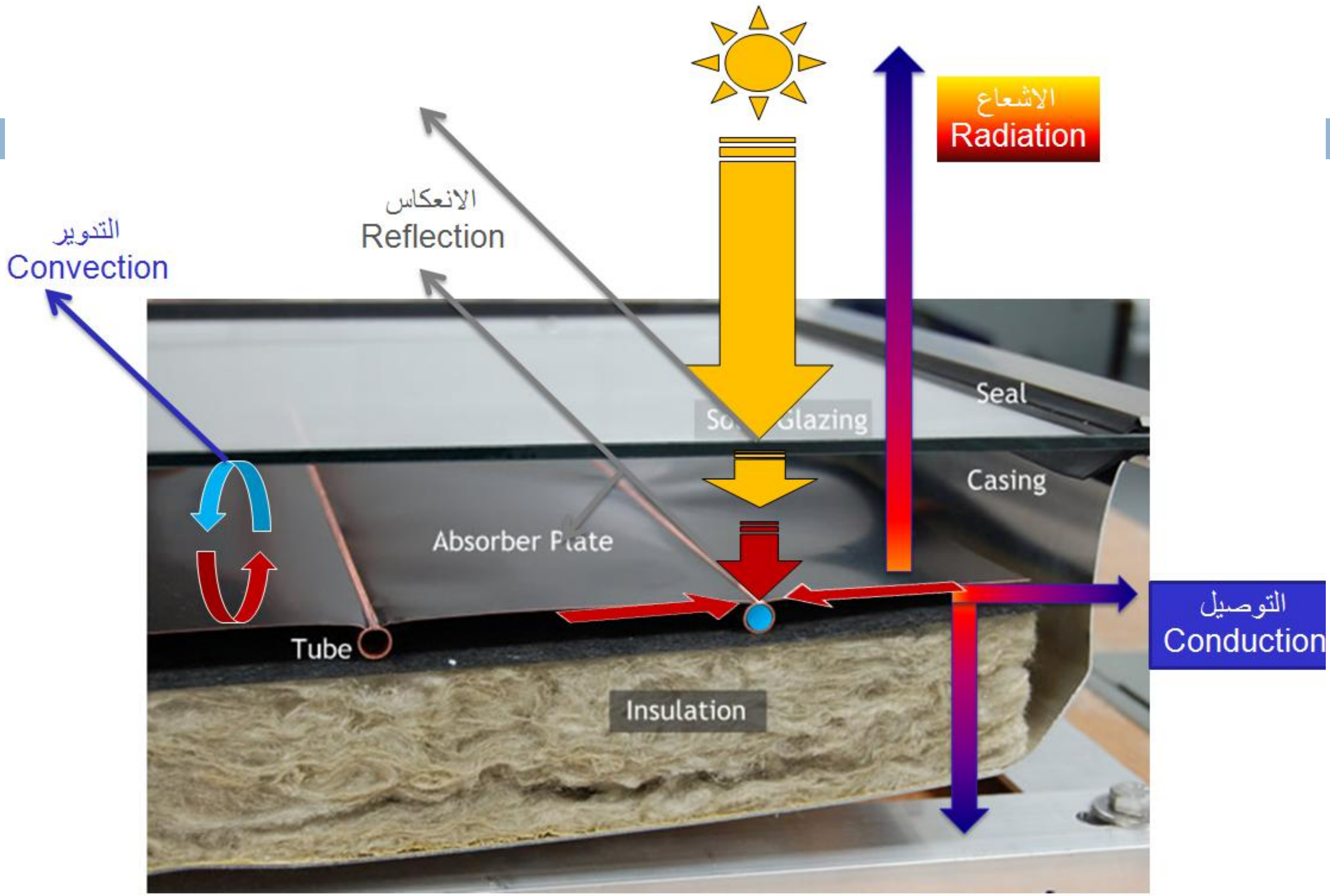


Manufacturing of a solar thermal collector

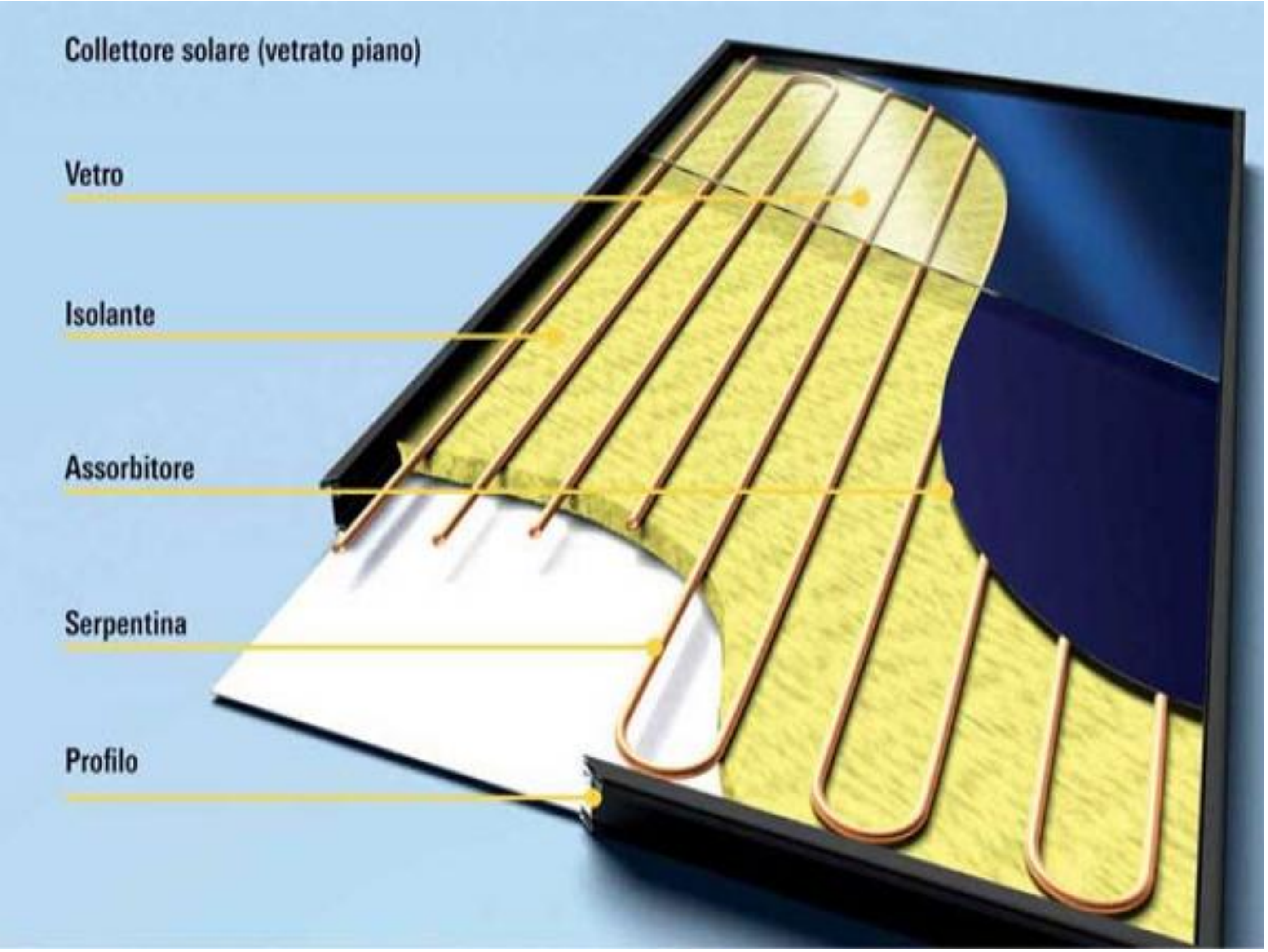


Source: Idaltermo, http://www.alliedsolar.ie

Thermal Energy Flow

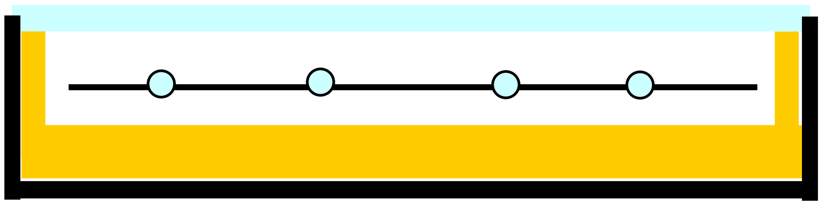


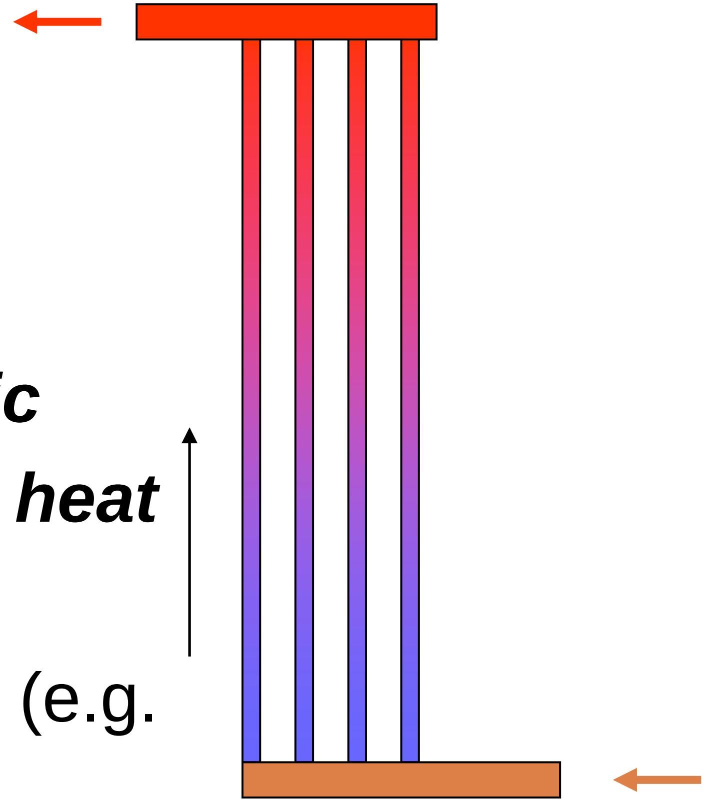
Absorber plate – serpentine shape



Source: Schuco

Absorber plate





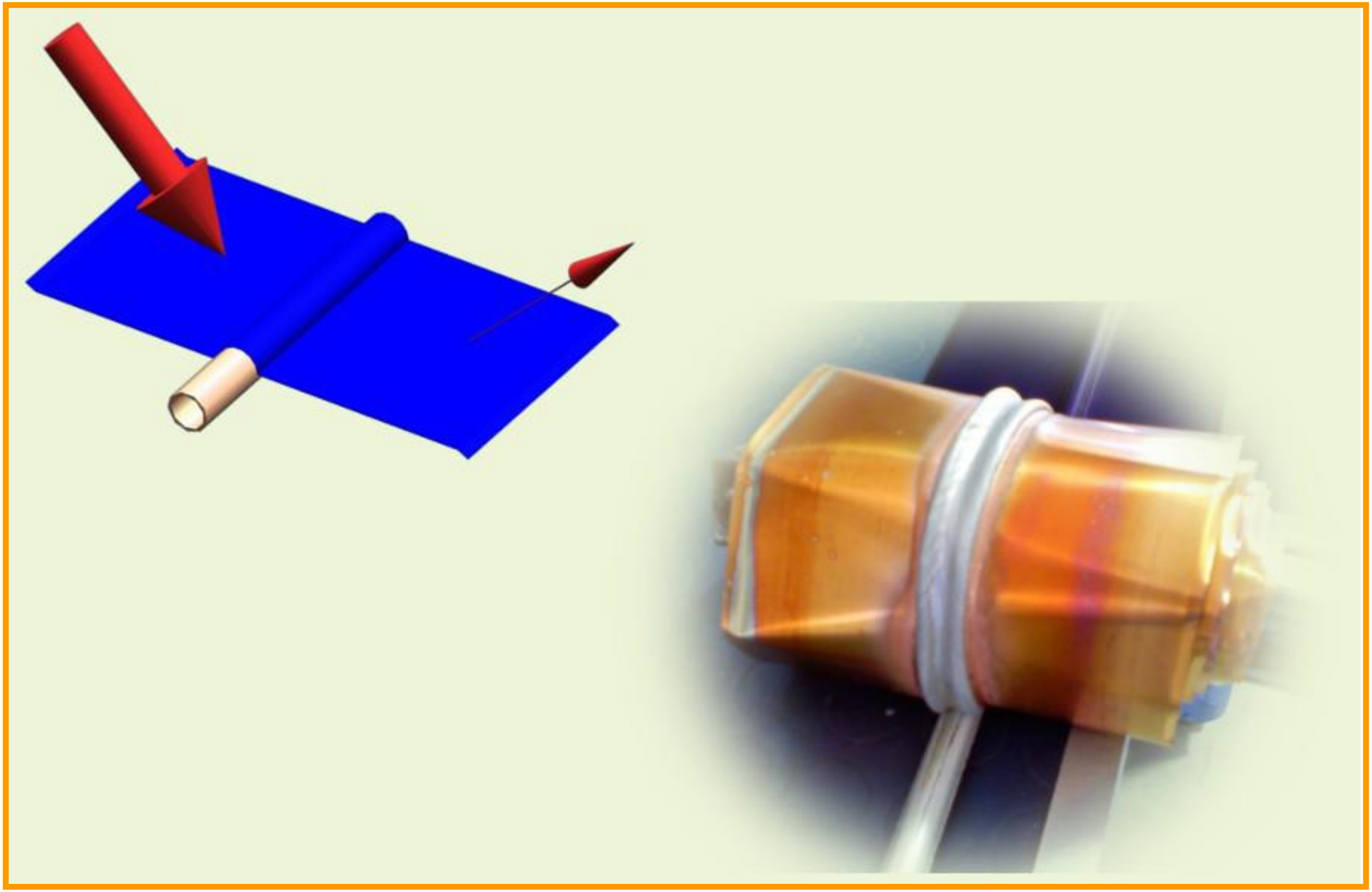
Receives sunlight (electromagnetic energy), transforms it into heat, leads heat into pipes:

Thermal resistance should be minimized (e.g. welding rather than joint)

سطح الامتصاص :

يصنع سطح الامتصاص في الغالب من معدن مطلي بألوان داكنة وذلك لزيادة معدل امتصاص حيث تتميز الألوان الداكنة بمعدل عال الامتصاص الأشعة الشمسية يصل إلى 98% ولكن يعاب على الألوان الداكنة قابليتها الشديدة لفقد الحرارة بطريقة الإشعاع حيث يصل ذلك المعدل إلى 90% بعبارة أخرى فإن السطح الماص الداكن قادر على امتصاص ما نسبته 98% من الطاقة الساقطة عليه ولكنه سيعيد إشعاع ما نسبته 90% من الطاقة المكتسبة لتصبح الاستفادة من جزء صغير فقط من الطاقة الشمسية الساقطة على السخان وستضيع النسبة الكبرى سدي من أجل ذلك تستخدم أنواع خاصة من الطلاء ذات معدل امتصاص عالي ومعدل إشعاع منخفض وتسمي مثل هذه الطلاءات بالطلاءات الانتقائية (Selective Coatings) ومن أمثلة هذه الطلاءات أكاسيد الكروم والكوبالت .

