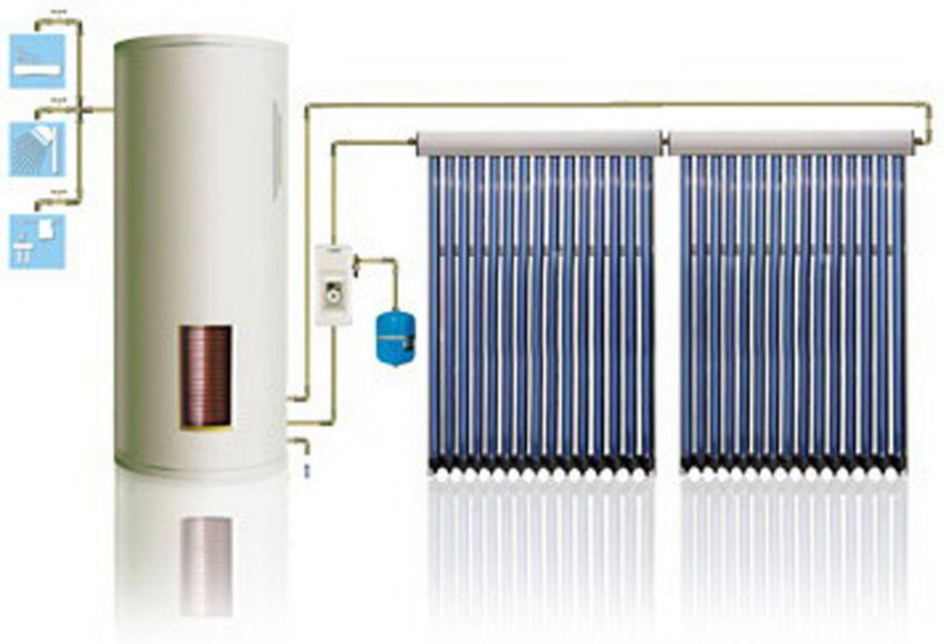
Solar Water Heater



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Introduction

Today there is a large problem of energy resources so we need to develop the emergent technologies and to show people that those technologies are ready for use.

The goal of this report is to highlight solar water heaters, their technology, use and cost/ benefit.

The first part of the report presents the technical features of the solar water heater. It then deals with the economic aspects, the cost of the solar water heater, the energy created and a comparison between the electric water heater and the solar water heater. This is followed by a hypothesis of a large scale set up and then concludes with the benefits of solar water heaters.

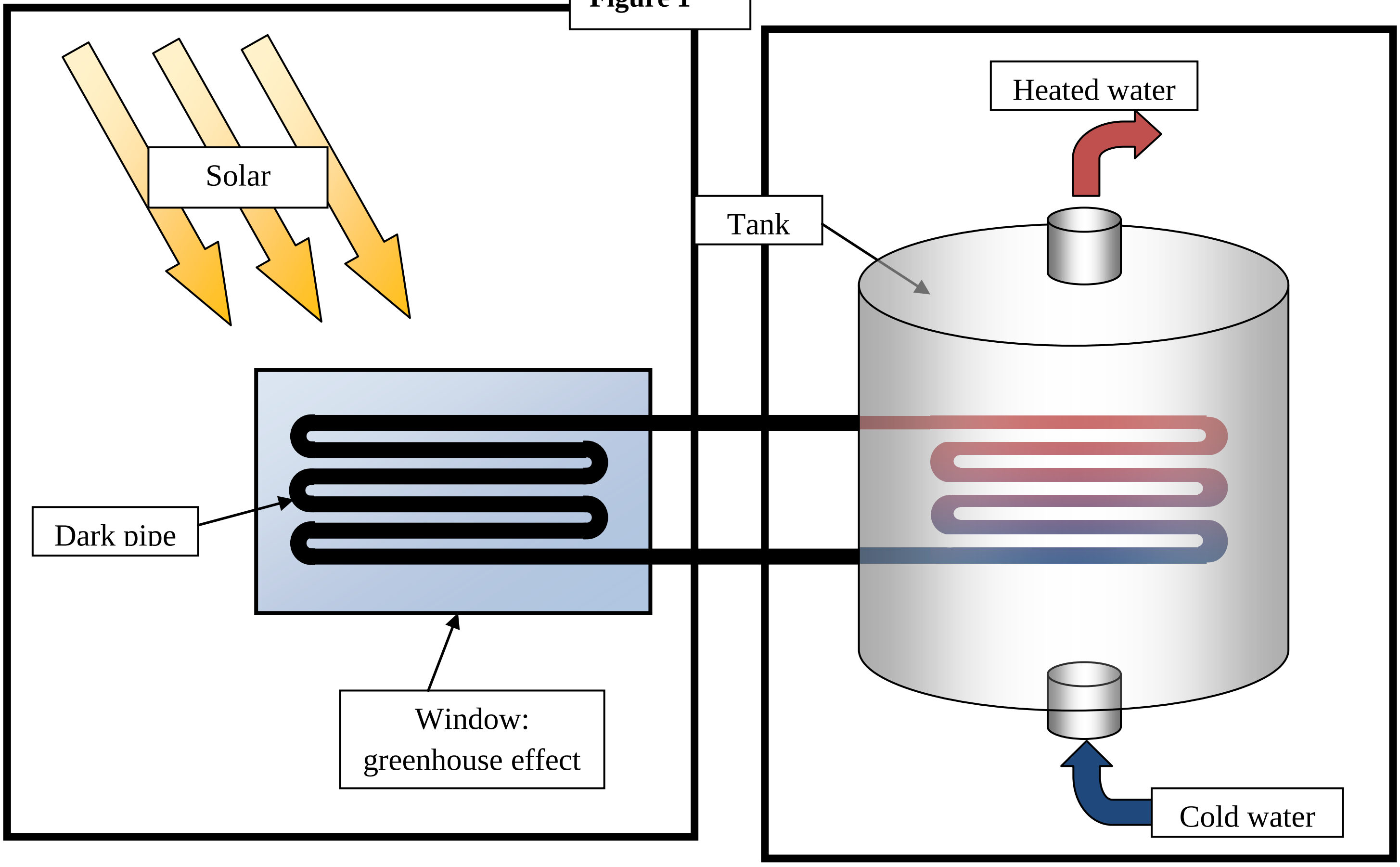
The foremost point of the report is the advantage of solar energy. The sun’s average power is approximately 1000 W/m^2, which represents 10,000 times the power required for the world’s population. Given our current challenges with global warming and the consequent climate change impacts, we can’t emphasize strongly enough the sheer waste of not using this resource, which is so readily available and inexpensive.

I] Technical study

1) Operating principle

The solar water heater is composed by 2 components (*Figure 1*), the solar sensor and the heated water tank:

Figure 1



a) The solar sensor:

The solar sensor is different than a photovoltaic panel, the aim of which is to transform solar energy in electrical energy.

The solar sensor is another system that transforms solar energy into thermal energy.

The operating principle is simple:

- A pipe warms up under the sun's rays.

- This pipe is in a box made of glass that allows the greenhouse effect to optimize the heating.
- Within the pipe is a heat transfer liquid called the “primary liquid.”
- The pipe flows into a tank of water that gets heated.

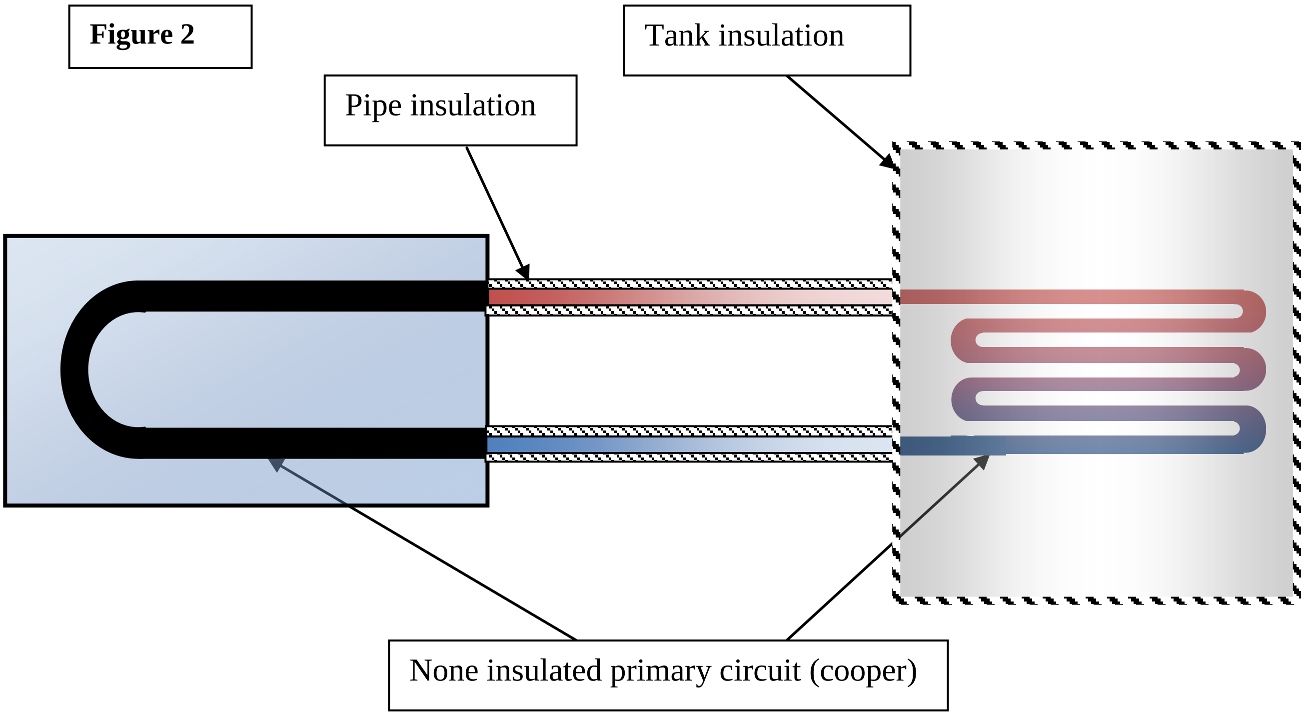
b) The hot water tank:

- Cold water arrives in this tank.
- The water is warmed up by the primary pipe.
- The heated water is stored in the tank.

System’s Isolation (*Figure 2*):

The pipe network must be thermally insulated to limit the heat loss.

Figure 2



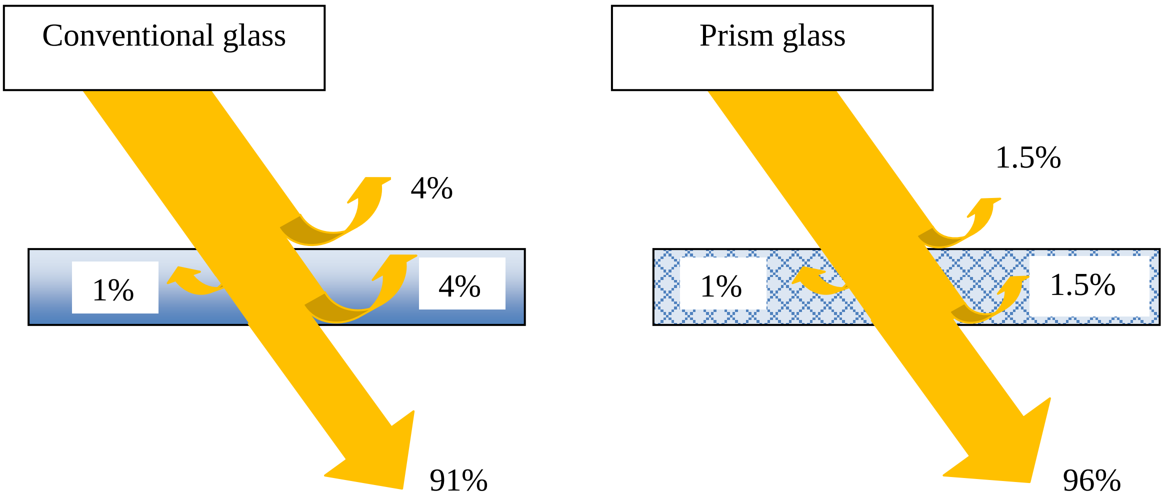
2) Different technologies

The circulation of the heat transfer liquid is either naturally by "thermo circulation" or through a small electric pump.

a) Different types of glass:

One of the most important phenomena in the solar water heater is the principle of the greenhouse effect; this principle leads to a general warming under the glass with nominal energy loss. So the type of glass is very important *(Figure 3)*, which is why we use a prism glass to improve efficiency by 5%.

