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Technology Portrait Thermal Solar Energy

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1 Why will the use of solar energy play a central role in the supply of energy in the future?

The concentration of gases in the atmosphere which have a greenhouse effect and the potential global warming and change in climate connected with this represent one of the greatest ecological dangers of our times. The anthropogenic reasons for this pending change in climate can in the main be put down to the use of fossil primary sources of energy such as oil, gas and coal for energy and combustion and the emission of CO₂ connected with this. According to experts a reduction by at least 50% of world-wide anthropogenic greenhouse gas emissions will be necessary in the next 50 to 100 years to effectively protect the climate.

There is no doubt that it would in principle be possible to have a complete supply of energy with energy services from renewable sources in the technologically highly-developed countries in the next 50 to 100 years since the amount of solar energy radiating on the land surface of the earth equals up to approximately 2,000 times the current world primary energy requirement. Even in Austria - a highly industrialised country which lies in a slightly more moderate zone as far as solar radiation is concerned - approximately 250 to 300 times more solar energy is accounted for than is required in the form of primary energy.

For the implementation of energy supply scenarios with more than 50% of renewable sources of energy in the next 50 to 100 years, measures are necessary which on the one hand demand widespread acceptance from society and on the other hand a basic reorientation with regard to the goals of technologies for the supply of energy due to the different energy density and availability of solar energy in terms of the time of year and the area in question. Other important prerequisites are flexible structures in the economics of energy, strong incentive mechanism to increase the efficiency of energy for energy suppliers, consumers and users and the purposeful use of ecological or energy taxes. At a global level strict international agreements are of significant importance in relation to the economic and ecological development and an intensification of the transfer of resources, technology and know-how from the industrial countries to developing and newly industrialising countries.

2 Thermal solar market in Austria – a situation analysis and an international comparison

By the end of 1999 a total of 2,0 million square meters of thermal sun collectors had been installed in Austria. The rate of growth since 1990 has been particularly striking. At the beginning of the 90's around 80,000 m² were installed per year. In 1995 however 200,000 m² collector area were mounted for the first time.

Around one quarter of the collector area installed comprises plastic absorbers which are used to heat swimming pools. The remaining 75% of the collector area, mainly flat plate collectors, are used to prepare warm water in single and multiple family houses and for space heating in single family houses.

More than 60 different types of collectors are currently being offered on the Austrian market by 35 manufacturers and importers /1/. These are mainly flat plate collectors. So far vacuum – tube collectors have not been able to assert themselves. For this reason they just have a market share of 1%.

Some companies are also very successful by exporting plants. In 1998 the export share of flat collectors manufactured in Austria equalled 21% (41,514 m²) and 37% for swimming pool absorbers which means 16,000 m² . However imports of flat plate collectors come up to 8,707 m² and imports of plastic absorbers only reach 5,455 m² /1/.

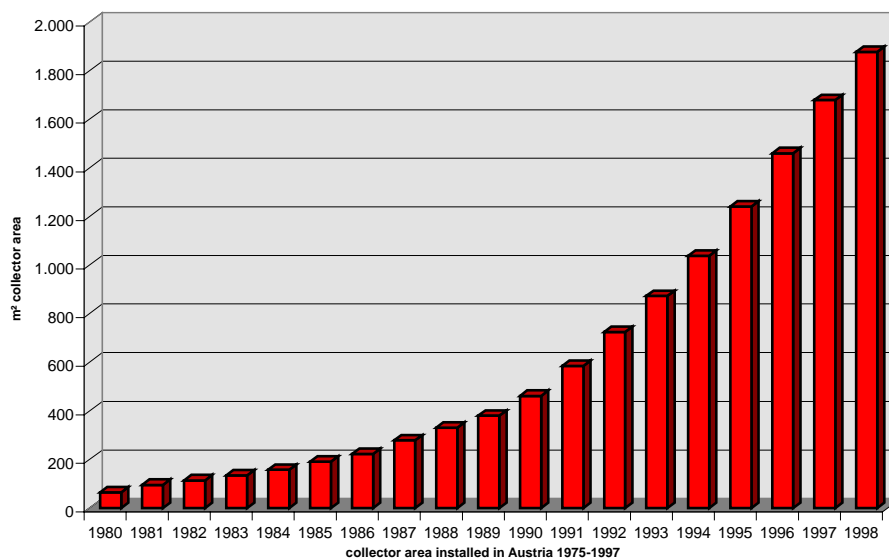


Figure 1: Collector area installed in Austria 1975-1997 /1/

The average system costs for thermal solar plants are somewhere between ATS 7,000 and 8,000 per m² (exc. VAT). Given the 200,000 m² installed yearly this corresponds to a turnover of approximately ATS 1.5 billion, 55% of which is accounted for by the collector (incl. assembly), and the rest by the storage tank, control system, pipes etc /3/.

If one compares the development of the Austrian market for thermal solar plants with other European countries then it becomes clear that Austria has the largest overall collector area per inhabitant following Greece (data including 1996) (see figure 2). Up until the early 1990's

the leading markets for sun collectors were in the eastern Mediterranean region. Since 1990 central European countries (Germany, Austria) have represented the dynamic markets for solar energy plants.

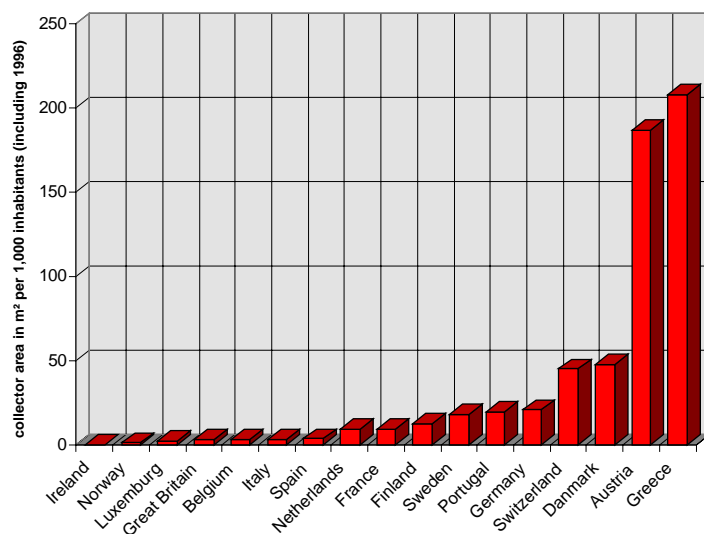


Figure 2: Collector area installed in European countries /4/ /

3 Preconditions for the utilisation of solar energy

The sun is the central energy producer in our solar system. A small fraction of the energy produced in the sun hits the earth making life possible on our planet. Solar radiation drives all natural cycles and processes such as rain, wind, photosynthesis, ocean currents and several others which are important for life. From the very beginning the overall world energy need has been based on solar energy. All fossil fuels (oil, gas, coal) are converted with the help of solar energy.

