Construction of solar collectors for warm water

Practical guide

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Safe energy for all

Women in Europe for a Common Future | WECF

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About WECF

WECF is an international network of over 100 women's and environmental organisations in 40 countries, implementing projects and advocating globally for a healthy environment for all. WECF's sustainable energy demonstration projects are implemented in the EECCA region (Eastern Europe, Caucasus and Central Asia).

About BMU / ICI

The International Climate Initiative of the Federal Republic of Germany ICI has been financing climate protection projects in developing and newly industrialising countries and in transition countries in Central and Eastern Europe since 2008. The International Climate Initiative receives funding from emissions trading and thus represents an innovative financing mechanism to support partner countries in the area of climate protection. With this new form of cooperation the Federal Environment Ministry supplements the existing development cooperation of the German government.

Solar water heaters

Our projects

The region has a great potential for renewable energy, especially solar energy. WECF and its local partners are working together with communities, universities and innovative businesses to demonstrate affordable energy solutions, using local knowledge and materials. In terms of solar energy, WECF and its partners have developed a low-cost, highly efficient solar collector model, which is easy to build with materials available at local markets, and can be used year round, even in harsh winter times.

Solar collectors

Warm water for washing, cleaning and laundry is an important factor for comfort and hygiene in daily life. Worldwide, water is traditionally heated by households using different kind of fuels, which are usually limited and often expensive. Especially in rural areas, extensive use of these fuels has severe impacts on the environment (e.g. local deforestation from fuel wood collection) as well as health impacts (respiratory problems of women and children from burning of unsafe fuels such as plastic waste). This brochure shows how you can use the energy from the sun for heating water in your household. It also makes life easier for women and reduces their daily labour burden.
Sun is everywhere on Earth and shines for everybody. It can also be a source of energy for the household. Even in countries with little radiation solar energy can be used. For example in Germany, an increasing number of people use solar collectors, even if it is more in the North and radiation is not so high. Solar water heaters, also called solar collectors, use the energy from the sun for water heating. They work without electricity supply. They provide hot water for showers, kitchen use, washing clothes and depending on the size, heating the house. Households using solar collectors have no extra fuel consumption for warm water heating and save money which they would otherwise have spent on fuel. Solar collectors are especially applicable in countries with high solar radiation and cold winters. They are used everywhere, but especially in rural areas and mountain areas with insecure energy supply.

There are different types of solar water heaters, all based on the simple idea that a black surface absorbs the heat from the sun and this heat is then transferred to the water. The easiest models can be constructed with simple materials and do not need any pumps or other electric devices. An effective solar collector even can be used in winter due to the use of antifreeze.

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Theory: Solar water heaters

Components of a solar water heating system

Solar collector

The collector collects the energy from the sun and converts it to heat.
The flat-plate collector consists of:

(1) a metal plate absorber of black colour, which intercepts and absorbs the solar energy, with metal tubes for fluid circulation welded to the metal plate
(2) a frame (wood)
(3) a transparent (glass) cover that allows solar energy to pass through but reduces heat loss from the absorber
(4) a heat insulating backing

The collector is connected to a hot water tank via pipes.

Hot water tank with heat exchanger for freeze protection

The heat exchanger transfers the heat produced in the collector to the warm water tank. It is a coil (made from metaloplast or copper) which is placed in the tank. The hot fluid from the collector circulates through the spirale and heats the water in the tank. This fluid can be just water during the warm period of the year, and in winter, a mixture of water and propylene glycol (which is used in the food industry) or antifreeze can be used
as a heat exchange fluid to protect against freeze damage.

On page 16 you will find the instructions for building a 2 m^2 solar collector with a 200 litre tank. The dimensions can be varied depending on your warm water needs.
The length of the exchanger and the size of the tank are interrelated with the surface of the collector, as it is shown in the table.

Collector surface	Tank capacity	Heat exchanger length
2 m^2	100-200 l	6 m
3 m^2	150-300 l	9 m
4 m^2	200-400 l	12 m
etc	etc	etc