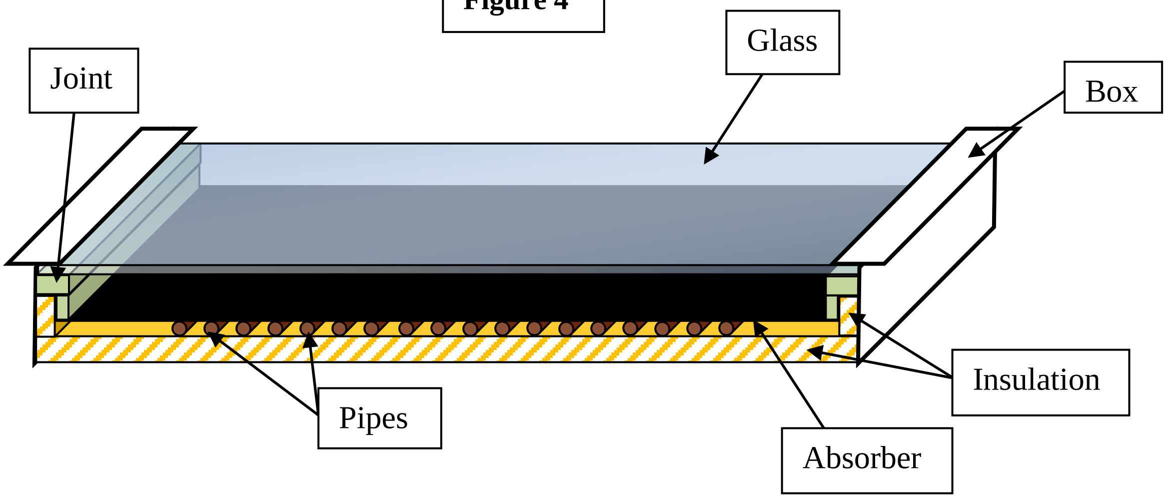
Figure 3



b) Different types of sensor

Glazed flat panel: Figure 4

Figure 4



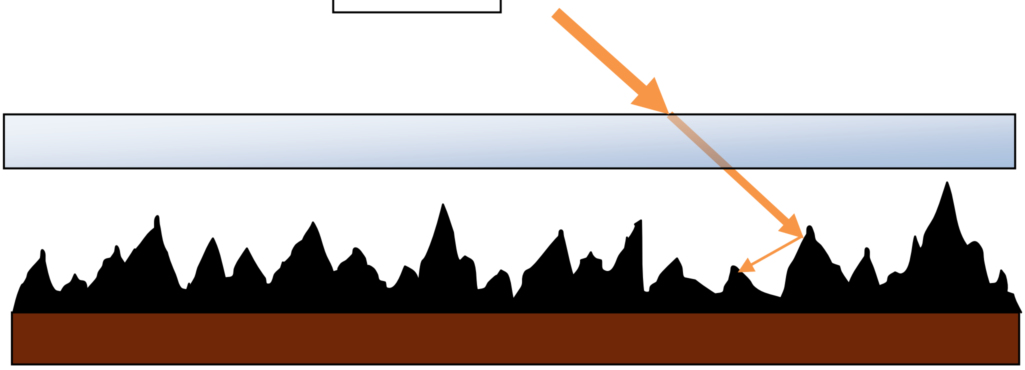
Absorber: Figure 5

The aim of the absorber is to increase solar heating. It is made with a metallic sheet, a good heat conductor, covered by a black paint. The paint must be a good conductor, too, and have an irregular surface to reflect possible rays that are not absorbed.

The absorption coefficient α depends on the type of materials used for the absorber sheet, but it's always about 90% - 98%.

For example, we can use black chrome painting on aluminum or on cooper.

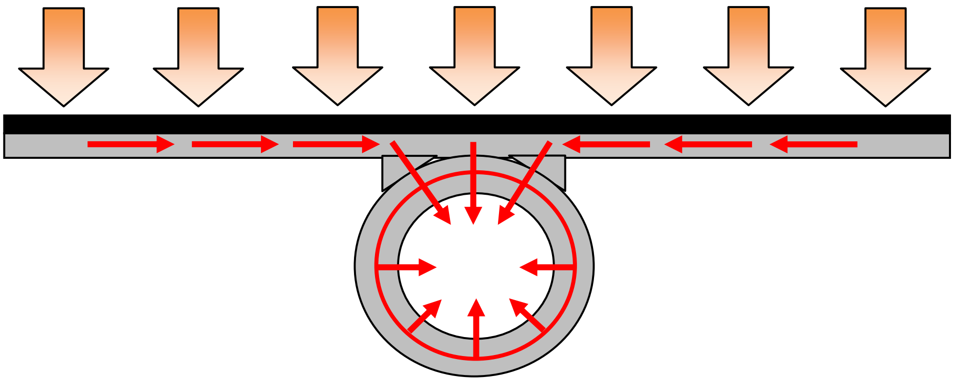
Figure 5



Link between absorber and pipes (Figure 6):

The link between the absorber and the pipes is quite important, because it is by this link that the heat is transmitted. The link is made by very precise laser welding.

Figure 6

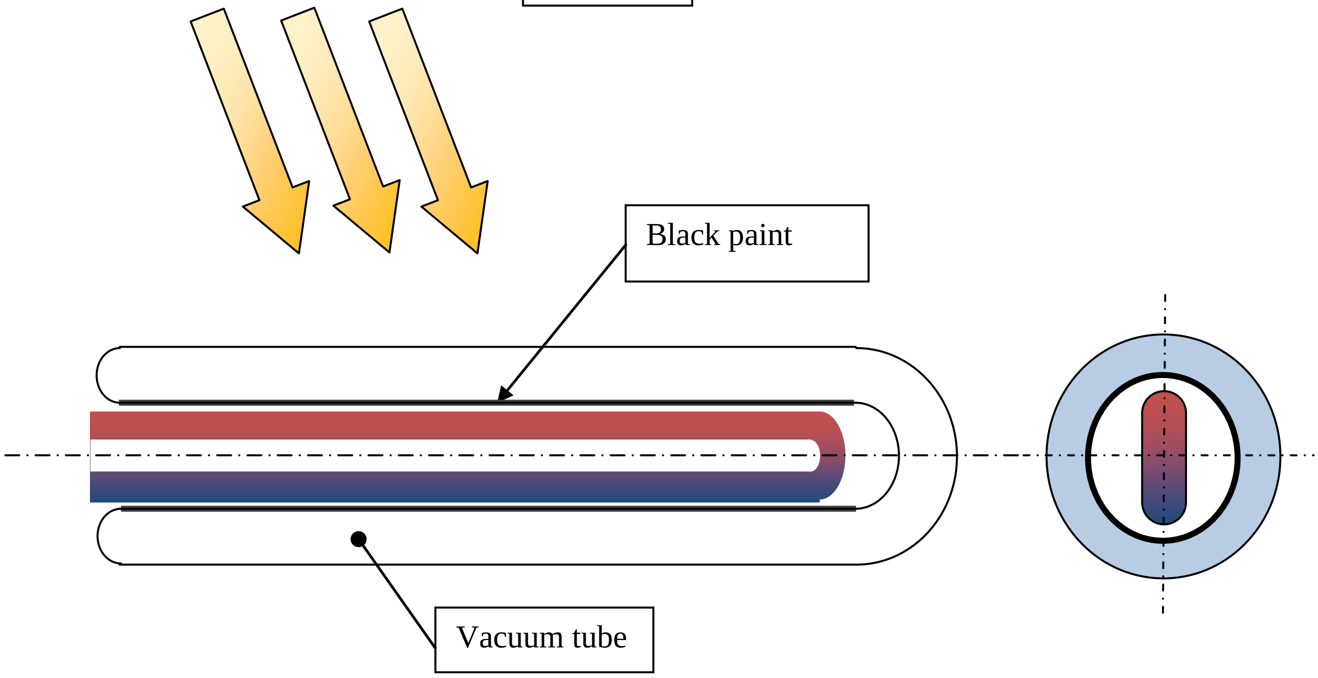


Solar sensor vacuum (Figure 7):

The benefit of this kind of solar sensor is to limit the thermal loss between the glass and the pipe due to the ambient thermal resistance and in the absorber heat transfer.

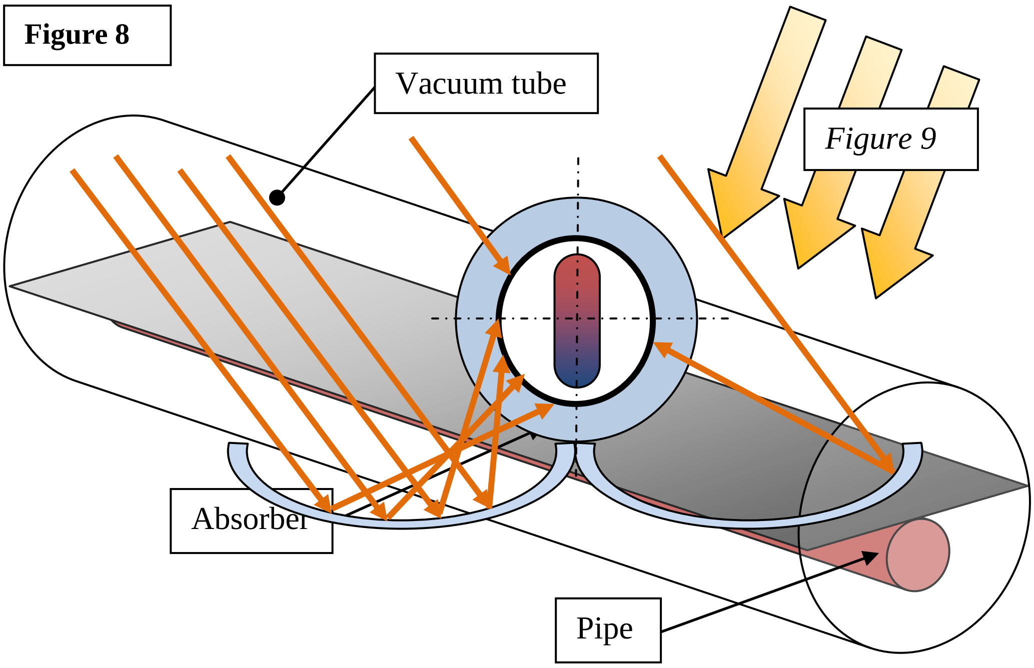
There are two types of vacuum sensors: the first is composed of two glass tubes that maintain a permanent vacuum between them.

Figure 7



The second one *(Figure 8)* is based on the same principle of the glazed flat panel - the pipes are under a black absorber in a vacuum glazed pipe.

