Title	Technical report on commissioning of solar water heaters
Authors	Politecnico di Milano: Matteo Muscherà
Review	Politecnico di Milano: Marco Calderoni
Approved	Politecnico di Milano: Mario Motta
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1. Introduction

With reference to the Methodology Paper, POLIMI monitored the following implementation activities:

- technical quality of supplied equipment, which must be consistent with specifications included in the offer;
- correct implementation of the foreseen time schedule;
- correspondence of performed works with proposals contents;
- basic checks of correct operation of the systems.

The equipment quality has been evaluated during the on-site visit in October 2017. POLIMI (Matteo Muscherà) and the consultant RESEDA (Roberto Salustri) checked the supplied material and all technical schemes provided by the installer MEDTOWN. All comments and remarks have been collected in the report **171018_Site-visit-SWH**.

During the last on-site visit, which took place on June 25-26th 2018, POLIMI with the support of its consultant checked the operation of installed plants. The aim of the inspection was to check in detail the operation of both forced circulation plants ("Cuisine Centrale" and "Internat Faidouzi") and the operation of a sample of natural circulation plants. The supervision about the correspondence of the total number of installed solar collectors with the tender document has been performed by AMEE during the official approval of works.

2. “Cuisine Centrale” plant

This forced circulation plant supplies hot water to the principal kitchen of the hospital. The solar field is 40 solar collectors of about 2 m^2 each, for a global solar field surface of 80 m^2. The storage volume is 6000 l, split into two tanks of 3000 l each.

Generally, all remarks and comments raised during the October 2017 on-site visit have been accepted by the installer:

- the placement of the solar field has been changed, with the result of a regular pattern of solar collectors which facilitates a uniform flowrate in the whole solar field
- the suggested connection scheme (Tichlemann) has been adopted
- balancing valves have been removed
- radiator for heat dissipation has been removed
- double safety valve has been removed, and the correct connection of safety valve and expansion vessel has been adopted
- solar expansion vessel has been replaced with a bigger one as suggested
- connection of internal heat exchangers of storage tanks has been modified as suggested
- filling of the solar circuit is no more automatic, but the filling pump is manual, as suggested
- steel structure of solar collectors has been painted against corrosion

Figure 2.1: Pictures of adopted suggestions (Cuisine Centrale).

During the last on-site visit, some issues have been detected and discussed with the installer. In the following section, all problems are listed and described, and for each issue the solution status is presented.

a. *Detected problems*

Lack of expansion vessels in domestic hot water circuit

Expansion vessel was installed only on solar circuit, while it is necessary also on domestic hot water side. Minimum volume is 6000 l · 0.06 = 360 l, the installer immediately provided and installed two expansion vessels of 200 l each, thus a global volume of 400 l.

Figure 2.2: Cuisine Centrale expansion vessels, installed on domestic hot water side.

Wrong position of sensor S6

The temperature sensor S6 (as in RESOL controller nomenclature) drives the 3-way valve for storage bypass. This function is used in the morning when the solar field temperature is not uniform. The pump is activated, the bypass is activated, and the solar fluid is circulated bypassing the storage until the solar field temperature is uniform. The uniformity of the solar field temperature is evaluated via the temperature difference between S1 (solar field temperature, placed on the roof) and S6. Sensor S6 was placed on the bypass pipe, while should be placed on the supply pipe, as illustrated in the RESOL scheme. The installer solved the issue placing the sensor in the right position.

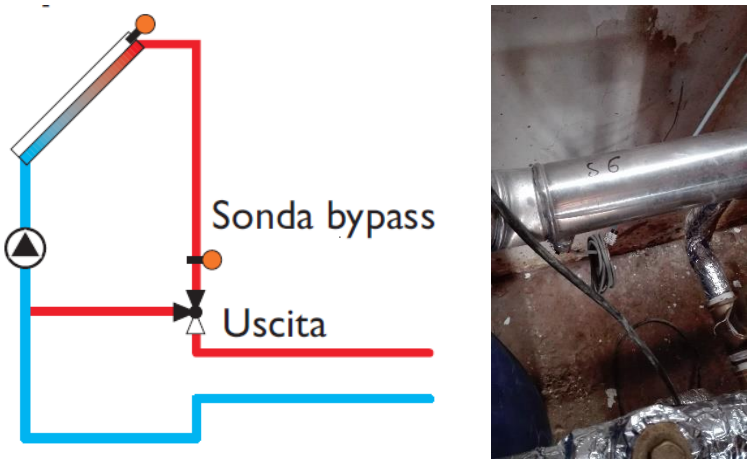

Figure 2.3: Cuisine Centrale, position of sensor S6 for bypass valve control.