The radiation intensity of the approximately 6000°C solar surface corresponds between 70,000 to 80,000 kW/m². Our planet receives only a very small portion of this energy. In spite of this, the incoming solar radiation energy in a year is about 219,000,000 billion kWh. This is more than 2,500 times the yearly energy need of the whole world. The solar radiation intensity outside the atmosphere equals on average 1,370 W/m² (solar constant). The duration of the sunshine as well as its intensity are dependent on the time of year, the weather conditions and naturally also on the geographic location. The amount of yearly global radiation on a horizontal surface may thus reach over 2,200 kWh/m² in sunny regions. In Northern Europe, the maximum values are 1,100 kWh/m².

Global radiation comprises direct and diffuse radiation. Direct solar radiation is the component which comes directly from the sun. The diffuse radiation component is created when direct solar rays are reflected from clouds, mountains, blank spaces etc. In this case the radiation becomes unbeamed. The amount of diffuse radiation is dependent on the climate and geographic location. The fraction of diffuse radiation in summer may be approximate 40 to 50%, In winter, however, it is much higher. The higher the amount of diffuse radiation, the lower is the energy content of global solar radiation.

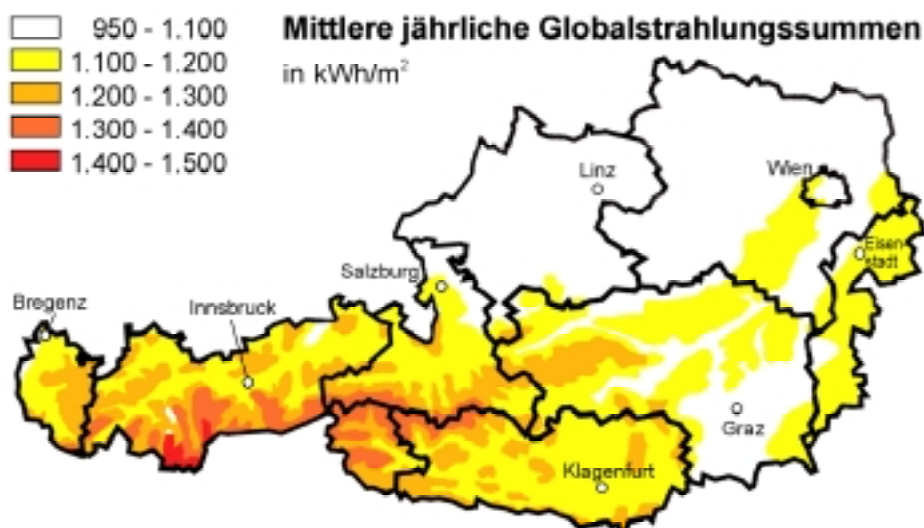


Figure 3: Solar radiation over the year in different regions in Austria /5/

4 Components of active thermal solar systems

4.1 Types of collectors

Active thermal solar systems are systems in which the entered solar radiation is converted using technical equipment (collector) for heating purposes and delivered to a consumer (hot water storage tank, space heating, swimming pool). The central part of a thermal solar system is the collector. The four typically collector constructions are:

- Plastic absorber
- Flat plate collector
- Evacuated collector

4.1.1 Plastic absorber for heating of a swimming pool

Due to their limited pressure and temperature durability, plastic absorbers are mainly used for the heating pool water. In this case, the desired temperature level is only a few degrees higher than the ambient temperature. Thus, simple plastic absorbers can usually be mounted uncovered on a flat roof or on a lawn. Since they are made entirely of plastic, they have the advantage of a single-circuit operation. The chlorinated pool water is directly pumped through the absorbers by a circulation pump and no heat exchanger is needed.



Figure 4: Plastic absorber for swimming pool heating

4.1.2 Flat plate collectors

The flat plate collector consists essentially of the collector box, the absorber, the heat insulation and the transparent cover.

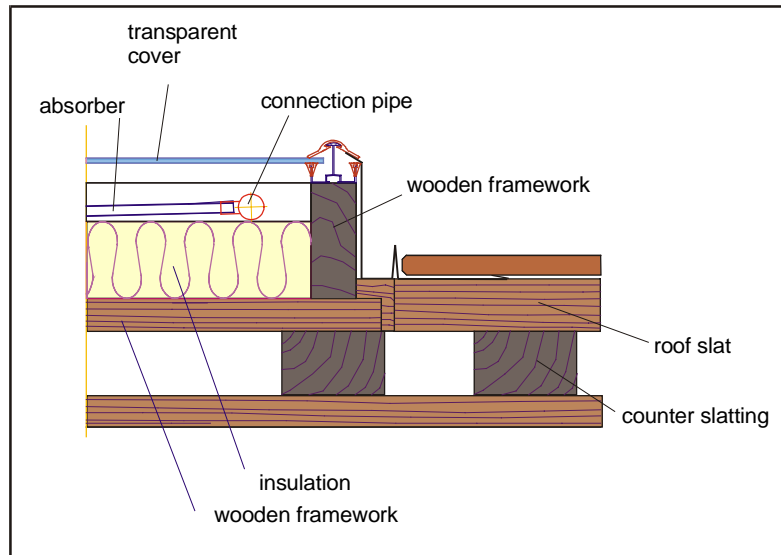


Fig. 5: Basic layout of a flat collector (assembly in roof)

In the first instance, solar radiation hits the transparent cover of the collector. Due to reflections both on the surface and at the interface (transmission) of the cover, some of the radiation is lost for further utilisation in the collector. Depending on the type of covering, the solar radiation which strikes the absorber is almost entirely converted to heat. The coating should have a high absorptance and the lowest possible emittance. The absorption capability is characterised by the absorption coefficient α and it is mainly determined by the black colour of the absorber. The absorption coefficient for a solar coating with a solar varnish as well as for good selective covering is between 0,94 and 0,97. The emission coefficient lies between 0,86 and 0,88 for coatings with solar varnish; for selective covering it is only 0,05 to 0,20.

The covering can be applied either by spraying (in the case of a coating with a solar varnish), by galvanic means or by means of an adhesive film (in the case of selective covering). Good selective coatings are offered since 1996 where the special physical process of sputtering has been used. Compared to galvanic methods, this technique results in a much more ecologically benign covering which also requires less energy.

Heat losses are also caused as a result of convection in the collector and occur at the back side of the absorber.

