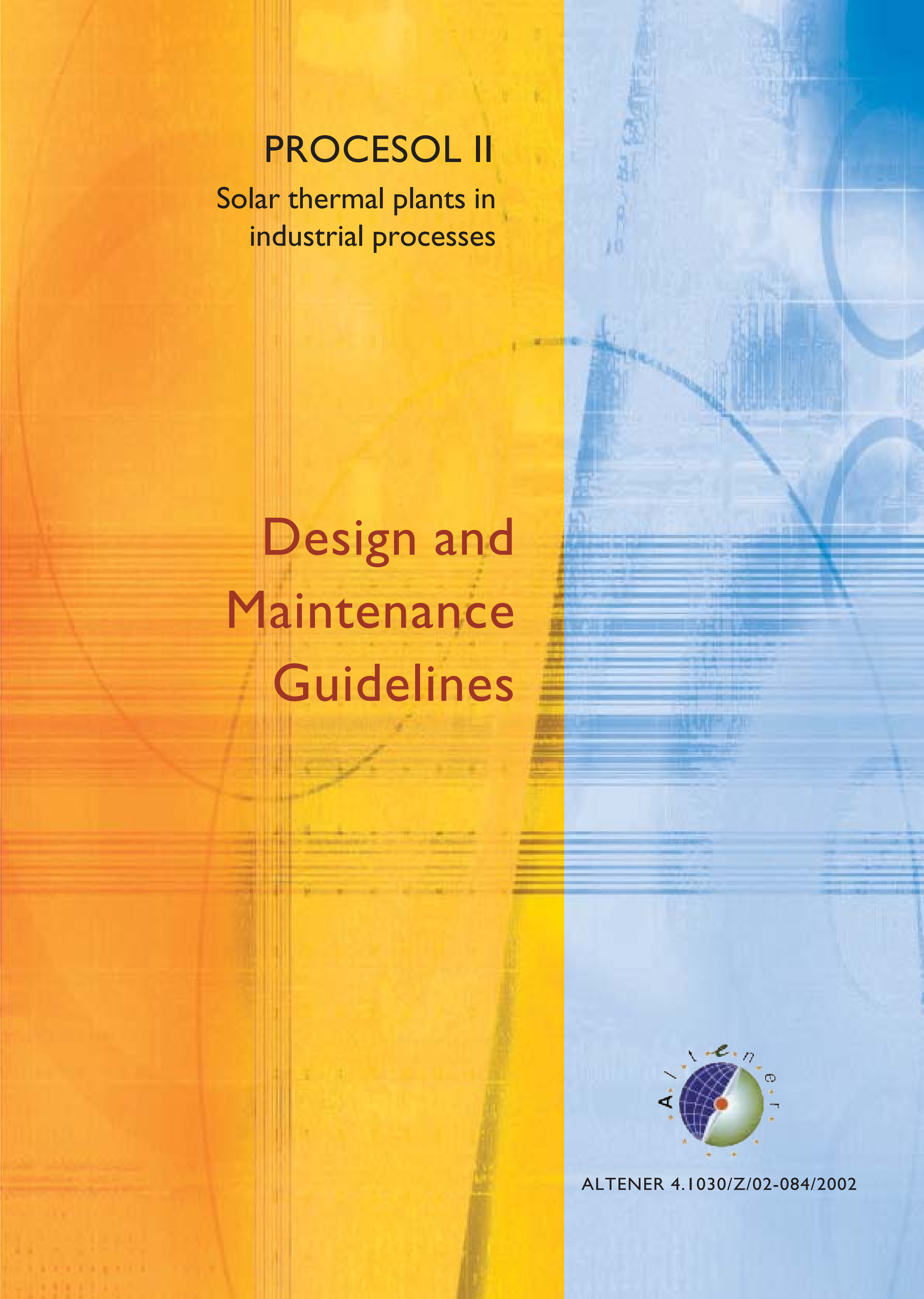

PROCESOL II

Solar thermal plants in industrial processes

Design and Maintenance Guidelines

ALTENER 4.1030/Z/02-084/2002

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INTRODUCTION

PURPOSE OF THIS BROCHURE

The **main purpose** of this brochure is to present in a simple and concise way some Design and Maintenance Guidelines for solar thermal plant applications in the industrial sector.

The current brochure has been prepared **in the context of the PROCESOL II project** (full title: Solar Thermal Process Heating coupled with Heat Recovery Technologies in Industrial Applications, contract number: ALTENER 4.1030/Z/02-084/2002).

The PROCESOL II project aims to promote the implementation of solar thermal systems coupled with heat recovery technologies in the industrial sectors of the participant countries (Greece, Spain, Portugal, Germany, Austria, France and Belgium). The industrial process loads examined are those using hot water with temperature requirements up to about 90^{0}C.

The brochure may concern, among others, the following categories: designers, consultants and decision-makers in the industrial sector with a technical background, solar thermal experts and technicians etc.

Why publish a brochure for solar plants in industry?

- Solar plants in industry have some specific characteristics. Moreover, they are becoming numerous and according to both the PROCESOL II project as well as IEA Task 33 [IEA, ongoing], their potential is high.
- The experience gained thus far has shown that the lack of correct design and maintenance has often been the main reason for unsuccessful solar applications.

It is worth noting that some of the important design and maintenance aspects are common for all central solar thermal plants (especially large ones); and the most crucial of those (e.g. stagnation and freezing protection) have been stressed here. On the other hand, it is not the purpose of this brochure to analyse all common design aspects of solar thermal plants (e.g. conventional hydraulic components like pumps, heat exchangers, valves etc., typical control strategies and so on). Those common aspects have been thoroughly analysed in other sources such as [Fink, 2004].

