SOLAR HEAT FOR INDUSTRIAL PROCESSES

Task 33 / Task IV : SHIP

Detailed papers to Newsletter No. 1

Solar Heat for Industrial Processes – Task 33/IV

A capacity of 70 GW_{th} of solar thermal collectors with around 100 million square meters were installed by the year 2001 worldwide. Until now the widespread use of solar thermal plants has focused almost exclusively on swimming pools, domestic hot water preparation and space heating in the residential sector.
The use of solar energy in commercial and industrial applications is currently insignificant compared to the use in swimming pools and the household sector. Most solar applications for industrial processes have been on a relatively small scale and are mostly experimental in nature. Only a few large systems are in use worldwide.
On the other hand, if one compares the energy consumption of the industrial, transportation, household and service sectors, then one can see that the industrial sector has the biggest energy consumption in the OECD countries at approximately 30%, followed closely by the transportation and household sectors.

Task 33/IV – A collaborative research project

To be able to make use of the huge potential for solar heat in industry and to open a new market sector for the solar thermal industry, Task 33/IV – a collaborative research project of the IEA Solar Heating and Cooling Programme and the IEA Solar PACES Programme - is going to carry out potential studies as well as to investigate the most promising applications and industrial sectors for solar heat.

The major share of the energy which is needed in commercial and industrial companies for production processes and for heating production halls, is below 250°C. The low temperature level (< 80°C) complies with the temperature level, which can easily be reached with solar thermal collectors already on the market. The principles of operation of components and systems apply directly to industrial process heat applications. The unique features of these applications lie on the scale on which they are used, system configurations, controls needed to meet industrial requirements, and the integration of the solar energy supply system with the auxiliary energy source and the industrial process.

For applications where temperatures up to 250°C are needed the experiences are rather limited and also suitable components and systems are missing. Therefore, for these applications high performance solar collectors and system components are going to be developed and tested in the framework of Task 33/IV.

The development of integral solutions for solar thermal energy applications for given industrial processes (based on the „PINCH-concept“) is also one of the main topics of the project.
Furthermore the development of design tools (based on TRNSYS simulations) and a software tool for fast feasibility assessment, economic analyses as well as the design and the erection of pilot plants in co-operation with industry are planed.

Task 33/IV was launched on November 1, 2003 and will be completed on October 31, 2007;
it involves 27 experts from Australia, Austria, the Czech Republic, Germany, Italy, Mexico, Portugal and Spain and 11 participants from the solar industry.

Cooperation with Industry

The Task is designed to attract as many as possible from engineering companies, solar manufacturers and system sellers.

Due to the nature of the solar industry, being composed of small to medium size companies, the Task defined two levels of participation for the solar industry:

- <u>an industry participant at level 1</u> should expect to participate in an annual workshop organized by Task 33/IV and to receive at least once during the Task duration a visit from a Task participant, and to answer technical and marketing questions on solar heat for industrial applications.

- an industry participant at level 2 should expect level 1 commitment and to participate in all Task meetings, bringing information and feedback from the market. Level 2 participation should be seen in close connection with the main participant of the country of origin of the industry.

Solar industries from all participating countries are invited to participate in the described work of Task 33/IV as well as to cooperate in the design and the erection of pilot plants.

If you are interested in a cooperation, please get in contact either with the Operating Agent of the Task (e-mail: w.weiss@aee.at) or with the Task participants of your country.

Web links: www.iea-ship.org
www.iea-shc.org
www.solarpaces.org

How to integrate solar heat into industrial processes

Overview of applications and the integration methodology

Introduction

The integration of solar heat into industrial production processes is a challenge to both: the process engineer and the solar expert. Usually the thermal solar system will be only a part of the total process energy system and will supply only a fraction of the total energy demand. Existing heating system – based on steam or hot water from a boiler – don't have to take care of temperature level too much. In general they are designed at much higher temperatures compared to what the processes need in order to keep temperature differences – and by that heat exchanger surfaces – small. Very often we can find steam temperatures at 150 to 180°C while the processes run below 100°C or even much lower. Applying solar heat, much more attention has to be paid to the temperature levels.

