Solar Water Heaters design

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CEDRO

Solar Thermal Energy

Solar energy is the most plentiful energy source in Lebanon

- ***Very regular all year-round***
- ***Average energy (4 meteo stations): 5,15 solar hour peak/day***
- ***12 % more than Barcelona (Spain) (4,5 Hp) and 31% (3,51 Hp) more than Munich (Germany)***

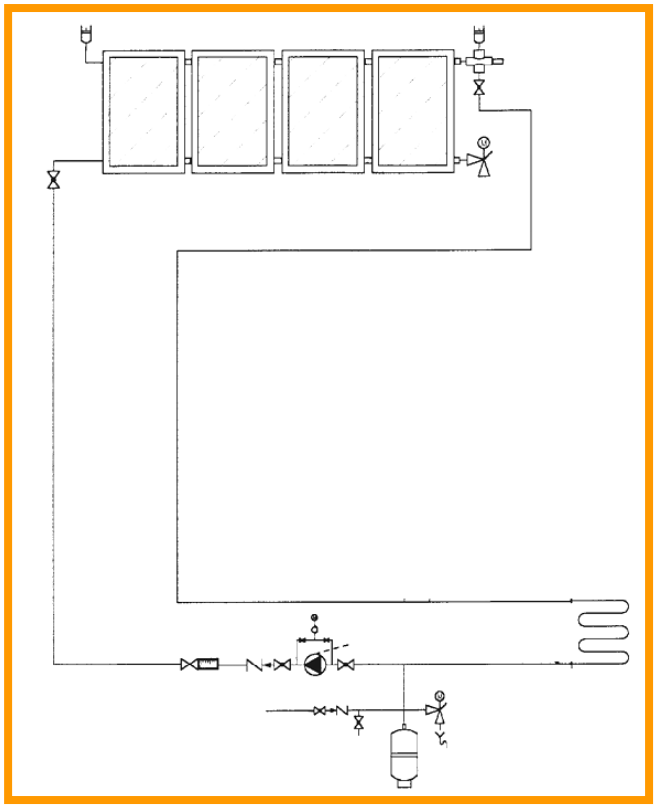
	Solar radiation incident at 40º (kWh/m2 mean average monthly day)			
	Tripoli	**Nabatiye et Tahta**	**Zahlé**	**Beirut**
	34°20'37" North, 36°0'25" East, Elevation: 1382 m.s.m	33°22'59" North, 35°26'59" East, Elevation: 403 m.s.m	33°50'34" North, 35°55'8" East, Elevation: 935 m.s.m	33°52'57" North, 35°30'46" East, Elevation: 61m.s.m
Jan	3.536	3.598	3.809	3.488
Feb	4.225	4.230	4.484	4.117
Mar	5.162	5.204	5.250	5.057
Apr	5.552	5.716	5.925	5.544
May	5.661	5.697	5.713	5.537
Jun	6.194	6.094	6.151	5.917
Jul	6.258	6.162	6.243	5.998
Aug	6.299	6.194	6.313	6.033
Sep	6.170	6.129	6.354	5.895
Oct	5.219	5.282	5.383	5.055
Nov	4.002	4.314	4.240	4.091
Dec	3.213	3.532	3.600	3.309
Año	5.128	5.183	5.291	5.007
Hp year	5,13	5,18	5,29	5,01

Solar Thermal Energy Applications

- **Hot water**
- **Space heating**
- **Solar cooling**
- **Swimming pools**

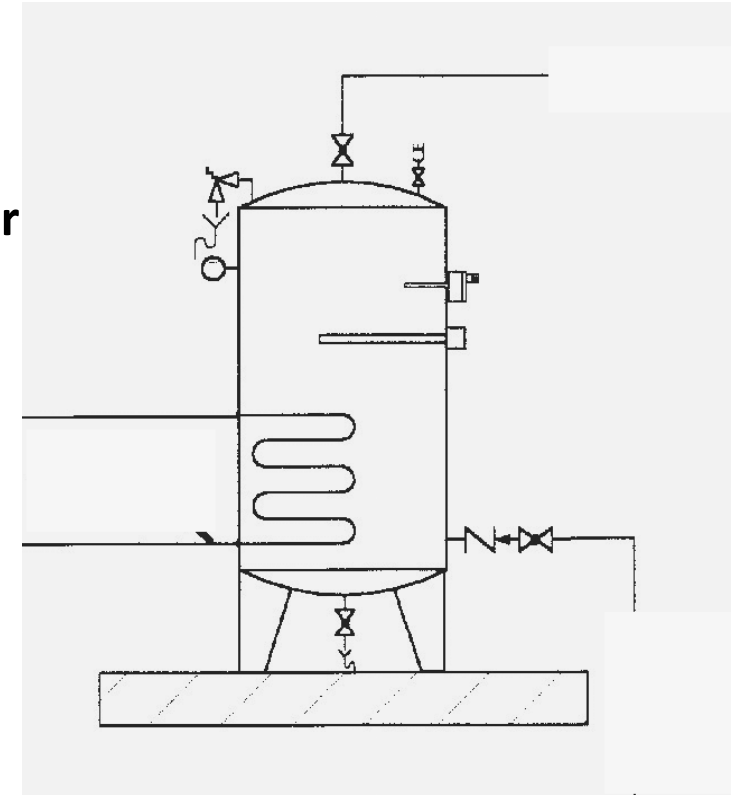
Solar water heating

- **Primary circuit :**
  - **Collectors array**
  - **Closed circuit**
  - **Pump and expansion tank**
  - **Regulation**
  - **Heat exchanger**



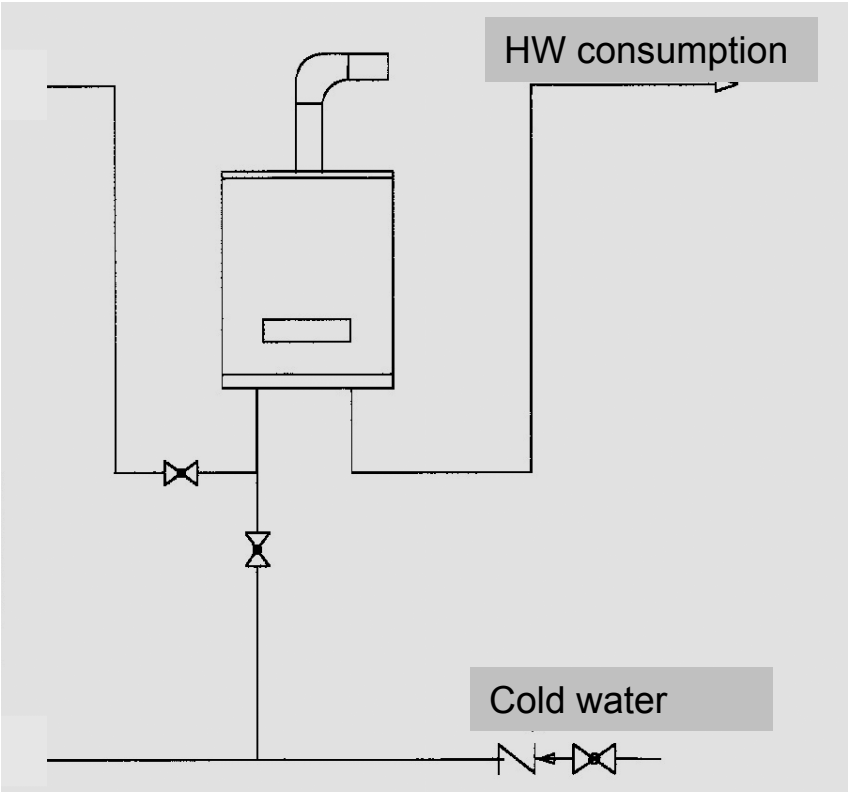
Solar water heating

- **Solar Tank :**
  - **External or internal heat exchanger**
  - **Vertical cylinder**
  - **Corrosion resistant material**
  - **Thermal insulation**
  - **Thermal sensor and termometer**



