THE EUROPEAN
GREENBUILDING PROGRAMME

Technical Module on Solar Hot Water

1. Introduction

The GreenBuilding Programme is a European Commission voluntary programme through which non-residential building owners and occupiers, private and public organisations, are aided in improving the energy efficiency and to introduce renewable energy sources in their building stock. Any enterprise, company or organisation (hereinafter defined as "organisation") planning to contribute to the GreenBuilding Programme objectives can participate.
By becoming a GreenBuilding Partner, your company can demonstrate its commitment to significantly reduce of the energy consumption and the use of renewable energy in its non-residential buildings, which are participating in this effort.
In the following, you may find assistance for your process of assessing and realising the use of solar energy for hot water and heating.
This technical guideline is one of several guidelines, which are published within the GreenBuilding Programme. Other technical guidelines are eg.:

Lighting
Financing
Office Equipment
Combined Heat and Power Module

This document is subsidiary to the GreenBuilding "Partner Guidelines". It provides useful information, on how to integrate solar thermal systems in buildings.

The basic principle of solar energy

The basic principle common to all solar thermal systems is simple: solar radiation is collected and the heat is transferred to a heat transfer medium, usually a fluid (sometimes air). The heated fluid is used either directly, (e.g.: hot water production), or indirectly by using a heat exchanger, transferring the generated heat to its final usage –(e.g.: space heating).
Sometimes, the produced hot water is stored for future use. This is the case whenever the production does not coincide with utilisation.
It is also possible, that the hot water is just preheated by the solar system before been fed to a conventional technology (Gas / oil / electricity) to provide the needed utilization temperature.

The Absorber

The heart of a solar collector is the absorber. Absorbers are usually painted black, as dark surfaces demonstrate a particularly high degree of light absorption. As the absorber warms up to a temperature higher than the ambient temperature, it gives off a great part of the accumulated solar energy in form of long-wave heat rays. The ratio of absorbed energy to emitted heat is indicated by the degree of emission.
In order to reduce energy loss through heat emission, the most efficient absorbers have a *selective surface coating*. This coating enables the conversion of a high proportion of the solar radiation into heat, simultaneously reducing the emission of heat. The selective coatings provide a degree of absorption of over 90%.
Different types of solar collectors can be found on the market:

- collector without glass cover/protection ("Swimming pool absorbers")
- Flat Collectors with glass cover
- Vacuum Absorber Tubes

Collector without glass cover/protection

A collector without glass cover – often called also swimming pool absorber – is an ideal application for the use of solar energy heating swimming pools during summer. Supply and demand coincide in this case. The maximum solar radiation during summer can be used with comparatively low technology. To reach the optimal heating for pool water, temperatures even below 30º C are good enough. In many instances an additional water tank is not necessary as the water of the pool serves to store the temperature, and a pump ensures circulation of the water through the surface of the absorbers. The solar control system, with temperature sensors at the water inflow point and at the absorbers, automatically and economically regulates the operation of the heating system.

Swimming pool absorbers are usually black plastic mats or tubes. Because of the low temperatures involved, the temperature stability requirements are markedly lower than those of solar heating systems for water heating or backup heating.

The absorber can be placed in simple way on the roof and is operate ready.

Flat Collectors with glass cover

A flat-plate collector consists of an absorber, a transparent cover, a frame, and insulation material. Usually an iron-poor solar safety glass is used as a transparent cover, as it transmits a great amount of the short-wave light spectrum. Simultaneously, only very little of the heat emitted by the absorber escapes the cover (greenhouse effect). In addition, the transparent cover prevents wind and breezes from carrying the collected heat away (convection) and also prevent the accumulation of dirt on top of the absorber surface. Together with the frame, the cover protects the absorber from adverse weather conditions.

The insulation on the back of the absorber and on the side walls lessens the heat loss through conduction. Insulation is usually of polyurethane foam or mineral wool, though sometimes mineral fibre insulating materials like glass wool, rock wool, glass fibre or fibreglass are used.

