Technical Study Report on

SOLAR HEAT FOR INDUSTRIAL PROCESSES

(SHIP)

State of the art in the Mediterranean region

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Abbreviations and acronyms

ADF	African Development Foundation
AEE INTEC	Arbeitsgemeinschaft Erneuerbare Energie, Institut für Nachhaltige Technologien
AMD	Advanced Market Deployment scenario
ANME	Tunisian National Agency For Energy Conservation
AR	Anti-Reflective
BaU	Business as Usual scenario
CDM	Clean Development Mechanism
CPC	Compound Parabolic Concentrator
DNI	Direct Normal Irradiance
DSWH	Domestic Solar Water Heating system
ESTIF	European Solar Thermal Industry Federation
ESTTP	European Solar Thermal Technology Platform
ETC	Evacuated Tube Collector
EU	European Union
FPC	Flat-Plat Collector
GEF	Global Environment Facility
GHI	Global Horizontal Irradiance
IEA-SHC	International Energy Agency's Solar Heat and Cooling Programme
IFPC	Improved Flat Plate Collector
KM	Knowledge Management
K4RES-H	Key Issues for Renewable Heat in Europe project
LFC	Linear Fresnel Collector
MEDREC	Mediterranean Renewable Energy Center
MEDREP	Mediterranean Renewable Energy Programme
NREA	New and Renewable Energy Authority - Egypt
OME	Observatoire Méditerranéen de l'Energie
PDD	Project Design Document
POSHIP	Potential of Solar Heat in Industrial Processes project
PROSOL	Programme Solaire - Tunisia
PTC	Parabolic Trough Collector
R&D	Research and Development
RDP	Full R&D and Policy scenario
RESTMAC	Creating Markets for RETs - EU RES Technology Marketing Campaigns- FP6 Project
SFPC	Standard Flat Plate Collector
SHIP	Solar Heat for Industrial Process
SLFC	Small Linear Fresnel Collector
SMCs	South Mediterranean Countries
SPTC	Small Parabolic Trough Collector
SSFA	Small Scale Funding Agreement
SWERA	Solar and Wind Energy Resource Assessment
SWH	Solar Water Heater
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNEP DTIE	United Nations Environment Programme, Division of Technology Industry and Economic
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United State Agency for International Development

Units

GW	Giga Watt
GW_{th}	Giga Watt thermal
m²	square metres
mm	millimetre
lt	litres
kW	Kilo Watt
kW_{th}	kilo Watt thermal
MW	Mega Watt
MW_{th}	Mega Watt thermal
t/hr	tonne per hour
tCO_2/yr	tonnes of CO_2 per year
toe/yr	tonne of oil equivalent per year
Pa	Pascal

Background of the project

The United Nations Development Programme (UNDP) and United Nations Environment Programme (UNEP) have initiated Global Knowledge Management (KM) and Networking activities within framework of their project “Global Solar Water Heating (SWH) Market Transformation and Strengthening Initiative”. The Observatoire Méditerranéen de l’Energie (OME) as a regional partner to the project is committed to the development of knowledge products and services for SWH applications in Morocco, Tunisia, Egypt, Jordan and Turkey.

Although strong market development has been evidenced in some Global Environment Facility (GEF) program countries, notably in China and Turkey, in many others, solar water heating is hardly utilized despite very favourable climatic conditions. By any standards, the global, economically feasible potential for increased use of solar thermal applications for hot water preparation is huge and comparable to any other form of renewable energy the GEF has supported during its operations. As demonstrated by the experiences in many developing countries, it is a technology that can provide cost-effective energy solutions also to the lower income part of the population and as further demonstrated, can become a mass product leading to permanent market shift at the national level for the benefit of both the end users and the environment. There can also be other considerations to stimulate solar water heating. In summary, it is an economic, commercially viable and available technology, which due to the different market barriers, however, has not reached the market penetration rate that it could reach on simply economic grounds.

With respect to the above discussion the GEF has mandated the United Nations Development Programme (UNDP) and United Nations Environment Programme (UNEP) to establish a project titled “Global Solar Water Heating (GSWH) Market Transformation and Strengthening Initiative” at a global level. The project consists of two components as follows:

- Component 1 - Global Knowledge Management (KM) and Networking: Effective initiation and co-ordination of the country specific support needs and improved access of national experts to state of the art information, technical backstopping, training and international experiences and lessons learnt.

- Component 2 - UNDP Country Programs: The basic conditions for the development of a SWH market on both the supply and demand side are established, conducive to the overall, global market transformation goals of the project.

OME as the leading partner for the Mediterranean region is committed to generate knowledge products and services to ensure that developmental experiences and benefits of knowledge can be effectively disseminated to other regional countries.

The present document was produced within the framework of "Global Solar Water Heating Market Transformation and Strengthening Initiative" under UNEP's Small Scale Funding Agreement (SSFA). The objective of this report is to provide an overview of the state of the art of Solar Heat for Industrial Processes (SHIP), to describe the main application existing worldwide and in particular in the Mediterranean and to draw recommendations in order to foster the use of this technology based on best practices and lessons learnt. A specific focus will be done on Morocco, Tunisia, Egypt and Turkey.

Executive Summary

Solar heat for industrial process (SHIP) applications are still at an early stage of development. At present, around 200 operating solar thermal systems for process heat are estimated worldwide, for a capacity of about 42 MW_{th} (60,000 m^2)[1], or only 0.03% of the total solar thermal capacity installed. Most of these systems are of small-scale experimental nature.

Despite the limited penetration of solar technologies in the industrial sector, its potential is quite large. Indeed, in 2007 the industrial sector represented 28% of the final energy consumption in the EU 27, and about 30% in the South Mediterranean Countries (SMCs)[2], with a large part of heat below 250°C required. Tapping into this potential would provide a significant solar contribution to industrial energy systems.

In the first phase of the technology development, SHIP is and will be mainly used for low temperature processes (< 100°C), but with a stronger RD&D programmes medium temperature applications (< 250°C) will be achievable. Currently available technologies for SHIP applications using flat-plate collectors and evacuated tubes collectors are already suitable to provide the low temperatures required by many processes in the food, textile, transport, equipment and beverage industries. Other technologies and collectors such as improved flat-plate plate collectors, compound parabolic concentrators, small parabolic trough collectors and linear Fresnel collectors are being developed in order to supply solar heat for medium temperature industrial processes. The development of an industrial solar market would also benefit from the development of new generation of heat storage systems to compensate for the intermittent availability of the solar source.

The integration of solar systems in industrial process is not an easy challenge and requires a comprehensive approach of the whole system taking into

[1] W. Weiss, “Solar Heat for Industrial Applications: Potential, Framework Conditions and Build Examples”, presentation of November 2010, Melbourne, Australia

[2] The SMCs are: Algeria, Egypt, Israel, Jordan, Lebanon, Libya, Morocco, Occupied Palestinian Territories, Syria, Tunisia, and Turkey

account several parameters: energy efficiency measures, integration of heat recovery processes, and a detailed analysis of the energy demand and the different temperature levels of the processes at different points in time.

Although SHIP is still in its infancy, the increasing number of experimental solar plants being developed especially in the European Union, are giving more experience and feedback in their field. Although benefiting from high solar radiations, the SMCs have only few SHIP installations. Nevertheless, they are increasingly interested in developing this technology, with the establishment of national programmes (such as the PROSOL Industrial in Tunisia) or through the development of CDM projects (as in Morocco), with the perspective of reducing fossil dependence.

Despite its promising potential, SHIP is facing a series of barriers, including: the relative high costs of SHIP systems, the lack of dedicated support mechanisms to make this technology competitive vis-à-vis its fossil alternatives, the low awareness of decision and policy makers, the mistrust of industrial investors and managers vis-à-vis new technologies, the need to develop more suitable technologies for medium and high temperatures processes, the absence of planning guidelines and tools, and the lack of education and training programmes. A specific barrier which is particularly relevant in the SMCs is represented by the subsidies given to fossil fuels, which prevent the creation of a level playing field for renewable energy technologies. Shifting these subsidies from fossil fuels to solar (and other renewable) technologies would be therefore the main recommendation in order to foster the development of a sustainable and long-lasting solar industry in the SEMCs. Other relevant recommendations are: to create awareness particularly among decision makers and industrial players, to increase the number of demonstration projects in order to gather a more solid knowledge, to provide financial incentives for solar systems, as well as RD&D funding programmes on solar components for industrial processes, and to implement training courses for professionals.

Keywords

Egypt; Jordan, Morocco; Solar Heat for Industrial Processes (SHIP); Solar Thermal collectors; South Mediterranean Countries (SMCs); Tunisia; Turkey.

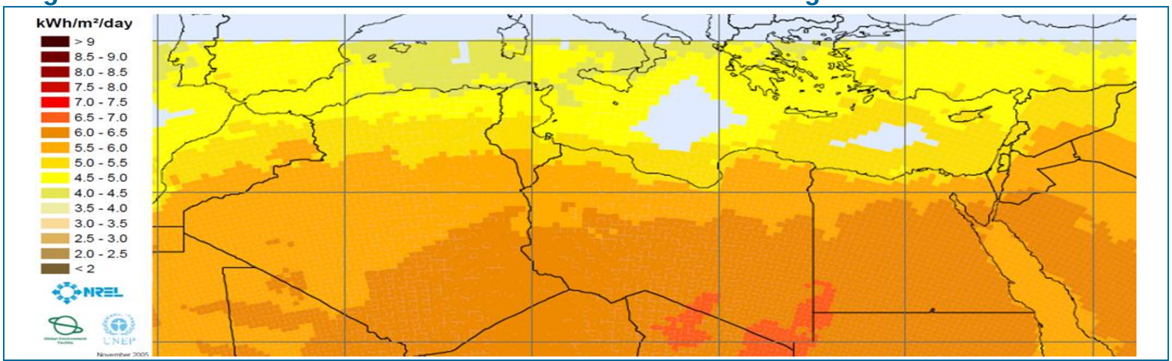
1. Background

According to the IEA-SHC programme[3], the installed solar thermal capacity worldwide by the end of the year 2010 is about 196 GW_{th}, corresponding to around 280 million square meters of collector area[4]. The SMCs represent about 10% of the total installed capacity, with more or less 20 million square meters installed[5]. Turkey is representing more than half of the total SMCs' capacity, with the remainder being split mostly in countries like Israel, Jordan and Tunisia.

The main applications of solar thermal plants are for domestic use like providing hot water or space heating. In addition to the residential sector, the solar thermal applications in industrial sector are more and more seen as an interesting option to lower the impact of fossil fuel in the energy balance of the countries.

Given the high level of solar radiation in the Mediterranean region (Figure 1 and Figure 2), the solar thermal energy for industrial process should be a real option to be considered in order to decrease the dependency on fossil fuels. Indeed, even though the investment costs of SHIP systems are relatively higher compared to conventional energy systems' investment cost, one can see the advantage to benefit from a free input -the sun- instead of a more and more fluctuating and expensive conventional fuel, especially if subsidized as in SMCs.

Figure 1: Global Horizontal Irradiance in the Mediterranean Region



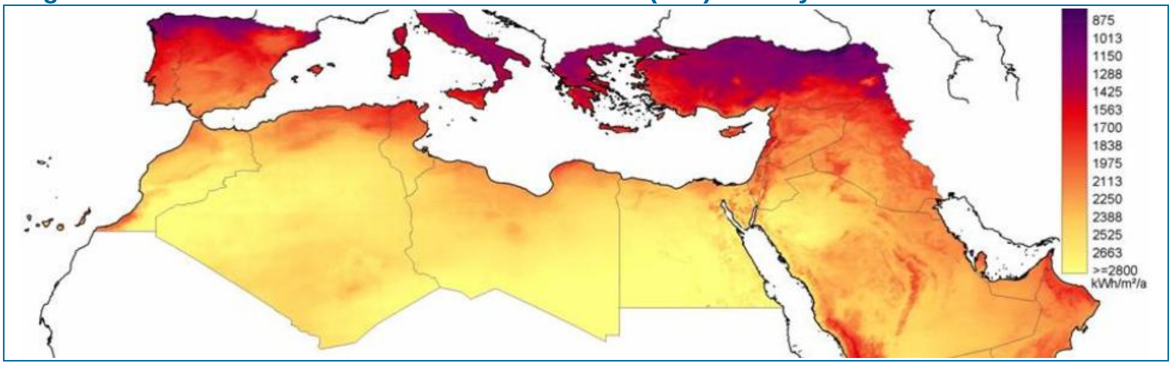
Source: Solar and Wind Energy Resource Assessment (SWERA)

[3] W.Weiss, F. Mauthner, Solar Heat Worldwide - Market and Contribution to the Energy Supply 2009, Solar Heating and Cooling Programme, International Energy Agency, 2011.

[4] The used factor is about of $0.7kW_{th}/m^2$ to derive the nominal capacity from the area of installed collectors, according to the methodology on which associations from seven countries agreed on, among them IEA SHC program and ESTIF

[5] See Observatoire Méditerranéen de l'Energie, D1.1 Initial Market Assessment, Solar Water Heating Market Transformation and Strengthening Initiative, 2010

Figure 2: Annual sum of Direct Normal Irradiance (DNI) in the year 2002



Source: DLR

In the following, we will first describe the SHIP technology aspects (components and integration process). Then, we will review the market potential and main applications for solar heat process. Finally, we will focus on existing SHIP installations in the world and in the Mediterranean region. This will allow to identify and cluster the main barriers hampering the deployment of the SHIP, and to draw recommendations in order to foster the use of the solar technologies in the industrial sector.

2. Solar process heat system components

An industrial solar installation consists of: i) a solar collector field, through which a working fluid (water, water and glycol or air) is circulated, ii) a regulation system (controllers), which controls this circulation depending on solar radiation intensity, iii) a heat exchanger which allows transforming solar energy to be used for the heating of liquids, air flows or for steam generation and, if necessary, a heat storage system[6].

1. Solar thermal collectors

The main component of a solar system is the solar collector. The solar thermal collector is a sort of heat exchanger which transforms the energy from solar radiation to internal energy of the transport medium. It converts the solar radiation into heat and transfers this heat to the working fluid circulating through the system.

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[6] For a complete description please refer to paragraph 2.3 "Integration of solar heat into an industrial process".

As shown in Table 1, solar thermal collectors can be classified following five characteristics: the motion of the system, the collector type, the absorber type, the concentrating or non-concentrating characteristic of the system and the range of the temperature delivered.

A stationary system does not use any mechanism to track the sun. Usually, such collector is oriented towards the equator with a tilt angle from the horizontal roughly equal to the latitude of the location for optimal year-round operation. The one single axis tracking system is a device allowing the solar system to follow the sun with one axis of rotation either along the east-west or north south directions. The two axis tracking system has two degrees of freedom that act as axes of rotation. The axes are normal to one another.

These collectors differ also regarding the type of absorber used to soak up heat from sunrays. Three different types of absorbers are used: flat, tubular or point. Flat absorbers are used in the panel which use all sunbeams (direct and diffuse) while tubular and point absorbers are used in concentrating systems. The reason of using concentrating systems is that the thermal energy obtained is at higher temperature.

Table 1: Solar Thermal collectors' characteristics

Motion	Collector type	Absorber type	Concentration	Indicative temperature range (°C)
Stationary	Flat plate collector (FPC)	Flat	No	30-80
	Evacuated tube collector (ETC)	Flat	No	50-130
	Compound Parabolic Concentrator (CPC) collectors	Tubular	Yes	80-200
Single axis tracking	Linear Fresnel reflector (LFR)	Tubular	Yes	60-400
	Parabolic trough collector (PTC)	Tubular	Yes	100-450
Two axes-tracking	Parabolic dish reflector (PDR)	Point	Yes	100-500
	Heliostats field collector (HFC)	Point	Yes	150-2000

Source: S.A. Kalogirou, 2004; T.A. Reddy et al., 2007; IEA-SHC Task 33/IV, 2008

Another characteristic of the solar collectors is the working fluid (liquid -water or oil- or air) used in the system, which are described in Table 2.

Most commonly used working fluids are water[7] and air. The air has poorer heat transfer characteristics with the solar absorber and therefore may operate at higher temperature than a system functioning with liquid working fluid. But the working fluid chosen will depend on the application (e.g. air for space heating or

[7] Glycol may be added to water to avoid freezing.

drying, liquid for hot-water application, even special oils for high-temperature applications because of better heat transfer characteristics).