Another challenge in applying solar thermal energy to industrial production processes is the time dependency of the solar energy supply and the heat demand of the processes. Only very few production lines run at constant loads all over the day. Most processes in smaller companies run for one or two shifts per day and are batch processes by themselves. The question of how to deal with batch processes will be discussed in a later newsletter.

Direct process heating or feeding into existing heating system

The easiest way of integrating solar thermal heat into industrial energy systems, is to supply it to the existing heating system (comp. fig. 2.1). In that case, the solar collector has to be operated at the same temperature level as the existing heating system, which will be above 100°C in general. The heat transfer medium should be water and not steam if possible. Such a set up is easy to install and to control, but the thermal efficiency will be low.

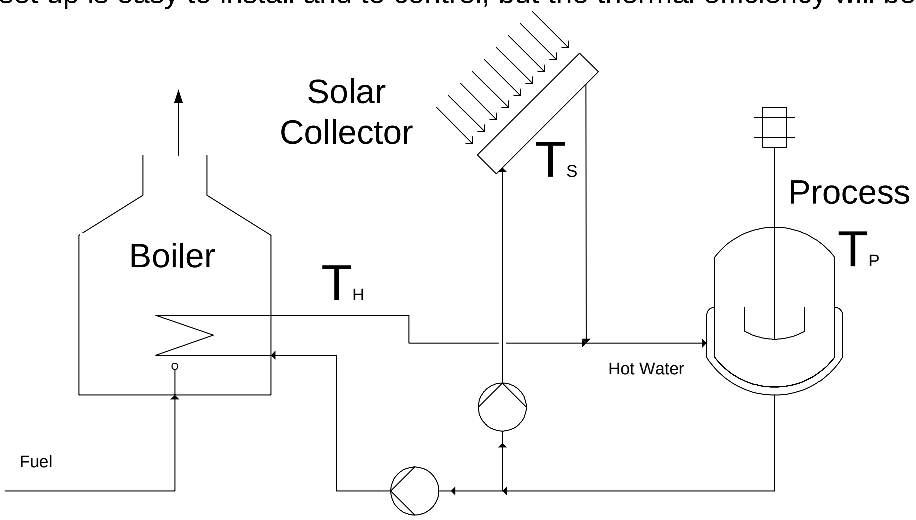


Figure 2.1: Solar thermal energy feeding into the existing hot water system.

Seen from the thermodynamic point of view, solar heat should be fed into the production process at the lowest possible temperature. That means that any further heat exchange between solar thermal collector and the process equipment has to be avoided. The difficulties that could arise from this are obvious (comp. fig.2.2). There has to be an additional heat transfer area in the production equipment as soon as the temperature T_S from the collector is different to that one of the heating medium T_H. On the other hand, T_S can be close to T_P, the temperature of the process, thus boosting the efficiency of the collector system.

