D6.1 Appendix C Summary Sheet

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D6.1 Appendix C Cartif offices building: Short Description
This document describes the demonstration building of Cartif offices.
Keywords: Cartif, offices, Valladolid, demonstration building

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Appendix C: Cartif offices building. Valladolid (Spain)

The Cartif Technological Centre is a research foundation located in the technological park of Boecillo, 15 km south of Valladolid, Spain. The building is situated in sector 205 of technological park.

Figure 1: Cartif 1 offices building location

1.1 General building information

Cartif 1 building is located in Boecillo, a small village 10 km south from Valladolid and 180 km north from Madrid. The altitude is 720 meters, and geographical coordinates are:

- latitude: 41,31'09" N
- longitude: 4,43'02" E

Boecillo is placed in the middle of "Meseta Castellana", as it is called the wide plain that constitutes the biggest part of the "Castilla y Léon" region. On the borders of the plain, stands an extended mountain range that decreases rains intensity and protects the inner area from cold and hot winds.

Only the west side (border with Portugal) is free of mountain: there, air masses from Atlantic sea can penetrate bringing important rainfall in autumn. Climate can tautly be defined as continental, with long and hard winters and dry, hot and short summers. It is interesting to describe the factors which affect it.

Winters are quite cold, with fairly low temperatures and generally cloudy days. Mornings or even entire days are often foggy due to irradiation. This situation is more severe into the valleys of the main rivers (i.e. the Duero), like Boecillo zone.

In summer, the diurnal temperature range is very relevant because of daylight flux of solar radiation, and also due to nightly radiative exchange to sky.

Considering these external conditions, it is possible to suppose a fairly high demand of heating during winter and necessity for internal cooling in summer. In the case of Cartif 1, demand further increase due to the large glass façades of the building. As shown in figure 3.3, relative humidity is very low during summer, this parameter is very important because it affects aspects like thermal comfort, need of humidification and possibility to efficiently use evaporative towers. The external air could be used for internal pre-conditioning of the spaces without the treatment of cooling devices. In the case of Cartif 1, this would require changes in the duct systems and in controls of the system.

Figure 2: External view of Cartif 1 office building

Table 1: General information of Cartif offices

Name	Cartif offices building	Envelopment area	4070,60
Address	Parque Tecnológico de Boecillo, 205	Glazed area	426,24 (10,5%)
City / Post code	Boecillo (Valladolid) / 47151	From factor (S/V)	0,375
Country	Spain	Heated Area (m^2)	2592,90
Contact Person	César Valmaseda	Heated Volume (m^3)	10701,87
e-mail of contact person	cesval@cartif.es	Cooled Area (m^2)	1870,13
Location	Latitude: 41,31’09" N	Cooled Volume	4955,84

(coordinates)	Longitude: 4,43’02" E	(m^3)	
Orientation	N S E W	Heating degree days (15.5ºC)	2025
Altitude (m)	720	Cooling degree days (15.5ºC)	868
Year of construction	1995	Average power consumption (kWh/m^2a)	128,06 kWh/m^2a
Typology of building	Offices	Average thermal consumption (kWh/m^2a)	55,75 kWh/m^2a
Floors	3 (basement, ground floor and first floor)	Heating system	Thermal active slabs Water source heat pumps Fan coils Convective radiators
Built area	2615,70	Cooling system	Water source heat pumps Fan coils
Net usable area	2650,39	DHW system	n.a.

Table 2: Climate values for Valladolid (reference period 1971-2000)

	T (ºC)	TM (ºC)	Tm (ºC)	R (mm)	RH (%)	DR (d)	DN (d)	DT (d)	DF (d)	DH (d)	DD (d)	I (h/mo)
Jan	4,0	8,3	0,0	40	83	7	3	0	11	17	4	100
Feb	6,1	11,4	0,9	32	72	6	2	0	4	12	4	141
Mar	8,4	15,0	2,3	23	62	5	1	0	2	8	6	209
Apr	10,1	16,3	4,0	44	62	8	1	1	1	4	4	222
May	13,8	20,5	7,2	47	61	9	0	4	1	1	4	260
Jun	18,1	25,9	10,7	33	54	5	0	3	1	0	7	310
Jul	21,7	30,4	13,3	16	47	3	0	3	0	0	15	352
Aug	21,6	29,8	13,6	18	49	3	0	3	0	0	13	330
Sep	18,1	25,7	10,9	31	56	4	0	2	2	0	8	244
Oct	12,8	18,8	6,9	42	69	7	0	1	3	1	5	176
Nov	7,7	12,6	2,9	51	78	6	0	0	8	8	5	114
Dec	5,0	8,8	1,3	56	84	8	1	0	10	13	3	81
Total	12,3	18,6	6,2	435	65	71	8	17	42	61	76	2534

T: monthly average temperature; TM: monthly average of highest daily temperatures; Tm: monthly average of lowest daily temperatures; R: monthly average of rainfall; RH: monthly average of relative humidity; DR: monthly average of rainy days (rainfall ≥ 1mm); DN: monthly average of snow days; DT: monthly average of storm days; DF:

monthly average of foggy days; DH: monthly average of frost days; DD: monthly average of cloudless days; I: monthly average of sunny hours.

2 Building use: distribution and occupancy

Building of Cartif 1, has a rectangular-plant with 3 floors (basement, ground floor and first floor). In the basement there are service spaces, like electrical controls and storage rooms. Boiler room and thermal-solar facilities are situated in two rooms close to the garage and exterior. All spaces are nor heated nor cooled.

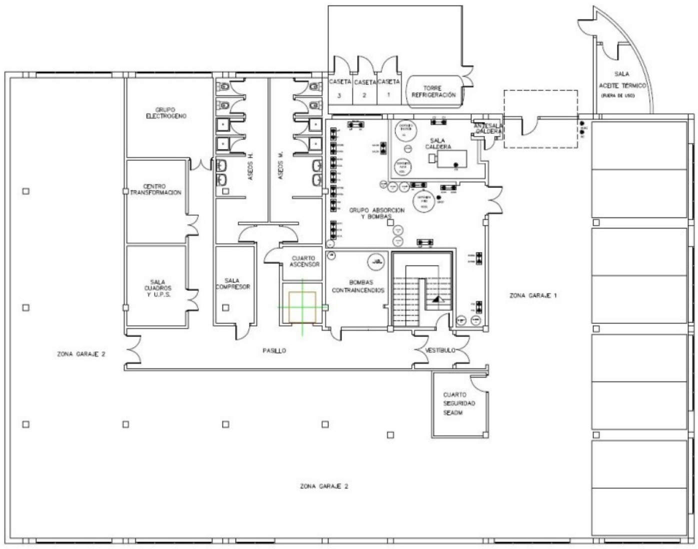


Figure 3: Cartif 1 offices basement plan

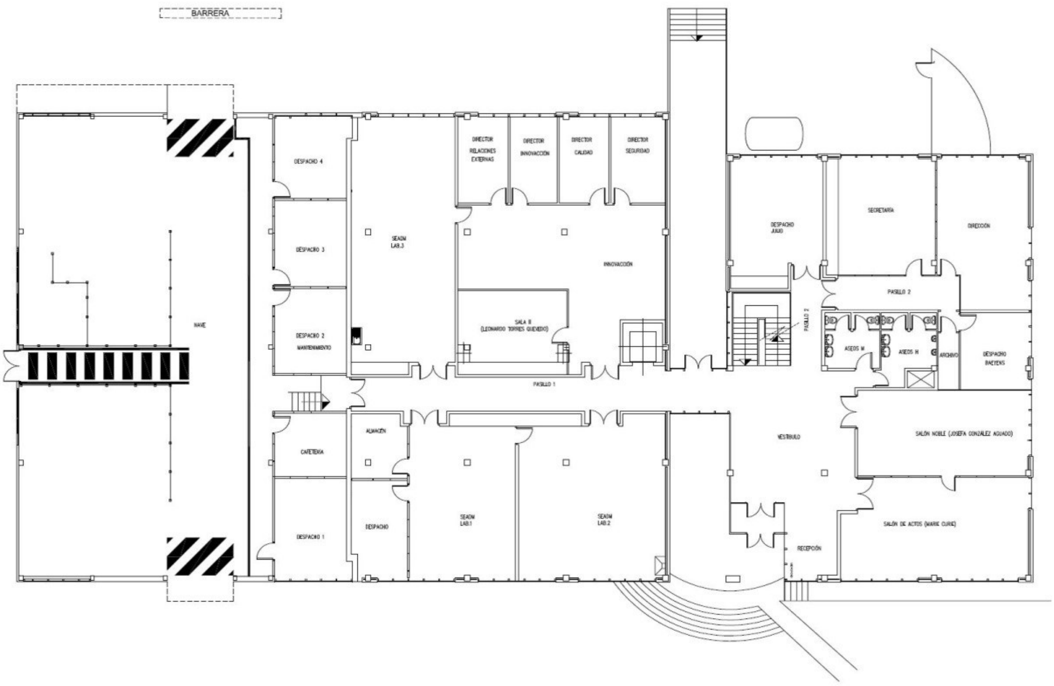


Figure 4: Cartif 1 offices ground floor plan

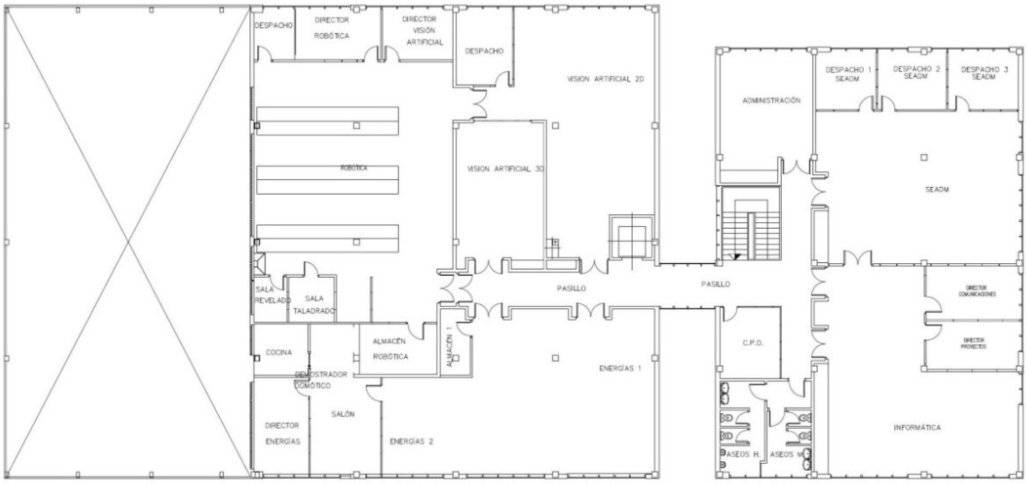


Figure 5: Cartif 1 offices first floor plan

In ground floor there are two main zones, offices and conference rooms are situated on the north side (administrative area). Research laboratories and the warehouse are located in the southern side.

On first floor there are research laboratories and head's offices. Energy Division laboratory is placed on South-East side.

Regarding the air conditioning of the internal spaces is done with several integrated technologies:

- thermal active slabs (TAS)
- water source heat pumps
- fan coils
- convective radiators

Table 3: Cartif offices building distribution / usage

Zone	Floor	Useful area (m^2)	H. (m)	Vol. (m^3)	% cond.	Occ. (pax)	TAS loops	Cond. services [1]
a. Industrial zone	1	722.77	7.95	5746.02	Only heating	0	-	AE
b. Industrial zone offices	1	100.45	2.65	266.19	100	4	SR1, SR2, SR3, SR8	UBC16
c. Multifunct. Area	1	84.75	2.65	224.57	100	-	SR5	UBC15
d. Innovation	1	164.59	2.65	436.16	100	7	SR7	UBC14

[1] Conditioning devices key: AE = heating fan coil, ubc = heat pump, fch = fan coil, dwk = ceiling fan coil.

e. SEADM	1	167.35	2.65	443.48	100	-	SR10	UBC17
f. Office 1	1	37.1	2.65	98.32	100	1	SR12	DWK1
g. Secretariat	1	85.46	2.65	226.47	100	5	SR13	DWK2, DWK3
h. Office 2	1	17.40	2.65	46.11	100	1	SR14	DWK4
i. Meeting room	1	47.77	2.65	126.6	100	-	SR15, SR16, SR19	DWK5, DWK6
j. Auditorium	1	61.62	2.65	163.29	100	-	SR17, SR18, SR20	UBC19
k. Corridor 2	1	18.70	2.65	49.56	100	-	-	FCH12A
l. Bathroom	1	30.22	2.65	80.08	0	-	-	-
m. Hall + corridor	1	212.95	2.65	564.32	100	-	SR11, SR13, SR21, SR22	UBC11, DWK7, FCH12B
n. Robotics	2	230.72	2.65	611.41	100	-	SR1, SR2, SR3, SR4	UBC9
o. Energy	2	183.58	2.65	486.49	100	20	SR6, SR7, SR8, SR12	UBC7, UBC8
p. Vision 2D	2	37.5	2.65	99.38	100	-	SR11	UBC5
q. Visión 3D	2	105.73	2.65	280.18	100	-	SR9, SR10	UBC6
r. Info. Warehouse	2	35.38	2.65	93.76	100	-	SR14	UBC4
s. SEADM	2	135.38	2.65	358.76	100	-	SR15, SR16, SR17, SR18, SR19	UBC1, UBC2
t. Informatics	2	130.83	2.65	346.69	100	6	SR19, SR20	UBC3, UBC2
u. Bathroom	2	27.27	2.65	72.27	0	-	-	-
v. CPD	2	12.87	2.65	34.11	100	-	SR21	UBC10

Figure 6: Thermal zones in ground floor

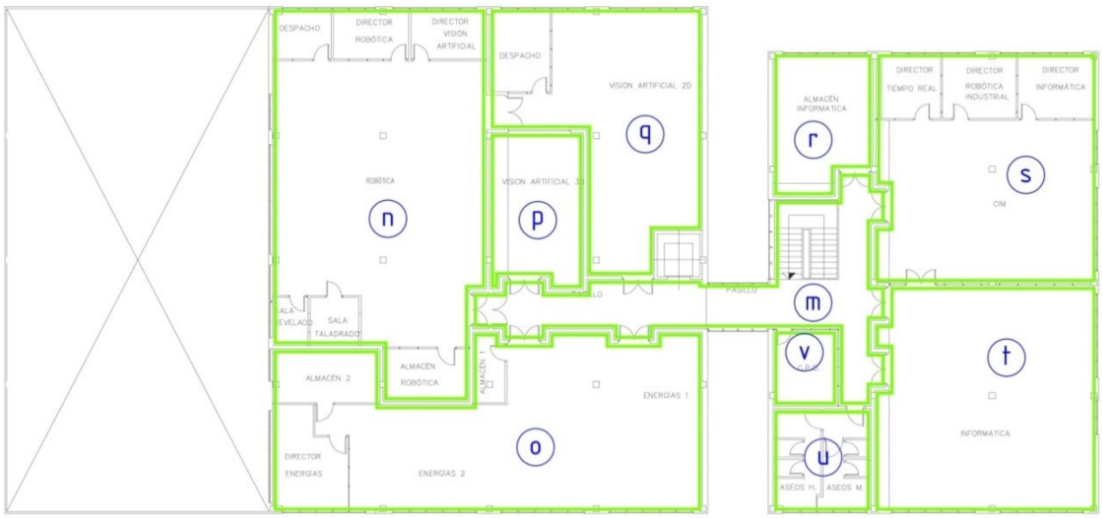
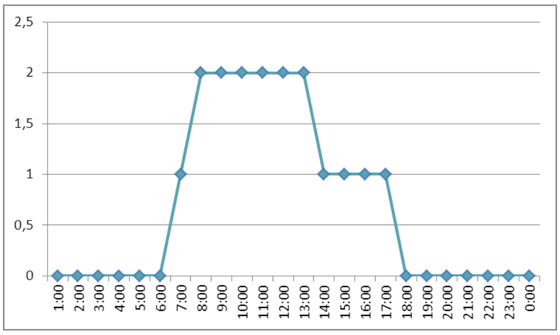


Figure 7: Thermal zones in first floor

Table 4: Building daily occupation profile of Cartif offices[2]

Hour	1	2	3	4	5	6	7	8	9	10	11	12
Mon-Fri	0	0	0	0	0	0	1	2	2	1	2	2
Weekend	0	0	0	0	0	0	0	0	0	0	0	0
Hour	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
Mon-Fri	2	1	1	1	1	0	0	0	0	0	0	0
Weekend	0	0	0	0	0	0	0	0	0	0	0	0

[2] (Not occup.=0; partially occup.=1; occup.=2)



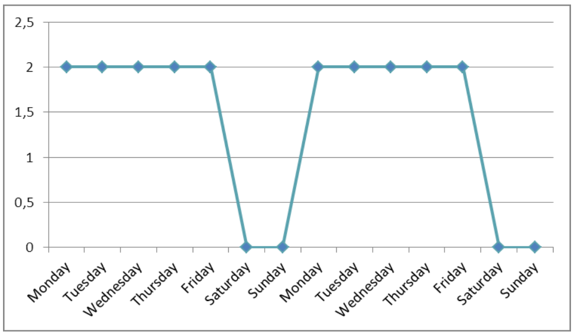


Figure 8: Building daily occupation profile of Cartif offices

Table 5: Building yearly occupation profile of Cartif offices

Week	1	2	3	4	5	6	7	8	9	10	11	12	13
Mon-Fri	1	2	2	2	2	2	2	2	2	2	2	2	1
Weekend	0	0	0	0	0	0	0	0	0	0	0	0	0
Week	14	15	16	17	18	19	20	21	22	23	24	25	26
Mon-Fri	2	2	2	2	2	2	2	2	2	2	2	2	2
Weekend	0	0	0	0	0	0	0	0	0	0	0	0	0
Week	27	28	29	30	31	32	33	34	35	36	37	38	39
Mon-Fri	1	1	1	1	1	1	1	1	1	2	2	2	2
Weekend	0	0	0	0	0	0	0	0	0	0	0	0	0
Week	40	41	42	43	44	45	46	47	48	49	50	51	52
Mon-Fri	2	2	2	2	2	2	2	2	2	2	2	2	1
Weekend	0	0	0	0	0	0	0	0	0	0	0	0	0

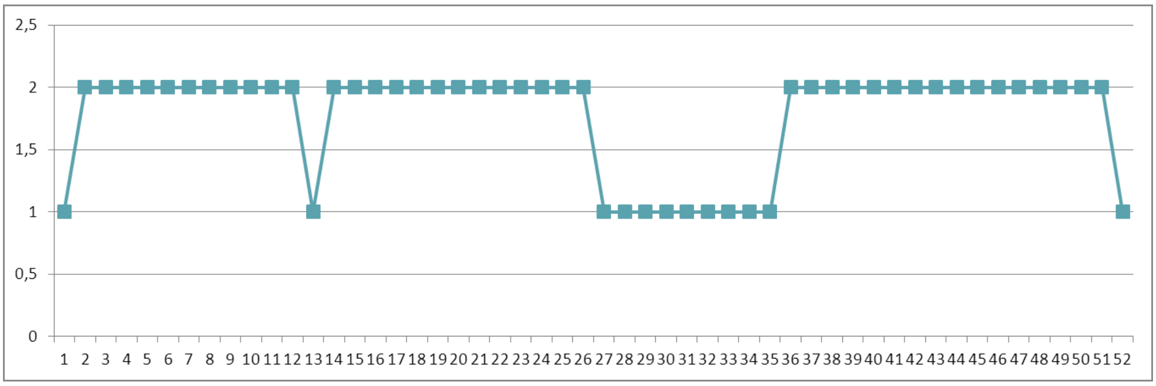


Figure 9: Building yearly occupation profile of Cartif offices

3 Building characteristics

3.1 Envelope elements and thermal characteristics

The structure of Cartif 1 was made in reinforced concrete and part in steel frames. Two floors are in reinforced concrete and the covering roof is in steel frame. All walls belong to the same 4 typologies; a particular feature is the amount of glass surfaces that characterizes all the façades. It was very difficult to find the right specifications about the windows that strongly influence the cooling loads during the summer.

It is possible to distinguish the following typologies of walls in Cartif 1 envelope:

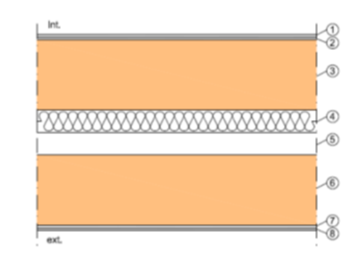
a. External wall: it is the kind of wall that composes all the external perimeter, it is mainly composed of perforated bricks and has an inside insulation layer;
b. Separation internal wall: it is a wall of perforated bricks thicker than the slim one. It is covered with a plasterwork on both sides;
c. Slim internal wall: a wall of perforated bricks covered with a plasterwork on both sides;
d. Dry-wall: it is made with plasterboard prefabricated wall; the commercial name of material is "Pladur". It has interesting insulation performance because of the inside layer of insulated material.

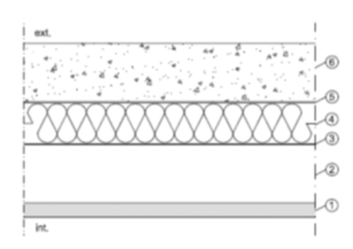
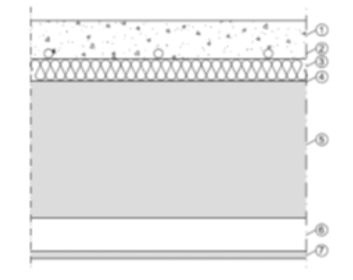
There are also two kinds of horizontal frames:

e. Roof: the roof has a steel structure. It is provided with insulation and water proof layers. The outside cover layer is in gravel.
f. Floor: it has a concrete structure; the above floor layer is embedded with pipes of thermal active slabs. The insulation panels are positioned at the bottom of this layer to improve the slabs performance.

In the following table it can be found the description of these envelope elements.