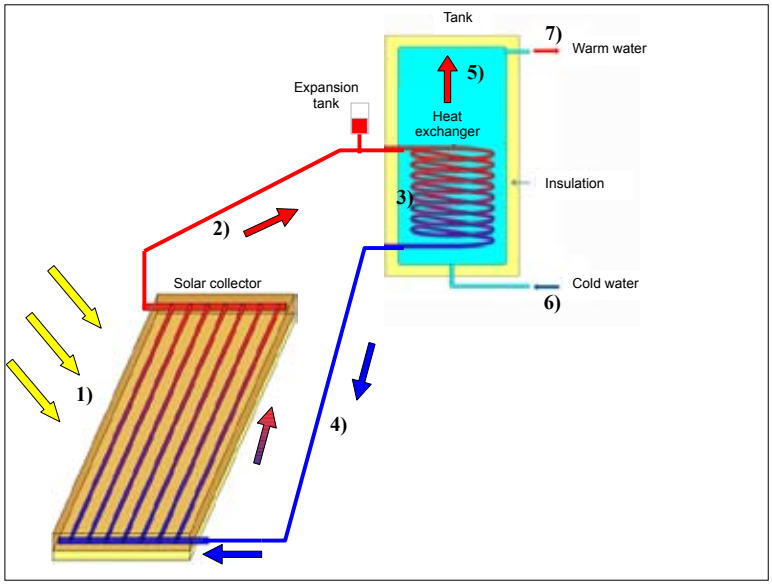
Theory: Solar water heaters

The principles of water circulation without pump

The solar collector system is a passive system which is independent from electricity. It has no pumps. The hot fluid is moved between the collector and the tank by convection, relying on the simple principle that warm water always rises.

The principle and operation of this solar system is as follows

1. The sun heats the fluid in the collector
2. The heated fluid goes up through the collector and the pipes to the tank
3. When the hot fluid enters the tank, the heat is transferred from the heat exchanger to the water in the tank
4. The fluid gets colder as it travels down the coil and drains back down to the collector through an outlet at the base of the tank
5. The water heated in the tank rises to the top of the tank, ready for use
6. The cold water from the fresh water supply replenishes the tank
7. Output of hot water ready for use in the home



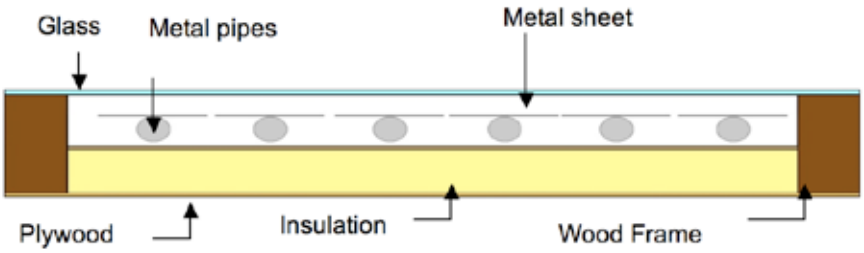
As long as the sun is shining on the collector, fluid is heated, goes up into the coil in the tank, hot water is used, colder fluid drains back into the collector and the tank is replenished with fresh cold water which is heated up again, so there is a constant circulation. This process provides a tank full of hot water within a few hours of sunshine during a sunny day.

Practice: Solar water heaters

A closer look at the different parts of the solar water heating system

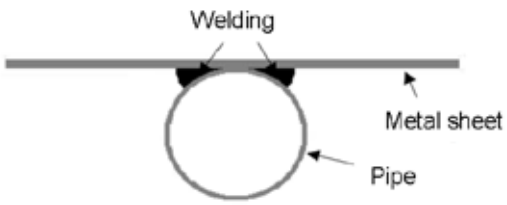
Metal flat-plate absorber

Inside the solar collector there is an absorber. Its function is to transfer the heat of the sun efficiently from the metal plate to the tubes of fluid. The absorber consists of a metal sheet which is welded to metal pipes. This gives to the absorber a big surface of absorption for the solar radiation, heating the water fast. Usually, an absorber for domestic conditions is of about 2 m2 size. The principle is to have several thinner pipes running along the length of the collectors, and connect them using two pipes of greater diameter placed at either end, as shown above .
To get a good water flow, the water inlet where the cold fluid comes into the collector (lower part of the absorber) has to be at one end of the collector and the outlet where the heated fluid goes out of the collector into the tank (upper part of the absorber) has to be at the other end of the collector (see picture on the right).



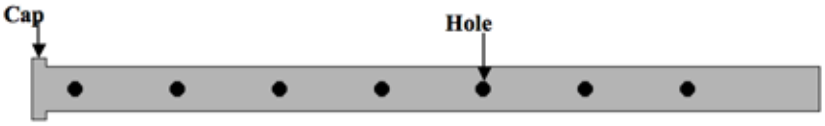
Cut view of the absorber plate

All connections between the various elements of the absorber are made by iron welding.
For a good heat transfer from the metal plate to the pipes, the connection is very important.
So the weld should be continuous and not only on some points.
The following picture shows a cut view of the type of welding to be achieved.



Practice: Solar water heaters

To fix the long pipe with the two horizontal pipes it is necessary first to perforate the two pipes in order to fix the pipe plate with them, and allow fluid to flow. The distance between each hole is identical. The picture below shows the pipe with location and size of the holes. (for exact measures see p. X (in der collector Anleitung step 6)



➢ **Pipe with location of holes**

At one end of each horizontal pipe, a metal cap must be welded to block the water. A good weld is needed to achieve a perfect seal. Before using the system, you should test the absorber by filling it with water to test if there are water losses. After the test, the metal sheet and pipes should be painted black for better absorption of sunlight.