Selective absorber



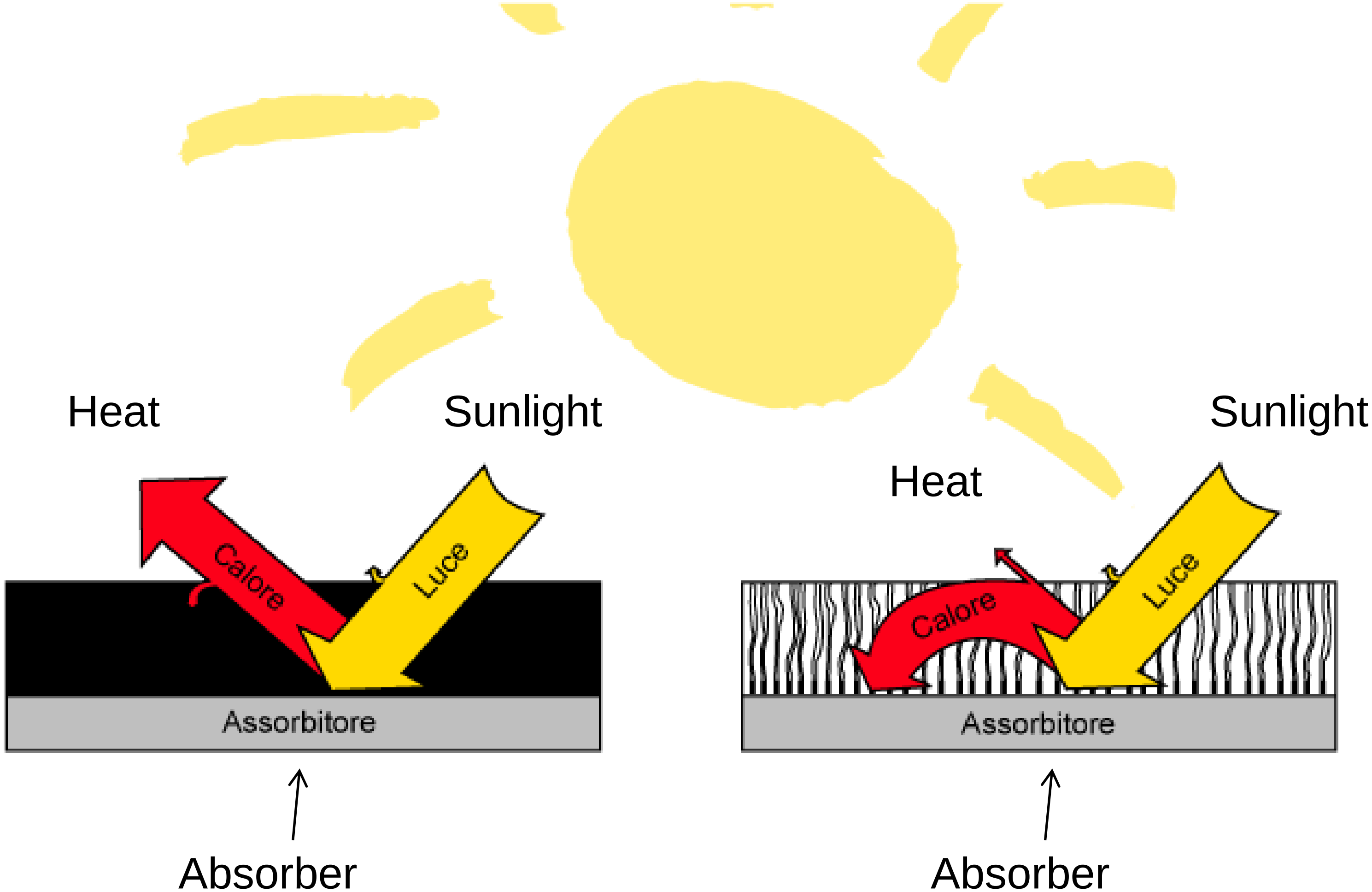
Source: Idaltermo

Absorber plate characteristics

- Usually made of **copper, aluminium or steel**, with surface treatment based on selective materials (chrome, black nickel)
- Sometimes made of **dark paint**
- Aim is to reduce reflexion and increase absorption. Low emission is required in infrared part of spectrum (50 - 100 °C)

- Absorption: 92-95%
- Emissivity of selctive treated surfaces: 5-10%
- Emissivity of dark paints: 85%-95%

Selective absorber



Source: Target/Wagner & Co

Insultaing material

Porous material, should reduce **conduction losses** to a minimum

Most common materials:

Polyurethane, polyester wool, glasswool, rockwool

(in plates, rolls, foam)

TIM (Transparent Insulation Materials).

- العازل الحراري :

عندما ترتفع درجة الحرارة داخل السخانات بالمقارنة بالجو المحيط بها يصبح هناك إمكانية لفقد هذه الحرارة .بالتوصيل وذلك عن طريق جوانب السخان والجهة السفلية منه ، وبالحمل ، والإشعاع عن طريق الغلاف الزجاجي ، وعليه يمكن الاستعانة بمواد وأساليب خاصة للحد من هذه الفواقد حسب نوعية الفقد وذلك على النحو التالي : -

الفقد بالتوصيل : ويمكن الحد منه بإحاطة جوانب وأسفل سطح الامتصاص وأنابيب التسخين بمواد خاصة ذات توصيلية حرارية متدنية مثل الصوف الزجاجي الألياف الزجاجية والبولي ستيرين .

الفقد بالحمل : ويمكن الحد منه بسحب الهواء الموجود بين الأغطية الزجاجية أو يوضع أنابيب التسخين مع السطح الماص دخل أنابيب زجاجية مفرغة من الهواء .

الفقد الإشعاع : ويمكن الحد منه باستخدام أغلفة زجاجية منفذة للأشعة القصيرة من الشمس وفي نفس الوقت معتمة بحيث تمنع انعكاس الأشعة ذات الموجات الطويلة الصادرة من السطح الماص .

Transparent cover

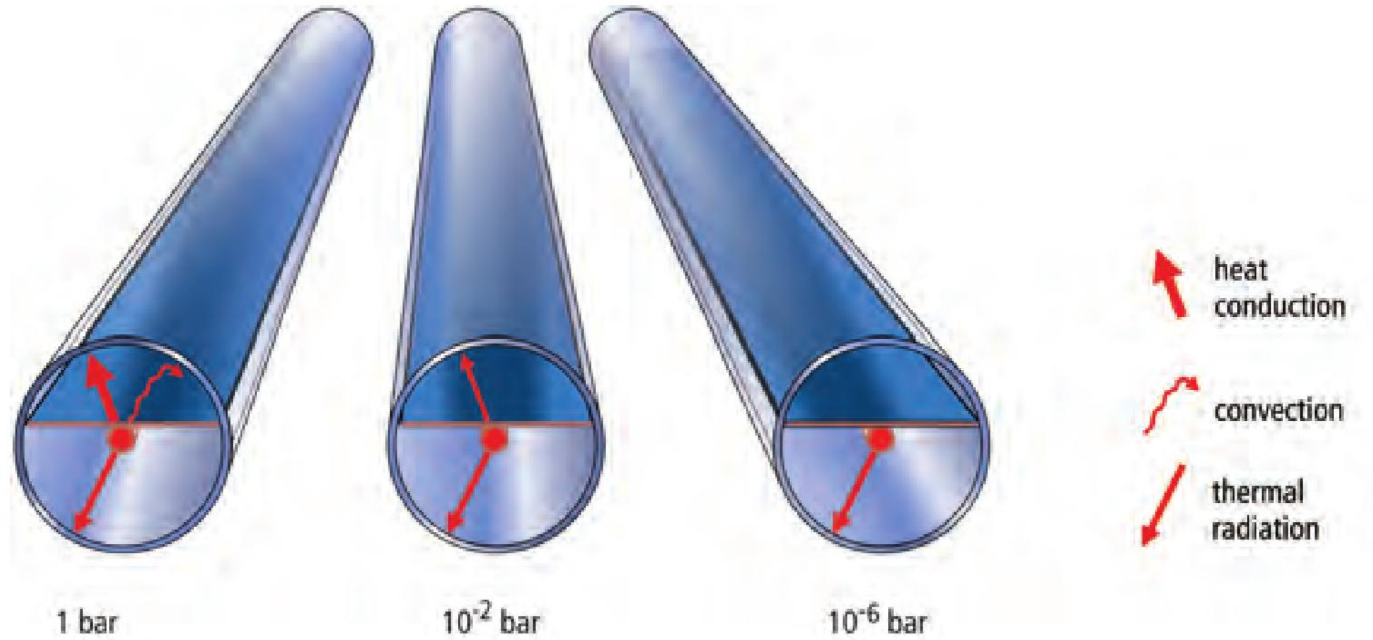
The transparent cover should:

- Let solar radiation wavelength go through
- Block infrared wavelenght

Most common materials

1. **Single glazing**
2. **Double glazing**

Vacuum tube collectors

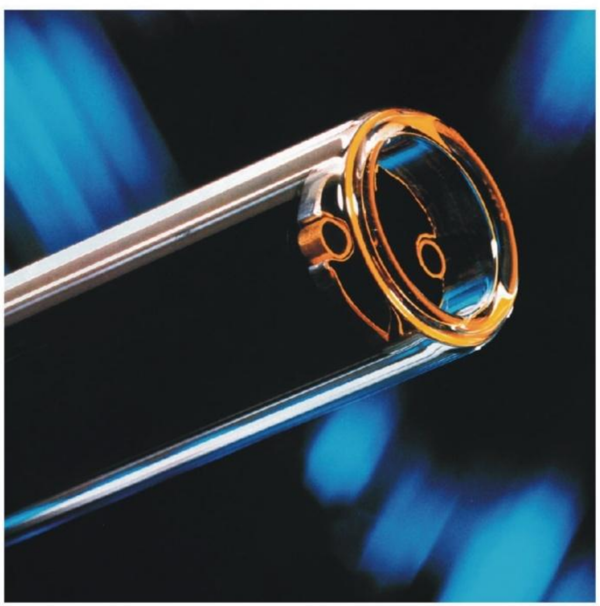


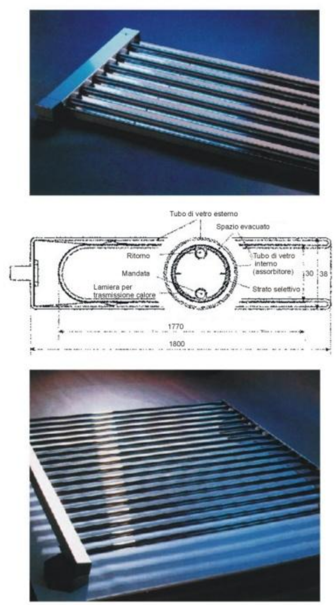
- To reduce the thermal losses in a collector, glass cylinders (with internal absorbers) are evacuated in a similar way to Thermos flasks.
- In order to completely suppress thermal losses through convection, the volume enclosed in the glass tubes must be evacuated to less than 10^{-2} bar (1 kPa).
- Additional evacuation prevents losses through thermal conduction.
- The radiation losses cannot be reduced by creating a vacuum, as no medium is necessary for the transport of radiation. They are kept low, as in the case of glazed flat-plate collectors, by selective coatings