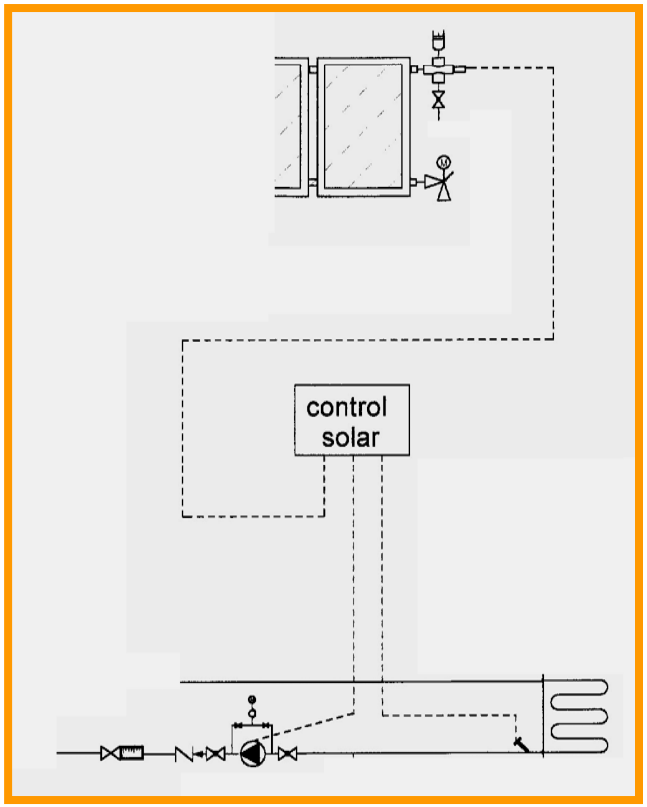
Solar water heating

- **Auxiliary heater : Boiler**
  - **Solar tank as a pre-heating before the boiler**
  - **Solar tank as a pre-heating of the SW tank heated by the boiler / or the modulant boiler**



Solar water heating

- Solar control
  - At least 2 thermal sensors (at the top of solar collector and the bottom of the solar tank)
  - The circulation pump turns on/off depending on temperature differential between both sensors



Solar collectors

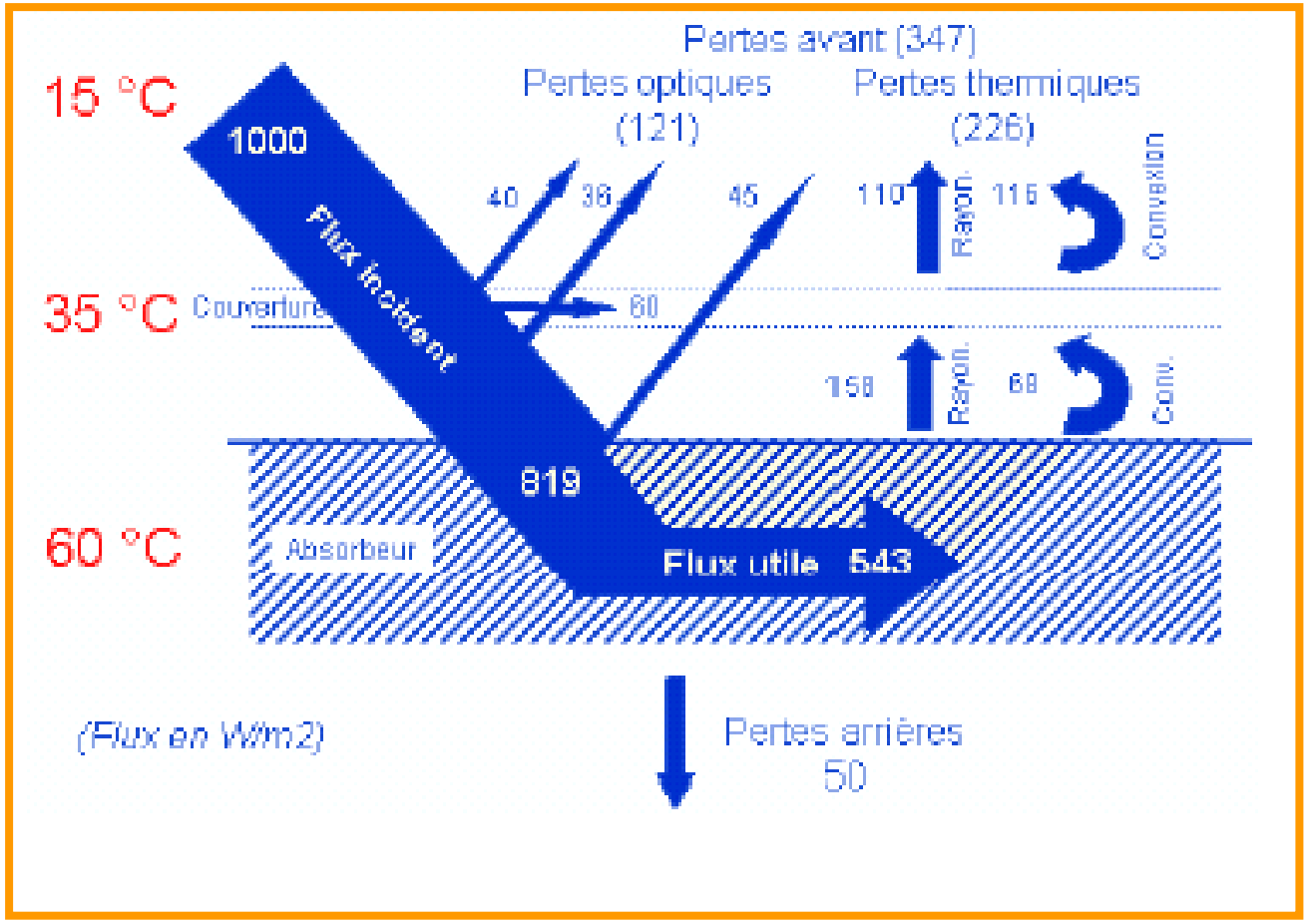
Flat plate

Evacuated tube

Flat plate collector

Flat plate collector heat balance:

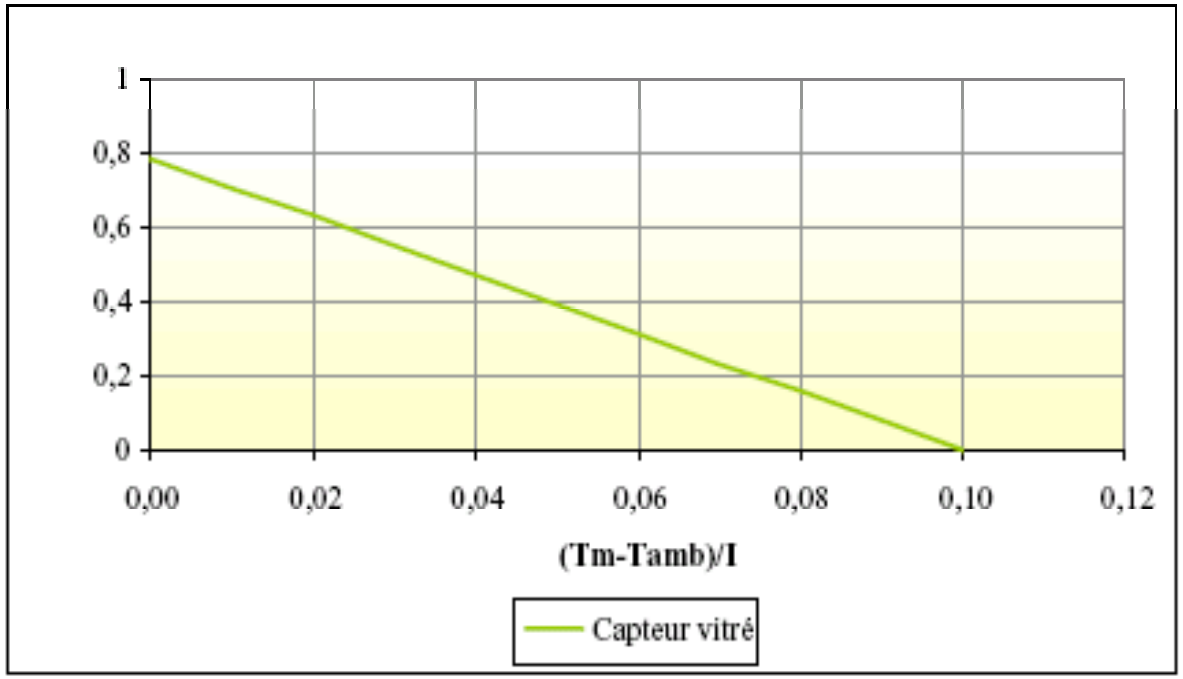
- **solar radiation absorption,**
- **thermal losses**
- **useful heat**