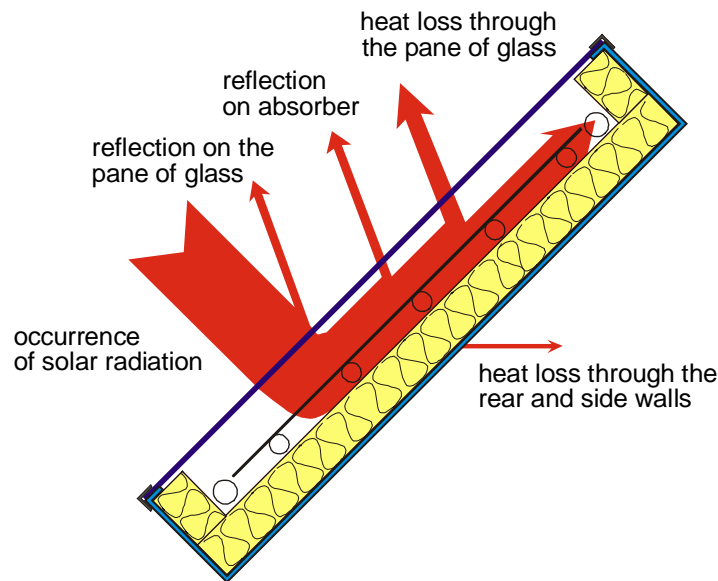


Figure 6: Losses of a flat plate collector

4.1.3 Evacuated collectors

For technical reasons, most of the evacuated collectors are constructed in the form of tube collectors. A thin absorber strip with selective coating is closed inside an heat-resistant glass tube of great light transmitting capacity. As a result of evacuation the collector has very little convection- and heat losses.



Figure 7: Vacuum-tube collector

Evacuated tube collectors obtain higher yearly solar yields per square unit in domestic hot water systems than flat plate collectors. However, as a result of their higher price, market penetration is still low. In Austria, the share of the market is about 1%.

Since the excess yield from vacuum tube collectors increases quite considerably, particularly in the high collector temperature range, they are ideally suited for the production of process heat.

4.1.4 Air collectors

The basic layout of air collectors is the same as for flat plate collectors. They comprise the collector box, the transparent cover, an absorber and thermal insulation on the back side. When it comes to the selection of materials the same basic rules are to be observed with regard to the components and weather-resistance as for a flat plate collector. Concerning the air collectors there are basically three construction types: collectors with a downstream, upstream or wetted absorber. Wherever higher air temperatures have to be reached, constructions with back-wetted absorbers would be advantageous since the heated air is not directly in contact with the cold upper cover.

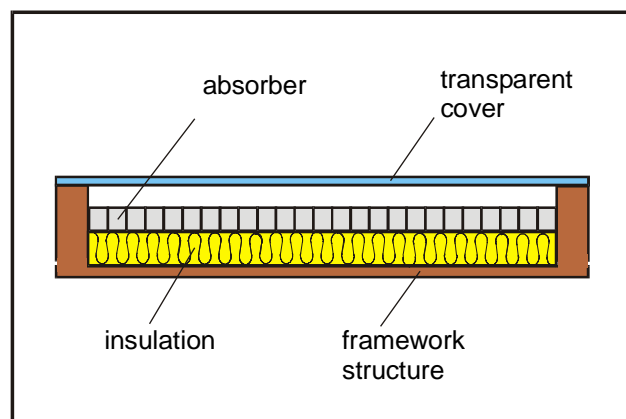


Fig. 8: Principal layout of a solar air collector with a back-wetted absorber

4.1.5 Applications for collectors

“Contrary to the promises made by the manufacturers, there is not a best collector but rather one or several suitable products for each application” /7/. A Selection of the suitable collector for the respective application is shown in figure 9.

Collector construction	Valuation
A: plastic absorber for pool heating	++ very qualified
B: flat plate collector (non selective covered)	+ qualified
C: flat plate collector (selective covered)	- not qualified
D: evacuated - tube collector	
E: air collector	

Application	A	B	C	D	E:
Pool heating for open-air swimming pool	++	+	+	-	-
Domestic hot water for single family houses	-	++	++	+	-
Domestic hot water for multiple family houses	-	++	++	-	-
Domestic hot water and space heating	-	+	++	++	+
Space heating	-	+	++	++	++
Commercial application for preheating up to 50°C (hotels, campsites, indoor pools)	-	++	++	-	-
Commercial application for temperatures up to 80°C (laundries, car wash)	-	+	++	++	-
Commercial application for process heating up to 150°C	-	-	-	++	-

Abb. 9: Applications for collectors

4.1.6 Characteristic values of flat plate collectors

The collector efficiency curve is an important physical property of a solar collector. The efficiency of a collector is defined as the ratio of the energy amount transferred from the collector to the heat transfer medium to the incident radiant energy on the collector. Especially for temperatures (heat transfer fluid) higher than 40°C, high efficiency values are desirable for flat plate and evacuated – tube collectors. The efficiency depends on the quality of the absorber surface, the geometry of the absorber, the heat conductivity of the absorber material, the transparency of the cover and the heat losses of the collector through infrared radiation, conduction, and convection. A quantitative comparison indicates that the efficiency is particularly dominated by the radiation losses. The efficiency for a certain collector is not a fixed value, but rather it is dependent on the application, e.g. temperature levels, wind speed, etc.

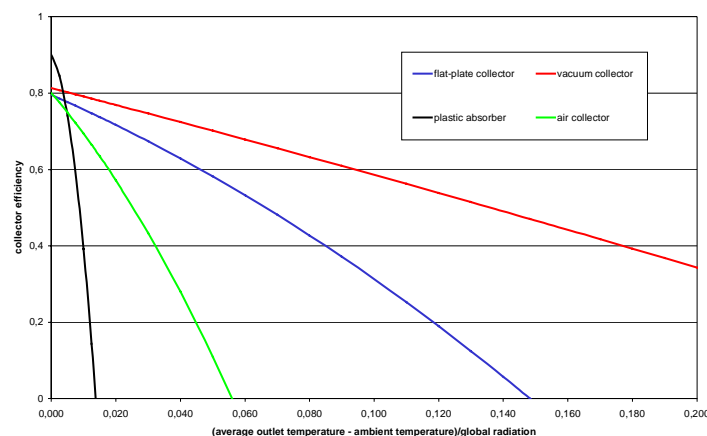


Figure 10: Collector efficiency curves for various types of collectors

4.1.6.1 Conversion factor η_0

The conversion factor η_0 is defined as the maximum efficiency of a collector under the precondition that the average temperature of the heat transfer medium in the absorber equals the ambient temperature.

4.1.6.2 Heat loss coefficient k

The heat loss coefficient is the average heat loss of a collector per m^2 effective collector area divided by the temperature difference between the absorber and the ambient temperature.

The k-value of the collector is described by the two values k_1 in accordance with the share dependent on the temperature and k_2 , the share that is not dependent on the temperature. The conversion factor η_0 of a collector should, therefore, be as high as possible and the k-value as low as possible. The collector parameters are ascertained using a standardised testing procedure conducted by an authorised test institute.