Table 2: Comparison of liquid and air systems

Characteristics	Liquid	Air
Efficiency	Collectors generally more efficient for a given temperature difference	Collectors generally operate at slightly lower efficiency
System configuration	Can be readily combined with service hot-water and cooling systems	Space heat can be supplied directly but does not adapt easily to cooling. Can preheat hot-water
Freeze protection	May require antifreeze and heat exchangers that add cost and reduce efficiency	None needed
Maintenance	Precautions must be taken against leakage, corrosion and boiling	Low maintenance requirements. Leaks repaired readily with duct tape, but leaks may be difficult to find
Space requirements	Insulated pipes take up nominal space and are more convenient to install in existing buildings	Duct work and rock storage units are bulky, but ducting is a standard HVAC installation technique
Operation	Less energy required to pump liquids	More energy required by blowers to move air; noisier operation
Cost	Collectors cost more	Storage costs more
State of the art	Has received considerable attention from solar industry	Has received less attention from solar industry

Source: SERI, Engineering Principles and Concepts for Active Solar Systems, Hemisphere Publishing Company, New York, 1989

In case of high temperature required for running the processes, collectors needed to provide these heat requirements will differ from the most commonly used collectors. Only few collectors are available in the market today, which allow to reach higher temperatures; therefore RD&D plays a paramount role to develop and optimise high performance collectors providing higher temperatures. In this respect, the International Energy Agency's Solar Heating and Cooling Programme (IEA-SHC) has developed and tested three categories of medium temperature collectors as part of their Task 33[8]:

- Improved flat plate collectors;
- Concentrating flat plate and evacuated tube collectors;
- Other – more highly – concentrating collectors (such as small parabolic trough collectors and Linear Fresnel collectors).

In the following, both common and new collectors are briefly described[9].

[8] http://www.iea-shc.org/task33/
[9] For more information, please refer to the IEA-SHC Task 33/IV's *Process Heat Collector* publication.

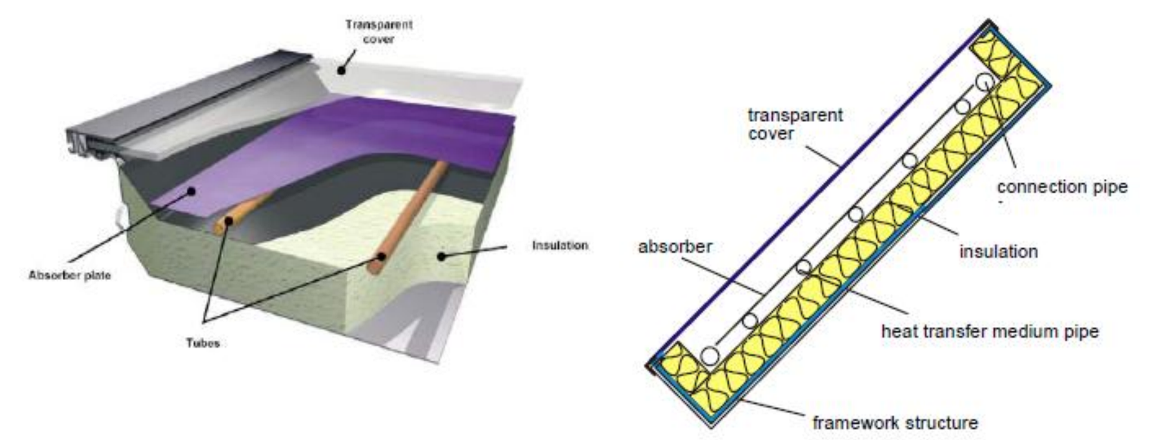
1.1 Flat plate collector (FPC)

1.1.1 Standard flat-plate collector (SFPC)

The most common collectors used nowadays are the SFPC since they are cheaper and appropriate for delivering energy at temperature ranging from 30 to 80°C. They fall in the stationary motion, use a flat absorber and absorb all radiation of the sun (direct and diffuse).They are of a very simple use as there is little maintenance and are relatively inexpensive.

The solar radiations pass through the transparent cover and reach the blackened absorber plate surface. Thus the radiation is absorbed by the plate and transformed into thermal energy which is transferred to the transport medium fluid within the tubes. The usual fluid is water/glycol mixture (with some additives) in order to avoid corrosion and frost damages (Figure 3).

Figure 3: Cross-section views of a flat-plat collector



Source: Consolar GmbH (left), AEE INTEC 2009 (right)

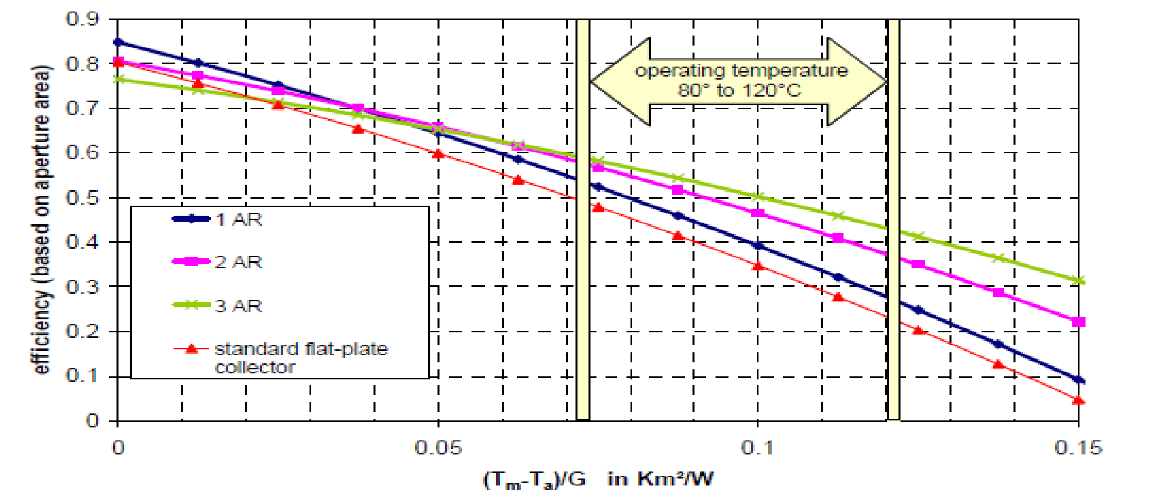
1.1.2 Improved flat-plate collector

Standard flat-plate collectors have high heat losses and need improvements to cope with higher operation temperatures. Therefore, improved flat plate collectors (IFPC) are being developed, which can operate at temperatures ranging from 80°C to 150°C. The main technological improvements are:

- Replacing the single glass by multiple glassed with anti-reflective (AR);
- Filling hermetically sealed collectors with inert gas;
- Create a vacuum in the collector;

These improvements take into account the necessary need of reducing the thermal losses and keeping high optical efficiency. The Figure 4 shows the results of these improvements on the efficiency of the collectors.

Figure 4: Comparison of the efficiency curves of a standard flat-plate collector and of a single, double and triple anti-reflective (AR) glazed collectors



Source: M. Rommel, Fraunhofer ISE

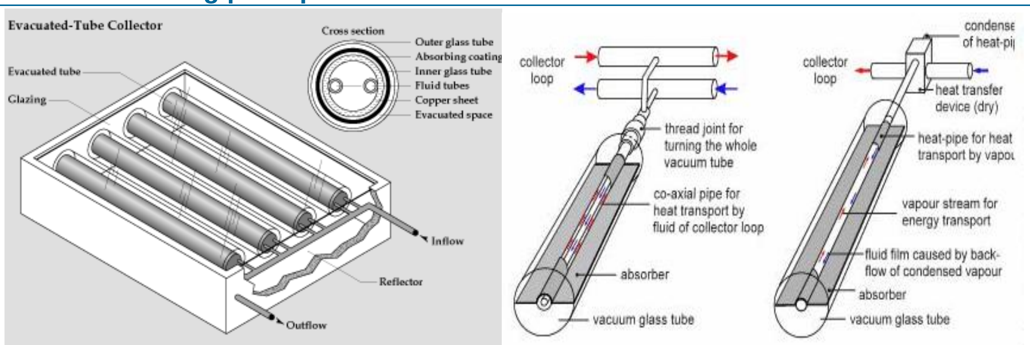
1.2 Evacuated Tube Collector (ETC)

The ETC are also quite common and can achieve higher temperature than SFPC ranging from 50 to 130°C. They also fall in the stationary motion system category, collect both direct and diffuse radiations, and use a flat absorber.

They are made up of vacuum glass tubes. The absence of air highly reduces convection and conduction thermal losses. There are several types of evacuated tubes in use for solar collectors. They have similar technical attributes:

- A collector consists of a row of parallel glass tubes;
- A vacuum (<10^{-2} Pa) inside every single tube extremely reduces conduction losses and eliminates convection losses;
- The form of the glass is always a tube to withstand the stress of the vacuum.

Figure 5: Functioning principle of evacuated tubes collectors



Source: your-solar-energy-home.com (left); H. Müller-Steinhagen 2008 (centre and right)

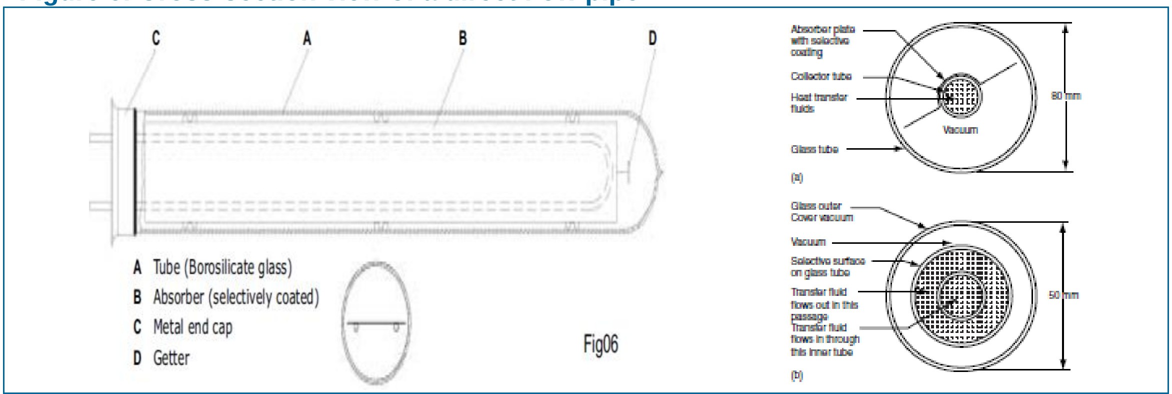
The evacuated tubes have also a barium getter component in common. The main role of the getter is to maintain the vacuum inside the tube and to give a visual indicator of the vacuum status. The silver colour of the barium will turn white in case of presence of air indicating the bad functioning conditions of the evacuated tube. Two main categories of evacuated tubes can be identified:

- *Direct flow principle:* the heat transfer fluid of the collector loop flows directly through the absorber via a co-axial tube (Figure 5 centre);
- *Heat pipes principle:* the heat of the absorber is transferred to the heat transfer fluid of the collector loop via a heat pipe system (Figure 5 right).

1.2.1 Direct flow evacuated tube collectors

Different arrangements are possible for configuring the evacuated tube collectors. The configuration shown in the diagram at the top right of Figure 6 is similar to a flat-plate collector with the working fluid passing through the collector tube. In the second configuration at the bottom right of the Figure 6, only the fluid outlet is connected to the absorber. Thus the working fluid being heated passes up the middle of the absorber tube, and the pipe for the inlet fluid is located inside the outlet fluid pipe. The main advantage of the second configuration is that it allows installing the collector at any desired tilted angle. New developments are ongoing as the Lenz tube improving the heat transfer (IEA-SHC Task33/IV, 2008).

Figure 6: Cross-section view of a direct flow pipe

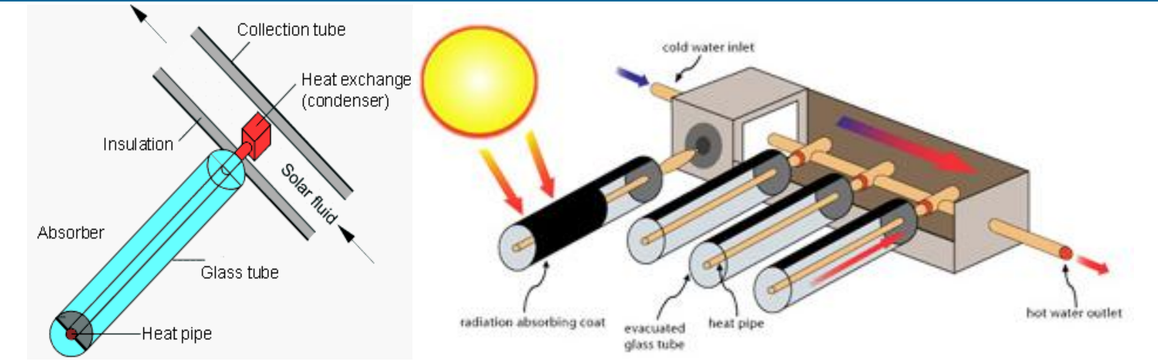


Source: IEA-SHC Task33/IV, 2008, T. A. Reddy et al., 2007

1.2.2 Heat pipe evacuated tube collector

The heat pipe design differs from the direct flow configuration as the heat carrier fluid is not connected to the solar loop (Figure 7). The pipes must be angled at a specific degree above horizontal so that the process of vaporizing and condensing can work properly. There are two types of collector connection to the solar circulation system. Either the heat exchanger extends directly into the manifold ("wet connection") or it is connected to the manifold by a heat-conducting material ("dry connection"). A "dry connection" allows exchanging individual tubes without emptying the entire system of its fluid.

Figure 7: Heat pipe evacuated solar collector diagram

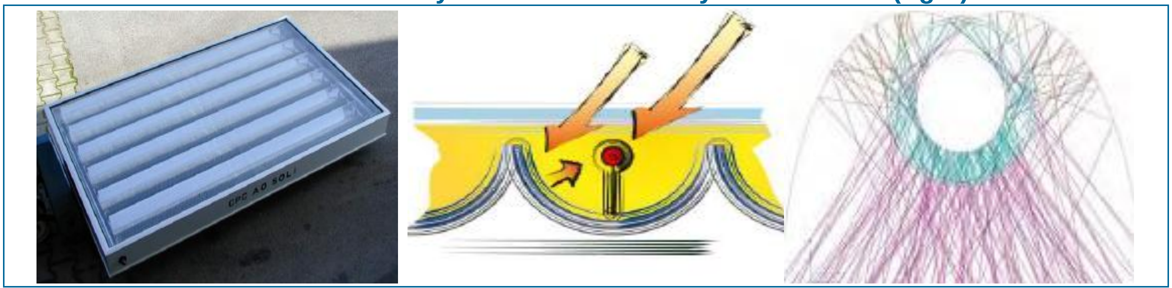


Source: Sky power (right)

1.3 Compound Parabolic Concentrator (CPC) collector

The CPC collectors have been conceived in order to reduce the heat losses of solar collector in reducing the area of absorber with respect to the collecting area (Figure 8), since the heat losses are proportional to the absorber area and not to the aperture area. The concentration is obtained using reflectors that force the radiation incident within a certain angle into the collector aperture in direction to the tubular absorber after one or more reflections (POSHIP final report, 2001).

Figure 8: photo of CPC collector (left) and cross section views of a CPC collector (center) and of the receiver of a Fresnel system with secondary concentrator (right)



Source: AO Sol Portugal (left), Solarfocus (center), IEA-SHC Task 33/IV (right)

CPC collectors are a natural candidate to bridge the gap between the lower temperature solar application field of flat-plate collectors (T<80°C) to the much higher temperature applications field of focussing concentrators (T>200°C) (IEA-SHC Task 33/IV).

CPC collectors can be designed for different level of concentration (low or high) depending on the acceptance angles. These concentrators can be stationary with only tilt seasonal adjustments.

There are several kinds of CPC collectors:

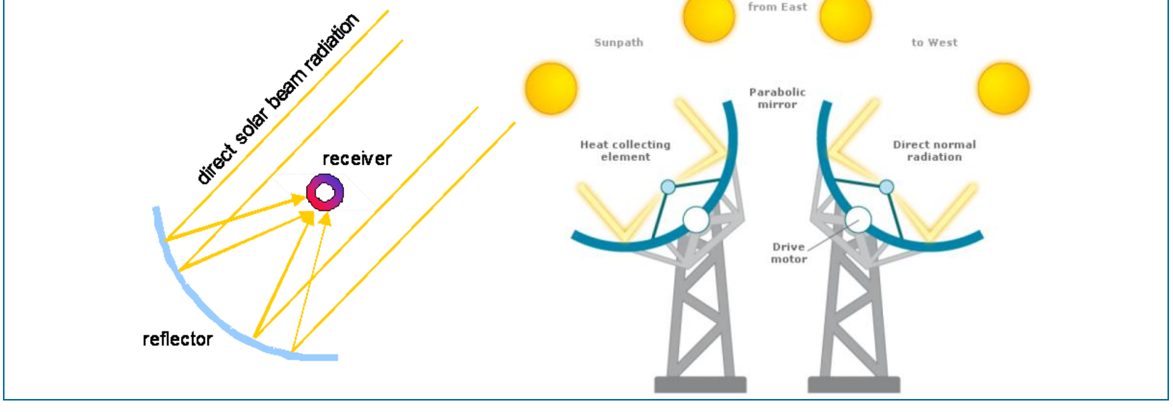
- *Low concentration:*
  - the non-evacuated CPC collectors which can deliver up to 100°C;
  - the evacuated tubes CPC collectors which can deliver up to 200°C;
- *High concentration:* Some collectors on the market today use this concept, where a second-stage CPC type concentrator further concentrates the radiation emerging from a linear primary concentrator of the Fresnel type (Figure 8).