Solar Flat Plate collector

Flat plate collector efficiency characterization

- **Optical losses**
- **Thermal losses (depending temperature difference between absorber and ambient)**



Tm = 35ºC
Ta = 27ºC
I = 800 W/m2

$$\frac{35 - 27}{800} = 0{,}01$$

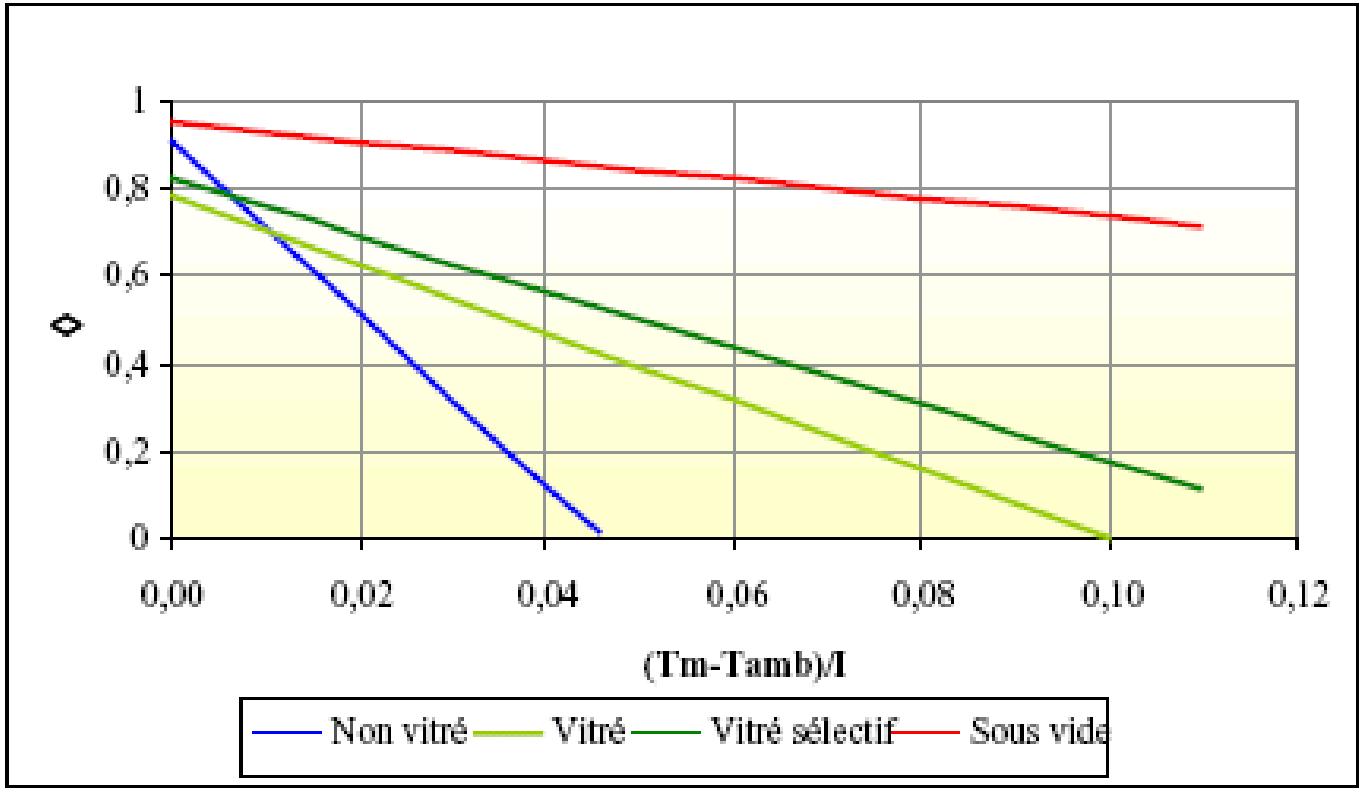
Tm = 50ºC
Ta = 8ºC
I = 700 W/m2

$$\frac{50 - 8}{700} = 0{,}06$$

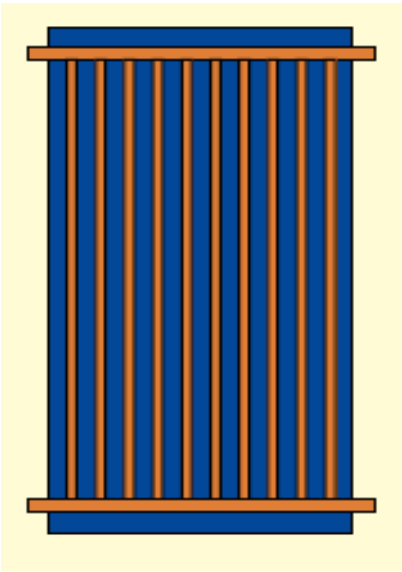
Solar Flat Plate collector

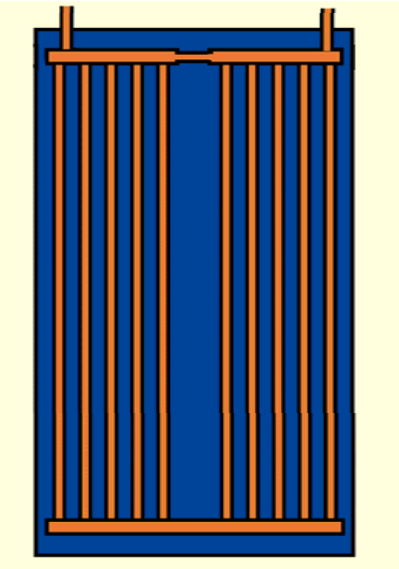
Different collectors efficiency characterization