Frame

The absorber is put into a wooden frame, covered with glass. The frame needs good insulation to keep the heat inside. The glass cover and the frame protect the collector and help to keep the heat: like in a greenhouse, the sun's rays enter through the glass and heat the collector, absorbed by the black colour, and the glass glazing prevents the heat from passing back through the glazing. Like the absorber, the frame is painted black, to absorb sunlight better.The glass also blocks air motion across the absorber: without glass cover, the collector would rapidly lose heat due to wind, rain or snow, or cold outside temperatures.

Practice: Solar water heaters

Black Paint

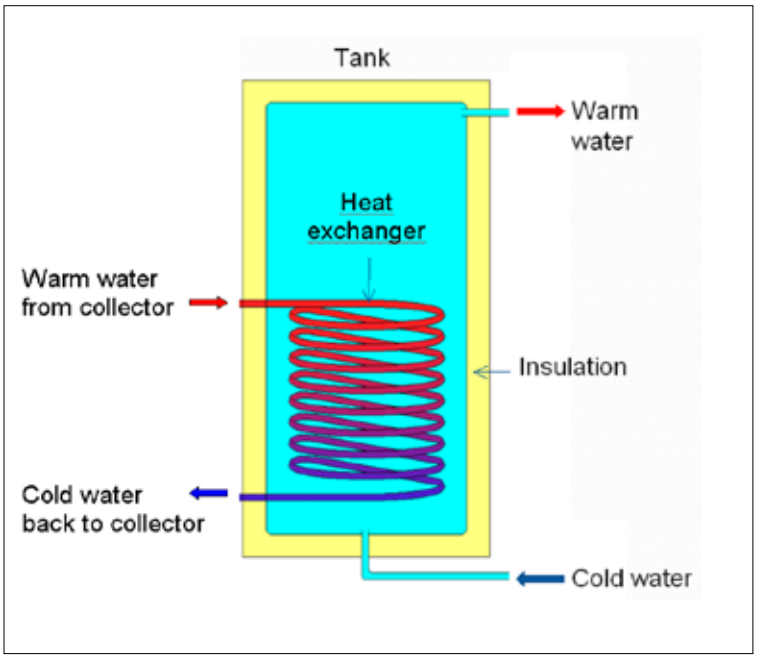
For painting the absorbing parts of the collector, a special solar paint is recommended, as normal black paints can evaporate when they get hot and after a while the cover glass will also become black. If there is no solar paint available, you should use where possible a non-toxic (water soluble) paint, e.g. pigment paint. You should make sure the paint is completely dry before you put the glass cover on, to avoid condensation.

Heat insulation

Insulation is the main factor to prevent heat losses. Insulation is needed for the collector, for the piping and for the tank. In a well insulated tank, the warm water can be kept warm for several days.

- **Insulation must be heat-resistant, otherwise it will melt** if it gets too hot. Natural materials like wood fibre or cellulose can be used up to max. 100°C (for the tank and the pipes).
- **The thickness of the insulation material should be at** least 5 mm.
- **Insulation must be installed in a way that no water can** enter inside the insulation. When insulation gets wet, its effectiveness will be significantly reduced.
- **Attention: If you use mineral wool, glass wool, etc. you** should be aware of the fact that inhaling the fibers is dangerous for your health and can cause cancer. These materials should be carefully handled .