4.2 Technologies for storage tanks

After the collectors, the hot water tank is the second most essential component in a thermal solar system. The correct choice and dimensioning contributes decisively to the solar fraction achieved. The most important hot water tanks used for preparation domestic hot water and for space heating will be described now:

4.2.1 Hot water storage tank

The most common building form is an upright cylindrical steel storage tank (hot water tank), which has to fulfil certain requirements according to what it is used for. Because of the constant inflow of cold water, that is also enriched with oxygen, the interior of the storage tank has to be coated with a non-poisonous coating as a protection against corrosion. The types of coatings range from very temperature-resistant enamel layers to the cheaper storage tanks with a plastic coating, which however can only be used for lower temperature ranges. Steel storage tanks often have an additional corrosion protection because of possible defects in the interior coating of the storage tank. The cathodic corrosion protection, consisting of a reactive anode or a external current anode, prevents copper ions from the pipeline or from the ribbed heat exchanger from being deposited on these defects and leading to contact corrosion there.

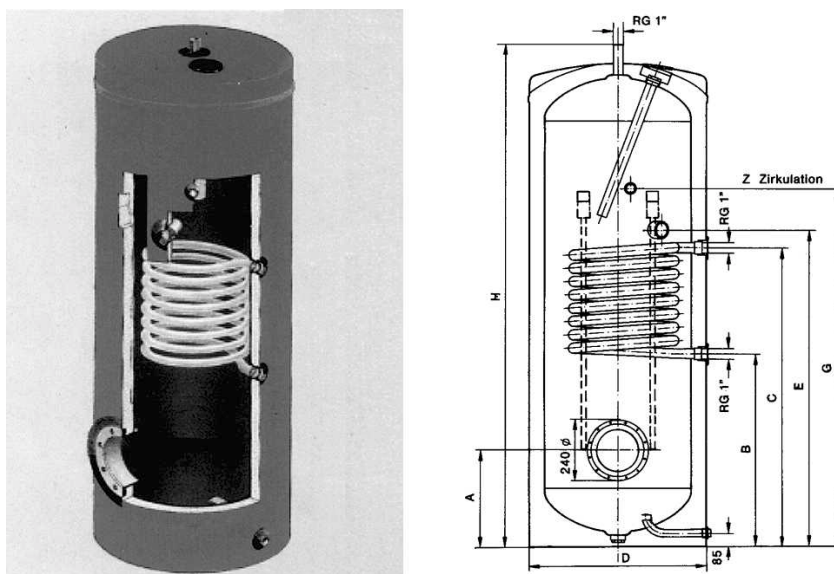


Fig. 11: Example of a solar storage tank: solar register storage tank (Austria Email)

Stainless steel storage tanks are more seldom but quite acceptable. Their distinguishing characteristics are a high corrosion resistance and durability.

Plastic storage tanks are not wide-spread. There are, however, some interesting new developments in the form of unpressurized operated heating energy storage.

The loading of energy in the domestic hot water storage tank is usually carried out via a pipe register (bare-tube heat exchanger) already permanently built-in, or via ribbed pipe heat exchanges, that can be subsequently built-in if necessary using flange plates.

4.2.2 Domestic hot water tank in space heating tank

The tank in tank represents a solution which is striking because of its very simplicity which is to include the domestic hot water storage tank in the energy storage tank. A boiler is welded onto an energy storage tank made of steel. The volume of the boiler is kept relatively small for reasons of hygiene, however, it suffices to prepare the warm water as a result of the combination of the storage tank and flow heater principle. The cold water inlet is modelled in the lower storage tank area as the preheating section in the form of a bare-tube heat exchanger. The advantage of this system is its hydraulic simplicity.

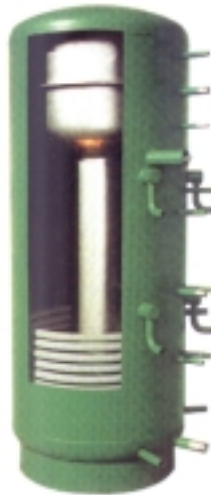


Fig. 12: Domestic hot water tank in space heating tank, energy storage tank with an integrated precious steel boiler (Feuron AG)

4.2.3 Energy storage tank for solar space heating

The size of the storage tank is determined on the one hand by the solar fraction desired and on the other hand by the additional heating system. Since only heating water with a low level of oxygen circulates in storage tanks of this kind, no special arrangements are needed with regard to corrosion. The storage tanks are only treated with a passivating coating on the outside. In a single family house it makes economic sense to use energy storage tanks with a size of 1 to 5 m³. To reduce the blending losses when loading the energy storage tank, we recommend that the energy storage tank should be designed with layer loading equipments. The operating principle for layer loading can be explained as follows:

As long as the water rising in the layer loader has a higher temperature than the water in the surrounding storage tank layer, the flaps remain closed due to the hydrostatic difference in pressure between the storage water and the water inside of the loader pipe. In the case that the temperature and the density are equal within and outside the pipe, the pressure is raised on the respective flap and the rising water can emerge through the flap. Another possibility

for layer loading is offered by valve control. This system comprises valves and several pipe connections (at different heights) to the energy storage tank. Depending on the water temperature (solar preheating temperature and water temperature in the energy storage tank) the layering of the water into the energy storage tank is performed by regulating the valves.



Fig. 13: Energy storage tank with the SOLVIS layer charging system (PINK)

4.3 Control Systems

A very important component in a thermal solar plant is the electronic control of the temperature difference: by the means of two temperature sensors, the absorber temperature and the storage tank temperature near the heat exchanger are compared with each other and the circulation pump is switched on when the absorber temperature is a defined value higher than the temperature in the storage tank. If these circumstances do not longer apply, the pump is switched off by the control system.

The regulating systems offered on the market by different manufacturers are designed in such a way that an electronic control system is also available for each hydraulic scheme. Furthermore, there is a strong tendency towards individually programmable control systems with which basically all the hydraulic standard versions and a number of alternatives are possible. In the same way different concepts for the preparation of domestic hot water are possible in combination with solar space heating.

5 Current use of thermal solar plants

The main applications for thermal solar plants are for example to warm water in swimming pools and prepare water for domestic use for single and multi family houses. Apart from these applications, there has also been a market trend in the past towards solar space heating. Moreover, more and more solar plants are being used in connection with biomass local heating networks. At the current moment in time solar air heating, another system, have only a very small market share in Europe. The area of solar cooling is currently at the development stage. Within the framework of different R & D projects some demonstration plants for solar cooling, have been installed in Europe. In the sector of transparent thermal insulation only a few isolated projects have been realised in Austria, in other European countries, however, a number of test houses have been installed with TWD facades.

- **Solar plant to warm water in swimming pools**
- **Solar plant to prepare domestic hot water for single houses**
- **Solar plant to prepare domestic hot water for multi family houses**
- **System for solar space heating**
- **Solar biomass local heating networks**
- **Solar air heating systems**
- **Solar cooling**
- **Transparent thermal insulation (TWD)**

5.1 Plastic absorbers to heat water for swimming pools

Due to their limited pressure and temperature durability, plastic absorbers are mainly used for heating pool water. In this case, the desired temperature level is only a few degrees higher than the ambient temperature. Thus, simple plastic absorbers, which can usually be mounted uncovered on a flat roof due to their low operating temperature, are sufficient. Since they consist entirely of plastic, they have the advantage of single-circuit operation. The chlorinated pool water is directly pumped through the absorbers by a circulation pump and no heat exchanger is needed.