- **unglazed**
- **glazed flat plate**
- **selective coat**
- **evacuated tube**

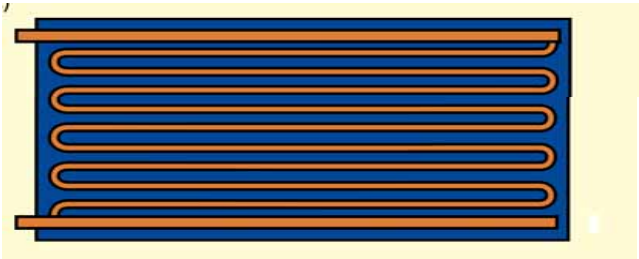


Solar Flat Plate collector





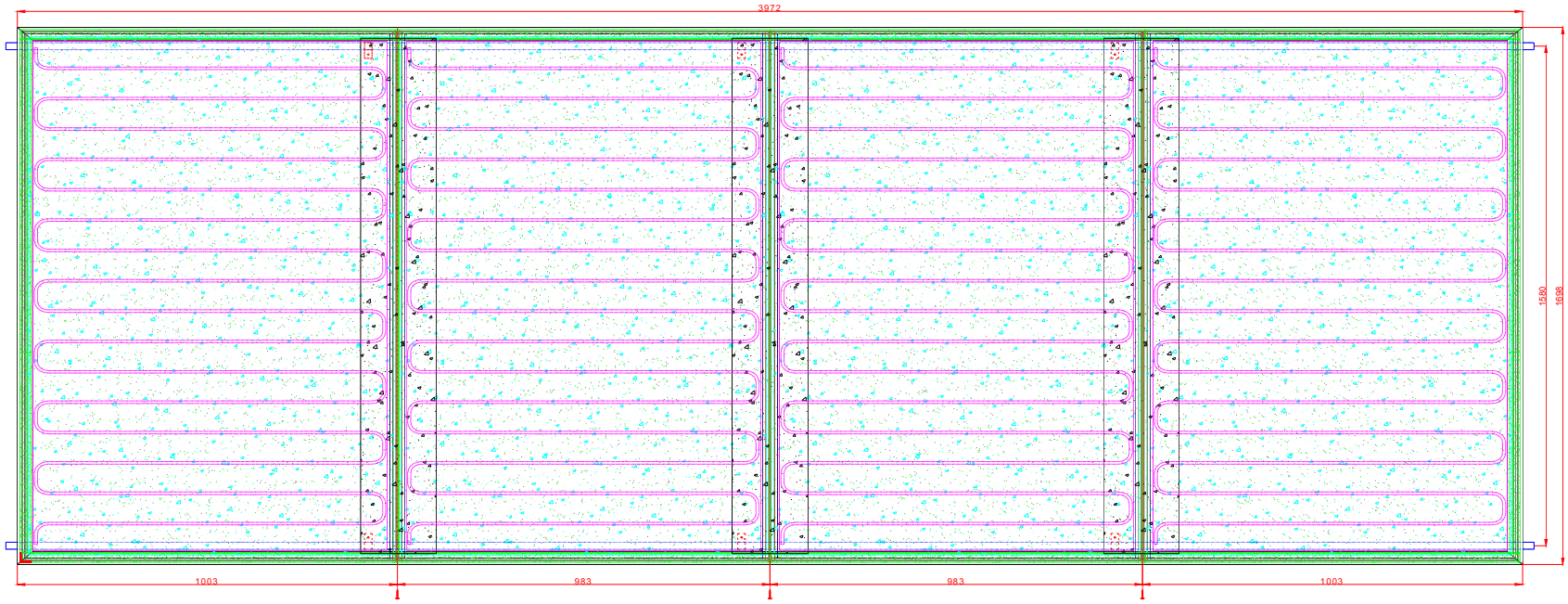
Absorber design: grill shape, serial grill, and meander shape

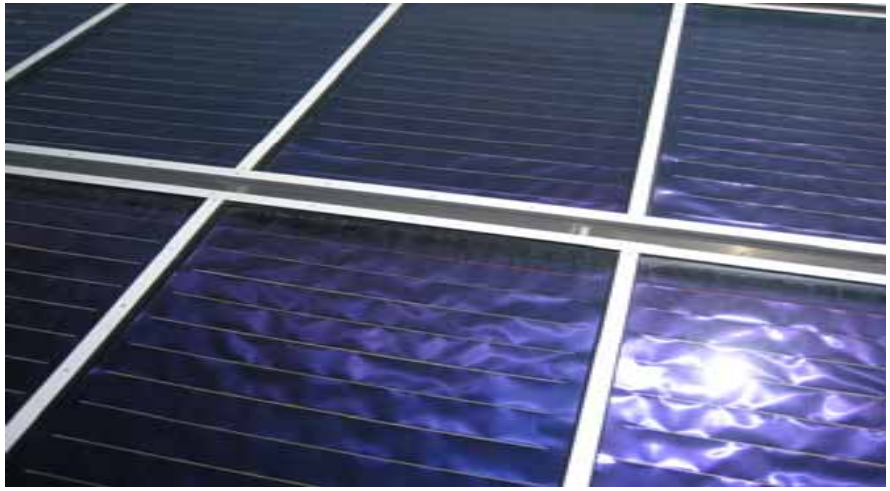


The flow per square meter is different in these three designs

Solar Flat Plate collector

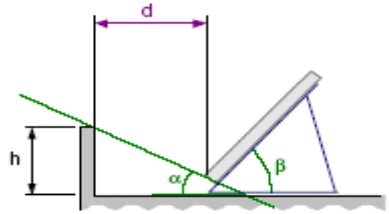
Most solar flat plate collectors are around 2 m2. But also larger solar collectors of 7, 10 or more m2 adequate for big installations: fewer connections, less thermal losses…

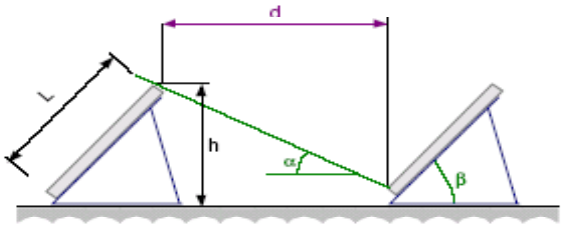


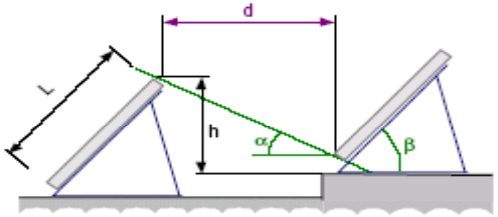


Example of large flat plate collectors

Distance from obstacles







d = h / tan α

d = (L sin β) / tan α

D = h x k Lebanon: 33º N

Latitud	28º	37º	38º	39º	40º	41º	42º
K	1,24	1,74	1,81	1,88	1,97	2,05	2,15
Referencia	Las Palmas	Sevilla	Murcia	Toledo	Madrid	Barcelona	Bilbao

Solar Flat Plate collector

CEDRO minimal performance requirements

- **optical efficiency: 0,7**
- **thermal losses: 5,5 W/m2 K**

If available space is not enough, a higher performance collector can be used

- **optical efficiency: 0,79**
- **thermal losses: 3,21 W/m2 K**

Solar collectors mounting

Strong wind can destroy solar installations if the structure or blocks that support per gravity are undersized

Structure and piping

Piping lengths shall be minimized to reduce heat losses and pressure drop (lower than 40 mm.wc./m)
The flow speed shall be calculated in the range of 2,5 -3 m/s.

Structure

The total load shall guarantee no risk of wind uplift of the solar collectors / support frames for wind speeds up to 120 km/hour.