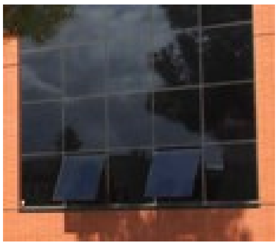
Table 6: Construction elements of Cartif offices

Envelope Element	Description (material and thickness)	Total thick. (m)	U-Value ($W/m^2 K$)	Abs int. – abs ext	Details section'sketch from inner face to outer face
External wall	1. Int. Plastering 0.005 2. Sand mortar 0.005 3. Brick 0.125 4. Polystyrene 0.04 5. Air. (Resistance 0.022 $h \cdot m^2 \cdot K/kJ$) 6. Perforated brick 0.125 7. Sand mortar 0.005 8. Plaster 0.005	0.31	0.593	0.3-0.7	

Internal Wall	1. Int. plastering. 0.010 2. Performated brick. 0.250 3. Int. plastering. 0.010	0.27	1.823	0.3-0.3	
Slim Internal wall	1.Int plastering 0.013 2.Perforated brich 0.125 3. Int. plastering 0.012	0.15	1.946	0.3-0.3	
Dry wall – pladur	1.Dry-wall 0.013 2. Insulation 0.054 3.Dry-wall 0.013	0.08	0.565	0.3-0.3	
Roof	1.Plaster ceiling 0.025 2.Air. (Resistance 0.022 h m2 K/kJ) 3. Zine plate 0.002 4. Polyurethane 0.080 5. Plastic 0.001 6. Gravel layer 0.100	0.21	0.382	0.3-0.7	
Floor	1.Concrete 0.06 2. Pipe active layer 3. Concrete 0.010 4. Polyurethane 0.04 5. Ribbed-slab floor 0.250 6. Air. (Resistance 0.022 h m2 K/kJ) 7. Paster Ceiling 0.013	0.4	0.637	0.3-0.3	

Regarding the windows, the entire building has the same kind of windows: Glass is Climalit Planitherm Cool-lite K manufactured by Saing Gobain. It is a type of glazing that ensures good performances inthermal insulation because of the low emissivity factor of the treated surfaces. It has also a good solar protection since the external surface is treated with a metallic layer. Glass plates are mounted on a steel frame, minimizing the thermal bridge effect. The features of glass are shown in the following table:

Table 7: Windows description of Cartif offices

Envelope Element	Description	U-Value (W/m^2K)	g	Details section'sketch from inner face to outer face
Window 1	Saint-Gobain. Cool-lite KN	1.1	0.2	

4 Energy flow

The heat system is based on a solar thermal system and a gas-fired boiler: together, they produce hot water for uses (radiators, thermal active slabs, heat pumps, DHW) in winter and for generator of Li-Br Chiller in summer. There is also a water-water heat pump used to feed the fan coils and active slabs (in cooling mode).

The evaporative cooling tower has also a relevant rule that is the condensing heat sink for Li-Br chiller and water source heat pump. It works only during summer season.

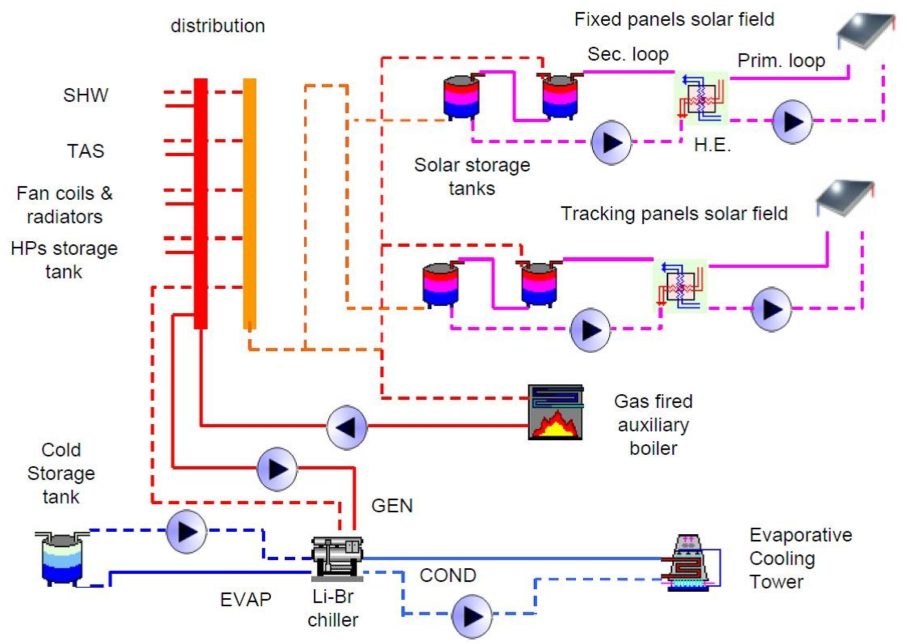


Figure 10: Pattern of solar thermal assisted cooling and heating system in Cartif offices

Regarding the air conditioning of the internal spaces is done with several integrated technologies:

- thermal active slabs (TAS): this system covers almost completely the floor surface of the building. The system guarantees a uniform flux of energy and generally a better thermal comfort for users. A drawback is the inertia of the systems that complicates the regulation. It is also provided with a backup system (heat pumps) to cover peak loads in heating and especially in cooling modality;
- water source heat pumps: are located in some laboratories. They permit an independent regulation for every space. They have an important role when it is necessary to cover peak demands. There are water-air heat pumps and one water-water heat pump.
- fan coils and air heaters: four air heaters are located in the industrial zone. Other small fan coils stand in administrative area; they both provide heating and cooling;
- convective radiators: installed only in administrative area at mezzanine floor to compensate cold wall effects (orientation is north).

In the following sections, a short description of the main features of each system will be given.

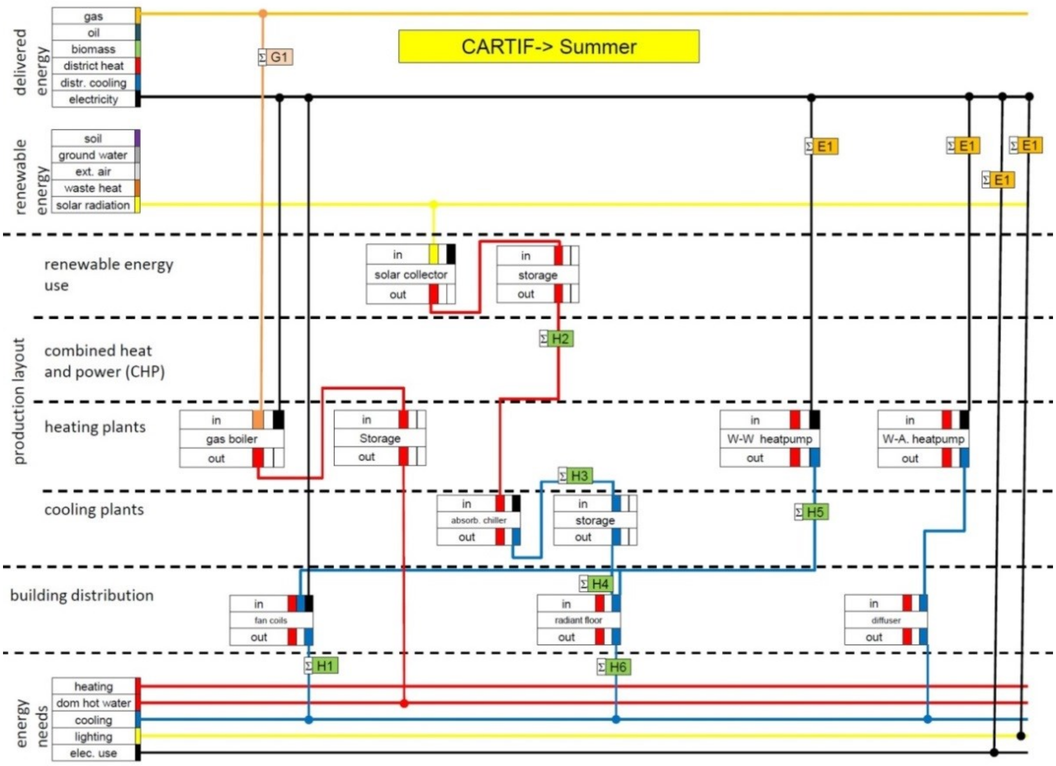


Figure 11: Summer energy flow

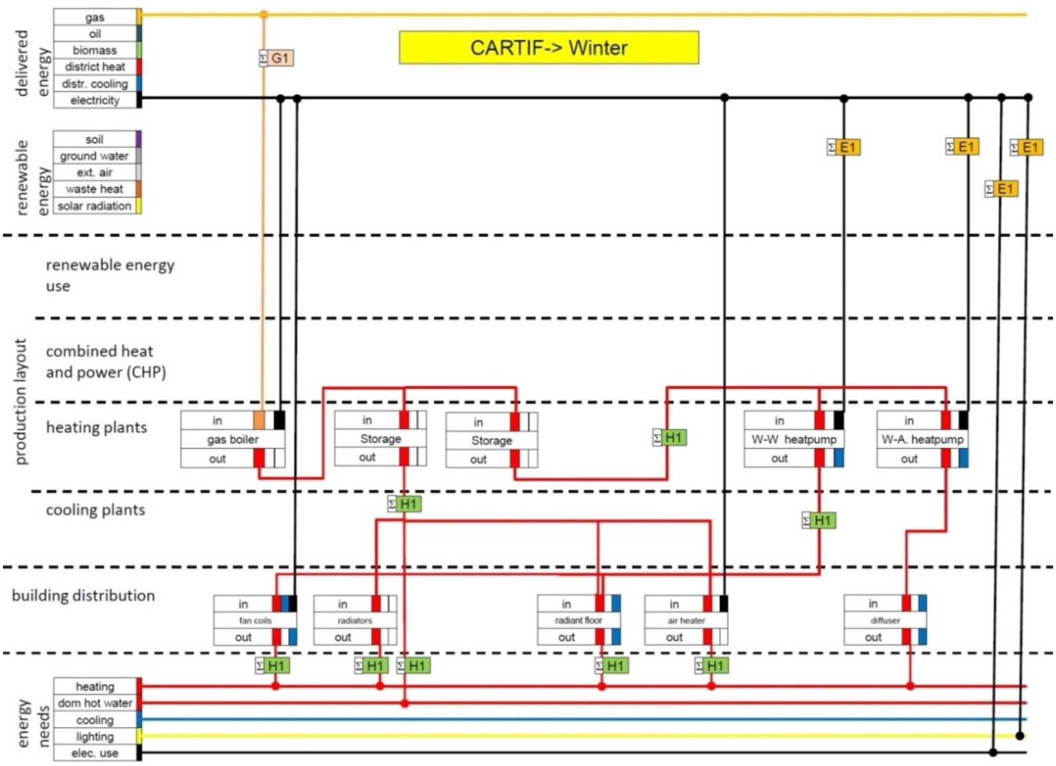


Figure 12: Winter energy flow

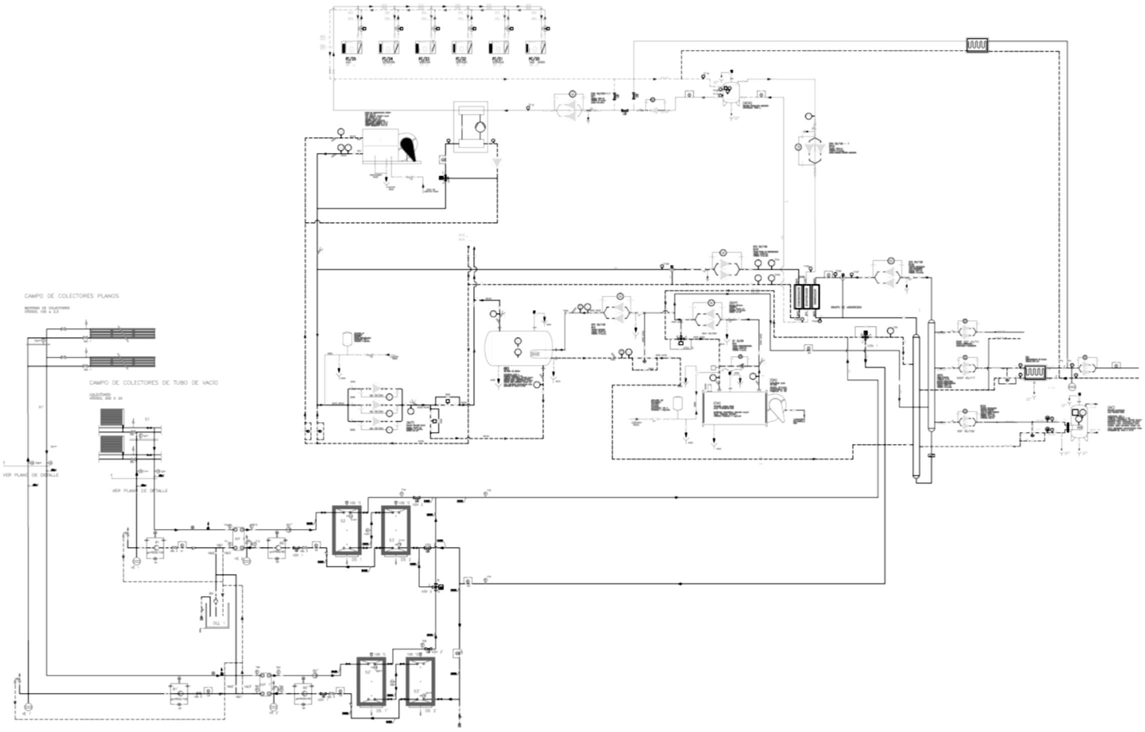
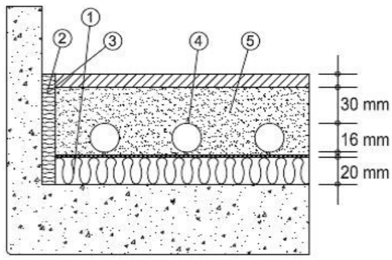


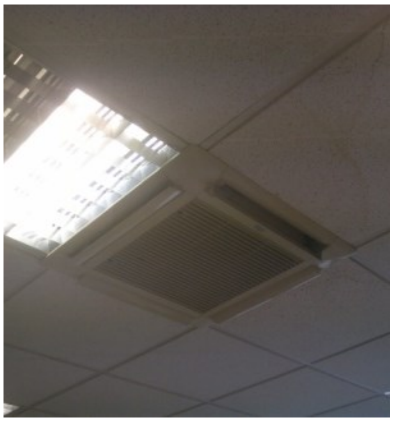
Figure 13: Facility scheme

Table 8: Energy flow elements of Cartif offices

HVAC PLANT	Installed system	Nº units	Picture
Heating	Solar thermal system 1	15 panels	
	Solar thermal system 2	16 panels	
	Boiler Heating power: 200.000 Kcal/h Working temp.: 90/80ºC Working pressure: 4kg/cm^2	1	

Cooling	Absorption chiller	1	
Heating/cooling	Water-air heat pumps (UBC)	16	
	Water-water heat pump	1	
Storage	Solar System	4 / 2.000 l 8.000 l	

	Cold energy	1 / 1.000 l	
	DHW	1 / 500 l	
Terminal units	Thermal active slabs	22 circuits	

	Fan coils (DWK)	7	
	Diffusers	56 circular diffusers 32 air supply grids	 
	Convective radiators	9	
	Air heaters	4	
Auxiliary systems	**Evaporative tower** Power dissipated: 325.000 Kcal/h Pump power: 1,1 kW Flow: 65.000 L/h Water regime: 29/34ºC Wet bulb temp.: 24ºC	1	

The location of the fan coils and heat pumps can be seen in the Table 3 and in the following figures. In these figures can be also seen the distribution of the diffusers and air supply grids.

There are 4 kinds of air supply grids distributed in the following way:

Table 9: Characteristics of air supply terminal units

	Dimensions (mm x mm)	Max Flow (l/s)	Range (m)	Quantity	Floor
Type 1	200x150	60	3.5	11	1
				2	2
Type 2	300x200	100	4	3	2
Type 3	300x300	150	4.3	9	2
Type 4	400x300	200	4.5	7	1

4.1 Solar thermal system

On the roof of Cartif 1 two combined systems with flat plate collectors are installed. The two systems have two independents loops, but the operation modality of both is the same: each one has a primary and a secondary pipe circuit.

The primary loop connects solar array to a plate heat exchanger. The fluid used in this circuit is a mixture of glicol-water (to avoid freezing). Circulation is obtained with incremental pump with a specific control. This kind of regulation permits to maintain safely temperatures in solar collectors and savings in electric consumption.

The secondary loop connects the other side of the plate heat exchanger to the solar storage tanks: here, as well circulation is guaranteed with a one speed pump. Thus, the hydraulic system is configured in two circuits to comply two requirements: In the outdoor part the circuit works with a mixture to avoid freezing (often temperatures decreases under zero), on the other hand, inside, it works with normal water that is the same fluid circulating in uses loops.

The storage tanks have an inertial storage function: they receive gradually heat from capitation system, depending of daily trend of solar radiation, accumulating it and minimizing losses. This permit to overcome mismatching between solar gains and cooling loads. Furthermore, natural thermal stratification guarantees adequate temperature levels, avoiding mixing with backup source.

Figure 14: Solar field 1

Figure 15: Solar field 2

One of the flat plate collector field is composed of 15 panels, with a total area of 37.5 m^2. They were arranged in three rows of 5 collectors with south orientation. This system is connected to two storage tanks with capacity of 2000 litters; Tanks are connected in series to take advantage from the thermal stratification. Circuit and tanks are accurately insulated to avoid heat losses.

The other field is composed of 16 flat plate collectors with a total area of $32m^2$. In this case the collectors stands on a tracking platform that allows an azimuthal movement to track the sun. In this way it is possible to earn the maximum energy ratio, having a 30% improvement of solar energy compared to an equal system without this motion. This system as well is connected in series to two storage tank obtaining a total capacity of 4000 litters.

4.2 Gas-fired boiler

The water boiler works with natural gas. The model of this gas boiler is Pyronette-Py 235 Ygnis and it has an useful power of 235kW and a nominal power of 255kW.

This gas boiler is used in winter and summer, because when there is demand of cold this boiler is used as support of the solar installation in order to cover the heat requirements of the generator of the absorption chiller. The solar thermal system would not be able to work without boiler support, so that, boiler is used to cover also small periods when solar tanks cannot reach requirements.

Summarizing, the uses that are fed by collector of solar and auxiliary boiler are:

- fan coils, air heaters and convective radiators T=60ºC and Q=3000 l/h;
- domestic hot water T=45ºC;
- heat pumps T=32ºC and Q=20000 l/h;
- thermal active slabs T=35ºC and Q=15000 l/h;
- Li-Br absorption chiller T=88ºC and Q=7500 l/h (operates only over the summer).

4.3 Absorption Chiller

The solar cooling producing systems are a single effect LiBr–H_2O absorption chiller, model Yazaki WFC10. The chiller is fed with hot water and refrigeration power is 34.9 kW. Nominal operating conditions are: 8ºC for outlet cooled water and 88ºC for inlet generator water, COP is 0,7.

The generator receives water from the solar tanks or direct from the boiler circuit depending on the temperature of the water stored in solar tanks. There is a valve system that includes or excludes the solar circuit in the return collector. The solar circuit can be connected in different ways: including one or both solar tanks with the possibility to work in series or in parallel.

Typically, in the first part of the day or in days with low radiation solar tanks water is below the set-point temperature for the generator (85ºC). In this case, the generator works with boiler consuming natural gas. Afterwards, typically from 11-12 hour till evening chiller works with solar water.

It is important to underline that a good performance (COP) in chiller cycle is achievable only when inlet water is continuously at high temperatures.

The water cooled from the evaporator is stored in a cold storage tank with a capacity of 1000 litters. This solution permits to accumulate "cold energy" and avoids frequently cycling of the chiller.

Cooling terminals (Fan coils and/or TAS) take water from there. At the beginning, the chiller was designed to supply fan-coils in the administrative area, but the load was quite low compared with the nominal capacity of chiller. Because of this, often the cycle time was very short and the performance of chiller not adequate. Another possibility is to supply the cooling slabs that have a higher load, but this requires a backup cooling system for fan-coils.

4.4 Heat Pumps

There is a water-water heat pump that can supply fan coils and leaves the chiller to work only radiant cooling floor. This heat pump is manufactured by Clivet.

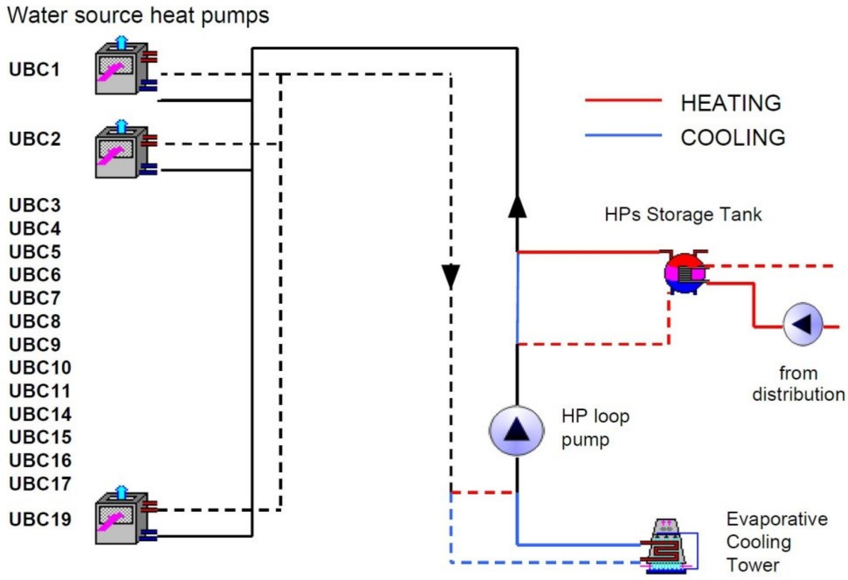


Figure 16: Scheme of water source heat pumps in Cartif offices

The main part of laboratories is equipped with water-air heat pumps; the sizes of these heat pumps are quite different (from 0,7 to 35 kW) because of the variable dimension of spaces and loads.

All water-air heat pumps are manufactured by McQuay and are model CCH, working with R-410A refrigerant.

These heat pumps are working with a boiler/tower application: This uses a simple two-pipe water circulating system that adds heat in winter, and removes heat in summer. Hot water is provided from heat pumps storage tank located in the boiler room. The condensing water is provided from the cooling tower that dissipates the heat. This circuit works with a pump with a nominal mass flow of 25000 l/h. The main part of treated air comes from the same conditioned spaces and a small part from outside. This application has a low cost, great flexibility and generally in Cartif 1 works at good conditions: water for heating at 32ºC and for cooling at 24ºC.