Figure 8



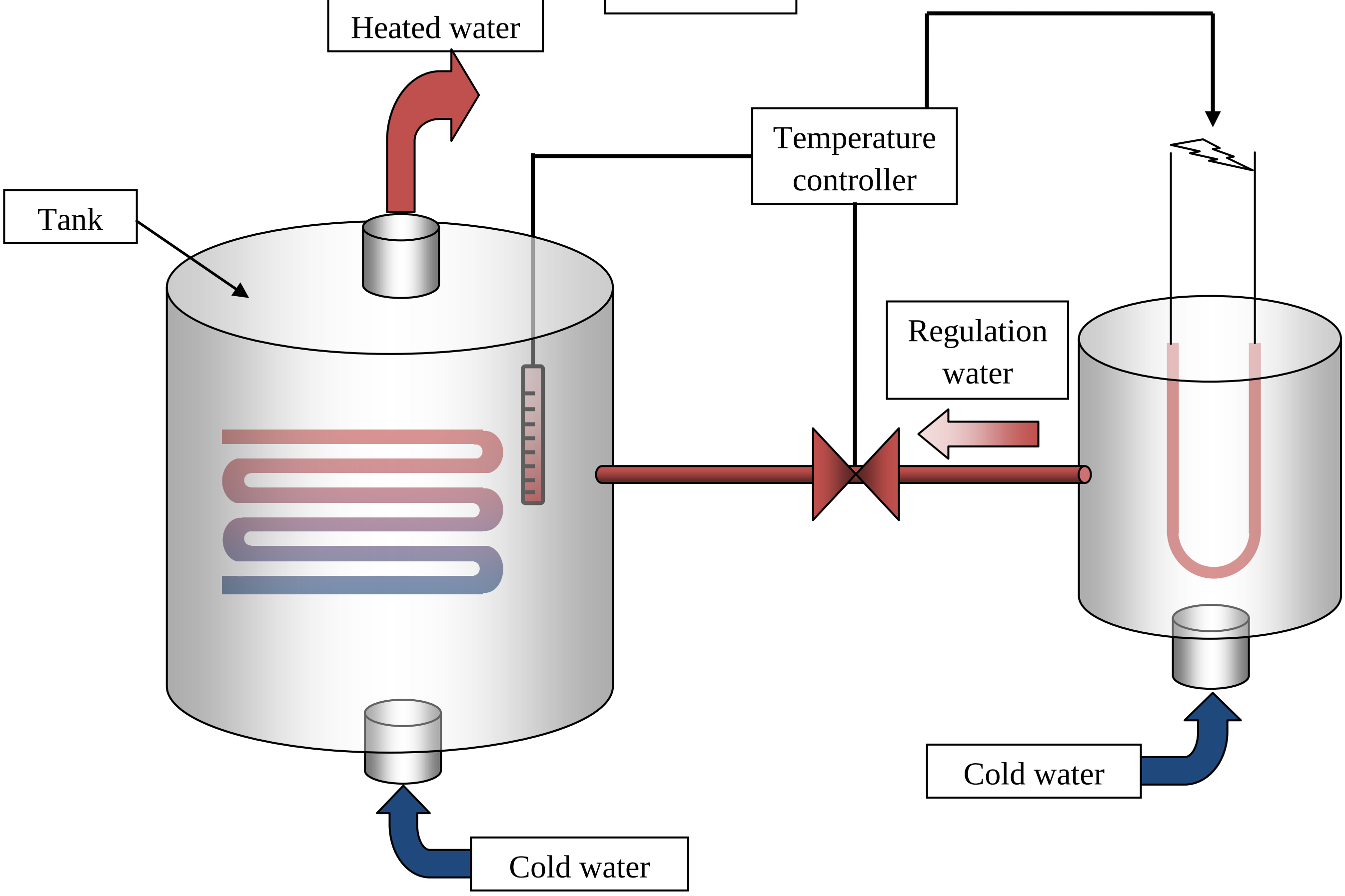
A lot of these solar vacuum sensors are used with cylindrical reflectors to optimize the sun's radiation *(Figure 9)*.

c) Different types of self-regulation:

The problem is that sometimes the sun is not sufficient to warm the water to the needed temperature. Therefore, we need to add a booster to raise the temperature of the water.

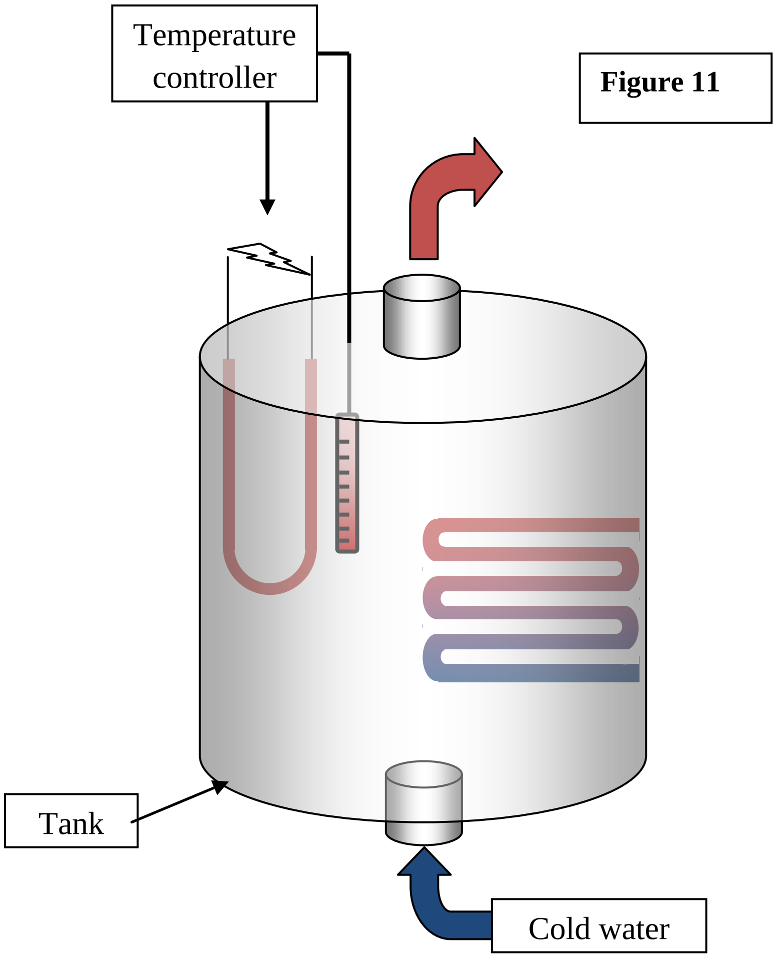
Heating self-regulation with electric water heater (Figure 10.):

Figure 10

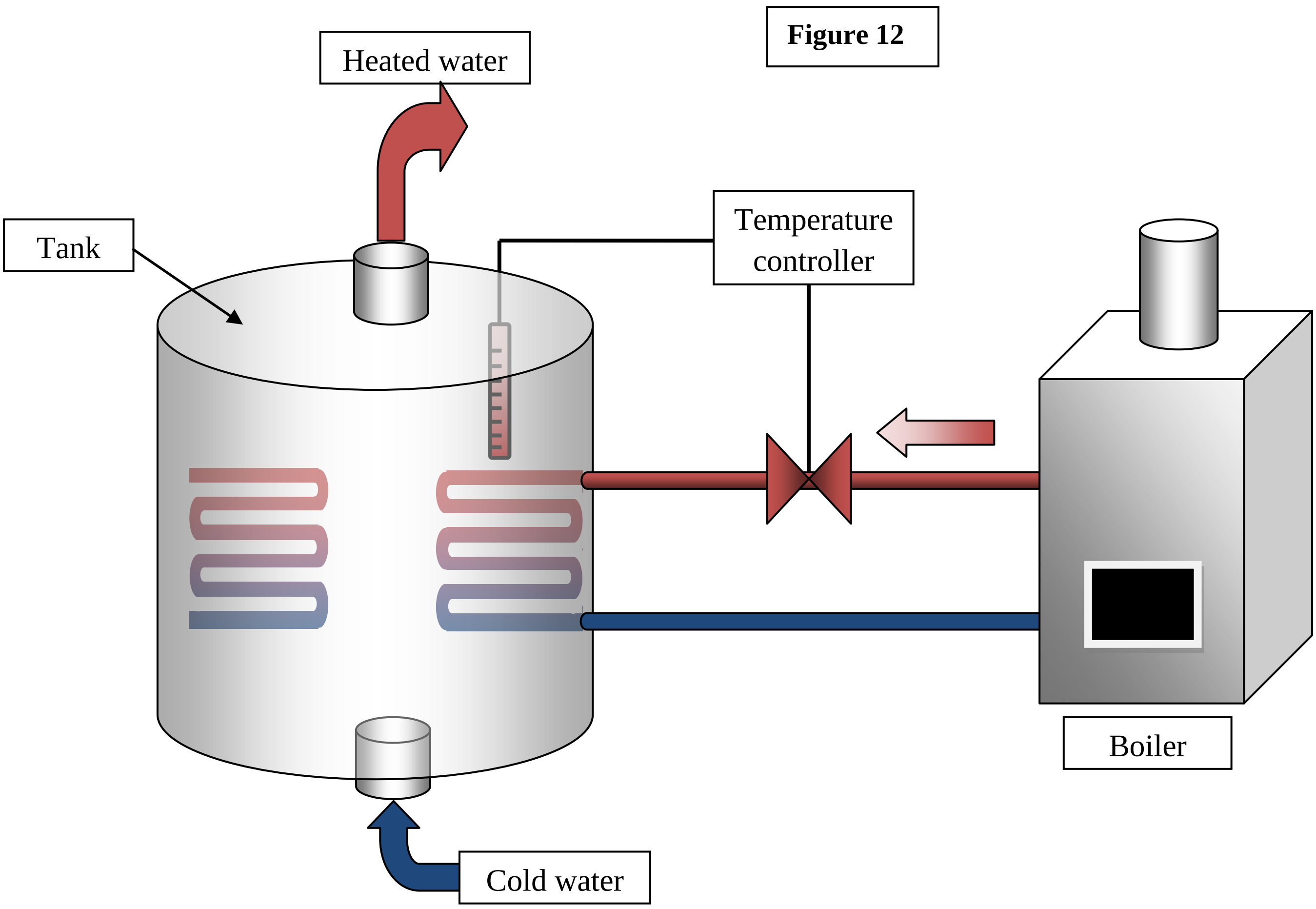


This kind of system is often used in case of an adaptation on an existing electrical system.

Heating self-regulation with direct electric resistance (Figure 11):



Heating self-regulation with boiler (Figure 12):



3) System set up

a) Basic rules

Basic rules are needed for a good installation:

- First of all, it is important to make a preliminary study and a good diagnosis of the needs to determine the best size for the specific installation.
- We need to identify a location well exposed to the sun with no shading (no shadows of a nearby buildings, vegetation, etc.).

Regular needs of the hot water heater for better efficiency:

- Make an assessment of the condition of the production system and the existing distribution system.
- The sensor must be as close as possible to the hot water tank to limit the loss of heat in the pipelines.
- The facility must be readily accessible for easy maintenance.

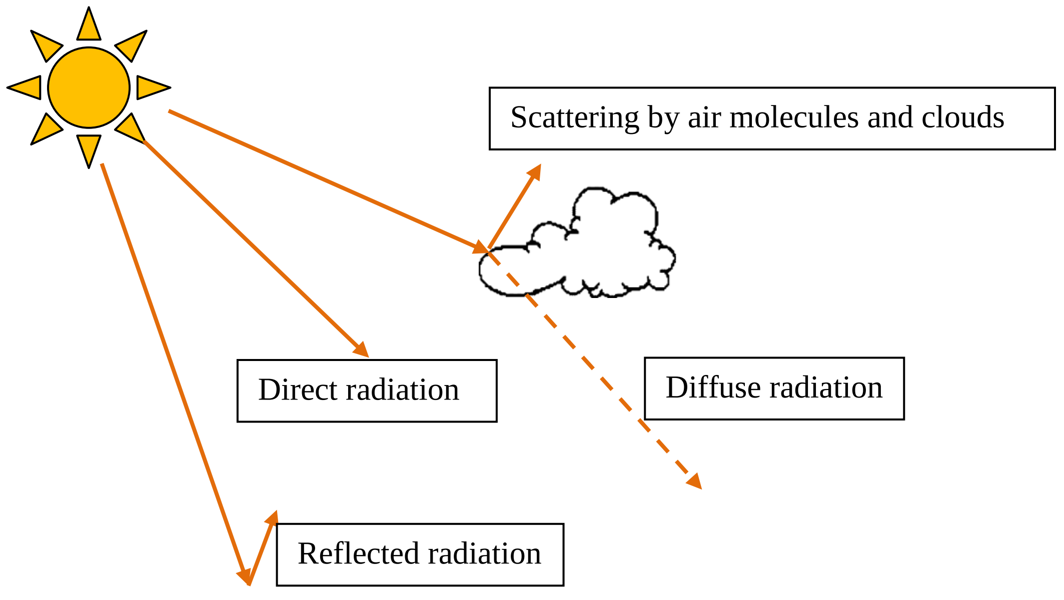
b) Sensor orientation

To set up a solar water heater, we need to study different parameters, such as the annual sun exposure and the orientation of the solar sensor.