Practice: Solar water heaters

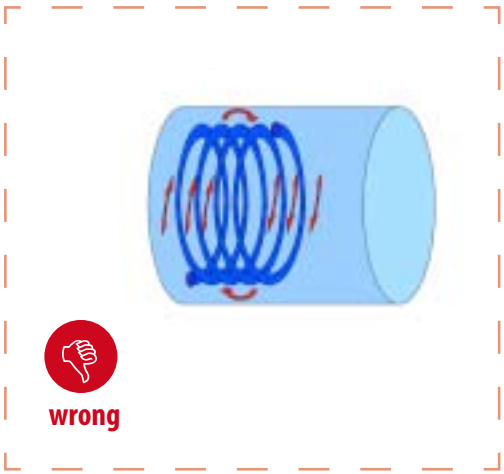


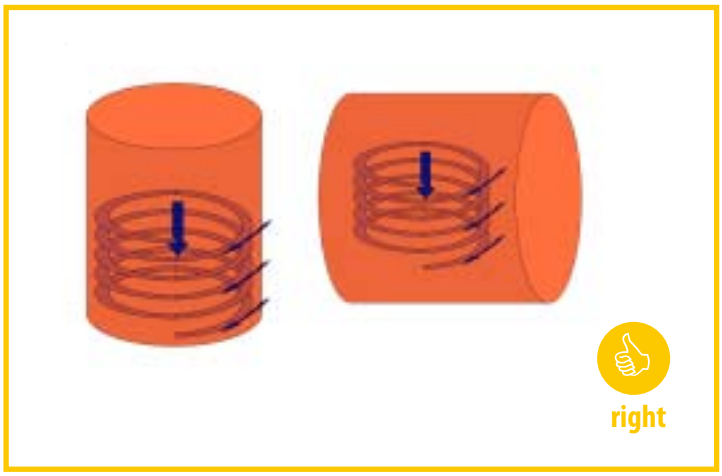
Hot water tank with heat exchanger

- The heat exchanger should be made from metaloplast tubes, because they transfer the heat very well. It can also be made from copper tubes, but copper is more difficult to work with.
- The heat exchanger must be located in the lower half of the tank, because the cold water inlet from the fresh water supply is at the lower end, and the heated water will then rise up to the top.
- If the water from the tank will be used for drinking / cooking, a special drinking water tank should be used .
- To preserve heat, the hot water tank has to be insulated very well.
- Fresh water supply: If you want to connect the tank directly to the central water supply, the tank must be watertight and resistant to 3 bar. Another option is to have a big extra water tank to supply the hot water tank with water. The extra tank must be placed in a higher position than the hot water tank to create water pressure. The cold water inlet from the water supply always has to be at the lower part of the tank. Since warm water rises, the hot water must be taken from the upper part of the tank.

Practice: Solar water heaters

The heat exchanger coil has to be mounted vertically (as it is shown in the pictures on the left) to allow circulation. If it is put horizontally, circulation will not work.





Connecting pipes

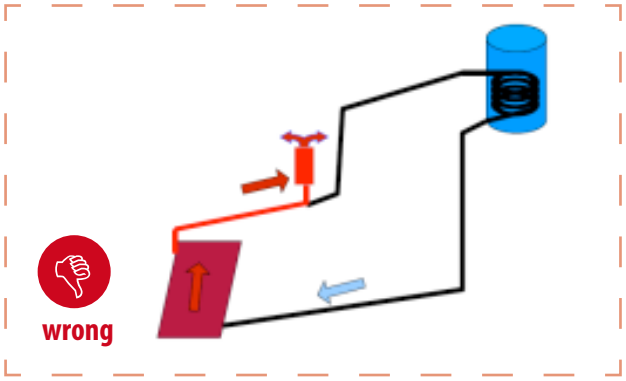
The collector is connected to the tank with pipes (plastic or copper pipes) that go from the collector to the tank via a heat exchanger and back to the collector. It is very important that the water can circulate in the pipes without obstacles (e.g. sharp bends).
Here, it is very important that the heat does not get lost on the way. To ensure this, try to make the distance between the collector and the tank as short as possible, and make sure the pipes are very well insulated.