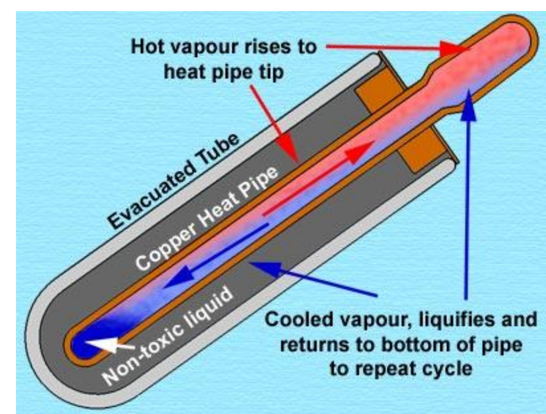
Source:Solar thermal systems

Evacuated Tube collector

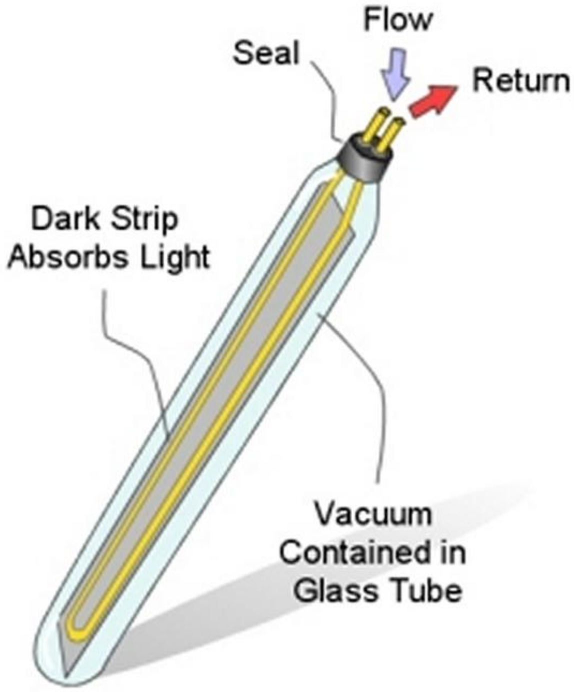
- Flow through
  - Pipe in pipe (coaxial tube)
  - U tube
- Heat pipe







Direct Flow



•variable installation methods.

• Flexible building integration – can be installed on façades or flat roofs.

• Heat transfer fluid is circulated in a coaxial movement.

Heat Pipe

•The dry connection between manifold and tube means tubes can be easily fitted and replaced, without the need to drain down the system.

• The system consists of two separate circuits: one in each individual tube inside the heat pipe and one through the manifold into the hot water tank

Sources: Kingspan, http://www.viridiansolar.co.uk

Collector positions

Collector Positions

1 Ideal slope 40˚
2 Roof kit angled 40˚
3 Elevated 20˚
4 Horizontal ideal slope
5 Horizontal façade
6 Flat
7 Vertical façade

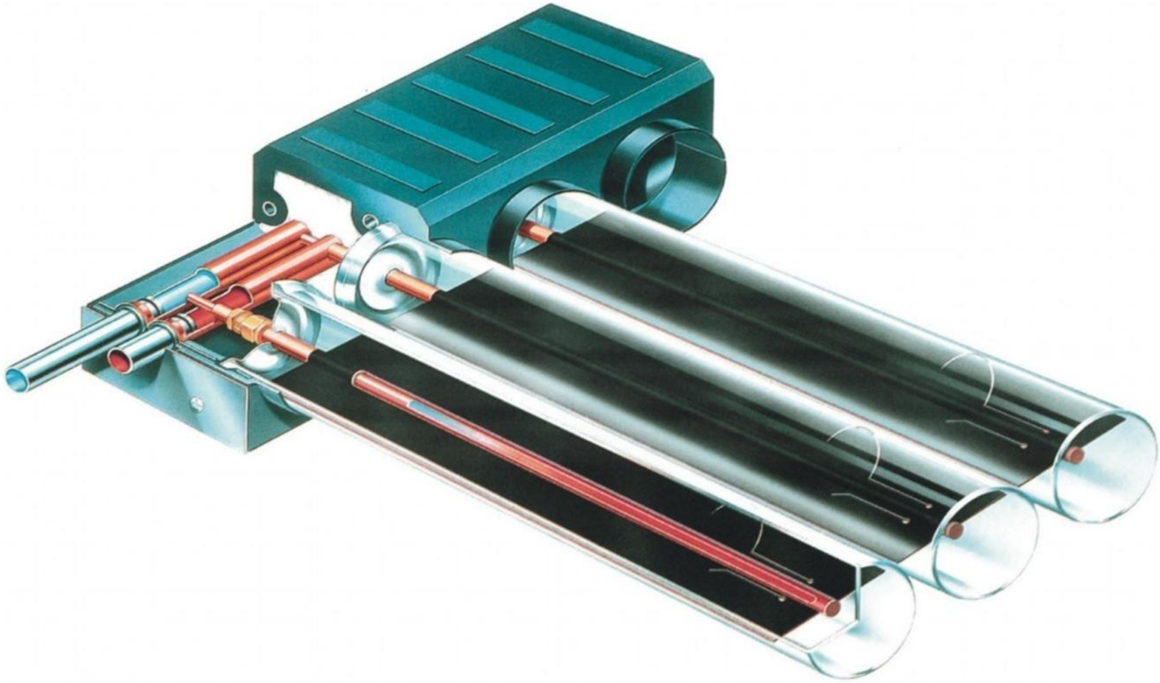
Direct Flow

Heat Pipe

For appropriate functioning of the tubes they must be installed at a minimum slpe of 25°C

Source: Kingspan

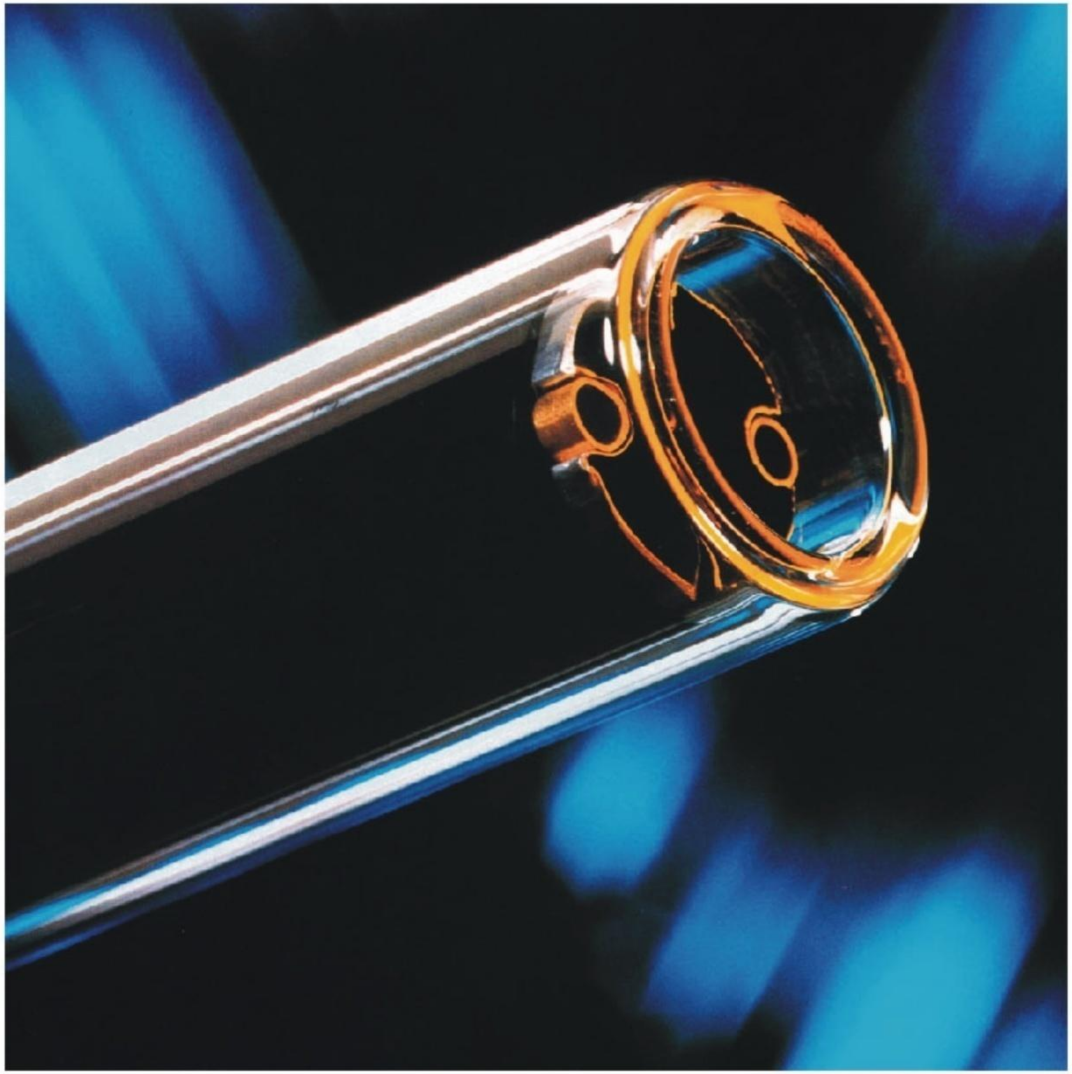
Direct flow evacuated tube collectors, Installed horizontally