First of all we need to understand the different kind of sun radiation *(Figure 13)*:

- Direct radiation
- Reflected radiation
- Diffuse radiation
- Scattering by air molecules and clouds

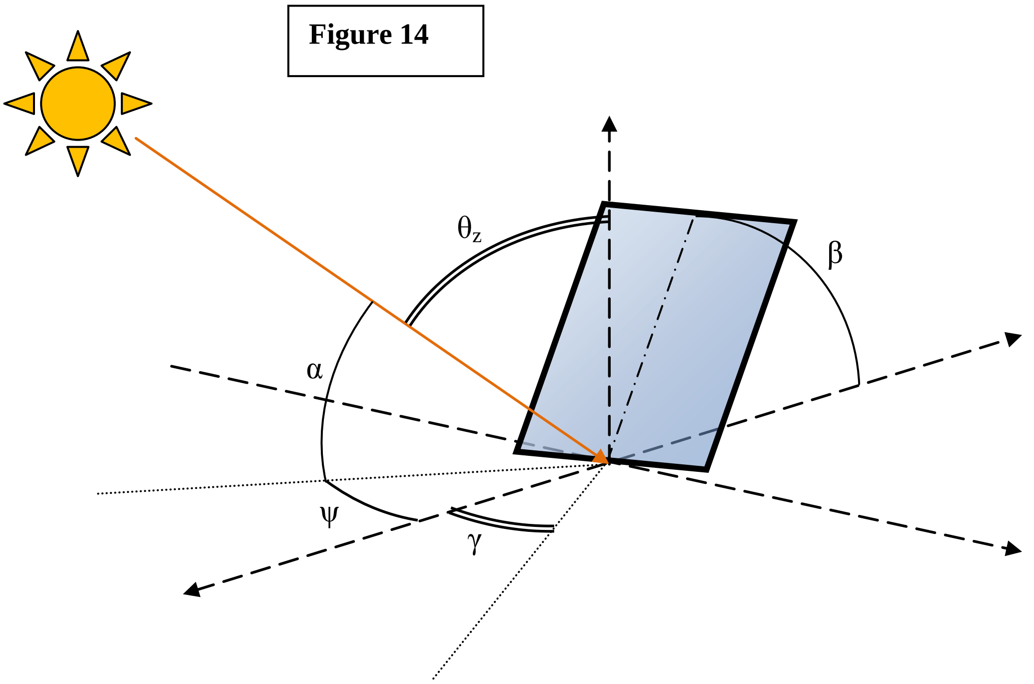
Figure 13



The orientation of the solar sensor must be calculated with 5 different angles *(Figure 14)*:

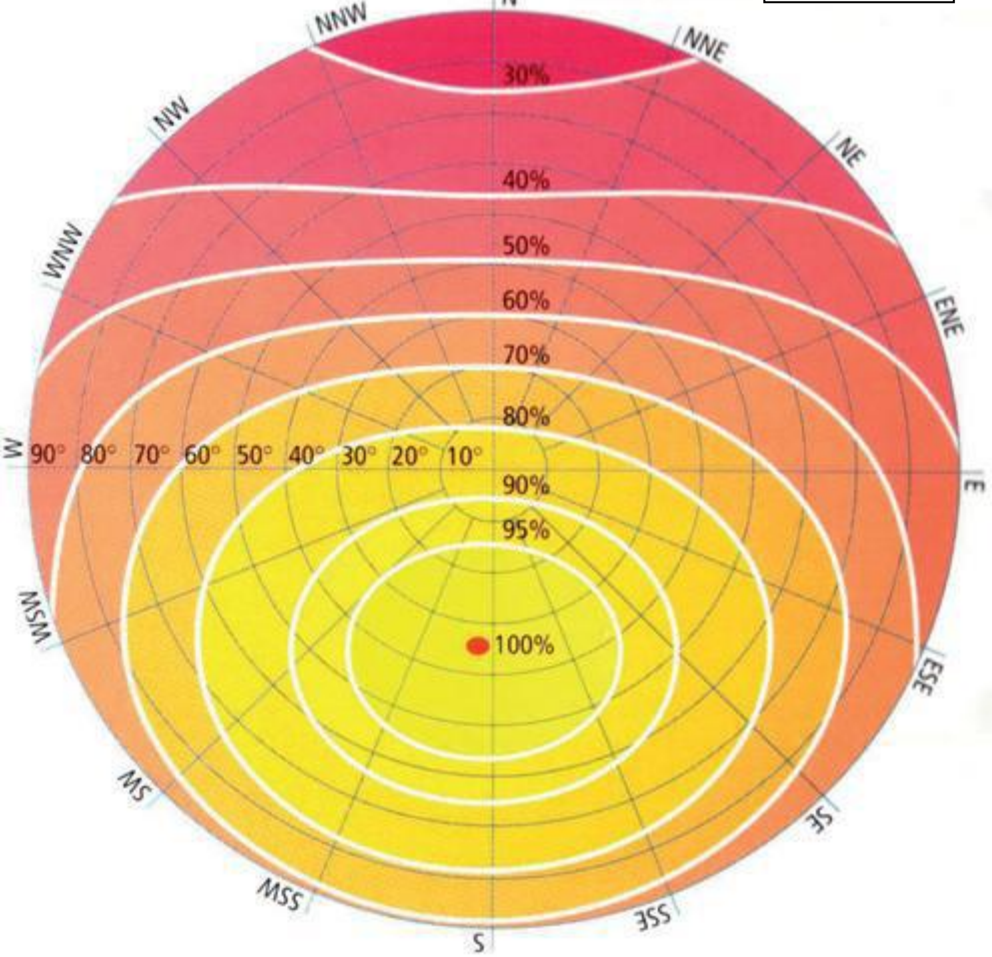
- β → sensor tilt angle
- γ → sensor azimuth
- θ_z → zenithal angle
- ψ → solar azimuth
- α → height

Figure 14



β and γ angle are calculated with this type of chart *(Figure 15)*:

Figure 15



According to this, we can see that in latitudes between 30° and 60°, we have to point the solar sensor with a β angle close to 35° and a γ angle close to 0°.

II] Economic study

1) Sun radiation principle

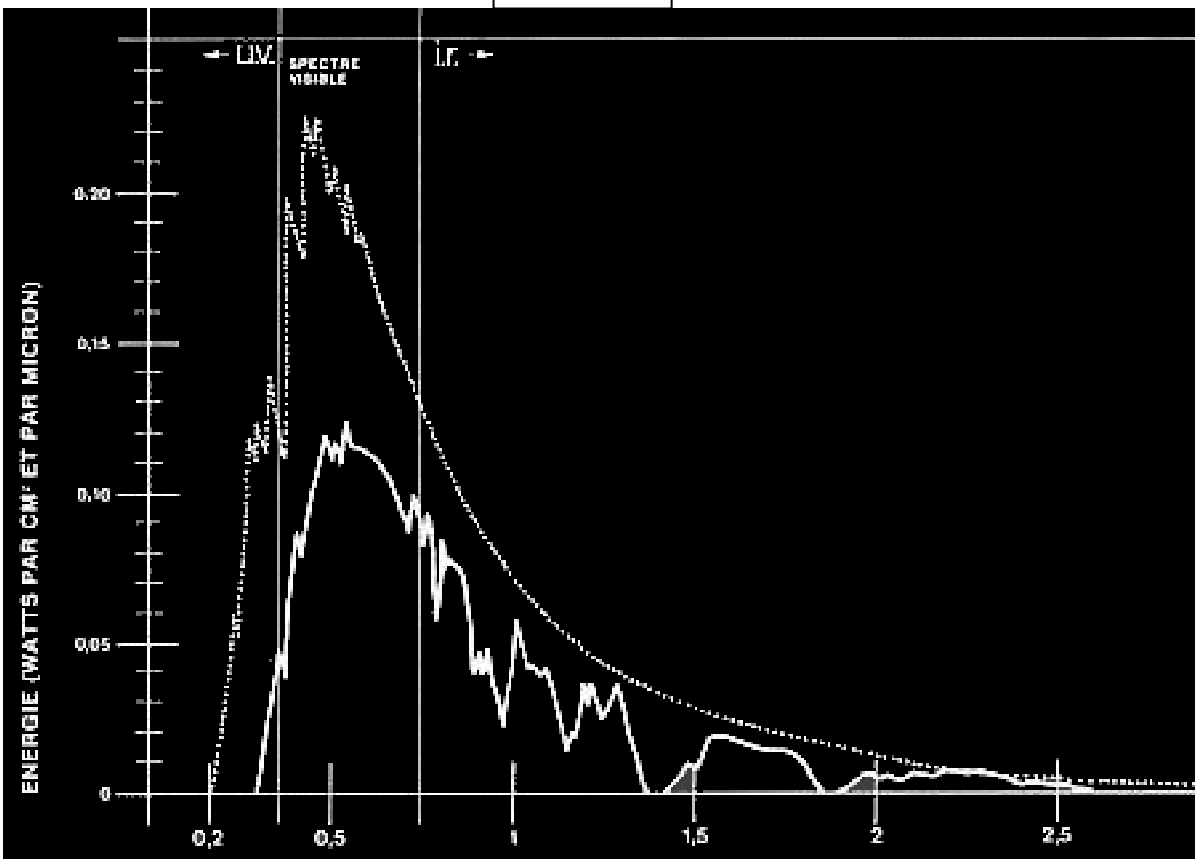
Before every yield study, it’s important to understand how solar energy works and which points are important for the best energy uptake.

First of all, the radiation emitted by the sun is a continuous spectrum, ranging from ultraviolet to infrared through the visible spectrum where it emits the maximum energy.

In traversing the atmosphere, gases and molecules absorb part of ultra-violet and infrared (IR). So on the surface of the earth, the solar radiation includes 5% UV, 40% of visible light and 55% IR, key holders of the heat.

The following graph represents the energy associated with this spectrum; the dotted line represents the energy at the boundary of the atmosphere; the other one represents the same energy on the ground:

Graph 1



The solar constant of 1,350 watts/m2 is the energy reaching a surface perpendicular to sunlight in the upper layers of the atmosphere. The effect of passage through the atmosphere that reflects, absorbs or distributes parts of the solar radiation significantly reduces this value.

It is important that this reduction is even stronger than the layer of atmosphere, and it is, therefore, a direct function of the height of the sun. In summer, the flux density reaching a surface can be increased in the best conditions to 900-1000W/m2.