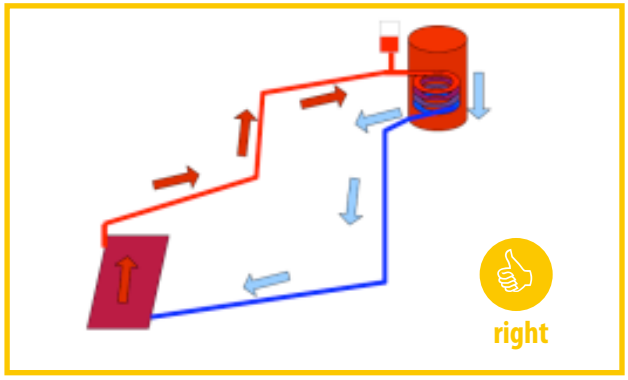
Practice: Solar water heaters

Expansion tank

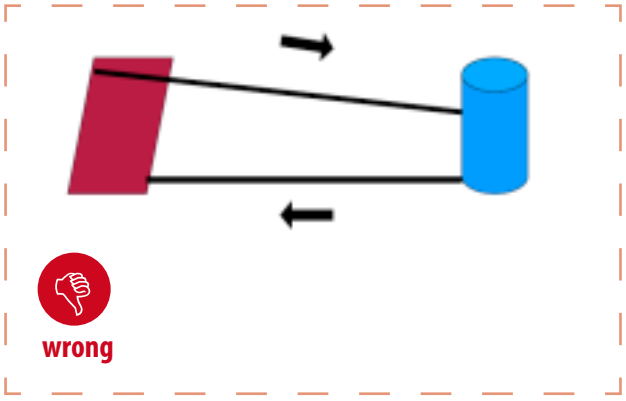
Rules for installation

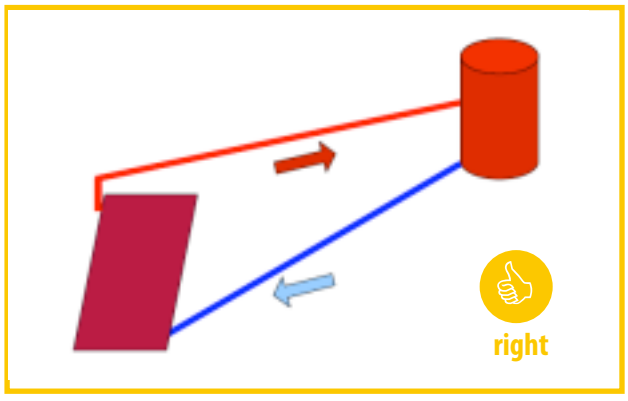
The expansion tank is used because heated water expands and needs more space, otherwise it will burst the pipes. The tank is an open reservoir and should be placed at the highest point place of the fluid circulation loop, to compensate the differences of pressure caused by temperature differences. It should be placed at least 0,5 metres higher than the collector. If there is air in the system, it also can escape there. The fluid can also be refilled via the expansion tank.





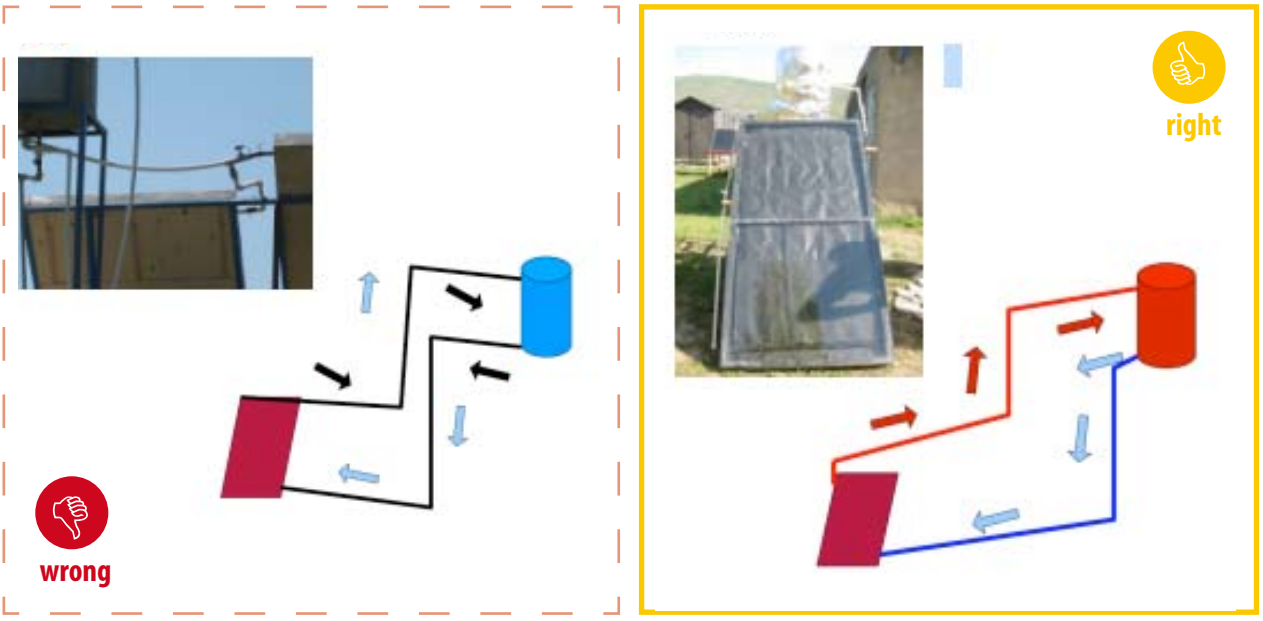
The tank has to be on a higher position than the collector to enable circulation (min. 0,5 m).
The water has to go up from the collector to the tank, to enable circulation without pump.



