Integration schemes and BOPs more commonly used in commercial SHIP applications

Subtask B: “Modularization”

Activity B1: “Modular system concepts for SHIP applications”

IEA SHC TASK 64 | IEA SolarPACES Task 4 | Solar Process Heat

Technology Collaboration Programme
by iea

Integration schemes and BOPs more commonly used in commercial SHIP applications

This is a report from SHC Task 64 / SolarPACES Task IV: Solar Process Heat and work performed in Subtask B: Modularization

E. Zarza, D. Alarcón (CIEMAT-PSA)
with contributions from M. Frasquet (SOLATOM) & P. Saini (ABSOLICON)
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Solar Heating and Cooling Technology Collaboration Programme (IEA SHC)

The Solar Heating and Cooling Technology Collaboration Programme was founded in 1977 as one of the first multilateral technology initiatives ("Implementing Agreements") of the International Energy Agency.

Our mission is *"Through multi-disciplinary international collaborative research and knowledge exchange, as well as market and policy recommendations, the IEA SHC will work to increase the deployment rate of solar heating and cooling systems by breaking down the technical and non-technical barriers."*

IEA SHC members carry out cooperative research, development, demonstrations, and exchanges of information through Tasks (projects) on solar heating and cooling components and systems and their application to advance the deployment and research and development activities in the field of solar heating and cooling

Our focus areas, with the associated Tasks in parenthesis, include:

- Solar Space Heating and Water Heating (Tasks 14, 19, 26, 44, 54, 69)
- Solar Cooling (Tasks 25, 38, 48, 53, 65)
- Solar Heat for Industrial and Agricultural Processes (Tasks 29, 33, 49, 62, 64)
- Solar District Heating (Tasks 7, 45, 55, 68)
- Solar Buildings/Architecture/Urban Planning (Tasks 8, 11, 12, 13, 20, 22, 23, 28, 37, 40, 41, 47, 51, 52, 56, 59, 63, 66)
- Solar Thermal & PV (Tasks 16, 35, 60)
- Daylighting/Lighting (Tasks 21, 31, 50, 61)
- Materials/Components for Solar Heating and Cooling (Tasks 2, 3, 6, 10, 18, 27, 39)
- Standards, Certification, and Test Methods (Tasks 14, 24, 34, 43, 57)
- Resource Assessment (Tasks 1, 4, 5, 9, 17, 36, 46)
- Storage of Solar Heat (Tasks 7, 32, 42, 58, 67)

In addition to our Task work, other activities of the IEA SHC include our:

- SHC Solar Academy
- *Solar Heat Worldwide*, annual statistics report
- SHC International Conference

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Our focus areas are organized in six tasks:

- Task I: Solar Thermal Electric Systems
- Task II: Solar Chemistry Research
- Task III: Solar Technology and Advanced Applications
- Task IV: Solar Heat Integration in Industrial Processes
- Task V: Solar Resource for High Penetration and Large Scale Applications
- Task VI: Solar Energy and Water Processes and Applications

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- SolarPACES International Conference.
- Review of CSP market and cost data with the International Renewable Energy Agency (IRENA).
- Joint project on solar resource for high penetration and large scale applications in collaboration with the TCP on Photovoltaic Power Systems (PVPS TCP).
- Project in solar process heat in collaboration with the TCP on Solar Heating and Cooling (SHC TCP).

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Contents

1 Executive Summary

The main objective of the Subtask B in the new Task 64/IV is the definition of modularized and "normalized" components/subsystems for applications in the field of Solar Heat for industrial Processes (SHIP), e.g. for the balance of plant (BOP), solar field, thermal energy storage and hydraulic circuit. The methodology to achieve this goal is composed of three steps:

1. Identification of components/subsystems that are used in commercial SHIP projects more often, taking into consideration the inputs delivered by the partners and information existing in current databases
2. Development of modular/standardized designs for these components/subsystems
3. Distinction between low and medium temperature SHIP applications

Step 1 was based on the analysis of the integration schemes that are more likely to be used in next commercial SHIP projects. It was assumed when preparing the work plan of Subtask B that during this analysis a small number of integration schemes would be identified as good candidates for next commercial projects. However, the integration schemes so far proposed by most of the industrial partners involved in Subtask B were quite different from each other, thus showing that the next commercial projects may use very different integration schemes, in both low and medium temperature range. To check to what extent this is true, the integration schemes so far proposed by the industrial partners are shown in this document (Section 2), together with information about the integration schemes used in the commercial projects included in the data base: www.ship-plants.info (Section 3).

For the above reasons, it was decided within Subtask B to adopt a new strategy. This new approach was based on the analysis of BOP options depending on the fluid required in the industrial process and the working fluid used in the solar field.

Once the list of these fluids was identified, the industrial partners were asked to perform an integration analysis of those combinations that were part of their business portfolio. Section 4 covers the contributions received to date.

2 Integration Schemes proposed by the industrial partners for commercial SHIP applications in the medium temperature range

The integration schemes proposed by PROTARGET, RIOGLASS, SOLATOM and ABSOLICON for the medium-temperature range are shown in this section. However, the integration scheme proposed by ABSOLICON could be used for the low temperature range also, depending on the solar field working temperature.

2.1 Integration scheme proposed by PROTARGET

PROTARGET has proposed an integration scheme with CPC (compound parabolic collectors) and PTC (parabolic trough collectors) delivering solar heat at both supply and process level, as shown in Figure 1.

The CPC solar field preheats the feed water of the steam boiler, with a thermal energy storage (TES) using the preheated feed water, thus delivering solar heat at supply level. The PTC solar field delivers solar steam at process level, though it could also deliver steam at supply level.

2.2 Integration schemes proposed by RIOGLASS

RIOGLASS is developing three different integration schemes, two of them shown in Figures 2 and 3. The first integration scheme (Figure 2) is aimed at recovering water from the brine rejection of reverse osmosis (RO) desalination plants. This option is very interesting for places with lack of water, because its recovery rate is 90%. The solar field outlet temperature is 120ºC.

The second integration scheme is designed for urban wastewater sludge dryers powered by solar thermal energy. It is specially designed to be used with bed-type dryers, so that the dryers are heated from the bottom using the thermal energy delivered by the solar field. Due to its simplicity, no diagram of this system is shown here.