Flat collectors can provide a good price-performance ratio, as well as a broad range of mounting possibilities (on the roof, in the roof itself, or unattached). They are very common and the main use of this kind of solar collector is for hot water.

Vacuum Absorber Tubes

A vacuum collector is a collector where the absorber strip is located in an evacuated and pressure proof glass tube. The heat transfer fluid (usually gas) flows through the absorber directly in a U-tube or in counter current in a tube-in-tube system. Several single tubes, serially interconnected, or tubes connected to each other via manifold, make up the solar collector. A heat pipe collector incorporates a special fluid, which begins to vaporize even at low temperatures. The steam rises in the individual heat pipes and warms up the carrier fluid in the main pipe by means of a heat exchanger. The condensed liquid then flows back into the base of the heat pipe.

Evacuated tubes offer the advantage that they work efficiently with high absorber temperatures (> 120℃) and with low radiation. Higher temperatures also may be obtained for applications such as hot water heating, steam production, and air conditioning.

Hot Water Storage Tank and Heat Exchanger

The purpose of the hot water storage tank is to stockpile energy for days with less solar radiation. Its volume capacity should be larger than the daily hot water consumption, to avoid a lack of hot water, when there is less sun.

Enamelled steel tanks are normally used, such as those known from conventional heating technology. They need magnesium-or an external current-anode for corrosion protection. Stainless steel storage tanks have a longer life expectancy, but are more expensive.

Good solar storage tanks have a slim, cylindrical form in order to develop a layering of temperature in the tank. This allows for optimal usage of the heated potable water in the upper storage region, thus the entire contents of the tank don't need to be heated to the desired temperature. Undesired mixing of the tank contents through incoming cold water is prevented through a special pipe construction or a baffle plate. The arrangement of the solar circuit heat exchanger in the lower part of the storage, makes it possible for the solar panel to work at higher efficiency due to the low incoming water temperature.
The heat exchanger of the conventional heater is located in the upper part of the storage to prevent it from heating unnecessary large volume of water.

Dimensioning of the systems

It is the best, if the calculation for the size of the collector field and the size of the hot water storage is done by an expert who is working with special software and is also using diagram for dimensioning.
Conceiving and sizing solar collector systems, collector and storage tank, should be done by properly trained technician, using adaptable software and diagrams.

For a first approach or for a simple calculation the following values can be used:
The heat output of solar systems depends on several factors like local radiation, orientation and gradient of the collector, relation between size of the collector and the water storage. In Austria it is calculated that the output is about 350 kWh/ m^2a for a flat collectors with glass cover and 50 l storage per m^2 collector (60 % of hot water demand covered by solar energy).
You get the best cost benefit, if the solar energy covers about 40 to 50% of the annual hot water energy. For smaller system (< 50 m^2) it should be more than 50%, for medium systems (70 – 130 m^2) it could be about 45 %. (The numbers presented are for the example of Austria)

A system which requires about 1.000 liter of hot water a day (> 55°C), the solar collector field should be sized between 77 and 100 m^2 and the hot water storage tank should be between 4.250 liter and 5.500 liter. It is important that the storage has sufficient calorific energy in order to satisfy the needs of the end user during periods of lower or lack of solar radiation. Sizing of solar storage tank depends of three main factors: install solar collector area, utilization temperature and the displacement between energy generation in the collector field, storage and consumption. Whenever the consumption does not coincide with utilization, such as the cases of homes and hotels, it is recommended that the storage be between 60 and 90 l/m2 of solar collector area. For the cases when a displacement is registered, for instance, industrial applications, it is suggested a preheating using an accumulator of about 35 to 50 l/m2 of solar collector area.
A system which requires about 500 liter of hot water a day, the solar collector filed should have the size of 35 m^2 and the hot water storage tank of about 2.000 liters.
For small systems it is possible to use standard solution, like they are available for the residential sector.
For smaller systems there is also a calculation tool on the web side: www.sonnenkraft.com (in German)

Dimensioning of a hot water and part time heating systems

In many cases it is also possible that the solar energy support the heating of the building. This is usually possible, where the heat demand is very small. Compare with a hot water system, the ratio of the size of the collector field to the tank is much larger than the solution for hot water only.