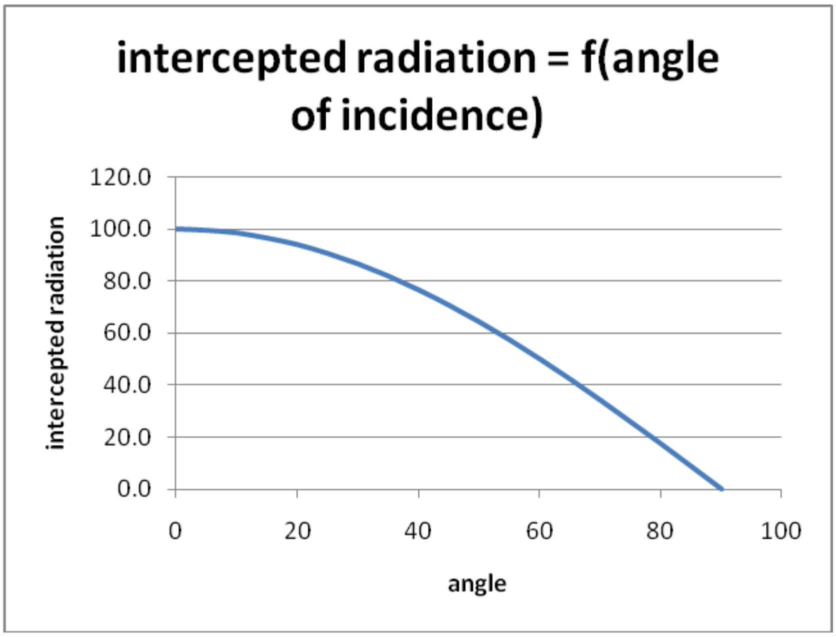
Intensity of solar radiation on a surface

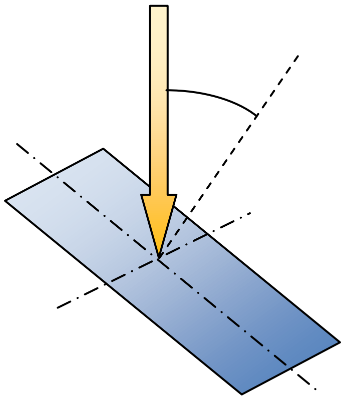
The angle of incidence characterizes the intensity with which the solar rays hit the surface: it is the angle between the perpendicular to the surface and the solar radius at the instant considered. The tilt direction of the surface and the direction of the solar rays allow us to estimate the angle of incidence. The more perpendicular the solar source is to the surface, the stronger the intercepted radiation.

Table 1

Angle of incidence	Intercepted radiation
°	%
0	100.0
5	99.5
10	98.5
15	96.5
20	94.0
25	90.6
30	86.6
35	81.9
40	76.6
45	70.7
50	64.3
55	57.4
60	50.0
65	42.3
70	34.2
75	25.8
80	17.4
85	8.7
90	0.0

Graph 2





What happens to the solar flux intercepted by a surface?

The solar flux incident is reflected, absorbed and transmitted along the surface characteristics.

The reflected solar flux depends on the solar reflectance of the surface material. It is mainly related to the color: black does not reflect anything, white reflects nearly all. The reflected solar flux is lost.

The following tables show the absorption coefficients depending on color and materials:

Table 2

Paint	Absorption coefficient
color	ø
white	0,18
yellow	0,33
orange	0,41
red	0,44
light green	0,5
dark red	0,57
brown	0,79
grey	0,75
dark green	0,88
dark blue	0,91
black	0,94

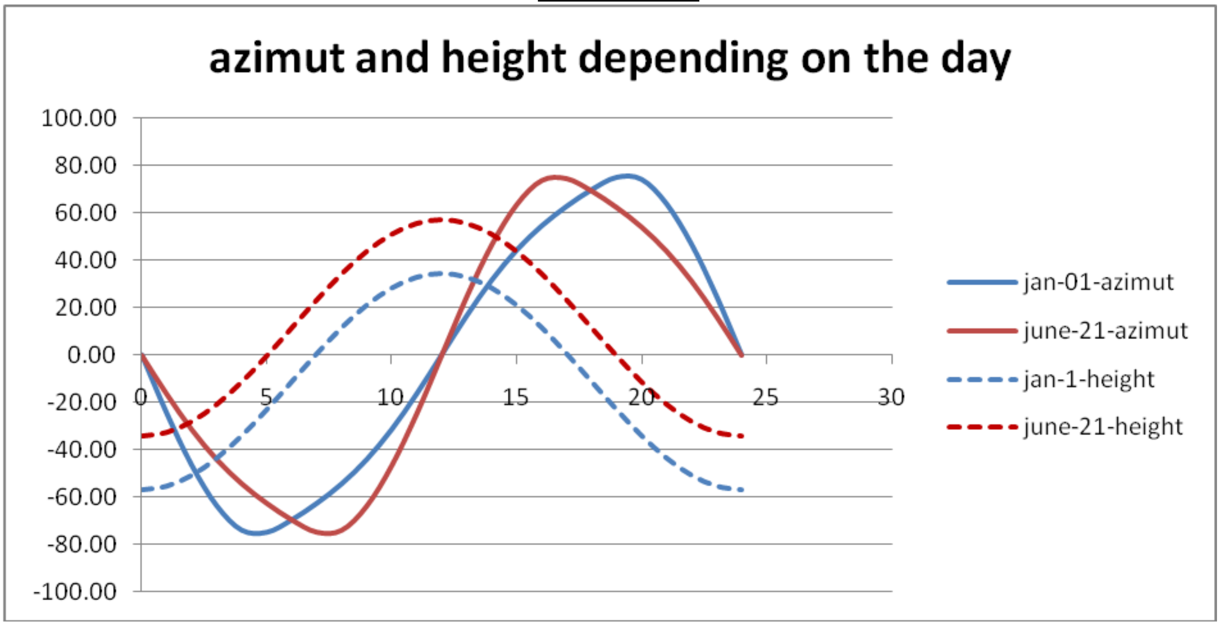
Material	Absorption coefficient
ø	ø
polished silver	0,07
polished aluminum	0,15
polished copper	0,18
white steel	0,45
aluminum	0,54
galvanized steel	0,64
tarnished copper	0,64
green steel	0,76
polished plumb	0,79
blue steel	0,8
red steel	0,81

Solar radiation absorbed is transformed into heat and raises the surface temperature of the material. The surface then exchanges with the environment along the three basic modes of exchange: by conduction inside the material, by convection with the surrounding air and by radiation to the adjacent objects. As seen in this chart, a black steel material offers the best absorption characteristics.

2) Sensors efficiency

The solar sensor efficiency depends on the orientation of the sensor. Here is the calculation in an Excel file of the solar irradiation for each day of the year based on the latitude.

Graph 3

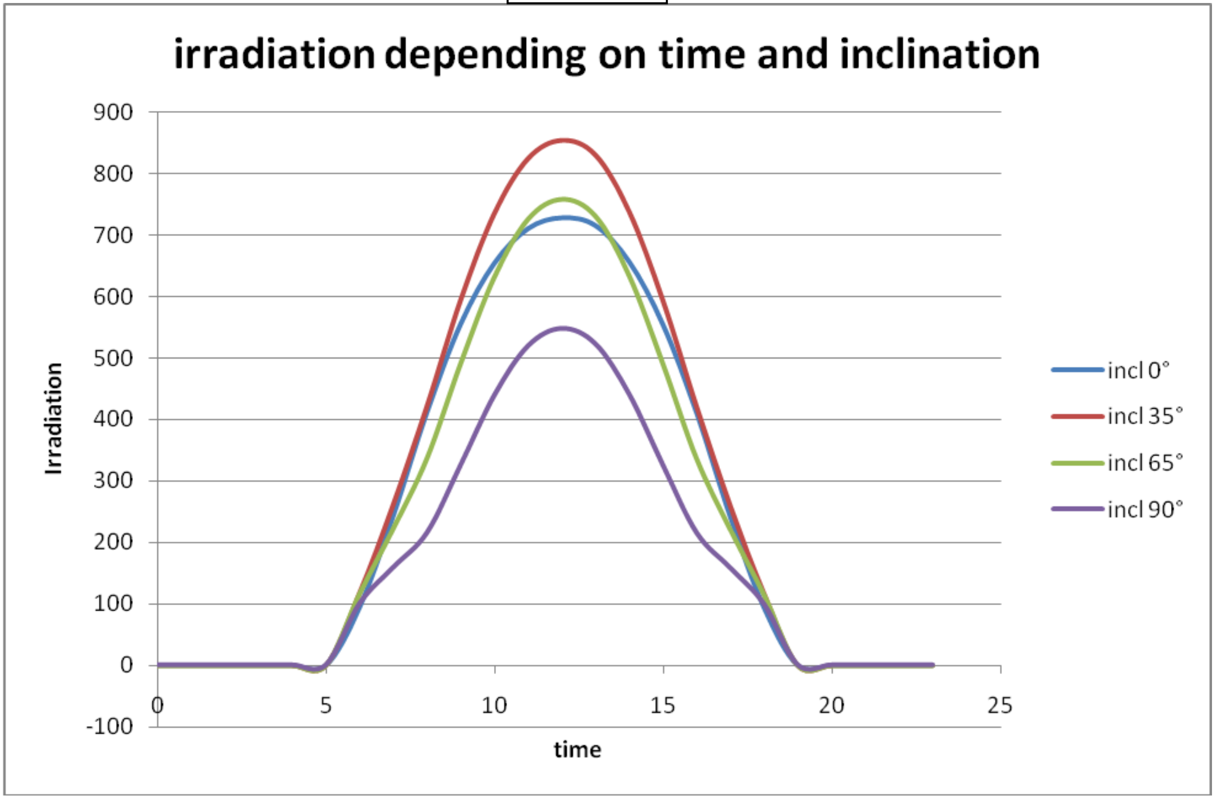


I have calculated the different irradiation (direct, diffuse and global) in Paris for the July 21st for every hour of the day. This file highlights the importance of the orientation and the inclination of the sensor.

Graph 4, **"irradiation depending on time and inclination,"** highlights the optimal inclination around 35°.

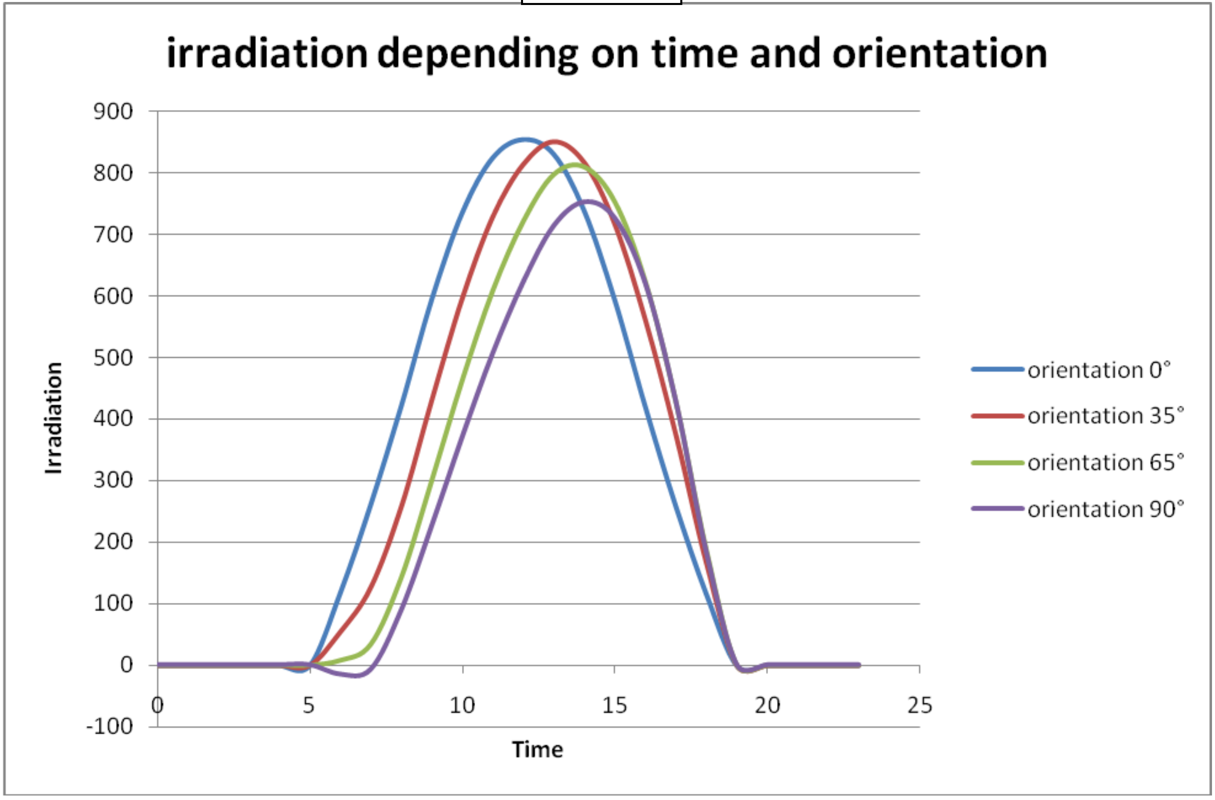
We easily see that a panel inclined at 65° is efficient but not as much as the first one. The one which is at 0° has less efficiency (that means that the panel is facing the sky, horizontally). And the last one, vertical, also has a very poor efficiency.