Finally, together with the maintenance guidelines, a list of periodic control rules have been provided; when respected, the effort and expenses required for maintenance are minimised.

PRELIMINARY DESIGN STEPS

Practically speaking, in order to obtain some of the necessary data needed for a design study an "ad loc" visit to the industrial plant is needed. The main actions to be taken (or data to be collected) can be divided in two categories as listed below:

I. Building /space availability – legal conditions

a. Make a drawing of the building(s), marking its/their basic characteristics. In practical terms this could be a simple sketch that shows basic dimensions of the building, orientation, obstacles etc.

b. Examine the roof availability and its state (indicate the unavailable areas), possible shading from nearby buildings or other obstacles and access possibilities. This last point includes access for the crane (if needed), the available space and openings for the solar tank installation etc.

c. Finally, the designer should investigate if there are legal requirements or obstacles to be faced concerning implementation of the solar plant.

II. Industrial process characteristics

a. Collect the available data on the industry's thermal loads. These data should include the kind of fuel used and its price, a rough estimation of the heating system efficiency and the time profile of the thermal load at least on a seasonal basis. In figure 1, the energy sources (electricity, fuels) used in a brewery in Germany are depicted.

b. Obtain an overview of all processes in order to examine the feasibility of coupling them with solar thermal techniques. Schemes of the processes are helpful. Some data splitting the load into the various processes (as seen in figure 2) are necessary. Moreover, the inlet and outlet temperature of each process should be known.

c. Identify possible heat recovery measures that could have priority in the industry under examination. Here are some possible aspects that could be investigated during a technical visit:

i) Whether there are any heat recovery measures already applied and what the owner's intention is in this regard in the future.

ii) Where steam is used as a transfer medium, whether there exist any steam condensate return circuits.

iii) Whether the state of the insulation on the hot pipeline circuit is in good condition.

iv) Whether there are any processes (e.g. cleaning of some equipment or floors) where heat recovery measures are not economically feasible

Industrial process optimisation

Optimisation of the industry's production should be considered before design of the solar thermal plant. There are a wide variety of strategies for industrial process optimisation. Moreover, heat recovery techniques and apparatus depend on the process itself. It is not among the objectives of this brochure to go into detail on such a broad subject. However, in order to show the high potential of recovery measures, an example from the food industry is illustrated in table 1.

Fig. 1:
Energy sources of a German brewery (source: ZAE)

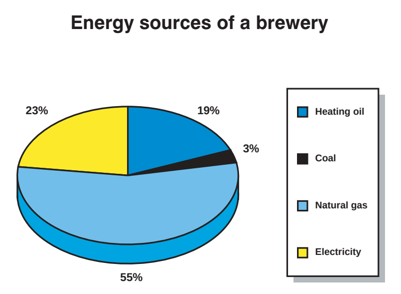

Fig. 1

Fig. 2:
Splitting-up of the process consumption of a German brewery (source: FFE99, ZAE)

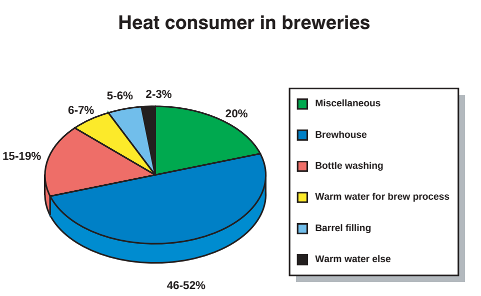

Fig. 2

Process	Crystallisation	Pasteurisation	Physical /chemical process	Sterilisation
Product	Cheese	Milk	Beer (brewing)	Milk
Heat recovery	75%	65-92%	90%	90%

Table 1: Heat recovery values for selected processes in the food industry (Source: ZAE)

Another possibility (for almost all industrial processes) with high amounts of recovered heat is combustion exhaust gas heat recovery.

Strictly speaking, process optimisation is subject to a "Pinch analysis". The Pinch analysis gives the minimum external energy needed for a process system by identifying all the possible heat recovery measures in all the thermal (and cooling) processes of an industry. A description of Pinch theory can be found in [Linnhoff, 1998] and [Gunderson, 2002].

With or without a complete Pinch analysis, the important point before taking decisions for the solar plant is to make a reasonable estimation of the minimum available temperature and flow after all possible heat recovery measures have been applied.

POSSIBLE PLANT CONFIGURATIONS

Figures 3 to 8 show various possible configurations of solar plants that assist industrial heating processes. The variety of cases presented here does not make any claim to be complete. However, efforts have been made to cover a wide range of plant schemes; many other possible configurations are simply combinations or small variations on those presented here.

In table 2, some brief comments are provided concerning the various configurations in terms of their suitability for solar plant installations.