Regulation

Often a simple differential controller is enough to regulate a small solar heating system for water heating.
The system can work with two temperature sensors – one by the collector and one by the tank. If the temperature in the collector is higher than in the tank, a circulation pumps begins to operate until a certain temperature in the tank is reached or even the temperature on the collector is about the same in the tank.
If the system is connected with a conventional heating system, through the use of four temperature sensors the system can be controlled very efficient. Whenever one uses four temperature sensors, they can be placed the following way:

1. At the solar circuit heat exchanger in the tank, which at the lower end of the tank
2. in the collector discharge
3. in the conventional boiler, which will heat up the water if there is not enough solar energy
4. At the “fossil” heat exchanger in the tank, which is in the middle of the tank

The regulation start the circulation pump, if the necessary temperature difference between the collector and tank (lower end) is between 5° C and 8° C. If this temperature difference sinks to 2° C to 3° C, then the solar regulator will shut off the solar circuit circulation pump. The “fossil” heat exchanger only operated if the temperature in the middle of the tank is lower than a certain temperature. This gives a guarantee, that always enough hot water is available.

Measuring the system

Measuring the solar thermal energy produced is not as easy as measuring electricity generation.
However, all solar thermal systems should be equipped with at least a simple measuring device. For the user it is often the only possibility to check that his system is still working efficiently. Measurements of the solar yield is also a necessary precondition for guaranteed result contracts and advanced policy support schemed based on the solar energy output rather than on the installation collector area.
In some areas, like the Bundesland Salzburg / Austria, you public subsidies for large solar thermal systems, can be provided only if a meter is including in the system and the average output of the system is higher than 350 kWh/ m^2. This requirement is applied to smaller system in Germany.

Aspect of costs

The following components and assembly works are to be assigned to the solar plant:

- Collector field inclusive pipe work system, completely installed and pressure-examined up to the riser in the roof
- Pipe work system of the solar circle up to the solar heat storage or up to the external heat-exchanger, inclusive pump, pressure-examined and heating fluid
- Necessary safety engineering (e.g. expansion tank, relief valve) and maintenance engineering (e.g. flow plate, bleed valve with shut-off valve)
- Pump controlling device and appropriate accessories, and some extra measuring technique
- Heat-transfer agent of the solar circle and solar memory, inclusive connection to read-lateral heat-transfer agent ((is void with in and two-storage concepts)

Whether the installation brings expected success to a solar plant depends on different number at factors, which are not limited by any means only to the collector field at the roof.

The consumption behaviour of the heat customers (customers) plays thereby a substantial role whereby the form of the energy distribution system on the one hand and the kind of the water heating on the other hand plays a key role. Energy distribution and water heating must be so conceived in the ideal case that the behaviour of the consumers does not have influence on the efficiency of the entire plant.
Experience in Austria show that for large solar system the system costs per m^2 are about 350 Euro/m^2 (excluding VAT) and the energy output is about 350 kWh/m^2 collector field.
For the circulation of the heat transfer medium a circulation pump is used. The annual energy consumption will be in the size of 100 kWh.
Periodically an expert should also check the quality of the head transfer medium, if it is still non-freezing. Maybe it is necessary to replace it after years.