Graph 4



Graph 5, **"irradiation depending on time and orientation,"** shows that the best orientation corresponds to 0°; that means it is facing South.

Graph 5



The theoretical productivity of the sensors is calculated from two factors:
- The coefficient "B" which characterizes the optical performance of the sensor
- The coefficient "K" which characterizes the heat-loss sensor

To ensure a high efficiency of a sensor, the coefficient "B" must be large and the coefficient "K" small.

The performance of a sensor is defined by the formula:

$$\eta = B - K\, x\, \frac{Tflow(°C) - Tout(°C)}{irradiation\ (W/m^2)}$$

T flow= temperature of fluid in the sensor in °C
T out = exterior ambient temperature in °C

We can see that the solar panel efficiency depends on the temperature gap between flow and ambient temperature.

The following table shows the efficiency of different types of solar water heaters as a function of the panels' coefficients, the sun irradiation in a complete day of July in Paris, the exterior temperature and the flow temperature wanted.

Most of the following figures have been taken from these following web sites:
http://www.outilssolaires.com/Fabricants/prin-compare.htm for coefficients of panels.

http://iamest.jrc.it/pvgis/apps/pvest.php?lang=en&map=europe for irradiation values.

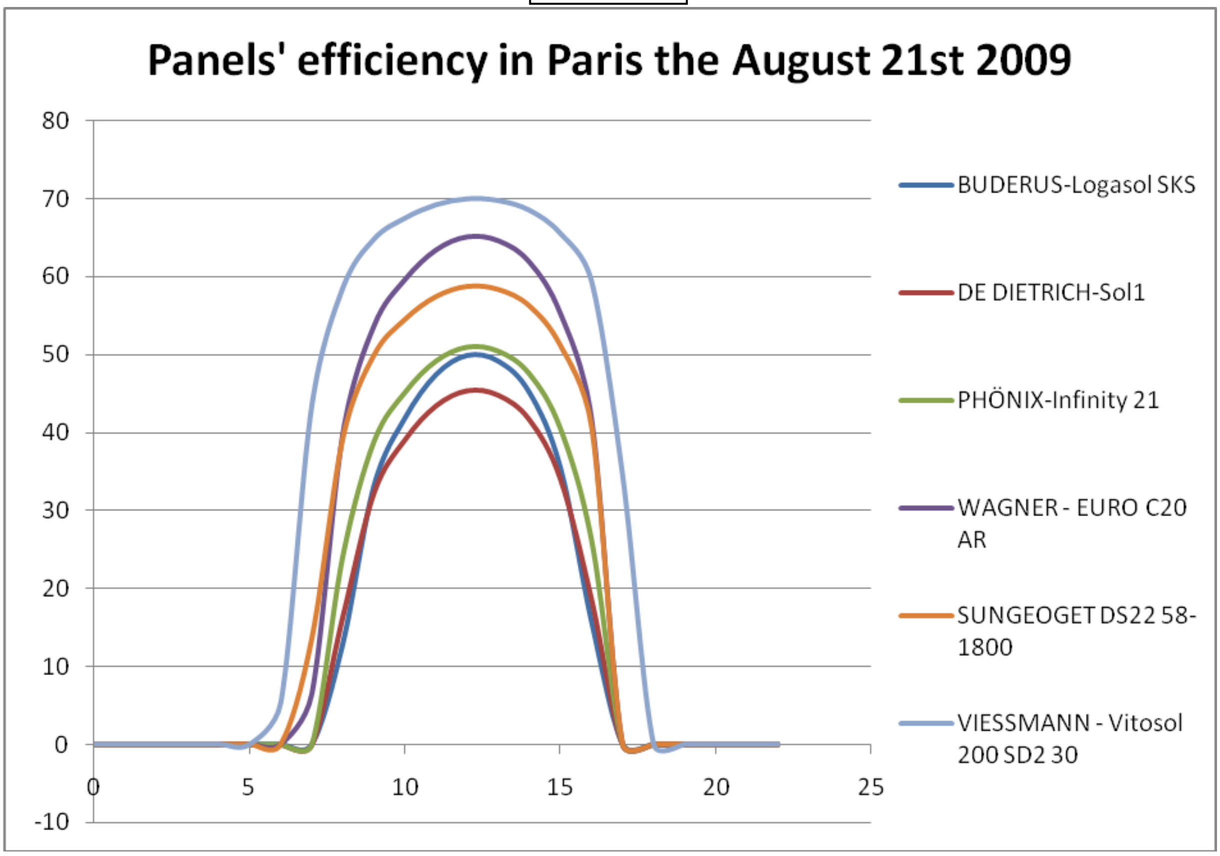
Table 3

Tflow°C	Glazed flat panels					Solar sensor vacuum:	
80	BUDERUS-Logasol SKS	DE DIETRICH-Sol1	PHÖNIX-Infinity 21	WAGNER - EURO C20 AR		SUNGEOGET DS22 58-1800	VIESSMANN - Vitosol 200 SD2 30
B →	0,79	0,68	0,72	0,85		0,74	0,79
K →	4,89	3,82	3,54	3,34		2,57	1,51
1:00	0	0	0	0		0	0
2:00	0	0	0	0		0	0
3:00	0	0	0	0		0	0
4:00	0	0	0	0		0	0
5:00	0	0	0	0		0	0
6:00	0,00	0,00	0,00	0,00		0,00	0,00
7:00	0,00	0,00	0,00	0,00		0,00	5,34
8:00	0,00	0,00	0,00	6,46		13,56	43,49

9:00	12,96	16,41	24,19	39,89		39,29	58,61
10:00	33,20	32,23	38,85	53,72		49,93	64,86
11:00	41,93	39,04	45,16	59,68		54,52	67,55
12:00	47,49	43,39	49,19	63,48		57,44	69,27
13:00	49,95	45,31	50,97	65,16		58,73	70,03
14:00	49,22	44,74	50,44	64,66		58,35	69,80
15:00	45,21	41,60	47,54	61,92		56,24	68,56
16:00	35,52	34,03	40,52	55,30		51,15	65,57
17:00	15,81	18,63	26,25	41,84		40,79	59,49
18:00	0,00	0,00	0,00	0,00		0,00	34,53
19:00	0	0	0	0		0	0
20:00	0	0	0	0		0	0
21:00	0	0	0	0		0	0
22:00	0	0	0	0		0	0
23:00	0	0	0	0		0	0

This graph represents the efficiency of different solar sensors. Dotted lines represent two solar sensor vacuums, and the other represents glazed flat panels.

Graph 6



In the following table, the efficiency of different solar sensors in Paris for 6 months in the year have been calculated, and then an average has been taken to calculate each sensor's productivity in a year.

Table 4

T° flow	60	°C								
Irradiation average	1390	W/m^2.s								
Latitude			48°48'46" North (Paris)						annual rate average	annual productivity
Month			Jan	March	May	July	Sept	Nov		
Irradiation average per day		W/m^2.day	513,62	595,65	537,97	536,61	581,20	443,11		
T° out	15	°C	3	7	14	19	16	7		

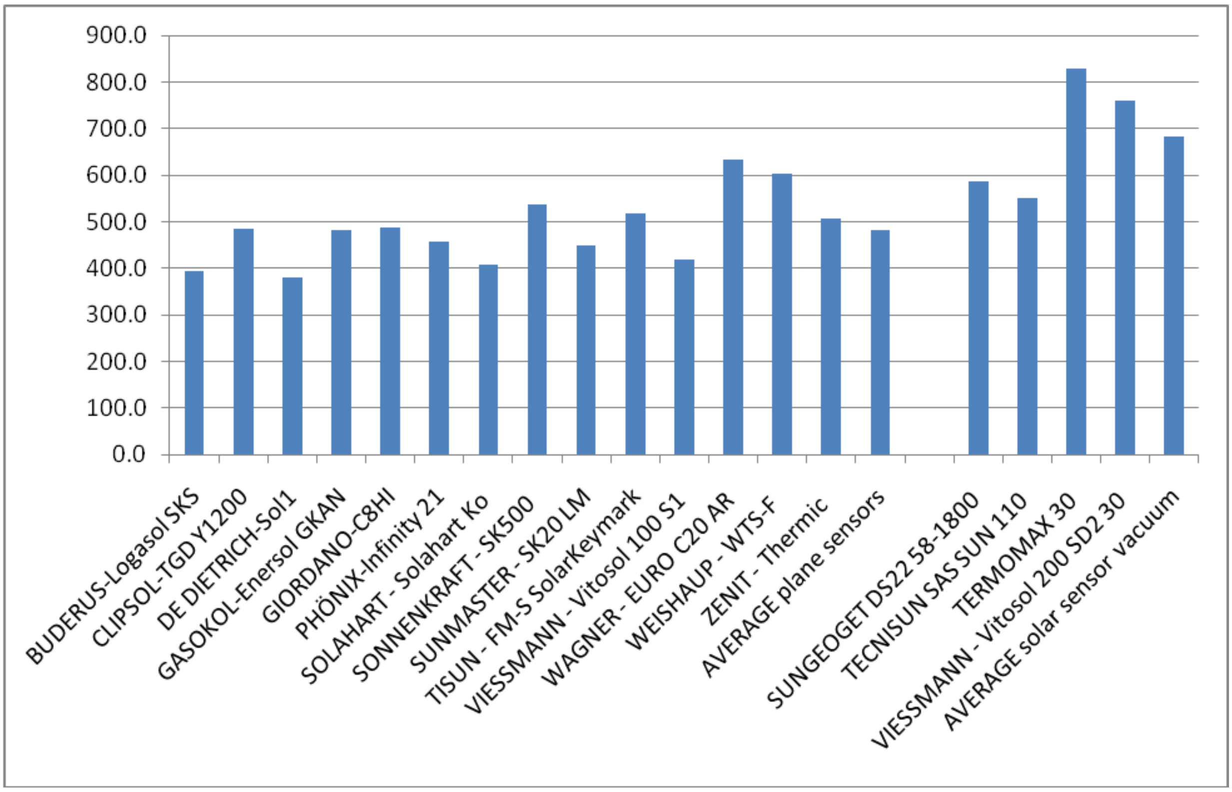
Glazed flat panel:

