Project acronym: GROUND-MED

Project title: Advanced ground source heat pump systems for heating and cooling in Mediterranean climate

Start date of project: 1 January 2009

Duration: 72 months

Deliverable D7.1: **Operation and performance of each demo system over a period of 12 months**

Demo site No 6 - **La Fabrica del Sol renewable energies exhibition centre, Barcelona**

Version: final

Due date of deliverable: 31 July 2014

Actual submission date: 15 December 2014

Organisation name of lead contractor for this deliverable:

- **ECOSERVEIS**
- **Centre for Renewable Energy Sources and Saving**

Project co-funded by the European Commission within FP7 Programme		
Dissemination level		
PU	Public	**X**
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the Consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

DEMO SITE MONITORING REPORT

BARCELONA

1. Introduction

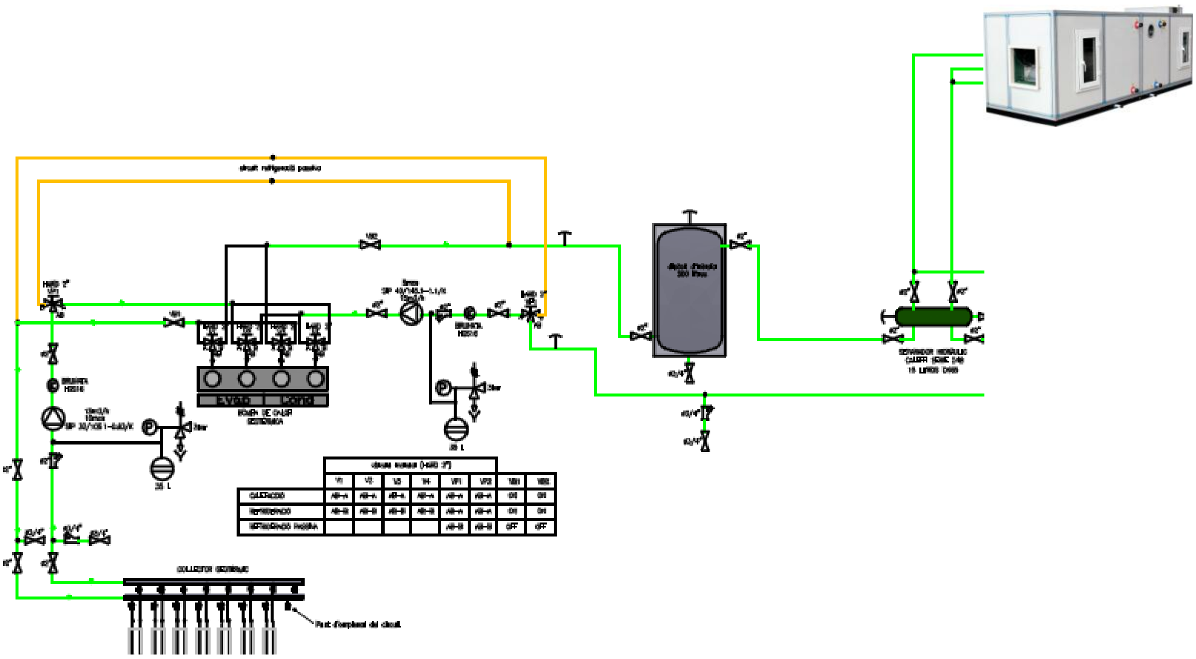
The GSHP is installed in the Sun-Factory Demo Site, in Barcelona. The building is used as a demo site to show the different kind of renewable energies applicable to buildings. Therefore the building has a complete heating & cooling system composed by: Solar Thermal Panels, Biomass Boiler, Absorption Machine and Geothermal Heat Pump. Nevertheless the old installation was not enough to heat both floors. Since the installation of the GSHP, it is used to heat and cool the ground floor, where the visitors can see the exhibitions, with 375 m2 of surface.