Temperature sensor S1 installation

The temperature sensor S1 is used to monitor the solar field temperature. The probe was not well installed, as it was not insulated. This causes a bad control of the plant (pump and bypass valve), as the sensor does not feel the real temperature of the solar fluid, but the measure is an average between solar fluid and ambient/sky temperature. The installer solved the issue insulating and protecting the sensor S1.

Figure 2.4: Cuisine Centrale S1 sensor.

Roof of technical room

The installer had to build a technical room to protect storages, pump, valves, safety components and electrical devices. The roof of this technical room was not finalized. The installer finalized the construction of the roof during the on-site visit.

Figure 2.5: Cuisine Centrale technical room.

Y Filter

The filter Y-type must be installed perfectly upright to ensure a proper performance. The installer solved immediately this issue.

Figure 2.6: Cuisine Centrale filter Y-type.

Additional filters to be installed

As reported in the tender, two additional filters must be installed, one physical and one chemical filter. The installer purchased and placed one wool-filter (physical) and one carbon filter (chemical).

Figure 2.7: Cuisine Centrale additional filters.

Collection system for solar safety valve

It is necessary to install a pipe and a tank at the outlet of security valve to collect solar fluid that potentially comes out in case of overpressure. The installer solved the issue immediately.

Figure 2.8: Cuisine Centrale collection system for solar safety valve..

b. *Monitoring data analysis*

The plant is equipped with a RESOL control unit, used to control the operation of solar pump and three-way bypass valve based to information of temperature sensors. This unit has an internal memory card, which saves all sensors readings and components control signals.

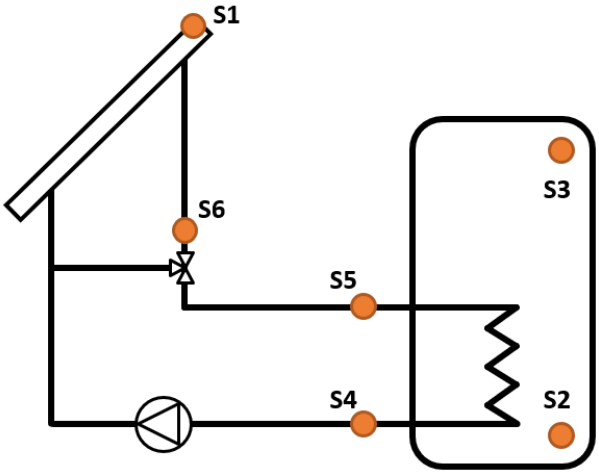

Figure 2.9: RESOL control unit scheme.

During the last on-site visit, these data have been analysed to check the plant operations. During the first day (June 25th), the pump activation was very irregular, as a continuous on-off cycle affected pump and bypass operation.

The identified reasons are:

- Wrong position of sensor S6 (refer to issue #2): the sensor has been placed on the bypass pipe, while the right position is on the supply pipe (as illustrated in Figure 2.9). This causes a continuous on-off cycle of the bypass three-way valve.
- Bad installation of sensor S1 (refer to issue #3): the sensor has not been insulated, thus the acquired temperature of solar collectors was not the real one. As a matter of fact, S5 and S6 temperatures was always higher than S1, while in normal conditions should be the opposite.