4.5 Evaporative Tower

The chiller condenser is connected to the evaporative tower circuit, and in this way it discharges heat. This unit is the same used by heat pumps: it is a closed loop evaporative tower. It is located outside, near the garage. It is equipped with a centrifugal blower (forced air circulation) and a 4kW electric resistance to avoid freezing problems. The choice of this technology was very adequate: in Boecillo relative humidity is low during summer periods, and this ensures a low wet bulb temperature and optimum performance of evaporative cooling.

4.6 Terminal units: fan coils, air heaters, radiators and thermal active slabs

Four air heaters are located in the industrial zone, providing only heating. Each one has a heating capacity of 27,18 kW with inlet temperature 65ºC and fan speed 1400 rpm. It should be stressed that this space is heated only few times during the cold season. Small convective radiators are placed in administrative zone (north side) on façades to avoid cold wall effect. This zone is conditioned with ceiling fan coils. These fan coils can work with two sources: a water-water heat pump or with water from cold storage tank.

The system is not only based on internal fan coils but is also integrated with a supplementary fresh air system that takes air from outside and ensures an adequate air change.

The system supplies heating and cooling to the internal spaces. At the beginning, in Cartif 1, this system was used only for heating but from 2010 is going to be also used in cooling modality, fed with solar cooling chilled water.

It consists of pipes circuits embedded in the superficial layer of the floor. They work as a wide heat exchanger, warming up or chilling the floor and the inside air. The floor layer is made with a special mortar that ensures good conduction performances, while the underlying layer is in insulating material to minimize losses.

There is one main circuit for the entire building that supplies 13 collectors. Each collector then supplies the single loops. Every loop can be by-passed with a three way valve controlled by the management system.

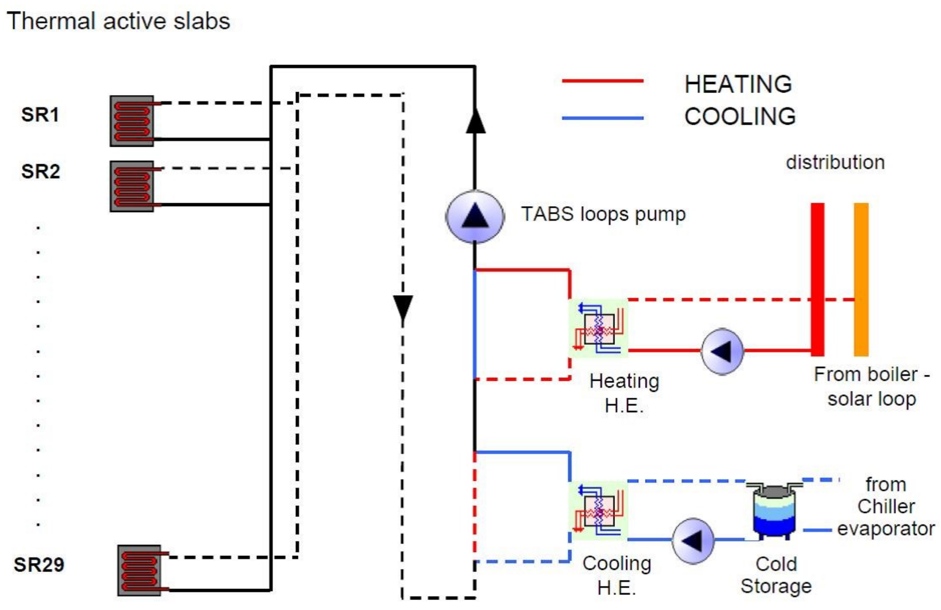


Figure 17: Scheme of thermal active slabs in Cartif offices

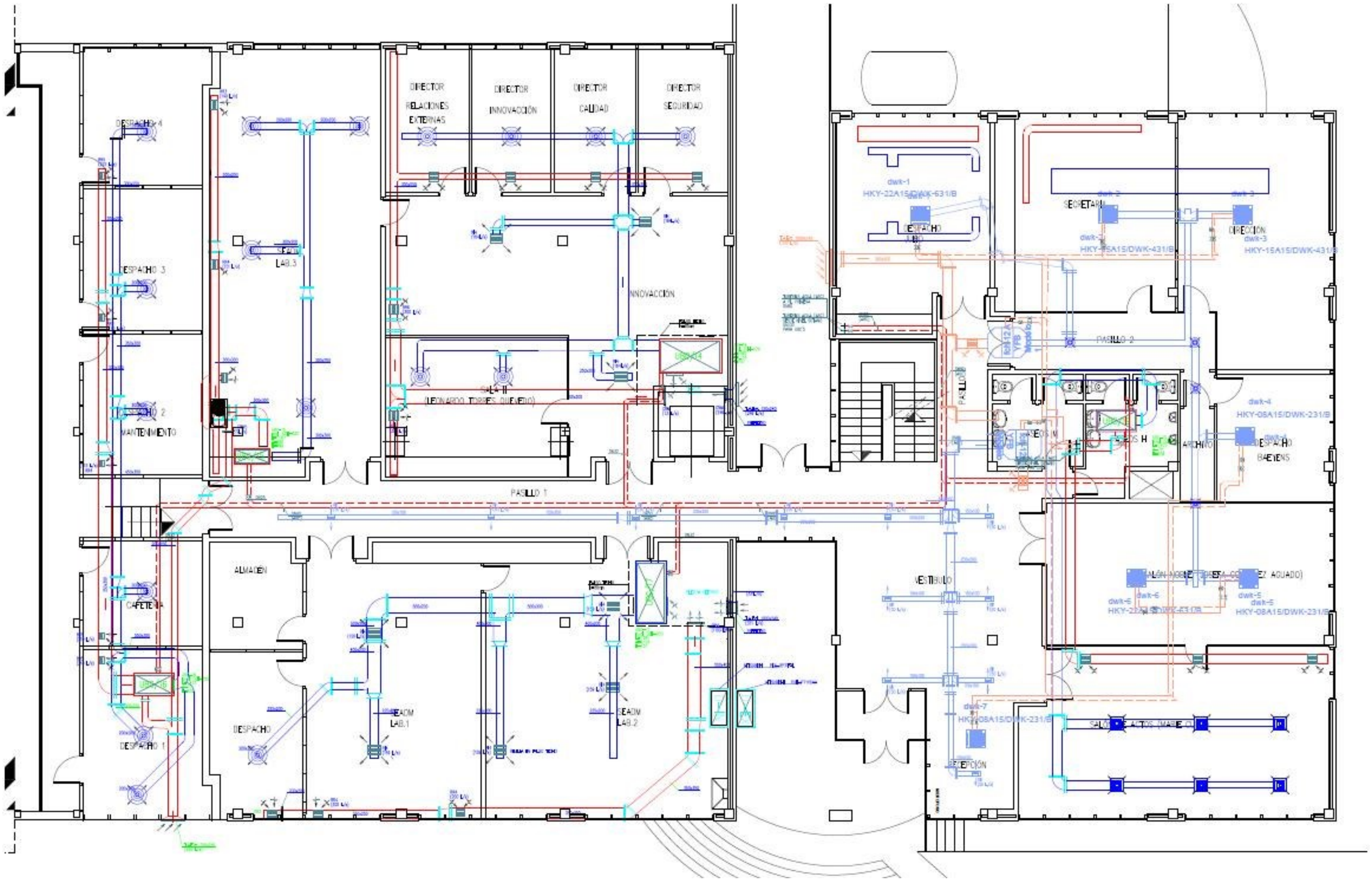


Figure 18: Distribution of terminal units, fan coils and heat pumps in ground floor of Cartif offices

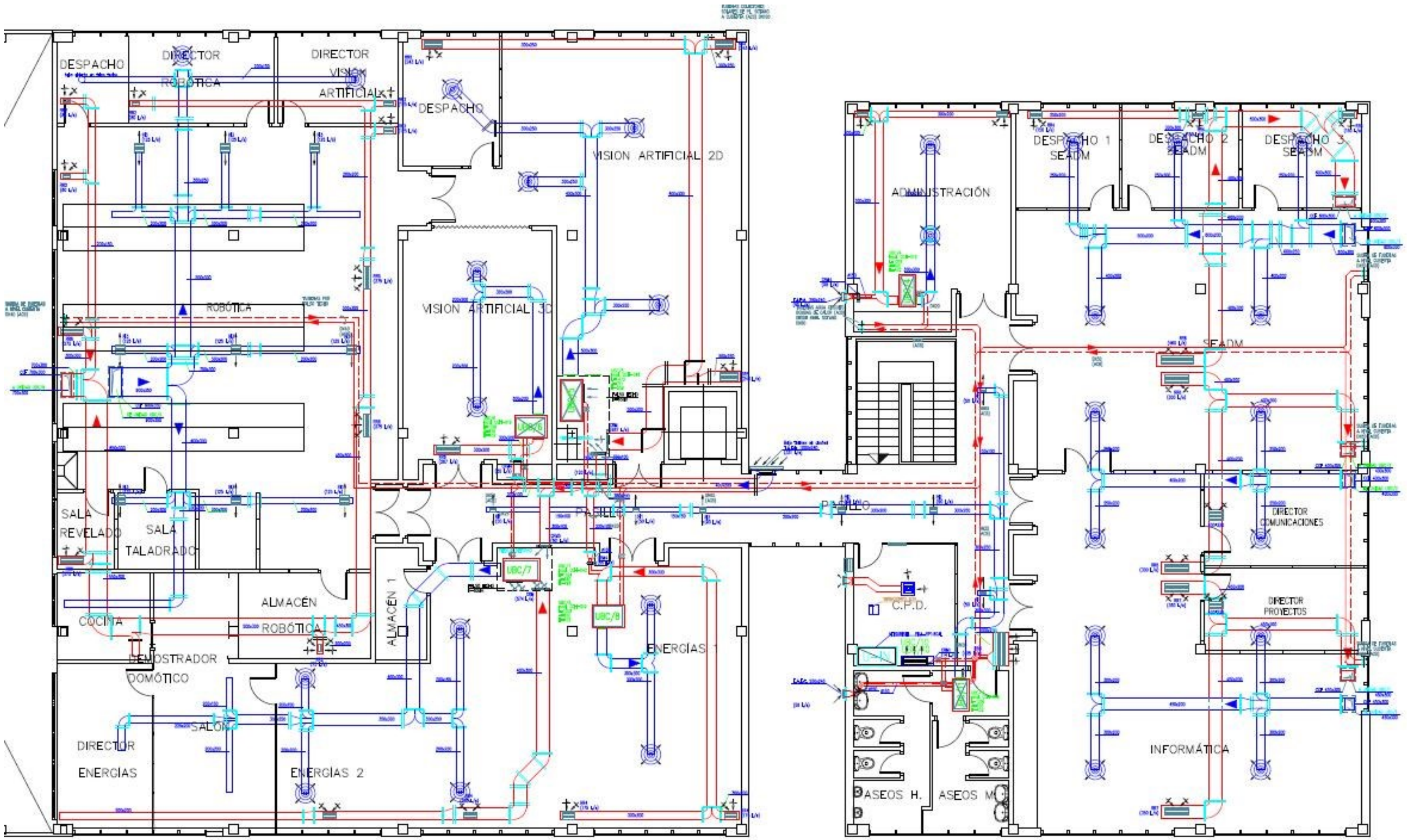


Figure 19: Distribution of terminal units, fan coils and heat pumps in first floor of Cartif offices

5 Energy supply and use

5.1 Electricity supply and consumption

Table 10: Information about electricity supply of Cartif offices

Energy supplier (Name of organization)	Iberdrola					
Tariff	ATR6.1					
Nº tariff periods	6					
Periods	1	2	3	4	5	6
Contrated power (kW)	400	400	400	400	400	451
€/kW	1.501852	0.751576	0.550029	0.550029	0.550029	0.250959
€/kWh	0.17296	0.137166	0.110583	0.08915	0.082469	0.067349

Table 11: Daily tariff period of Cartif offices

P6 includes Saturdays, Sundays and public holidays

In June, from 1st to 15th the periods are distributed in the same way that in September. From 15th to 30th, the distribution of periods is the same that in July.

Table 12: Electricity consumption of Cartif offices

	Jan	Feb	Mar	Apr	May	Jun
kWh	29033.67	31331.67	31318	26502.67	29384.67	31823.33
€	4823.99	5129.35	3795.39	3076.02	3392.61	4884
	Jul	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
kWh	32208	31999.67	25485.67	24893.33	22490.33	22940
€	5862.44	3409.54	3554.77	3100.22	3201.80	3977.09

Total (kWh): 339,411.0

Total (€): 48,207.22

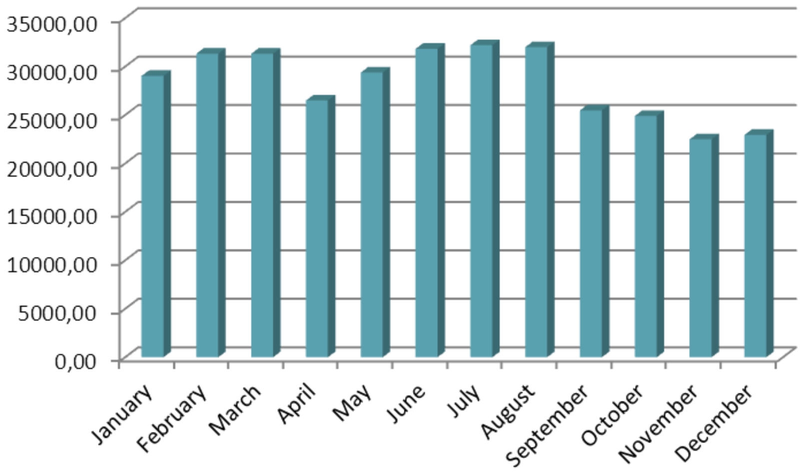


Figure 20: Electricity consumption (kWh) of Cartif offices

Table 13: Summary of electricity demand monitored for some periods of Cartif offices

Period	Day		Night/weekend	
	P_{ave} (kW)	P_{max} (kW)	P_{ave} (kW)	P_{max} (kW)
15/04/2010 - 22/04/2010	62	95	29	48
24/08/2010 - 30/08/2010	100	130	19	44
22/09/2010 - 28/09/2010	79	117	13	40

5.2 Fuel supply and consumption

Table 14: Information about fuel supply of Cartif offices

Energy supplier (Name of organization)	Gas Natural Fenosa
Contratred energy/flow	>100.000 kWh/year
Tariff	3.4
Nº tariff periods	1
€/kWh	0.049232
€/kWh Special Tax Hydrocarbon	0.002340

Table 15: Gas consumption of Cartif offices

	Jan	Feb	Mar	Apr	May	Jun
kWh	34299.75	27821.5	15654.25	12750.75	6977.75	1851.75
€	1900.32	1559.20	877.31	738.46	411.94	109.47

	Jul	Aug	Sep	Oct	Nov	Dec
kWh	1379	1548.5	1580.75	6106.25	16304	18280
€	82.31	92.72	97.06	380.19	1005.08	1125.97

Total (kWh): 144,554.25

Total (€): 8380.02

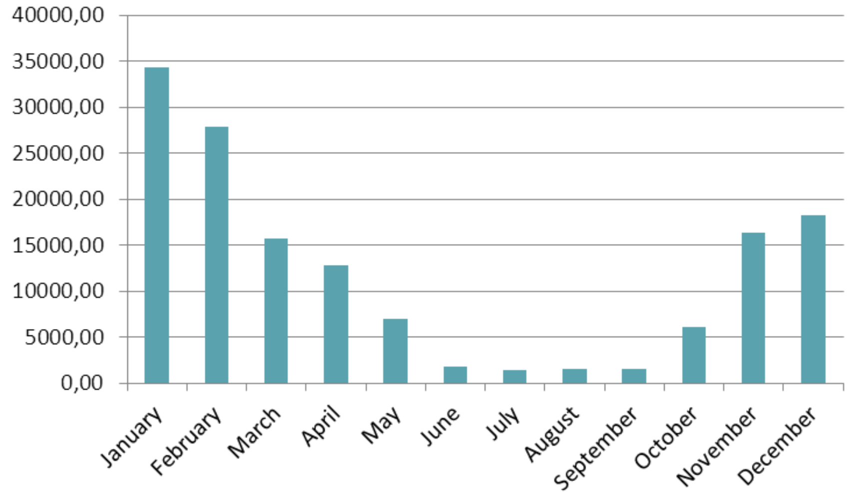


Figure 21: Gas consumption (kWh) of Cartif offices

6 Building Management System

Cartif is provided with a monitoring and control network that covers a wide range of applications. The technology chosen was a LonWorks® network: it is a distributed system that guarantees reliability and soundness with a low cost compared with other similar systems. The network involves the solar facilities (solar thermal collectors, TAS, gas-fired boiler, heat pumps and solar cooling), the photovoltaic field, lighting and access system.

A LonWork® Network is composed of nodes communicating to each other through a LonTalk® protocol based on OSI model. The physical media of communication are several. Subsystems of the network are:

- Controllers Neuron Chip and its firmware (this includes support for LonTalk® protocol);
- Transceivers that permits to connect different physical media;
- Control modules Lonwork® (include Neuron Chip, transceivers and external memory);
- Routers that connects sub-networks and physical media;
- Networks interfaces that permits to connect elements not based on LonTalk protocol as PC, PLC;
- Tools for setup, configuration and diagnosis of nodes and network;
- Tools for application development, Neuron C compiler, purifiers.

It is a technology that permits the development of nodes based on Neuron Chip with a specific hardware for the application involved. However, in many cases, some devices are provided by manufacturer with compatible applications. Another advantage is that every subsystem is independent and it is possible to reprogram them without interfere on other subsystems.

As a result, every facility and all its elements are monitored. It is possible to check variables and also status on displays. Specials applications permit to follow the system via Ethernet, internet and e-mail. In this way management strategies can be changed and testes, and faults in facilities can quickly be detected and solved.

6.1 Zonal monitoring network

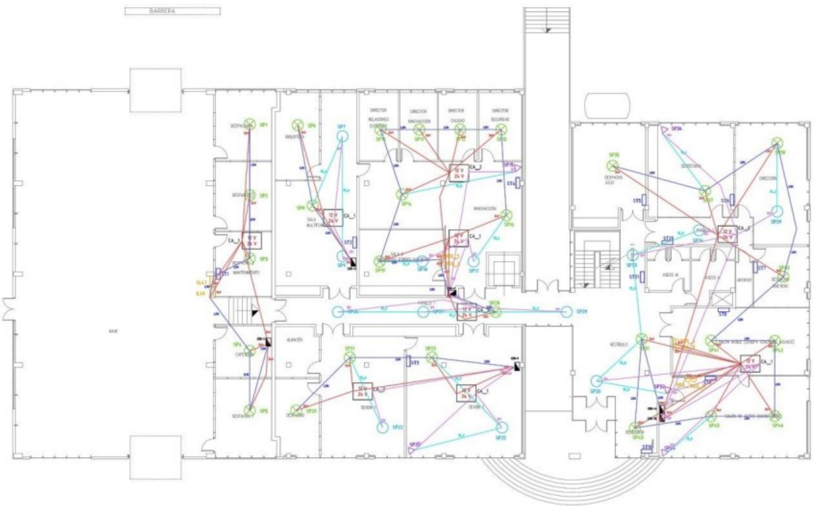


Figure 22: Ground floor sensors network of Cartif offices

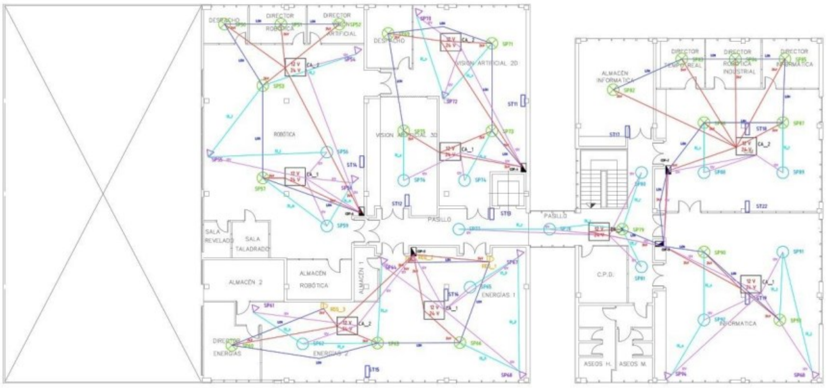


Figure 23: First floor sensors network of Cartif offices

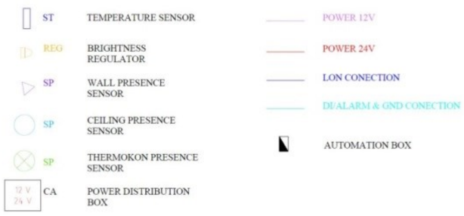


Table 16: Installed devices per zone of Cartif offices

Devices installed per thermal zone								
Zone	**Pressence sensors**	**Dimmers**	**Temperature sensors**	**WSHP (UBC)**	**Fan coils (DWK)**	**Lighting circuits**	**Luminaries with ballasts**	**TAS circuits**
a. Industrial zone								
b. Industrial zone offices / cafeteria	5	-	1	1	-	10	-	4
c. Multifunct. area	5	-	1	1	-	3	-	2
d. Innovation	13	2	2	1	-	7	4	5
e. SEADM	7	-	1	1	-	3	-	3
f. Office 1								
g. Secretariat								
h. Office 2								
i. Meeting room								
j. Auditorium								
k. Corridor 2								
l. Bathroom								

m. Hall + corridor	17	4	11	1	7	16	23	7
n. Robotics	10	-	1	1	-	6	-	4
o. Energy	8	3	2	2	-	4	14	3
p/q. Vision 2D/3D	8	-	2	2	-	3	-	3
r. Informatics warehouse			1					
s. SEADM	8	-	2	2	-	-	-	6
t. Informatics	11	-	1	1	-	9	-	1
u. Bathroom								
v. CPD								
TOTAL	**92**	**9**	**24**	**24**		**61**	**41**	**38**