1.4 Parabolic Trough Collector (PTC)

The PTC only use the direct solar radiation, thanks to mirror surfaces curved in a parabolic shape towards an absorber tube running the length of the trough. The troughs are normally designed to track the sun along one axis oriented in the north-south or east-west direction (Figure 9).

The reflecting surface is often an aluminium sheet or a reflective coating applied directly to the curved glass section forming the parabola. The receptor consists of an absorber tube of an area usually 25 to 35 times smaller than the aperture (of about 6 metres). The fluid to be heated is circulated through the absorber piping. Water and thermal oil are typically used as working fluids.

Figure 9: Parabolic trough diagram



Source: DLR (left), Abengoa (right)

Parabolic trough collectors are the most mature concentrating solar technology to generate heat at temperatures up to 450 °C for solar thermal electricity generation or process heat applications.

PTC can run following two operation modes:

- *Indirect mode:* the heat transfer medium (usually thermal oil) does not evaporate in the collector field;
- *Direct mode:* steam is directly generated in the collector field. The main challenge in this mode is the freezing of the transfer medium (usually water).

1.4.1 Small Parabolic Troughs Collector (SPTC)

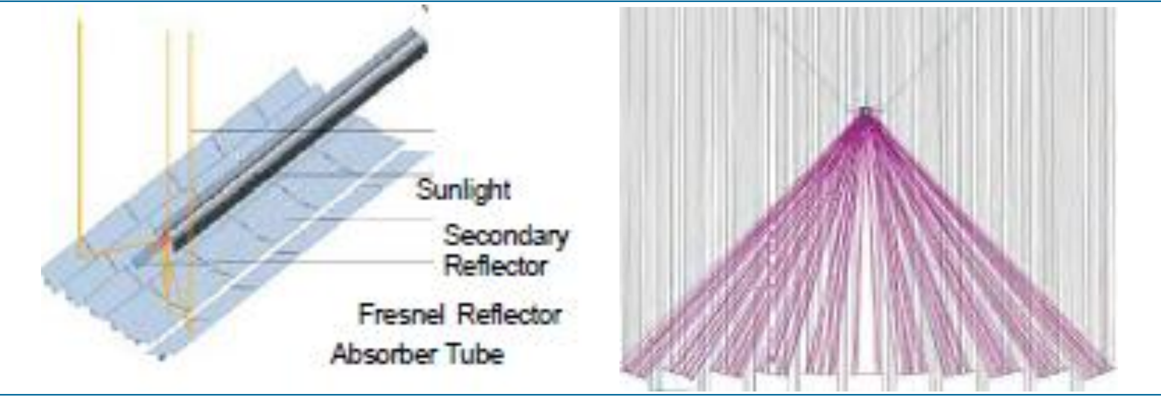
Small parabolic trough can operate at lower temperatures ranging from 100°C to 250°C. The aperture of the trough is lower and comprised between 50 centimetres and 2.3 metres. One of the main advantages of these SPTC compared to the ones used in power generation is that they are lighter and easier to install (they can be installed even on roofs).

SPTC have been mainly developed in recent years, a few demonstration systems are in operation.

1.5 Linear Fresnel collector (LFC)

The LFC is composed of several line reflectors (usually flat mirrors) which reflect the DNI on the receiver situated alongside the collector. As for PTC, these reflectors are normally designed to track the sun along one axis oriented in the north-south or east-west direction. They have high concentration ratio and thus can reach high temperatures around 400°C.

Figure 10: Diagram of LFC (left); Cross section view of LFC (right)



Sources: IEA-SHC Task 33/IV

At the early stage of development, LFC were developed for large-scale solar thermal power. As for PTC, in order to lower temperature output, LFC have to be designed scaling down: Small Linear Fresnel Collectors (SLFC). In doing this, SFLC meet the special boundary conditions for the generation of industrial process heat (IEA-SHC Task 33/IV, 2005):

- The collector can be used for processes starting with a thermal capacity of around 50 kW and up to several MW.
- The collector is easy to mount on flat roofs as a result of good weight distribution and low wind resistance. It also allows very high surface coverage so that the heat can be produced close to where it is needed and to where space is not so freely available.

2. Controllers

As the brain of a system, a controller's key function is to monitor temperatures and to control the pumps ensuring that any available solar energy is delivered to the heat system.

Up to now, there are not standardised controllers for SHIP due to the variety of industrial processes, which make such standardisation very complicated. A lot of sensors and controllers are already available on the market, but the key challenge to address is the configuration of the control system: the control strategy must be tailored to the concrete heat demand and system (K4RES-H project, ESTIF, 2004). As a matter of fact, the development of more demonstration projects will allow developing best practice guidelines and defining more standardised control systems for SHIP applications.

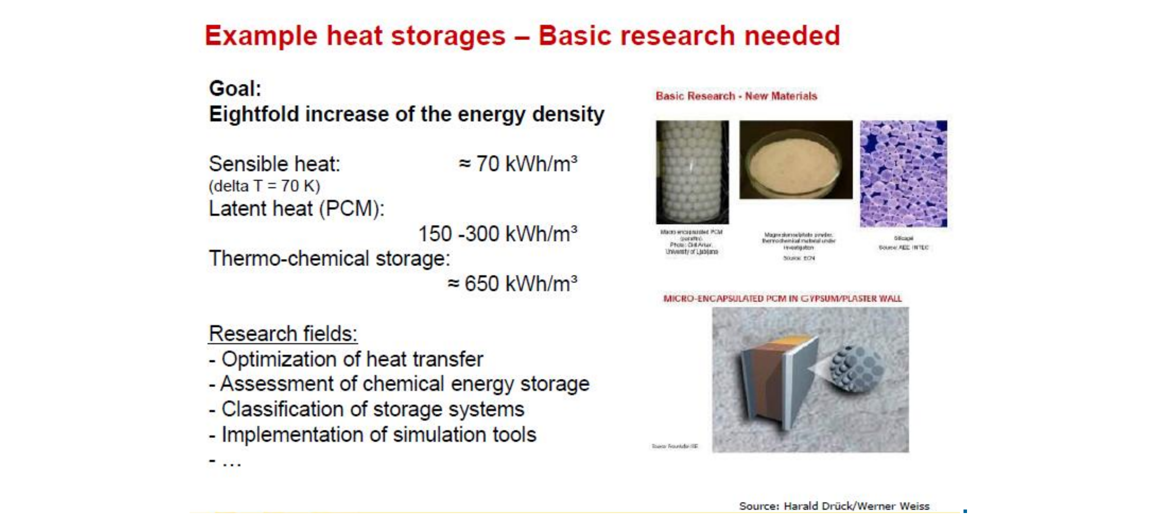
3. Heat storage

The use of heat storage can be required or advantageous depending on the conditions of the whole heat system, and when there is a mismatch between thermal energy supply and energy demand. Up to now, the widely heat storage used is the water-based storage, which is relatively inexpensive but had the inconvenient of a low energy density and decreasing overtime.

In order to address deployment of solar thermal market, the storage systems have to be more efficient for longer periods of time. The ongoing RD&D projects on advanced storage technologies, such as concepts with phase change materials or with thermo chemical materials, are giving promising results as they could store large amounts of energy and larger period than sensible heat storage.

The main goal of these ongoing RD&D activities is to eightfold increase the energy density of storage systems (Figure 11) reaching higher value than available market storage systems.

Figure 11: Example of heat storages research



Source: G. Stryi-Hipp, ETP-RHC, ESTEC 2009

3. Industrial solar system concepts

The integration of solar energy into an industrial process requires studying and analysing the existing heat supply system and determining the potential energy savings and the energy flows and temperatures levels of the process.

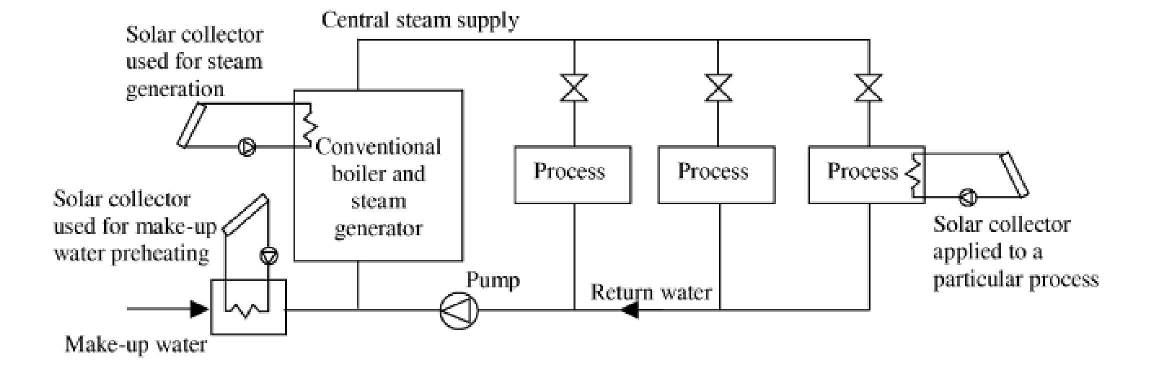
1. Integration of solar heat into an industrial process

Integrating solar heat into industrial process is a complex operation compared to others conventional heat supply systems. The best integration of a solar process into an industrial process requires taking into consideration all aspects related to energy efficiency and heat recovery that could lead to economical, technical and organisational improvements. Solar integration into industrial process needs to pay particularly attention to energy saving potentials through a technological optimisation of the process in itself and a system optimisation of the whole production.

In general, the solar system will provide only a part of the overall process energy demand. While conventional heat systems most often do not pay attention to the temperature level (and consequently are over dimensioned), the integration of solar heat systems in the process implies taking care of the temperature levels of the whole system.

In most factories, the central system for heat supply is working with hot water or steam at a pressure corresponding to the highest temperature needed among the different processes. Thus solar systems can be coupled with the conventional heat supply system for preheating water (or other fluids) used for processes or for steam generation or by direct coupling to an individual process working at lower temperature than that of the central steam supply (Figure 12).

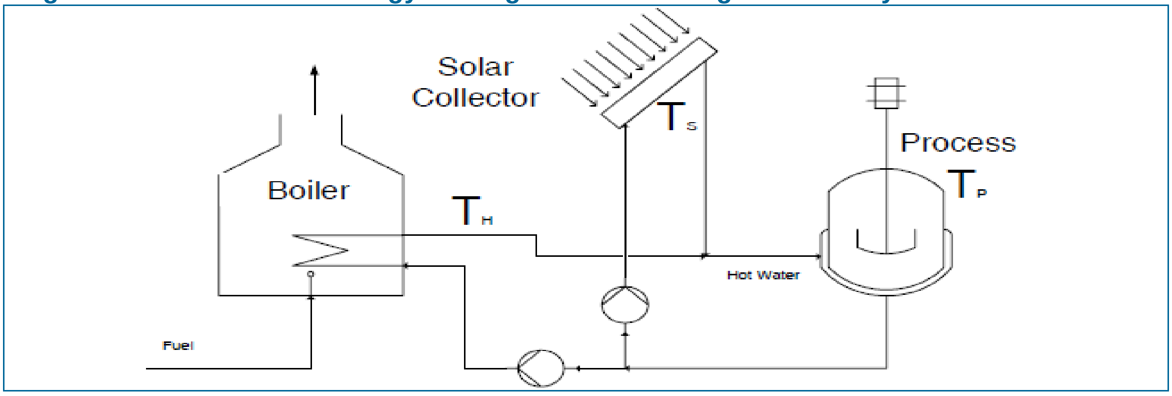
Figure 12: Possibilities for the coupling of the solar system with the conventional heat supply



Source: S.A. Kalogirou, 2004

The integration of solar thermal heat into industrial processes can also be done by integrating the solar heat directly into the existing heating system (Figure 13). Such integration requires that the solar collector operates at the same temperature than the existing heating system. While it is the easiest way to integrate solar thermal into the process both in terms of installation than of control, the thermal efficiency should be lower, and the best heat transfer medium would be water to the largest extant.

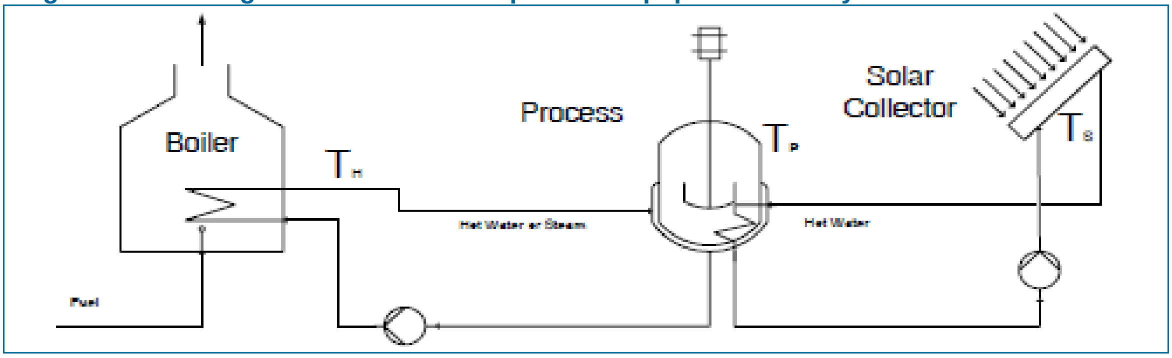
Figure 13: Solar thermal energy feeding into the existing hot water system



Source: IEA-SHC Task 33/IV

Another possibility of integrating solar system in the conventional heat system is to integrate it directly in the process heat (Figure 14). This implies to integrate another heat transfer in the production area if the temperature from solar system differs from the temperature coming from the heating medium. In this configuration, the efficiency of the solar collector can be boosted when the temperature of the process is close to the temperature from the solar collector.

Figure 14: Feeding of solar heat to the process equipment directly

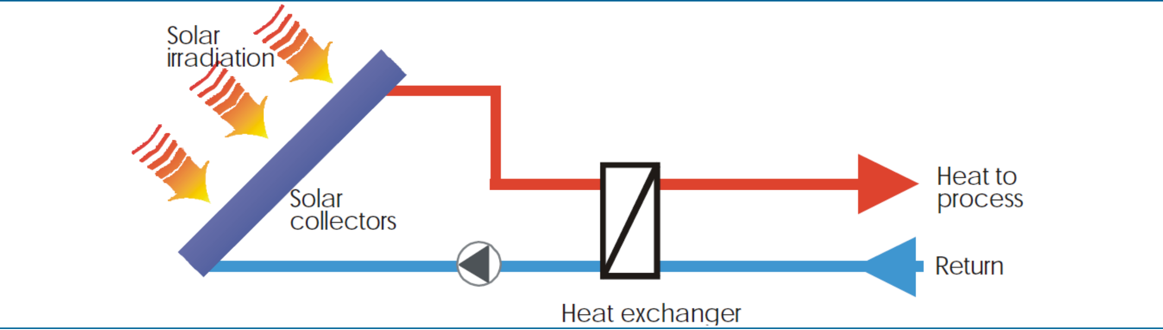


Source: IEA-SHC Task33/IV

Industrial solar systems without storage

In a lot of industries, the implementation of solar system does not require a storage system as the heat needed is higher than the heat provided by the solar system. This could happen when the process requires a continuous operation and/or a load always higher than the supply of heat by the solar system. In this case, the installation of solar energy system remains low cost, avoiding high storage related costs. In such configuration, the solar heat will be fed directly to the process or to the already existing heat supply (Figure 15).