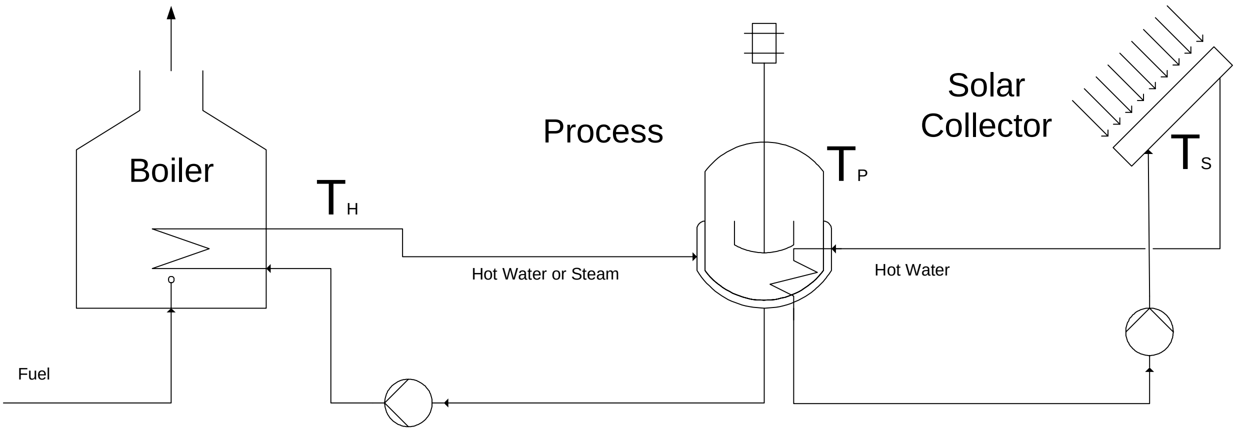


Figure 2.2: Feeding of solar heat to the process equipment directly

Typical applications and most promising sectors of industry

Favourable conditions for solar thermal energy mean temperatures as low as possible, processes that need a constant amount of energy during sunlight hours and high energy prices in the existing system.

Although one will not meet favourable conditions too often, there are suited processes in many sectors of industry, if one has a closer look.

<u>Cleaning</u> is a processes that occurs in many forms. Cleaning of bottles, cans, kegs and process equipment is the most energy consuming part in food industry. But also metal treatment plants (galvanizing, anodizing, painting,…) have cleaning processes of parts and surfaces. Textile industry and laundries clean fabrics and service stations clean cars. All of them need warm water at temperatures below 100°C and even below 60°C very often. They provide an excellent application for solar thermal energy. Storage and the integration into the existing heat supply system is rather easy in these cases since storage tanks exist very often water is the main medium.

<u>Drying</u> is also very energy intensive. Most of the washing processes require subsequent drying Although the drying medium will be warm air in general, it will be heated up through water/air – heat exchangers in general. Preheating with solar heat might be a viable option in that case.

<u>Evaporation</u> seen from the viewpoint of thermodynamics is not very different to drying: the more volatile component has to change phase through the input of energy. Application can be found in food industry and chemistry mainly.

<u>Pasteurisation and sterilisation</u> need heat of 75 or 105°C respectively. In food industry and biochemistry there are numerous applications. With liquids, pasteurisation can be performed in heat exchangers, for solids (cans, bottles,…), there is a need for a heat transfer medium like water, air or steam.

<u>Preheating boiler feed</u> water is another possible application for solar heat in the process industry. Since this is a low temperature heat sink, solar energy is suited very well, but there might be other heat sources available in the process at cheaper conditions.

<u>Heating of production halls</u> will be necessary in many countries in wintertime. Although heating is not purely an industrial application, there might be special challenges due to the fact, that the heat supply system might be the same for processes and space heating.

<u>Solar cooling</u> with absorption systems is a very special application of solar heat in industry. Integrated into the whole energy system of the industrial plant it might offer special chances in some branches like the food industry.

Table 2.1. gives a rough overview over the processes suited for solar heat and the industrial sectors where they might typically occur.

*Table 2.1: Operations an processes in some important industrial sectors (**x**…important, **X**…very important)*

process \ industry sector	food	textile	building material	galvanizing, electroplating	fine chemicals	pharmaceutical and bio chemical	service industry	paper industry	automobile supply	tanning	painting	wood and wood products
cleaning	X	X	x	X	x	X	X		x	x	X	
drying	X	X	x		x	X	X	x	x	X	X	X
evaporation and distillation	X				x	X						
pasteurisation	X					X						
sterilization	X					X						
cooking	X											
general process heating	x	x	x	X	x	x	X		x			x
boiler feed water preheating	X	X	x		x	x		x		x		
heating of production halls	X	X		x	x	x	x		X	X	X	X
solar absorption cooling	X			x		X	X					

Economic consideration

In industry the demands on the economic performance of investments usually is very high. Payback times of 3 years and less are required for production equipment, but 10 years are accepted for infrastructure as buildings and energy systems. Such numbers are difficult to obtain with solar systems if energy savings are considered as the only benefits but there exist examples that it is possible even at present energy and equipment prices. There are also new and promising considerations offering solar-contracting solutions to industry. In this contracting models, the solar energy supplier takes the investment costs of the solar equipment and the enterprise pays for the energy delivered.