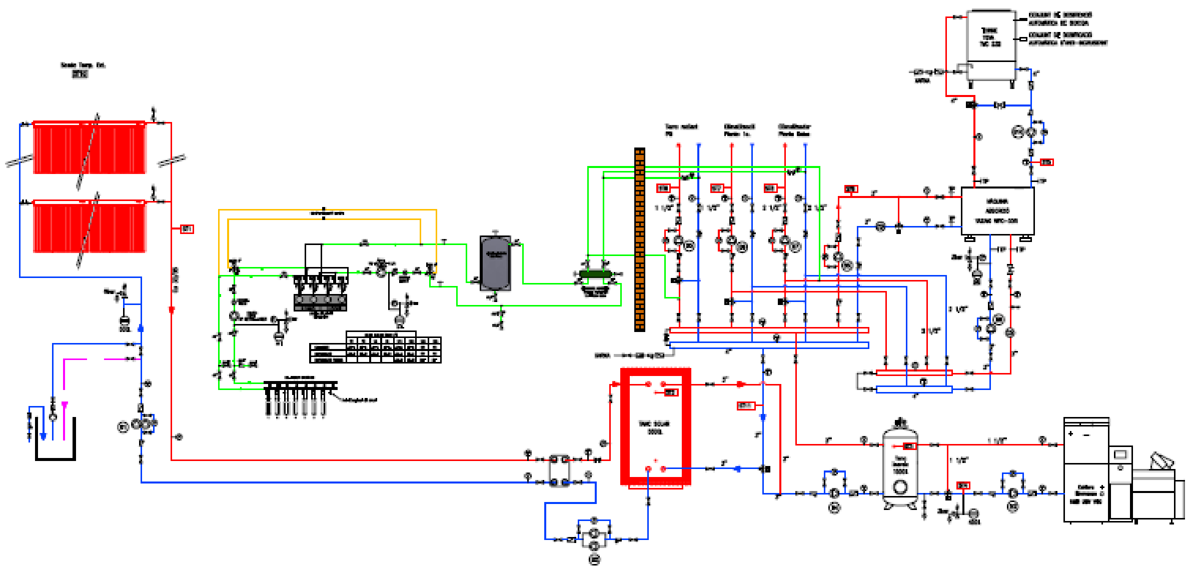
The system is composed by 7 borehole heat exchangers with a total length of 1.400m, a tandem CIAT 60KW Heat Pump and an Air Handling Unit.

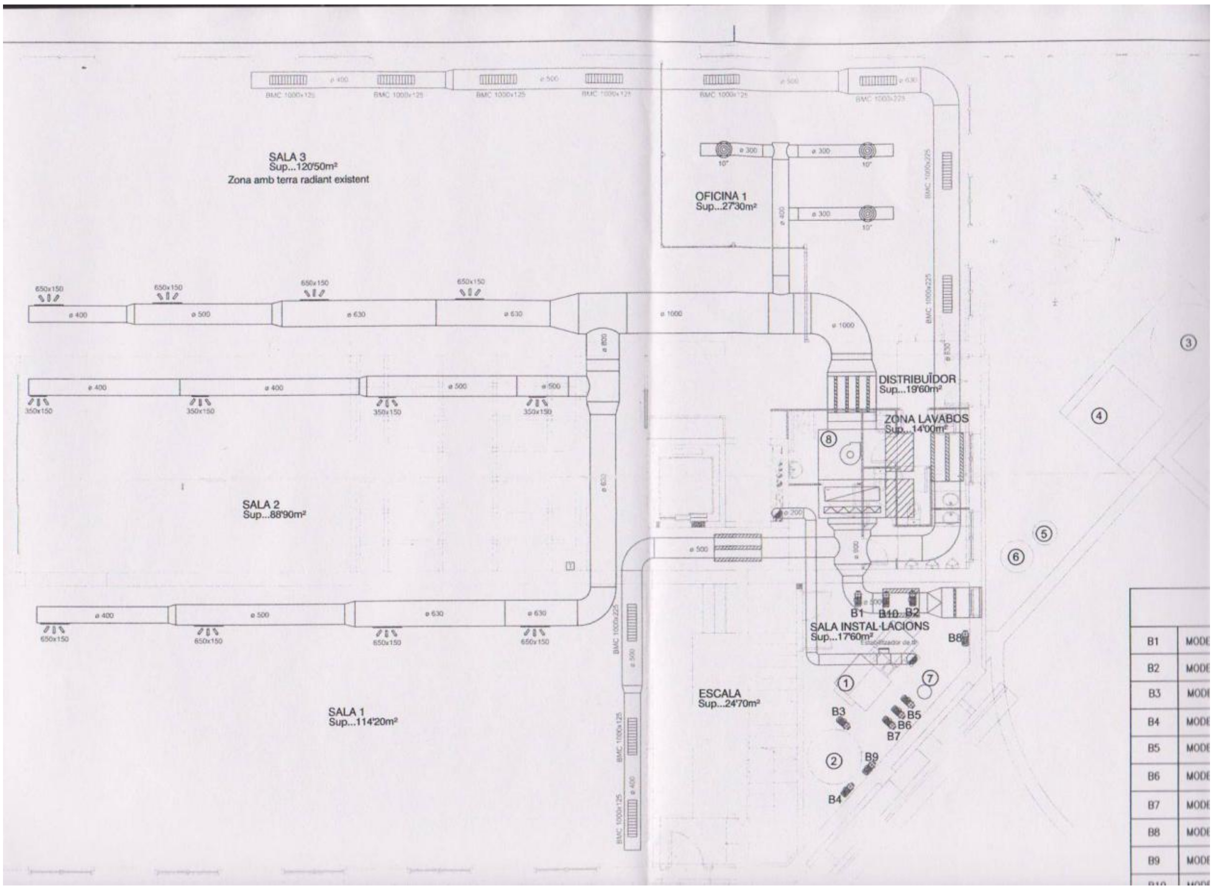
Country	**Spain**
Building type	Museum – Demo Site
Year of construction	1842
Year of last major renovation	2000
Heated/ cooled building area	375 m²
Specific heat load	160 W/m²
Specific cooling load	133 W/m²
Heat pump type	Electric Heat Pump
Year of installation	2011
Purpose...	Heating and Cooling
Heat source/sink	Water/Water
Heat source system	7 vertical borehole heat exchangers
Distribution system	Air Handling Unit
Design heating temperature	supply: 40°C / return: 35°C
Design cooling temperature	supply: 10°C / return: 15°C
Operation mode	Monovalent
Refrigerant	R410a
Alternative/ complementary heating system	Thermal Solar