Figure 15: Sketch of a solar system without storage



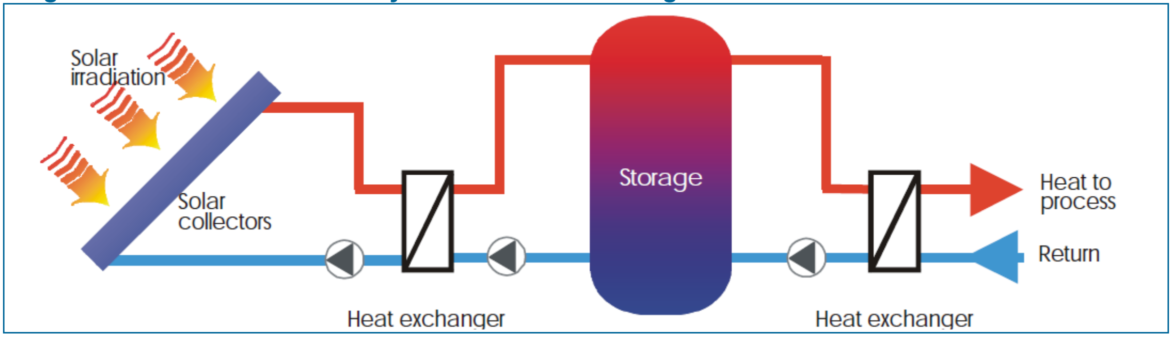
Source: POSHIP project, final report, 2000

Figure 15 is representing a system which needs a heat exchanger as the working fluid of solar system is a special fluid to protect the collector from freezing and corrosion.

Industrial solar systems with heat storage

Most industrial processes do not operate in a continuous mode over time, being ticked over at some time with strong fluctuation of the process heat demand during the operational periods. In these cases, a storage tank can be coupled to the solar system (Figure 16), which will store the unused solar energy collected during the operating-breaks (week-ends, short break of operation…) and will restore this energy collected to the process system during the working process periods.

Figure 16: Sketch of a solar system with heat storage



Source: POSHIP project, final report, 2000

The sizing of the storage tank will depend on the fluctuation of the demand over time (Figure 17).

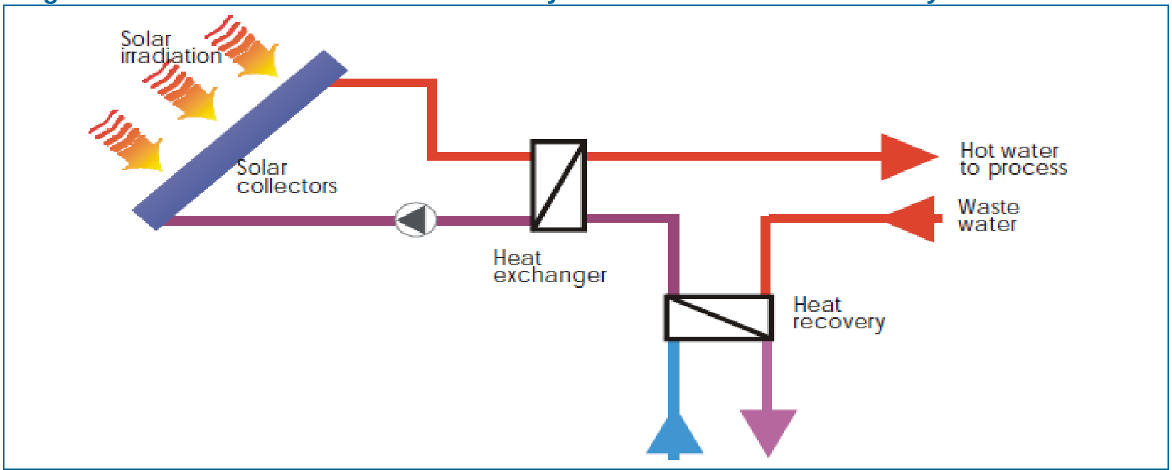
Figure 17: Heat storage size depending on daily and weekly heat demand profiles

	Demand profile Daily	Demand profile Weekly	Storage size
Constant daily demand in sunny hours (7 days/week)			No storage needed
Fluctuating daily demand in sunny hours (7 days/week)			20–80 l/m[2] (depending on consumption profile)
Fluctuating daily demand in sunny hours (5 days/week)			80–150 l/m[2]

Source: T.A. Reddy et al., 2007

As explained above, the integration of solar energy systems has to be thought within an approach which takes into consideration energy efficiency measures of which the waste heat recovery is one of the main measures. Thus solar heat should be introduced after a first preheating by waste heat recovery systems, and not as an alternative to these systems. Even if waste heat recovery raises the working temperature in the solar system, the combination of both systems yields better results than a solar system at lower temperature without heat recovery (Figure 18).

Figure 18: Combination of solar thermal system and waste heat recovery



Source: POSHIP final report

Figure 19 represents all the system concepts that could be experimented in the industrial sector. This chart was developed within the IEA-SHC Task Force 33/IV in 2005.

2. Designing a solar system for industrial process

The Intelligent Energy for Europe (IEE) "Solar Process Heat" (SO-PRO) project, which aims to trigger the starting-up of markets for solar process heat in 6 European regions[10], is performing studies for installations within industrial process running at temperatures below 100°C. The project targets to increase awareness for industrial decision makers, to train professionals, to develop planning guidelines and 12 pilot projects

Two reports were published by the project consortium in early 2011: i) "Checklist for companies" and ii) "Solar Process Heat Generation: Guide to Solar Thermal System Design for Selected Industrial Process"[11] which are addressed to solar companies, installers, specialised planners, energy advisors and researchers. These reports are short, practice-oriented documents providing technical information on how solar thermal can be integrated into four selected industrial processes: heating of hot water for washing or cleaning; heating of make-up water for steam networks; heating of baths or vessels; convective drying with hot air.

The SO-PRO reports suggest that a preliminary analysis composed of four consecutive steps is required before designing the appropriate solar thermal system: analysis of building and boundary conditions; analysis of process characteristics and heat distribution network; discussion of future plans of the company; potential analysis for process optimisation and energy efficiency measures. This methodology has to be applied individually to each plant, as the plants have their own heat supply systems within different conditions.

The preliminary analysis gives the most important framework conditions and energy efficiency measures that should be put in place. For the design of a solar thermal system generating industrial process heat the following steps are recommended (S. Heß, A. Oliva, 2011):

- "Calculate the thermal load for the solar thermal system (the thermal energy the solar plant could theoretically provide to the connected

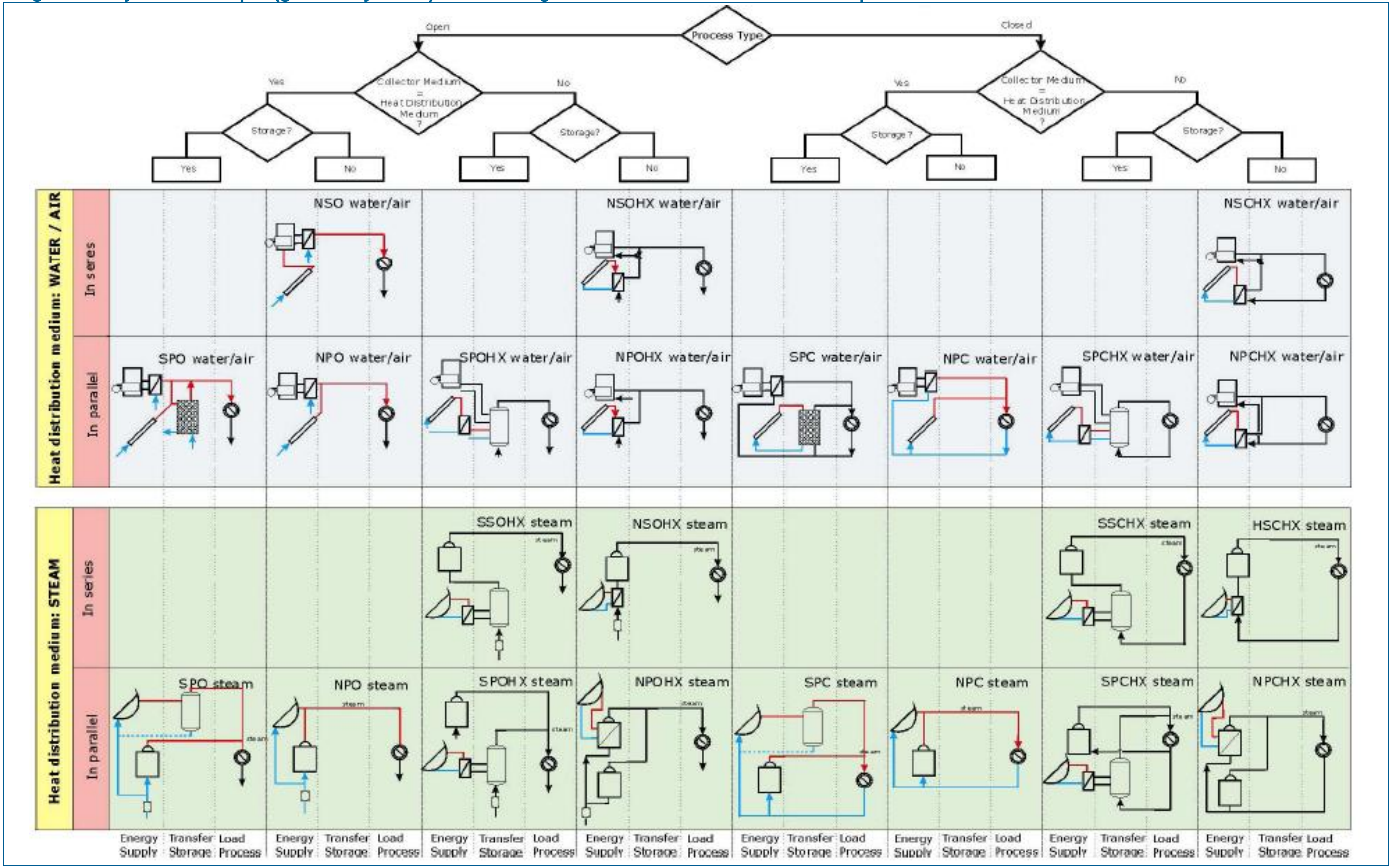
[10] Upper Austria -Austria-, Regions of Castillas y Madrid -Spain-, South Bohemia -Czech Republic-, North-Rhine Westphalia and Saxony -Germany-, and Podravje region -Slovenia

[11] The report is downloadable from www.solar-process-heat.eu.

processes) and generate an overall thermal load profile (temporal distribution of the thermal load);

- Determine roughly the necessary collector area and storage volume to get a feeling for the resulting size of the installation and to find reasonable starting points for the simulation of the solar thermal system;
- Perform system simulations varying the size of the collector field, the collector type and the storage volume, possibly also the solar thermal system concept and the supported processes;
- Decision for one variant of the solar thermal system considering economical, technical, public relation and future aspects of the industrial company."

Figure 19: System concepts (generic systems) for the integration of solar heat into industrial processes



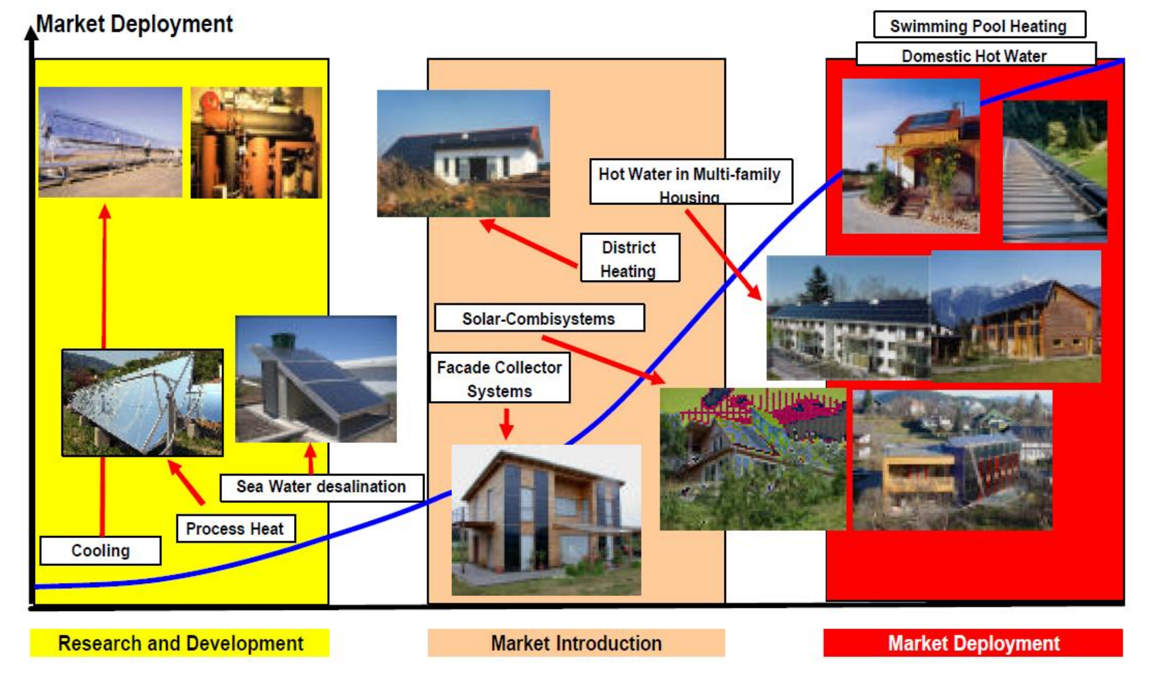
Source: IEA-SHC Task33/IV, 2005

4. Potential for solar heat in industrial processes

1. Market potential

Solar thermal systems are wide-spreading at world level. As mentioned already, up to know the main applications have been in the domestic sector (Domestic solar water heaters – DSWH- and collective solar water heater installations) and swimming pool heating which are in a market deployment stage. Other applications, as district heating, are in a market introduction stage with more and more installations being developed especially in Europe. Solar process heat (as well as solar water desalination and solar cooling) systems are still in a development stage, requiring more experience trough experimental projects implementation (Figure 20).

Figure 20: Market Deployment of solar thermal systems

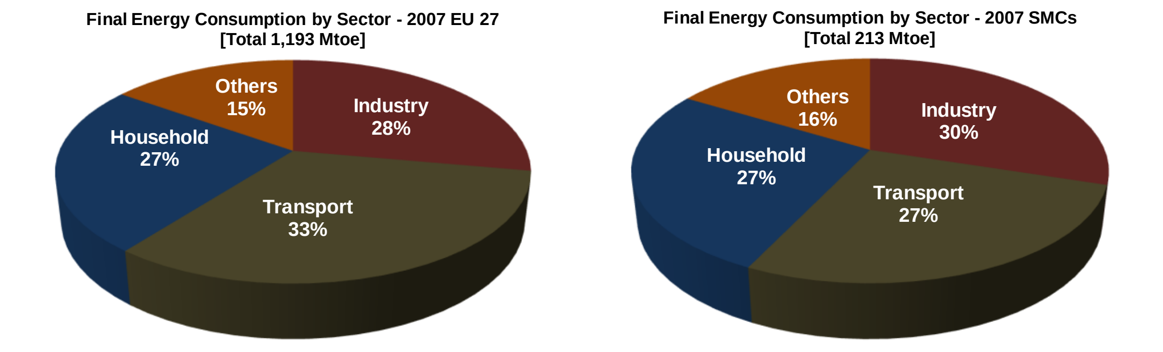


Source: G. Faninger, 2010

Industry represents a key sector in the objective to increase the share of renewable energy in the energy mix due to its importance in the total energy consumption. In 2007, the share of industry sector in the EU total final energy consumption was about 28% (Figure 21) while in the SMCs it represented about 30% (OME, 2010). So far there is limited experience in SHIP applications at global level, and even those experiences are not very well documented. According to the most recent statistics available (C. Vannoni et al., 2008) as of

October 2007, the share of solar thermal applications in industry represented only 0.03% of the total solar thermal capacity installed worldwide.

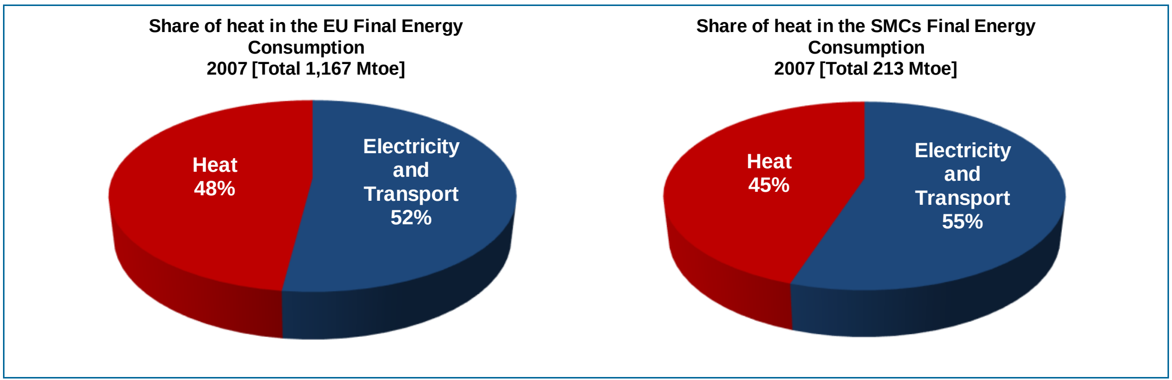
Figure 21: Final energy consumption by sector in EU 27 in 2007 (left) and in SMCs in 2007 (right)



Source: Eurostat, OME

Total heat demand in the final energy consumption is estimated at about 48% in EU27 and 45% in the SMCs (Figure 22).