	B	K	rate %						%	kWh/m^2.year
BUDERUS-Logasol SKS	0,79	4,89	24,7	35,5	37,2	41,6	42,0	20,5	33,6	393,3
CLIPSOL-TGD Y1200	0,75	3,62	34,8	42,8	44,0	47,3	47,6	31,7	41,4	484,6
DE DIETRICH-Sol1	0,68	3,82	25,6	34,0	35,3	38,8	39,1	22,3	32,5	380,9
GASOKOL-Enersol GKAN	0,77	3,86	34,2	42,7	44,0	47,5	47,8	30,8	41,2	481,9
GIORDANO-C8HI	0,76	3,71	34,8	43,0	44,3	47,7	47,9	31,6	41,5	486,5
PHÖNIX-Infinity 21	0,72	3,54	32,7	40,5	41,7	45,0	45,2	29,7	39,1	458,2
SOLAHART - Solahart Ko	0,79	4,76	26,2	36,6	38,3	42,6	43,0	22,1	34,8	407,5
SONNENKRAFT - SK500	0,82	3,9	38,7	47,3	48,7	52,2	52,5	35,4	45,8	536,1
SUNMASTER - SK20 LM	0,77	4,17	30,7	39,9	41,3	45,1	45,4	27,1	38,3	448,2
TISUN - FM-S SolarKeymark	0,79	3,75	37,4	45,6	46,9	50,3	50,6	34,1	44,2	517,3
VIESSMANN - Vitosol 100 S1	0,76	4,34	27,8	37,4	38,9	42,8	43,1	24,1	35,7	418,0
WAGNER - EURO C20 AR	0,85	3,34	47,9	55,3	56,4	59,5	59,7	45,1	54,0	632,1
WEISHAUP - WTS-F	0,77	2,75	46,5	52,5	53,5	56,0	56,2	44,1	51,5	602,6
ZENIT - Thermic	0,77	3,62	36,8	44,8	46,0	49,3	49,6	33,7	43,4	508,0
AVERAGE plane sensors	0,77	3,86	34,2	42,7	44,0	47,6	47,8	30,9	41,2	482,5

Solar sensor vacuum:

	B	K							%	kWh/m^2.year
SUNGEOGET DS22 58-1800	0,74	2,57	45,5	51,1	52,0	54,4	54,5	43,3	50,1	587,1
TECNISUN SAS SUN 110	0,64	1,83	43,7	47,7	48,4	50,0	50,1	42,1	47,0	550,4
TERMOMAX 30	0,76	0,55	69,9	71,1	71,3	71,8	71,8	69,4	70,9	830,1
VIESSMANN - Vitosol 200 SD2 30	0,79	1,51	62,2	65,6	66,1	67,5	67,6	60,9	65,0	760,9
AVERAGE solar sensor vacuum	0,73	1,62	55,3	58,9	59,4	60,9	61,0	53,9	58,3	682,1

Graph 7


900.0
800.0
700.0
600.0
500.0
400.0
300.0
200.0
100.0
0.0
BUDERUS-Logasol SKS
CLIPSOL-TGD Y1200
DE DIETRICH-Sol1
GASOKOL-Enersol GKAN
GIORDANO-C8HI
PHÖNIX-Infinity 21
SOLAHART - Solahart Ko
SONNENKRAFT - SK500
SUNMASTER - SK20 LM
TISUN - FM-S SolarKeymark
VIESSMANN - Vitosol 100 S1
WAGNER - EURO C20 AR
WEISHAUP - WTS-F
ZENIT - Thermic
AVERAGE plane sensors
SUNGEOGET DS22 58-1800
TECNISUN SAS SUN 110
TERMOMAX 30
VIESSMANN - Vitosol 200 SD2 30
AVERAGE solar sensor vacuum

3) Cost/Energy rate comparison

It is not easy to determine the hot water needs of a family. Generally, we estimate the consumption at 50 liters at 50°C per day per person, but those figures can change by as much as 20%.

The productivity of a solar water heater must be around 1.5 times the daily needs. To have a more precise idea of the heated water tank volume, we use this formula:

$$V = \frac{Vp\ x\ Np\ x\ (Thw - Tcw)}{(Tst - Tcw)}\ x\ 1.5$$

Vp = Volume needed per person per day
Np = number of people
Thw = heated water temperature
Tst = stored water temperature
Tcw = cold water temperature

Generally, the hot water tank is quite voluminous, and the maximum temperature that can be reached the system in the cold period of October-April is inefficient. For this reason, it is very important to have a booster system, as explained in the followings paragraphs.

In the following example, I chose a family of 4 that consumes 50 liters per day (a 200 liter tank), but the attached excel file allows us to change these parameters.

During the day, on July 21, 2009, in Paris, the solar power received will be around 17,900 Wh (Ps = 17.9kWh) for the sensor “WAGNER – EURO C20 AR.” The hot water tank in the morning is around 35°C (Ttm = 35); the booster starts below a tank temperature of 50°C (Tbst = 50) and only at the end of the day. In the evening, the hot water tank will be (Thwed):

$$Thwed = \frac{Ps}{V\ x\ Cp} + Ttm = \frac{17{,}900}{200\ x\ 1{,}163} + 35 = 112°C$$

Knowing that the maximum temperature in a tank is generally 90°C, we would have:

$$Thwed = 90°C$$

The need for heated water is around 50 liters per person at 38°C, and the cold water temperature is about 13°C. The heated water consumed is:

$$Vhw = Vp\ x\ Np = 200\ liters$$

That leads us to a hot water consumption per person per day Vc:

$$Vwc = Vp\ x\ \frac{(Thw - Tcw)}{(Tst - Tcw)} = 50\ x\ \frac{38 - 13}{50 - 13} = 33.8\ liters$$

At the end of the day, the hot water used at 90°C will be:

$$V_{90°C} = V\ x\ \frac{(Thw - Tcw)}{(Tst - Tcw)} = 200\ x\ \frac{38 - 13}{90 - 13} = 64{,}9\ liters$$

Those 64.9 liters will be mixed with cold water at 13°C to have a 38°C water.

The average temperature of the tank after using heated water will be (Tau):

$$T_{au} = \frac{V_{90°C}\ x\ Tcw + (V - V_{90°C})\ x\ Thwed}{V} = \frac{64.9\ x\ 13 + (200 - 64.9) x\ 90}{200} = 65°C$$

For this example day, it is not necessary to start the booster.

If we now do the same calculation with a less efficient sensor such as the "BUDERUS-Logasol SKS," we have 4 degrees less in the tank at the end of the day.

The same sensor with a 300 liter tank with the same usage conditions leads to a tank temperature around 44°C at the end of the day; it is necessary to start the booster even on the July 21st.

These calculations are extendable to the whole year and allow us to know the percentage of energy needs that are covered by the sun in a year (Graph 8).

Graph 8

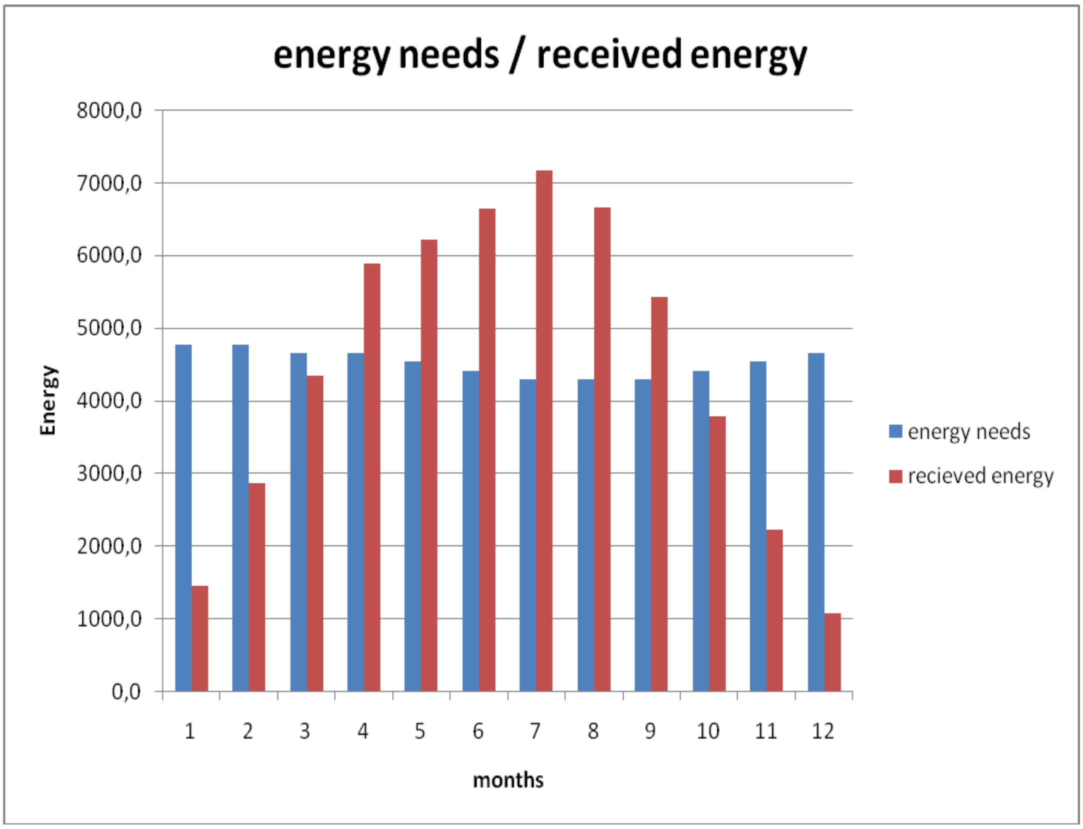
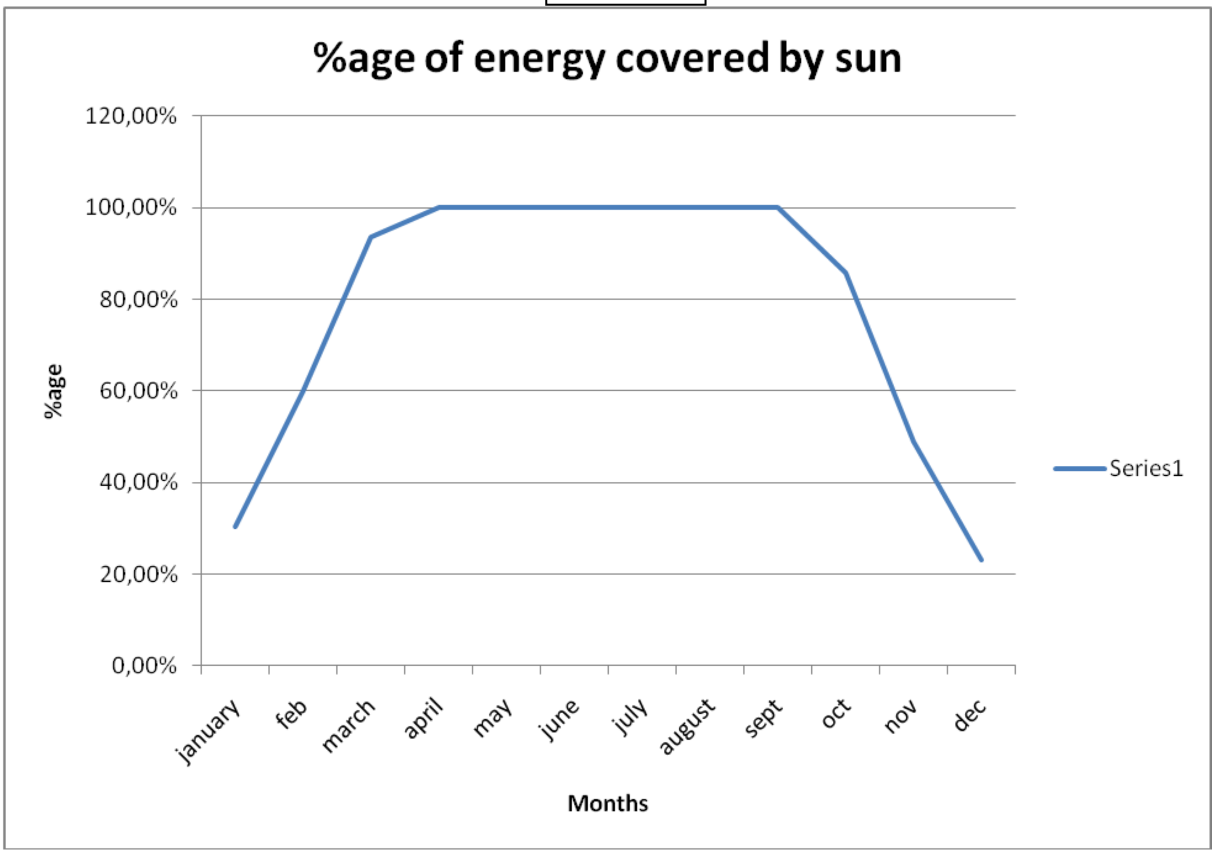

energy needs / received energy
8000,0
7000,0
6000,0
5000,0
4000,0
3000,0
2000,0
1000,0
0,0
Energy
1
2
3
4
5
6
7
8
9
10
11
12
months
energy needs
recieved energy

Table 5

	Comparison			
	Needs	Received	If received > needed its lost energy	% of energy needs covered by sun
January	4768,3	1449,85	1449,85	30,41%
February	4768,3	2860,57	2860,57	59,99%
March	4652,0	4350,19	4350,19	93,51%
April	4652,0	5883,94	4652,00	100,00%
May	4535,7	6226,73	4535,70	100,00%
June	4419,4	6639,71	4419,40	100,00%
July	4303,1	7179,80	4303,10	100,00%
August	4303,1	6664,13	4303,10	100,00%
September	4303,1	5433,63	4303,10	100,00%
October	4419,4	3785,77	3785,77	85,66%
November	4535,7	2220,40	2220,40	48,95%
December	4652,0	1070,89	1070,89	23,02%

Graph 9



III] Large scale set ups

The goal of this part is to see what has been done so far by country, what has caused this and what changes could be made by the others.