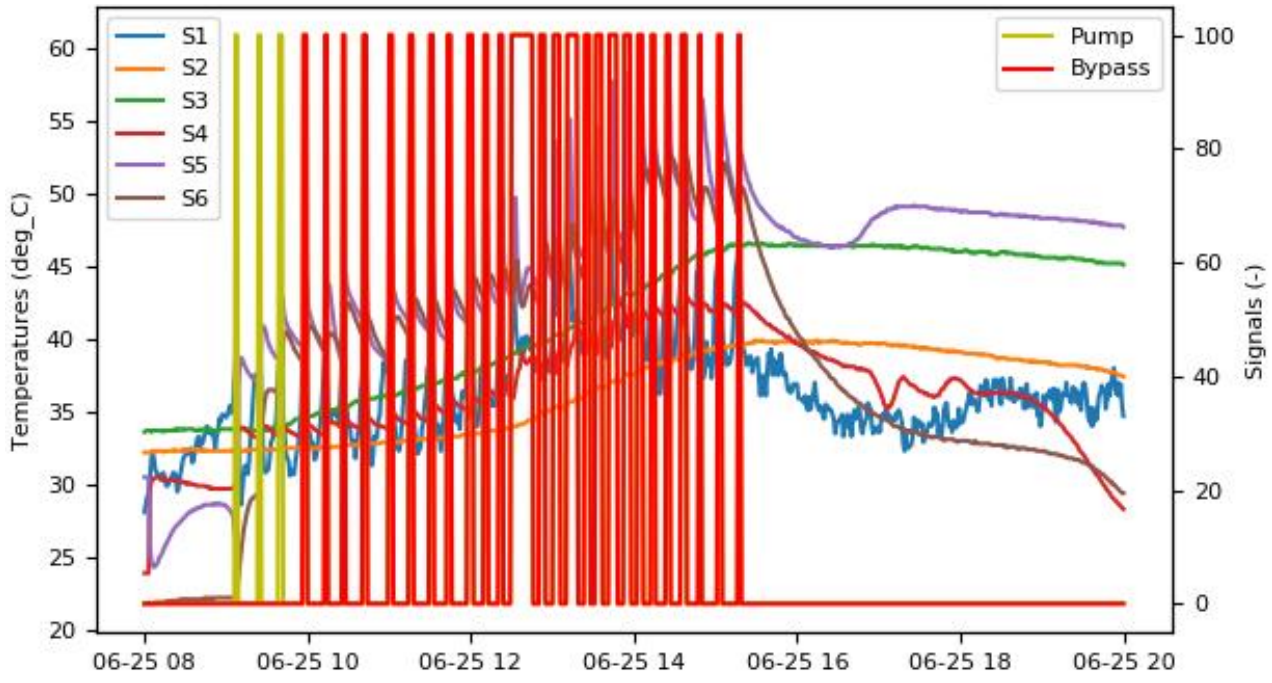

Figure 2.10: Cuisine Centrale plant operation in June 25th.

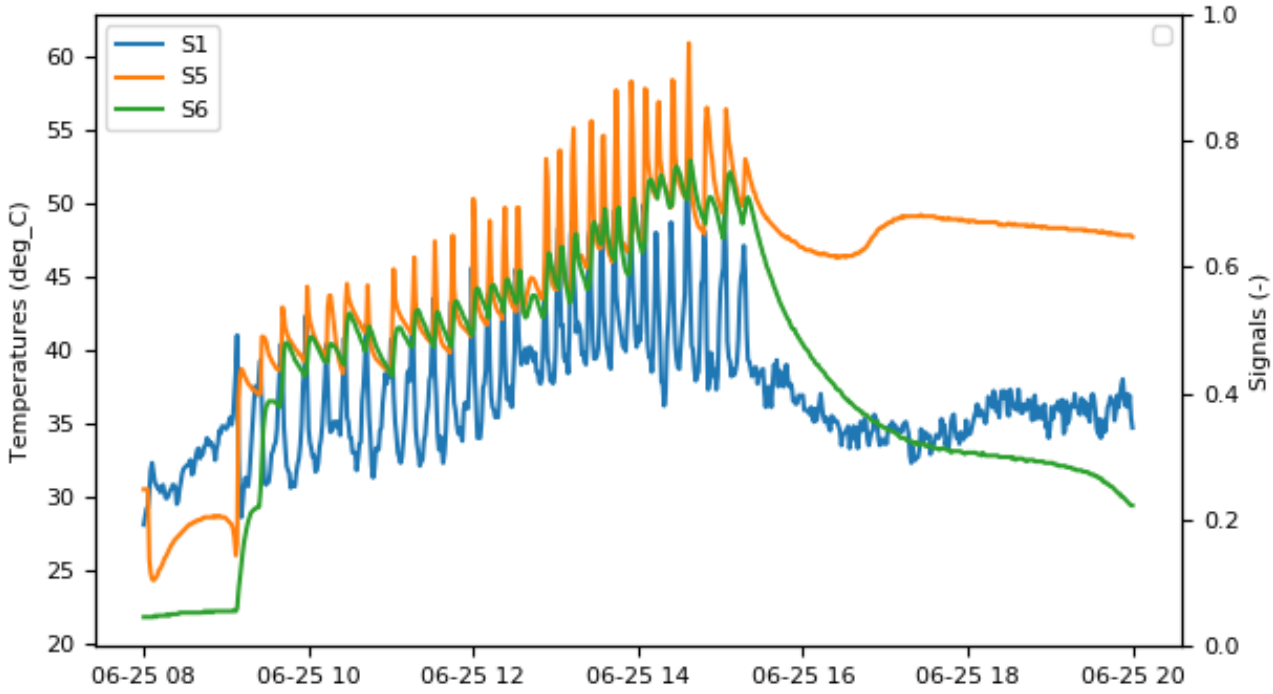

Figure 2.11: Cuisine Centrale plant operation in June 25th, detail of solar loop temperatures.

After the solution of these issues, plant operations can be considered acceptable.