Figure 22: Share of heat in final energy consumption in EU 27 (left) and in SMCs (right) in 2007

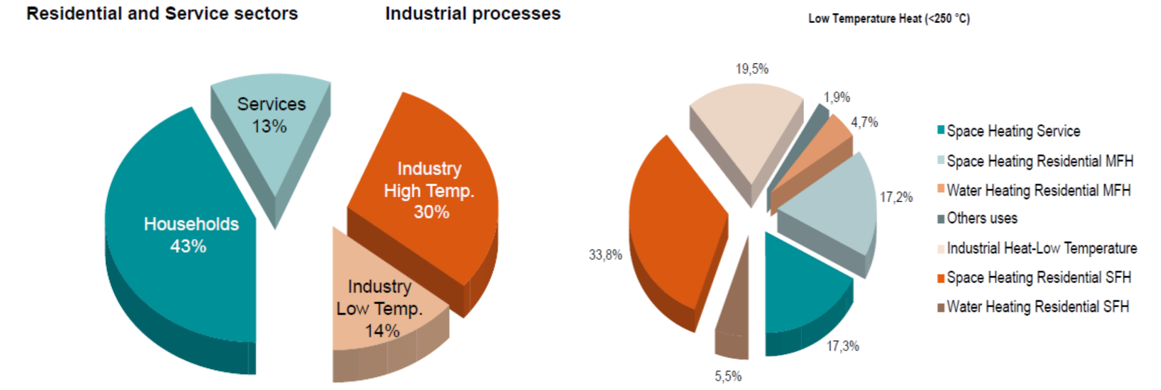


Source: RHC 2011 (left), OME 2010 (right)

An in-depth study carried out by ESTIF based on data for the year 2006[12], identified the share of low temperature (< 250°C) and high temperature (> 250°C) heat in the total final energy consumption in EU 27. According to this study, 34% of the final energy consumption is low temperature (<250°C) heat and 15% is high temperature heat. The low temperature represents 70% of the heat market in EU, strongly driven by the household heat demand (Figure 23). The distribution of heat users within the low temperature range for the year 2006 is given in Figure 23.

[12] Weiss W. Biermayr P., Potential of solar thermal in Europe, ESTIF 2009.

Figure 23: Distribution of heat by use types in EU 27 (left) and distribution of low temperature heat by use type in EU 27 (right)

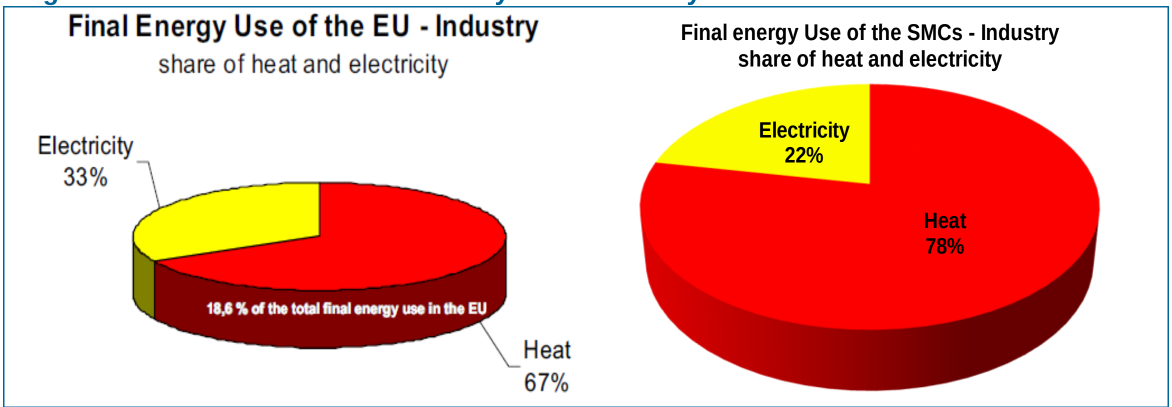


Sources: RHC 2011

The relatively high penetration of DSWH installation is mainly due both to the high share of low temperature demand in households sector and the cost-effectiveness of the technology available for such applications (mainly SFPC and ETC). However looking at Figure 23 one can see that industry low temperature heat demand reaches 20% in 2005 in EU 27, thus representing a potentially attractive market for solar thermal application. In order for this market to take off, strong RD&D activities are needed, as well as more SHIP demonstration plants to prove the reliability and economical viability of such technology (Figure 23).

In EU, only around one third of the energy demand in industrial sector is related to electricity, the remaining being related to heat while in SMCs less than a fourth is related to electricity (Figure 24).

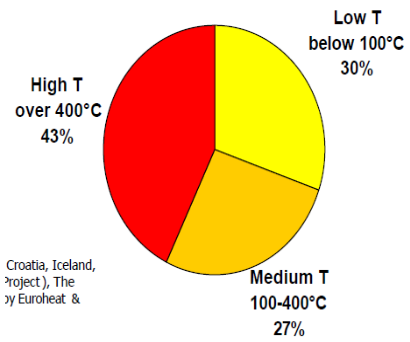
Figure 24: Share of heat and electricity in the industry in EU and SMCs



Sources: Green Paper - Towards A European Strategy For The Security Of Energy Supply, Brussels, 2001 (left); OME (right)

The ECOHEATCOOL project made an evaluation of the heat demand in industrial sector in 32 countries by temperature and by industrial sector (Figure 25). The fact that a significant share of the heat consumed and needed in industrial companies (Figure 25) is in the low (<100°C: 30%) and medium temperature range (between 100°C and 400°C: 27%) suggests that solar thermal applications are promising and suitable for industrial sector notably among others in the chemical, paper, food processing, textile sectors, etc. The possible areas of application include different processes such as drying, washing, process steam production, chemical reaction, boiling, etc[13].

Figure 25: Share of industrial heat demand by temperature in industrial sector (Data for 2003, 32 countries: EU25 + Bulgaria, Romania, Turkey, Croatia, Iceland, Norway and Switzerland)



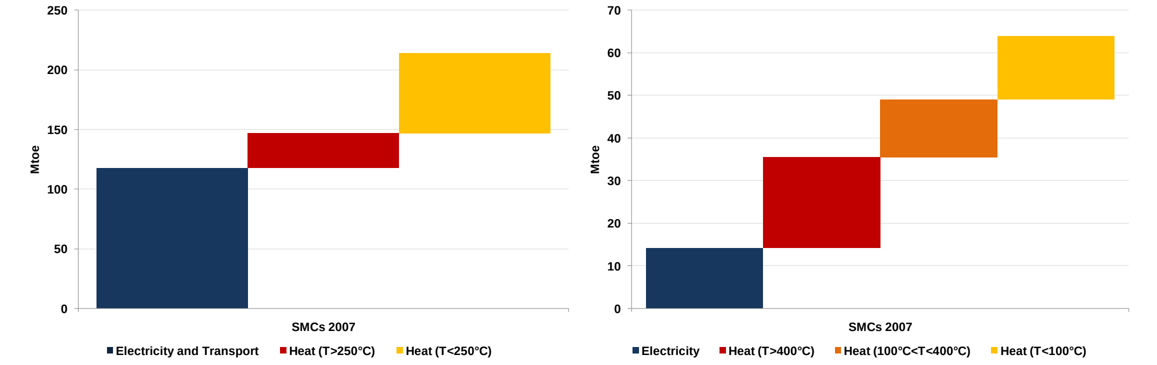
Source: ECOHEATCOOL project, 2006

Given the lack of specific information on industry process profiles in the SMCs, a preliminary estimate of the potential for SHIP applications in this region can be based on the statistics regarding the industrial heat temperature level distribution shown in Figure 25. By applying the same share to the SEMCs a very preliminary idea of the volume market for SHIP applications can be gathered. It is worth signalling however, than a more precise analysis of the different processes in the industry sector in the SEMCs is needed in order to get a more analytical picture.

The results of this preliminary exercise are shown in Figure 26. As one can see, the maximum amount of low temperature heat in final energy consumption that could be potentially covered by solar heat in the SEMCs is estimated at 67 Mtoe in 2007. As for the industrial sector, 28 Mtoe of the energy consumption heat is temperature below 400°C.

[13] see 4.3 Potential in different industrial sectors

Figure 26: Distribution of heat in final energy consumption in SMCs in 2007 (left), Distribution of heat in industrial final energy consumption in SMCs in 2007 (right)



Sources: Eurostat (left), OME (right)

2. Scenario for the market deployment of solar thermal system

The following section reports the results of a series of scenario analysis and prospects for solar thermal carried out at European level. For example within the framework of the RESTMAC project, a study was released (W. Weiss and P. Biermayr, 2009) aiming at assessing the contribution of solar thermal to the 20% EU renewable energy target (directive 2009/28/EC). To this end, detailed surveys were conducted in five representative countries (Austria, Denmark, Germany, Poland and Spain). The information gathered was then extrapolated to the 27 EU countries and the future heating and cooling demand was calculated for 2020, 2030 and 2050, taking into account a decline of the overall energy demand due to energy efficiency measures. The study calculated the EU 27 solar thermal share in the heat and cooling demand. In addition, the study develops 3 scenarios: Business as usual (BaU)[14], Advanced Market Deployment (AMD)[15] and Full R&D and Policy (RDP)[16].

[14] BaU assumptions:

- No reduction of the heating and cooling demand compared with 2006.
- Moderate political support mechanisms: Except for a few countries at the forefront no solar obligations for new residential buildings; subsidies (10-30% of the system cost) for residential buildings and moderate energy prices of fossil energy.
- Low R&D rate and therefore no solution for high energy density heat stores or new collector materials; no sufficient and cost competitive solutions for solar thermal cooling.
- Main focus on solar thermal systems for hot water preparation (solar fractions 50 - 70%) in the residential sector; solar combisystems with low solar fraction (10-20%); marginal market diffusion in all other sectors.
- Low growth rates of installed capacity (7-10% per annum until 2020).

[15] ADM Assumptions:

- Moderate reduction of the heating demand compared with 2006 (depending on the country but on average: -5% by 2020, -10% by 2030 and -20% by 2050).
- Political support mechanisms: Solar obligations for all new residential buildings; subsidies for existing residential, service and commercial buildings as well as for industrial applications (subsidies: 10 - 30% of the system cost) or constantly moderate rising energy prices of fossil energy.

The main results of this scenario analysis are (Figure 27 and Figure 28):

- The BaU scenario shows moderate growth rates of the annually installed capacity until 2035. Around 2035, the installed capacity is expected to be saturated. Indeed under this scenario the main application of the solar thermal systems considered is hot water preparation and solar combisystems[17] with low solar fractions. By 2030 nearly the full potential for these applications should be exploited and the annually installed capacity will be reduced mainly to the replacement of old systems;
- Both the RDP and the AMD scenarios are based on the assumption that the main application of solar thermal technologies is space heating (solar combisystems) systems in the residential and service sectors in central and northern European countries and combined systems providing space heating, hot water and air conditioning in the Mediterranean countries;
- In addition, a moderate to substantial market diffusion in the other sectors is assumed. Solar combisystems will provide heat for hot water and space heating (also cooling where needed) and will have the ability to switch to high density energy storages when available without changes to the collector area. Using high density energy storages would increase the solar fraction significantly.

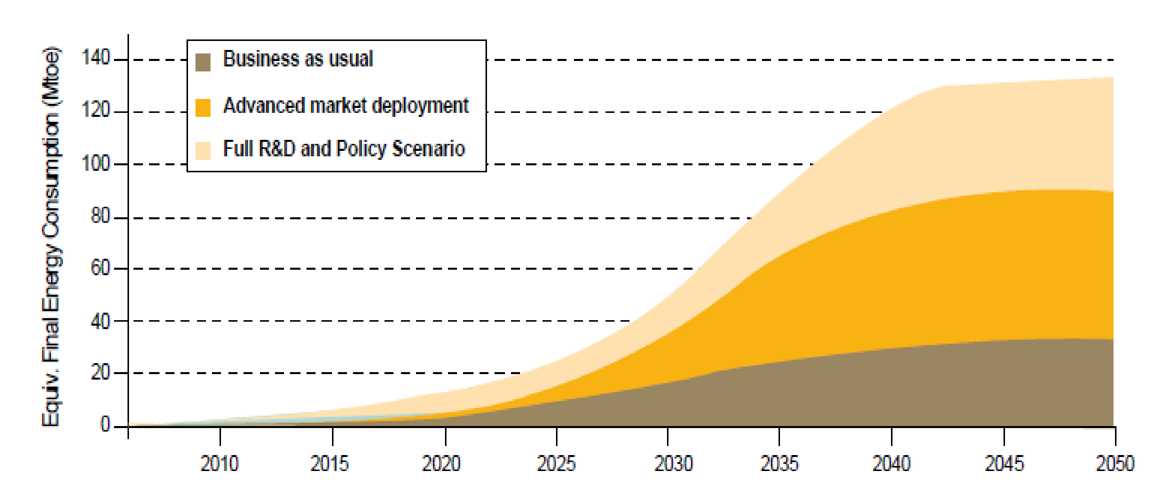
- Medium R&D rate and therefore solutions for high energy density heat stores and new collector materials; sufficient and cost competitive solutions for solar thermal cooling by the year 2020.
- Main focus on solar combisystems for hot water preparation and space heating in the residential sector; solar combisystems with low solar fraction (10-20%) until 2020 and medium solar fraction (20-50%) from 2020; moderate market diffusion in all other sectors.

[16] RDP assuptions:

- Significant reduction of the heat demand compared with 2006 (depending on the country but on average: -10% by 2020, -20% by 2030 and -30% by 2050).
- Full political support mechanisms: Solar obligations for all new and existing residential, service and commercial buildings as well as for low temperature industrial applications or high energy prices of fossil energy.
- High R&D rate and therefore solutions for cost efficient high energy density heat stores and new collector materials; sufficient and cost competitive solutions for solar thermal cooling available by 2020.
- Main focus on solar combisystems for hot water preparation and space heating in the residential sector; solar combisystems with low solar fraction (10-20%) until 2020 and high solar fraction (50-100%) from 2020; substantial market diffusion in all other sectors.
- High growth rate of installed capacity (~25% per annum until 2020).

[17] A combisystem is a solar system which provides both solar space heating and cooling as well as hot water from a common solar thermal collector.

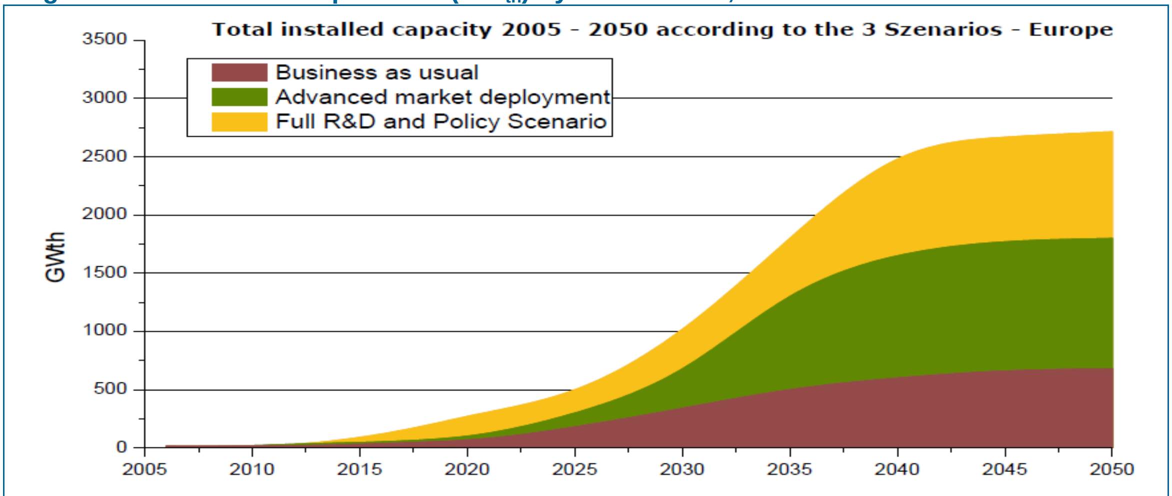
Figure 27: Solar thermal potential (Mtoe) by 2050 in BaU, AMD and RDP scenarios in EU 27



Source: W. Weiss and P. Biermayr, 2009

The results of the study show that solar thermal energy could supply from 33 Mtoe to 133 Mtoe (respectively in the BaU and RDP scenario) of final energy in EU (Figure 27). This corresponds to an installed capacity between 679 to 2,716 GW_{th} (Figure 28).