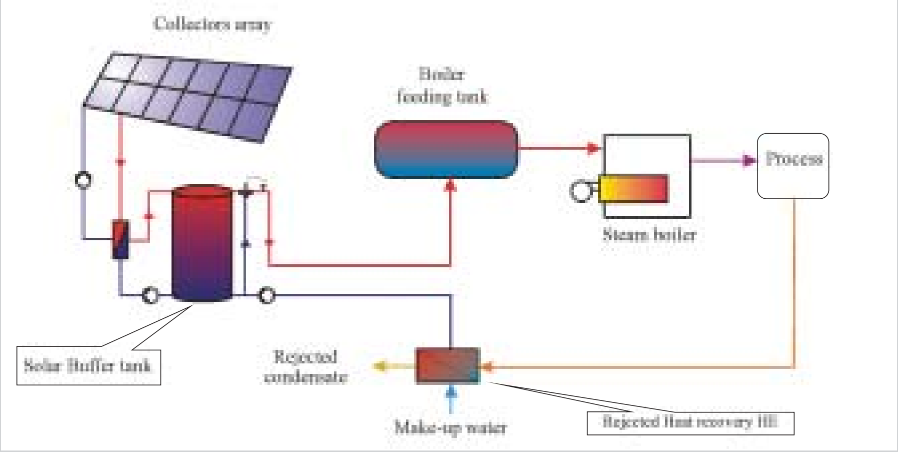

Fig. 3

Open steam loop with heat recovery (Acronym: Open, HR). Source: ITW, CRES

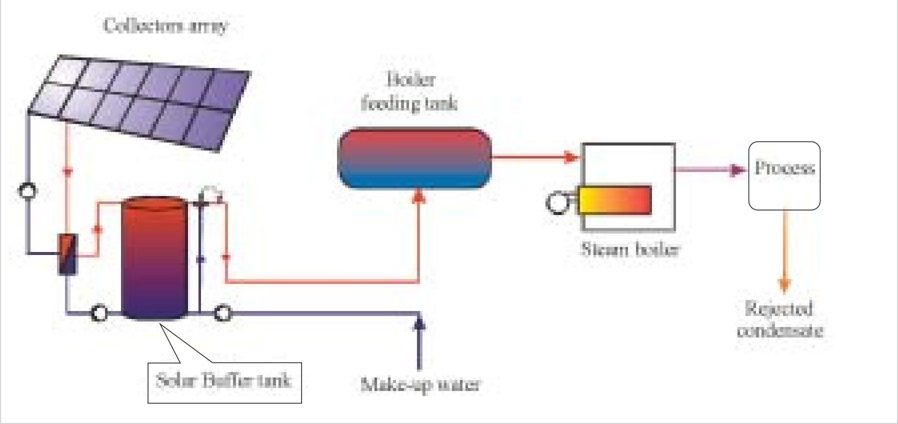

Fig. 4:

Open steam loop without heat recovery (Acronym: Open, NO HR). Source: ITW, CRES

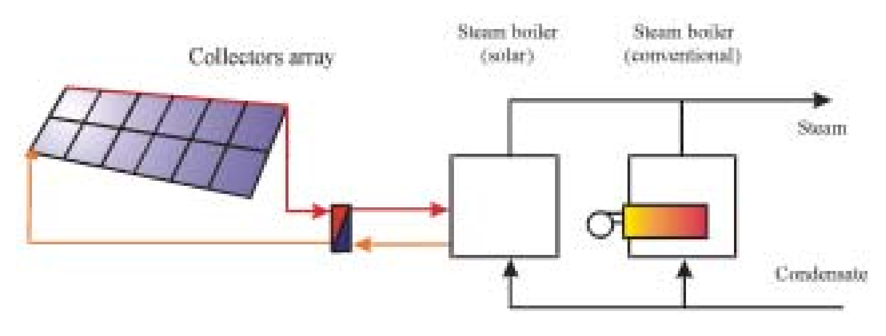

Fig. 5:

Closed steam loop (Acronym: Closed). Source: ITW, CRES

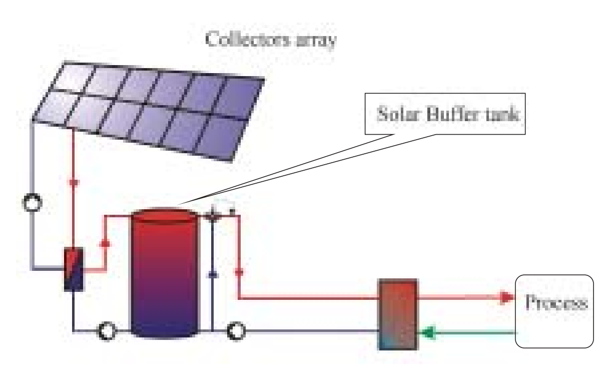

Fig. 6:

Hot water driven process – with storage (Acronym: HW, Storage). Source: ITW, CRES

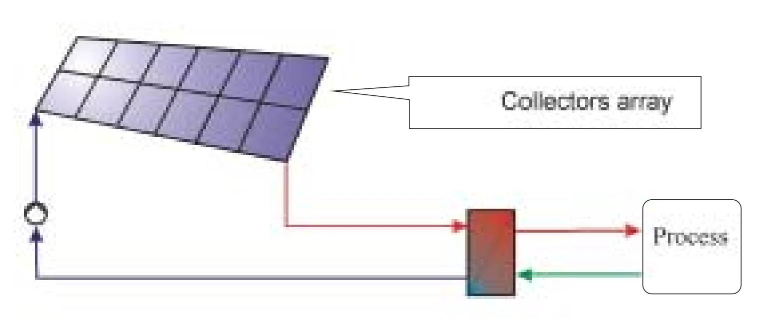

Fig. 7:

Hot water driven process– without storage (direct) (Acronym: HW, Direct). Source: ITW, CRES

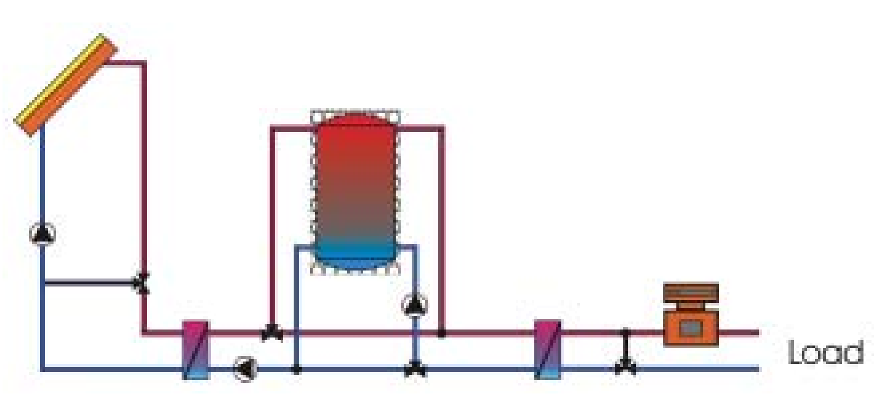

Fig. 8:

Hot water driven process/mixed (Acronym: HW, mixed). Source: ZAE

Configuration Acronym (see figures 3 to 8)	Brief comments on "solar suitability"
Open, HR	Suitability depends on the temperatures reached by the heat recovery process (T_{HR}). If T_{HR} <50°C, there is suitability.
Open, NO HR	High suitability. The solar plant can heat (or pre-heat) the water from very low temperatures. However, cases in industry where HR measures cannot be applied are rare.
Closed	No suitability for common collectors. Need for special collector types
HW, Storage	Very high suitability. Hot water instead of steam is used directly in the process, making the "available load for solar" actually equal to the total industry load. Storage is needed to cover load fluctuations and/or load requirements outside the sunny hours. In some cases (when a substantial part of the load occurs duringsunny hours), storage tank requirements are reduced. High solar fractions are possible.
HW, Direct	Very high suitability. Hot water instead of steam is used directly
	in the process, making the "available load for solar" actually equal to the total industry load. Solar fractions achieved are generally lower compared with the "HW, Storage" case.
HW, mixed	This is simply a configuration with the possibility to operate both in a direct way (see case "HW, Direct") as well as with storage (see case "HW, Storage").

Table 2: "Solar suitability" of some industrial process configurations

MAIN DESIGN ASPECTS

Necessary considerations-calculations

Once all the information and data described in the "preliminary design steps" have been obtained, the aspects to examine are described below.

Suitability of the minimum available temperature

As already stressed, it is essential for the feasibility study of the solar installation to estimate the "minimum available temperature" after the (hypothetical) application of all realistic heat recovery measures. If this temperature is equal, for instance, to 80°C in a certain industry, a solar plant (at least one with flat plate collectors) makes no sense for that industry. On the other hand, if it is 50°C, then there is concrete potential for a solar installation. In this last case, the solar plant can contribute to heating the water from 50°C up to the temperature required by the process (or up to a lower temperature if the solar plant is designed just for preheating). Figure 9 shows an example of an industry with both an open and a closed process. Supposing that the heat recovery measures are applied correctly, we can notice the potential for a solar plant installation to heat the water from 50°C upwards.

Suitability of thermal profile

The suitability of the thermal load profile has to be examined. Good profiles are those that are quite constant on a daily and seasonal basis (of course they are even better if they somehow follow the solar radiation profile e.g. if they have a daily peak at midday and seasonal peak in summer). Practically speaking, the load should pass the following tests:

1. Load should last for more than 3/4 of the year and should include summer.
2. Load should last for at least 5 days per week.
3. The mean daily summer load should not be lower than the mean daily load for the rest of the year.

Calculating the load

The load that is addressed to the solar plant should be estimated. If a nomogram is available (as with the one examined later), then it is enough to know the daily flow request (e.g. 7500 l/day) and apply the nomogram directly by assuming a certain solar fraction. However, it should be stressed that, in order to obtain utilisable results, the nomogram should be based on conditions similar to the real case examined in terms of weather conditions, temperature requirements, the type of collectors and the load profile.

When a nomogram is not available, the designer should calculate the load analytically, i.e. by applying the equation $E= m*Cp*\Delta T$ and calculating the resulting thermal kWh. For example, if the mean daily requirements of an industry are 15 m^3 that have to be heated from 50^{0}C to 90^{0}C, the resulting mean daily thermal load is about 700 kWh while the annual industry thermal load is about 250 MWh. This can provide a rough estimation of the collector area that is needed to obtain a certain solar fraction. Following the above example (and making the hypothesis for the specific solar gain to be about 500 kWh/m^2) we obtain a collector area of about 200 m^2 if we choose the solar fraction to be 40%.

Dimensioning of the solar collector array

There is no unique or standard way to dimension a solar thermal plant, either for industrial or other purposes. However, there are certain common sense considerations that may offer some guidelines. First of all, in the case of relatively constant load profile, reasonable solar fractions cannot be higher than 60-70%. This maximum threshold is usually reduced for the particular category of industrial processes[1] to about 50%. On the other hand, a too low solar fraction (e.g. less than 10%) leads to negligible solar energy savings and to little economic interest from the End User point of view.

The criteria for the choice of a solar fraction from the remaining range (10 to 50%) include the following:

- **Space restrictions for installation of solar collectors.** The available area for the collectors installation should be calculated (excluding shaded parts, obstacles etc.) and divided by a factor of about 2.5 in order to obtain the maximum collector area that can be installed.

- **Economic reasons:** upper restrictions on the investment or identification of the optimum investment solution. In the second case, the following issue should be considered. Higher solar fractions generally result in slightly lower specific solar gains; on the other hand the -specific- price of solar systems reduces as they become larger.

- **Environmental considerations.** One of the End User's priorities may be to create an "environmental friendly" industry; therefore he may choose the highest reasonable solar fraction. Such a choice, among other advantages, may also have economic benefits in the long term.

Dimensioning of the accumulators

As far as tanks are concerned, usually the typical value of 50 litres per m^2 of collector is enough. Simulations have shown that higher specific volumes only slightly increase the solar gains. In the case of low solar fractions, values less than 50 l/m^2 could also be used. The criterion for the minimum possible specific tank volume should be to avoid overheating and, in this way to avoid reduced collector efficiency. As far as the layout of the storage configuration is concerned, the main aspects are listed below:

- The use of a unique storage tank is usually the best solution from an economic and energy point of view.