If a filter pump already exists, it can also be used for the solar circuit. In this case, the adequate dimensioning of the pump is very important. Plastic collectors are only operated during the summer months and have to be emptied before the first frost sets in.

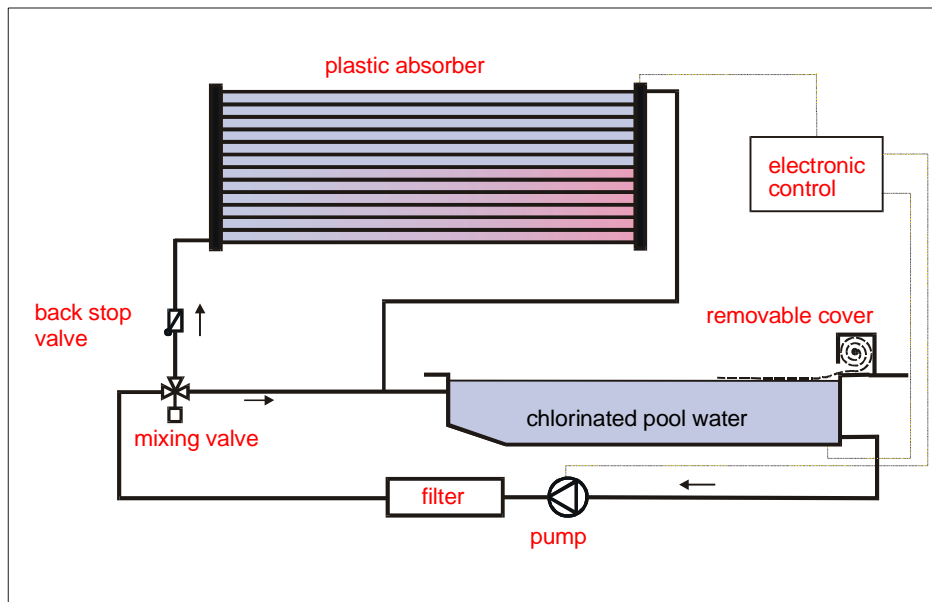


Figure 14: Solar heating system for a swimming pool (single circuit system)



Figure 14a: Solar plant for pool heating

5.2 Thermal solar systems for preparation domestic hot water (single family houses)

In Central Europe, domestic hot water is usually heated either by using electricity or by a boiler operated with solid fuels, gas or oil. If this heating system is used in summer only to heat water, the boiler operates with an extremely low efficiency. During this period, the domestic hot water can be heated in an ecologically beneficial and economic way by a solar heating system.

During the summer the energy supplied by the sun is sufficient to cover between 80% to 95% of the hot water demand, depending on the dimensioning of the system. During the transitional period and winter months, the solar energy supply is still sufficient to pre-heat the domestic water, i.e. the temperature of the fresh water has to be raised only by a small amount by the heating boiler or electric heating element. In the cold winter months, water temperatures between 30 to 50°C can still be reached on sunny days. Thus, the energy saving effect in winter may still be considerable. The past few years have shown that these thermal solar systems are already technically mature and reliable.

5.2.1 Description for a thermal solar system to prepare domestic hot water

Incoming solar radiation is converted by the collector into heat. This heat is transported by a heat transfer medium (water/anti-freeze mixture) in pipes to a storage tank. There the heat is transferred through a heat exchanger to the domestic water. The storage tank should be dimensioned in such a way that its volume corresponds to the hot water demand of at least two days. The installation of an additional (e.g. electric) heater ensures that sufficient amounts of domestic hot water are available even during long and continuous periods of overcast weather.

Concerning the hydraulic scheme (see figure 15) the heat transfer medium is circulated by a circulation pump (1). An electronic control system ensures that the pump is only turned on when an energy gain from the solar collector is expected, i.e. when the medium in the collector is warmer than the domestic hot water in the tank. Both the storage tank and the pipes are well insulated to avoid unnecessary losses.

Additionally, thermometers (4, 7) in the loading preliminary and reverse pipe belong to the basic equipment of the system. They are installed preferably close to the storage tank. Temperature-dependent volume changes in the fluid are compensated by the expansion tank (8), keeping the operating pressure in the system constant.

The gravity brake (2) prevents the heat from flowing back to the top if a standstill occurs in the system. A pressure relief valve (5) allows the fluid to escape if the system pressure becomes too high. An air escape valve (6) is installed at the highest point allowing air in the pipes to escape. Inlet and outlet taps complete the system (10).

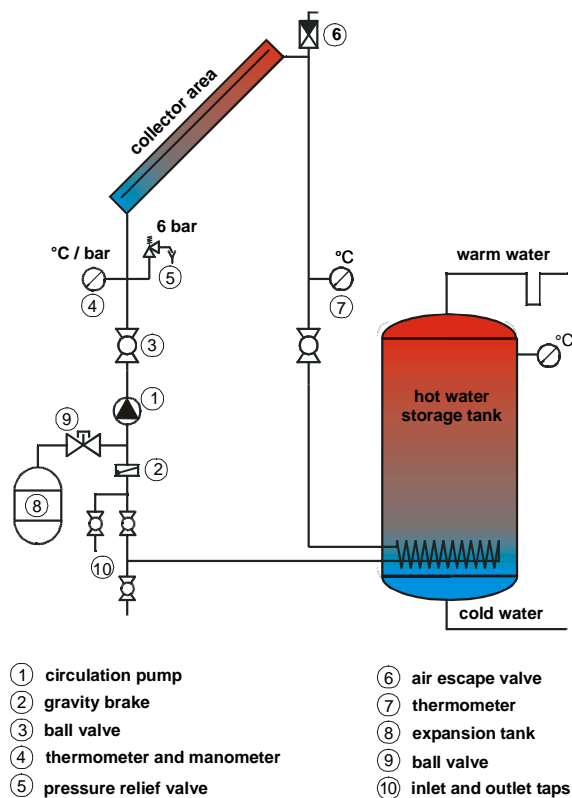


Figure 15. Illustration of a hydraulic scheme



Figure 15a. Single family houses with solar hot water systems

5.3 Solar plants in multi family houses

Approximately 43% of the Austrian population lives in multi family houses(ÖSTAT, 1991). As a rule the hot water is prepared in these houses using decentralised systems. A common supply system for a dwelling comprises a small storage tank (100 to 200 l) heated using electricity (night power) to cover consumption in the bath room as well as an electrically heated flow heater (5 to 10 l) to cover smaller consumption rates in the kitchen.

By the end of 1999, approximately 500 thermal solar plants were installed in Austria in multi family houses. If one considers this fact then one clearly recognises market potential for solar plants in this field. Apart from the existing market potential, multi family houses favour the installation of solar plants since they are of a compact design compared to single family houses. Whereas naturally only decentralised small-scale plants are installed in single family houses, larger, central solar plants could be realised in such multi family houses. This leads in greater potential to save on CO₂ with less system costs.