Looking closer to the energy systems of industrial installations, one can find other options for energy conservation or energy efficiency in many cases. Heat exchange can provide low temperature heat from outgoing process streams. Cogeneration with gas turbines, steam turbines and/or diesel motors provides low temperature heat at reasonable prices as well. More than this, new technological developments can shift the energy demand from heat to power and will change the future demands.

But there is a market for solar thermal energy in the process industry as soon as strategic considerations are being made in addition to simple payback calculations. Investments in sustainable solutions like solar energy will improve the supplier's position in the market through image gained, through increased workers engagement and a long term stability of energy prices.

Overview of existing solar process heat plants

Within the IEA Task 33/IV information has been collected on solar industrial process heat plants operating world wide. From the 49 plants that have been reported, the majority of the projects are in the sectors of food and beverage, textile, transport and chemistry with a large majority of food processes. Indeed, in the food industry, there are 12 cases over the 49 SHIP plants, working in the subsector of dairy, fish, meat and olives. In the transport sector, it emerges a majority of washing installations; in the textile industry, laundry companies.

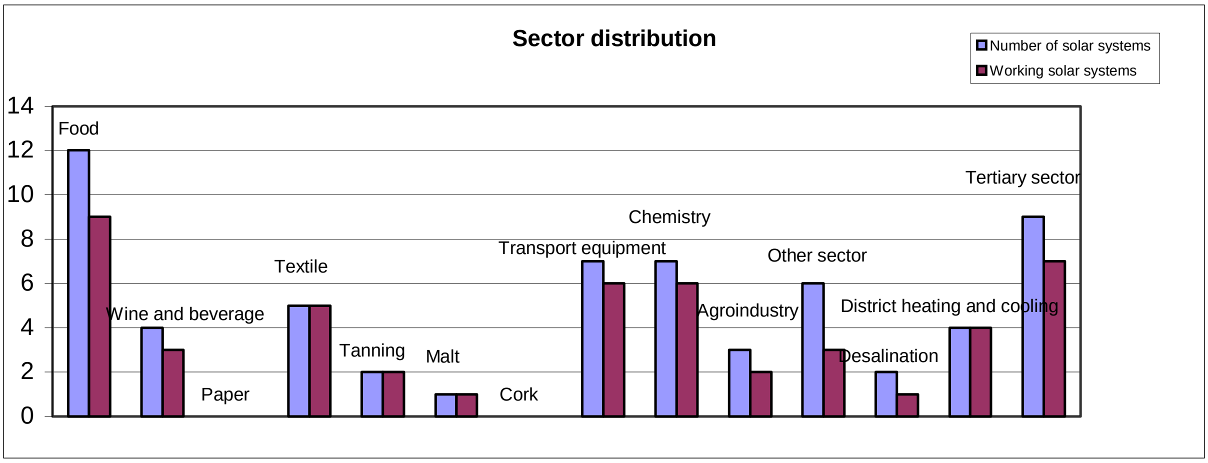


Figure 3. Distribution of solar plants reported to Task 33/IV. Number of projects: (a) total and (b) plants still in operation. State: April 2004.

The majority of the operating plants are in the countries which have now the most important solar industrial development. Indeed, in Austria, Greece, Spain and the USA, where there have been several plants built during the 90ies, there are more than 67 % of the reported plants.