- When more than one storage tank has to be used (for example due to limited height of the storage room), then there are no major differences between the "in series" and "in parallel" connections.

- An important point to ensure in all configurations is tank(s) stratification.

Using a nomogram

The nomogram seen in figure 10 was created in accordance with [Fink, 2004] with some necessary adaptations. Before using the nomogram, the load (in l/day) as well as the chosen solar fraction should be known.

For the sake of completeness, the plant utilisation factor "U" (used in the x-axis) is explained here. "U" is defined as the ratio of the mean daily flow requirements divided by the collector's gross area. Although it does not correspond to any familiar physical quantity, it is a valuable tool in order to obtain a nomogram that is independent of the solar plant size. Increased U values correspond to higher load per m^2 of collector (and therefore to low solar fractions) and vice versa.

An example of dimensioning a solar plant with the help of the nomogram is presented below.

The mean daily hot water demand of a textile dyeing process is 7,500 litres at 80°C. The hourly demand

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[1] *Reasons for this reduction could be high temperature requirements, the uncertainty of the load in the long term, etc.*

profile is quite stable from 6:00 until 20:00. The daily profile is constant from Monday to Friday, halved on Saturday and zeroed on Sunday. All monthly profiles are identical. The minimum available temperature for the solar plant is 30°C. For this specific example, the solar fraction is set at 40% and the fraction V/A (storage volume per m^2 of collectors) is supposed to be equal to 50 l/m^2. The steps needed to define the collector area and the storage volume are as follows:

- The horizontal line "1" is drawn from the value of 40% (on the left y-axis) to the intersection with the solar fraction curve.
- Starting from the previous intersection point and going vertically downwards (see line "2a"), we obtain a utilisation factor (U) value on the x-axis equal to about 70 litres/m^2. Therefore, the collector area needed is calculated dividing the mean daily demand (7,500 l) by the U factor (70 l/m^2): the result is equal to 107 m^2.
- Once the collector area has been defined (107 m^2) the storage volume is simply obtained multiplying by 50 l/m^2. Therefore, the total storage volume is 5,350 l (obviously the final choice for the storage volume will be adapted to market availability and to space limitations, e.g. one tank of 3,000 and one of 2,500 or 2,000 litres).

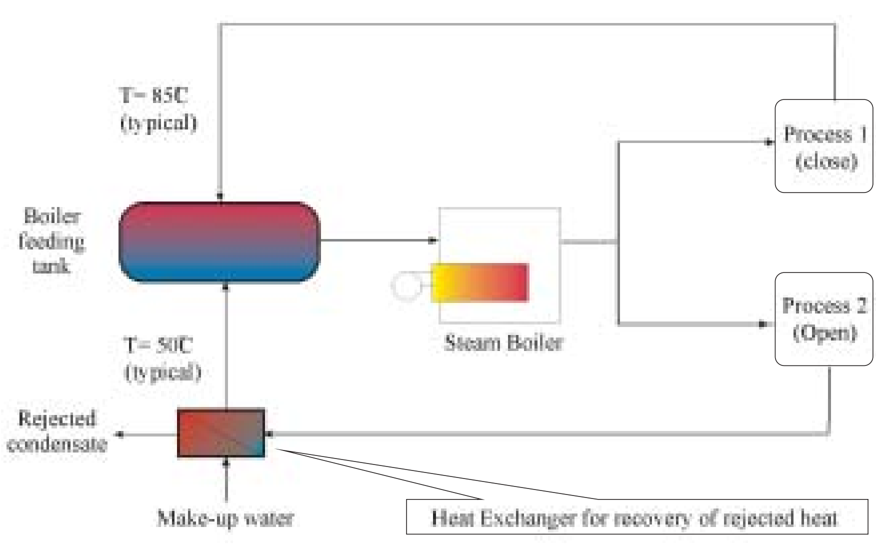

Fig. 9:

Diagram for two (coupled) industrial processes. Source: CRES

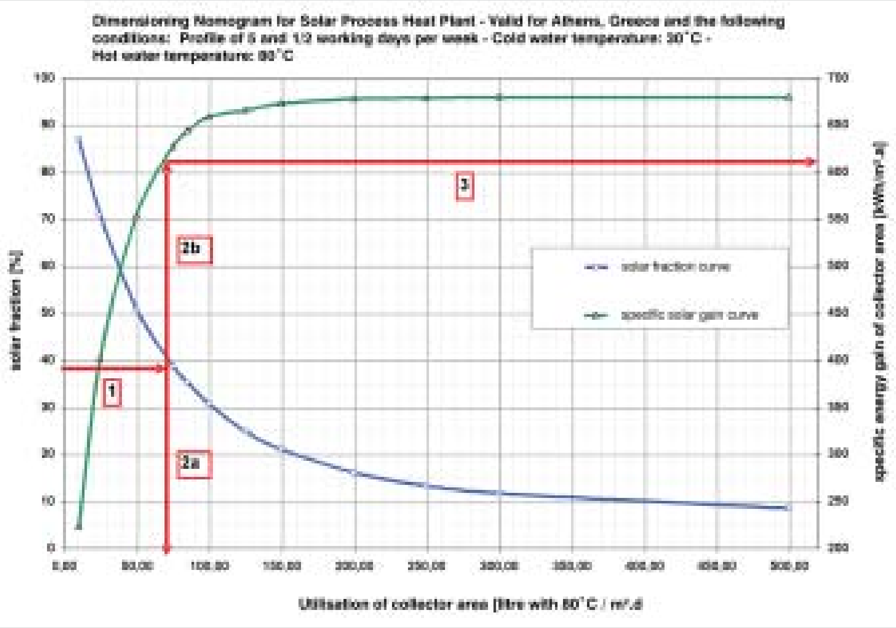

Fig. 10:

Nomogram with an example of use. Source: CRES, based on an AEE methodology

- In order to identify the solar gains draw line "2b" upwards, until it intersects with the upper curve (specific gains curve). Thus, following the horizontal line "3" until the intersection with the right y-axis, we can read the specific solar gain of our plant [the figure resulting is approximately 625 kWh/(m^2.a)]. The total plant production is simply calculated by multiplying the collector area found before (107 m^2) by the specific plant production. The total solar gain is therefore approximately 67 MWh per year.