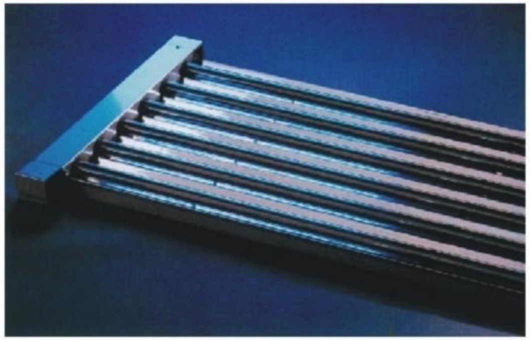


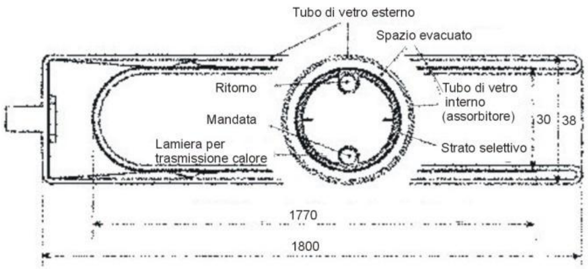
Source: Viessmann

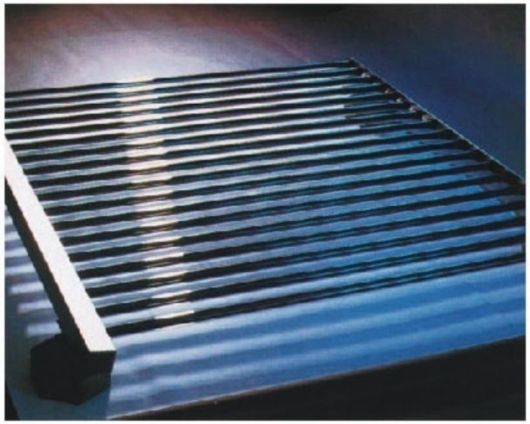
Vacuum tube collectors

Vacuum tube collectors – Sydney tube







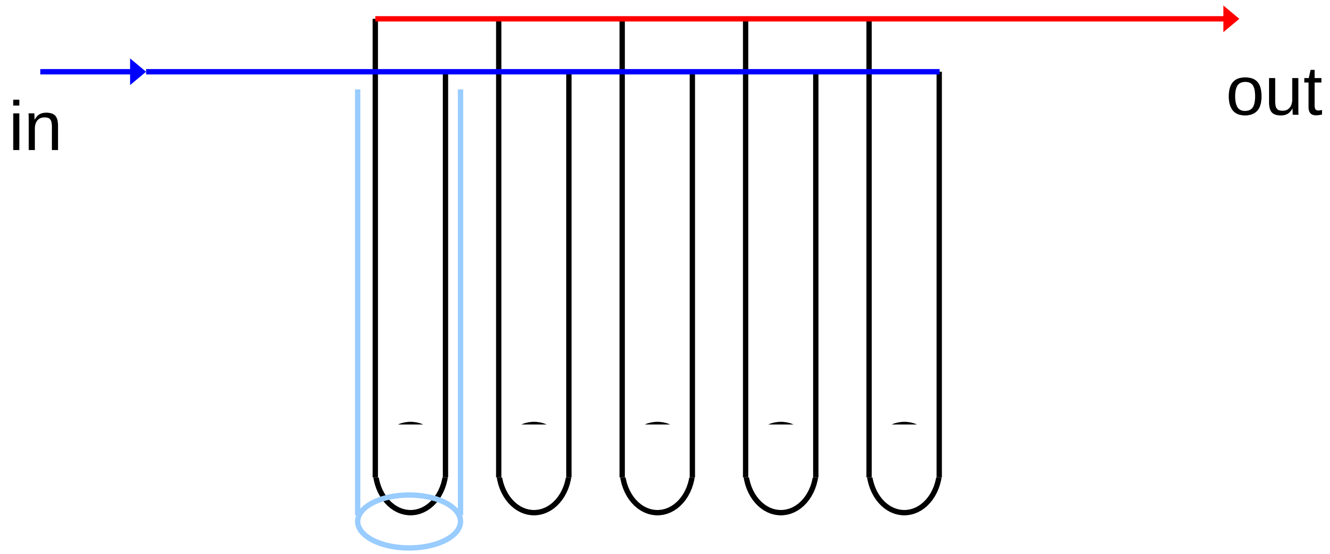


Source: Microtherm

Vacuum tube collectors

Type 1:

Themal fluid flows inside U pipes, which are directly connected to the absorber plate.



Vacuum tube collectors

Absorber can be

Cylindric:
adheres completely to the inner glass tube: **vacuum is created in the interspace between the 2 glass tubes**

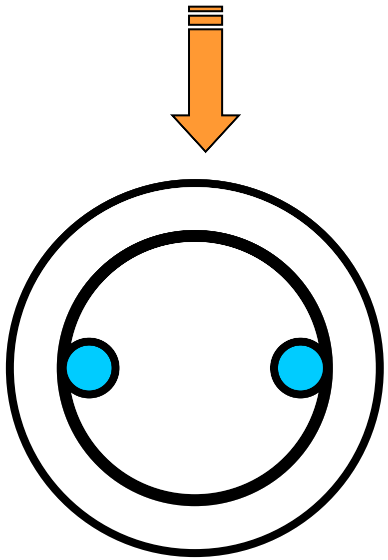
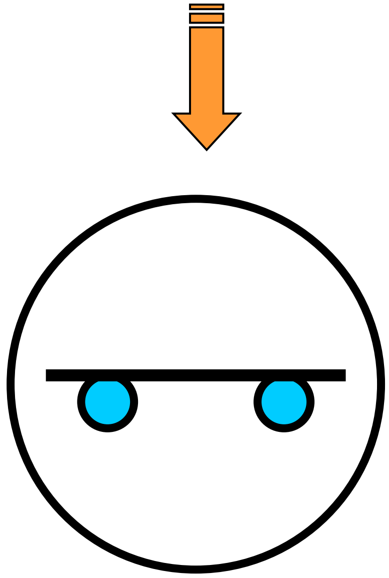
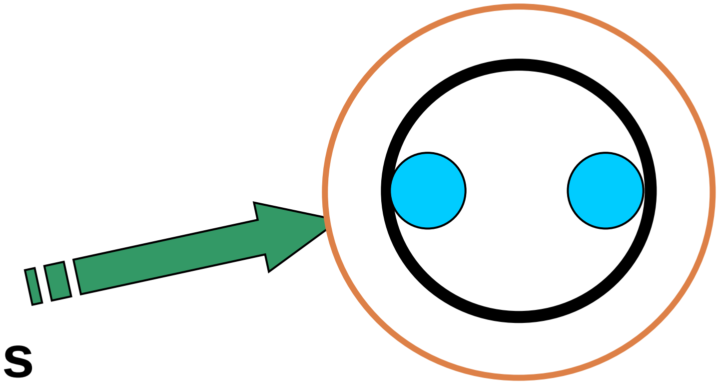


Plate:
(the whole glass tube is evacuated)



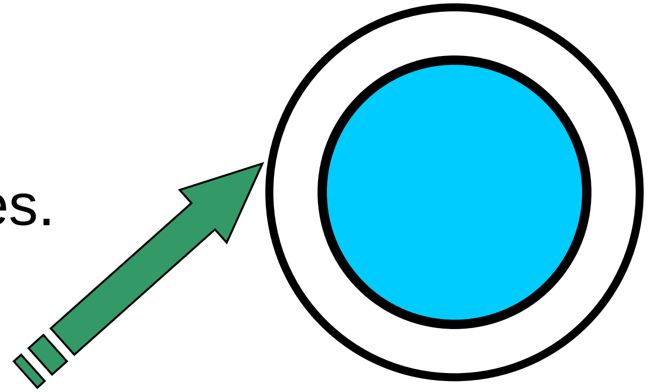
Vacuum tube collectors

Type 2:
Selective (or normal) paint is on the external surface of the inner glass tube



No metal absorber plate is used. Vacuum is created in the interspace between the 2 glass tubes

Some collectors are constructed as simple glass tubes with vacuum interspace, without metal pipes. The **glass tubes are directly filled with water**, which moves thanks to natural circulation (integrated storage).