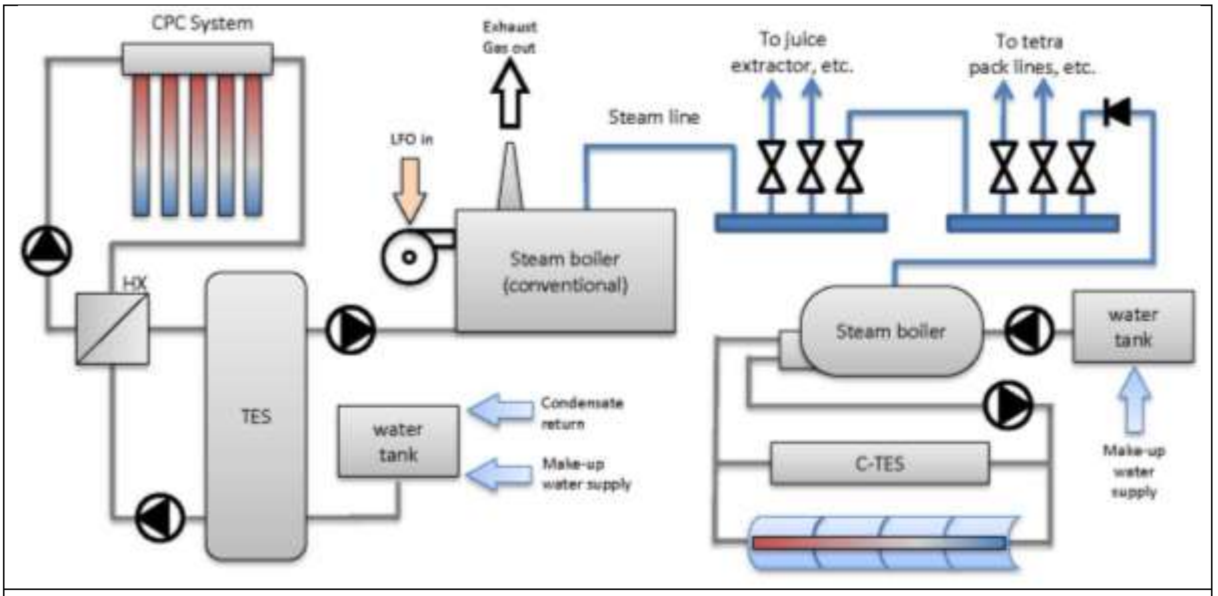


Figure 1. Integration scheme proposed by PROTARGET.

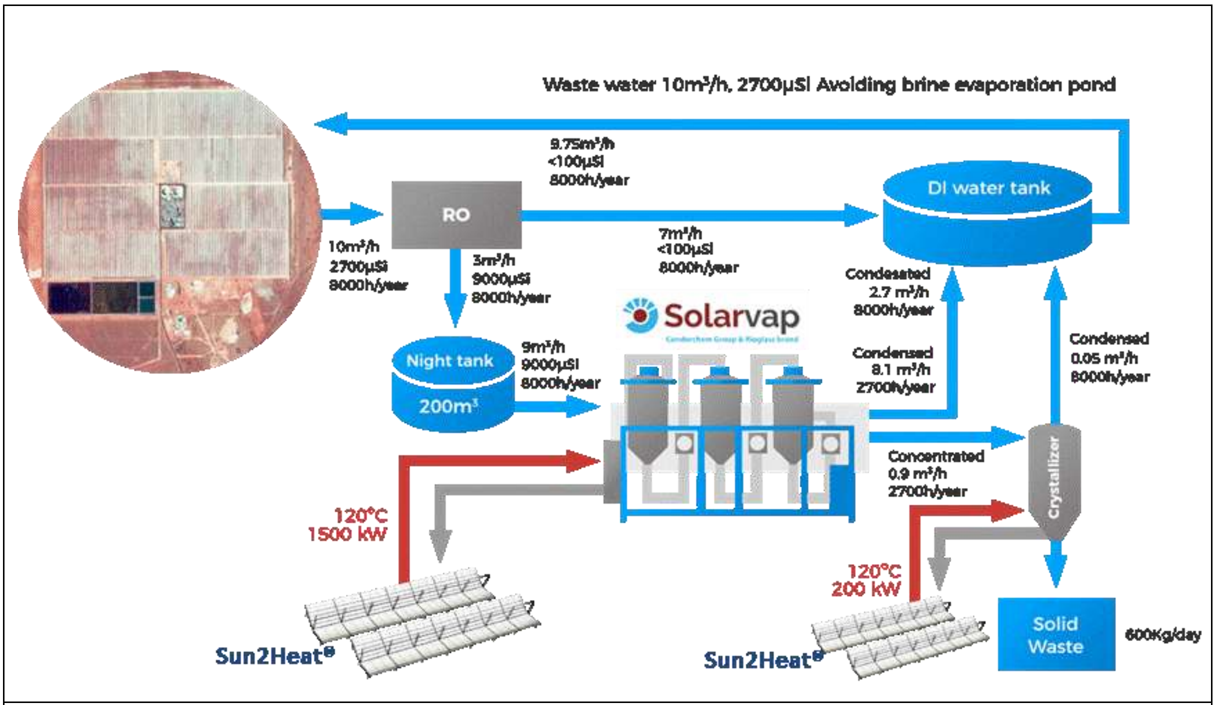


Figure 2. Integration scheme for water treatment/recovery with a Multi-Effect-Distillation (MED) plant.

The third integration scheme proposed by RIOGLASS (see Figure 3) is designed for cogeneration (combined heat and power, CHP). Thermal energy delivered by a concentrating solar field is used to produce electricity with an Organic Rankine Cycle (ORC) and the waste heat from the ORC is used to feed a water desalination/treatment plant using multi effect distillation (MED) or membrane distillation (MD).