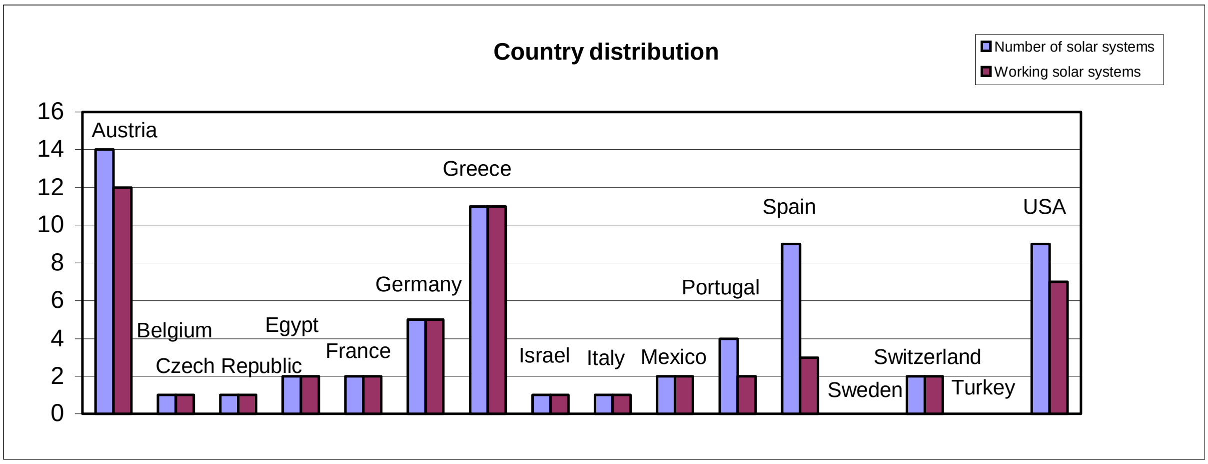


Figure 4. Solar plants reported to Task 33/IV: distribution by countries. State: April 2004.

Most of the reported SHIP plants supply heat at temperature levels between 60 °C and 100°C (output temperature of the solar system to load). Some plants are working at temperatures above 160 °C and there is only one project operating in the intermediate range from 100 to 160 ºC. Five of the plants working at more than 160 °C are 2 prototypes and 3 processes of space heating and cooling with double effect absorption machine (steam production). Analyzing the reported plants, as already stated above it appears a broad range of working temperature but they there is no significant correlation with the solar field size. For working temperatures above 150 ºC there are no very small plants (< 100 m2). This is due to the fact, that concentrating solar collectors are market available from this plant size on.

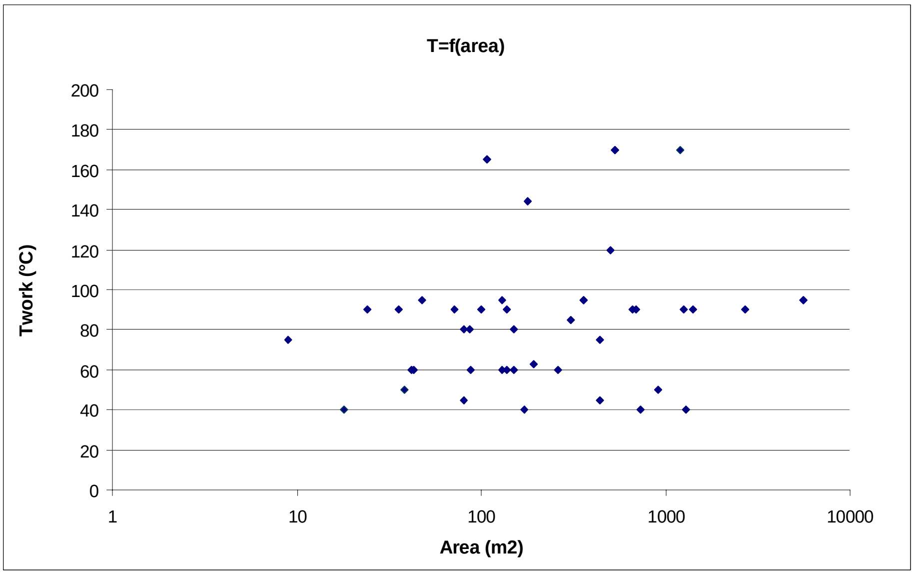


Figure 5. Solar plants reported to Task 33/IV: correlation of working temperature vs. solar field size. State: April 2004.

Since the year 2000, the number of new solar systems has increased, almost doubled, but some of the older systems have been shutdown. For example in Spain, the systems installed before 1990 were shutdown some years later for a lack of maintenance. Up to now, there is only very few information available on the operation behaviour of the reported plants and the reasons for the shutdown in some cases. This is intended to be done in the future work of Task 33/IV by gathering more detailed information on the projects.