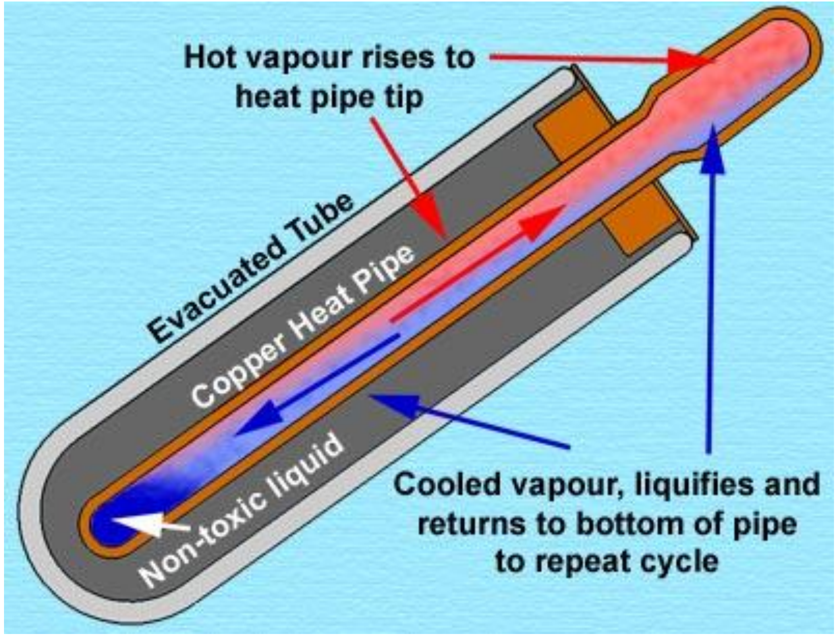


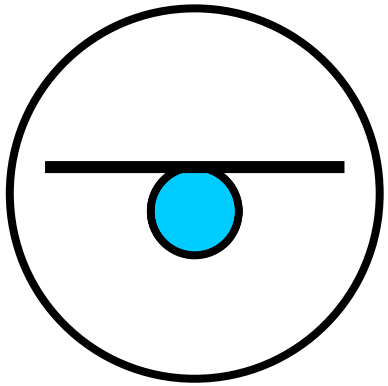
Vacuum tube collectors with “heat pipe”

Type 3:

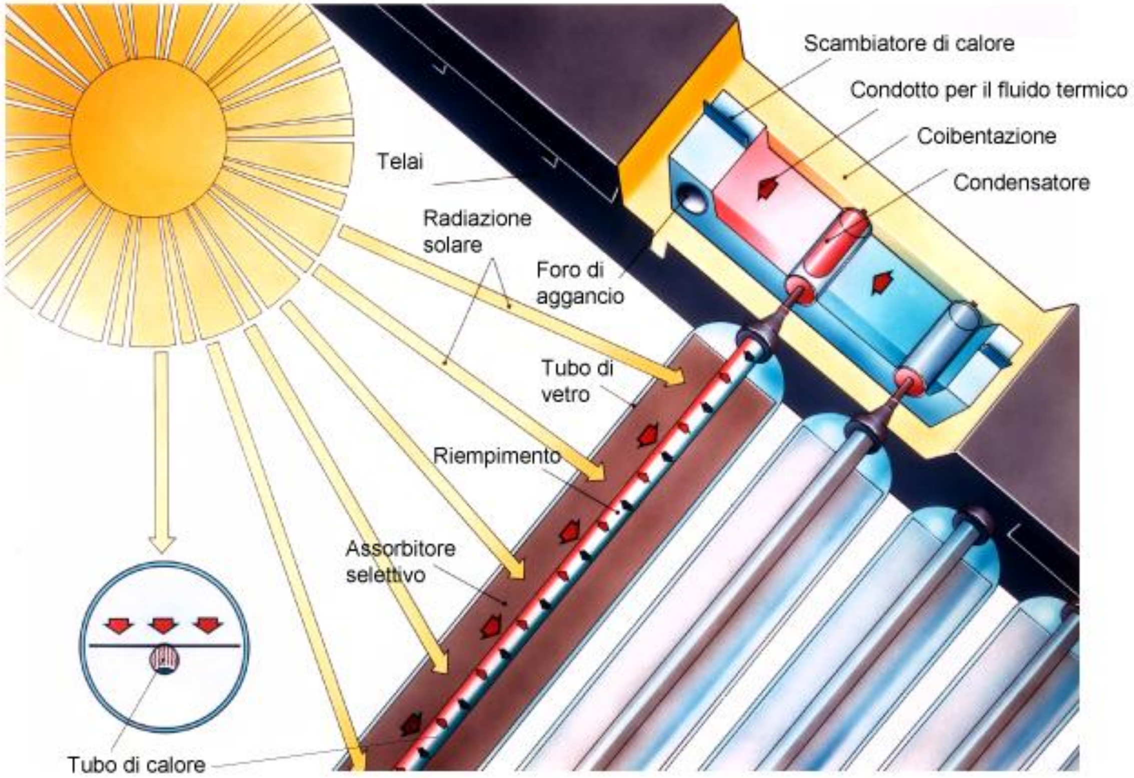
Fluid at very low pressure (usually distilled water) is closed inside the metal pipe (**heat pipe**). One end of the metal pipe is immersed in the primary circuit of the solar loop and works as heat exchanger. Inside the metal pipe, part of the low pressure fluid evaporates and rises towards the upper end, where it transfers its thermal energy to the fluid in the primary circuit, thus condensing and falling back into the vacuum tube.

In order to work, this collector must be installed with a certain slope angle (ca. 20 °).





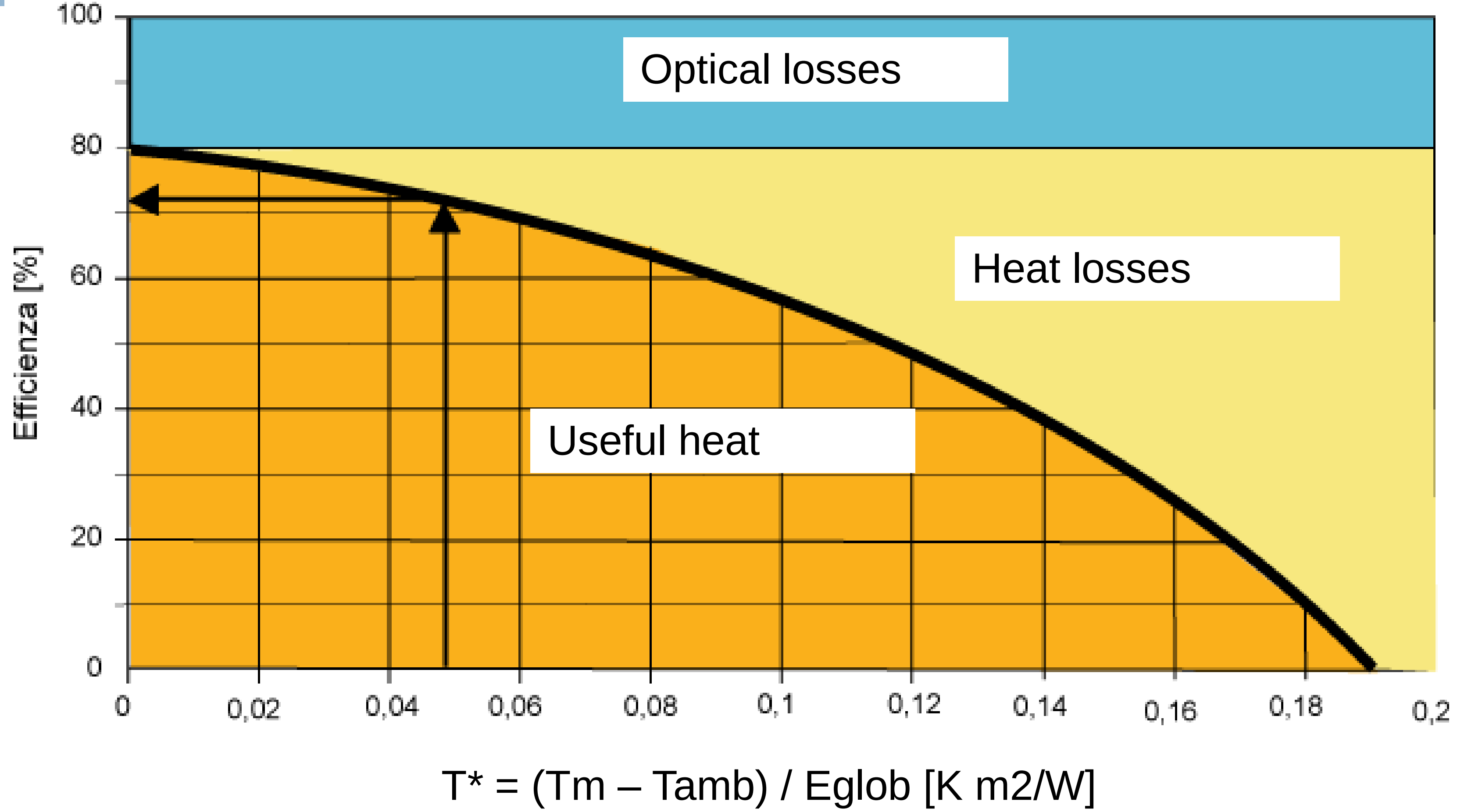
Vacuum tube collectors with “heat pipe”