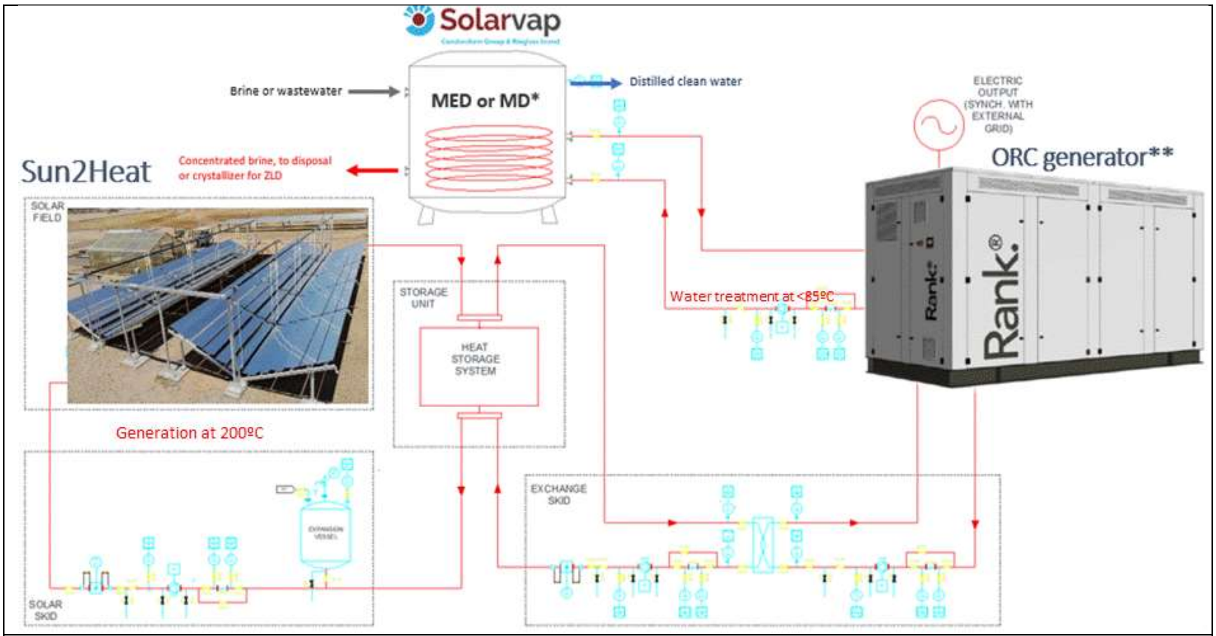


Figure 3. Integration scheme for combined heat and power

2.3 Integration schemes proposed by SOLATOM

The Spanish company SOLATOM has proposed an integration scheme mainly focused on steam generation, because:

- most of the industries with thermal processes use a steam generator (boiler) fed by fossil fuels (natural gas or diesel, usually), even when they need hot liquid water only. Saturated steam is an excellent heat supplier because it releases a significant amount of thermal energy at constant temperature during the condensation process.
- Solar steam generation allows the parallel integration with the conventional fossil-fired boiler (integration at Supply Level instead of al Process Level). Users are quite reluctant to introduce modifications in their processes and are more open to connect the solar system in parallel with the conventional boiler at supply level.
- Steam generation is usually not feasible with low-temperature solar collectors, thus providing concentrating collectors manufacturers with a strong argument to use their collectors in commercial SHIP applications.

There are two main options for solar steam generation (i.e. indirect generation using pressurized liquid water in the solar field connected to a Kettle boiler, and direct steam generation in the solar field) and SOLATOM is especially interested on solar direct steam generation, and they propose this option for standardization/modularization in Subtask B, because direct steam generation has the following benefits:

- lower working pressure in the primary circuit and avoidance of thermal oil in the solar circuit, with the environmental benefits associated to the replacement of the oil by water.
- it is more cost-effective than the indirect steam generation option.

The integration scheme proposed by SOLATOM is shown in Figure 4, while Figure 5 shows a skid developed by SOLATOM for such an integration.

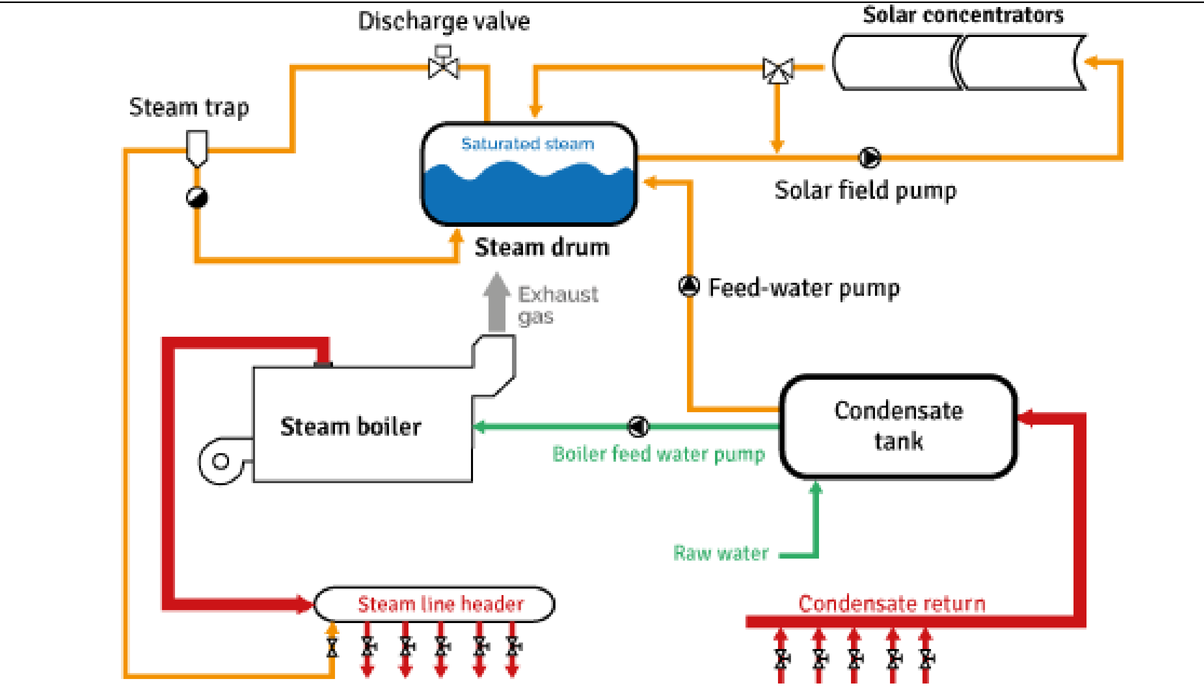


Figure 4. Integration scheme proposed by SOLATOM

Figure 5. Skid developed by SOLATOM for the integration scheme shown in Figure 4.

2.4 Integration schemes proposed by ABSOLICON

Figure 6 shows the simplified scheme of the integration proposed by the company ABSOLICON, which is specially designed for breweries. The final integration scheme for this case is centered around using a large, pressurized storage tank (>1000 m^3), and then adapting the complete steam network to use these lowered temperatures for various processes.

The heat carrier to processes is now pressurized hot water, and not steam. The pre-requisite for an efficient integration of solar thermal system is the stratification of the tank, which is maintained using stratifying elements within the tank. The tank enables to decouple all the heat sources, and heat sinks, and also allows to use multiple heat source to utilize for process heating. As shown in Figure 6, the solar field is used on supply side to increase the water temperature from low to medium temperature range. Solar field receives water from bottom of the tank and heat it to the temperature corresponding to middle layer of the tank. A heat pump is used as backup to solar heat. The high temperature heating is achieved using a boiler, which now operates at much lower temperatures. On the process side, controls are provided to divide the return water lines based on their temperature to maintain stratification of the tank.