It is worth mentioning that the nomogram used for the dyeing process is also applicable for all processes with characteristics that are similar to the one examined. Therefore, it is valid for flat plate collectors, the same temperature range (30-80°C), a heat load similar to the above and for weather conditions analogous to Athens, Greece. By using this simple tool, a designer can obtain a quite clear idea of the plant dimensions and the energy savings that correspond to certain solar fractions. Figure 11 below shows a solar-assisted textile dyeing process in diagrammatic form.

Software tools

The use of a simulation tool may help with both the dimensioning of a solar plant as well as its optimum configuration. There are various tools available on the market; some are quite user-friendly while others are intended for experienced users only. One important thing to stress here is that, quite often, simplified system configurations that require little effort on the PC may offer substantial help, at least in the first stage of system design. One example is depicted in figure 12, where the T-SOL program has been used with a very simplified configuration (one can mention the internal heat exchanger in the tank) that, however, has offered important results.

The most significant value obtained from the simulations is the specific solar gain. This value can offer a basis for comparison between various solar system options. Generally speaking, the lowest acceptable value for the specific solar gains is about 350-400 kWh per m^2 of collector annually.

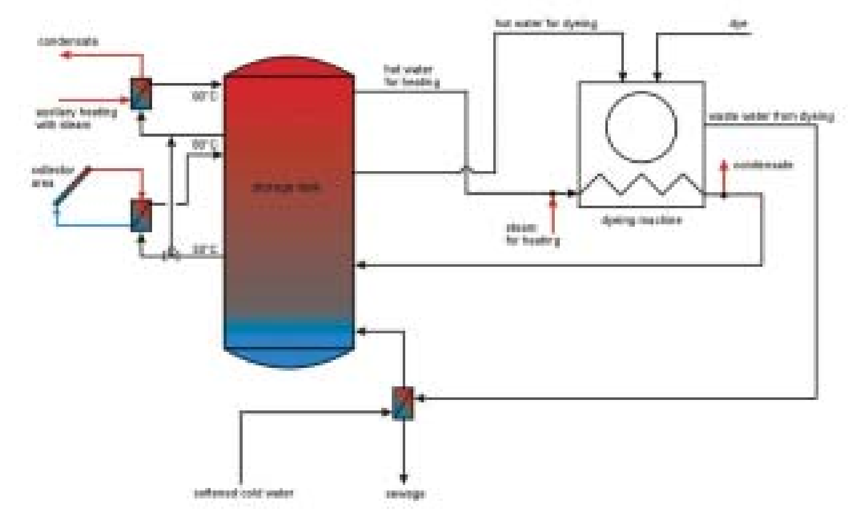

Fig. 11:

Solar assisted textile dyeing process (Source: AEE)

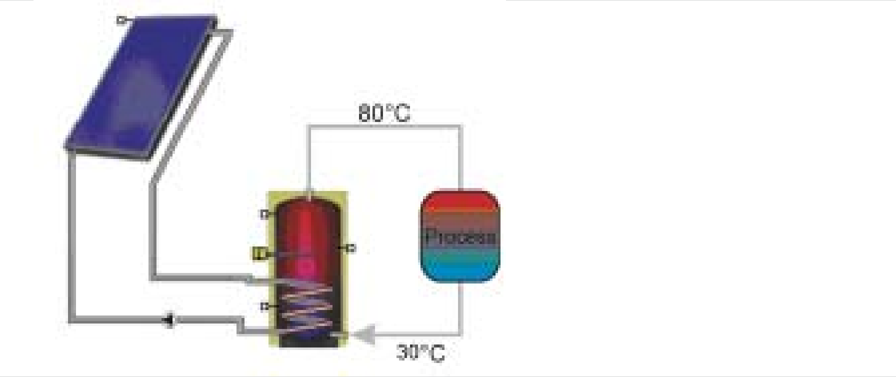

Figure 12:

Simplified system configuration using the T-SOL simulation program

SPECIFIC DESIGN ASPECTS

Specific requirements for certain components/properties

Some main components that differ from conventional heating installations are pointed out below:

Antifreeze liquid

Usually, the antifreeze liquid used in solar thermal plants is a mixture of water, propylene glycol and corrosion inhibitors. This mixture has to be produced specifically for solar plants (and should therefore be resistant to high temperatures). The procedure to establish the required percentage of glycol in the mixture is described in the paragraph entitled "Freezing protection". One important aspect is that for the dimensioning of most hydraulic parts of the primary circuit (pumps, piping, heat exchangers, expansion vessel etc.), consideration has to be given to the fact that the glycol mixture has different physical properties from water. These properties are available from the liquid producer.

Collector orientation and inclination:

Obviously the most favourable orientation is south. However, deviations up to $\pm 30^0$ are acceptable without any substantial change in collector dimensioning. The same flexibility occurs with collector inclination. Its optimum value depends on the seasonal load distribution and, of course, on the location's latitude. For Mediterranean areas and quite constant seasonal load distribution, the optimum inclination value is about 30^0 with respect to the horizontal.