Fone: Target/Stiebel Eltron

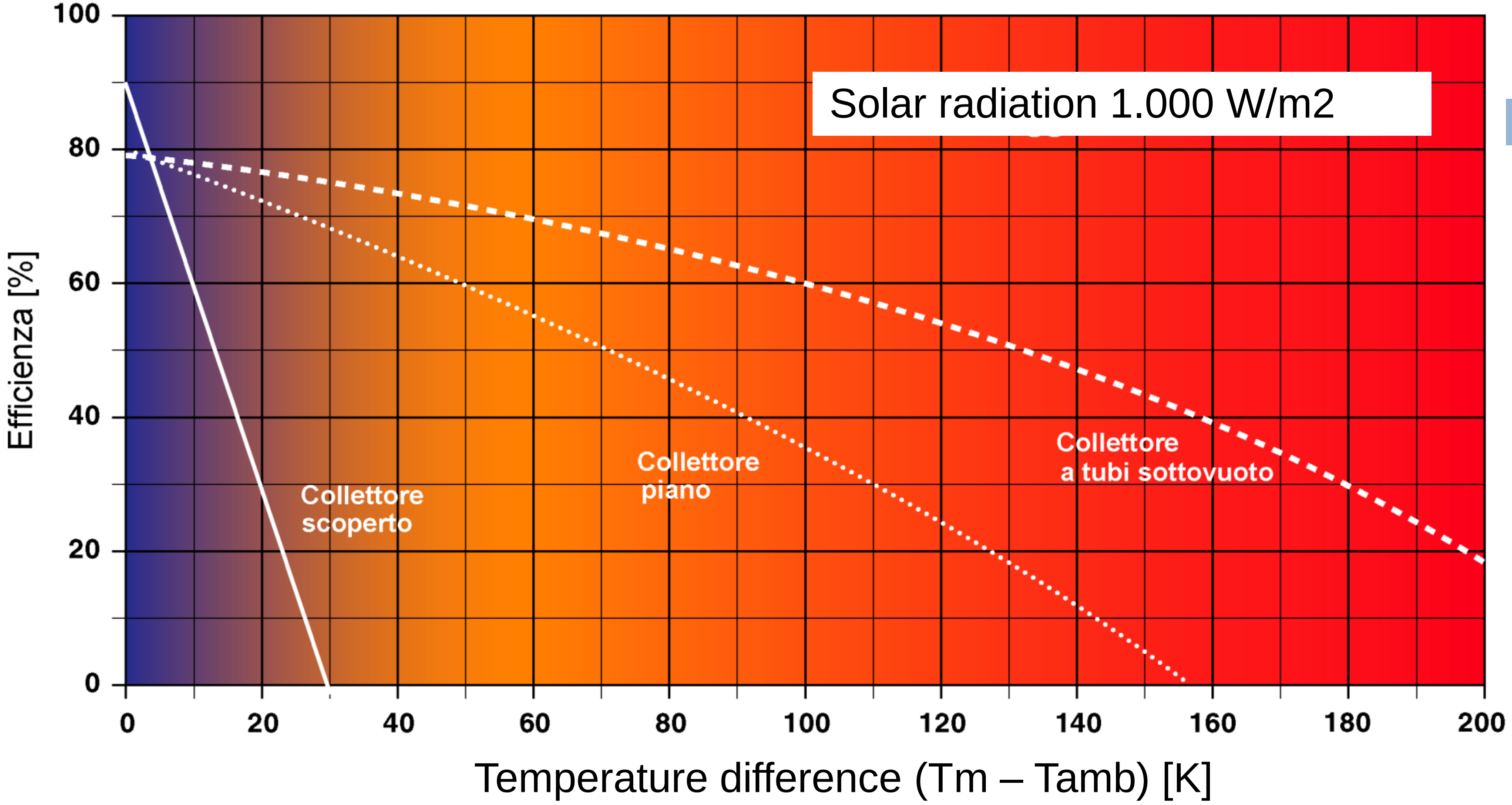
Type of Solar Panel	Pros	Cons
Flat Plate	• Simple • Robust • Better aesthetic • Can be roof-integrated • Cost-effective	• Marginally larger roof area needed.
Evacuated Tube	• Easier to retro-fit • Good for industrial applications	• Complex • Vacuum life • Aestheticaly difficult to integrate • Expensive