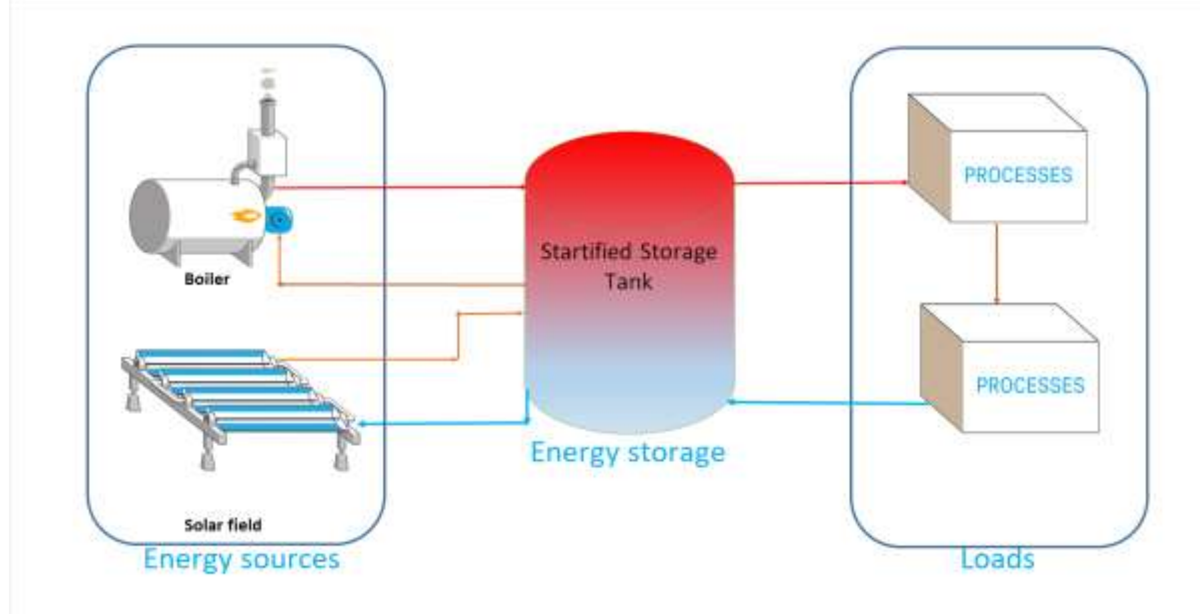


Figure 6. Integration scheme proposed by Absolicon

The reasons to choose this integration schemes are:

- Better solar field, and energy network efficiency due to lower operating temperatures.
- Possibility of adding waste heat/other heat sources in the tank, and thus reduction in fuel consumption.
- The expansion of the solar field is much easier, as storage tank is already in place. The field size no more depends on the load profile of the process.
- Improvement in overall system efficiency due to the use of a stratified storage tank.

3 Integration schemes used for commercial SHIP applications in the low temperature range

In this section, the different integration schemes found in the projects included in the data base *www.ship-plants.info* are summarized, giving the number of commercial projects using each of the eight different integration schemes defined in this data base. Figure 7 shows an overview of the different integration schemes considered in www.ship-plants.info.

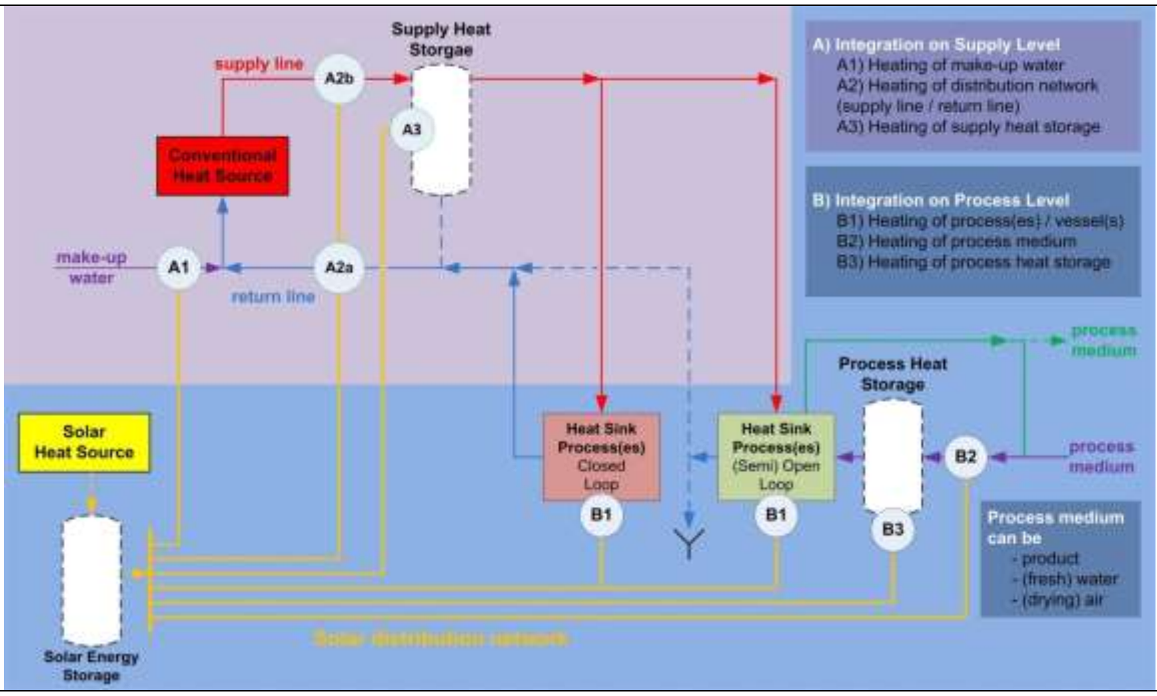


Figure 7. Different integration schemes considered in the data base www.ship-plants.info

The equivalence between the integration schemes showed in Figure 7 and those defined in [1] is sometimes easy and sometimes very difficult or even impossible, as shown in Table 1.

Table 1: Equivalence between the integration schemes showed in Figure 7 and those defined in [1].

Description	**Code in Fig. 7**	**Code in Ref [1]**
Solar heating of make-up water	A1	SL_S_MW
Solar Heating of distribution network return line / Solar return flow boost	A2a	SL_L_RF
Solar Heating of distribution network supply line / Parallel integration	A2b	SL_L_P
Solar heating of supply heat storage / Solar heating of storage	A3	SL_L_SC
Solar heating of process(es) or vessel(s)	B1	------
Solar heating of process medium	B2	PL_E_PM
Solar heating of process heat storage	B3	------
Other integration schemes	C	------

The analysis of the integration schemes used in the projects currently included in the data base www.ship-plants.info has given the results shown in Table 2.