Outdoor piping insulation protection

Aluminum sheet

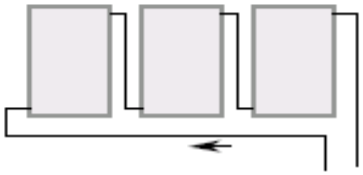
Flexible plastic sheet

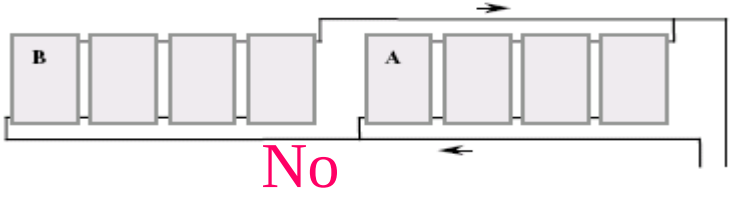
Paint coat

Collectors connection

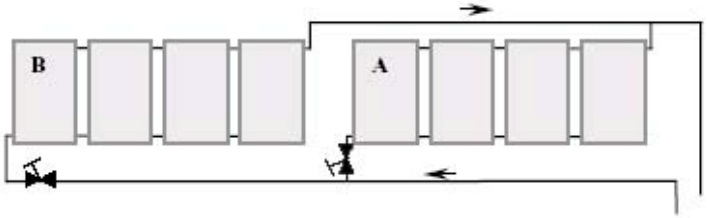
parallel

serial

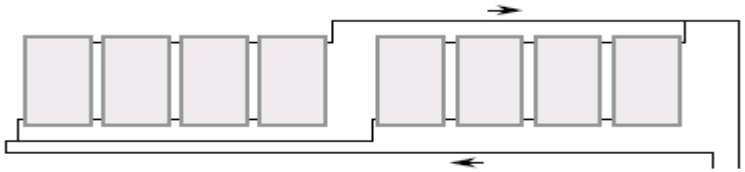




No



Balance by valves

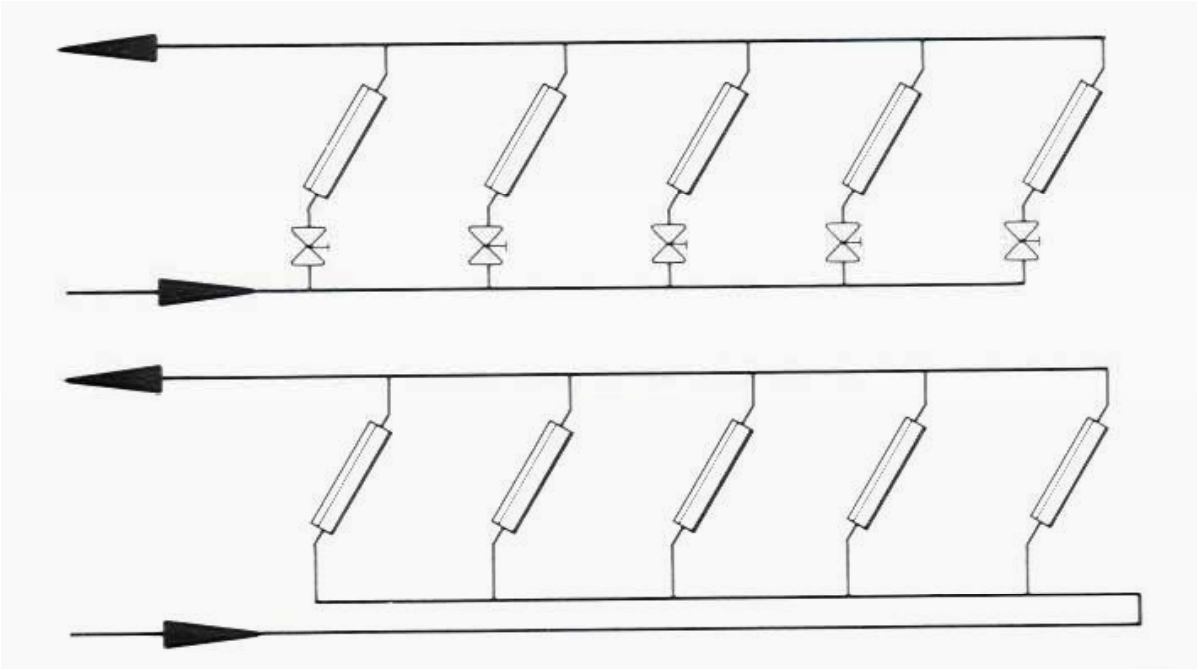


Balance by
reverse return

Collectors

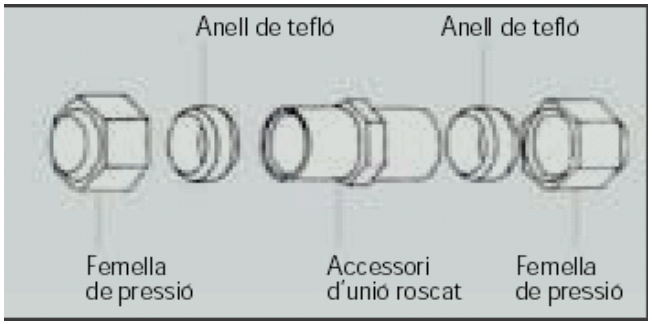
Balance by valves

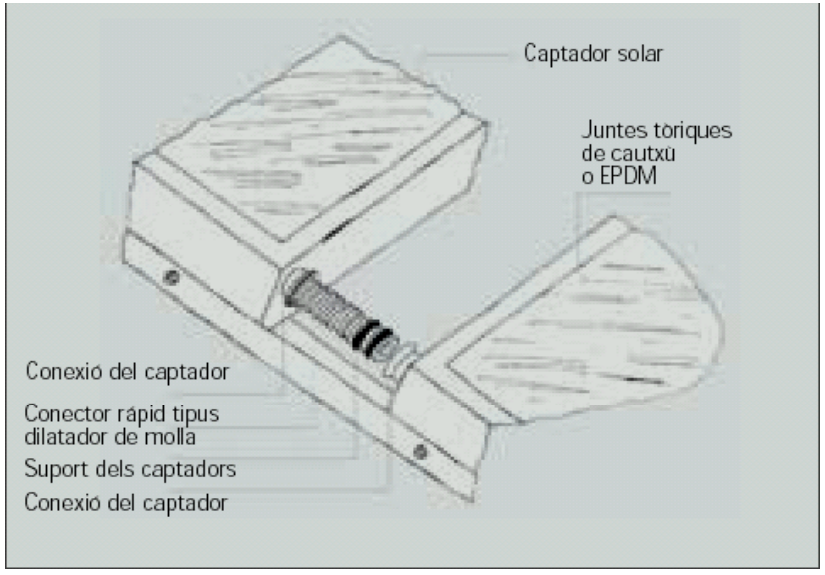
Balance by reverse return



Coupling and connection terminals

Threaded coupling for connecting tubes or accessories conical pressure, etc..



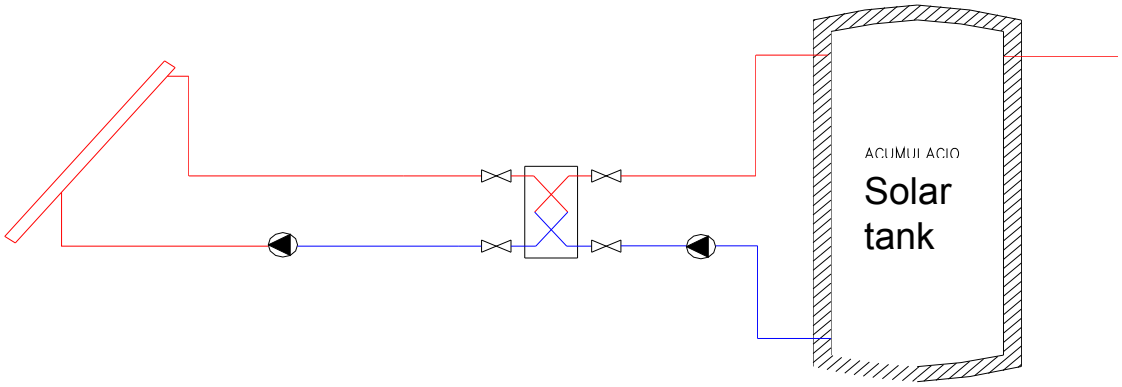


Thermal expansion absorber

Primary circuit

- Piping: cooper or stainless steel
- Slope at least 1% for drainage preferable without airlocks
- Pipe diameter sizing: pressure drop < 40 mm w c per lineal meter
- Pipe flow speed: 2 m/s (indoor), 3 m/s (outdoor)
- Flow rate: usually 50 l/h per m2 of collector (refer to collector manufacturer)
- Thermal insulation: 20 to 30 mm (indoor) and 30 to 40 mm (outdoor)
- Insulation protection against UV radiation and mechanical erosion (outdoor pipes)
- The thermal transfer fluid non freezing under the colder local event. Safe for the use in such applications and environmentally suitable .
- All circuit components shall resist the maximum design temperature (valves, air vents, etc.)

Heat exchanger



Sizing: its rated power shall be no less of 500 x collectors surface.

The heat exchangers shall be suitable selected and installed to optimize the heat transfer efficiency and easy to remove for periodic cleaning.