$$\eta = \eta_0 - k_1^* \Delta T / E_{glob,k} - k_2^* \Delta T^2 / E_{glob,k}$$



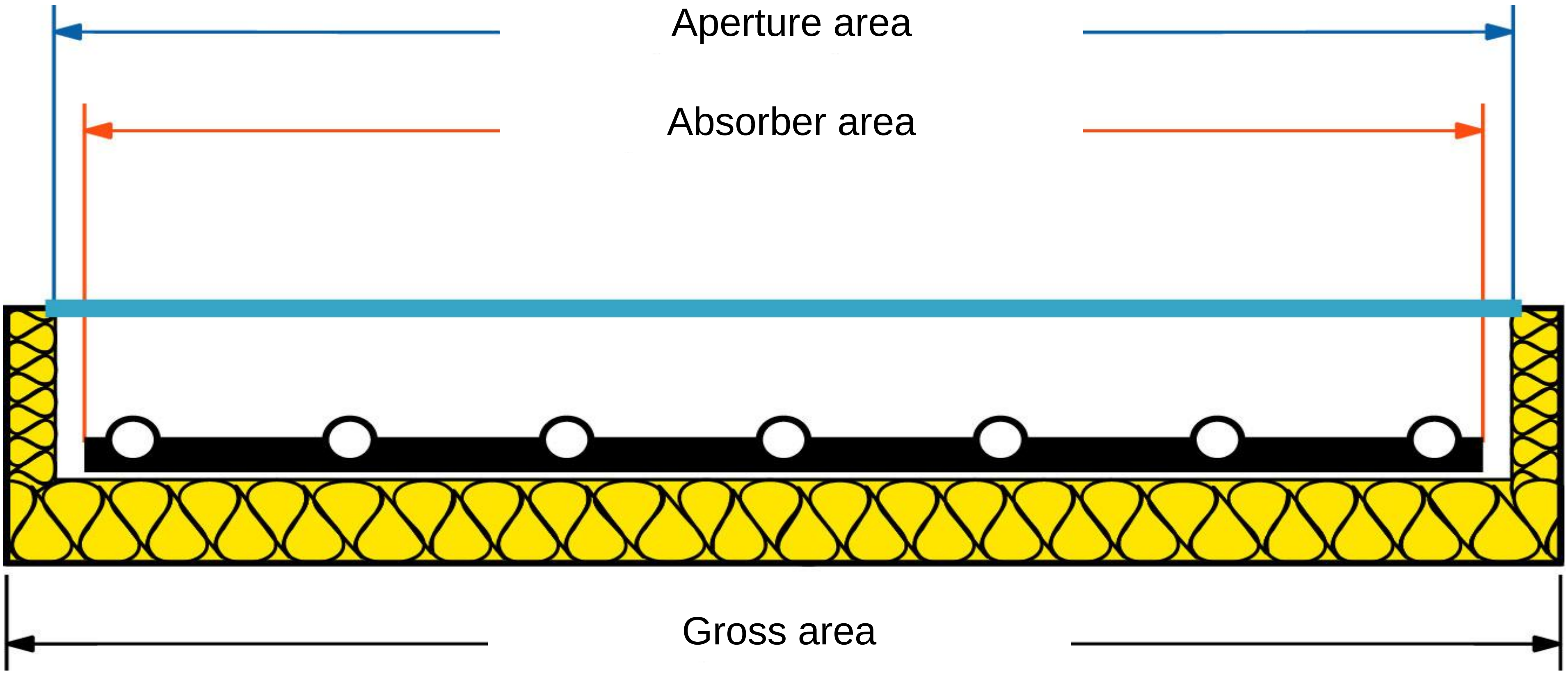
Source: Ambiente Italia

Comparing efficiency curves



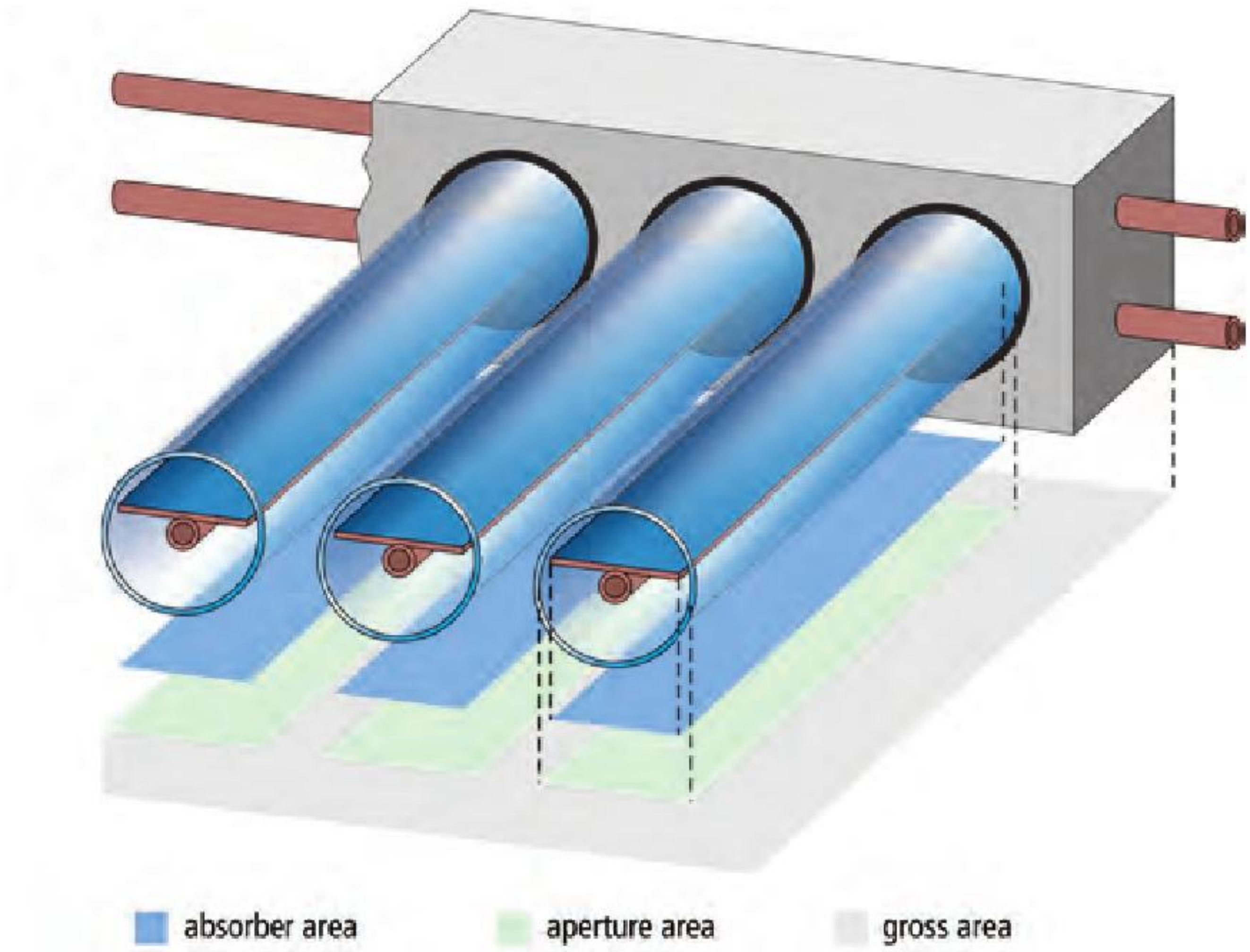
Source: Target/DGS

Definition of collector areas



Source: Target

Definition of collector areas



Source:Solar thermal systems

Technical sheet

Specification

Type SP3A		2 m²	3 m²
Number of tubes		20	30
Gross area*1	m^2	2.87	4.32
Absorber area	m^2	2.00	3.02
Aperture area*2	m^2	2.15	3.23
Dimensions			
Width a	mm	1420	2129
Height b	mm	2040	2040
Depth c	mm	143	143
Optical efficiency*3	%	80.9	80.4
Thermal loss correction value k_1*3	$W/(m^2 \cdot K)$	1.37	1.33
Thermal loss correction value k_2*3	$W/(m^2 \cdot K^2)$	0.0068	0.0067
Thermal capacity*3	$kJ/(m^2 \cdot K)$	8.5	8.4
Weight	kg	58	87
Liquid content (heat transfer medium)	litres	1.13	1.65
Permiss. operating pressure*4	bar	6	6
Max. idle temperature*5	°C	273	273
Connection	Ø mm	22	22
Requirements of base structure and fixings		with sufficient ballast to counteract prevailing wind forces	

Source: Isofoton

SPF Solartechnik Prüfung Forschung

C398

Solar Collector Factsheet Winkler VarioSol E

Model	VarioSol E
Type	Flat plate collector
Manufacturer	Winkler Solar GmbH
Address	Räterweg 17
	AT-6800 Feldkirch
Telephone	+43 (05522) 76139
Fax	+43 (05522) 76139-21
Email	solar@winklersolar.com
Internet	**www.winklersolar.com**
Test date	04.2000

☑ Performance test EN12975
☑ Quality test EN12975

SPF Quality Label

Dimensions

Total length	2.017 m
Total width	4.000 m
Gross area	8.068 m^2
Aperture area	7.324 m^2
Absorber area	7.168 m^2
Weight empty	245 kg

Technical data

Minimum flowrate	160 l/h
Nominal flowrate	500 l/h
Maximum flowrate	960 l/h
Fluid content	5.1 l
Maximum operating pressure	6 bar
Stagnation temperature	-- °C

Types of mounting

☐ Construction for sloping roof
☑ Integration into sloping roof
☑ On flat roof with stand
☑ Facade

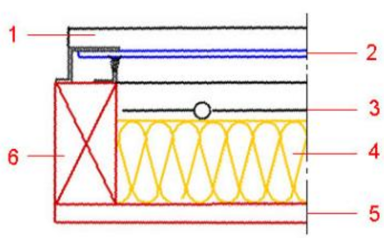
Further information

☑ Units in different sizes available
☑ Glazing replaceable

Hydraulic connection

Copper pipe, nominal diameter 22 mm

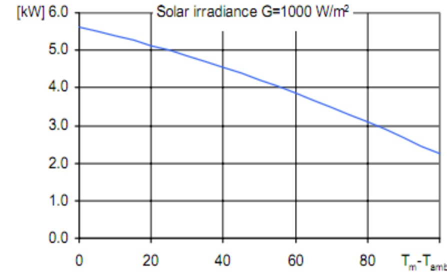
Construction



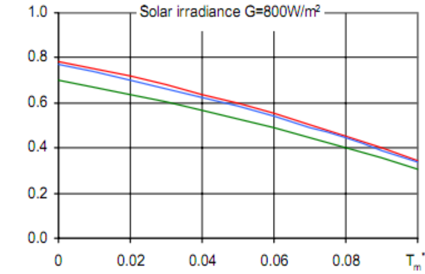
1 Cover rail
2 Glazing
3 Absorber
4 Thermal insulation
5 Rear panel
6 Casing

Source: www.solarenergy.ch

Peak Power per collector unit W_{peak}



Relative efficiency η

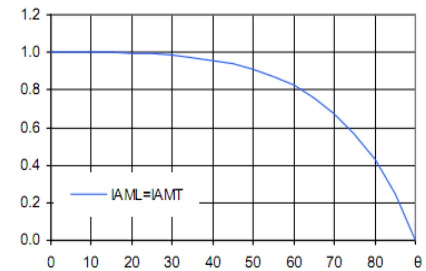


Peak Power W_{peak}	5634 W
Thermal capacity*	25.9 kJ/K
Flowrate during test	457 l/h
Fluid for test	Water-Glycol 33.3%

Reference	**Gross**	**Aperture**	**Absorber**
η_0	0.698	0.769	0.786
a_1 [$WK^{-1}m^{-2}$]	2.80	3.08	3.15
a_2 [$WK^{-2}m^{-2}$]	0.0141	0.0156	0.0159

*) Specific thermal capacity C of the collector without fluid, determined according to 6.1.6.2 of EN12975-2

Incident angle modifier IAM



K1, transversal IAM at 50°	0.91
K2, longitudinal IAM at 50°	0.91

Pressure drop Δp

Pressure drop at nominal flowrate

Δp = -- Pa (T=20°C)

SPF Simulation of systems using Polysun

Short description of the system Climate: Central Switzerland, orientation of the collectors: South, Cold water 10°C, Hot water 50°	**Surface demand**** **Number of collectors**	**Solar yield****
Domestic hot water: Fss* = 60% Tank 450 l, collector inclination 45°, Daily energy demand 10 kWh (4-6 persons) Energy demand of the reference system 4200 kWh/year	5.07 m^2 0.7 collectors	502 kWh/m^2
Water pre-heating: Fss* = 25% 2 Tanks: 1500 l & 2500 l, collector inclination 30°, Domestic hot water consumption 10'000 l/day (200 persons) Daily heat losses (circulation and tanks) 60 kWh, Energy demand of the reference system 191'700 kWh/year	66.7 m^2 9.1 collectors	720 kWh/m^2
Space heating system: Fss* = 25% Combined storage1200 l, collector inclination 45°, Daily energy demand 10 kWh (4-6 persons), Building 200 m^2, moderately heavy construction, well insulated, Heating power demand 5.8 kW (ambient temperature -8°C), Energy demand space heating 12140 kWh/year, Energy demand of the reference system 16340 kWh/year	15.8 m^2 2.2 collectors	341 kWh/m^2

*) Fractional solar savings: Proportion of the final energy that, thanks to the solar system, can be saved compared to a reference system.
**) Surface demand and solar yield are given with respect to the aperture area.

Test standards

- **UNI EN 12975-1:2006** Thermal solar systems and components - Solar collectors - Part 1: General requirements
- **UNI EN 12975-2:2006** Thermal solar systems and components - Solar collectors - Part 2: Test methods
- **UNI EN 12976-1:2006** Thermal solar systems and components - Factory made systems - Part 1: General requirements
- **UNI EN 12976-2:2006** Thermal solar systems and components - Factory made systems - Part 2: Test methods

Test standards - collectors

- energy performance: efficiency curve
- reliability and durability:
    - resistance to internal pressure
    - resistance to mechanical load
    - resistance to high temperatures
    - resistance to internal and external thermal shocks
    - exposition to the sun
    - impermeability
    - resistance to impacts

Useful internet links

www.estif.org

www.solarkeymark.org

www.solarenergy.ch