Table 2: number of commercial projects in *www.ship-plants.info* using the same integration scheme (total number of projects analysed: 325).

Integration scheme used	Number of projects
A1	64
A2a	6
A2b	40
A3	23
B1	63
B2	34
B3	12
C (others)	83

Although the information about the supplied temperature is not available for each project, the information about the type of solar collector implemented is useful to have an idea on the solar field outlet temperature. Table 3 gives several types of collectors and the number of projects using each type of collector in www.ship-plants.info.

Table 3: Types of solar collectors and number of projects using them

Collector type	Number of projects
Air collector	20
Evacuated Tube Collector	49
Flat Plate Collector	155
Fresnel	17
Parabolic trough	58
Unglazed	3
Others	31

From the numbers given in Table 3, it seems reasonable to think that more than 60% of the projects included in this data base belongs to the low temperature range and therefore Table 2 shows that several integration schemes are currently used in the low temperature range.

4 Definition of generic BOPs

Due to the variety of integration proposals received from the industrial partners, the decision was made to approach the problem from a different perspective. This new strategy consisted of defining a list of the most common fluids used in industrial processes as well as the most common working fluids used in the solar field. Once this list had been drawn up, the combinations that were most viable from both a technical and commercial point of view were identified. Figure 8 shows the result of this analysis exercise.

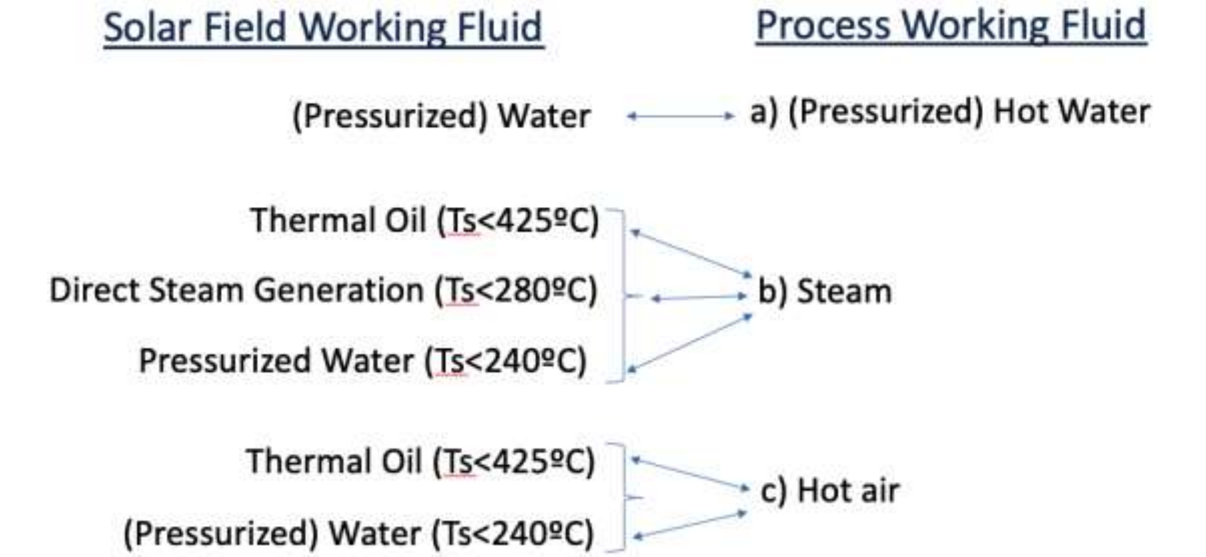


Figure 8. Different combination of process fluid and solar field working fluid considered for the analysis of generic BOP configurations

The group of industrial partners participating in Subtask B were asked to choose the combination or combinations they considered appropriate in order to carry out the exercise of proposing a generic BOP analysis based on the selected pair of fluids. The sequence of steps stipulated for such an analysis is as follows:

1. Definition of a generic BOP configuration/scheme for each combination of "Solar field working fluid" and "process working fluid", stating the limits for validity
2. Identification of the main elements (equipment) for each BOP scheme/configuration, and definition of their:
    a. Parameters required for design and manufacturing (e.g., nominal power, pressure and temperature)
    b. Instrumentation required for safe operation, maintenance and control
3. Identify (at conceptual level) the thermal energy storage options for each BOP scheme
4. Define the key technical parameters of each BOP configuration for modularization (e.g., power and/or temperature and/or pressure levels)

The following subsections show the contributions collected up to the date of edition of the present version of this deliverable.

4.1 Generic BOP for direct steam generation proposed by SOLATOM

The generic BOP design for direct steam generation (SL_S_PD) follows the scheme described in Section 2.3. The proposed design is valid up to 12 bar of operating pressure, and it can be scale up to 2 MW_t of design power. The BOP consists mainly of a steam drum that provides the phase separation, a solar pump to feed water (in saturation conditions) to the solar field, a feed pump to provide fresh water to the steam drum, and a discharge system to control the steam discharged to the industrial steam grid. Figure 9 shows the diagram of the generic BOP.