However we are far away from accomplishing the wide-spread market introduction of solar plants in Austria. Co-operative residential building associations tend to be sceptical of solar technologies since they require additional planning, co-ordination and financial input when it comes to constructing or reconstructing of the building. In contrast to private "home builders", where the decision to install a solar plant is mainly of an emotional nature, economic considerations tend to dominate amongst co-operative residential building associations.

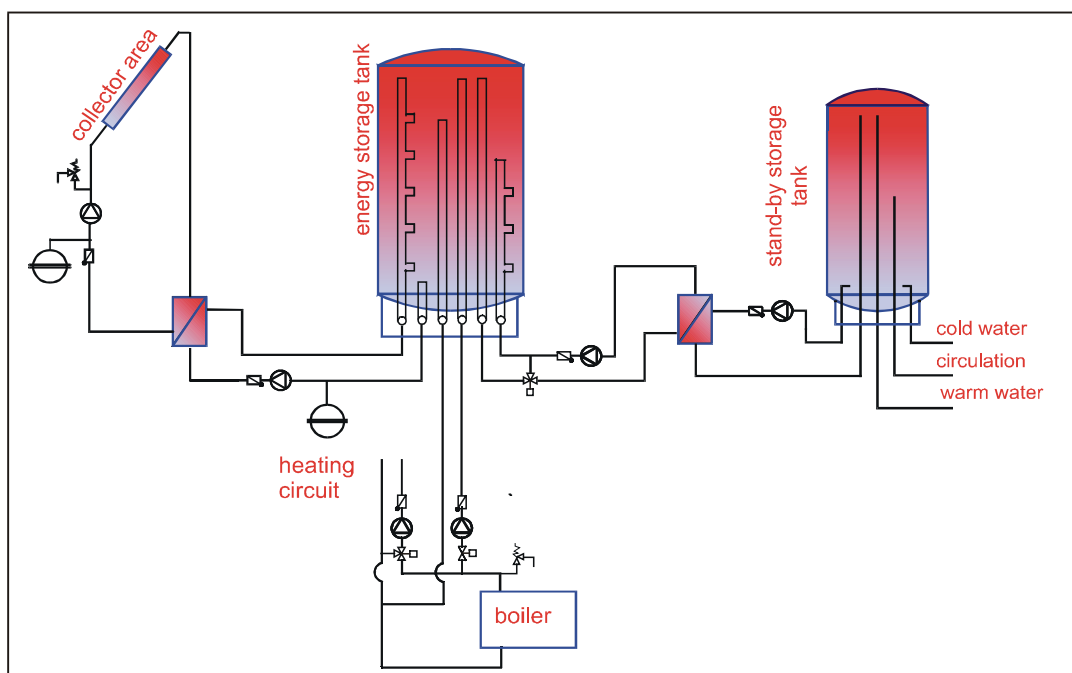


Figure 16: Hydraulic scheme of a thermal solar system for a multi family house (energy storage tank and stand-by storage tank)



Figure 16a. Hot water preparation in a multi family house

5.4 Combisystems for solar space heating

At the current moment in time fossil forms of energy (oil, gas and coal) mainly provide space heating. In a similar way to the wide-spread market introduction of solar plants for preparation of domestic hot water it is once again the private builder who has realised the very first solar space heating in the past. The characteristics of the plant and the yields which can be obtained with regard to numerous plants were recorded and evaluated. The results led to considerable system optimisations. In this field Austria has assumed a pioneering role by European comparison. In 1998 approximately 50% of the complete collector area installed in buildings was accounted for by solar space heating. This corresponds to around 20 to 25% of the plants totally installed [1].

As the energy supply is inversely proportional to the energy demand - i.e. during summer when only little energy for heating purposes is required, the energy supply is high, and during winter when much energy is needed, the supply is low - the key question is how to store the energy from the summer to the winter.

Various systems completed in recent years demonstrate that it is possible to store the heat from summer to the winter in large water tanks (seasonal storage with 50 to 80 m³ for 100 m² living area), and thus to use only solar energy for heating. From an economical point of view, seasonal storage for single family houses and two-family houses is quite expensive and so not generally applicable.

The second economically more interesting concept for single family houses is that of partly solar space heating. If collector areas of 20 to 50 m² are combined with storage tanks (1 to 5 m³) which are able to store heat for some hours (overnight) or for some days or for some weeks, solar fractions of up to about 20 to 60% can be achieved at reasonable costs compared to systems with seasonal storage. The remaining energy consumption is ideally covered by a wood combustion plant (piece wood boiler, pellets or wood chip boiler).

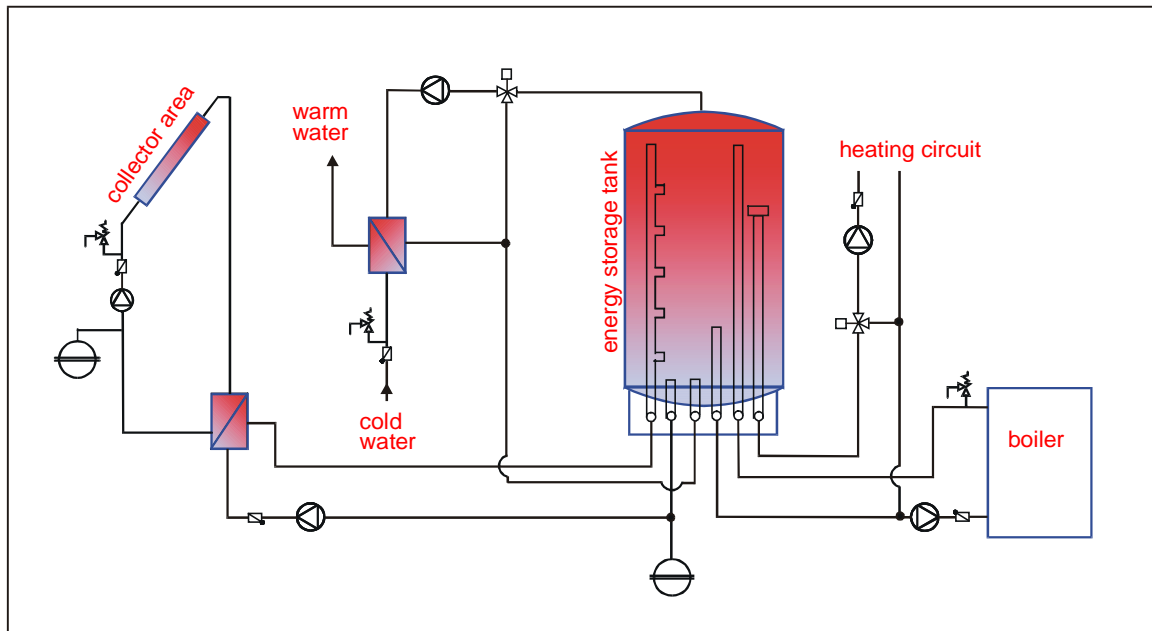


Figure 17: Hydraulic scheme of a partly solar space heating system (central energy storage tank and external heat exchanger for preparing domestic hot water)