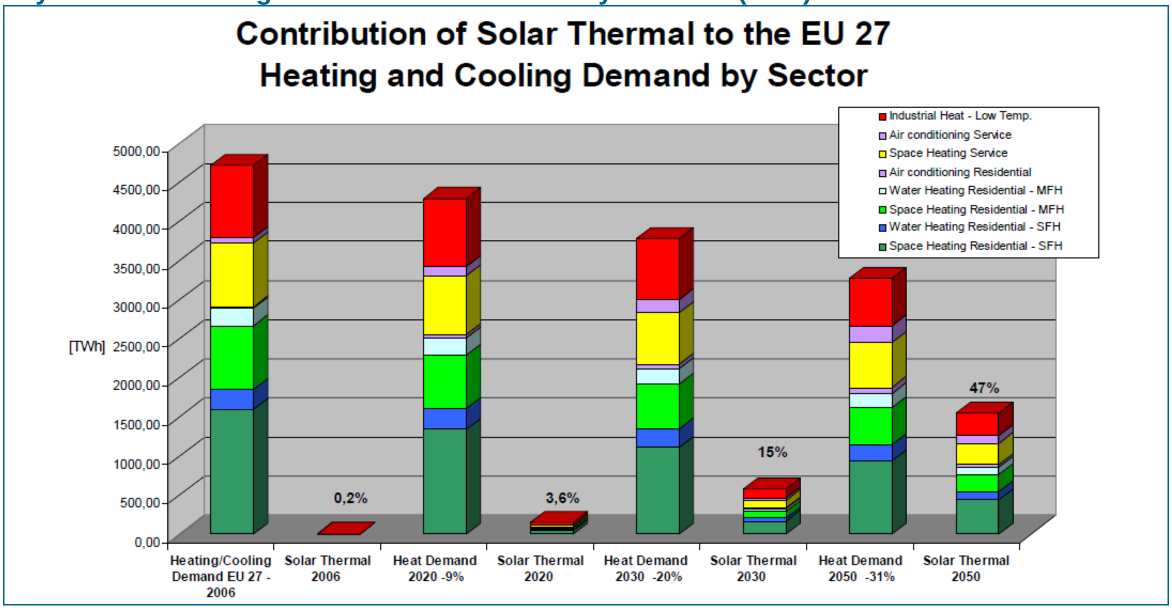
Figure 28: Solar thermal potential (GW_{th}) by 2050 in BaU, AMD and RDP scenarios in EU 27



Source: W. Weiss and P. Biermayr, 2009

The contribution of solar thermal systems to the low temperature heat demand of the EU-27 would be between 8% under the BAU scenario and 47% under the RDP scenario (Figure 29) by 2050, against 0.2% in 2006, if a 31% reduction of the heat demand compared to 2006 level is assumed. The resulting total collector area would be between 970 million m² (BAU) and 3.88 billion square metres (RDP).

Figure 29: Total heating and cooling demand of EU-27 and contribution of solar thermal by sector according to the Full R&D and Policy scenario (RDP)



Source: W. Weiss and P. Biermayr, 2009

Considering the RDP scenario, the industrial heat (low temperature) from solar thermal systems will represent around 20% of the solar thermal contribution and around 45% of the total heat demand in industrial low temperature demand (Figure 29).

3. Potential in different industrial sectors

The most favourable conditions for the integration of solar thermal energy in industrial applications are represented by: processes requiring low temperatures and needing a constant amount of energy during sunny hours, as well as high prices of conventional energy in the existing system to make the solar application economically viable. There are not so many sectors which are gathering all these conditions but several studies have shown that some processes in different industry sectors are suitable for solar process heat.

According to these studies, the most significant sectors where solar heat can play a role are in the food and beverage industries, in the textile industries, in the chemical industries and in the service industries. The main processes used in these industries are cleaning, drying, bleaching, pasteurisation, pre-heating of boiler feed water, boiling, distilling, and chemical processes.

The temperatures required fit with the temperature that solar system composed of flat-plate or evacuated tubes collectors can easily reach. Beyond the typical low temperature processes up to 80°C suitable for solar thermal use, there is also strong potential for processes running in the medium temperature range from 80°C to 250°C, but in these cases there is a strong need of optimising and further developing medium temperature collectors[18]. Table 3 and Table 4 show these main potential sectors and processes for solar thermal uses.

Table 3: Operations and processes in some important industrial sectors

(• : important, X: very important)

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

Source: IEA-SHC Task33/IV, 2004

Table 4: Industrial sectors and processes suitable for solar thermal use

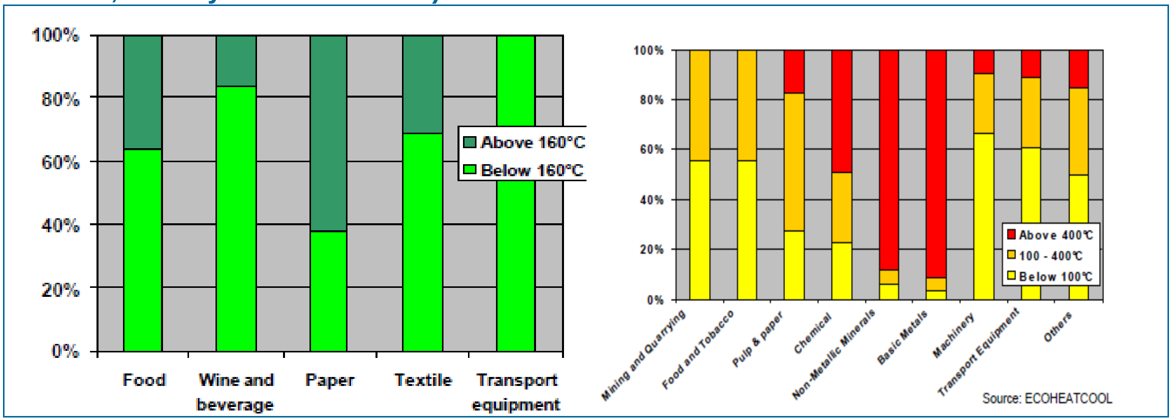
Sector	Processes	Temperature (°C)
Brewing and malting	Wort boiling	100
	Bottle washing	60
	Drying	90
	Cooling	60
Milk	Pasteurization	60–85
	Sterilization	130–150
Food preservation	Pasteurization	110–125
	Sterilization	<80
	Cooking	70–100
	Scalding	95–100
	Bleaching	<90
Meat	Washing, sterilization, cleaning	<90
	Cooking	90–100
Wine and beverage	Bottle washing	60–90
	Cooling (single effect absorption cooling)	85
Textile	Washing, bleaching, dyeing	<90
	Cooking	140–200
Automobile	Paint drying	160–220
	Degreasing	35–55
Paper	Paper pulp: cooking	170–180
	Boiler feed water	<90
	Bleaching	130–150
	Drying	130–160
Tanning	Water heating for damp processes	165–180 (steam)
Cork	Drying, cork baking	40–155

Source: POSHIP, Final report, 2001

[18] As for example those develop and tested as part of the IEA-SHC Task33/IV. For a discussion of these technological aspects, please see the 1.1 "Solar thermal collectors" section.

Within the POSHIP[19] project, an evaluation of the heat requirements for different industrial processes has been carried out especially in Spain industry sector. Figure 30 shows these results and confirm that the most promising field for solar heat technology deployment is in the food, textile and transport equipment industries with more than 60% of the heat required below 160°C (even 100% for transport equipment). Wine and beverage is also very suitable industry for such applications with around 80% of temperatures required below 160°C.

Figure 30: Temperatures required in industrial sector (data for 34 industries of the Iberian Peninsula) and share of industrial heat demand by temperature level and industrial sector (right) (Data for 2003, 32 countries: EU25 + Bulgaria, Romania, Turkey, Croatia, Iceland, Norway and Switzerland)



Source: POSHIP final report, 2001; ECOHEATCOOL project, 2006 (right)

Other surveys were conducted within the ECOHEATCOOL project, for 32 countries. Results are similar although the range of temperature studied is not the same.

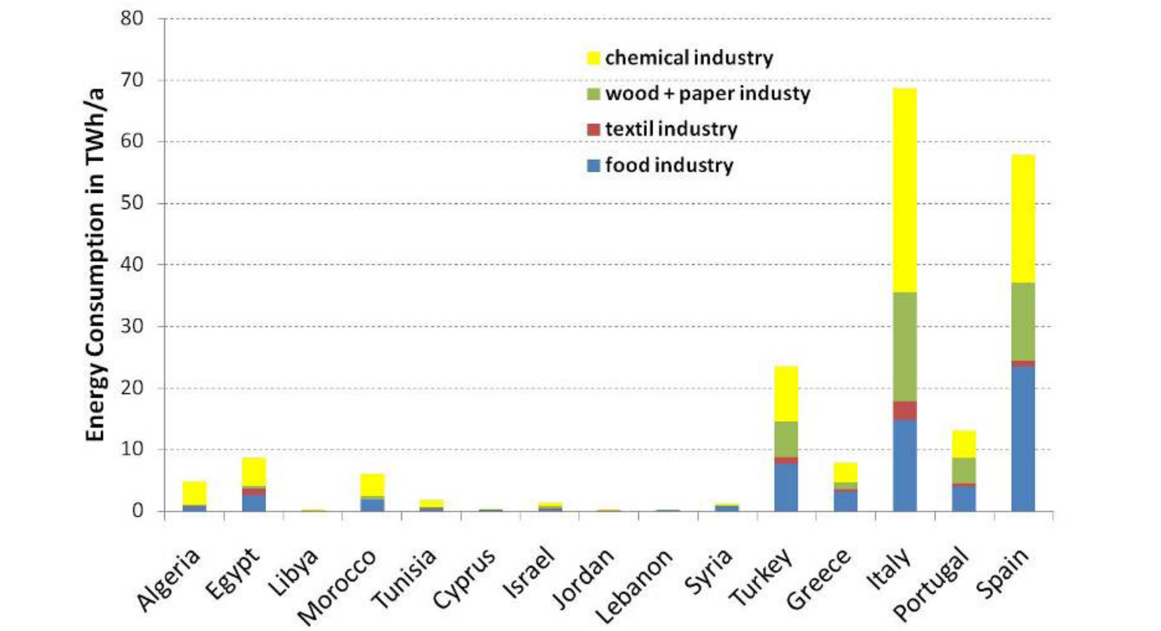
Among the industrial processes which require medium-temperatures, desalination and water treatment are particularly promising for the use of solar thermal energy, as these applications are often necessary in areas with high solar radiations. Within IEA-SHC programme, a new proposed work concerns the Solar Heat Integration in Industrial Processes topic, and will build on the results of IEA-SHC Task 33. The main objectives will be to further develop solar process heat collectors, to optimize processes for a more efficient solar integration, to identify new applications (e.g. SunChem and water treatment), to develop planning tools, calculation tools and design guidelines, and to install

[19] " Potential Of Solar Heat for Industrial Processes" project, EU-Project No NNE-1999-0308

and monitor large-scale demonstration systems (IEA-SHC Newsletter, Solar Update No 53 - January 2011).

Figure 31 shows the energy consumption by industry within the Mediterranean countries. The chemical and the food industries appear to be the most promising sectors for SHIP applications in these countries as they represent a large share of the industrial energy consumption. A more detailed survey analysis is recommended in order to define the temperature level required in the concerned industries on a country per country level (especially Algeria, Egypt, Morocco and Turkey).

Figure 31: Industrial energy demand in Mediterranean countries



Source: C. Paul, 2008

Potential in Tunisia:

The PROSOL INDUSTRIAL programme

The PROSOL industrial programme initiative launched early 2008, in collaboration between Italian Minsitry for the Environment, Land and Sea, ANME and UNEP-DTIE, has the aim to promote the installation of solar systems in theindustrial sector. The PROSOL industrial is structured in several phases. The first 3 actions are:

1) Evaluation of hot water needs for industrial processes in 80 companies in the Agro-food, textile, chemistry, paper mills industries;

2) Development of pre-feasibility studies to install SHIP systems in those companies meeting the criteria established by ANME and project partners (40 companies shortlisted);

3) Setting up of in-depth technical and financial studies in shortlisted companies selected according to specific criteria:

- Willingness to invest in solar
- Availability of space for the realization of the solar system;
- Status of ownership of the site;
- Technical feasibility of solar system;
- Focus on industries using LPG and fuel oil;
- Financial situation of the industry and easy access to credit;
- Ability to support the integration of solar technology;
- Willingness to engage in training programme and capacity building;
- Monitoring of the project with the ANME.

The 10 companies selected for the pre-feasibility studies are operating in the agro-food industry (6 companies), in the textile – leather – clothing industry (3 companies) and in the chemical industry (1 company).

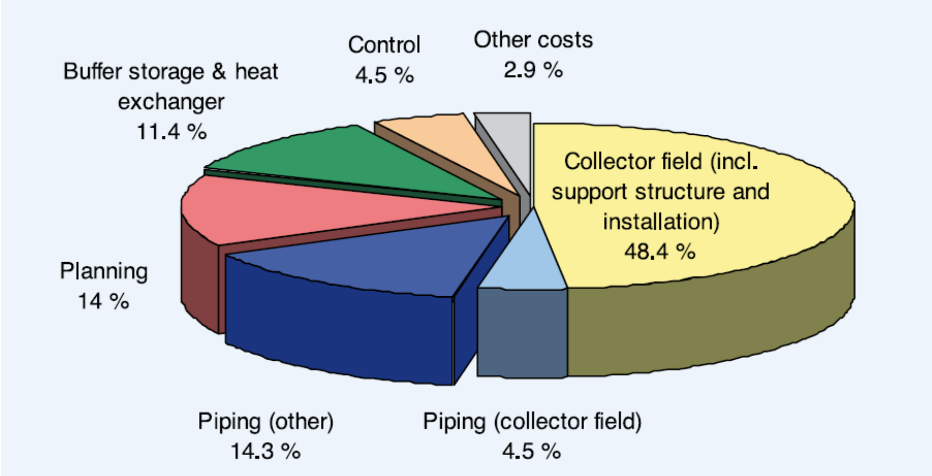
The first results (end of 2010) of the technical and financial studies indicate that around 10% of the annual consumption of the process could be provided through solar technologies.

Source: ANME and personnal communication from Italian Ministry for the Environment, Land and Sea

4. System costs

The cost of solar thermal process heat installations in Europe ranges from 180 up to 500 €/m^2 (SO-PRO, 2011). This cost depends on the system design, the size, the selected components (e.g. the choice of the collector type) and on country-specific factors (e.g. salaries). Figure 32 shows the distribution of installation costs.

Figure 32: Distribution of installation costs for larger solar thermal systems in Germany



Source: So-PRO project, EU 2011

Regardless of the sectoral application, the solar thermal process heat installation costs are still higher than conventional systems. But if properly planned and maintained, the lifetime of a solar system can be more than 20 years and in that case it can become competitive. The solar heat generation costs for low temperature process can even range between 2 and 8 c€/kWh, highly depending on location, the process supported and the temperatures required.

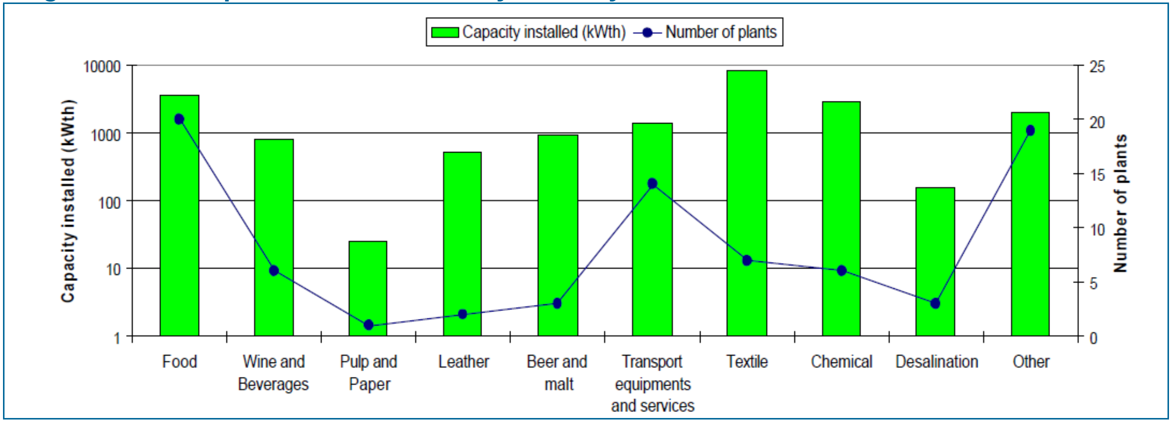
Up to now, incentives are needed in order to shorten the financial payback time and to align it with commercial requirements. Most European countries have set up dedicated support schemes, sometimes also differentiating depending on the geographic situation or technology aspects. However, solar thermal technologies still receive limited support compared to renewable energy technologies for electricity generation.