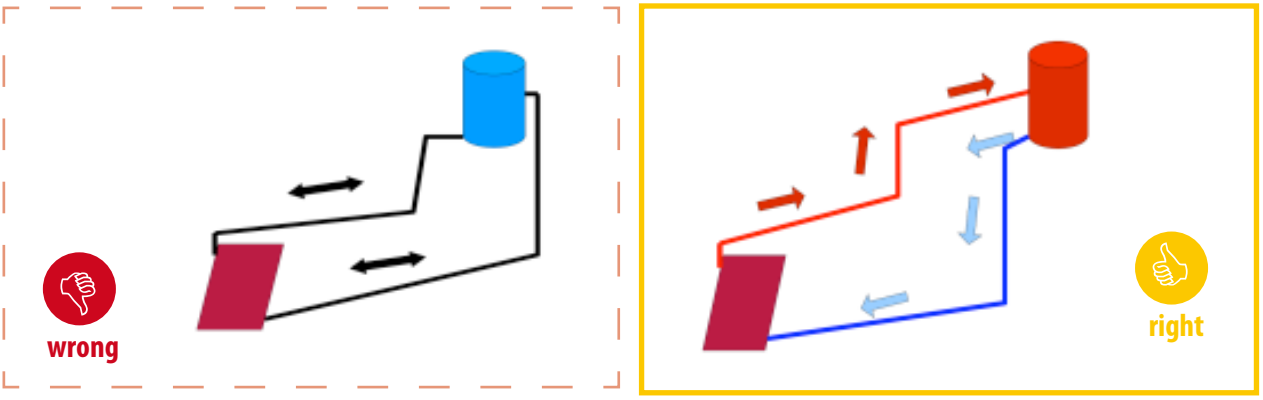


Practice: Solar water heaters

This circulation system is based on the principle that the warm water has to go straight up to the highest point at the heat exchanger inlet and down from there to the lowest point at the collector inlet in a direct way without obstacles. Any ups and downs will cause problems.



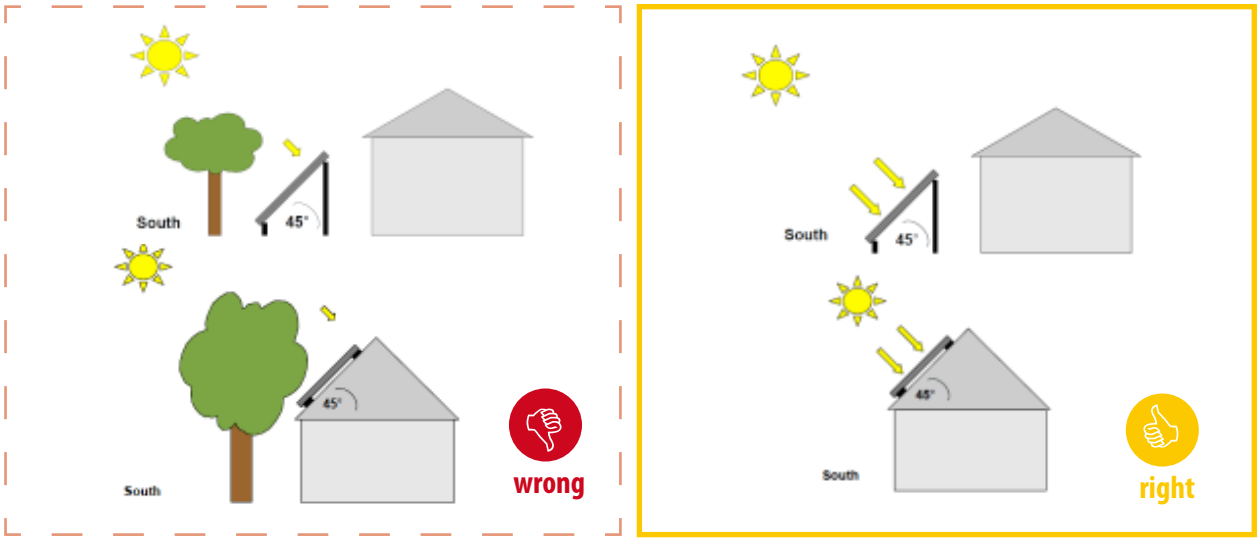
The warm water inlet has to be at the upper side of the tank, and the cold water outlet downside. If it is the other way round, the circulation principle will not work!



Practice: Solar water heaters

Positioning and mounting

The optimal collector position is facing directly to the south, at a place where there is no shadow from trees or other objects. In other words, to maximise the amount of sunlight. The collector can be mounted on a roof (if the roof is strong enough) or on the ground. The disadvantage of putting the collector on the roof is that the tank has to be higher than the collector. The best place for the tank is inside the house under the roof, where it is better protected against cold outside temperatures, rain and snow. Anyway, it has to be insulated the same way than outside.



Angles (between collector and ground):
- for use whole year round: 45°
- for use only in winter: 60°
- for use only in summer: 30°

Maintenance

To make sure your collector works well, you should regularly do the following:
- check and refill the fluid for circulation (check fluid level in the expansion tank)
- clean the glass cover so the sun's rays can pass through easily
- check the insulation of all parts to prevent heat losses (e.g. can water enter the insulation?)
- check the pipes and connections that there are no leaks
- always make sure the warm water tank is filled with water

How to build a solar collector ?