Pumps

The primary circuit pumps should (inter alia) be durable in relation to the following:

- water glycol mixtures and their corrosion inhibitors.
- maximum possible temperatures at the collector circuit runback.
- high ambient temperatures (it could be 40°C or more in the boiler room)

Flow rates

Generally speaking, large-scale solar plants (i.e. plants with collector areas greater than 200 m^2) implement the so-called "low flow" strategy. This means typical values for the flow rate in the primary (collector) circuit of about 12-15 l /(m^{2}*h) (litres per square meter and per hour). The main advantages of a low-flow system [compared to the typical high flow systems with about 50 l /(m^{2}*h)] are as follows:

- Simpler hydraulic configurations are possible (many collectors in series).
- Smaller (and shorter) tubes are required.
- Smaller pumps are needed.

However, there is one aspect that should be examined before applying the low flow strategy in industrial plants: this is the case of plants that are designed to deliver a low ΔT (as happens with plants that cover small solar fractions just for water preheating). In this last case, the flow should be defined according to the ΔT needed.

Other aspects

- Due to the wide range of operating temperatures in the collector circuit the thermal expansion of the piping has to be taken into account.

- The high temperatures that can occur during stagnation should be taken into account for various components of the primary circuit: pipe insulation materials, valves, membrane of the expansion vessel, pipe soldering and so on.

- The insulation material mounted outside should not absorb humidity, should be able to with - stand UV-rays as well as the external atmospheric conditions and mechanical impact due to mice or birds.

Freezing protection

For all locations where freezing temperatures may occur, it is necessary to fill the primary (collector) circuit with an antifreeze mixture of propylene glycol and water. The concentration of glycol in the mixture should be such that no freezing problems will occur even in extreme weather conditions. A strategy often adopted [Pauschinger, 2004] is to design the plant so that it can stand the "freezing safe" Temperature (T_{fs}), defined below: $T_{fs} = T_{ref} – 10$ K

T_{ref} is a temperature here called "reference" that is equal to the nominal winter temperature used for calculating the maximum power required for the building heating system. In most countries this nominal winter temperature is defined for all main cities; thus it can be taken as a concrete base for calculating the "freezing safe" Temperature (T_{fs}).

An alternative method has been applied in the past in a number of solar plants in Europe. This consists of filling the primary circuit with water from the mains coupled with an automated mechanism that activates the pump in case of frost. This last method is not suggested for the following reasons:

- In order to overcome possible failure of primary pump activation, a second pump is required. The pumps should be connected to a power generator in case of power interruption.
- The installation of more than one temperature sensor in the collector array is required in order to deal with sensor failure. However, once again, this does not ensure 100% protection.
- If the method fails only one single time during frost conditions, the damage can be very extensive (multiple fractures of pipes in the primary collector circuit).

Another method is the use of water in the primary circuit that is emptied (and then collected in a container) each time the operation of the pump is interrupted. This method (drain-back) is effective; however it assumes a high specialisation installation and may present (in addition to other problems) practical difficulties in the positioning of the collectors (so that they can empty perfectly). Consequently this method is suggested only when planning and installation companies have a solid experience in it.

An important point that should be particularly stressed is that in any case no automatic refill valve connected with the mains should be present in the primary circuit. Such a mistake could (for various reasons, such as a small leakage) result in the loss of glycol and the filling of the primary circuit with water without any indication of this (since the pressure will remain constant). The consequences can be devastating for the system (multiple fractures of piping in the primary circuit will occur in case of frost).

Stagnation protection

A solar system is in a state of stagnation if the primary circuit pump is not in operation but there is still incident radiation on the collectors, which are heated up. This state can be caused by a technical defect in the system, by a power failure, or simply by the lack of thermal load. As reported in [Fink, 2004], there are extended analyses on this topic. The most crucial aspects are described below:

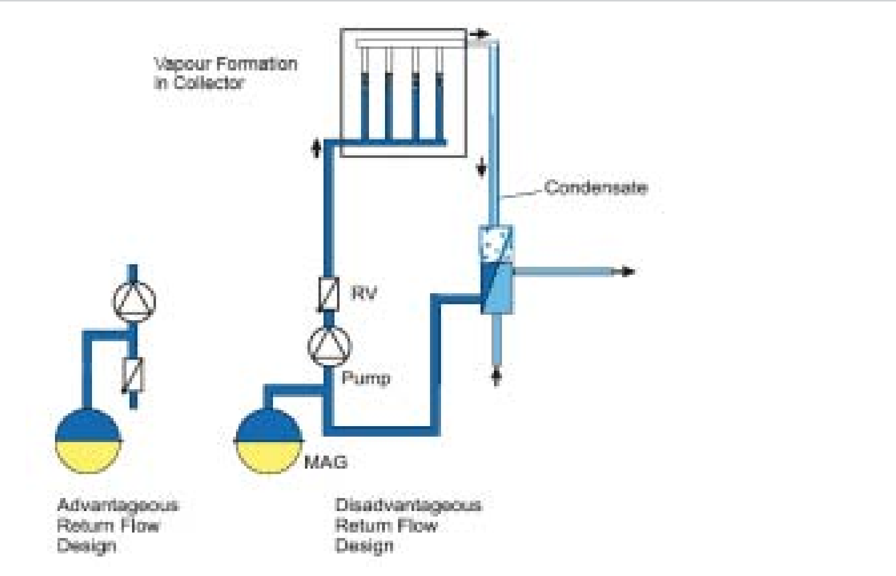

Fig. 13:

Vapour creation in stagnation / return valve position. Source: [Fink, 2004]

- If the incident radiation is strong enough, vapour will be generated in the collectors since their temperature may reach values as high as 200°C (see fig. 13).
- The piping inside the collectors is emptied (partially or fully, depending on the collector connections configuration) due to the vapour creation. The glycol mixture is pushed out from the collector pipes and is directed to the rest of the primary circuit. As a result, the pressure will rise.