Figure 17a: Single family house with solar space heating

5.5 Solar Assisted Biomass Local Heating Network

These plants for the supply of heat (space heating, preparation of water for domestic use) principally comprise biomass combustion, the solar plant including the storage tank and the local heating network. As a result of the combined use of energy from biomass and solar radiation, heat can be comfortably supplied to villages and towns from renewable sources of energy. These combined plants should in the main be used in applications where for economic and ecological reasons it does not make sense to heat with biomass combustion in the summer months. Since according to experience lots of customers only join the local heating network when services are offered all year round it makes sense to prepare warm water in the summer months using a central solar plant. This is normally assembled directly on the roof of the building for the biomass heating plant central (boiler room and biomass fuel storage hall). For the reasons mentioned several operators of biomass local heating networks have added a thermal solar system to their plants in the past.

It is in this respect extremely positive that it is not just small local heating networks which use solar energy but rather there is a trend towards biomass heating plants for large collector areas (collector area larger than 1.000 m²). It has been seen that the use of large area collectors (8 to 12 m²) has advantages at the assembly stage. Apart from the collector area, the correct dimensioning of the storage tank is also very important. In these storage tanks the solar heated medium is disposed in layers in a temperature-oriented manner and transported to the consumers via the local heating network. In the three months in the summer it is possible to obtain a solar fraction of more than 90% and subsequent heating is only necessary in longer periods of bad weather. So a backup system with a small biomass or oil boiler should be used. With the storage tank installed for the solar plant it is possible to accommodate peak capacity in the short-term in the winter heating period so that the biomass boiler can be dimensioned smaller which once again has a very positive effect on the investment costs.

Recent plants

So far there are 15 solar biomass heating networks with a collector area of up to 1,250 m² in operation. The following table shows all the solar biomass heating plants operating in Austria.

The first solar biomass heating network in Austria (Deutsch Tschantschendorf) built in 1994 was monitored from 1995 to 1997 by the operator and AEE.

	Year of construction	Performance of boiler [kW]	Network [m]	Storage tank [m ³]	Collector area [m ²]
<i>Deutsch Tschantschendorf</i>	1994	600	2.500	34	325
<i>Bildein</i>	1995	1.000	2.960	38	450
<i>Obermarkersdorf</i>	1995	750	3.400	68	567
<i>Unterrabnitz</i>	1995	650	3.800	58	477
<i>Gnas</i>	1996	1.640	2.200	40	441
<i>Urbersdorf</i>	1996	450	1.650	60	350
<i>Bad Mitterndorf</i>	1997	4.000	3.500	140	1.120
<i>Eibiswald</i>	1997	2.000	3.200	105	1.250
<i>Lindgraben</i>	1997	350	1.300	37	350
<i>Poysbrunn</i>	1997	1.000	3.140	85	870
<i>Nikitsch</i>	1997	2.250	6.900	60	780
<i>Kroatisch Minihof</i>	1997	700	3.100	60	740
<i>Soboth</i>	1998	300	-	10	200
<i>Schwanberg</i>	1998	500	-	50	470
<i>Stadl/Mur</i>	1998	-	-	60	490

Figure 18: Solar assisted local heating plants in Austria



Figure 18a: Heat from the sun and from biomass

5.6 Solar air heating systems

Concerning air collectors one means sun collectors which use air as a heat transfer medium. Starting with the first developments at the end of the 19th century in the USA, a number of different solar air technologies have been developed around the world without these however being widely spread so far.

Air heating systems are suitable for applications which require direct warm air. Good applications for air collectors are indicated in the examples which follow:

- Systems for space heating: In air heating systems which are used in the building sector one has to differentiate between the direct and indirect introduction of air. The direct introduction of air is given preference when heating halls and storage rooms. In single and multi family houses, office buildings etc. the air is introduced mostly indirectly or by a combination of direct and indirect. The indirect introduction of air is performed by hyposcausts respectively murocaust systems or sometimes also using intermediate wall systems. In this respect the heat release in the rooms is performed in the form of heat radiation. The direct introduction of air takes place via controlled aeration and ventilation. In general rock storage tanks or storage walls are used for heat storage in air heating systems. Air heating systems can accommodate a large amount of the space heating requirements provided that the overall system is correctly dimensioned. Complete coverage is, however, not possible due to unfavourable solar energy conditions in the winter.
- Plants for drying agricultural or commercial products such as cereals, seeds, medicinal plants and herbs, building materials, wood etc. The drying potential of the air collector plants equals about 0.2 to 0.7 kg of water per hour and m² of collector area. The drying of sewage sludge is another interesting application.

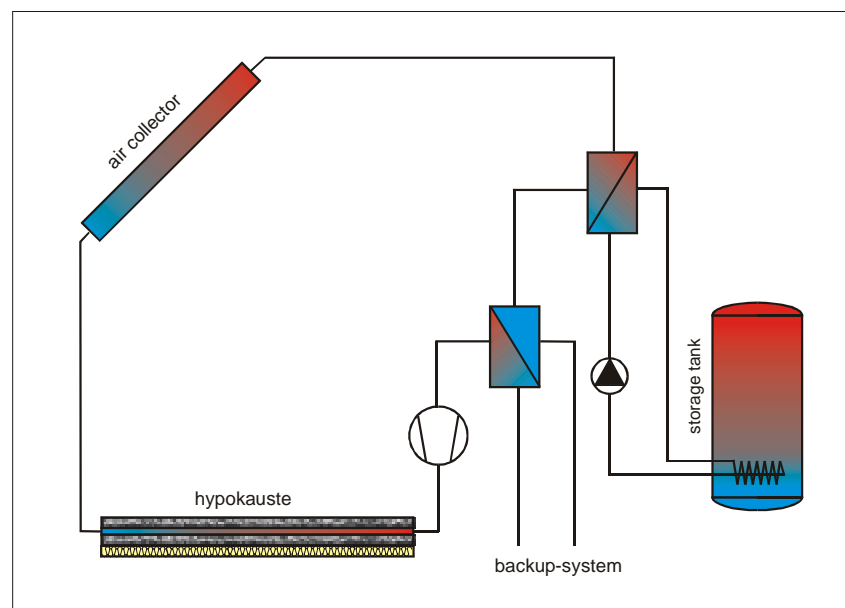


Fig. 19: Hydraulic diagram of an air heating system with a hypocaust for heat release and a domestic water storage tank for the preparation of domestic water in the summer



Figure 19a: Solar air system in a single family house

5.7 Solar cooling

In Central-European regions air conditioning in the summer is as a rule only employed in large administrative buildings, in commercial buildings etc. whereas in Southern Europe air conditioning systems are being also used increasingly in the residential sector. Since the time of the year in which air conditioning corresponds very well with the time of the year for solar radiation, it makes sense to develop solar supporting systems for air conditioning in the summer.