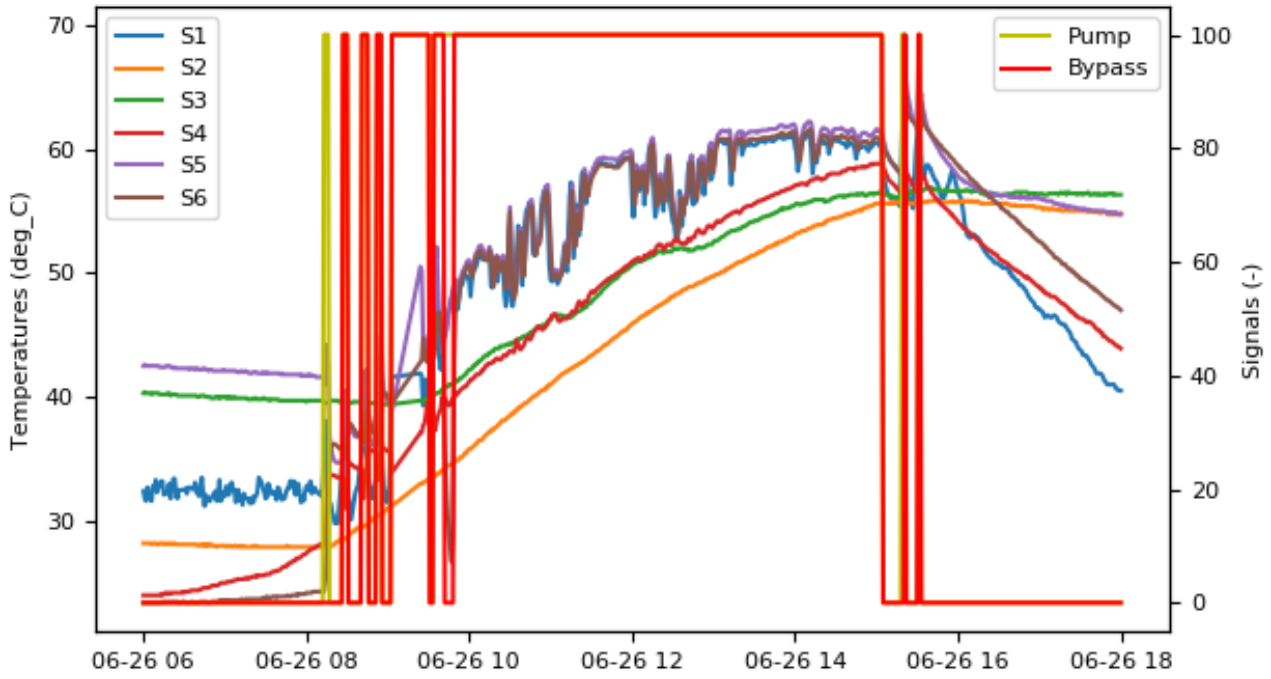

Figure 2.12: Cuisine Centrale plant operation in June 26th.

In these 4 days of operation (from 25 to 28/06) the plant production is summarized in the following:

- 2018-06-25: 64.0 kWh
- 2018-06-26: 138.4 kWh
- 2018-06-27: 108.4 kWh
- 2018-06-28: 63.7 kWh

The total production is 374.5 kWh, equivalent to more than 12500 l of domestic hot water at 45°C.

3. “Internat Faidouzi” plant

This forced circulation plant supplies hot water to the medical residence called “Faidouzi”. The solar field is 24 solar collectors of about 2 m^2 each, for a global solar field surface of 48 m^2. The storage volume is 1500 l, split into three tanks of 500 l each.

Generally, all remarks and comments raised during the October 2017 on-site visit have been accepted by the installer. These remarks are the same of “Cuisine Centrale” plant, except for the collector filed placement, which in this case was already acceptable.

During the last on-site visit, some issues have been detected and discussed with the installer. In the following section, all problems are listed and described, and for each issue the solution status is presented. Most of problems are in common with the “Cuisine Centrale” plant.

Figure 3.1: Pictures of adopted suggestions (Internat Faidouzi).

a. *Detected problems*

Lack of expansion vessels in domestic hot water circuit

Expansion vessel was installed only on solar circuit, while it is necessary also on domestic hot water side. Minimum volume is 1500 l · 0.06 = 90 l, the installer immediately provided and installed one expansion vessel of 140 l.

Figure 3.2: Internat Faidouzi expansion vessel, installed on domestic hot water side.

Wrong position of sensor S6

The temperature sensor S6 was placed on the bypass pipe, while should be placed on the supply pipe, as illustrated in the RESOL scheme. The installer solved the issue placing the sensor in the right position.

Figure 3.3: Internat Faidouzi, position of sensor S6 for bypass valve control.

Temperature sensor S1 installation

The temperature sensor S1 was not well installed, as it was not insulated. The installer solved the issue insulating and protecting the sensor S1.

Figure 3.4: Internat Faidouzi S1 sensor.

Additional filters to be installed

As reported in the tender, two additional filters must be installed, one physical and one chemical filter. The installer purchased and placed one wool-filter (physical) and one carbon filter (chemical).