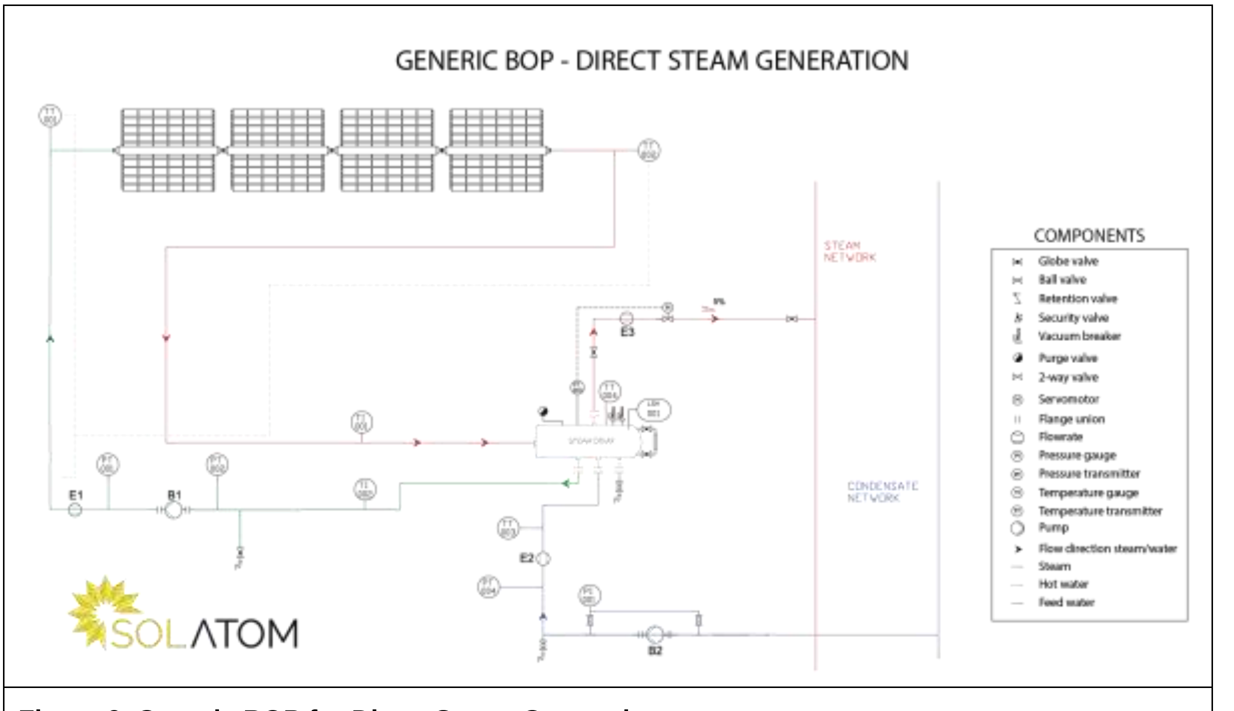


Figure 9. Generic BOP for Direct Steam Generation

The feed system (blue line in Figure 9) is connected to the client's condensate network (usually the main condensate tank). The feed pump (B2) is controlled using the level inside the steam drum. Depending on the size of the steam drum, a simple on/off control can be used. If the use of on/off controls produce temperature inside the steam drum fluctuate (usually with a sawtooth pattern), it is recommended to implement a recirculation bypass. E2 represents an energy meter (temperature + flowrate). This device is optional, and it is usually included when is necessary to perform the energy balance in the steam drum.

The solar field is connected to the BOP using the inlet and outlet pipes (orange and green lines in Figure 9). B1 is the solar pump. Since B1 is pumping liquid water close to saturation conditions, it should be at a sufficient negative height relative to the steam drum. Variable frequency drives provide flexibility in the system, but they are not necessary to control the solar field when working at low steam quality.

The discharge system (red line in Figure 9) provides saturated steam to the factory's steam network. The discharge valve controls the steam flowing out of the steam drum. This vale is controlled using the pressure inside the steam drum. The discharge system often includes a steam flow measurement downstream the valve.

The steam drum is the core of the direct steam generation BOP. The internal pressure of the drum controls the discharge, and the level of the water volume inside the drum controls the feed pump. It is also necessary to include a system for purging the drum. The purging can be manual but automatic is recommended.

4.1.1 Design parameters of main components

The main components in a BOP designed for direct steam generation are the following:

- **Steam drum:** The steam drum is the main component of the BOP. During the design process it is necessary to define the steam output, the heat input, and the operating pressure. The internal volume of the steam drum can be defined from the steam output/heat input using commercial values, but if the steam drum is used as ruth storage, it might need adhoc calculations. Other parameters like the operating temperature are derived from the pressure. Unlike conventional fossil fuel system where the steam drum works most of the time at nominal conditions, steam drums with DSG undergo daily start and stop cycles. Depending on the fluid used to fill the steam drum after operation (usually air or water), additional components might be necessary.
- **Solar pump:** The solar pump feeds the solar field with liquid water close to saturation conditions. In the design of the solar pump is important to avoid cavitation and uncontrolled vaporization.
- **Discharge system:** The discharge system controls the steam delivered from the steam drum to the steam network. The system usually combines a steam regulating valve which controls the outlet pressure, and a steam flowmeter. The most important design parameters are the pressure and flowrate operating range. Depending on the solar conditions, the amount of steam coming out of the steam drum can vary greatly, so it is important to verify that the selected components cover the entire operating range (especially the low range). Components with different measurement ranges may need to be combined to allow measurement across the entire operating range.
- **Feed water system:** The feed water system consists of a water pump and an energy meter. The energy meter is usually only placed when it is necessary to perform an energy balance in the steam drum. The feed water pump provides fresh water to the steam drum. In the design of the pump is important to consider the necessary flowrate and the operating pressure of the steam drum. Depending on the control of the pump (on/off or proportional), an additional recirculation line might be needed.

Figure 10 shows the main components in a generic BOP for direct steam generation. The main design parameters of each component are summarized in Table 4.

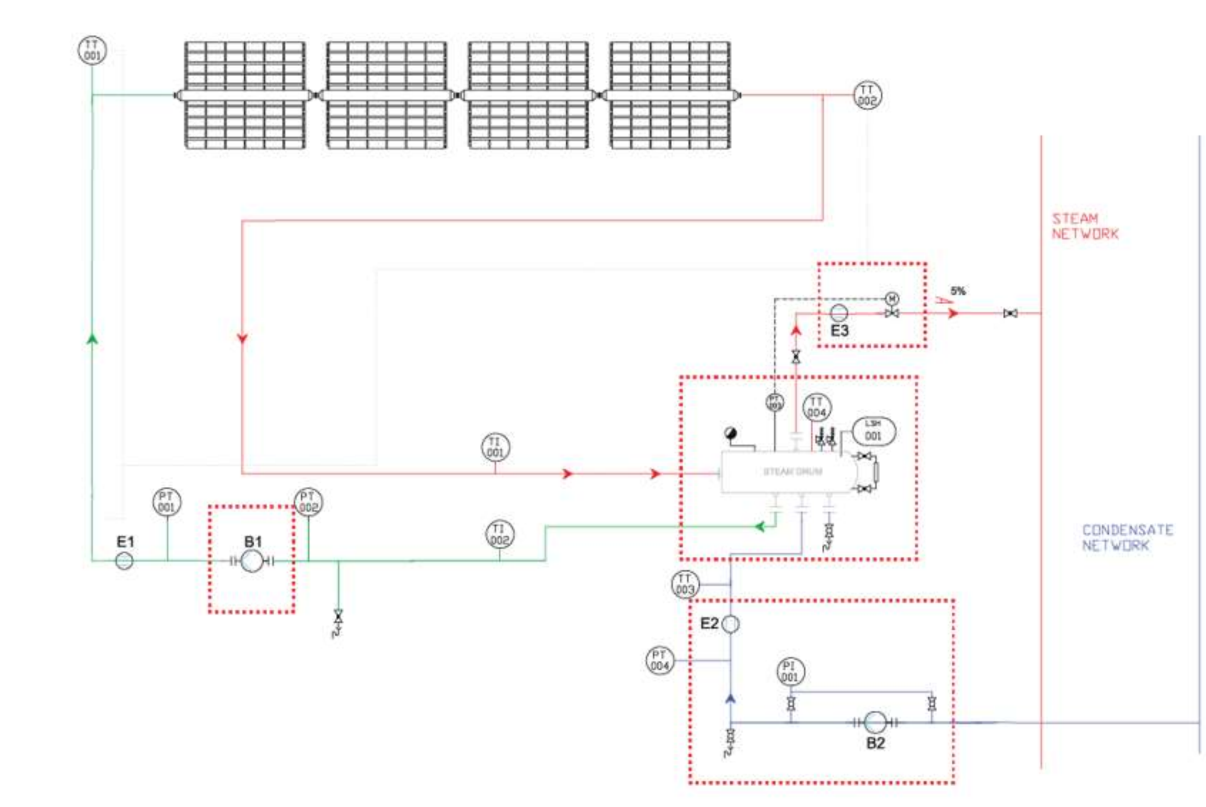
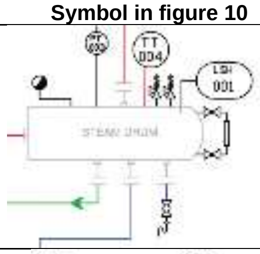
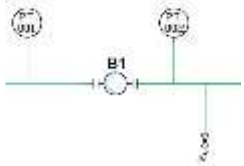
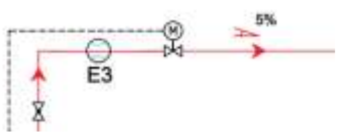
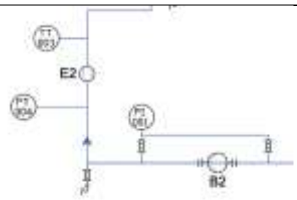