Figure 13 also shows the importance of non-return valve positioning. The correct position is shown on the left side, where the entire path from the expansion vessel to the collectors is free, thus giving the fluid the option to move backwards.

The points below list the measures needed in order to avoid stagnation problems:

1. Use of collectors and collector arrays with good emptying behaviour.
2. The non-return valve should not be between the expansion vessel and the collectors.
3. In existing plants without proper design for stagnation, a cooler (a liquid/air heat exchanger) should be installed on the tube that connects the expansion vessel with the primary circuit.
4. Correct dimensioning of the expansion vessel in order to be able to absorb the whole volume or the collector piping. The above method is usually adopted for relatively small solar plants (up to about 200 m^2). For larger plants, since the expansion vessels required become huge, in stagnation conditions a valve would allow the glycol mixture to be collected in a vessel and then refilled again into the primary circuit when possible.
5. Correct dimensioning of the safety valve (usually 6 bar) in order to withstand the maximum pressure during stagnation.
6. Ensure the following controller function: no pump operation at collector temperatures more than 120°C (this inhibits the restarting of the system during stagnation state).
7. Use of the correct heat transfer media: a glycol mixture that maintains its properties at high temperatures.

MAINTENANCE GUIDELINES

Once the design and construction phases have been concluded properly, solar thermal plants require little maintenance in order to operate efficiently for their lifetime (estimated to be about 20 years) and the actions required are low cost. Apart from pure maintenance, most of the necessary actions during the solar plant's operation are periodic inspections. They are listed in table 3 below, together with an indication as to their frequency:

Maintenance or periodic inspection	Frequency	Comments/ clarifications
Condition of collector array	Once a year	Visual inspection of possible internal or external degra dations (broken glass, loose-jointed frames and connections etc). Remove and replace the broken or damaged parts.
Transfer fluid testing	Twice a year (before summer and before winter)	Check the antifreeze solution percentage (by measuring its density) and the pH level (pH level should not fall below 7).
Pressure of the primary circuit should be constant	Twice a year or more often if easy	The inspection should be carried out when there is no incident radiation (e.g. in the eveningtime)
ΔT created by the collectors (during sunny hours) should be near the design value (e.g. about 20°C)	Twice a year	A higher value indicates a flow reduction due to obstacles or pumping problems. Lower values indicate either a too high flow or efficiency problems.
Collector temperature should be almost equal to the collector array outlet	Twice a year	These temperatures are near to each other. Differences in the controller indications are due to malfunction of the sensors or of the controller itself.
Primary circuit pump is off when there is no sun.	Twice a year	If not, there is some problem either with the sensors or the controller.
Presence of air in the primary circuit (noise) Collector glass should not become dirty	Once a year Once a year	Remove trapped air – refill circuit at correct pressure (if needed). This is rare; glass needs to be cleaned only when very dirty and it has not rained for a long time.
Energy meter in "good operating conditions" should show more than about 3 kWh /m^2 in one day	Twice a year or more often is easy	"Good operating conditions" here means a sunny dayi with normal heating load

Table 3: List of maintenance actions and periodic inspections fro solar plants

Except for the foregoing suggested maintenance actions for the solar thermal plant, the remaining conventional components of the installation (pumps, tanks, valves, piping, control systems, etc.) follow the respective instructions suggested by manufacturer's for proper and good lifetime operation (as in a common hydraulic installation).

MANAGEMENT AND FUTURE ASPECTS

Solar plants for industrial processes represent an interesting option for the future. This brochure has pointed out the main design and maintenance guidelines for such systems. It is important to stress again that correct design and installation minimises maintenance requirements. Moreover, in order to obtain the maximum possible efficiency from a large solar thermal system assisting an industrial thermal process, it is important to adopt an appropriate management and monitoring approach.

As far as management is concerned, the following points have been identified as being the most crucial:

- Appropriate start-up and subsequent adjustments based on several months data from the plant basic measurements (solar gain, temperatures, flow-rates, etc.).
- Detailed drawings and guidelines for operation and maintenance should be available to the person(s) responsible for plant operation.
- Periodic controls (described previously) should be ensured. They are simple and easy but crucial for correct plant operation.
- Continuous monitoring via remote control with the possibility of fault alarms (e.g. via SMS) is useful (tuning is easier, "ad hoc" personnel inspections can be drastically reduced and technical problems can be dealt with at an early stage, thus minimising deterioration risks).
- Someone should be responsible for plant operation. This responsibility is of great importance and should be assigned to skilled people (experience has shown that the construction company itself is perhaps the best plant manager). In various successful examples not only has operation but also realisation and investment responsibility been taken from the constructor through a "solar contracting" scheme.

Finally, although this brochure (as well as the entire PROCESOL II project) is addressed to industrial processes with temperature requirements up to 90°C, it is worth mentioning a few aspects for higher temperature requirements (the so-called medium temperatures).

- Recent research has shown that with few modifications (i.e. the use of double glazing), flat plate collectors can operate with good efficiency up to 150°C.
- By addressing medium temperatures, the potential for solar integration in the industry will increase substantially.
- An interesting project on this area has been undertaken by the experts of IEA Task 33 [IEA Task 33, ongoing]. Information is available on the site http://www.iea-ship.org

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