Solar hot water tank

Solar tank characteristics

-Good thermal insulation

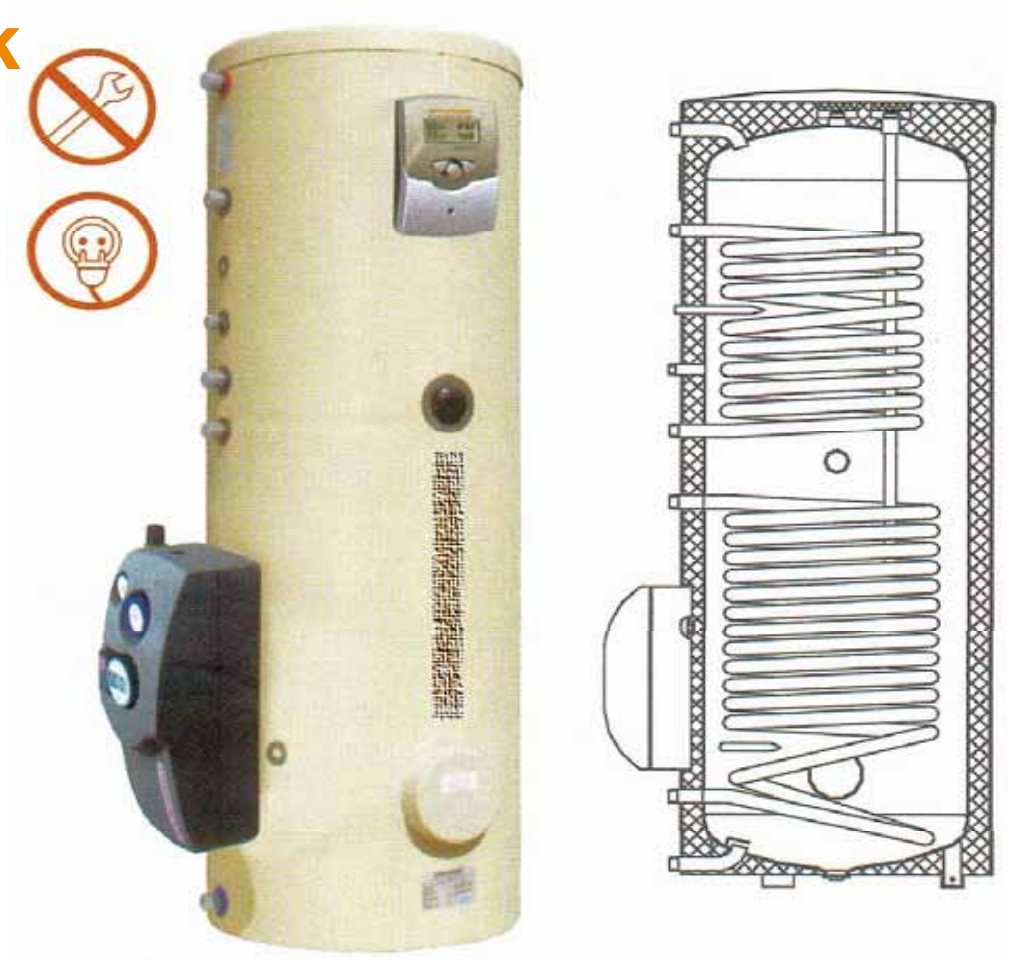
-Height > than diameter and vertically installed

-External protection

-Heat exchanger: internal or external

-Internal surface protection

-Anticorrosive device



Solar hot water tank

Solar tank location

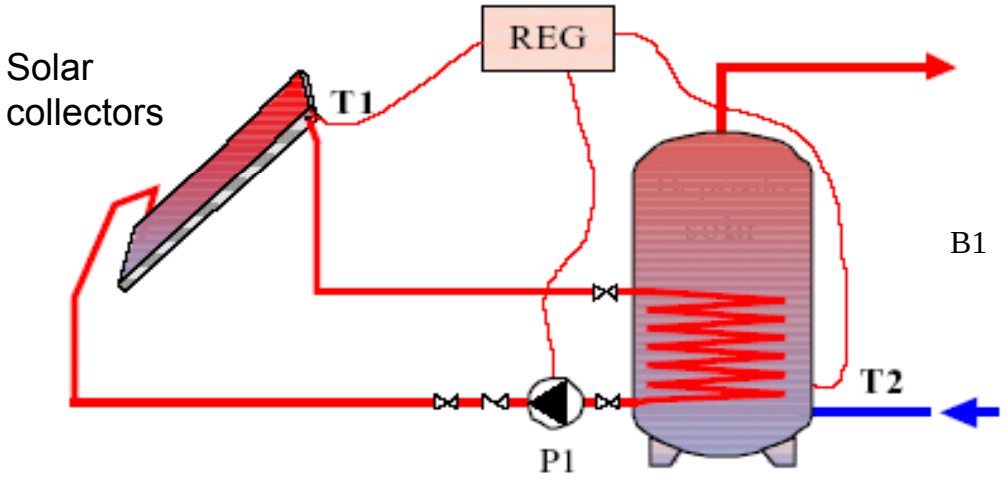
- As close to the solar array than possible
- Better inside a technical room than outdoor

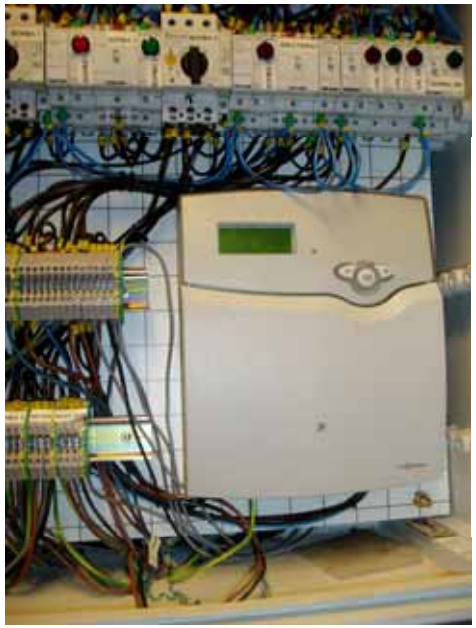
The tank insulation polyurethane with minimum thickness of 50 mm

Solar hot water tank

- When more than one solar tank is necessary, they are connected in series

Regulation

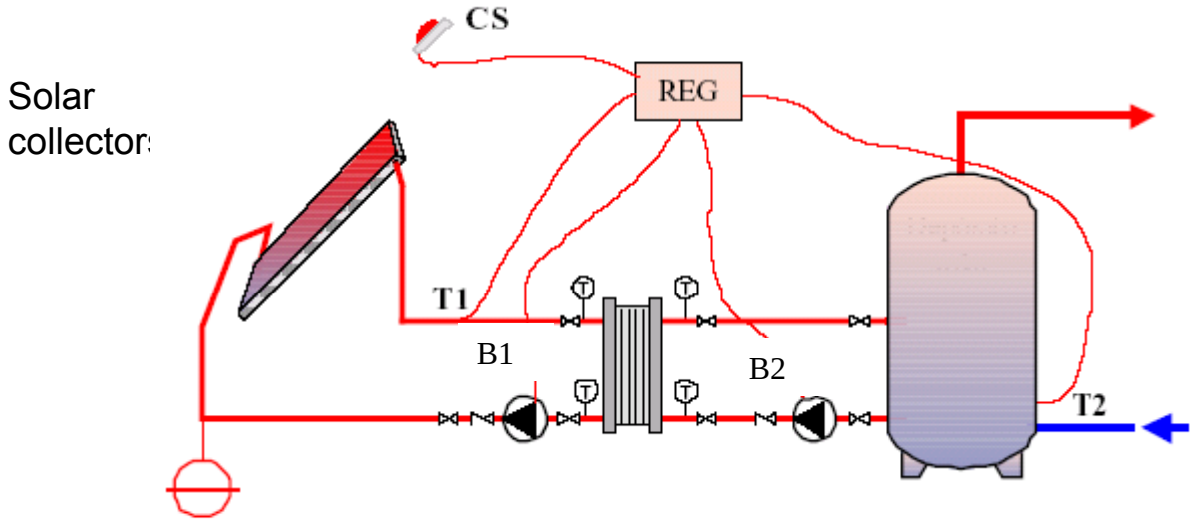




B1 **turns on when** ΔT = T1 - T2 > *ex: 4-7ºC*

B1 **turns off when** Δ T = T1 - T2 < *ex:1- 2ºC)*

Regulation



B1 **turns on when** Solar radiation is > ex. 300 W/m2

B2 **turns on when** Δ T = T1 - T2 = *ex: 4ºC)*

B2 **turns off when** Δ T = T1 - T2 = ex: 2ºC)