Figure 10. Main components of the generic BOP with Direct Steam Generation

Table 4: Types of solar collectors and number of projects using them

Component	Symbol in figure 10	Design parameter
Steam drum		Heat input
		Operating pressure
		Steam output
		Internal volume
Solar pump		Flow rate
		NPSH design
		Operating temperature
		Pump head
Discharge system (Steam regulating valve and steam flowmeter)		Flow rate range
		Pipe diameter
		Operating pressure range
Feed water system (feed water pump + energy meter)		Flow rate
		Pump head
		Type of control used for feed water supply (On/Off vs proportional)

4.1.2 Storage options for direct steam generation

Although there are several storage alternatives for storage in direct steam generation for SHIP applications, most of the commercial projects currently in operation do not include significant storage. An alternative for short-term storage is the so-called ruth accumulator. This type of storage takes the advantage of the flash evaporation that occurs in the steam drum, which filled with saturated boiling water and the associated vapour phase, when the pressure is reduced by opening the discharge valve. To achieve a significant energy stored the accumulator requires a sufficient pressure differential and internal volume in the steam drum.

In addition to ruth accumulators, other innovative solutions are being tested. Among the most studied alternatives are PCM (Phase Change Materials) and concrete storages, but neither has a significant commercial deployment.

4.1.3 Key technical parameters for the design of direct steam generation BOPs

Section 4.1 describes the technical parameters of the main components used in BOPs with DSG. The following table summarizes the key technical parameters for the overall design the BOP. Design parameters specific of components within the BOP have not been included since they are already described in section 4.1.1.

Table 5: Key technical parameters for BOPs with DSG

Type	Parameter	Description
Primary parameters	BOP Design power	The design power is the main technical parameter of the BOP. The design of the steam drum, the discharge valve, the solar pump and the feed water system depend on this parameter
	Operating pressure	The operating pressure (together with its maximum value) influences the selection of the components. It also influences startup times and the amount of steam that is supplied from the BOP
	Feed water quality	The quality of the feed water influences the purge system of the steam drum and the selection of materials in the BOP
Secondary parameters	Operating temperature	The operating temperature is defined by the saturation temperature of the steam at operating pressure. This parameter is important for component selection and the design of the insulation in the BOP
	Steam quality output	The steam quality in design conditions influences the selection of the solar pump. Working with lower steam qualities in the solar field usually means higher recirculation ratios, and therefore bigger pumps.

4.2 Generic BOP for pressurized water + hot air proposed by ABSOLICON

The generic BOP design chosen for this subsection is based on a specific configuration chosen to generate hot air as a process media, and pressurized hot water as solar field working media. Such configuration can be realized for drying of various industrial products such as in tea, pharmaceutical, textile and dairy industry etc. The coupling of solar field with process requires stringent controls, and heat transferring elements which are usually included in BOP. The standardization of BOP in terms of equipment specifications, instrumentations, and control strategy can allow existing and upcoming industrial suppliers to leverage the information for a robust, and reliable solar heating solutions.

The configuration analyzed in this document uses pressurized water a working media up to maximum temperature of 160ºC. Concentrating solar collectors such as parabolic tough collectors (PTC) can be used to produce heat up to this temperature range. The process media considered is hot air up to temperature of 130ºC. This is a typical maximum temperature required for drying process in many industries. The system considers an open loop, where the ambient air is used for heating without any re-circulation of air. A water-based storage tank is considered to overcome the mismatch between load demand, and heat supply from solar collectors. The storage tank can be pressurized, and non-pressurized depending on the hot air temperature required. A concept scheme for hot air generation using PTC is shown in Figure 11 below, where solar field is used to charge the storage tank, which is further used to generate hot air using an interface unit. In case no storage tank is considered, then solar field can be directly connected to the interface unit.