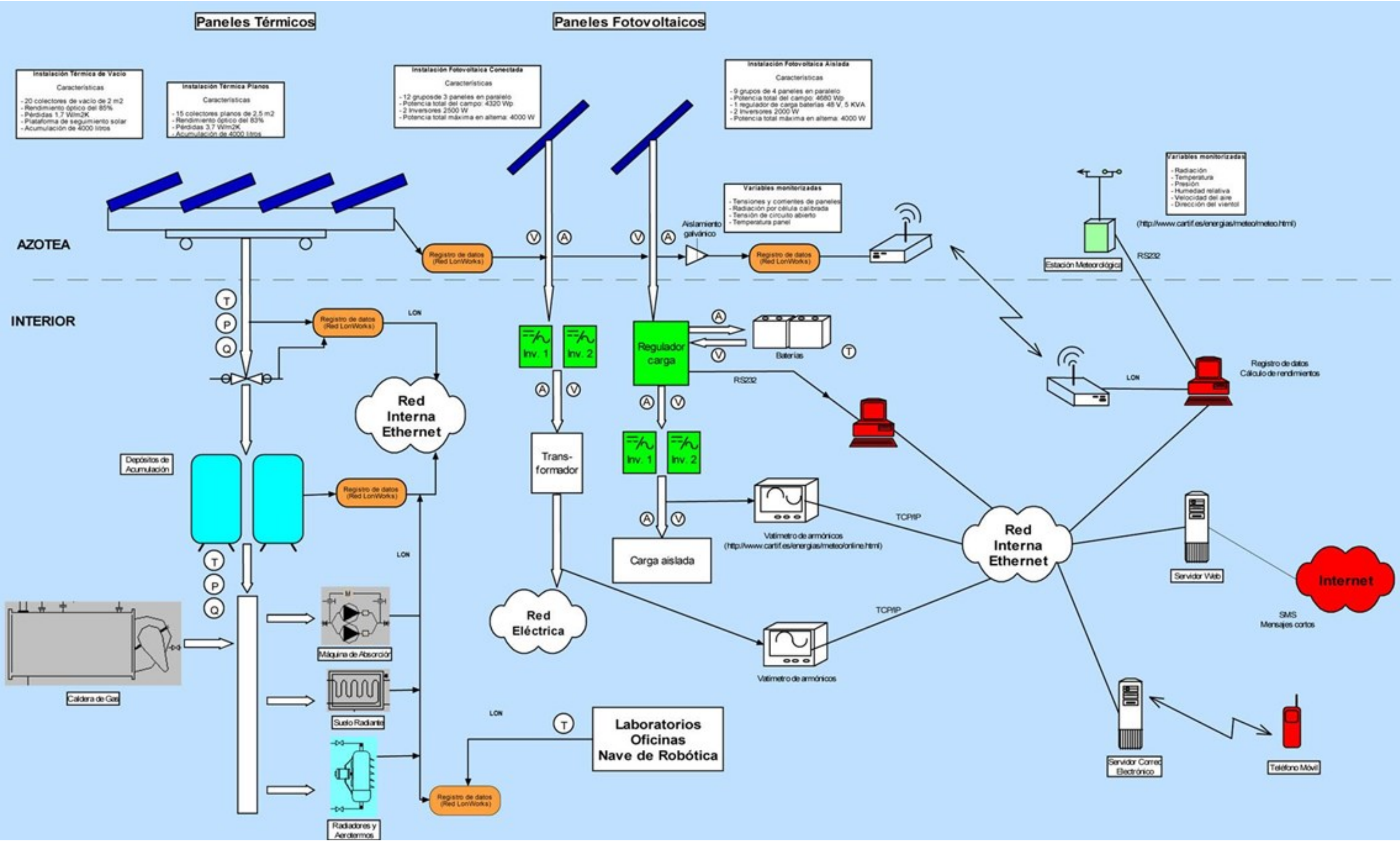


Figure 24: Monitoring network architecture of Cartif offices

6.2 Energy generation monitoring and control

A software tool to analyse the working status and performance of the solar cooling system of Cartif was also developed. In particular this application –developed in LABVIEW environment– permits to calculate directly every important parameter of solar facilities (energy balances, powers, COP, etc.). This application is very important when it is required to detect the performances of the system. It permits also to directly compare the real system with the simulated system in transient models.

Figure 25: BMS interface of Cartif offices

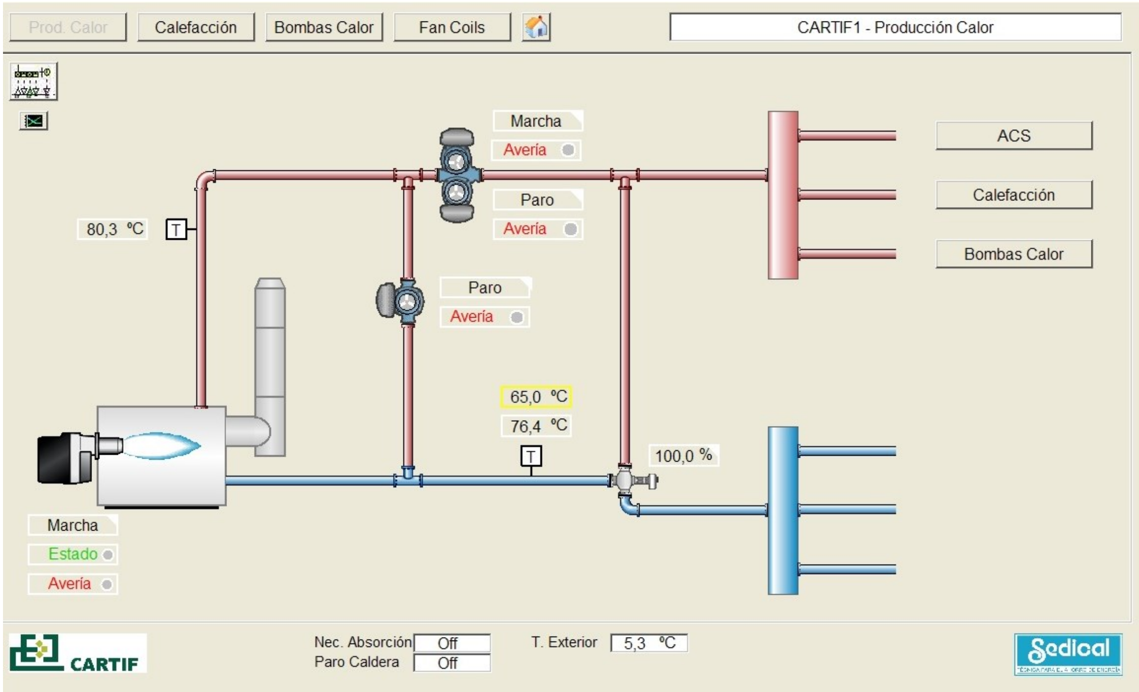


Figure 26: Heat production management of Cartif offices

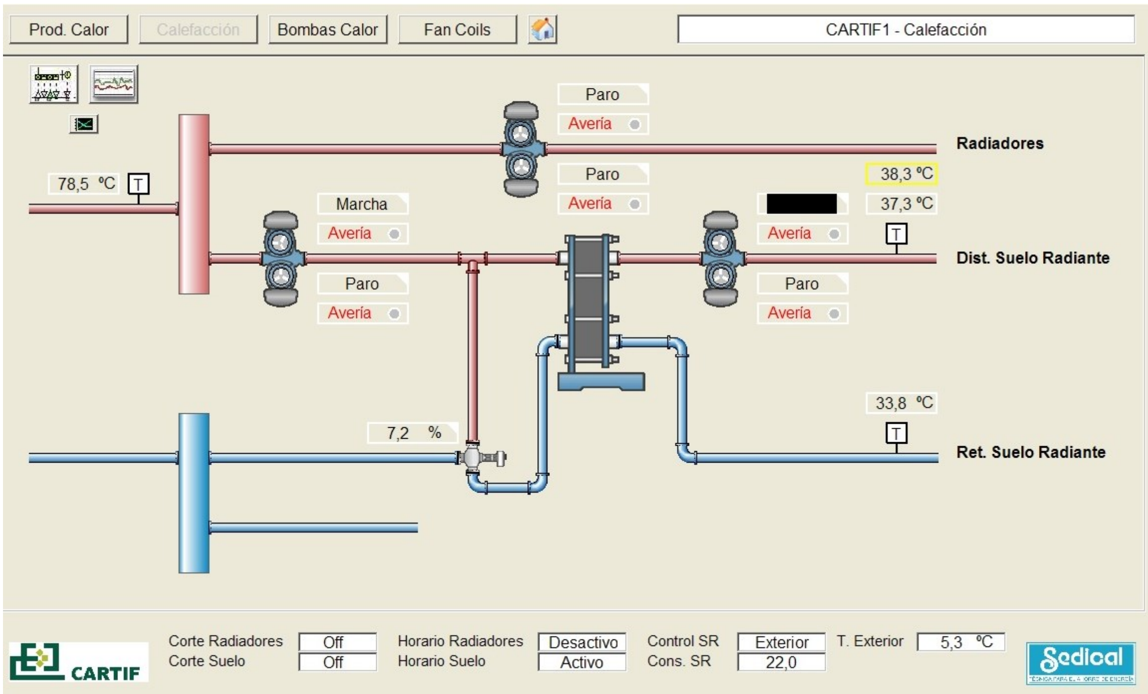


Figure 27: Heating system management of Cartif offices

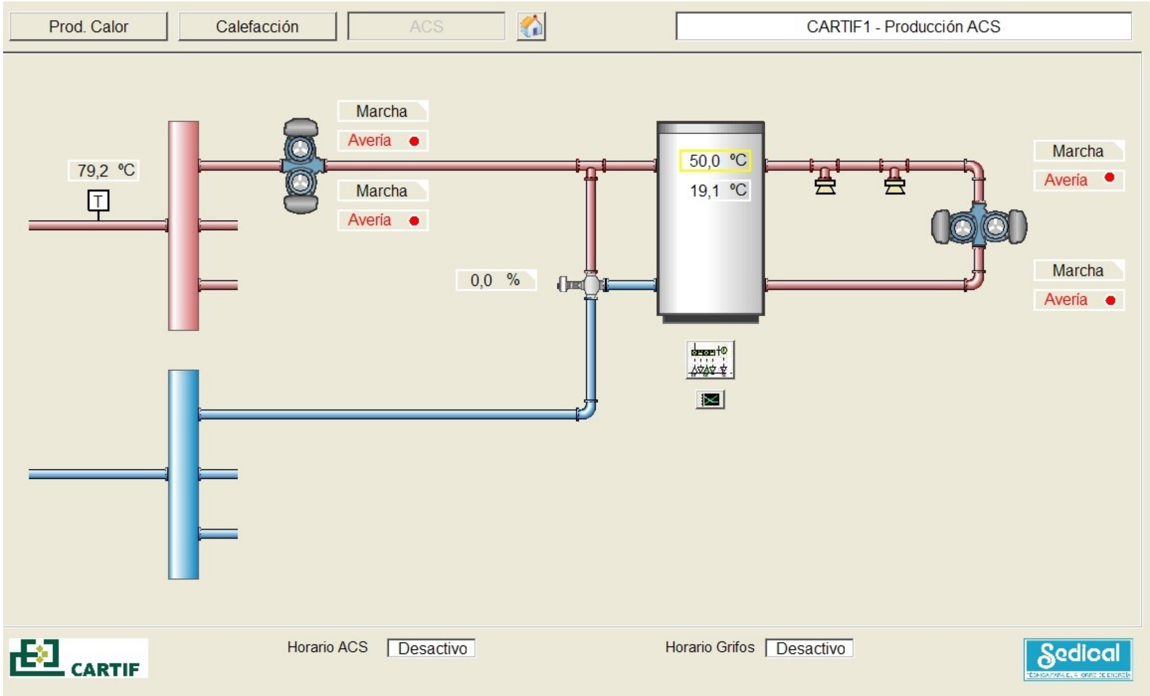


Figure 28: DHW production management of Cartif offices

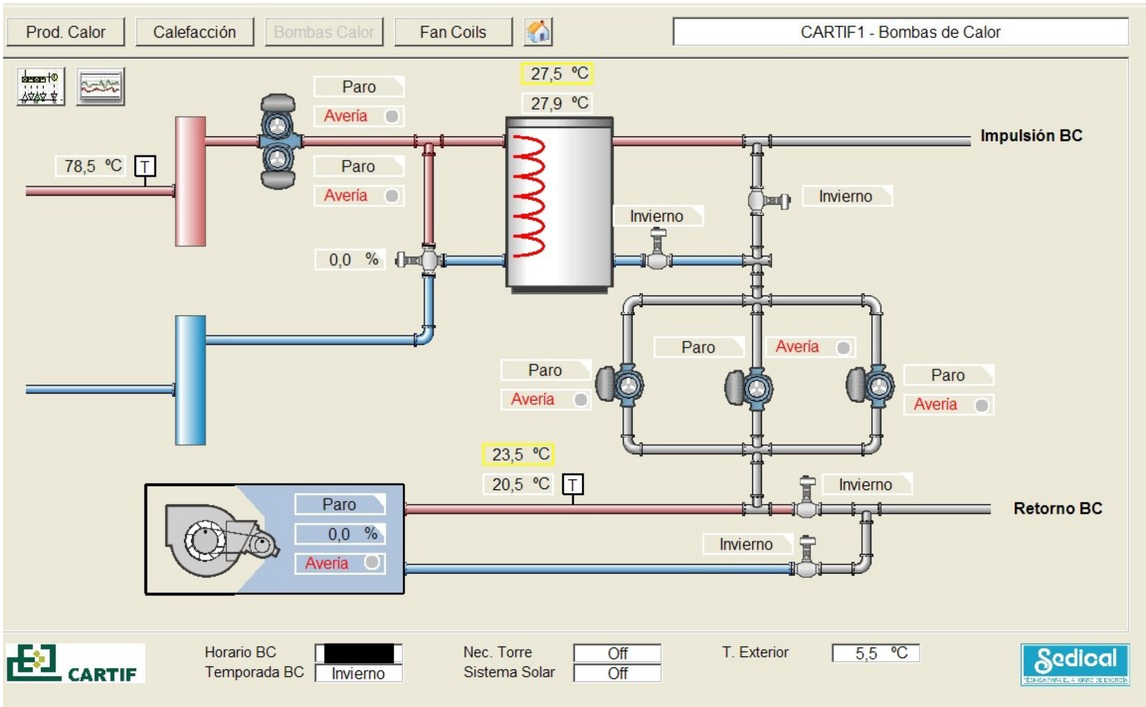


Figure 29: Management of energy production for heat pumps of Cartif offices

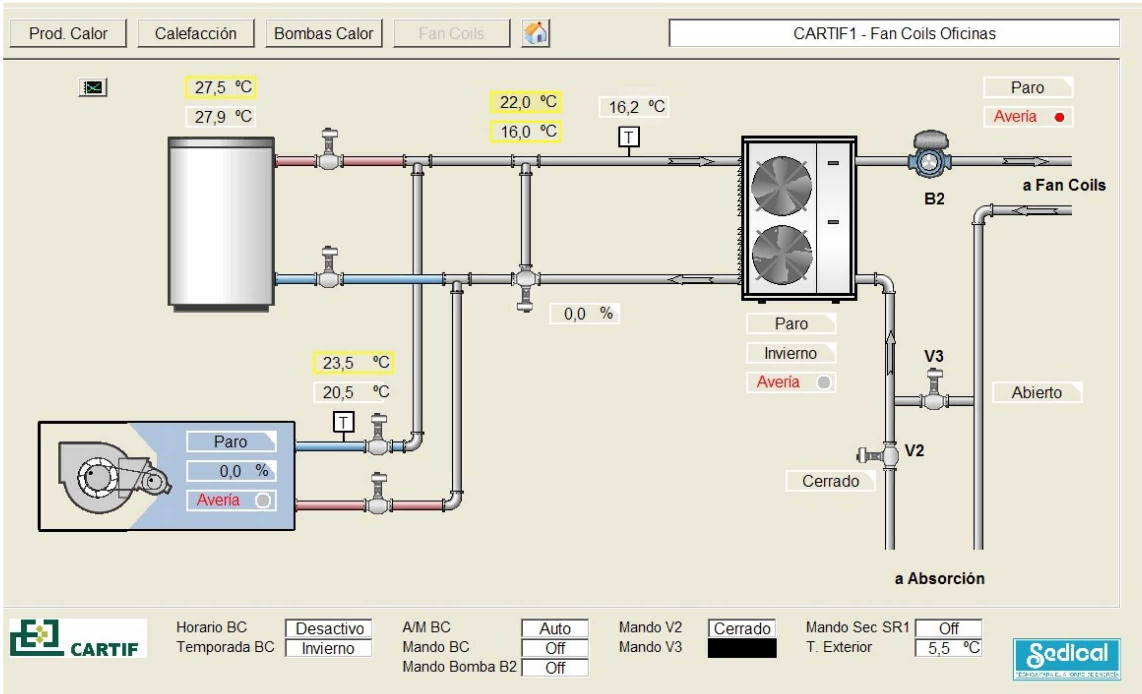


Figure 30: Management of energy production for fan coils of Cartif offices

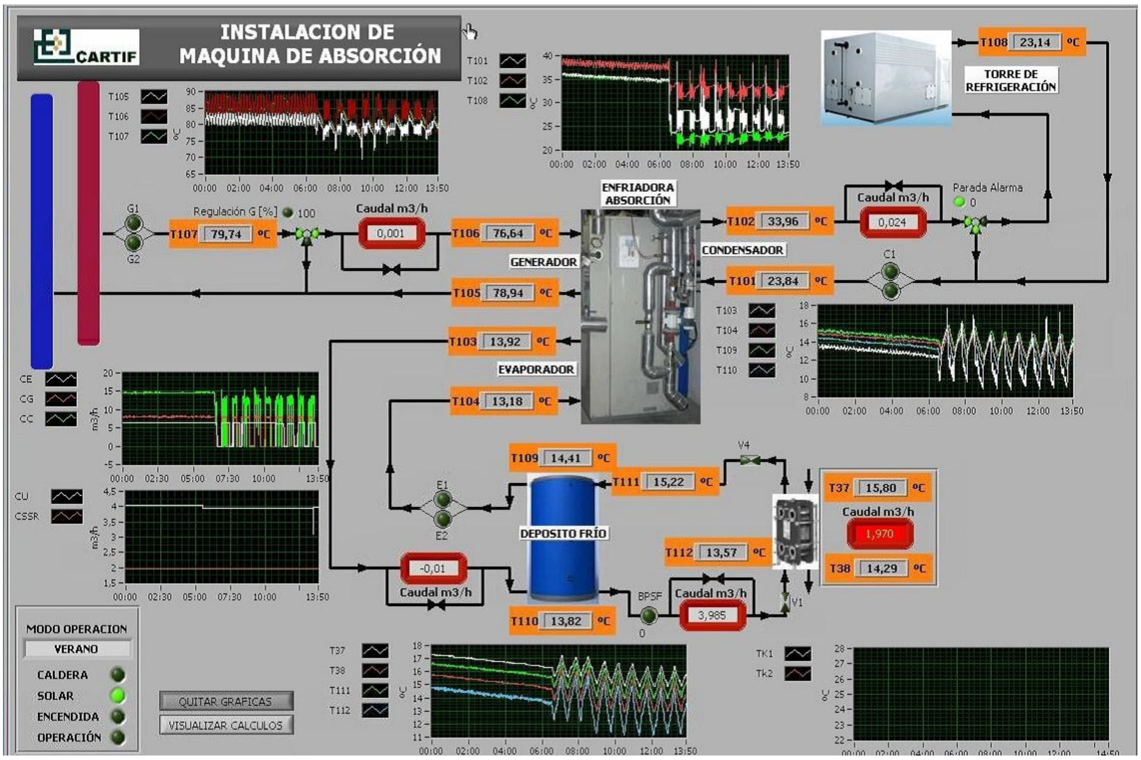


Figure 31: Management of solar cooling facility of Cartif offices

6.3 Energy use monitoring and control

On the distribution side, the building is provided with some devices used for the control of the radiant floor, fan coils and lighting system. The sensor and actuator network has been designed under the LonWorks® standard. In the following table are shown the installed devices and the power balance of them.

All the system is wired with shielded signal cable with section of 1,5mm (max.) and with the number of threads needed for each device. The connection with the LON network is with twisted cable.