The system is including:

- GSHP for heating and cooling of measured SPF >5 in Barcelona
- 50kW heating and 50kW cooling - ground floor 375m^2 (4 areas)
- 10-12 kW electrical needs
- 7 x 110m depth boreholes

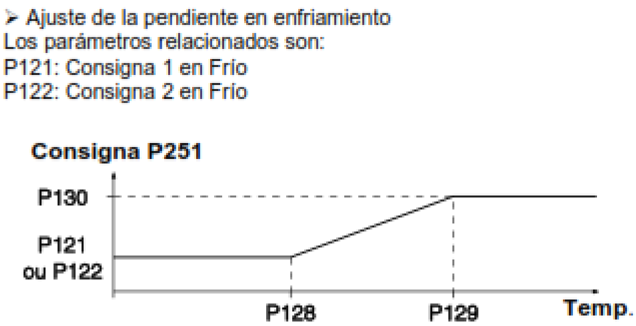




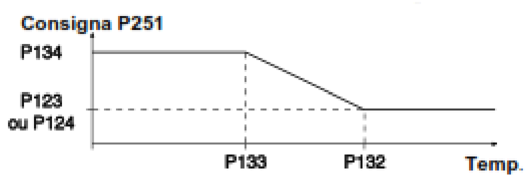


2. System controls

The HP is controlled by inlet water temperature and the set-points temperature is related to the exterior temperature using a linear relation.
In cooling mode, the HP is only providing full cooling power whenever the ambient temperature is greater than 35ºC. Inlet temperature is dynamically set up in a range of 15ºC-20ºC depending on this ambient temperature. The set-point for the indoor thermostat was 26ºC.



During summers 2013 and 2014 the pump has provided cooling using just one of the compressors, resulting in improved the SPF during these cooling periods.
In heating mode, the HP is only providing full heating power whenever the ambient temperature is lower than 5ºC. Inlet temperature is dynamically set up in a range of 30ºC-38ºC depending on this ambient temperature. The set-point for the indoor thermostat was 21ºC.