Constructing solar collector with metal heat absorber

Materials for collector

1. Pine beams 100 mm x 50 mm with few knots, 6 m
2. Wood strips 50mm x 50 mm, 4 m
3. Plywood 0.4 mm, 2 m^2
4. Insulation, 2 m^2
5. Metal tin 1.5-2mm, 2 m^2
6. Metal pipe ½, 15 m
7. Metal pipe ¾, 2 m
8. Galvanized nails with small heads, 0.5 kg
9. Sixteen drywall screws 80mm
10. 750g matt black paint (non-toxic; for inside paints e.g. pigment paint)
11. Half kilogram of solar varnish/lacquer or usual matt black paint
12. Glass for cover, 2 m^2
13. One tube silicone glue
14. 2mm Welding die
15. Materials for plumbing
    - Eight 3/4 to ½ adaptors
    - Four ½ T's
    - Four Six Four x ½ X ½ X ¾ T's
    - Two ¾ T

One pressure relief valve

Collector building instruction

Step 1. Cut framing boards and assemble frame

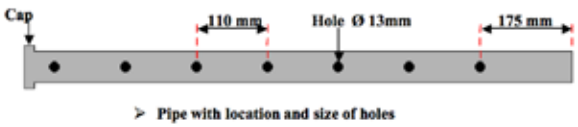
Step 2. Fasten collector bottom and sides

Step 3. Cover the bottom frame with plywood

Step 4. Install insulation

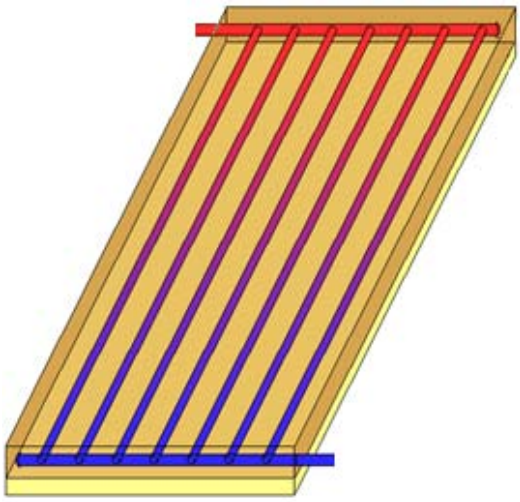
Step 5. Cover the upper part of the frame with plywood, paint black

Collector building instruction



➢ Pipe with location and size of holes

Step 6. Drill 8 holes 13 mm in ¾ metal pipes at a distance of 11 cm



Step 7. Weld the ½ pipes to ¾ pipes, and close the pipe with a cap at one end (see scheme)

Step 8. Weld to each other the metal sheet and the pipes

Collector building instruction

Step 9. Cover with black matt paint or solar lacquer the absorber from both sides

Step 10. Drill inlet, outlet and ventilation holes

Step 11. Install the absorber into the frame

Step 12. Put connection wood bar for glass installation in the middle and cover with black matt paint

Step 13. Cover the frame with 4 mm thick glass using silicon glue

Collector building instruction

Step 14. Install plumbing outlets and inlets

The collector is ready

How to build a heat exchanger tank ?

How to make a solar heat exchanger

Materials for heat exchanger

1. Plastic compound pipe
   (e.g. pipes for floor heating) 15-20 mm, 6 meter
2. Adapters
3. Plastic reservoir 2 L for expansion tank
4. Water installation pipes
5. Insulation material for pipes and tank
6. Antifreeze / glycol fluid for circulation –
   about 10 L

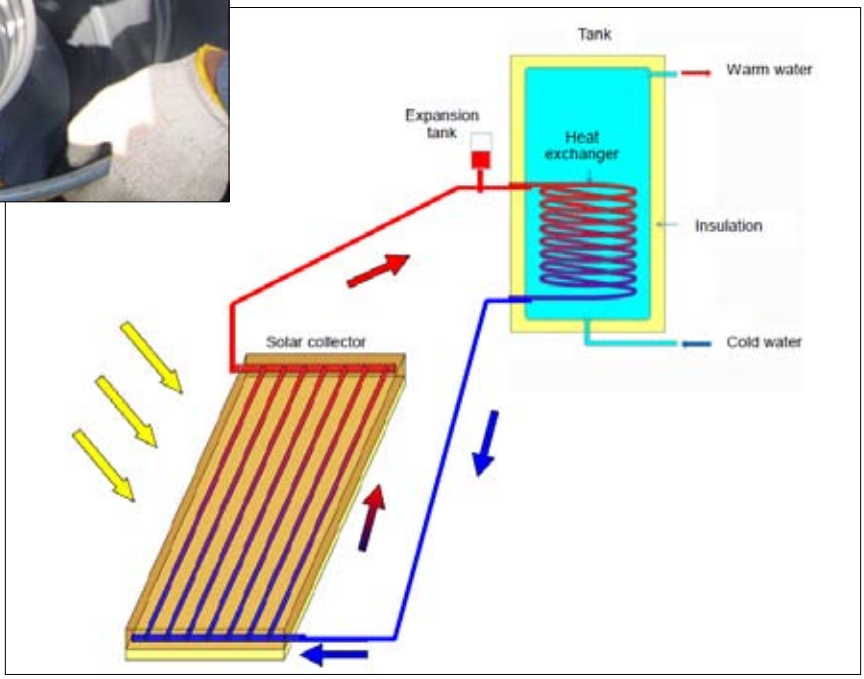
Step 1. Make the serpentine

Step 2. Adjust the adapters at both ends of the serpentine

Heat exchanger tank building instruction

Step 3. Drill the holes for adapters to the heat exchanger in the tank on the down part and for the connection to the collector one hole on the upside (water out), one hole on the downside (water in)