Table 17: BMS installed devices and power balance of Cartif offices

Device	Model	Manufacturer	Power (W)	Voltage (V)
Mod. LON 6R	LON I/O module REG W 6W	SVEA	1,08W / 24V AC 3W / AC	24V DC 220V AC
Mod. LON Fan coil controller	Xenta 121-FC/230	TAC	90W	220V AC
Multisensor	Mdsl 206	Thermokon	4,2W	24V DC
Presence sensor PIR 360º	RK2000DPC	Gardtec	1,5W	12V DC
Presence sensor PIR wall	EW005P-RS	Gardtec	1W	12V DC
Electronic ballast	QTi 4x18 DIM	OMROM	72W	220V AC
Luminosity sensor LON	Li04 LON	Thermokon	0,720W	24V DC
Dimmer LON	Double tactile sensor	Thermokon	2,2W	24V DC
Switch LON	Single tactile sensor	Thermokon	2,2W	24V DC
Temperature sensor LON	WRF04 LON	Thermokon	0,600W	24V DC
LON Power supply	Lon Power Supply LPS-W	SVEA	0,2W	220V AC
Dimmer SVEA LON	Dimmer SVEA LON I/O Module REG-M DIM 1-10V	SVEA	0,300W	FA LON

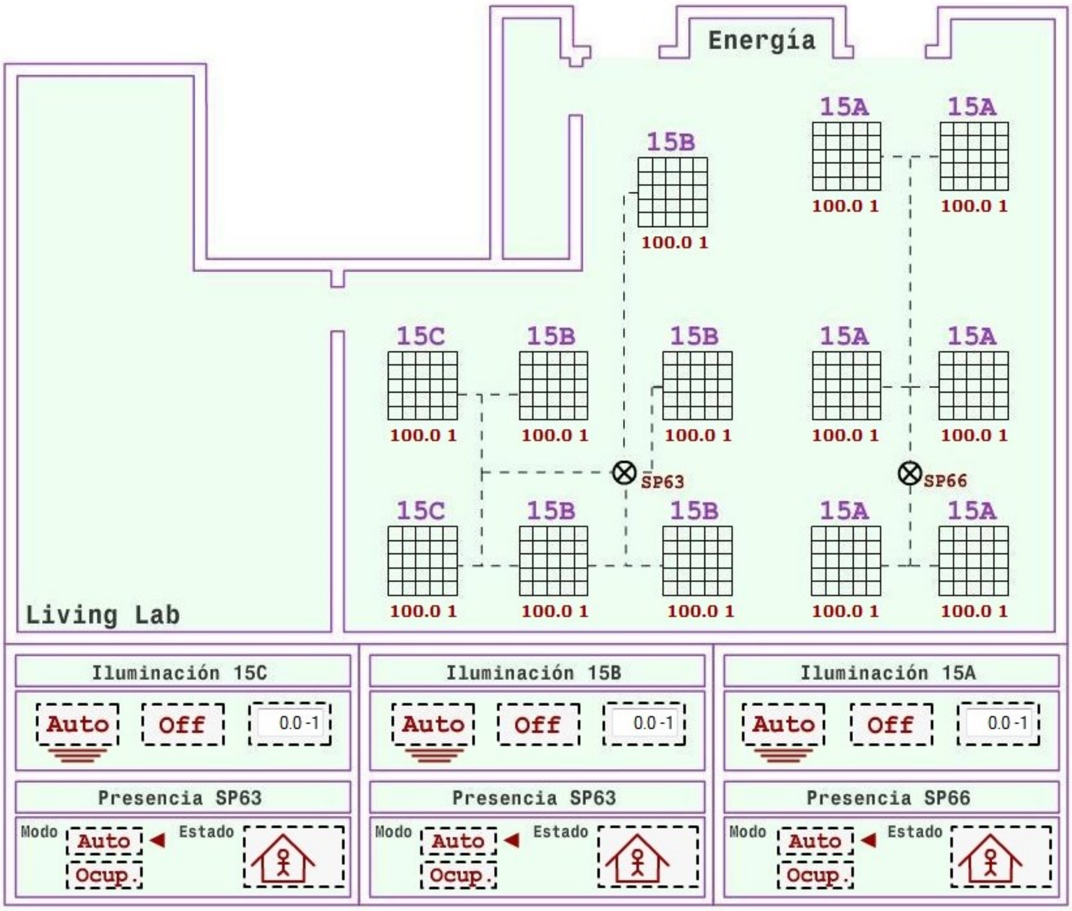


Figure 32: Lighting management of Energy laboratory in Cartif offices

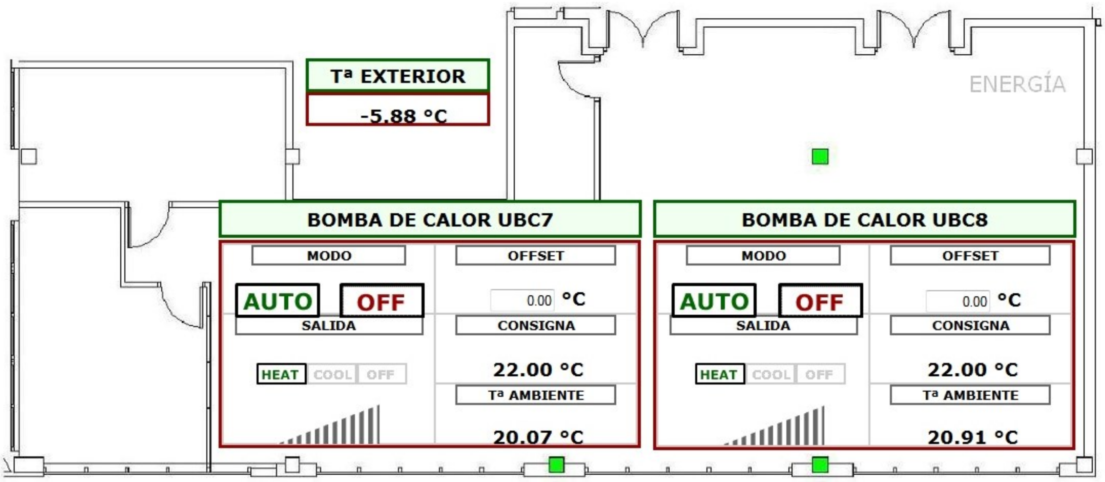


Figure 33: Heat pumps management of Energy laboratory in Cartif offices

6.4 Control strategies

6.4.1 Energy generation level existing control

6.4.1.1 Hot water generation: boiler

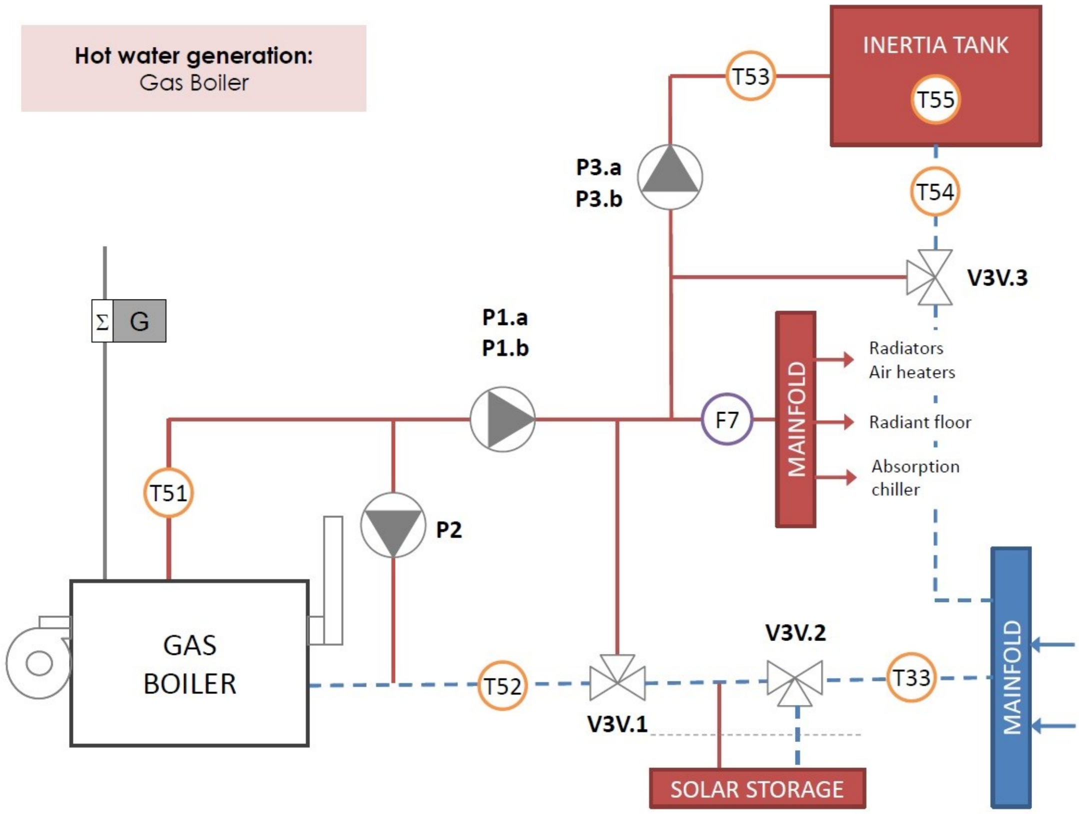


Figure 34: Boiler operating scheme

Table 18: Boiler related sensors

System	ID	Description	Unit
BOILER	T51	Supply temperature from boiler	°C
	T52	Return temperature to boiler	°C
	T53	Supply temperature to inertia tank	°C
	T54	Return temperature from inertia tank	°C
	T55	Inertia tank temperature	°C
	T33	Return temperature	°C
	F7	Boiler flow	m^3/h

Table 19: Boiler related objects

System	ID	Description	Control
BOILER	ON/OFF BOILER BURNER	Boiler on/off	On when: BOILER_SCHEDULE = ON T51 <= 90ºC
	P1.a P1.b	Pump Boiler Distribution	On when: BOILER_SCHEDULE = ON (it starts 2 minutes later once the state of BOILER_SCHEDULE is ON) or: SOLAR_GENERATION = ON (it starts 3 minutes later once the state of SOLAR_GENERATION is ON)
	P2	Pump Boiler recirculation. It recirculates the supply water to the boiler when the supply temperature is lower than the set point.tank	On when: ON/OFF BOILER BURNER = ON and (one of the followings): T52 <= T_MIN_T52 (65ºC) T51 >= 81ºC
	P3.a P3.b	Pump to inertia tank	On when: T55 <= T_MIN_T55 (27.5 ºC)
	V3V.1	3 ways valve. It mixes the return water with the supply water	Always open
	V3V.2	3 ways valve. It circulates water to the solar plant or directly returns to the boiler	~~Open when:~~ ~~SOLAR_GENERATION = ON~~ It stops the boiler through the variable BOILER_STOP
	V3V.3	3 ways valve. It recirculates the hot water to the inertia tank	Open when: -

	ON When…		
BOILER_SCHEDULE	ZONE_SCHEDULE = ON		
	RADIATORS_SCHEDULE = ON		
	ABSORPTION_DEMAND = ON		
	HEAT_PUMP_SCHEDULE = ON		
	DHW_SCHEDULE = ON (always OFF)		
BOILER_STOP	When: V3V.2 = 0 (open to solar storage)		
ZONE_SCHEDULE	Working days	From 6h30 to 16h00 at 21ºC (room set point)	P16 = ON
		From 16h00 to 6h30 at 19ºC (room set point)	P16 = ON

RADIATORS_SCHEDULE	Working days	From 6h55 to 9h00	P17 = ON
ABSORPTION_DEMAND	External variable depending on Solar-Absorption chiller operation		
HEAT_PUMP_SCHEDULE	All week	From 5h00 to 21h30	P12 = ON

6.4.1.2 Cold water generation: solar-absorption chiller

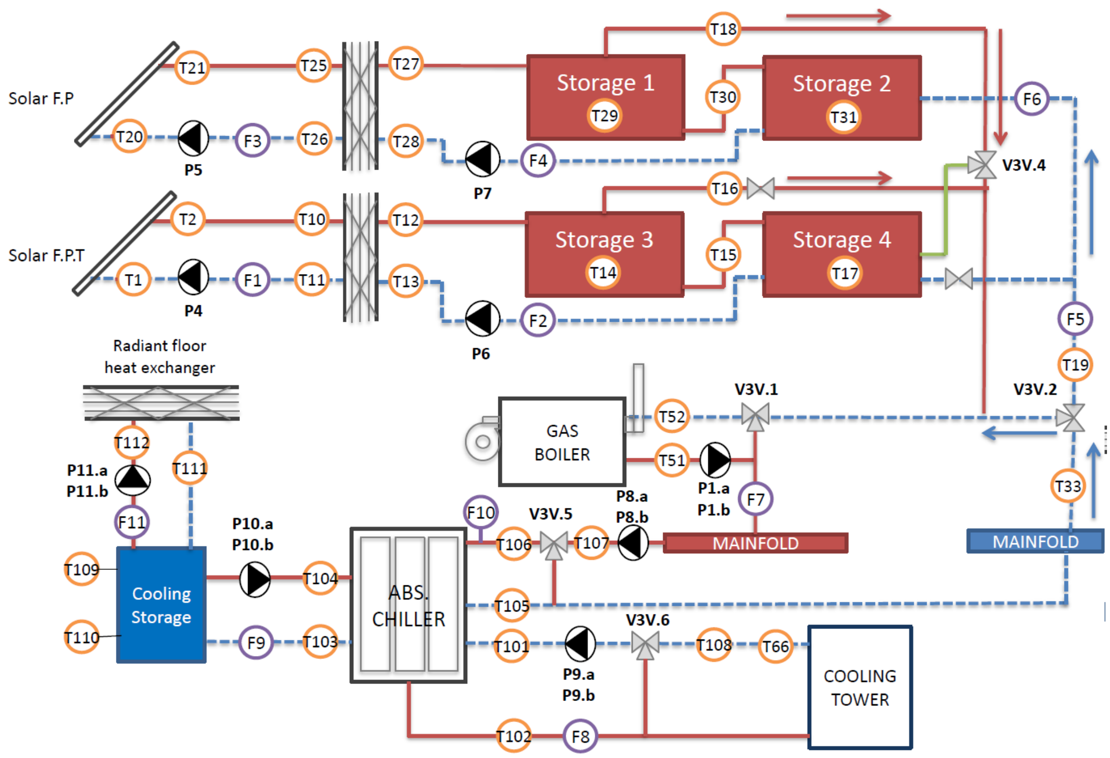


Figure 35: Solar-absorption chiller operating scheme

Table 20: Solar-absorption chiller related sensors

System	ID	Description	Unit
SOLAR FLAT PLATE TRACKING FIELD	T1	Tracking field inlet temperature (cold)	°C
	T2	Tracking field outlet temperature (hot)	°C
	T3	Collector evacuated tube auxiliary temperature (in collector)	°C
SOLAR FLAT PLATE FIELD.	T20	Collector flat plate inlet temperature (cold)	°C
	T21	Collector flat plate outlet temperature (hot)	°C
	T22	Collector flat plate auxiliary temperature (in collector)	°C
SOLAR FLAT PLATE	T10	Heat exchanger primary inlet temperature (hot)	°C
	T11	Heat exchanger outlet temperature (cold)	°C

TRACKING FIELD - HEAT EXCHANGER	T13	Heat exchanger secondary inlet temperature (cold)	°C
	T12	Heat exchanger secondary outlet temperature (hot)	°C
SOLAR FLAT PLATE FIELD - HEAT EXCHANGER	T25	Heat exchanger flat plate primary inlet temperature (hot)	°C
	T26	Heat exchanger flat plate primary outlet temperature (cold)	°C
	T28	Heat exchanger flat plate secondary inlet temperature (cold)	°C
	T27	Heat exchanger flat plate secondary outlet temperature (hot)	°C
FLAT PLATE TRACKING FIELD – BUF. TANK	T14	Upper temperature in buffer storage tracking field	°C
	T15	Middle temperature in buffer storage tracking field	°C
	T17	Lower temperature in buffer storage tracking field	°C
SOLAR FLAT PLATE FIELD – BUF. TANK	T29	Upper temperature in buffer storage flat plate	°C
	T30	Middle temperature in buffer storage flat plate	°C
	T31	Lower temperature in buffer storage flat plate	°C
SOLAR STORAGE	T18	Solar temperature outel to uses	°C
	T19	Solar temperature inlet from uses	°C
	T33	Load return temperature	°C
ABSORTION CHILLER	T101	Condenser inlet temperature	ºC
	T102	Condenser outlet temperature	ºC
	T103	Evaporator outlet temperature	ºC
	T104	Evaporator inlet temperature	ºC
	T105	Generator outlet temperature	ºC
	T106	Generator inlet temperature	ºC
	T107	Generator Tree way valve inlet temperature	ºC
	T108	Tree way valve mixed cooling tower temperature	ºC
COLD STORAGE	T109	Top of the tank	ºC
	T110	Bottom of the tank	ºC
SOLAR FACILITY PRESSURES	PR1	Solar flat plate tracking field pressure drop	bar
	PR2	Flat plate pressure drop	bar
	PR3	Solar flat plate tracking field pressure hydrostatic	bar
	PR4	Flat plate pressure hydrostatic	bar
	PR5	Pressure hydrostatic in buffer storage solar flat plate tracking	bar
	PR6	Pressure hydrostatic in buffer storage flat plate	bar
SOLAR FACILITY WATER FLOWS	F1	Primary solar flat plate tracking flow rate	m^3/h
	F2	Secondary flat plate tracking flow rate	m^3/h
	F3	Primary flat plate flow rate	m^3/h
	F4	Secondary flat plate flow rate	m^3/h

	F5	Solar flow rate from uses	m^3/h
	F6	Solar flat plate flow rate from uses	m^3/h
	F7	Boiler flow rate	m^3/h
	F8	Condenser flow rate	m^3/h
	F9	Evaporator flow rate	m^3/h
	F10	Generator flow rate	m^3/h
	F11	Uses chiller water flow rate	m^3/h

Table 21: Solar-absorption chiller related objects

System	ID	Description	Control
BOILER	ON/OFF BOILER BURNER	Boiler on/off	On when: BOILER_SCHEDULE = ON T51 <= 90ºC
	P1.a P1.b	Pump Boiler Distribution	On when: BOILER_SCHEDULE = ON (it starts 2 minutes later once the state of BOILER_SCHEDULE is ON) or: SOLAR_GENERATION = ON (it starts 3 minutes later once the state of SOLAR_GENERATION is ON)
	V3V.1	3 ways valve. It recirculates the hot water to the return circuit if the temperature set point is not achieved	Always open
	V3V.2	V3V2 =1 when hot water goes from cold manifold to boiler. V3V2= 0 when hot water goes from cold manifold to solar storage. Winter Mode 3 ways valve. Select when the heating system works it from either gas boiler or solar plant. Summer Mode. 3 ways valve. Select when the absorption chiller work it from	**Winter mode.** When : P17 is On and T29<70ºC or T24<70ºC P15 is On and T29<40ºC or T24 or T24<40ºC P14 is On and T29<30ºC or T24<30ºC. V3V2 =1 When : P17 is On and T29≥71ºC or T24≥70ºC P15 is On and T29≥41ºC or T24

			either gas boiler or absorption chiller	or T24≥41ºC P14 is On and T29≥31ºC or T24≥31ºC. Boiler is Off and V3V2 =0 **Summer mode.** If absorption chiller is On V3V2 = 0 and Boiler is Off If absorption chiller is Off. V3V2 =1.
ABSORPTION CHILLER (Only summer)		Abs. chiller on/off		Manual control, and switched on if either T29> 80ºC or T14 > 80ºC Switched off if: T110<9,5ºC Switched On if T110≥9,5ºC +3ºC.
		P10a P10b	Pump 10. From cooling storage to the evaporator of the absorption chiller	P10 is switched on iF: 10 seconds after Abs chiller On And T104<40ºC
		P9a P9b	Pump 3. From cooling tower to the condenser of the absorption chiller	P9 is switched on, if: 10 seconds after Abs chiller On
		P8a P8b	Pump 4. From hot water manifold to the generator of the absorption chiller	If abs chiller is switched on.
		V3V.5	3 ways valve. It recirculates the hot water to the return manifold if the temperature set point is not achieved	If T107>75ºC + 2ºC the valve is opened. And hot water goes to absorption chiller.
		V3V.6	3 ways valve. It recirculates the condenser water to the return to the cooling tower if the temperature set point is not achieved	If T108<xxºC then the water is re-circulated to the return circuit
		P11	P11 cold water from cooling storage to radiant floor heat exchange	Manual control.
SOLAR	Solar Flat	P4	Primary circuit pump	Switched on.

PLANT	Plate tracking			if: Solar Radiation (I). I > I $_{v\_cr\_on}$ $I_{v\_cr\_on}$=6.25(T17+10ºC-T_{out}) Switched off. If: Solar Radiation (I), I< I $_{v\_cr\_off}$ $I_{v\_cr\_off}$=6.25(T17+5ºC-T_{out})
		P6	Secondary circuit pump	Switched on. If P4 is on and T12>T14 +5ºC Switched off. If. P4 is off or T12< T14
	Solar Flat plate	P5	Primary circuit pump	Switched on. if: Solar Radiation (I). I > I $_{p\_cr\_on}$ I $_{p\_cr\_on}$=6.25(T31+10ºC-T_{out}) Switched off. If: Solar Radiation (I), I< I $_{p\_cr\_off}$ I $_{v\_cr\_off}$=6.25(T31+5ºC-T_{out})
		P7	Secondary circuit pump	Switched on. If P5 is on and T27>T29 +5ºC Switched off. If. P5 is off or T27< T29
		V3V.4	3 ways valve, select when the storage tank work it in either series or parallel	When it is want to work with four storage in serie V·3V4 = 1 When it is want to work in parallel two and two V3V4 = 0 (is main mode)

6.4.1.3 Water-to-water heat pump

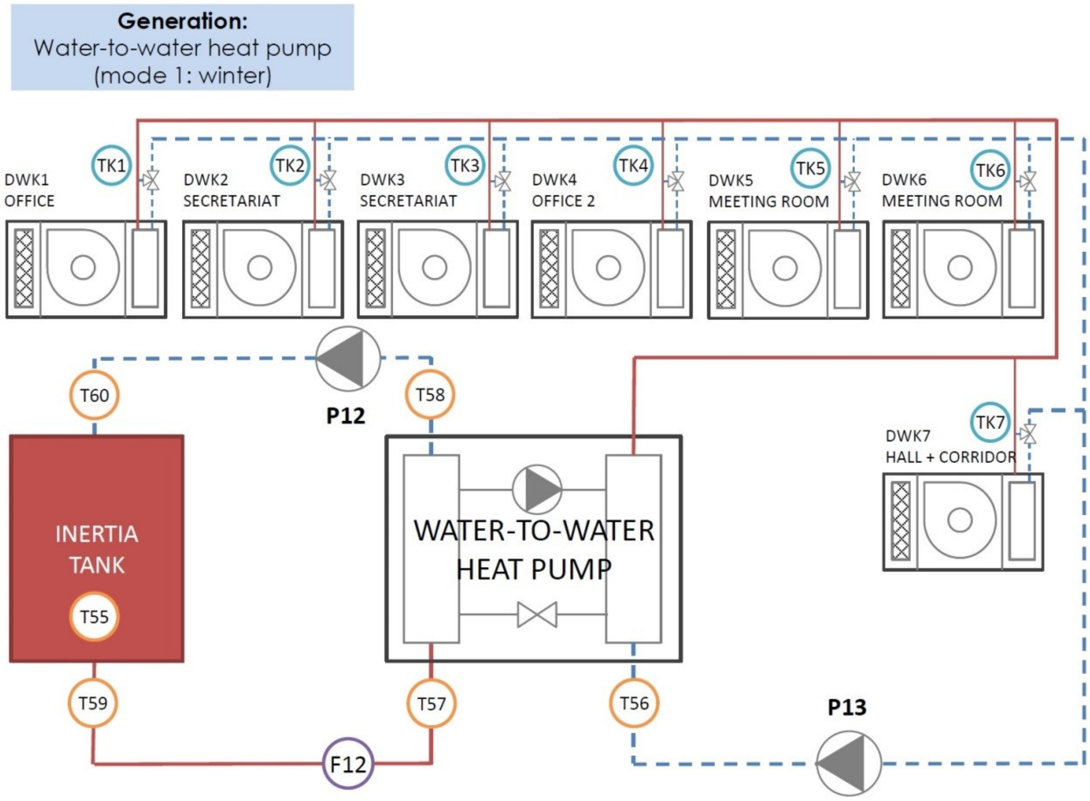


Figure 36: Water-to-water heat pump operating scheme (winter operation)