Apart from thermal processes which involve the sorption technique, the photovoltaic technique with compression cooling plants currently plays a role when it comes to the sector for the generation of coldness using solar energy /6/.

Processes are favourable for the use of thermal solar collectors in which the temperatures required to generate coldness are as low as possible so as to be able to operate the collector field efficiently. Roughly these processes divide on the one hand into the type of process control – open or closed – and on the other hand into the type of sorption agents used – solid or liquid.

Vefahren	geschlossen		offen	
Kältemittelkreislauf	geschlossener Kältemittelkreislauf		Kältemittel (Wasser) in Konakt mit Atmosphären	
Verfahrensprinzip	Kaltwassererzeugung		Luftentfeuchtung + Verdunstungskühlung	
Sorptionsmittel	fest	flüssig	fest	flüssig1)
typische Stoffsysteme (Kälte/Sorptionsmittel)	Wasser-Silikagel, Ammoniak-Salz	Wasser-Wasser-Lithiumbromid, Ammoniak-Wasser	Wasser-Silikagel, Wasser-Lithiumchlorid-Zellulose	Wasser-Calciumchlorid, Wasser-Lithiumchlorid
marktverfügbare Technik	Adsorptionskältemaschine	Adsorptionskältemaschine	sorptionsunterstützte Klimatisierung	-
marktverfügbare Leistung [kW Kälte]	50 bis 430 kW	20 kW bis 5MW	20 bis 350 kW (pro Modul)	-
Wärmeverhältnis (COP)	0,3 bis 0,7	0,6 bis 0,75 (einstufig)	0,5 bis 0	>0
typische Antriebstemperatur	60 bis 90 °C	80 bis 110°C	45 bis 95 °C	45 bis 70 °C
Solartechnik	Vakuurröhren-, Flachkollektoren	Vakuurröhrenkollektoren	Flachkollektoren, Solarluftkollektoren	Flachkollektoren, Solarluftkollektoren

Figure 20: Classification of thermally driven cooling processes for air conditioning in buildings

Apart from the preparation of domestic hot water and partly solar space heating, solar air conditioning is another important application for the use of thermal solar energy in the building sector. Up until now plants have mostly been constructed within the framework of subsidised demonstration projects. An IEA-Task was started to promote research activities within the field of solar air conditioning.

5.8 Transparent thermal insulation (TWD)

The principle of transparent thermal insulation is that when using transparent thermal insulation materials (TWDM) heat losses are at least partly compensated by solar gains respectively it can be used as heat gains (e.g. for the heating of buildings) compared to conventional thermal insulation in which as a rule only transmission losses are reduced. Thus compared to light impenetrable (opaque) insulation materials, TWDM's have two main properties which are of energetic importance:

- a good heat-insulating effect (i.e. the lowest possible values for the thermal diffusion coefficient k-value)
- a high permeability for solar radiation (i.e. the highest possible values for the overall energy diffusion rate g)

TWD materials obtain their thermal insulation effect as a result of a high content of air and by subdividing the air layers into small volumes. As far as the geometric structure and the materials are concerned, in principle absorber-parallel layer structures, absorber-vertical structures (channel, honeycomb and capillary structures), chamber structures (grouser plates, transparent foam, hollow balls) and quasi-homogeneous materials (aero-gels) made of glass or transparent plastics are possible. The TWD structures most frequently used are absorber-vertical tubes or honeycomb structures manufactured in the extrusion processes of light-permeable plastics such as polymethylmetacrylat (PMMA) and polycarbonate (PC).

Depending on the layer thickness of the TWD structure, values of $k = 0,7 - 1,5 \text{ W/(m}^2 \text{ K)}$ are typically reached for the heat losses when used behind a glass plate to protect against climate effects and $g_{\text{diff}} = 50$ to 70% for the diffuse-hemispheric overall energy diffusion rate.

The systematic development of so-called transparent thermal insulating materials commenced really only at the beginning of the 1980's and has led to a range of new concepts for thermal solar energy utilisation.

In this respect the most important application is the transparent insulation of the outer walls of buildings. Here solar energy is directly attained without any supporting energy and without the help of moved parts. In these passive systems even a very small amount of radiation causes a reduction in the heat losses, with a medium amount of radiation losses and gains balance one another and when there is more sun this will result in net heat gains.

Another application which is already very widely spread is the use of TWD elements in the window sector where no look-through is required. Systems of this kind are deliberately employed with skylights to control and distribute the light.

New developments deal with the use of TWD's in special collectors to prepare warm and hot water. If a TWD is attached to the side and towards the back of a very well insulated flat collector, then similar to a vacuum-tube collector, very high operating temperatures can be reached (100 - 150°C for the preparation of process heat) with a good rate of efficiency. In the event of a standstill – absorber temperatures of 260°C were measured - the TWD materials are exposed to a high temperature load which means that glass capillaries are necessary.

Whilst until now only isolated projects have been realised with TWD-systems in Austria, there is a range of test houses with TWD-facades in other European countries (BRD, CH, UK). The results to date lead us to expect that the use of TWD systems in buildings, both new and old, will make a considerable contribution towards the saving of fossil sources of fuel /3/.



Figure 21: Terrace house estate with TWD - facade

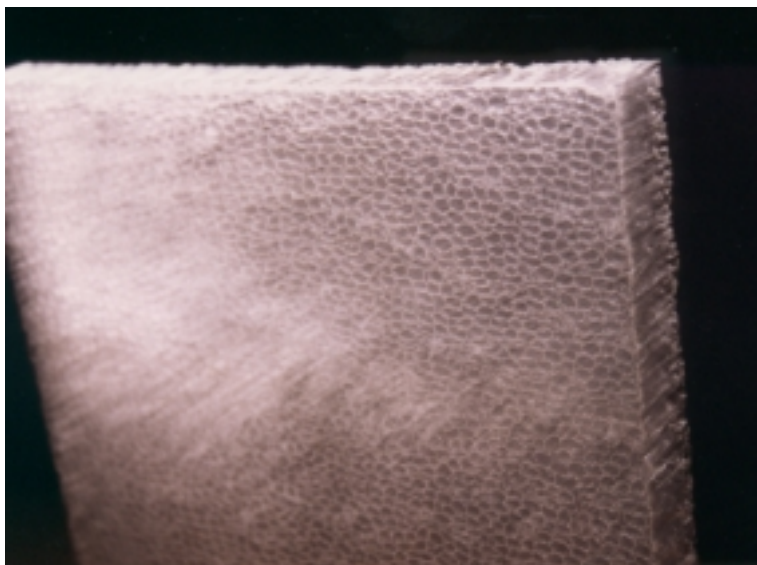


Figure 21a: Example for a TWD-material

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