New developments of 'medium temperature' collectors for 80° to 250°C

The new term 'medium temperature collectors' is used to address collectors with operating temperatures in the range of 80°C to 250°C. The aim is to develop collectors that are suitable for applications in this temperature range in which up to now only very limited experience exists. In order to give a short overview, three categories may be introduced:

- improved flat plate collectors
- stationary low concentration collectors
- small parabolic trough collectors.

Improved flat plate collectors
Especially for applications in the temperature range of 80 to 120°C there exists a number of possibilities to improve flat plate collectors such that they become suitable for those applications. In order to achieve this, it is necessary to reduce the collector heat losses without sacrificing too much of the optical performance at the same time. To mention two important possibilities: double glazed flat plate collectors with anti-reflection glazings and hermetically sealed collectors with inert gas fillings, or even a combination of both.

Figure 1 shows estimated efficiency curves of single, double and triple glazed flat plate collectors when newly developed anti-reflection glazings ('AR-glass') are used.

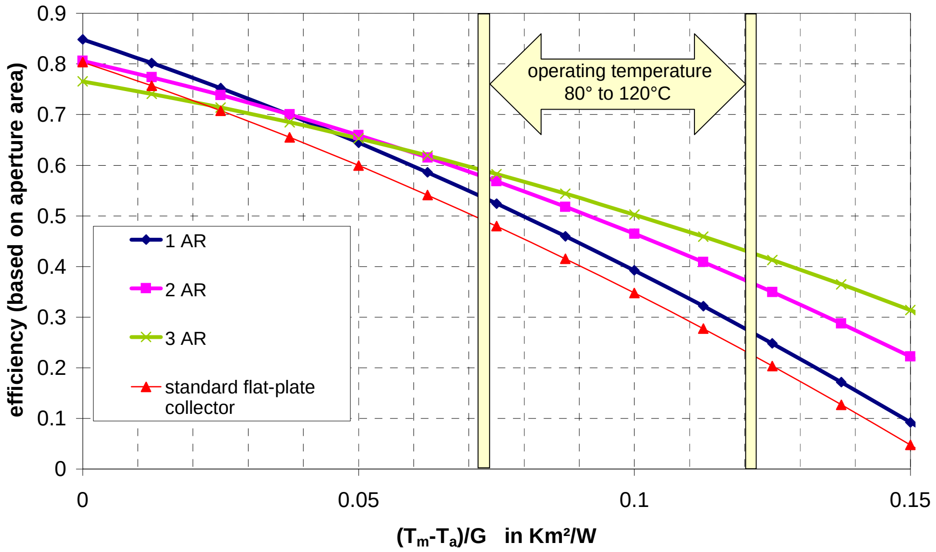


Figure 1: Efficiency curves of a single, double and triple glazed AR collector in comparison with a standard flat-plate collector with normal solar glass.

Low concentration collectors
An important possibility for the development of medium temperature collectors is to reduce heat losses by concentration. For example INETI in Portugal is investigating a stationary CPC type collector without vacuum for medium temperature applications. The concentration factor is in the range of 2.

Also the developments of MaReCo's (=maximum reflector collectors) of Vattenfall and Finsun Energy AB in Sweden is based on using reflectors for improved performance at higher temperatures.

Small parabolic trough collectors

Especially for the temperature range of 150°C to 250°C it is extremely interesting to consider the parabolic trough collector technology. A lot of experience is available from the high temperature applications where parabolic trough collectors are used at 400°C to 600°C for electric power production. But adjustments have to be made for the medium temperature range. Current developments which are involved in Task 33/4 are carried out i Spain, Austria, and Germany.

Example 1: EL NASR, Pharmaceutical Chemicals (Egypt)

Application: Production of process steam for a pharmaceutical company

Location:	El Cairo, Egypt
Installed capacity:	1330 kW
Collector Area:	1900 m^2
Collector type:	parabolic trough
Heat transfer medium:	steam (8 bar)
Operating temperature:	173 ºC
Storage:	not specified
Year of operation start:	2004 (January)

Owner: NREA (New and Renewable Energy Authority, Cairo); financed by ADF (African Development Fund, Abidjan, Ivory Cost); Contractor: Lotus Solar Technologies (Cairo, Egypt); Engineering Consultant:Fichtner Solar GmbH (Stuttgart,