Table 22: Water-to-water heat pump related objects (winter operation)

System	ID	Description	Control
WATER-TO-WATER HEAT PUMP (winter)		Water-to-water heat pump on/off	Manually
	P12	Pump 12. Water-to-water heat pump primary circuit	On all week From 5h00 to 21h30
	P13	Pump 13. Fan-coils return	When Fan coils are On
FAN-COILS	DWK1 ON/OFF	Fan-coil 1 on/off	If TK1 < 21ºC then the fan coil is switched on
	DWK2 ON/OFF	Fan-coil 2 on/off	If TK2 < 21ºC then the fan coil is switched on
	DWK3 ON/OFF	Fan-coil 3 on/off	If TK3 < 21ºC then the fan coil is switched on
	DWK4 ON/OFF	Fan-coil 4 on/off	If TK4 < 21ºC then the fan coil is switched on
	DWK5 ON/OFF	Fan-coil 5 on/off	Manual set point temperature
	DWK6	Fan-coil 6 on/off	Manual set point temperature

	ON/OFF		
	DWK7 ON/OFF	Fan-coil 7 on/off	If TK7 < 21ºC then the fan coil is switched on

Table 23: Water-to-water heat pump related sensors (winter operation)

System	ID	Description	Associated thermal system	Unit
ROOM TEMPS.	T_{K1}	Office 1 room temperature	DWK 1	°C
	T_{K2}	Secretariat room temperature	DWK 2	°C
	T_{K3}		DWK 3	°C
	T_{K4}	Office 2 room temperature	DWK 4	°C
	T_{K5}	Meeting room temperature	DWK 5	°C
	T_{K6}		DWK 6	°C
	T_{K7}	Hall + corridor room temperature	DWK 7	°C
WATER-TO-WATER HEAT PUMP	T55	Inertia tank water temperature		°C
	T56	Return water temperature from uses to the heat pump		°C
	T57	Return water temperature from primary circuit to the heat pump		°C
	T58	Supply water temperature from primary circuit to the heat pump		°C
	T59	Supply water temperature from inertia tank		°C
	T60	Return water temperature from inertia tank		°C
	F12	Water-to-water heat pump primary circuit flow		m^3/h

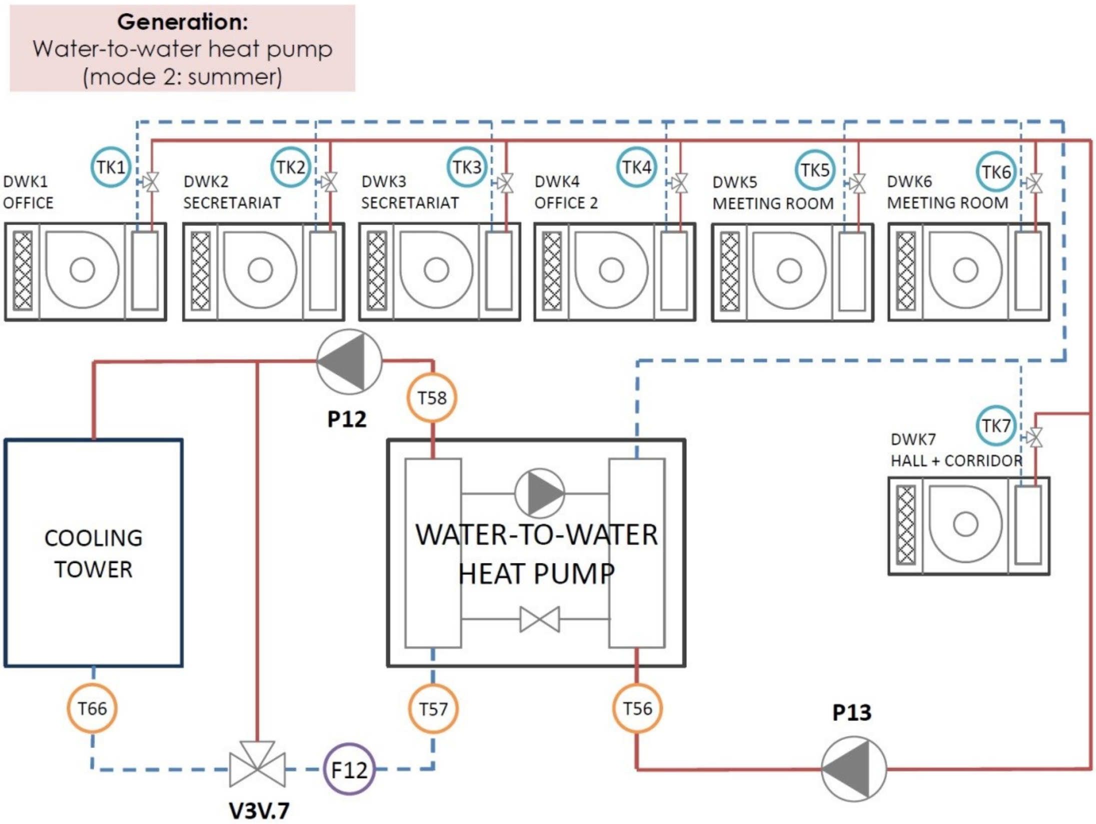


Figure 37: Water-to-water heat pump operating scheme (summer operation)

Table 24: Water-to-water heat pump related objects (winter operation)

System	ID	Description	Control
WATER-TO-WATER HEAT PUMP (summer)		Water-to-water heat pump on/off	
	P12	Pump 12. Water-to-water heat pump primary circuit	On all week From 5h00 to 21h30
	P13	Pump 13. Fan-coils return	When Fan coils are On
	V3V.7	3 ways valve. Recirculation of the primary circuit to the cooling tower	If T57<22ºC V3V7 is opened and water goes to cooling tower
FAN-COILS	DWK1 ON/OFF	Fan-coil 1 on/off	If TK1 > 26ºC then the fan coil is switched on
	DWK2 ON/OFF	Fan-coil 2 on/off	If TK2 > 26ºC then the fan coil is switched on
	DWK3 ON/OFF	Fan-coil 3 on/off	If TK3 > 26ºC then the fan coil is switched on
	DWK4 ON/OFF	Fan-coil 4 on/off	If TK4 > 26ºC then the fan coil is switched on
	DWK5 ON/OFF	Fan-coil 5 on/off	Manual set point temperature

	DWK6 ON/OFF	Fan-coil 6 on/off	Manual set point temperature
	DWK7 ON/OFF	Fan-coil 7 on/off	If TK7 > 26ºC then the fan coil is switched on

Table 25: Water-to-water heat pump related sensors (summer operation)

System	ID	Description	Associated thermal system	Unit
ROOM TEMPS.	T_{K1}	Office 1 room temperature	Fan-coil 1 (DWK 1)	°C
	T_{K2}	Secretariat room temperature	Fan-coil 2 (DWK 2)	°C
	T_{K3}		Fan-coil 3 (DWK 3)	°C
	T_{K4}	Office 2 room temperature	Fan-coil 4 (DWK 4)	°C
	T_{K5}	Meeting room temperature	Fan-coil 5 (DWK 5)	°C
	T_{K6}		Fan-coil 6 (DWK 6)	°C
	T_{K7}	Hall + corridor room temperature	Fan-coil 7 (DWK 7)	°C
WATER-TO-WATER HEAT PUMP	T56	Return water temperature from uses to the heat pump		°C
	T57	Return water temperature from primary circuit to the heat pump		°C
	T58	Supply water temperature from primary circuit to the heat pump		°C
	T66	Cooling tower supply temperature		°C
	F12	Water-to-water heat pump primary circuit flow		m^3/h

6.4.1.4 Water-to-air heat pumps

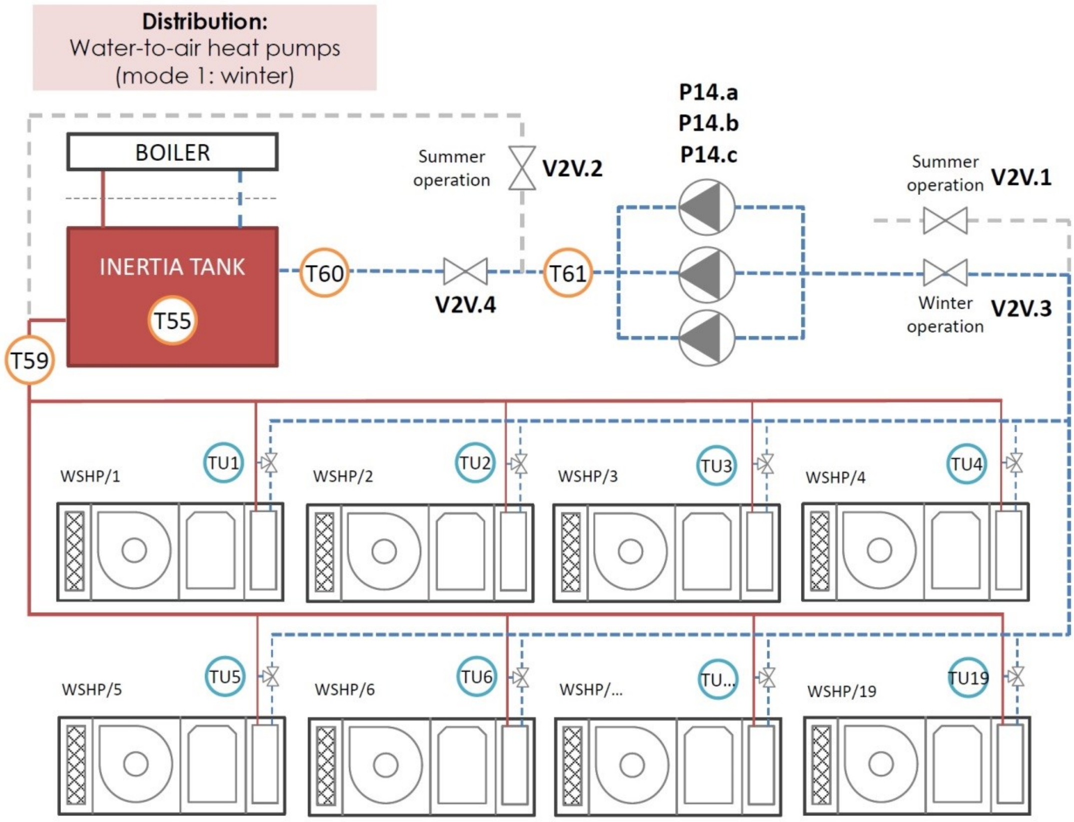


Figure 38: Water-to-air heat pumps operating scheme (winter operation)

Table 26: Water-to-air heat pumps related objects (winter operation)

System	ID	Description	Control
BUILDING WINTER-SUMMER OPERATION	V2V.1	2 ways valve. It changes the operation mode from winter to summer operation in the supply circuit	Manually
	V2V.2	2 ways valve. It changes the operation mode from winter to summer operation in the return circuit	Manually
	V2V.3	2 ways valve. It changes the operation mode from summer to winter operation in the supply circuit	Manually
	V2V.4	2 ways valve. It changes the operation mode from summer to winter operation in the return circuit	Manually

WATER-TO-AIR HEAT PUMPS	P14a P14b P14c	Pump 14. Water-to- air heat pumps supply pump	On when water to air heat pump is opened.
	UCB1 ON/OFF	Water-to-air heat pump 1 (SEADM 2)	If TU1 < 23ºC then the heat pump is switched on
	UCB2 ON/OFF	Water-to- air heat pump 2 (SEADM 2)	If TU2 < 23ºC then the heat pump is switched on
	UCB3 ON/OFF	Water-to- air heat pump 3 (informatics)	If TU3 < 23ºC then the heat pump is switched on
	UCB4 ON/OFF	Water-to- air heat pump 4 (informatics warehouse)	If TU4 < 23ºC then the heat pump is switched on
	UCB5 ON/OFF	Water-to- air heat pump 5 (vision 2D)	If TU5 < 23ºC then the heat pump is switched on
	UCB6 ON/OFF	Water-to- air heat pump 6 (vision 3D)	If TU6 < 23ºC then the heat pump is switched on
	UCB7 ON/OFF	Water-to- air heat pump 7 (energy division)	If TU7 < 23ºC then the heat pump is switched on
	UCB8 ON/OFF	Water-to- air heat pump 8 (energy division)	If TU8 < 23ºC then the heat pump is switched on
	UCB9 ON/OFF	Water-to- air heat pump 9 (robotics)	If TU9 < 23ºC then the heat pump is switched on
	UCB11 ON/OFF	Water-to- air heat pump 11 (hall + corridor)	If TU11 < 23ºC then the heat pump is switched on
	UCB14 ON/OFF	Water-to- air heat pump 14 (innovation)	If TU14 < 23ºC then the heat pump is switched on
	UCB15 ON/OFF	Water-to- air heat pump 15 (multifunctional area)	If TU15 < 23ºC then the heat pump is switched on
	UCB16 ON/OFF	Water-to- air heat pump 16 (industrial area offices)	If TU16 < 23ºC then the heat pump is switched on
	UCB17 ON/OFF	Water-to- air heat pump 17 (SEADM 1)	If TU17 < 23ºC then the heat pump is switched on
	UCB19 ON/OFF	Water-to- air heat pump 19 (auditorium)	If TU19 < 23ºC then the heat pump is switched on

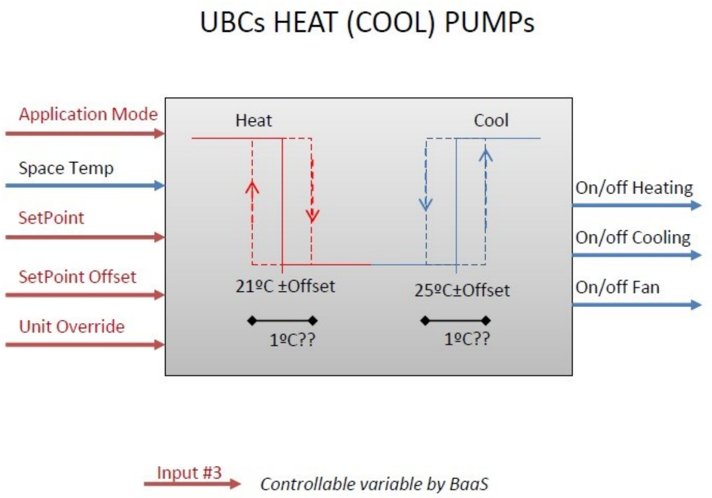


Figure 39: Water-to-air heat pumps winter control

Table 27: Water-to-air heat pumps related sensors (winter operation)

	ID	Description	Associated thermal system	Unit
ROOM TEMPS.	T_{U16}	Industrial zone offices temperature	UBC 16	°C
	T_{U15}	Multifunct. Area temperature	UBC 15	°C
	T_{U14}	Innovation room temperature	UBC 14	°C
	T_{U17}	SEADM1 room temperature	UBC 17	°C
	T_{U19}	Auditorium temperature	UBC 19	°C
	T_{U11}	Hall + corridor temperature	UBC 11	°C
	T_{U9}	Robotics room temperature	UBC 9	°C
	T_{U7}	Energy room temperature	UBC 7	°C
	T_{U8}		UBC 8	°C
	T_{U5}	Vision 2D room temperature	UBC 5	°C
	T_{U6}	Vision 3D room temperature	UBC 6	°C
	T_{U4}	Info. Warehouse temperature	UBC 4	°C
	T_{U1}	SEADM2 room temperature	UBC 1	°C
	T_{U2}		UBC 2	°C
	T_{U3}	Informatics room temperature	UBC 3	°C
WATER-TO-AIR HEAT PUMPS	T55	Inertia tank water temperature		°C
	T59	Supply water temperature from inertia tank		°C
	T60	Return water temperature from inertia tank		°C
	T61	Supply temperature to water-source-heat-pumps		°C

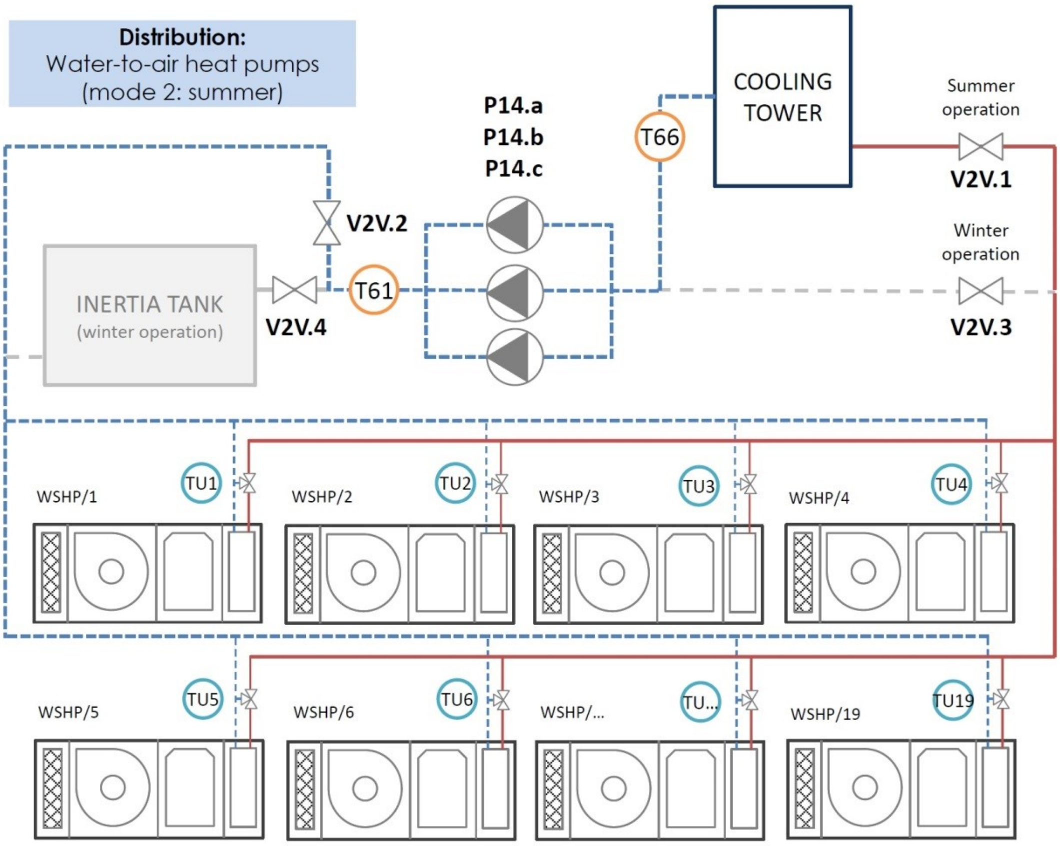


Figure 40: Water-to-air heat pumps operating scheme (summer operation)

Table 28: Water-to-air heat pumps related objects (summer operation)

System	ID	Description	Control
BUILDING WINTER-SUMMER OPERATION	V2V.1	2 ways valve. It changes the operation mode from winter to summer operation in the supply circuit	Manually
	V2V.2	2 ways valve. It changes the operation mode from winter to summer operation in the return circuit	Manually
	V2V.3	2 ways valve. It changes the operation mode from summer to winter operation in the supply circuit	Manually
	V2V.4	2 ways valve. It changes the operation mode from summer to winter operation in the return circuit	Manually

WATER-TO-AIR HEAT PUMPS	P14a P14b P14c	Pump 14. Water-to- air heat pumps supply pump	On when water to air heat pump is opened.
	UCB1 ON/OFF	Water-to- air heat pump 1 (SEADM 2)	If TU1 > 25ºC then the heat pump is switched on
	UCB2 ON/OFF	Water-to- air heat pump 2 (SEADM 2)	If TU2 > 25ºC then the heat pump is switched on
	UCB3 ON/OFF	Water-to- air heat pump 3 (informatics)	If TU3 > 25ºC then the heat pump is switched on
	UCB4 ON/OFF	Water-to- air heat pump 4 (informatics warehouse)	If TU4 > 25ºC then the heat pump is switched on
	UCB5 ON/OFF	Water-to- air heat pump 5 (vision 2D)	If TU5 > 25ºC then the heat pump is switched on
	UCB6 ON/OFF	Water-to- air heat pump 6 (vision 3D)	If TU6 > 25ºC then the heat pump is switched on
	UCB7 ON/OFF	Water-to- air heat pump 7 (energy division)	If TU7 > 25ºC then the heat pump is switched on
	UCB8 ON/OFF	Water-to- air heat pump 8 (energy division)	If TU8 > 25ºC then the heat pump is switched on
	UCB9 ON/OFF	Water-to- air heat pump 9 (robotics)	If TU9 > 25ºC then the heat pump is switched on
	UCB11 ON/OFF	Water-to- air heat pump 11 (hall + corridor)	If TU11 > 25ºC then the heat pump is switched on
	UCB14 ON/OFF	Water-to- air heat pump 14 (innovation)	If TU14 > 25ºC then the heat pump is switched on
	UCB15 ON/OFF	Water-to- air heat pump 15 (multifunctional area)	If TU15 > 25ºC then the heat pump is switched on
	UCB16 ON/OFF	Water-to- air heat pump 16 (industrial area offices)	If TU16 > 25ºC then the heat pump is switched on
	UCB17 ON/OFF	Water-to- air heat pump 17 (SEADM 1)	If TU17 > 25ºC then the heat pump is switched on
	UCB19 ON/OFF	Water-to- air heat pump 19 (auditorium)	If TU19 > 25ºC then the heat pump is switched on

Table 29: Water-to-air heat pumps related sensors (summer operation)

System	ID	Description	Associated thermal system	Unit
ROOM TEMPS.	T_{U16}	Industrial zone offices temperature	UBC 16	°C
	T_{U15}	Multifunct. Area temperature	UBC 15	°C
	T_{U14}	Innovation room temperature	UBC 14	°C

	T_{U17}	SEADM1 room temperature	UBC 17	°C
	T_{U19}	Auditorium temperature	UBC 19	°C
	T_{U11}	Hall + corridor temperature	UBC 11	°C
	T_{U9}	Robotics room temperature	UBC 9	°C
	T_{U7}	Energy room temperature	UBC 7	°C
	T_{U8}		UBC 8	°C
	T_{U5}	Vision 2D room temperature	UBC 5	°C
	T_{U6}	Vision 3D room temperature	UBC 6	°C
	T_{U4}	Info. Warehouse temperature	UBC 4	°C
	T_{U1}	SEADM2 room temperature	UBC 1	°C
	T_{U2}		UBC 2	°C
	T_{U3}	Informatics temperature	UBC 3	°C
WATER-TO-AIR HEAT PUMPS	T61	Supply temperature to water-source-heat-pumps		ºC
	T66	Supply temperature from cooling tower		ºC