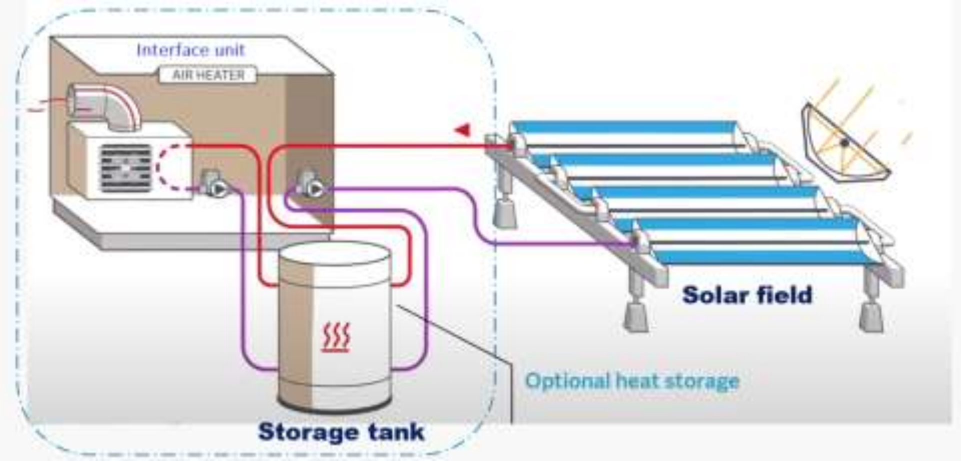


Figure 11. Concept scheme for solar air heating system

4.2.1 Design parameters and main components

This section describes the integration scheme for solar air heating system, main components of identified BOP scheme, and important parameters required for system design.

a) Integration scheme

Most of the industries seek retrofitting of solar thermal solution into their existing system. A typical air heating system in industries consist of an air/steam heat exchanger (HX) connected to the boiler network as shown in Figure 12 below. Solar thermal field can be connected in series or parallel to existing system. In a series connection, hot air from solar “system” (i.e solar field + BOP) is fed at the inlet of existing HX. The key function of solar field is in this scheme is the pre-heating of ambient air before entering the existing HX. This scheme is more flexible, as the backup is always available to ramp up the temperature level of hot air coming from solar field. This ensures that hot air fed to the drying product is always in the acceptable range. Moreover, the solar field can operate can at relatively lower temperatures, with simple controls, and without need of any large storage tank, making the overall integration quite effective. In a parallel integration, solar system is designed to produce hot air at temperature required by the drying product (therefore no pre-heating). The hot air stream at designed temperature is mixed with air stream from boiler, and finally fed to the boiler. A combination of series, and parallel integration can also be realised, where the solar field can operate in series during low irradiation conditions, and in parallel during peak sun hours. The optimal integration scheme depends on several parameters such as process characteristic, temperature range, and thus need to be analysed for individual project.

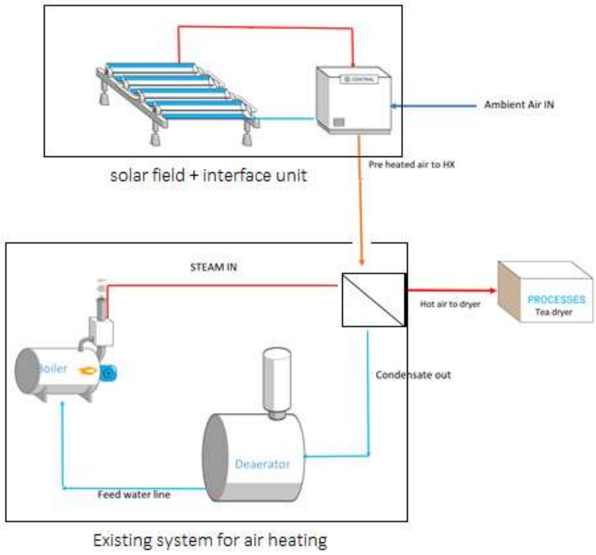


Figure 12. Integration for solar field with existing air heating system

b) Key components and design parameters

Air/water heat exchanger

The heat exchanger is the key elements to transfer heat from pressurized water to ambient air stream. This heat exchange unit can be a combination of fan unit and heat exchanging coil. The following parameters are critical for this design

- Peak heat output from solar field (kW): Heat exchanger are usually sized based on the peak heating output from solar collector. However, it an auxiliary backup is available, and if the storage tank is provisioned in the system design, then it is recommended to dynamically analyse the heat output from solar field to see the hourly variation in the heat output, and then optimise the heat exchanger capacity to avoid its oversizing. The excess heat from solar field can be stored in the storage tank, and later discharged to the heat exchanger.
- Design ambient air temperature (ºC): As the heat transfer capacity of HX varies with ambient air inlet temperature, therefore it is appropriate to define a designed ambient air temperature for system sizing, depending on the location of installation.
- Designed outlet air temperature (ºC): If the outlet air temperature from solar field exceeds the set point air temperature required by the process, then it is important to have a control system to keep the temperature within acceptable range. This can be done by a) either providing a damper at the air outlet from HX, to mix the fresh air b) or by increasing the air flow rate in the heat exchanger to keep the outlet temperature within limits.
- Designed outlet water temperature from solar field (ºC): The control in the solar field should be provided to limit the outlet water temperature within Heat exchanger design limits.
- Fan for air flow: Pressure drop curve for selected fan is critical to avoid excessive power consumption. Current and voltage tolerance should be monitored. Fan IP rating, and outdoor performance should be considered for design. A variable flow fan is usually required to control the outlet air temperature from HX.

Hydraulic equipment

- Design parameters for Water pump: Maximum flow, minimum flow, working fluid, temperature drop across the heat exchanger, power consumption.
- Design parameters for Expansion vessel: Field design temperature, pressure in the solar field, working fluid.
- Damper: Opening/closing of damper to be control based on tolerance on design temperature.

Instrumentation

Temperature sensor, pressure sensor, flow sensor, Pressure relief valve, Water strainer, Flange joints, 3-way valve, level sensors in tanks.

Control strategy

The suitable control strategy for BOP is dependent on integration scheme, flexibility in outlet air temperature, and the motive for solar field installation (demonstration/pilot/full scale field). The controls can be applied to both air and water side of Heat exchanger. For example, a variable speed fan can be used to deliver higher air temperature in the morning and late evening by reducing the air flow, at an expense of HX capacity. Another possibility is to vary the fan speed depending on irradiation level to follow the energy output from solar field (high fan speed in day time and lower in morning and evening). A variable Water flow can be used to ensure a maximum temperature drop across HX unit. This temperature drop is usually restricted by the controls used for solar field operation, and can differ depending on manufacturer. Controls can be adapted based on load profile of the customer. For example, if it is required to discharge the storage tank quickly, then it is required to maximise the HX unit capacity for few hours of operation to utilise complete tank capacity.

5 Conclusions

The work carried out within Activity B1 (Modular system concepts for SHIP applications) has clearly shown the difficulty of identifying a reduced set of integration schemes for implementation in commercial projects. This fact has led to an approach in which after the identification of the most commonly used fluid pairs for both process and solar field, generic BOPs and their corresponding analysis have been proposed. In this document, to date, two analyses have been incorporated but it is an open document to the incorporation of new contributions.

6 REFERENCES

[1] IEA SHC Task 49 Deliverable B2 “Integration guidelines”. Available at: https://task49.iea-shc.org/Data/Sites/1/publications/150218_IEA%20Task%2049_D_B2_ Integration_Guideline-final1.pdf