Example 2: 100 percent renewable energy for a production hall and an office building

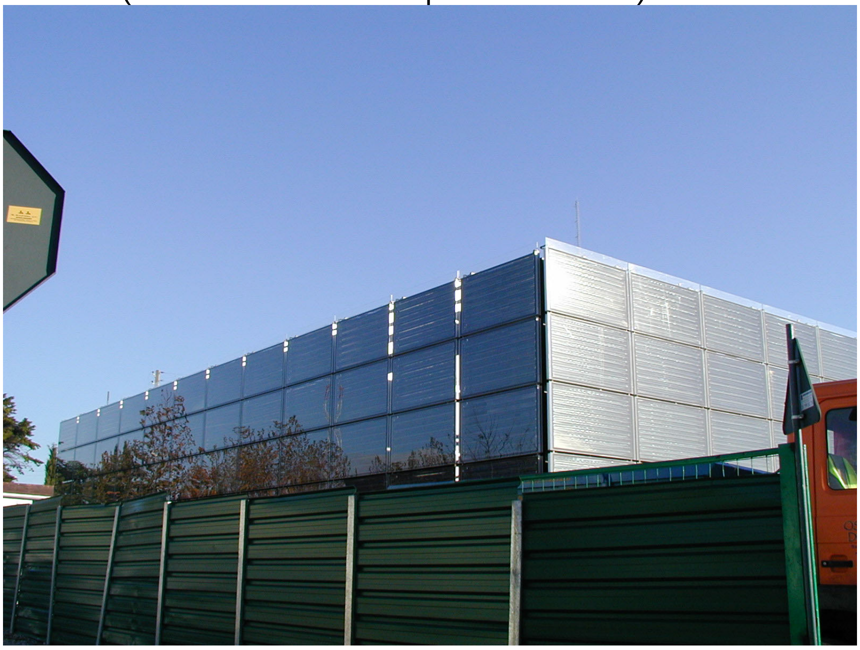
In Austria about 20 production halls are currently supplied with solar heat for space heating in wintertime. The solar fraction of these systems equals 20 to 100% of the total space heating and hot water demand of these companies.

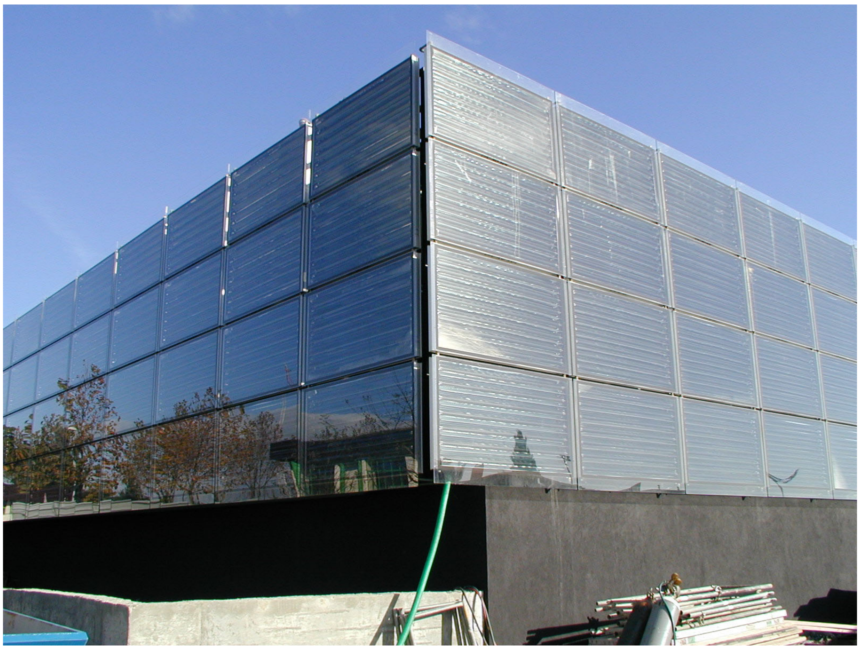
One typical system, on the factory building of the companies „Doma Solartechnik“, „Stromaufwärts Photovoltaik“ and „SAG Solarstrom“ were opened in Satteins, Austria in spring 1999. The energy and electricity demand for the offices with 470 square meters and the production hall with an floor area of 1,380 m^2 is covered exclusively from renewable energies.
The building was constructed in accordance with plans elaborated by two Austrian architecture companies „Gruppo Sportivo“(Bludenz) and MHM (Dornbirn). As a result of the architectural concept, the south orientation of the building and corresponding heat insulation, the specific energy demand was calculated with 50 kWh/m².a.