6.4.1.5 Radiant floor

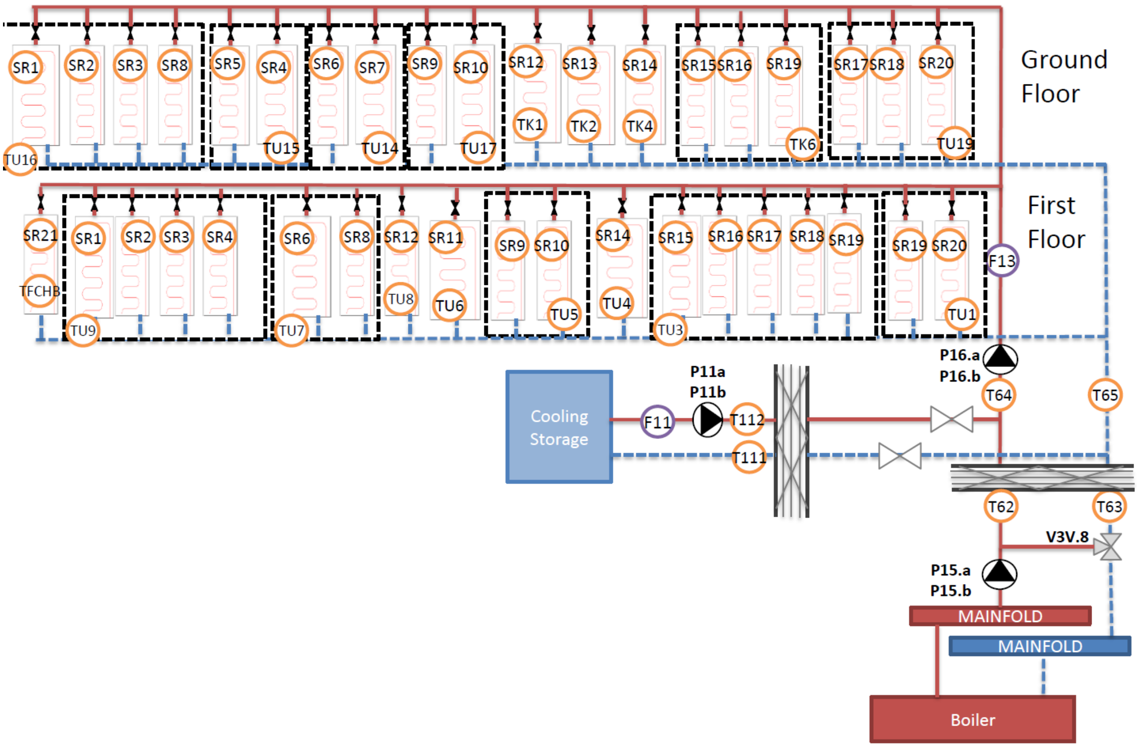


Figure 41: Radiant floor operating scheme

Table 30: Radiant floor related sensors

ID	Description	Associated thermal system	Unit
T_{UBC16}	Industrial zone offices	UBC 16	°C
T_{UBC15}	Multifunct. Area	UBC 15	°C
T_{UBC14}	Innovation	UBC 14	°C
T_{UBC17}	SEADM	UBC 17	°C
T_{DWK1}	Office 1	DWK 1	°C
T_{DWK2}	Secretariat	DWK 2	°C
T_{DWK3}		DWK 3	°C
T_{DWK4}	Office 2	DWK 4	°C
T_{DWK5}	Meeting room	DWK 5	°C
T_{DWK6}		DWK 6	°C
T_{UBC19}	Auditorium	UBC 19	°C
T_{DWK7}	Hall + corridor	DWK 7	°C
T_{UBC19}		UBC19 - FCH A	°C

T_{UBC19}		UBC19 - FCH B	°C
T_{UBC11}		UBC 11	°C
T_{UBC9}	Robotics	UBC 9	°C
T_{UBC7}	Energy	UBC 7	°C
T_{UBC8}		UBC 8	°C
T_{UBC5}	Vision 2D	UBC 5	°C
T_{UBC6}	Vision 3D	UBC 6	°C
T_{UBC4}	Info. Warehouse	UBC 4	°C
T_{UBC1}	SEADM	UBC 1	°C
T_{UBC2}		UBC 2	°C
T_{UBC3}	Informatics	UBC 3	°C

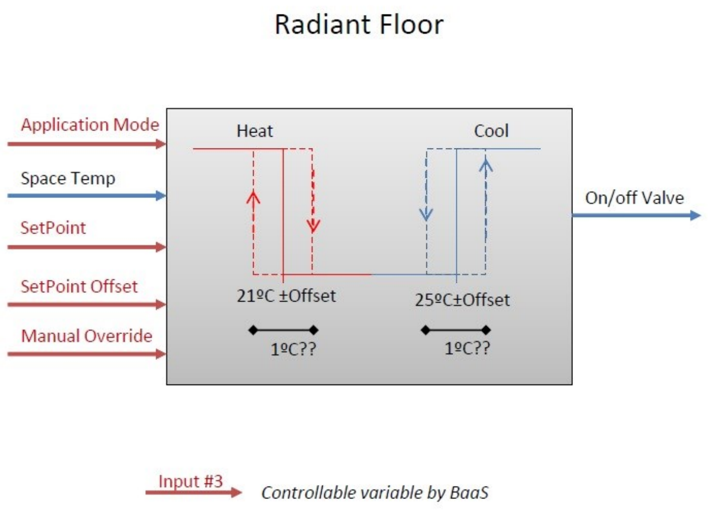


Figure 42: Radiant floor control

Table 31: Radiant floor related objects

Zone	ID	Description	Control
	P15a P15b	Pump 15. Supply hot water from boiler to heat exchange (On only in winter)	If P16 is ON in winter If P11 is ON in summer
	V3V.8	3 ways valve. Control of the supply temperature goes to heat exchange (Mix between supply and return exchange water until T62 reach set point)	-
	P11a P11b	P11supply cooling water from cooling storage to absorption floor heat exchange (On only in summer)	Manual control

	P16a P16b	Pump 16. Supply water to radiant floor circuits.	From 6h30 to 16h00 at 21ºC (room set point) From 16h00 to 6h30 at 19ºC (room set point)
Industrial Zone offices	SR1	2 ways valve, open the SR1 radiant floor circuit	If TU16 < 21,5ºC then the valve is opened (winter mode) If TU16 > 25ºC then the valve is opened (summer mode)
	SR2	2 ways valve, open the SR2 radiant floor circuit	If TU16 < 21,5ºC then the valve is opened (winter mode) If TU16 > 25ºC then the valve is opened (summer mode)
	SR3	2 ways valve, open the SR3 radiant floor circuit	If TU16 < 21,5ºC then the valve is opened (winter mode) If TU16 > 25ºC then the valve is opened (summer mode)
	SR8	2 ways valve, open the SR8 radiant floor circuit	If TU16 < 21.5ºC then the valve is opened (winter mode) If TU16 > 25ºC then the valve is opened (summer mode)
Multifunction Area	SR5	2 ways valve, open the SR5 radiant floor circuit	If TU15 < 21,5ºC then the valve is opened (winter mode) If TU15 > 25ºC then the valve is opened (summer mode)
	SR4	2 ways valve, open the SR4 radiant floor circuit	If TU15 < 21,5ºC then the valve is opened (winter mode) If TU15 > 25ºC then the valve is opened (summer mode)
Innovation	SR6	2 ways valve, open the SR6 radiant floor circuit	If TU14 < 21,5ºC then the valve is opened (winter mode) If TU14 > 25ºC then the valve is opened (summer mode)
	SR7	2 ways valve, open the SR7 radiant floor circuit	If TU14< 21,5ºC then the valve is opened (winter mode) If TU14 > 25ºC then the valve is opened (summer mode)
SEADM	SR9	2 ways valve, open the SR9 radiant floor circuit	If TU17 < 21,5ºC then the valve is opened (winter mode) If TU17 > 25ºC then the valve is opened (summer mode)
	SR10	2 ways valve, open the SR10 radiant floor circuit	If TU17 < 21,5ºC then the valve is opened (winter mode) If TU17 > 25ºC then the valve is opened (summer mode)
Office I	SR12	2 ways valve, open the SR12 radiant	If TK1 < 21,5ºC then the valve

		floor circuit	is opened (winter mode) If TK1 > 25ºC then the valve is opened (summer mode)
Secretariat	SR13	2 ways valve, open the SR1 radiant floor circuit	If TK2 < 21,5ºC then the valve is opened (winter mode) If TK2 > 25ºC then the valve is opened (summer mode)
Office 2	SR14	2 ways valve, open the SR14 radiant floor circuit	If TK4 < 21,5ºC then the valve is opened (winter mode) If TK4 > 25ºC then the valve is opened (summer mode)
Meeting Room	SR15	2 ways valve, open the SR15 radiant floor circuit	If TK6 < 21,5ºC then the valve is opened (winter mode) If TK6 > 25ºC then the valve is opened (summer mode)
	SR16	2 ways valve, open the SR16 radiant floor circuit	If TK6 < 21,5ºC then the valve is opened (winter mode) If TK6 > 25ºC then the valve is opened (summer mode)
	SR19	2 ways valve, open the SR19 radiant floor circuit	If TK6 < 21,5ºC then the valve is opened (winter mode) If TK6 > 25ºC then the valve is opened (summer mode)
Auditorium	SR17	2 ways valve, open the SR17 radiant floor circuit	If TU19 < 21,5ºC then the valve is opened (winter mode) If TU19 > 25ºC then the valve is opened (summer mode)
	SR18	2 ways valve, open the SR18 radiant floor circuit	If TU19< 21,5ºC then the valve is opened (winter mode) If TU19 > 25ºC then the valve is opened (summer mode)
	SR20	2 ways valve, open the SR20 radiant floor circuit	If TU19 < 21,5ºC then the valve is opened (winter mode) If TU19 > 25ºC then the valve is opened (summer mode)
Hall and corridor	SR21	2 ways valve, open the SR21 radiant floor circuit	If TFCHB < 21,5ºC then the valve is opened (winter mode) If TFCHB > 25ºC then the valve is opened (summer mode)
Robotics	SR1	2 ways valve, open the SR1 (first floor) radiant floor circuit	If TU9 < 21,5ºC then the valve is opened (winter mode) If TU9 > 25ºC then the valve is opened (summer mode)
	SR2	2 ways valve, open the SR2 (first floor) radiant floor circuit	If TU9 < 21,5ºC then the valve is opened (winter mode)

			If TU9 > 25ºC then the valve is opened (summer mode)
	SR3	2 ways valve, open the SR3 (first floor) radiant floor circuit	If TU9 < 21,5ºC then the valve is opened (winter mode) If TU9 > 25ºC then the valve is opened (summer mode)
	SR4	2 ways valve, open the SR4 (first floor) radiant floor circuit	If TU9 < 21,5ºC then the valve is opened (winter mode) If TU9 > 25ºC then the valve is opened (summer mode)
Energy	SR6	2 ways valve, open the SR6 radiant floor circuit	If TU7 < 21,5ºC then the valve is opened (winter mode) If TU7 > 25ºC then the valve is opened (summer mode)
	SR8	2 ways valve, open the SR8 (first floor) radiant floor circuit	If TU7< 21,5ºC then the valve is opened (winter mode) If TU7 > 25ºC then the valve is opened (summer mode)
	SR12	2 ways valve, open the SR12 (first floor) radiant floor circuit	If TU8 < 21,5ºC then the valve is opened (winter mode) If TU8 > 25ºC then the valve is opened (summer mode)
Vision 2D	SR11	2 ways valve, open the SR11(first floor) radiant floor circuit	If TU6 < 21,5ºC then the valve is opened (winter mode) If TU6 > 25ºC then the valve is opened (summer mode)
Vision 3D	SR9	2 ways valve, open the SR9 (first floor) radiant floor circuit	If TU5 < 21,5ºC then the valve is opened (winter mode) If TU5 > 25ºC then the valve is opened (summer mode)
	SR10	2 ways valve, open the SR10 (first floor) radiant floor circuit	If TU5 < 21,5ºC then the valve is opened (winter mode) If TU5 > 25ºC then the valve is opened (summer mode)
Info Warehouse	SR14	2 ways valve, open the SR14 (first floor) radiant floor circuit	If TU4 < 21,5ºC then the valve is opened (winter mode) If TU4 > 25ºC then the valve is opened (summer mode)
SEADM	SR15	2 ways valve, open the SR15 radiant floor circuit	If TU3 < 21,5ºC then the valve is opened (winter mode) If TU3 > 25ºC then the valve is opened (summer mode)
	SR16	2 ways valve, open the SR16 (first floor) radiant floor circuit	If TU3< 21,5ºC then the valve is opened (winter mode) If TU3 > 25ºC then the valve is

			opened (summer mode)
	SR17	2 ways valve, open the SR17 (first floor) radiant floor circuit	If TU3 < 21,5ºC then the valve is opened (winter mode) If TU3 > 25ºC then the valve is opened (summer mode)
	SR18	2 ways valve, open the SR18 (first floor) radiant floor circuit	If TU3 < 21,5ºC then the valve is opened (winter mode) If TU3 > 25ºC then the valve is opened (summer mode)
	SR19	2 ways valve, open the SR19 (first floor) radiant floor circuit	If TU3 < 21,5ºC then the valve is opened (winter mode) If TU3 > 25ºC then the valve is opened (summer mode)
Informatics	SR19	2 ways valve, open the SR19 (first floor) radiant floor circuit	If TU1 < 21,5ºC then the valve is opened (winter mode) If TU1 > 25ºC then the valve is opened (summer mode)
	SR20	2 ways valve, open the SR20 (first floor) radiant floor circuit	If TU1 < 21,5ºC then the valve is opened (winter mode) If TU1 > 25ºC then the valve is opened (summer mode)

6.4.1.6 Radiators and air heaters

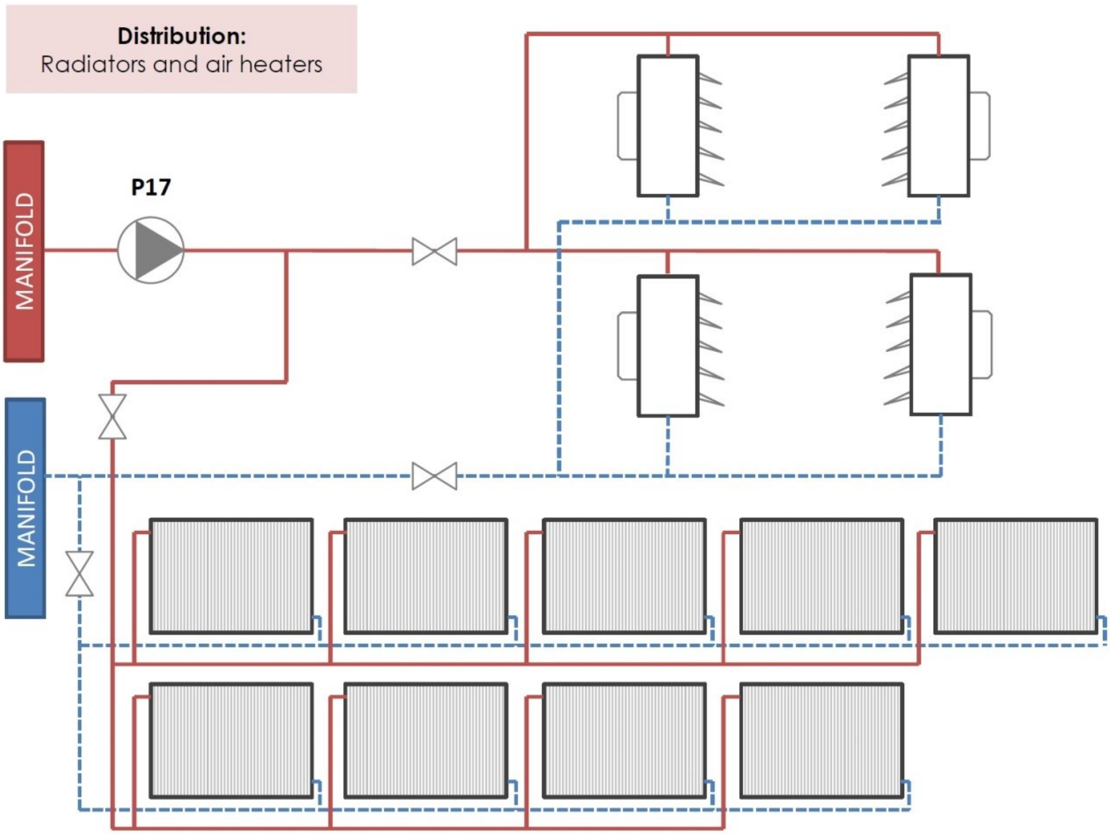


Figure 43: Radiators and air heaters operation

6.4.2 Room level existing control

Control strategy for heating and cooling systems at room level can be split by room types, depending on equipment and use of them:

1. Room types by equipment:
    a. Radiant heating floor + heat pump
    b. Radiant heating floor + fan-coil + radiator
    c. Radiant heating floor + heat pump + radiator
    d. Radiant cooling floor + heat pump
    e. Radiant cooling floor + fan-coil
    f. Air heaters
2. Room types by use:
    a. Variable use (meeting rooms) where the set-point remains at 20ºC in working periods with hysteresis of 1ºC. In non-working periods the system will remain as normal use rooms except when use of the room is detected, when the set point is moved to 22ºC±1ºC.
    b. Normal use (laboratories) with set point in working periods of 22ºC±1ºC.

Each of existing equipment must meet certain conditions in order to be ready for its use. The control system is in charge of verifying these conditions in order to decide if the system will start working at room level:

- Radiant floor:
    - Winter: adequate flow temperature (output of exchanger)
    - Summer: adequate flow temperature (absorption chiller) and adequate floor temperature
- Fan-coil:
    - Winter: adequate incoming water temperature (water-to-water heat pump)
    - Summer: adequate incoming water temperature (water-to-water heat pump)
- Heat pump:
    - Winter: adequate inertia tank temperature
    - Summer: adequate cooling tower temperature
- Radiators: in winter adequate water flow temperature
- Heaters: in winter adequate water flow temperature

In some cases this could condition the equipment start and could be necessary some set-points modification (especially radiant floor, whose performance depends on set-points that are different from comfort conditions).

Control strategies implemented are based on following information:

- Room temperature set point between 6h30 and 16h30 (working period)
- Room temperature set point between 16h30 and 6h30 (non-working period)
- Room temperature set point with occupancy between 16h30 and 6h30
- Radiant floor supply temperature (this temperature will be selected with the related variable of the Symmetre: control software for system generation)
- Inertia tank for heat pumps temperature
- Cool tank temperature
- Radiators switch on
- Heaters switch on
- Year period
- Room type

6.4.2.1 Control strategies for heating of rooms with heat pump and radiant floor

Control strategies are based in the use of the radiant floor and to cover the demand peaks with existing heat pumps, in the way the floor inertia which cause overheating periods (and the necessity of opening windows with the energy losses derived) can be eliminated. The set point will be of 22ºC±1ºC in working periods and intermittent occupancy (presence sensors, special schedules…) and 19ºC±1ºC in the rest of time.

- In **winter** the radiant floor set point managed by the Symmetre must be of 19ºC, in the way the control can calculate the supply temperature depending on this set temperature and outdoor temperature. In this sense rooms overheating (at late hours in the morning in rooms with large glazing façade southeast oriented) can be avoid since peaks (22ºC) will be given by heat pumps.
  In *non-working periods* and with *no occupancy*, room set point is of 19ºC, the same than the fixed for the radiant floor since this system is the only operating in these periods with a hysteresis of ±1ºC, so it will works from 18ºC to 20ºC.
  In *non-working periods* and with *occupancy*, the working strategy will be the same than the defined below for working periods.
  In *working periods* the radiant floor keeps working in order to have the circuits heated all this period. This is possible opening the hysteresis to higher values:

  - At 6h30 heat pumps will start working to reach room temperature of 22ºC when radiant floor will stop. At 23ºC also heat pumps will stop and both systems will restart at 21ºC.
  - Both set points are modifiable by a thermostat in a range of 21-25ºC for the room which means 20-24ºC for radiant floor and 21-25ºC for heat pumps.
  - If the room has radiators, they will keep closed.
- In **autumn/spring time** the radiant floor will not be operative so the only heating system will be heat pumps. From 6h30 to 16h30 the room set point will be 22ºC±1ºC and out of this period the system will be off. In case of occupancy the set point is the same than the one defined for working periods. This set point can be changed in the range of 21-25ºC.

6.4.2.2 Control strategies for heating of rooms with radiant floor, fan-coil and radiators

The control strategy is the same than the aforementioned strategy for rooms with radiant floor and heat pump, using the fan-coils with the same set points defined for the heat pumps. The only missing strategy is the one that can control fans speed. Radiators will work manually.

6.4.2.3 Control strategies for cooling of rooms with heat pump and cooling floor (energy laboratory)

Cooling floor will work in only experimentally, by scheduling, considering the set point the floor temperature and fixing it at 21ºC±1ºC for water supply temperature of 16-19ºC.

Heat pumps will work with fixed set point at 23ºC±1ºC that can be changed by thermostat in the range between 21-25ºC and scheduled from 6h30 to 16h30, or defined by occupation.

In autumn/spring time cooling floor will not work and the system will be heat pump based with the same working conditions aforementioned.

6.4.2.4 Control strategies for cooling of rooms with fan-coil and cooling floor

Cooling floor will work in only experimentally, by scheduling, considering the set point the floor temperature and fixing it at 21ºC±1ºC for water supply temperature of 16-19ºC.

Fan-coils will work with fixed set point at 23ºC±1ºC that can be changed by thermostat in the range between 21-25ºC and scheduled from 6h30 to 16h30, or defined by occupation.

In autumn/spring time cooling floor will not work and the system will be fan-coil units based with the same working conditions aforementioned.

6.4.2.5 Control strategies for warehouse

The set point for the warehouse has been set at 22ºC±1ºC, controlling the speed of the fans. However, the strategy for the speed change has not been defined.