5. Existing solar heat plants

1. Worldwide existing plants

At the end of 2007, about 90 operating solar thermal plants for industrial application for a total capacity of 25 MW_{th} (~34,000 m^2) were reported at world level (IEA-SHC task 33/IV). Food industries and transport equipment and services represent the industries with the most number of SHIP applications Textile, food, and chemical are the industries with the high capacity installed (Figure 33).

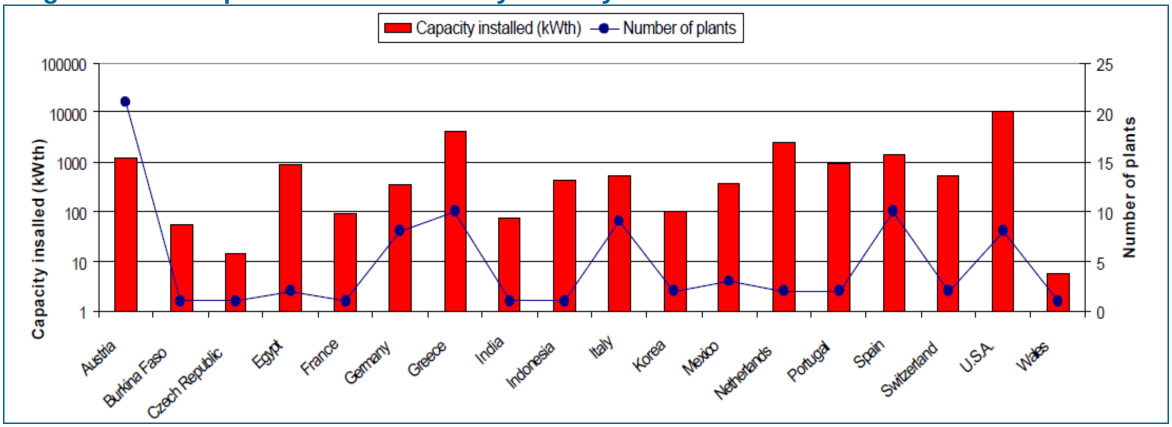
Figure 33: SHIP plants - distribution by industry sector as of October 2007



Source: IEA-SHC Task 33/IV, 2008

Geographically speaking, most solar plants for heat processes are installed in the EU (Figure 34) and particularly in Austria, which is a pioneer in the use of this technology, with a lot of small scale demonstration plants. Greece and Spain are also very active, also given their particularly favourable conditions in terms of solar resource availability.

Figure 34: SHIP plants - distribution by country as of October 2007



Source: IEA-SHC Task 33/IV, 2008

More recent investigations found out that in 2010 the number of solar plants for process heat doubled, reaching approximately 200 operating solar thermal plants for process heat worldwide - including space heating of factory buildings (IEA-SHC Task 33/IV and investigation AEE INTEC 2010). This represents a total capacity of about 42 MW_{th} (~60,000 m^2).

2. South European installation examples

As shown in the Figure 34, Austria is the country with the largest amount of solar thermal for heat process plants installed but South European countries are very active in the deployment of solar heat for industrial process technology due to their good solar endowment which improves the cost-effectiveness of solar plants. Italy, Greece, Portugal and Spain gathered together one third of the installed plants as of October 2007.

Transport sector

Contank plant (Parking Service Castellbisbal S.A., Castellbisbal (Barcelona), Spain)

The basic target for the solar thermal installation is the cleaning of containers used to transport liquid goods by rail. This demonstration solar plant has been built within the IEA-SHC Task 33/IV as one of the first demonstration systems and was installed in 2004.

Figure 35: Photo of the solar field of the Parking Service Castellbisbla S.A. company

Source: Aiguasol Engineering, Spain

The main heat-consuming process in the company is the washing process of the containers, which needs hot water at 70 – 80 ºC (approx. 46% of the total heat requirement) and steam (the remaining 54%). The hot water required is in a range of 70 - 80 m^3/day. In addition to the solar system, there is a gas-fired steam boiler for the preparation of hot water.

The solar thermal system installed is composed of two solar fields with flat-plate collectors of around 500 m^2, representing a total installed capacity of 357 kW_{th}, and by a storage system of 45 m^3. A steam boiler functioning with natural gas has been installed as back-up.

According to the IEA-SHC Task 33/IV, the yearly heat production is about 429 MWh (which represents 588 kWh/kW_{th}) and solar energy makes up around 22% of the energy used in the company.

The total investment cost is estimated to be around 270,000 € (752 €/kW_{th}) and was co-funded for 48%. The amortization of the solar system is estimated to be around 10 years, assuming a gas price at 25 €/MWh (annual cost saving estimated to 14,300 €).

Food industry sector

<u>Tyras S.A. dairy plant in Trikala, Greece</u>

In 2001, a solar system with capacity of more than 706 kW_{th} representing more than 1000 m^2 of flat-plat collectors has been installed by the Sol Energy Hellas company in a dairy in Greece. The basic target for the solar thermal installation has been to design a centralized thermal solar field at maximum efficiency (thus high energy output for a set area of thermal solar field) in order to feed the sanitary hot water network. One of the main difficulties for the design team has been to overcome the very large temperature difference between summer and winter periods (with sub zero winter temperatures and summer temperatures exceeding 40°C). A LPG fired boiler has been installed as back-up and the plant has storage system of 50 m^3 which already existed.

Figure 36: Photos of the Tyras S.A. thermal solar field installation (solar field -left- and tank boiler -right-)

Source: Sol Energy Hellas

The solar system has been designed to cover 80% of the load during the summer period in order to achieve the highest possible financial performance.

The average yearly production of the facility is around 700 MWh and solar heat installation provides around 7% of the total heat requirement of the dairy. According to Sol Energy Hellas, the yearly energy output of the solar field allows to save 95,400 lt of diesel which represent a yearly saving of 71,500 € with 2008 fuel prices.

The total investment cost (without the storage tank) is estimated to 175,000 € (248 €/kW_{th}) and the plant was co-funded at 50%. The return on investment of such an installation (using 2008 fossil fuel prices and without projecting their yearly increase) will achieve payback in less than 2.5 years. This installation is in uninterrupted operation since 2001 without failures and with stable energy output. The return of investment, with 2001 prices, was achieved in less than 3 years.

Chemical industry sector

Keminova Italiana s.r.l. cosmetic plant in Brescia, Italy

The installation of the solar thermal plant in Keminova Italiana s.r.l company is for pre-heating of working fluids, heating of emulsions and factory building heating. The plant has been installed in 2008. The solar field is composed by 90 m^2 of flat-plate collector with a total capacity of 63 kW_{th}. In addition, heat storage has been installed with a tank capacity of about 5 m^3. The back-up system is the existing natural gas fired boilers.

Figure 37: Solar thermal installation of Keminova Italiana z.rl (left) and equipement for the production of the emulsions

Source: Keminova Italiana s.r.l

The main heat demand is needed for the production of cosmetic emulsions and for heating of production halls in winter time. The solar thermal plant has been integrated to the existing gas fired thermal power plant for hot water production in substitution to 4 electrical devices used for heating the working fluid (electricity demand for the emulsions around 24 MWh/yr). The solar thermal system is used to heat up the heat supply medium (water) used to pre-heat the chemicals and the water required for the emulsion production. The solar plant provides also the energy required to maintain the process temperature constant during the operation (at 80°C) instead of electricity. In summer days the solar ratio can reach 100% of the supply heat system.

The total Investment cost is estimated to 70,000 € with a co-funding of 50%. The annual average electricity costs reduction is estimated at 6,000€.

3. Most innovative installations in South Mediterranean Countries

In the Mediterranean region, the number of applications is limited, but some pilot projects have been carried out or are in the pipeline.

Egypt

In the 1990's, NREA formulated a program for field-testing and dissemination of "Solar Industrial Process Heat and Waste Heat Recovery System" in the Egyptian industry. With this program, the New and Renewable Energy Authority (NREA) implemented two "solar heat for industrial processes" pilot project plants (one in the food industry and the other in the textile industry) within the "Renewable Energy Field Testing" (REFT) project. The projects were co-financed by the United State Agency for International Development (USAID) and by NREA.

<u>The poultry processing plant project:</u>

The first project started in 1990 and stopped functioning in 2005 when the owner, the United Chicken Company (Ministry of Agriculture), sold the factory to a private investor who decided to replace the solar heat system by a conventional one. The project objectives were to demonstrate and field test SHIP and waste recovery systems in food industries. It incorporated the design, construction, operation, training and testing of the systems.

Figure 38: The poultry SHIP project in Egypt

Source: NREA

The project implemented three subsystems which were the solar water heating system, the waste heat recovery system and a meteorological data acquisition system.

The solar system was composed of 350 m² of locally manufactured flat-plate collectors producing 26 m^3/day of hot water at 50-60°C. The waste heat recovery system was a flash steam system which feeds 2 scalders, and a condensate return system to preheat the boiler.

During the operation lifetime some technical problems appeared related to the operation and maintenance but they were overcome (see the interview with NREA). The total system allowed saving 300 toe/year (around 30% of the total energy consumption of the plant) and 1,200 tCO_2/year.

The Misr-Helwan textile project:

The second project started in 1993 and also stopped in 2005 for the same reasons than for the poultry farm. It was hosted by the Misr Helwan Textile Company (Ministry of Industry). The project objectives were also to demonstrate and field test SHIP and waste recovery systems in food industries. It incorporated the design, construction, operation, training and testing of the systems.

Figure 39: The textile SHIP project in Egypt

Source: NREA

The project implemented three subsystems which were the solar water heating system, the waste heat recovery system and a meteorological data acquisition system.

The solar system was also composed of 350 m² of locally manufactured flat-plate collectors producing 26 m^3/day of hot water at 50-60°C. The waste heat recovery system was waste heat exchanger in order to recovery the hot water being discharged to drain and to be used in the bleaching process.

Plant had problem linked to Operation and maintenance but also with external elements as the implementation of a cement factory bringing a lot of dust. The total system allowed saving 1,500 toe/year (around 30% of the total energy consumption of the plant) and 8,500 tCO_2/year.

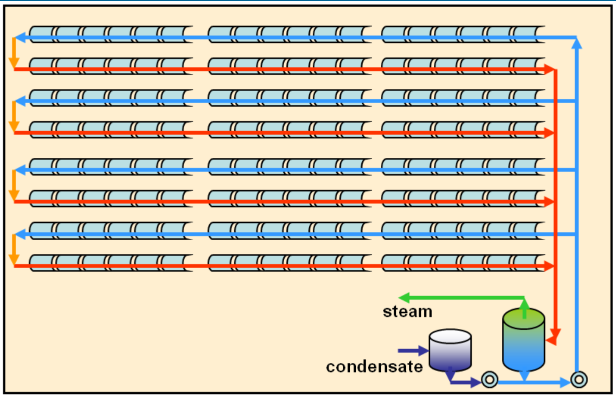
The acquired experience on operation and maintenance of the solar system has been useful for the evaluation of other project design and site selection, and especially the environmental conditions with the industrial smog and cement particles in the air which act on the efficiency of solar collectors.

The El Nasr Pharmaceutical factory:

As a result of a study carried out within the framework of a comprehensive planning of Solar Industrial Processes Heat and waste heat recovery systems for medium temperature in Egypt (1997 - 2012) a pilot plant has been built at El Nasr near Cairo. The study aimed at forecasting, through field energy audits, the potential of SHIP and waste heat recovery systems for six industrial sub-sectors. The study was financed by the African Development Fund (ADF) with $2.2 million.

The plant is made of 144 parabolic trough collectors (6 metres long by 2.3 metres wide) with a net reflective surface area of 1,900 m^2. The reflectors have been locally built and installed. The solar field is organised into 4 identical loops, each loops composed by 6 collectors' groups of 6 parabolic trough collectors (Figure 40);

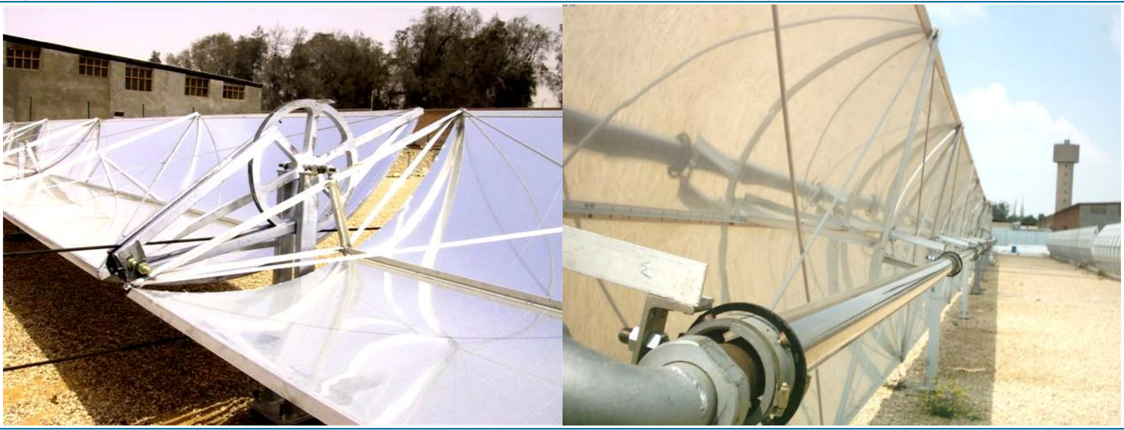
Figure 40: Schematic diagram of El Nasr solar field



Source: NREA

The heat absorber is manufactured of carbon steel and coated with a black nickel with highly effective absorptions. In a first design, the heat absorber was surrounded by glass envelope to minimize the heat losses, before being replaced by a hot box composed of 3 glasses layer.

Figure 41: Photos of solar system at El Nasr Pharmaceutical plant



Source: NREA

In operation since 2003, the plant produces around 1.3 t/hr of steam saturated at 175°C and 8 bar equivalent to 0.9 MW_{th} to feed the steam network of the company, thereby reducing the fuel consumption. However, due to technical problems the plant is actually not functioning and is being repaired.

The solar-heated condensate is collected into a condensate tank return to the flash drum at about 23 bar. As the pressure inside the flash drum is kept at some 7.5 bar, flash steam is generated due to the sudden pressure drop.

The installation of the solar system allowed replacing seven old mazout burners by dual burners suitable for mazout and natural gas with installation of automatic control system. In addition, there is a data acquisition system.

Figure 42: New dual burners with automatic control system in El Nasr factory

Source: NREA

The total system allows saving 1,200 toe/year (around 30% of the total energy consumption of the plant) and 3,500 tCO_2/year.

Interview with Eng. Reda Abdel Azim Younes Elnavrawy

Chief Engineer of Solar Thermal Energy & Energy Efficiency Department,
New & Renewable Energy Authority (NREA)

The aim of the interview is to get some first-hand information about the solar pilot plants installed in Egypt, through a semi-structured interview with Eng. Reda Abdel Azim Younes Elnavrawy.

OME: What is the invlovement of NREA in the SHIP development?

Eng. Reda: NREA is developing solar thermal technologies since 1980's, mainly for three applications: domestic solar water heating (DSWH), solar industrial process heat (SHIP) and solar thermal electricity generation (STE). Regarding SHIP applications, NREA decided to develop this activity because about 50% of the total national primary energy consumption is used in industrial sector and about 60% of the industrial energy consumption is used in industrial process heat. Thus using solar thermal technology would have a significant impact on energy demand. NREA has developed three solar pilot plants with waste heat recovery system, as about 20%/30% of the industrial energy consumption is wasted, due to low maintenance and inefficient process.

OME: Could you describe the pilot projects?

Eng. Reda: The first two were developed in the early 1990's - one in the food industry (poultry firm) and the other in the textile industry-. They were developed by NREA with co-operation and financed by USAID. The solar systems were the same for both projects: 350 m² of flat plate collectors delivering 26 m3/day of hot water at 50-60°C. The waste heat recovery system of the poultry farm was a flash steam feeding 2 scalders and of which the condensate served to preheat the boilers. The waste heat recovery system of the textile farm was a waste heat exchanger to recover energy from hot water being discharged to drain & to be used in the bleaching process. More recently, in 2003, a third plant was developed by NREA in the chemical industry - El Nasr Pharmaceutical project- and financed by the African Development Fund (ADF). The solar field is composed of 1,900 m² of parabolic trough collectors and the plant produces 1.3 t/hr of steam saturated at 175°C and 8 bar equivalent to 0.9 MWth to feed the steam network of the company.