Cost Effectiveness

Success varies with the demand structure, the location and the kind of energy, which is replaced by the solar energy.
In Austria for example for large solar thermal systems (> 50 m^2) the best cost effectiveness will be reached if the solar energy covers about 40 to 50 % of the hot water demand.
The Internal Rate of Return (IRR) for energy efficiency investments in solar energy typically ranges between 4 % and 7 % (with subsidies), depending on the system, energy prices and financing frameworks.
The cost efficiency can be become higher, if some mayor changes have to be done on the heating system anyway. In this case the extra cost for some components like the hot water storage tank) and the installation work can be much lower, because a part of the cost is included in the modernisation work.
There are also subsidies for solar systems are available in many countries. The national solar organisation will inform you about these subsidies.
In this case the IRR will be higher than 10 %.

ACTION PLAN

This section intends to help you to establish an action plan to study carefully the proposed actions, set a timetable to implement the actions and estimate the expected savings. A template for an Action Plan form is included in the Annex.
The action plant is to be used as a starting point to study the technical and economical viability of a thermal solar system or to improve the performance the situation, how hot water is used in the building, today. The first step pf this Action plan is the energy audit (Annex 1).
The first step of the Action plan is to analyse the kind and amount of hot water demand. Within this analyse it should be checked it is possible to reduce the hot water demand, too. Water-saving armatures can have a great impact on a higher efficiency.

ANNUAL REPORT

This section provides you assistance to periodically report to the Commission on the improvements undertaken and the degree of completion and maybe on what is planned for the future. It is important to know the effect of improvements on energy consumption/ indicators, as well as the resulting money savings.

The report should include the following:

1. Description what lesson have been learned by making the AUDIT for the solar system.
2. Report, if the audit about consumption has been repeated.
3. Report, what has been changed since the last report.
4. Energy and economic performance of the new solar system after the implementation or of the new components.

ANNEX 1:

Energy audit (for new and existing thermal solar systems)

An energy audit is a systematic gathering and analysis of energy use and can be used to determine energy efficiency improvements of the hot water consumption. The energy audit can include the following parts:

- Collect basic information and description of the existing energy supply and demand system. The sources of information for this task can be the technical documents of the plant, walkthrough inspection, information on the equipment plates, estimation etc.
- Check if sufficient space and the place to connect the tank with the storage are available to install a solar system.
- Collect information on the operating conditions, such as temperatures, operating hours and schedule, type and characteristics of the heating system. How old is the boiler and when will it be replaced. What is the size of the existing hot water storage? Is it possible to make a better isolation to the tank?
- Collect information about the structure of the hot water consumption during the day, the week and the year. Prepare the building's electricity, heating and cooling load profile as accurate as possible using counters, electricity and fuel bills, etc.
- Calculate the actual energy supply unit prices and other energy related costs.

Audit about the hot water system in the Building

A further important factor for the realization of solar plants is the condition of the hot water system and hot water demand.

- How much hot water is used in the building?
  - Is there a meter for hot water?
  - Is it possible to us the energy consumption of gas or oil during summer to calculate the hot water demand?
  - Is there an existing energy bill, which can give you information about the hot water consumption?
  - How many people need how much hot water?
  - Will the hot water consumption change in the near future?
  - Are there any fix holidays or vacation?
  - Is there the same hot water consumption over the year?

	Average hot water demand	Less consumption during summer
Kind of building	Liter / Person with 60℃	- % from the annual average
Residential building	20-40	-20%
Hospital	100-300	-10%
Hotel	40-100	+/- 0%
Pension	30	+/- 0%
Office Building	0-10	+/- 0%
School (with shower)	30-50	-90%

- Is a new boiler necessary?
  - Low-temperature and condensing boilers (younger than 10 years) can be usually re-used. The available power of the boiler must fit to the necessary reheating power demand.

- Can existing old hot water storage be used as hot water buffer?
    - If you have a boiler system which has the hot water storage including in the boiler, it is possible to use it! In this case, a new water storage system should be bought.
- How large (kW) is the energy dissipation?
    - Many hot water systems use a circulation system with circulation pumps to raise the comfort (Hot water is available soon). By switching off the circulation pumps during weekends and during the night, it is possible to save quite a lot of electricity.
        - The dissipation can be estimated by an expert or a calculation can be done. Usually the dissipation range from 8W/m^2 (new systems) to 12 W/m.