6.4.2.6 Summary of control strategies

In following tables are summarized control strategies aforementioned:

Table 32: Systems level control strategies of Cartif offices

RADIANT FLOOR	Programming	NORMAL	
	Days	working days	
	Set points	21ºC	19ºC
	Scheduling	6h30 - 16h00	16h00 – 6h30
DHW	Programming	STOP	
	Days	all week	
	Set points		
	Scheduling		
RADIATORS	Programming	WORKING DAYS	STOP
	Days	working days	weekend
	Set points		
	Scheduling	6h55 – 9h00	
HEAT PUMPS	Programming	WINTER	
	Days	all week	
	Set points	30ºC	
	Scheduling	5h00 – 21h30	

Table 33: Room level strategies of Cartif offices

RADIANT FLOOR	Programming	NORMAL	HALL - WEEKDAY	HALL - WEEKEND
	Days	all week	working days	weekend
	Set points	19,5ºC	22ºC ON 19,5 ºC OFF	19,5ºC

	Scheduling	00h30 – 10h00	05h30 - 13h00	-
HEAT PUMPS UBC8, UBC4, UBC5, UBC6, UBC7, UBC9, UBC11, UBC14, UBC15, UBC16, UBC19	Programming	WORKING DAYS	STOP	HEAT PUMPS LOCKED AT 19h00
	Days	working days	weekend	
	Set points	22ºC		
	Scheduling	6h30 – 19h00		

6.4.3 Lighting system existing control

The systems actuates to the analogic entrance of the electronic ballast of the luminaries in order to control the lux level in rooms to fulfil the regulations.

According to *UNE-EN 12464-1:2003* for indoor working spaces the average luminance level in horizontal surfaces must be 500lux.

All rooms can be divided in two types related to the lighting system control:

- Rooms with lighting control system: luminaries are equipped with ballasts for controlling luminance level:
  - meeting rooms
  - energy laboratory
  - assembly hall
- Rooms without lighting control system: luminaries are only equipped with an on/off control by using an adequate reactance for fluorescents.

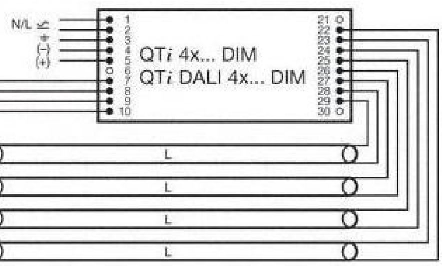


Figure 44: Luminaire connection with the electronic ballast

Electronic ballasts used for this purpose are optimal for fluorescents luminaries with 4 tubes and 18W (1-10v QTI 4x18 DIM with reference Osram: 4008321070012). These electronic devices have a voltage regulation entrance of 1-10V. In order to ensure this variable voltage LON regulation devices are installed (LON: REG-M DIM 1-10V) manufactured by SVEA. This Dimmer LON controller has an analogic output for connecting to the electronic ballast entrance.

7 Historical data: existing data base

7.1 Existing data base

Currently there is a PostgreSQL® database in order to store all data from the BMS including comfort parameters included in the LonWorks sensor network. PostgreSQL is an open source and object-relational database available for the main software platforms and operating systems. It is compliant with the ANSI-SQL2008 standard so as to manage information stored (insert, delete, update, etc.). It implements serializable transaction isolation levels. It fulfills with the integrity of data through some features included in the development.

In the following figure, it is shown the entity-relationship scheme, which is described in following paragraphs.

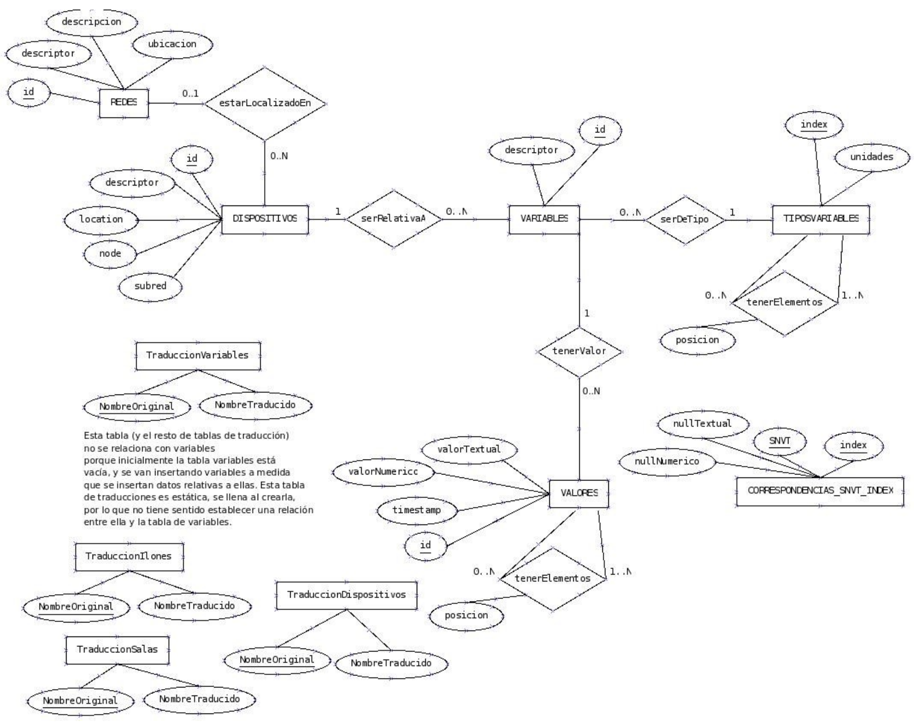


Figure 45: LonWorks database scheme

7.1.1 Relational database

The entities that compound the database scheme are described below jointly the fields making up these entities. Underlined it is highlighted the primary keys (single or complex) of the table. The primary key is a unique identifier in order to index the entries of the entity. On the other hand, the foreign keys which relates different entities are in italics:

- **SNVT_INDEX** (snvt, index, nullTextual, nullNumerico)
- **REDES** (idRed, descriptor, descripcion, ubicación)
- **DISPOSITIVOS** (idDispositivo, *idRed*, descriptor, location, node, subred)
- **TIPOSVARIABLES** (index, unidades)
- **TIPOSVARIABLES_TIPOSVARIABLES** (indexVar1, indexVar2, posicion)

- **VARIABLES** (idVariable, descriptor, *idDispositivo*, *indexTipoVariable*)
- **TRADUCCIONVARIABLES** (nombreOriginal, nombreTraducido)
- **VALORES** (idValor, *idVariable*, timestamp, valorTextual, valorNumerico)
- **VALORES_VALORES** (idValor1, idValor2, posicion)

Due to performance issues, 4 tables have been created, dividing the month in 4 periods as following:

- In "valores1" will be stored data from 1st to 8th of each month (inclusive)
- In "valores2" will be stored data from 9th to 16th of each month (inclusive)
- In "valores3" will be stored data from 17th to 24th of each month (inclusive)
- In "valores4" will be stored data from 24th to 31th of each month (inclusive)

Thus, the database is optimized because it is limited the amount of rows that can be stored in each table. If a file is downloaded just at the start or the end of "limit days" is possible that some data appear in the incorrect table.

7.1.2 Data dictionary

SNVT_INDEX: this table stores the correspondences between "snvt" and "index", and other interesting data related to the index:

- snvt: descriptor of variable type for which will be defined the related index (text)
- index: index related to each variable type (number)
- nullTextual: defines which is null value for variable type in case this should be defined by text (text)
- nullNumerico: defines which is null value for variable type in case this should be defined by number (number)

REDES: this table stores different networks for which variables are stored:

- idRed: id assigned directly to each network (auto-increment/sequence number)
- descriptor: name of the network (text)
- description: description of the network (text)
- ubicacion: location of the network (text)

DISPOSITIVOS: this table stores existing devices:

- idDispositivo: id assigned directly to each device (auto-increment/sequence number)
- idRed: id of the network in which device is installed (number)
- descriptor: name assigned to each device (text)
- location: location of the device (text)
- node: name attribute similar to the one extracted from lon file (text)
- subred: name attribute similar to the one extracted from lon file (text)

TIPOSVARIABLES: this table stores existing variable types:

- index: number that identifies variable type (number)
- unidades: units in which collected values will be stored (text). If variable is an enumeration it will be set as "array".

TIPOSVARIABLES_TIPOSVARIABLES: this table contains information about variable types composed by other different variable types (it means, variables whose values will be enumerations):

- indexVar1: id of the variable for which will be specified a variable contained in (from TIPOSVARIABLES table)
- indexVar2: id of the variable contained in a higher variable (identified in "indexVar1" table)
- posicion: location of the element defined by "indexVar2" in the variable type "indexVar1" (integer)

VARIABLES: this table stores the variables collected for each existing device:

- idVariable: id assigned automatically to each variable (auto-increment/sequence number)
- descriptor: text that identifies each variable (text)
- idDispositivo: id of the device to which corresponds the variable (from "DISPOSITIVOS" table)
- indexTipoVariable: index that identifies the variable type to which the variable corresponds (from "TIPOSVARIABLES" table)

VALORES: this table stores collected values for variables:

- idValor: id assigned automatically to each collected value (auto-increment/sequence number)
- idVariable: id of the variable to which corresponds the value (from "VARIABLES" table)
- timestamp: time in which value was collected (timestamp)
- valorTextual: text value collected (text)
- valorNumerico: numeric value collected (number)

VALORES_VALORES: this table stores values in case of composed variables (it means, variables whose values will be enumerations defined in "TIPOSVARIABLES_ TIPOSVARIABLES" table). When a variable is an enumeration, the tuple in "VALORES" table corresponding to index "idValor1" will not represent an important value, while interesting values are those "inside" given by corresponding tuples in "VALORES" table and with ids defined in "idValor2" of each tuple containing the interesting "idValor1":

- idValor1: id of the value for which will be specified another contained value (from "VALORES" table)
- idValor2: id of the value contained in a higher value (defined by "idValor1" from "VALORES" table)
- posicion: location of the element in the array (integer)

TRADUCCIONVARIABLES: this table stores translations among variables' names as they appear in "VARIABLES" table and translated names (given in an understandable way):

- nombreOriginal: original name of the variable for which is going to be given a translation (text)
- nombreTraducido: descriptive name associated to aforementioned variable (text)

TRADUCCIONILONES: this table stores translations among iLons' names as they appear in "REDES" table and translated names (given in an understandable way):

- nombreOriginal: original name of the iLon for which is going to be given a translation (text)
- nombreTraducido: descriptive name associated to aforementioned variable (text)

TRADUCCIONDISPOSITIVOS: this table stores translations among devices' names as they appear in "DISPOSITIVOS" table and translated names (given in an understandable way):

- nombreOriginal: original name of the device for which is going to be given a translation (text)
- nombreTraducido: descriptive name associated to aforementioned variable (text)

TRADUCCIONSALAS: this table stores translations among locations' names as they appear in "DISPOSITIVOS" table and translated names (given in an understandable way):

- nombreOriginal: original name of the locations for which is going to be given a translation (text)
- nombreTraducido: descriptive name associated to aforementioned variable (text)

All the data are available in the database for the latest month and via FTP for the historical logs of the data-points. For connectivity details, this information is gathered in the D6.2.

7.2 Existing historical variables

From the energy generation system, the controller manages an internal database, historical database and there are backups containing also these historical logs. As far as BaaS project is using the historical logs for populating the DWH, the only data source for that purpose are the back-ups files. These files are Excel ones which store weekly data from the variables listed for the energy generation in this document. The format of these data logs contains a header with metadata regarding the filters used to retrieve the data-points. Next, every variable is shown in the same way; a header with the name of the data-point, and two columns, one for the timestamp and the second one for the value.

Table 34: Consumed energy parameters of Cartif offices

Consumed Energy				
Concept	**Application**		**Measurement[3]**	**Monitoring point and location**
Fossil fuel (biomass, natural gas, etc.)	Heating	Y	F	
	Cooling	N	F/E	
	DHW	N	F	
Electricity	Heating		E	
	Cooling		E	
	DHW		E	
	Ventilation		E	
	Lighting		E	
	Appliances		E	
District energy	District heating	N	-	n.a.
	District cooling	N	-	n.a.

[3] Electricity meter (E), Fuel meter (F), Water meter (W), Hot/cold water meter (HC), None (N)

Table 35: Delivered energy parameters of Cartif offices (solar-absortion chiller)

Delivered energy				
Concept	**No.**		**Explanation**	**Unit**
Flat plate collectors field	1	t_1	Collector evacuated tube outlet temperature (hot)	ºC
	2	t_2	Collector evacuated tube inlet temperature (cold)	ºC
	3	t_3	Collector evacuated tube auxiliary temperature (in collector)	ºC
Solar tracking platform	4	t_{20}	Collector flat plate outlet temperature (hot)	ºC
	5	t_{21}	Collector flat plate inlet temperature (cold)	ºC
	6	t_{22}	Collector flat plate auxiliary temperature (in collector)	ºC
Flat plate collectors field - Heat exchanger	7	t_{10}	Heat exchanger evacuated tube primary inlet temperature (hot)	ºC
	8	t_{11}	Heat exchanger evacuated tube primary outlet temperature (cold)	ºC
	9	t_{13}	Heat exchanger evacuated tube secondary inlet temperature (hot)	ºC
	10	t_{12}	Heat exchanger evacuated tube secondary outlet temperature (hot)	ºC
Solar tracking platform - Heat exchanger	11	t_{25}	Heat exchanger flat plate primary inlet temperature (hot)	ºC
	12	t_{26}	Heat exchanger flat plate primary outlet temperature (cold)	ºC
	13	t_{28}	Heat exchanger flat plate secondary inlet temperature (hot)	ºC
	14	t_{27}	Heat exchanger flat plate secondary outlet temperature (hot)	ºC
Flat plate collectors field – Buf. tank	15	t_{14}	Upper temperature in buffer storage evacuated tube	ºC
	16	t_{15}	Middle temperature in buffer storage evacuated tube	ºC
	17	t_{17}	Lower temperature in buffer storage evacuated tube	ºC
Solar tracking platform – Buf. tank	18	t_{29}	Upper temperature in buffer storage flat plate	ºC
	19	t_{30}	Middle temperature in buffer storage flat plate	ºC
	20	t_{31}	Lower temperature in buffer storage flat plate	ºC
Solar storage	21	t_{18}	Solar temperature inlet	ºC
	22	t_{19}	Solar temperature outlet	ºC
	23	t_{33}	Load return temperature	ºC
	24	t_{36}	Room Machine temperature	ºC
Absorption chiller	25	t_{101}	Condenser inlet temperature	ºC
	26	t_{102}	Condenser outlet temperature	ºC
	27	t_{103}	Evaporator outlet temperature	ºC
	28	t_{104}	Evaporator inlet temperature	ºC
	29	t_{105}	Generator outlet temperature	ºC

	30	t_{106}	Generator inlet temperature	ºC
	31	t_{107}	Tree way valve inlet temperature	ºC
	32	t_{108}	Tree way valve mixed cooling tower temperature	ºC
Cold storage	33	t_{109}	Top of the tank	ºC
	34	t_{110}	Bottom of the tank	ºC
Solar facility pressures	33	p1	Collector evacuated tube pressure drop	bar
	34	p2	Flat plate pressure drop	bar
	35	p3	Collector evacuated tube pressure hydrostatic	bar
	36	p4	Flat plate pressure hydrostatic	bar
	37	p5	Pressure hydrostatic in buffer storage evacuated tube	bar
	38	p6	Pressure hydrostatic in buffer storage flat plate	bar
Solar facility water flows	39	C1	Primary evacuate tube Flow rate	m^3/h
	40	C2	Secondary evacuate tube Flow rate	m^3/h
	41	C3	Primary flat plate Flow rate	m^3/h
	42	C4	Secondary flat plate Flow rate	m^3/h
	43	C5	Solar total flow rate	m^3/h
	44	C6	Solar flat plate flow rate	m^3/h
	45	C7	Boiler flow rate	m^3/h
	46	C8	Condenser flow rate	m^3/h
	47	C9	Evaporator flow rate	m^3/h
	48	C10	Generator flow rate	m^3/h
	49	C11	Uses chiller water flow rate	m^3/h

Table 36: Indoor ambient parameters of Cartif offices

Indoor ambient parameters				
Concept	**Measurement**		**Quantity**	**Monitoring point and location**
Indoor conditions	Temperature	Y	24	Defined on the following tables
	Relative humidity	N	-	-
	Illumination level	Y	21	Defined on the following tables
	CO_2 concentration	N	-	-
	Occupancy	Y	21	Defined on the following tables
	Window status	N	-	-

All the temperature sensors are WRF04 NTC manufactured by Thermokon and they are located where is indicated in the following table. Moreover, in the table is shown the thermal system related to each temperature sensor.

Table 37: Zone temperature sensors of Cartif offices

<table>
<tr><th></th><th>Floor</th><th>Area</th><th>Associated thermal system</th></tr>
<tr><td>T1</td><td>1</td><td>b. Industrial zone offices</td><td>UBC 16</td></tr>
<tr><td>T2</td><td>1</td><td>c. Multifunct. Area</td><td>UBC 15</td></tr>
<tr><td>T3</td><td>1</td><td>d. Innovation</td><td>UBC 14</td></tr>
<tr><td>T4</td><td>1</td><td>e. SEADM</td><td>UBC 17</td></tr>
<tr><td>T5</td><td>1</td><td>f. Office 1</td><td>DWK 1</td></tr>
<tr><td>T6</td><td rowspan="2">1</td><td rowspan="2">g. Secretariat</td><td>DWK 2</td></tr>
<tr><td>T7</td><td>DWK 3</td></tr>
<tr><td>T8</td><td>1</td><td>h. Office 2</td><td>DWK 4</td></tr>
<tr><td>T9</td><td rowspan="2">1</td><td rowspan="2">i. Meeting room</td><td>DWK 5</td></tr>
<tr><td>T10</td><td>DWK 6</td></tr>
<tr><td>T11</td><td>1</td><td>j. Auditorium</td><td>UBC 19</td></tr>
<tr><td>T12</td><td rowspan="3">1</td><td rowspan="4">m. Hall + corridor</td><td>DWK 7</td></tr>
<tr><td>T13</td><td>UBC19 - FCH A</td></tr>
<tr><td>T14</td><td>UBC19 - FCH B</td></tr>
<tr><td>T15</td><td>2</td><td>UBC 11</td></tr>
<tr><td>T16</td><td>2</td><td>n. Robotics</td><td>UBC 9</td></tr>
<tr><td>T17</td><td rowspan="2">2
2</td><td rowspan="2">o. Energy</td><td>UBC 7</td></tr>
<tr><td>T18</td><td>UBC 8</td></tr>
<tr><td>T19</td><td>2</td><td>p. Vision 2D</td><td>UBC 5</td></tr>
<tr><td>T20</td><td>2</td><td>q. Vision 3D</td><td>UBC 6</td></tr>
<tr><td>T21</td><td>2</td><td>r. Info. Warehouse</td><td>UBC 4</td></tr>
<tr><td>T22</td><td rowspan="2">2</td><td rowspan="2">s. SEADM</td><td>UBC 1</td></tr>
<tr><td>T23</td><td>UBC 2</td></tr>
<tr><td>T24</td><td>2</td><td>t. Informatics</td><td>UBC 3</td></tr>
</table>

Each area is identified by one letter and these are represented in the Figure 6 and Figure 7.

8 External data sources: weather data

Two meteorological stations are located on the roof of Cartif 1, meteo station 1 and 2, managed by Cartif. These two stations are working regularly since more than 10 years. The 2nd station has more functionalities than the other one (diffuse radiation, wind at 2 elevations). Station 2 is composed of the following devices:

- piranometer (Kipp & Zonen model CM6B)
- shaded piranometer (Kipp & Zonen model CM6B)
- thermometer (Campbell)
- barometer (Campbell)
- hygrometer (Campbell)
- anemometer (Vaisala)
- weather vane (Vaisala)

Instruments are positioned on a tower, 2 - 3 meters over the roof. In particular, wind sensors (anemometer and weather vane) are on 7 and 12 m of elevation. Meteo station is fed from a small photovoltaic panel with a regulator that ensures no-stop working.

Instruments of station are connected to a data logger Campbell scientific. It is able to gather and to store data. Nevertheless, in the case of Cartif meteo station data are stored in a dedicated PC that stands in the Energy Division. On this PC a LABVIEW application stores, treats, and monitors data, in particular data are saved in daily files. Data are also available on line (www.cartif.es).

Data logger gathers instantaneous data every 20 seconds and transmits these values to a LABVIEW application. Final values are obtained averaging these instantaneous values to a single value every minute. One minute step is enough to show relevant variation in meteorological variables and permits to manage adequately the facilities.

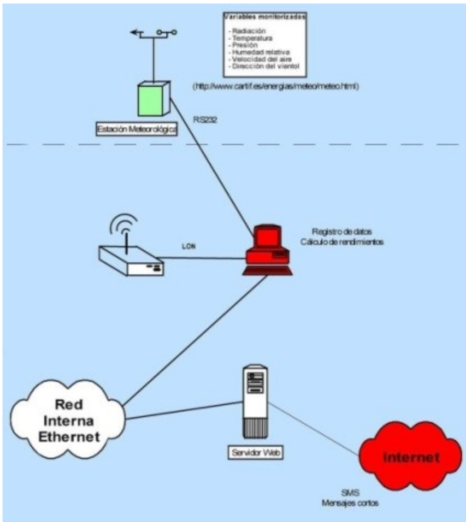


Figure 46: Schematic configuration of the Cartif meteo station

Nowadays, almost 15 years of data are available in the meteorological database of Cartif. As previously mentioned, this resource is used for live control: yet these data, if appropriated treated, could be used as an input in design projects or transient simulations.

Table 38: Outdoor ambient parameters of Cartif offices

Outdoor ambient parameters				
Concept	**No.**		**Explanation**	**Unit**
Outdoor ambient param.	1	q_{gh}	Global horizontal irradiation	W/m²
	2	q_d	Diffuse horizontal irradiation	W/m²
	3	t_U	Ambient temperature	°C
	4	w_{w7}	Wind speed (7 m)	m/s
	5	w_{d7}	Wind direction (7 m)	º
	6	w_{w12}	Wind speed (12 m)	m/s
	7	w_{d12}	Wind direction (12 m)	º
	8	pt	Precipitation	l/m^2
	9	HR	Hygro-Thermo	%

References

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