Monitoring

Calorimeter

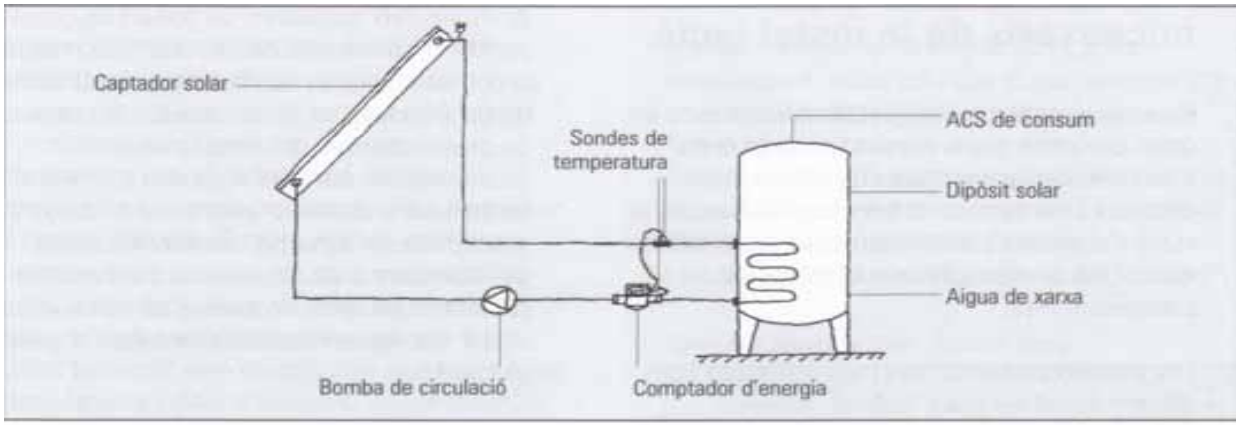
Flow meter

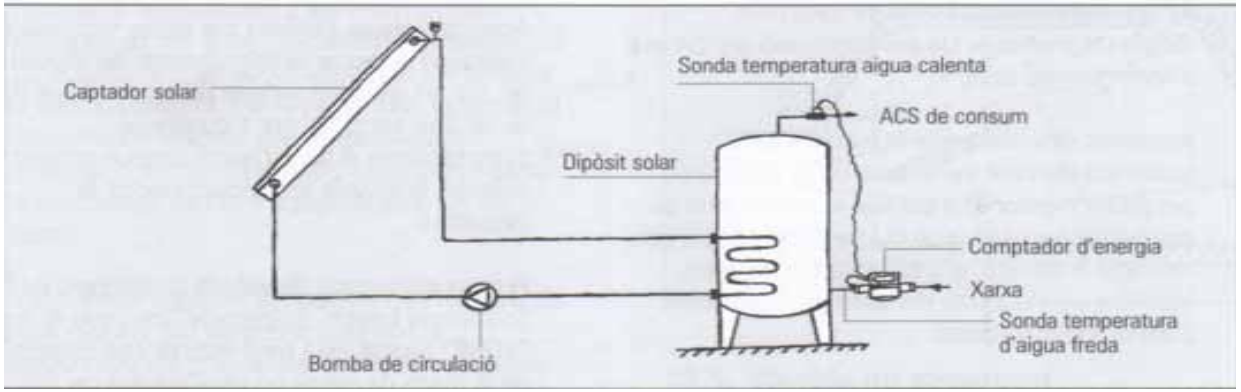
Calorimeters

Measure solar energy produced

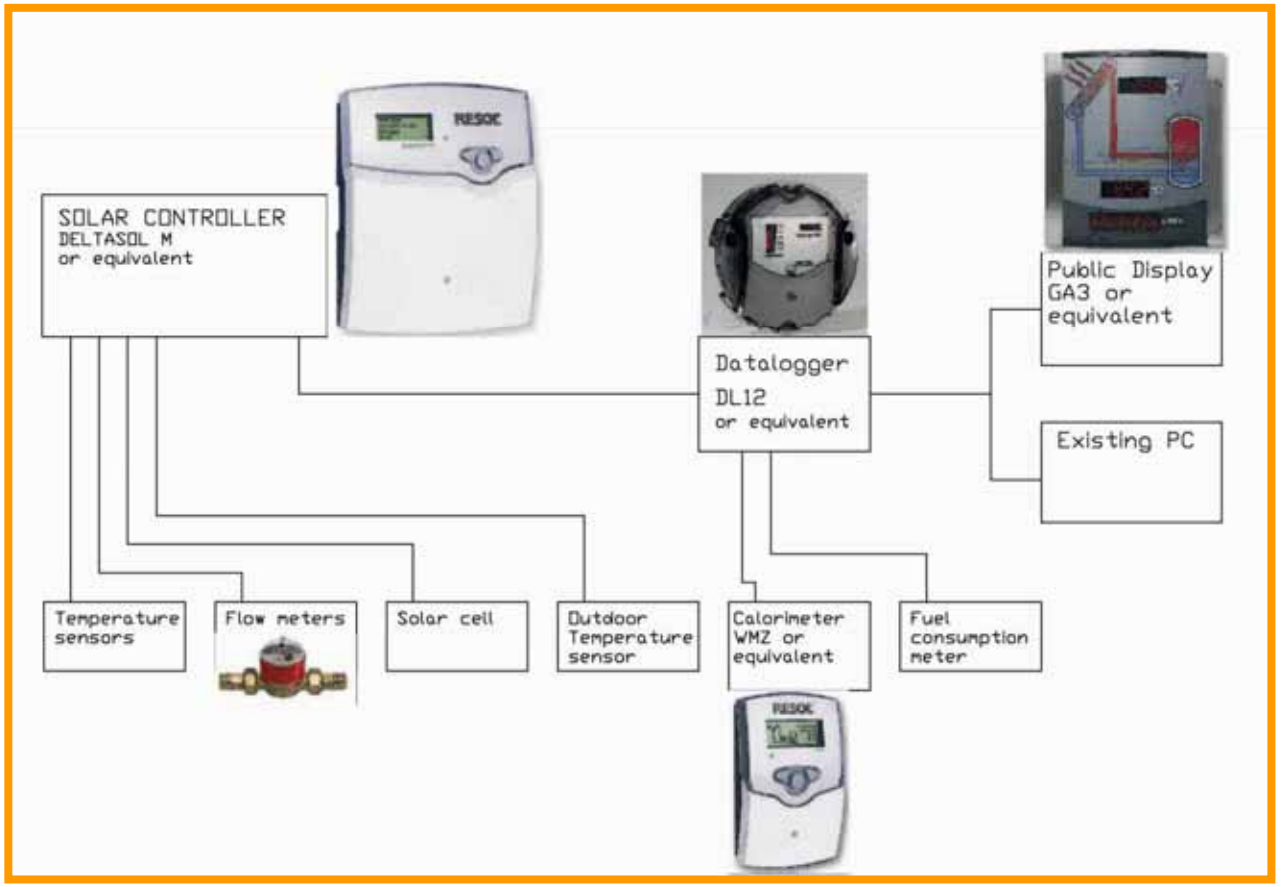
Measure Hot Water energy consumed

$$Q = V \cdot \delta \cdot c_e \cdot \Delta t$$





Data logging and performance indicators

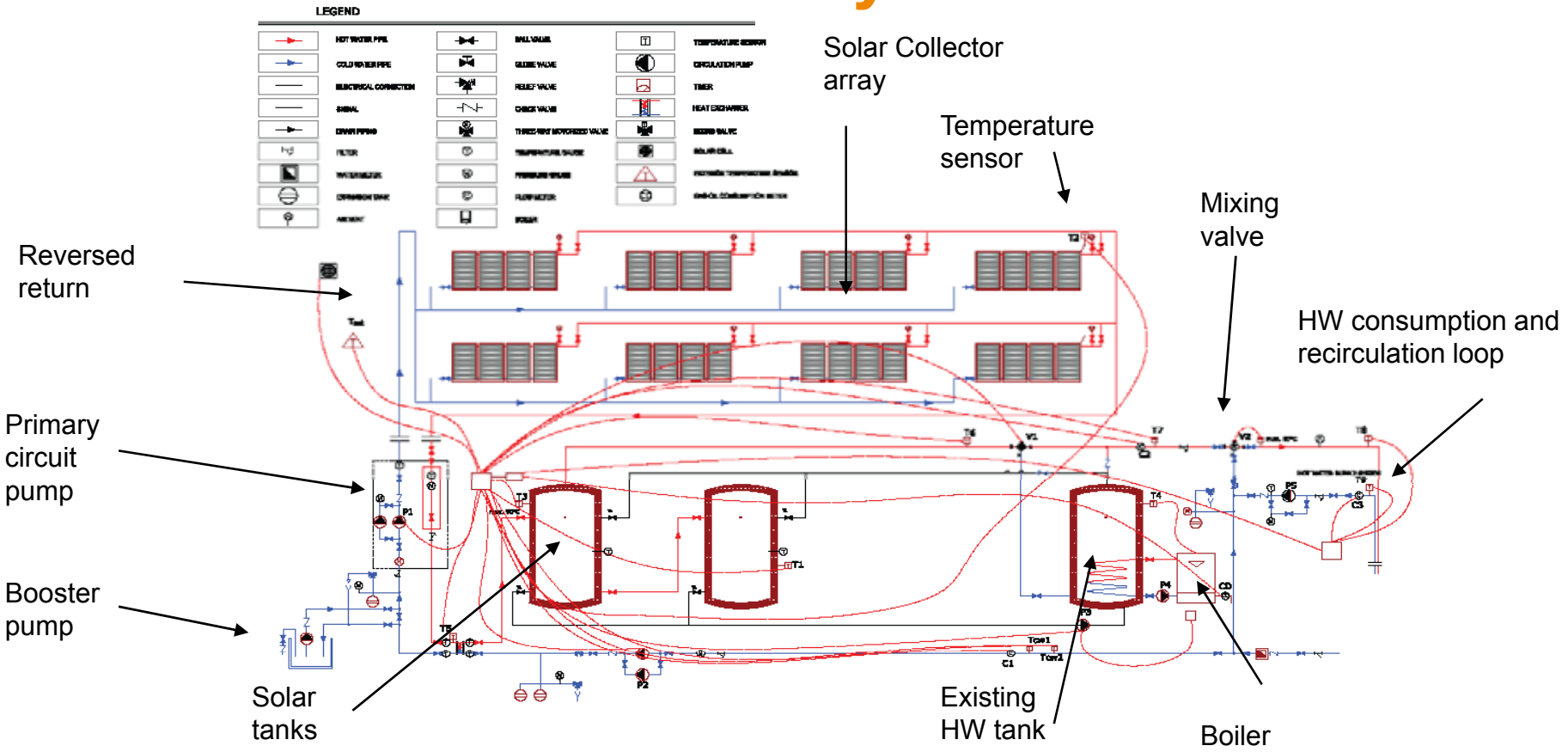


Anti legionella circuit

Thermal treatment against the legionella bacteria

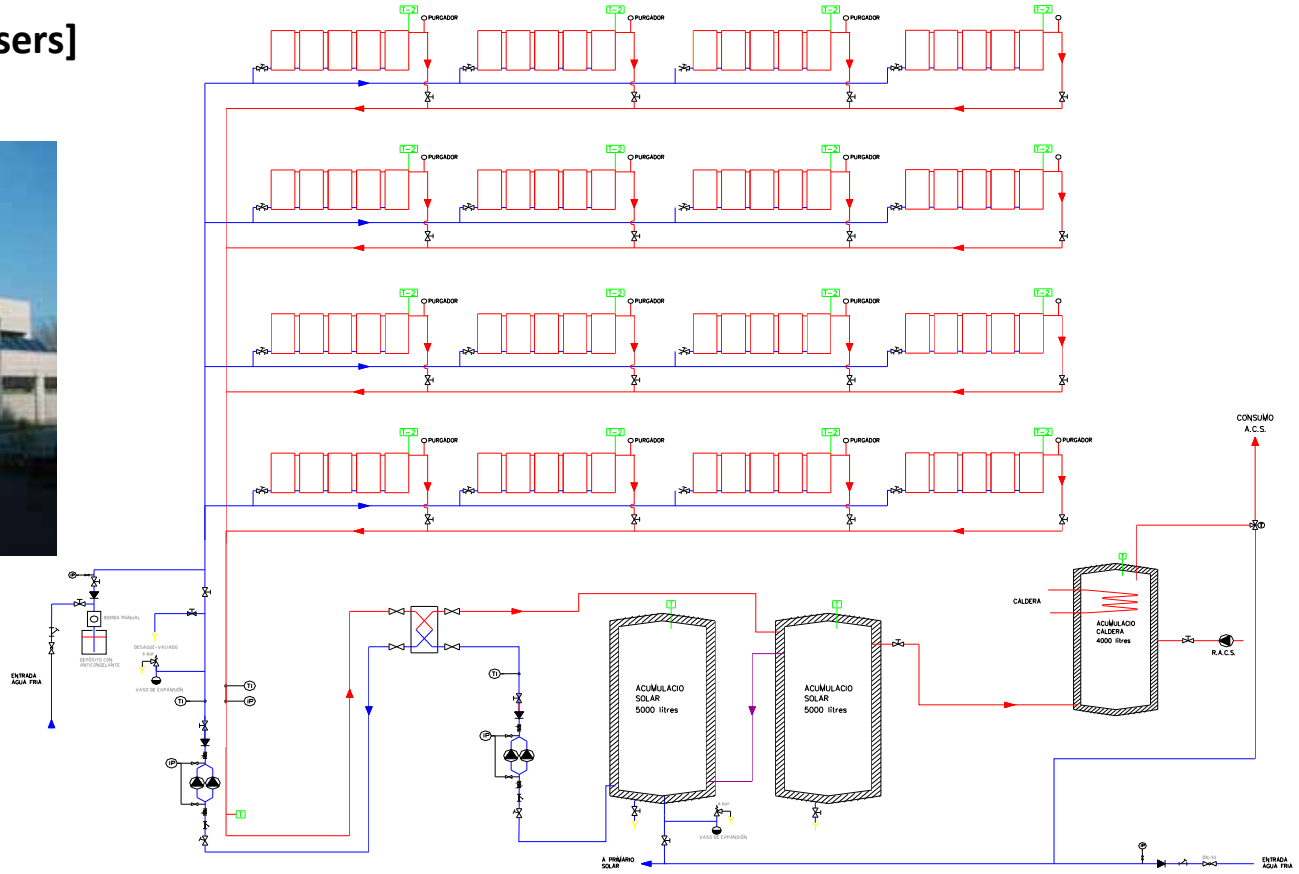
- The legionella bacteria is harmful when inhaled via micro droplets or aerosol (example at a shower)
- The optimal development temperature for the legionella bacteria is 35 – 37ºC, but can reproduce between 25 and 45ºC. At 70ºC or more is destroyed
- To prevent the legionella sickness a regular thermal treatment of the HW installation is recommended (is compulsory for public buildings in many countries)
- A specific recirculation circuit is needed to transfer hot water from the boiler tank to the solar tanks untill 70ºC degrees are attained. Sometimes these temperatures are also reached with solar energy

CEDRO SHW reference hydraulic schematics



Sports arena: hydraulic schematics

25.000 HW litres/day [235 users]
f=35%.



Sports arena: solar collectors and heat dissipation

Sports arena: solar tanks and pumps

Heat dissipation

When the maximum solar tanks temperature is reached, the circulation pump turns off and a heat dissipation may be necessary

Active dissipation

Passive dissipation

Reference values for a SWH model

GENERAL SPECIFICATION			
Demand		Daily hot water demand (Rated output temperature 60ºC)	2200 L/day
Solar array		Type	Flat-plate
		Tilt/orientation	45±5º/0±20º S
		Total Collector area	(1) 45 m^2
Piping system	Primary circuit	Pressure drop	≤40 mmwc
		Flow velocity	2,5-3 m/s
	Secondary circuit	Pressure drop	≤40 mmwc
		Flow velocity	2,5-3 m/s
Pump		Flow	2025 L/h
		Pressure drop	6 mwc
Hot Water Tank		Number/Capacity	1/2000 L; 1/100L
		Connection	Series inverted
		Installed capacity	3000 L
Expansion tank		Volume	~ 160L
Heater exchanger		External	~ 32 kW
Minimum Data logger and processor			Performance evaluation: temperatures, water consumption, solar energy produced, energy balance, reference radiation and ambient temperature.