Energy supply to office building and production hall
Besides the passive solar energy gains, the energy façade on the south side of the building forms the central part of the energy supply for the building. In this façade, which totals 220 m^2, 80 m² of solar collectors with an installed capacity of 56 kW are producing the heat for space heating (office and production hall) and hot water preparation. For longer periods of overcast weather two combined heat and power plants, operated with biodiesel, were installed with 10.2 kW thermal and 5.4 kW electrical power each. The two CHP plants are in operation only if heat is required and if the thermal yield of the solar façade is not sufficient.
In addition, a photovoltaic plant connected to the grid is integrated in the south façade, which consist of 143 polycrystalline photovoltaic-modules with a power of 17.16 kW_{peak}.
Thus 100% of the electricity, heat for space heating and hot water demand are supplied by renewable energy - which means also CO_2-neutral.
The heat distribution in the office building is performed via wall panel heating. In the production hall the heat is released via a floor heating system integrated in the concrete floor. The concrete floor (90 cubic meters) is used both as a radiator as well as a heat store. As a result of the excellent thermal insulation of the building and the corresponding dimensioning of the wall- and floor heating systems, the system can be operated with very low flow temperatures. In the office building the flow temperature equals a maximum of 30°C given an outside temperature of -14°C, in the production hall this is a maximum of 25°C. These low supply temperatures offer ideal conditions for the operation of the solar thermal plant.

Example 3: Solar Powered Air Conditioning System for a Road Traffic Control Center in Carcavelos, Portugal

1. Photo (to be chosen from the picture overview)





2. Hydraulic scheme (???)

3. Technical data

Location: Carcavelos (BRISA), Portugal;
Collector area: 663,3 m^2 (335 CPC AO SOL solar collectors);
Collector type: CPC Solar Collectors;
Heat transfer medium: water glycol;
Operating temperature: 80 - 90 ºC;
Application: Space heating and cooling with a single effect Lithium-Bromate 79kW absorption machine;
Storage: 20 m^3;
Year of operation start: 2004 (January);

4. Application (short description)
The Road Traffic Control Center in Carcavelos, Portugal, belongs to the Portuguese Company BRISA, which is the responsible for majority of the high-ways in Portugal. The idea proposed by

Brisa for the building hosting this road traffic control center was a fully closed building skin in order to obtain an undisturbed environment inside. The building area would be 400 m^2. Due to the location previewed for the building, near a high-way, the building openings had to be projected in the North Façade. This made available the other façades for installation of solar collectors.
The installation of collectors in the façades allowed for thermal energy collection for the heating and cooling system, shading of the building external skin and improvement of the acoustic insulation. The collector area installed is given in the next table:

Façade	Total area (m^2)
East	95
West	95
South	180
Roof	293
Total	663

The collectors used are CPC type collectors from the company Ao Sol. In the vertical façades, the collectors used are an adaptation of the common collector produced, where the usual glass fixation system (an aluminum frame) was replaced by a perimeter fixation system allowing the glass in each collector to have a higher area then the usual gross area of the collector.
The cooling system installed is a single effect Lithium-Bromate absorption machine with 79kW cooling power.
The climate control in the main traffic control room and a set of connected offices is obtained with displacement ventilation in a raised floor configuration with inflow in the room perimeter. Outflow for all spaces occurs only through the main room

5. Solar fraction
At the moment only design simulation results are available, which predict a solar fraction higher then 70%.

Reference:
G. Carrilho da Graça, L. Andrade, M. Boucinha (2004), Design and simulation of a solar powered air consitioning system for a road traffic control center in Carvcavelos, Portugal, Comunication to the Climamed Conference, Lisbon