OME: Are these plants still in operation?

Eng. Reda: Both plants developed during the 1990's were stopped in 2005. The two companies which hosted the systems, the United Chicken Company -Ministry of Agriculture- and the Misr-Helwan Textile Company -Ministry of Industry-, have been sold to private entities which decided to replace the solar systems by conventional heat supply systems. As for the El Nasr Pharmaceutical factory, it is still in operation but not working right now because it is facing technical problems.

OME: Taking about technical problems, what were the main difficulties met during the operation lifetime of these plants?

Eng. Reda: As for the poultry farm system, the major problems met were linked to equipment degradations as corrosion of the header pipes and leakages in the collector pipes. Despite these problems, the solar system has been in operation until 2005 before being replaced by the new private owner of the factory. The Misr-Helwan textile plant faced similar problems added to an external element which disrupted the well functioning of the solar system. A cement factory was installed nearby the plant, which resulted in lot of dust in the air. The solar system lost in efficiency and needed to be cleaned very often. As for the poultry farm system, the new owner decided to replace the solar system by a conventional heat supply system.

The El-Nasr plant faced also some technical problems notably some leakage in the flexible joint of the tracking system which led to break the joint. Thus some of the parabolic troughs are no longer tracking the sun. In addition the cover glass, placed above the mirrors to protect them from dust, have been deteriorated by leakage in the absorber pipes and have been replaced by hot boxes composed by 3 glasses layered. But a lot of dusts soaked between the 3 layers of the hot box which is difficult to be removed from. These technical problems hamper the solar field to feed the system at a sufficient temperature. The solar field is being repaired.

OME: What are the main lessons learnt from these experiences?

Eng. Reda: The development of the two first demonstration plants allowed to gather more experience on operation and maintenance and has been useful for the evaluation of other project designs and site selection for future projects.

OME: Does NREA envisage to install other similar plants in the future?

Eng. Reda: NREA had a mandate which included implementation of renewable energy projects but there are two important barriers which prevent further installation of these plants. The first one is the lack of funding and the second - related to the previous one - is that this technology is still not competitive compared to conventional systems.

OME: You have highlighted two important barrier. What are additional barriers which are relevant according to your experiences? How would you classify them?

Eng. Reda: From our experience, the main barriers are:

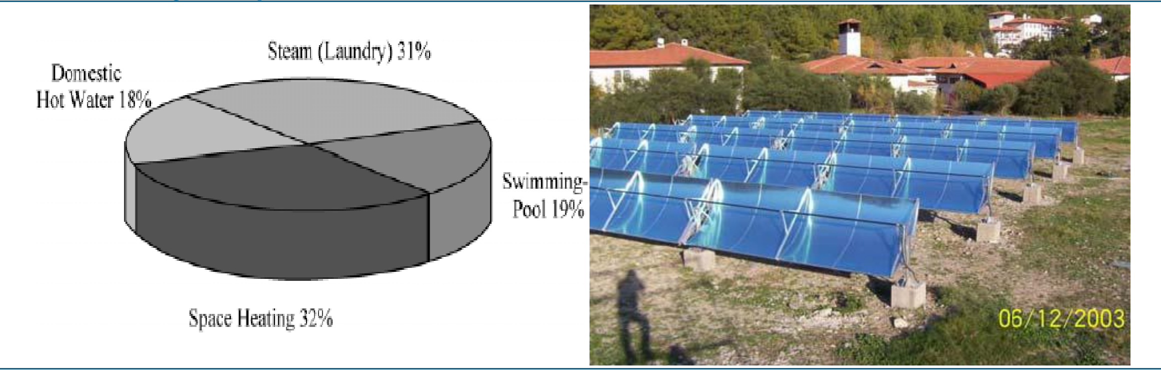
- High capital cost;
- Need for very large thermal storage;
- Need for very large area to install solar collectors;
- Lack of trust in the technology by some decision makers, who think that solar thermal applications are not reliable;
- need for more operation and maintenance in order to ensure that the plant works properly.

Turkey

Although there is a huge potential of solar heat for industrial processes applications in Turkey, there is no recorded solar system implemented in the industry sector. Nevertheless, the majority of the solar thermal plants operating today provide hot water to house or hotels, which could be use for process as in a laundry.

This is the case in the “Iberotel Sarigerme park” in the southern coast of Turkey wich has a PTC solar sytem operating since 2004. Indeed, the thermal load of the hotel is mainly from the laundry (31%) and for space heating (32%).

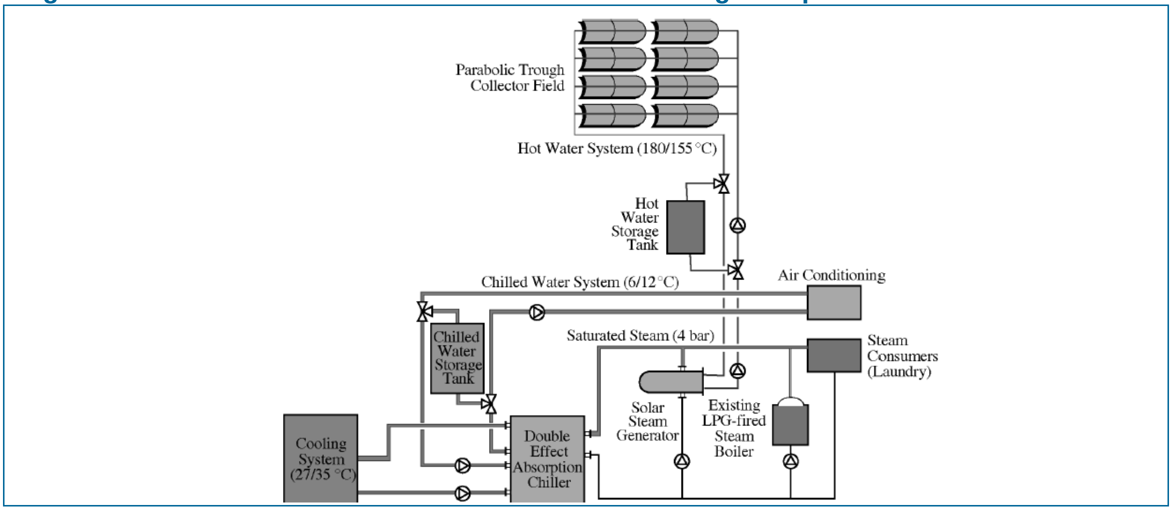
Figure 43: Heat consumption distribution of the hotel (left); photo of solar field (right) in Iberotel Sarigerme park



Source: DLR (right)

The PTC solar field is composed of 5 loops, each loop comprises 4 modules, and each PTC module has a net surface of 9 m^2 (5 metres long by 1,8 metre wide) with a total area equal to 180 m^2.

Figure 44: Heat distribution scheme of the Iberotel Sarigerme park



Sources: TBC

The concentrator is made with high reflectivity aluminium sheets. The receiver pipe has a diameter of 38 mm, and is coated with a selective coating and encapsulated within an atmospheric pressure glass pipe.

Inlet and outlet PTC temperatures are 155°C and 180 °C respectively, allowing the production of steam at 4,3 bar.

Morocco

Morocco has no SHIP installation up to now, but a project has been developed under the framework of the CDM mechanism. The project design document (PDD) has been submitted to the CDM Executive Board of the United Nations Framework Convention on Climate Change.

The project aims to implement a solar plant providing steam for 8 fish meals plants near the city of El Marsa (20 kilometres south-west of the city of Laâyoune at the Atlantic coast). The project aims at reducing greenhouse gas emission in the 8 fish meal plants, by switching the steam produced with fossil fuel by a solar heat system.

The innovative aspect of this project lies in the installation of a central solar plant which will supply the 8 fishmeal plants with steam (from a Fresnel collector) and hot water (flat-plate collector) plus a back-up fuel oil system. All companies will be connected to a centralized steam grid.

The current yearly energy demand of the 8 fish companies is about 7,910 t/yr heavy fuel oil, which equals 87 GWh/yr (in total 24 boilers). The fuel demand should be reduced to about 82 GWh/yr due to boiler replacement and continuous steam-demand. The current minimum/maximum energy demand of all companies is estimated to range between 6 and 36 MW.

The design of the hybrid plant is the following: base load energy will be provided by the solar field with a maximum capacity of 6 MW, producing approximately 11,712 MWh/yr. Further energy demand (back-up, peak and night) would be covered by a heavy fuel oil boiler (of around 36 MW). The total land area requirement is around 20,000 m² (of which 17,000 m²for the solar field).

Over 21 years, the estimated CO_2 emissions reductions are more than 100,000 tCO_2. This estimation does not take into account the saving from the avoidance of several hundred start-ups from the previous 24 single boilers.

Figure 45: Site photos in Laâyoune

Source: Clean Development Mechanism Project Design Document from of the project

Tunisia

Up to now, there is no solar heat for industrial processes running in Tunisia. Nevertheless and following the high success of the PROSOL residential programme, the programme has been extended to the tertiary and industrial sector.

Indeed, in the framework of the “Mediterranean Renewable Energy Programme” (MEDREP) and with the support of the “Mediterranean Renewable Energy Center” (MEDREC), the Italian Ministry for the Environment, Land and Sea, the Tunisian Ministry of Industry, Energy and Small and Middle Size Enterprises (IMELS), the Tunisian National Agency For Energy Conservation (ANME) and the United Nations Environment Programme, Division of Technology Industry and Economic (UNEP DTIE), signed, on January 24, 2008, an agreement to jointly implement a project for the development of solar heating systems for the industrial sector in Tunisia (PROSOL Industrial), implementing also a capacity building program, training activities and a communication and awareness raising program.

To reach this goal, funds from IMELS will be devoted to:

- Development of an assessment study on the targeted sector and on the implementation of a financial support mechanism;
- Development of a capacity building program, an awareness raising program and the communication campaign;
- Implementation of the financial mechanism “PROSOL Industrial”. With the involvement of the governmental institutions and following the success of the solar water heating project for domestic use (PROSOL Residential), will be evaluated the possibility to establish, in collaboration with the local banks, a Loan Facility for Industrial SWH Systems;
- Preparation of the Project Idea Note (PIN) and the Project Design Document (PDD) up to its validation;

Currently the program is in the start-up phase, the following activities being already performed:

- Energy audits have been carried out on 80 Tunisian manufacturing companies, belonging to the following fields: Agro-food; Textile – Leather – Clothing; Chemistry; Paper mills; 40 pre-feasibility studies have been elaborated for the installation of solar systems providing hot water/steam to industrial processes.

A team of experts from "Politecnico di Milano" University will provide technical assistance to Tunisian National Agency for Energy Conservation for the realisation of feasibility studies for integration of solar thermal technology into industrial processes.

In particular "Politecnico di Milano" University is going to perform detailed feasibility study for three Italian Companies already operating in Tunisia, willing to implement solar technologies and seven further studies on Tunisian firms will be developed by local experts.

The team from Politecnico di Milano will then finalize the "Decision Making Support Tool" designed in order to guide through a step by step technology assessment and pre-dimensioning of solar systems in industrial processes.

Others countries: Jordan

The Jordanian factory is another demonstration project in the South Mediterranean area. The total solar field is composed of 96 flat-plate collectors, of 1.3 m^2 each one) representing 128 m^2 with a storage tank of 5 m^3. The solar heating of water was an improvement to the process of dissolving powder milk that produces reconstituted milk. Cold water was used for this process; however, in order to reduce the process time and consequently to reduce electrical power consumption of blenders, hot water quality of 40° - 50°C temperature is needed. The hot water is also needed for container washing purposes with water quality of 60°C. The fabrication of all components (collectors, tank...) as well as the complete installation was carried out by the Royal Scientific Society personnel.

Figure 46: Solar thermal installation in a dairy factory in Russeifa, Jordan

Source: SOLATERM project

6. Existing barriers and recommendations

The review of literature, the analysis of the energy context in both the EU and the South Mediterranean countries and some interviews with selected experts have allowed to identify the main barriers which are currently preventing solar thermal technologies from satisfying a significant portion of the final energy demand.

A main barrier which is common to most renewable energy is the high investment cost compared to traditional systems. This is particularly relevant since most financiers only look at the return of their investment, regardless of the socio-economic and environmental benefits attached to it. Overcoming this barrier requires the implementation of specific incentive programs, which help reduce the cost gap between solar thermal technologies and their traditional alternative. This is an issue in many SEMCs, as subsidies are given to fossil fuels, thus reducing the market prospects for renewable technologies.

A second barrier which is common to many renewable energy technologies is represented by a certain mistrust which characterizes several investors as well as some policy makers vis-à-vis new technologies. Much more awareness raising is needed in order to prove that these technologies are reliable and can become competitive if the right signals are given to market operators.

A third barrier which is specifically related to SHIP applications is the lack of specific skills of many designers and installers, who might not have the necessary knowledge to install a complex system in a reliable and sustainable way. Additionally, as the development of SHIP applications is quite recent, only a limited number of engineering companies are able to develop a SHIP project and only few planning guidelines and tools are available. As highlighted also by some experts in the SEMCs, operation and maintenance of SHIP applications seem to be a critical issue. Specific training programmes are therefore needed to build capacity and provide market operators with the necessary competencies to install, maintain and repair such systems.

Technological barriers are quite important, too. Industrial processes require high temperatures that cannot be provided by the technology used in the traditional applications. Technological improvement and more R&D are needed if SHIP is to satisfy a significant portion of the heat demand.

Furthermore, there is a significant lack of reliable data and statistics on the development of SHIP applications. Also the limited experiences at world level are not very well documented and this creates an additional barrier to the successful development of the technology. Developing and maintaining a database is of paramount importance if we want SHIP technologies to become mainstream. In this respect, initiatives like the "Global Solar Water Heating Market Transformation and Strengthening Initiative" represent a very relevant step forward in terms of knowledge sharing and access to data.

The following Table 5 summarizes the barriers met by SHIP applications and the main recommendations to overcome them.

Table 5: SHIP barriers and recommendations

Barriers	Recommendations
Relative high costs of SHIP systems	As many other renewable energy technologies, SHIP systems are capital-intensive and have high investment costs. However, in the long-term, using these technologies will allow saving conventional energies throughout their operation life, but up to now financial payback times are often beyond commercial requirements. A way to brifge the financial gap is to implement financial incentives. Such mechanisms as the one developed in Tunisia within the “PROSOL” program, would make the access to the technology easier.
Mistrust of industrial investors and managers vis-à-vis new technologies	In general most managers and investors tend to choose long-term proven technology, especially when mission-critical heating processes are concerned. The financial risk linked to potential delay or interruption in the production process seems more dangerous to them than reliance on unpredictable higher future prices of conventional fuels. Developing more and more demonstration plants, helping to gain more experience and bring visibility of the SHIP reliability and suitability in the long-term, would allow industrial investors and managers having more confidence in SHIP applications.
Low awareness of decision and policy makers	A lot of decision and policy makers in relevant industries have never heard of or even seen a SHIP system. This barrier is key to the broad dissemination of SHIP. To overcome this barrier, the setting up of specific awareness raising campaigns targeting at decision and policy makers in the industries most suitable for solar thermal process heat (e.g. food and textile industry) could be an adequate solution.
Lack of suitable technology for medium and high temperatures processes	Many industrial processes require higher temperatures than the typical solar thermal applications (domestic hot water, space heating, swimming pool heating). Strong RD&D programs are required to enhance the development of new designs, but also new materials, which are needed to address the technical challenges from process running at higher temperature. A stronger funding of RD&D into new technologies, can improve the suitability and viability of SHIP installations, e.g. medium temperature collectors, improved heat transfer fluids, etc…
Lack of suitable planning guidelines and tools	Only few engineering offices and research institutes have experience with SHIP installations. Once again, in developing more experimental projects in the industrial sector, with cooperation between research institutes will disseminate faster the know-how and will allow drawing suitable planning guidelines and tools for typical industrial use cases which are still missing.
Lack of education and training	Only few professionals (manufacturers, installers…) have been trained with courses on SHIP. Only large training programs on national level will allow professionals acting in the field to propose SHIP applications to industrialists. Implementing training courses for professionals will raise awareness and overcome the current lack of expertise amongst professionals.
Lack of data/documentation	To develop and maintain a database. Initiatives like the “Global Solar Water Heating Market Transformation and Strengthening Initiative” represent a very relevant step forward in terms of knowledge sharing and access to data.

Source: OME based on literature review and interviews with experts

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