Figure 3.5: Internat Faidouzi additional filters.

Collection system for solar safety valve

It is necessary to install a pipe and a tank at the outlet of security valve to collect solar fluid that potentially comes out in case of overpressure. The installer solved the issue immediately.

Figure 3.6: Internat Faidouzi collection system for solar safety valve.

Wrong installation of one solar collector

One solar collector has been installed in reverse way. The installer solved the problem immediately.

Figure 3.7: Reversed solar collector.

Glycol leakage from solar pump

During the visit a small glycol leakage was detected. The installer solved the problem cleaning and tightening the connection of the pump.

Figure 3.8: Internat Faidouzi solar pump.

Pre-charge of solar expansion vessel

Due to the height of the Internat Faidouzi building, we suggested to increase the precharge of the solar expansion vessel from 1.5 to 2.0 bar.

Figure 3.9: Internat Faidouzi solar expansion vessel.

Pump light in electric panel

In the electric panel has been installed a green light useful to see if the pump is active or not. During the site visit this light was out of order. The installer solved the problem replacing the light bulb.

Figure 3.10: Internat Faidouzi electrical panel.

Unprotected sensors wire connections

All electrical connections must be protected from water, especially electrical connections installed outdoor. The installer solved the problem with a thermo-plastic membrane.

Figure 3.11: Protection of electrical connections.

b. *Monitoring data analysis*

Detected problems are the same of "Cuisine Centrale" plant, as installation issues are quite the same. During June 25th operations, there is an on-off cycle of pump and valve, caused by sensor S6 wrong position and S1 bad installation.

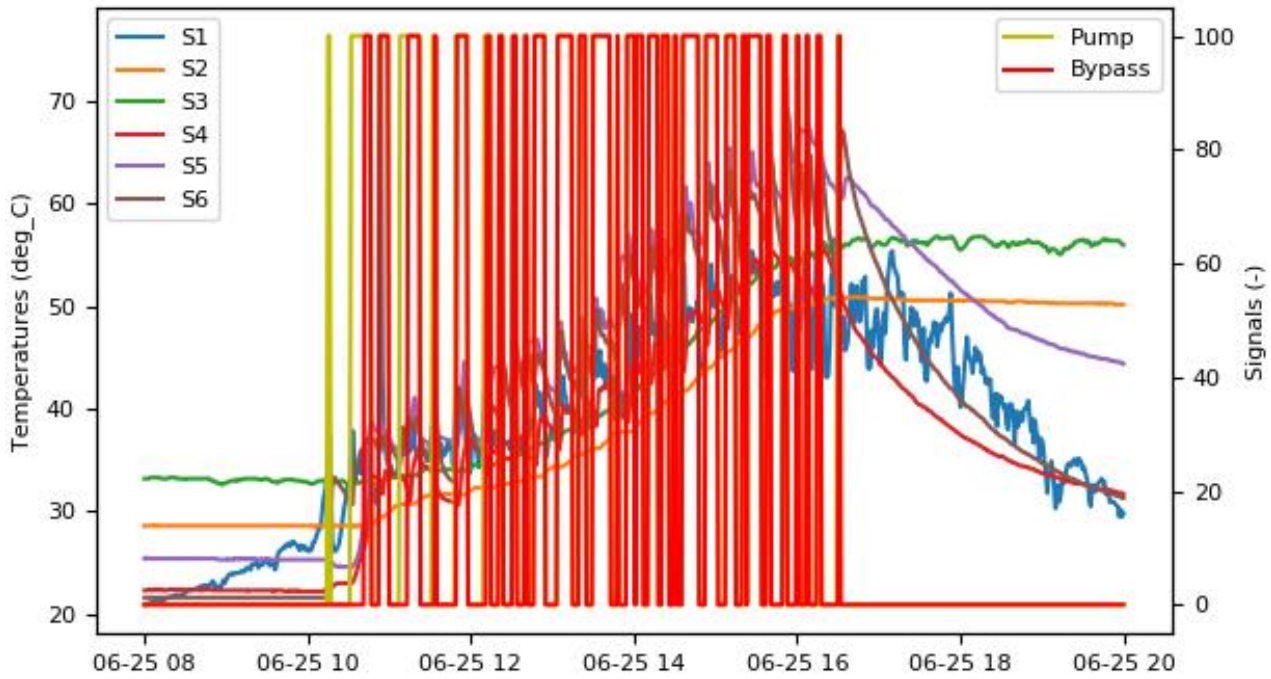

Figure 3.12: Internat Faidouzi plant operation in June 25th.