The following part is extracted from http://en.wikipedia.org/wiki/Solar_water_heating

"*There are records of solar collectors in the United States dating back to before 1900, comprising a black-painted tank mounted on a roof. In 1896, Clarence Kemp of Baltimore, USA enclosed a tank in a wooden box, thus creating the first 'batch water heater' as they are known today. Although flat-plate collectors for solar water heating were used in Florida and Southern California in the 1920s, there was a surge of interest in solar heating in North America after 1960, but especially after the 1973 oil crisis.*

Solar Thermal Works in Israel

Flat plate solar systems were perfected and used on a very large scale in Israel. In the 1950s, there was a fuel shortage in the new Israeli state, and the government forbade heating water between 10 p.m. and 6 a.m. Levi Yissar built the first prototype Israeli solar water heater and in 1953, he launched the NerYah Company, Israel's first commercial manufacturer of solar water heating. Despite the abundance of sunlight in Israel, solar water heaters were used by only 20% of the population by 1967. Following the energy crisis in the 1970s, in 1980 the Israeli Knesset passed a law requiring the installation of solar water heaters in all new homes (except high towers with insufficient roof area). As a result, Israel is now the world leader in the use of solar energy per capita with 85% of the households today using solar thermal systems (3% of the primary national energy consumption). Estimated to save the country two million barrels of oil a year, it is the highest per capita use of solar energy in the world.

Other countries

The world saw a rapid growth of the use of solar warm water after 1960, with systems being marketed also in Japan and Australia. Technical innovation has improved performance, life expectancy and ease of use of these systems. Installation of solar water heating has become the norm in countries with an abundance of solar radiation, like the Mediterranean, and Japan and Australia. Colombia developed a local solar water heating industry thanks to the designs of Las Gaviotas, directed by Paolo Lugari. Driven by a desire to reduce costs in social housing, the team at Las Gaviotas studied the best systems from Israel and made adaptations as to meet the specifications set by the Banco Central Hipotecario (BCH) which prescribed that the system must be operational in cities like Bogotá where there are more than 200 overcast days. The ultimate designs were so successful that in 1984, Las Gaviotas offered a 25-year warranty on any of its installations. Over 40,000 were installed and still function a quarter of a century later.

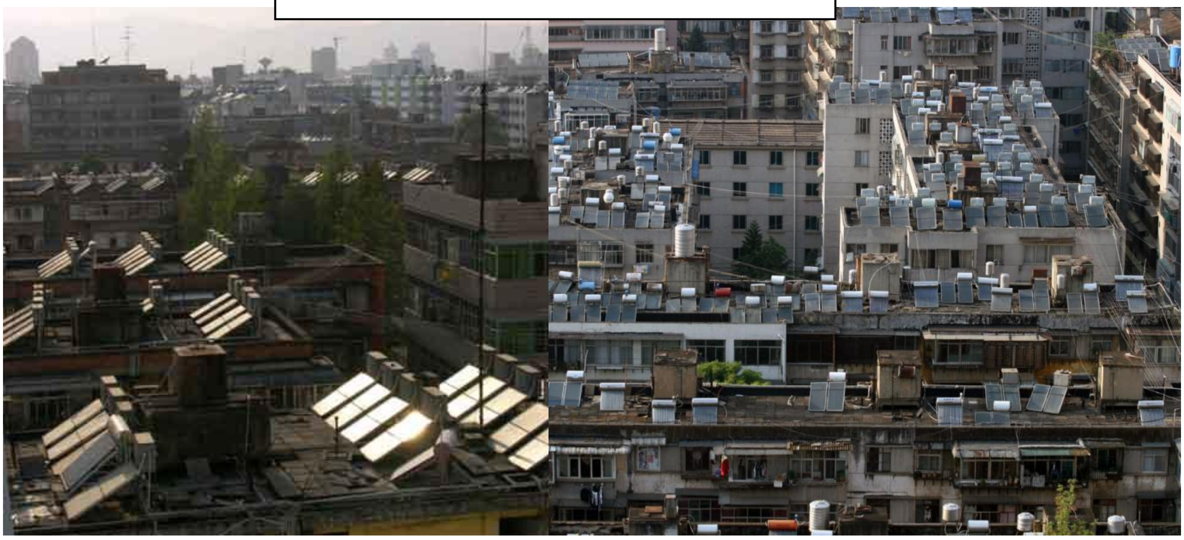
In 2005, Spain became the first country in the world to require the installation of photovoltaic electricity generation in new buildings, and the second (after Israel) to require the installation of solar water heating systems in 2006.

Australia has a variety of incentives (national and state) and regulations (state) for solar thermal introduced starting with MRET in 1997.

Solar water heating systems have become popular in China, where basic models start at around 1,500 yuan (US$190), much cheaper than in Western countries (approxiamately 80% cheaper for a given size of collector). It is said that at least 30 million Chinese households now have one system, and that the popularity is due to the efficient evacuated tubes which allow the heaters to function even under gray skies and at temperatures well below freezing. Israel and Cyprus are the per capita leaders in the use of solar water heating systems with over 30%-40% of homes using them."

Mostly a mountainous region, Yunnan in China remains little advanced in the economic sense, despite the development of tourism, but we can see the rush to sustainability.

Figure 16: Rooftop solar water heaters

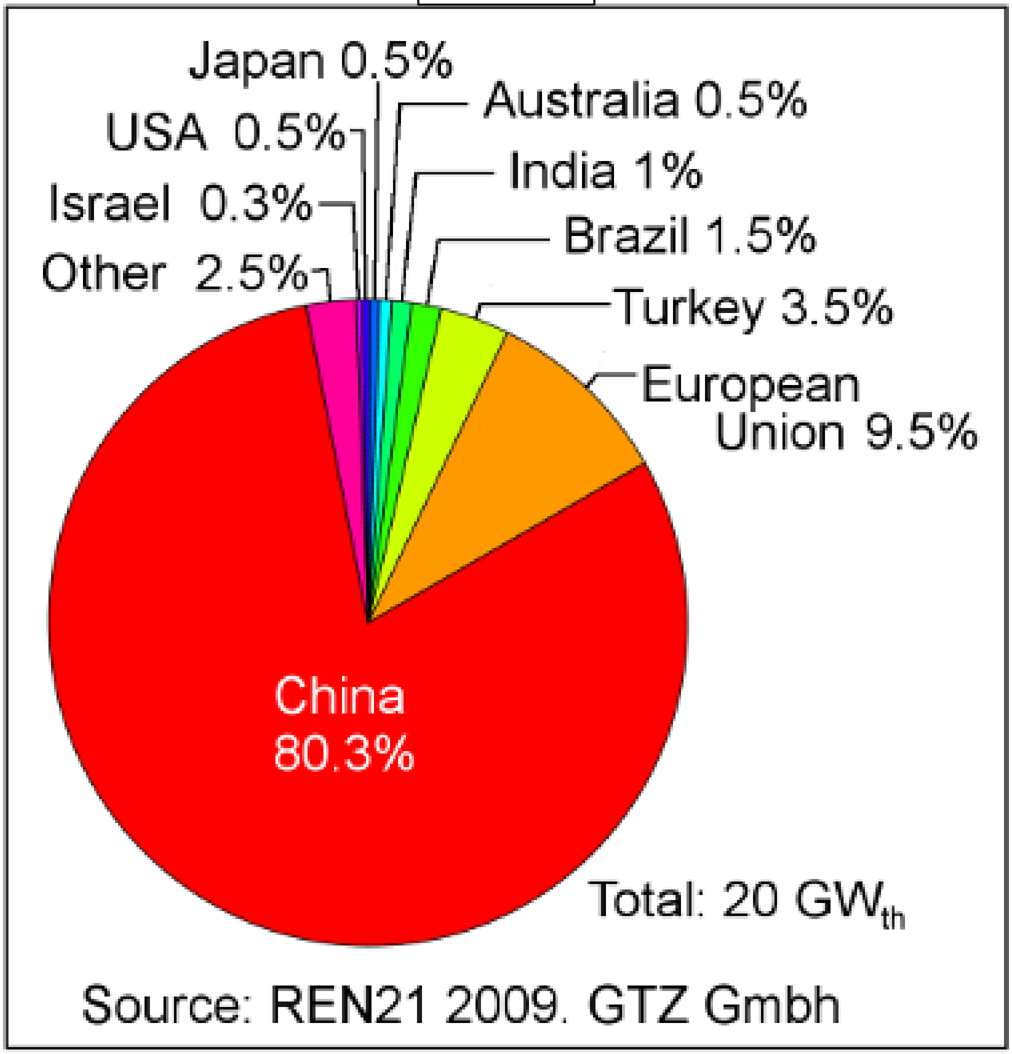


The main reason people use sustainable energy is that the government provides assistance, especially in the current times of crisis. As we can see in the previous paragraph in Israel, despite the end of nighttime heating prohibition, people continue to use these Solar Water Heaters.

In China the problem is a bit different, but the final result is the same. The price of solar water heater is very cheap compared to electricity, and given the living standard of the people, it is also a better investment.

The following chart shows us that developed countries are lagging behind the use of Solar Water Heater, definitely because of the standard of living.

Graph 10


Japan 0.5%
USA 0.5%
Australia 0.5%
Israel 0.3%
India 1%
Other 2.5%
Brazil 1.5%
Turkey 3.5%
European Union 9.5%
China 80.3%
Total: 20 GWth
Source: REN21 2009. GTZ Gmbh

Conclusion

This report shows the growing interest in solar water heaters in specific nations. The author sees great potential for all nations in the latitudes between Tropic and Cancer and Capricorn. We can easily see that SWH are very efficient, and using this innovative system can reduce our electricity needs and costs for heating water nearly 75% annually.

Objectively, the SWH can't be the only sustainable power in a house because while very good, its efficiency can vary depending on the amount of solar available on a given day.

The best way to be a green power consumer is to install both photovoltaic panels for electricity production and a solar water heaters on our rooftops.

Table of Figures, Tables and Graphs

Internet links

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Calculation software for irradiation :

http://www.pedagogie.ac-nantes.fr/1214223614078/0/fiche___ressourcepedagogique/&RH=PEDA

Efficiency calculation software:

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