Step 4. Put the exchanger into the tank and fix the ends with adapter plate (see also scheme below)



Heat exchanger tank building instruction

Step 5. Install expansion tank

Step 6. Connect to the collector (upside: water in, downside: water out) and to the water supply system (downside: cold water in from storage tank or water supply; upside: warm water out to user)

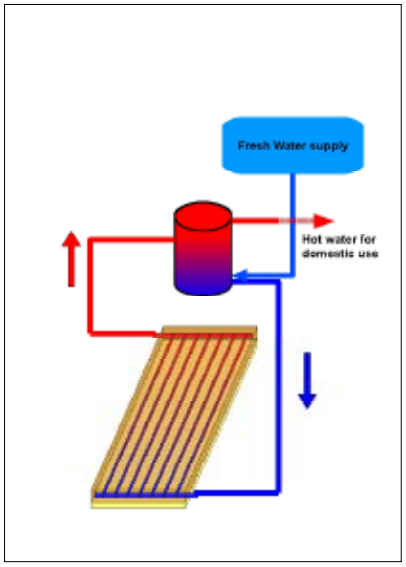
Step 7. Insulate tank and pipes

Step 8. Fill collector with anti-freeze liquid
Step 9. Fill tank with water

Other solar water heater models

Summer model without heat exchanger

If there is no danger of freezing or the collector is not be used during winter time, the system can be built without a heat exchanger. Then, the warm water inlet from the collector has to be at the upper part of the tank, and the cold water outlet to the collector from the down part of the tank. The external cold water supply inlet is on the down part as well. Warm water for domestic use is taken from the upper part.



Solar collector from radiators

If available from somewhere, very simple and cheap solar collectors can be constructed using old radiators (see picture). The radiators have to be painted with black colour, and put into a wooden frame with insulation and glass cover. Because they are not so efficient, these collectors are more suitable for single-loop systems without heat exchanger.

Other Solar water heater Models

Solar collector from plastic tubes

You can also use black plastic tubes instead of a metal flat plate. The tubes can be painted black with a heat resistant paint. The big disadvantage is that most plastic tubes are not heat resistant. Tubes have to be tested before use on a hot place in the sun under a glass cover, if you find some which are heat resistant it might turn out cheaper than iron. In this case, the plastic tubes have to be mounted in a way the water can also go constantly up within the collector to ensure proper circulation (see pictures below). Metaloplast tubes can also be used, but we do not recommend it because they are very hard to work with.

Solar Collector from copper

A similar solar collector as it is described above can be made from copper, if you have the possibilities of working with copper soldering. Copper is without any doubt the most appropriate and most effective material for solar collectors, and is usually used in high performance solar collectors, as it has the best heat conducting properties. For low-cost solar collectors, copper is probably not the first choice, because it is more expensive than iron and special tools for soldering are needed.

System with pump

All these systems can also be built with a pump, then there is no need to put the tank above the collector. They have the disadvantage that they will not work during electricity shortcuts. If there is no sun, the pump has to be switched off, otherwise it will pump cold water from the collector into the warm water tank.

Solar water heaters

Outlook

Solar energy is available all over the world, and you do not have to pay for it. The use of solar energy has no negative impact on the environment and saves rare resources like wood and other fuels. With decreasing availability of resources, increasing environmental damages and impredictability of the climate, this is getting more and more important. Furthermore, aside from the initial investment for material and construction of a solar collector, the use of solar energy causes nor extra costs nor work burden, thus increasing the disposable income and comfortability of its users.
This manual intends to spread the knowledge about solar collectors and to encourage interested persons, to build themselves a solar collector they can easily install at their homes, to achieve maximum benefit with minimum investments.
In a second step, especially in countries with high sun radiation with a big potential for solar energy on the one hand, and scarce resources and insufficient energy infrastructure e.g. in rural areas on the other side, it will be the task of the governments to encourage and support citizens to use sustainable energy sources like solar energy by actively promoting sustainable energy solutions (as it is already happening in countries like Germany).

This manual presents a low-cost, highly efficient solar collector model, developed by WECF and its partners. Many types of solar water heating systems exist. The model shown has been proven to work in climates with cold winters.

Here you can find full instructions for how to build and install a solar collector for using energy from the sun to provide hot water for your home, using materials available from local markets. This solar collector functions all year round, including winter, without the need for electricity .

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