AUDIT of the building

The following information of the building and its roof situation should be collected and be clear:

- Potential maximum size of the area, where solar collectors can be armed:
  - Are there legal obstacles (monument protection, delivery contract with district heating system)?
  - Permits the static of the roof an additional load?
    - A calculation should include possible permissible wind loads by the collector field.
  - Is the roof covering new, or should it fixed before the installation of the collectors?
    - Reorganizations after fixing the collectors are possible only under less favorable conditions and with increasing costs.
  - Is there a kind of shadow (of buildings, trees, …) during the day?
    - Flat roofs should have about three times of the size of the collectors to avoid shadows of one collector to the other.
    - There is about the same energy output (95% of the optimum), if the solar collectors are aligned about 40° to the West and 30° to the east from the south.
  - Is it possible to use the collectors to make shadows for a parking place?
  - Can a place in front of the building be used for the solar collectors to promote the sustainable idea of the company?
- How is it possible to connect the solar collectors with the solar storage tank or the central heating systems?
  - Is a chimney, which is not longer used, existing? In this case, the connecting pipe between the solar collectors and the solar storage tank can use this chimney.
  - Is it possible, to make a hole in the roof and to make the connection inside the building.
  - Is it possible to make the connection over on side of the facade? In this case a good protection against wind and low temperature would be quite useful.
- Is it possible to place the solar storage tanks on the roof beside the solar collectors or very close.
  - This can happen mainly in the frost free climate in the south of Europe.
  - When the solar storage tank is reheated by the central heating system, it is better to place the tank close to the central heating system.
- Is it possible to arm the solar storage tank higher than the collectors? In this case a Thermo siphon systems can be use. Thermo-siphon systems use gravity to circulate the heat transfer medium (e.g. Water) from the collector, and do not need electricity for the circulation pump. These systems are very common in the frost free climate in the south of Europe.
  - When the collectors are armed on a facade or on an area before the building, the solar storage tank can be placed above.
- How large is the inclination of the roof.
  - The maximum energy output of a solar collector with an inclination of 50° (for the situation in Austria).
  - If it is flat roof, special constructions are needed to reach an inclination of the solar collectors.
  - If the solar system should only preheat the water the inclination can be less down to 20°.

Tubing, place of the hot water storage

The connection between the collector field and the hot water storage should be as short as possible. In many cases it is also not necessary to make some kind of cutting works.

- Are the ways and the doors broad enough that the hot water tanks can be brought to the place?
  - Partially also a weld can take place in the room!
  - By same systems the insulating material can be taken off?
- Is the height of the room large enough that the storage can stand in the room?
  - In a few cases, it is possible to dig a hole in the floor.

Nominal value	Height	Diameter	Tilting height	Net weight
[liter]	[m]	[m]	[m]	[kg]
1.500	2,25	1,2	2,55	230
2.000	2,25	1,3	2,85	360
3.000	2,85	1,5	3,25	460
4.000	3,00	1,6	3,35	550
5.000	3,00	1,8	3,45	650
6.000	3,30	1,8	3,75	750

- Are there still enough places in the heating room for the tanks?

Selection of measures to be implemented

The selection of the then solar concept should be made using the following criteria: performance, capacity and spatial requirements, first cost, operating cost, reliability, flexibility and maintainability. This work can be done already with an expert.

Evaluation of alternatives

Perform the complete energy balance for other alternative like reducing the hot water demand by 50 %.
Check the opportunities to reduce the hot water consumption or use the hot water to reduce other energy (e.g.: dish water connected with the hot water).
Check the electricity consumption for the circulation pumps (power and operating hours).

Implementation

Give an answer, why what decision was chosen and define a timetable to carry out next or other steps.

Further Information:

http://www.solarserver.de/wissen/index-e.html
http://www.soltherm.org/