After the solution of discussed issues, the operation can be considered acceptable. In this case, the temperature difference between S1 and S5 (or S6) is not ideal, as acquired collectors temperature is still lower than supply pipe temperatures. The suggestion is to frequently check plant operations, and if necessary to improve the insulation and protection of S1 sensor.

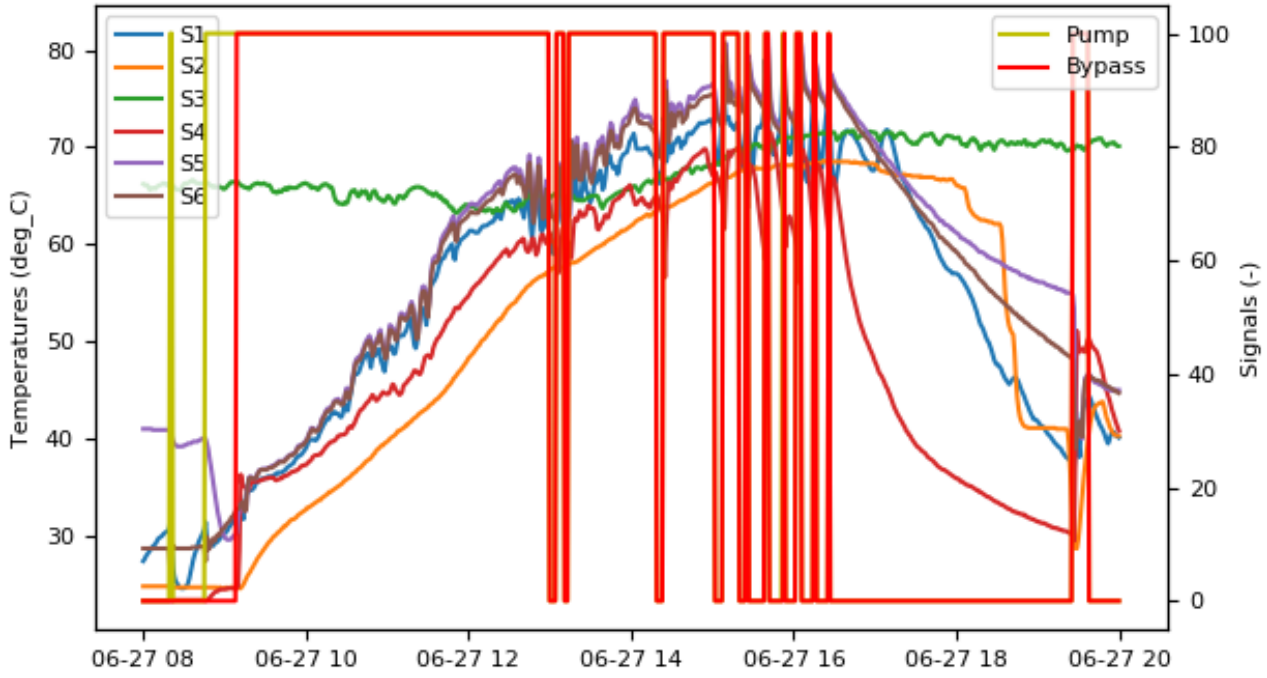

Figure 3.13: Internat Faidouzi plant operation in June 25th.

In these 4 days of operation (from 25 to 28/06) the plant production is summarized in the following:

- 2018-06-25: 41.6 kWh
- 2018-06-26: 53.0 kWh
- 2018-06-27: 74.2 kWh
- 2018-06-28: 69.6 kWh

The total production is 238.4 kWh, equivalent to more than 8000 l of domestic hot water at 45°C.

4. Natural circulation plants

As stated in the tender document, 26 natural circulation plants must be installed. During POLIMI site visit, only a representative sample of natural circulation plants has been examined, in particular:

- Hopital des Enfants
- Pole Maternité
- Chirurgie Generale

In the following section, all problems are listed and described, and for each issue the solution status is presented.

a. *Detected problems*

Domestic water pipes installation

Particular attention should be paid to pipes installation, regarding thermal expansion of materials. Some connections are too tightly fixed, and others are directly placed on the floor, preventing the natural expansion of pipes. This could cause the distortion of pipes, that might in some cases result in leakages.

Figure 4.1: Domestic water pipes installation.

It was not possible during the on-site visit to check all installations; thus, the suggestion is to monitor frequently the situation, possibly fixing worst cases of pipes distortion.

Expansion vessels placement

Some expansion vessels on domestic water side have been installed horizontally (expansion vessels without feet). The direct contact with the floor could cause corrosion of the external surface of the vessel if the roof draining is not perfect. When possible, expansion vessels should be placed on the concrete basement of the solar collector structure. If not possible, at least the expansion vessel should be risen. The installer solved with some plastic pipe pieces used to rise expansion vessels from the floor.

Figure 4.2: Expansion vessels placement.

b. *On-site measurements*

Natural circulation plants are not equipped with a control unit, as there are no pumps or valves to operate. To check qualitatively the operation of a sample collector, a thermocouple reader has been used, to evaluate the temperature difference between inlet and outlet of solar collector.

Figure 4.3: Thermocouple placement during natural circulation system check.

The measure has been performed in a sunny condition and in a cloudy condition, with results illustrated in following figures.

Figure 4.4: Temperatures reading during sunny condition in two different moments. Left: higher and lower temperatures. Right: delta-T and lower temperature.

Figure 4.5: Temperatures reading during cloudy condition in two different moments. Left: higher and lower temperatures. Right: delta-T and lower temperature.

5. Conclusions

Regarding solar plants installation, the situation was very positive, as the installer proved to be very receptive to all comments and remarks moved by POLIMI. All found problems have been immediately solved following POLIMI suggestions. At this regard, the following table summarizes all issues and indicates the final status.

Table 5.1: Summary of detected issues and status.

Issue #	Description	Plant	Status
1	Lack of expansion vessels in domestic hot water circuit	Cuisine Centrale	SOLVED
2	Wrong position of sensor S6	Cuisine Centrale	SOLVED
3	Temperature sensor S1 installation	Cuisine Centrale	SOLVED
4	Roof of technical room	Cuisine Centrale	SOLVED
5	Y Filter	Cuisine Centrale	SOLVED
6	Additional filters to be installed	Cuisine Centrale	SOLVED
7	Collection system for solar safety valve	Cuisine Centrale	SOLVED
8	Lack of expansion vessels in domestic hot water circuit	Internat Faidouzi	SOLVED
9	Wrong position of sensor S6	Internat Faidouzi	SOLVED
10	Temperature sensor S1 installation	Internat Faidouzi	SOLVED
11	Additional filters to be installed	Internat Faidouzi	SOLVED
12	Collection system for solar safety valve	Internat Faidouzi	SOLVED
13	Wrong installation of one solar collector	Internat Faidouzi	SOLVED
14	Glycol leakage from solar pump	Internat Faidouzi	SOLVED
15	Pre-charge of solar expansion vessel	Internat Faidouzi	SOLVED
16	Pump light in electric panel	Internat Faidouzi	SOLVED
17	Unprotected sensors wire connections	Internat Faidouzi	SOLVED
18	Expansion vessels placement	Natural circ.	SOLVED

Regarding purchased material, all components comes from European market (Venman, Caleffi, Wilo, Resol, …) and the quality is high. As a general comment, often the chosen material is even more than necessary. E.g., solar pumps are more powerful than needed. Resol control unit has 12 inputs and can control up to 14 components, as only 2 components must be controlled in solar plants.

The on-site visit underlined the necessity of a specific training, not only for solar plant principles (training module done by POLIMI on June 27th), but in general for all hydraulic design and installation principles (materials to be used, expansion vessels placement and calculation, welding techniques, …).

A suggestion for a possible follow-up of the project is to organize training modules regarding design, installation and maintenance principles of hydraulic systems (both in general and in detail on solar plants), and simultaneously a workshop with hydraulics and solar plants components manufacturers to show market opportunities. The aim should be to move the quality perception and the amount of investments from components to installation and maintenance.

Finally, a very important comment must be done regarding domestic water plants of hospital buildings. Now that all solar plants are operative, not all users are in good conditions. E.g., both for Cuisine Centrale and for Internat Faidouzi, the expected users are not connected to the solar storage. The result is that the solar plant will be most of time in overheating condition (stagnation).

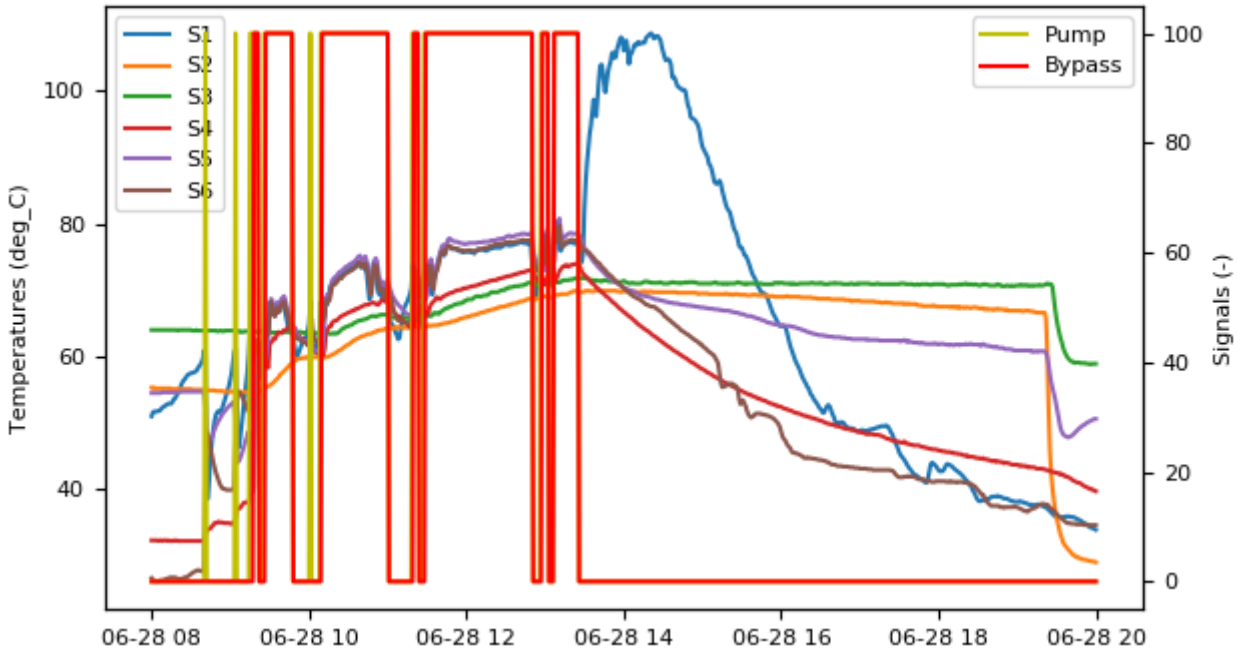

Figure 5.1: Stagnation condition of Cuisine Centrale plant on June 28th.

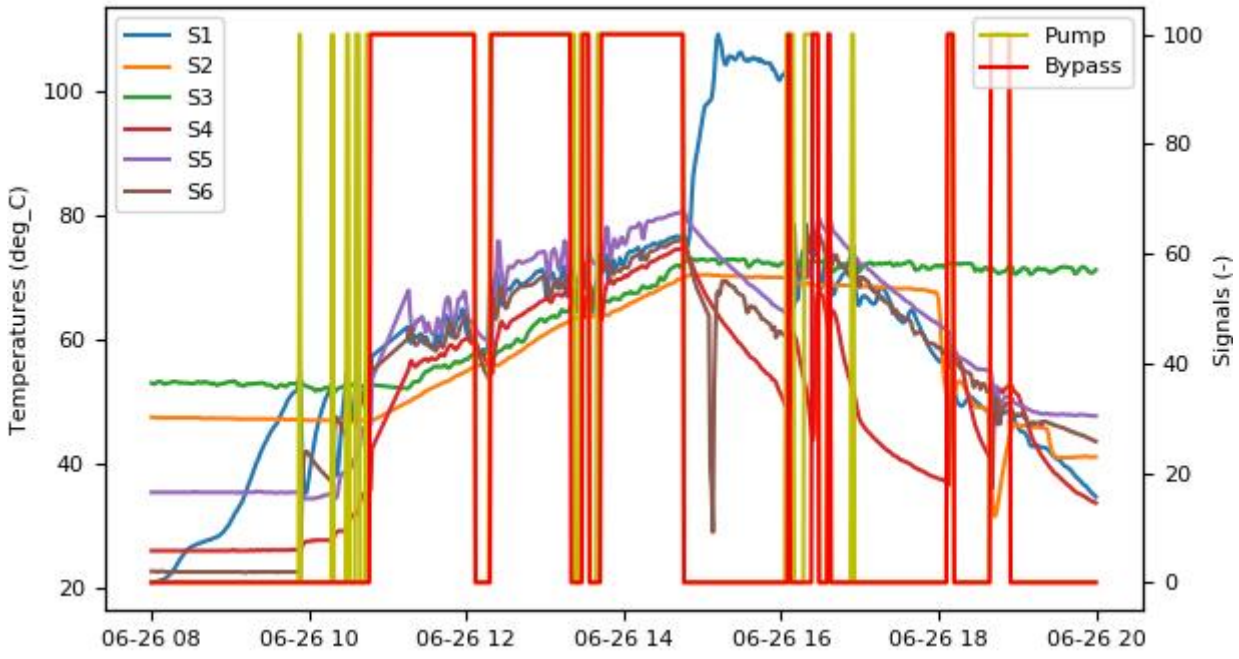

Figure 5.2: Stagnation condition of Internat Faidouzi plant on June 26th.

The same situation has been detected for some natural circulation solar plants. We strongly suggest pushing hospital technicians and managers to fix all problems related to hydraulic circuit supplied with solar energy. In addition to wasting the possibility to have hot water for hospital patients, this is a risk for solar plants lifetime, which could be sensibly reduced due to constant stagnation condition.