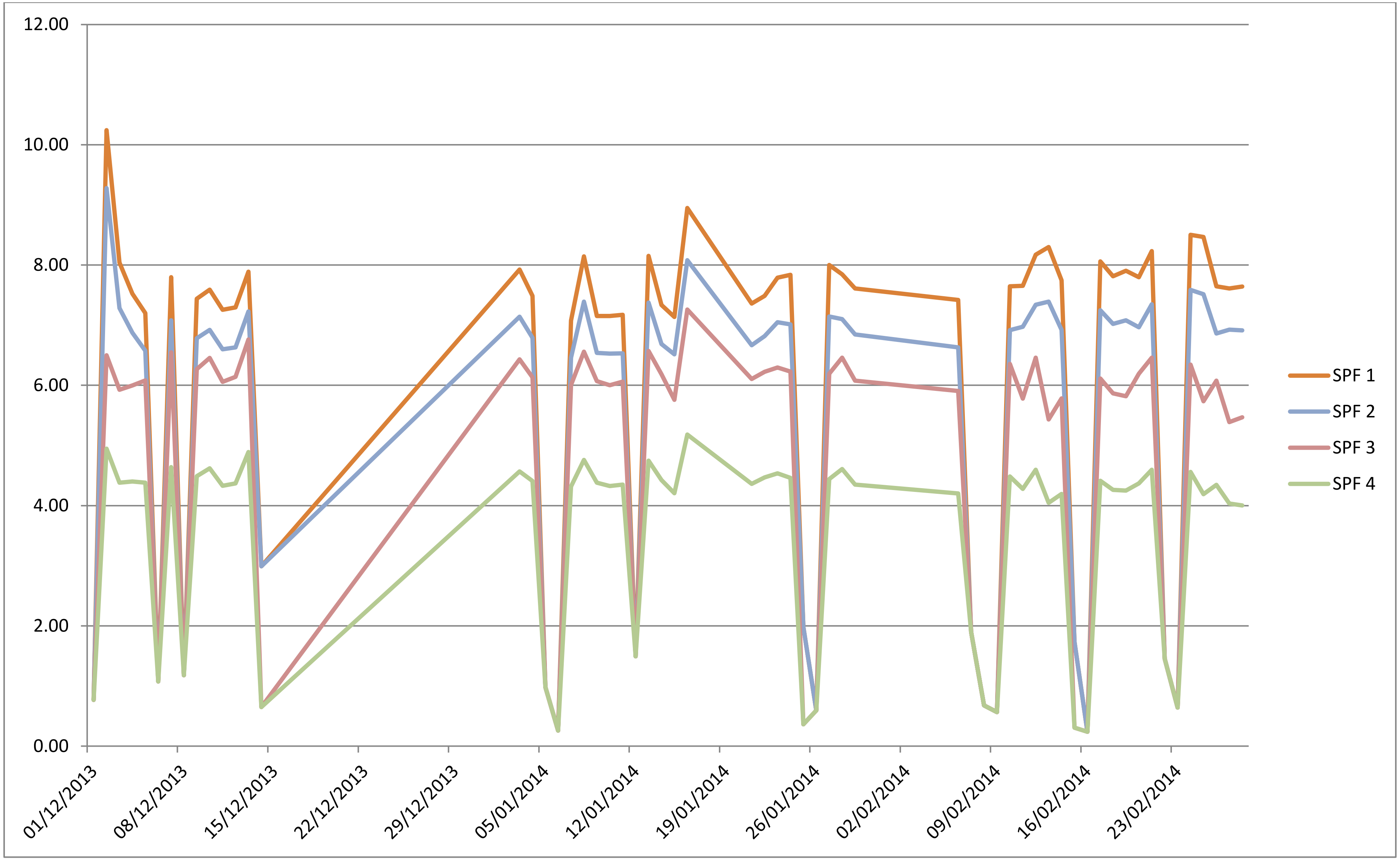
During winter 2013-14 the pump has provided heating mainly using just one of the compressors which improved the SPF for this period.

In both cooling and heating modes, the circulation pumps are working at the maximum speed but they switch off whenever there are no heating/cooling needs. This strategy was introduced during August 2013 and improved a lot the SPF3.

3. Seasonal performance: heating

The heating period began in December 2013 and finished in February 2014. The following graphs and table summarizes the performance of the system.

Summary	SPF1	SPF2	SPF3	SPF4
Heating period	7,60	6,89	6,10	4,41
Thermal Energy	HP	External Pump	Internal Pump	Air Handling Unit
10476 kWh	1378 kWh	142 kWh	196 kWh	659 kWh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SPF 1
SPF 2
SPF 3
SPF 4

4. Seasonal performance: cooling

Summer 2013

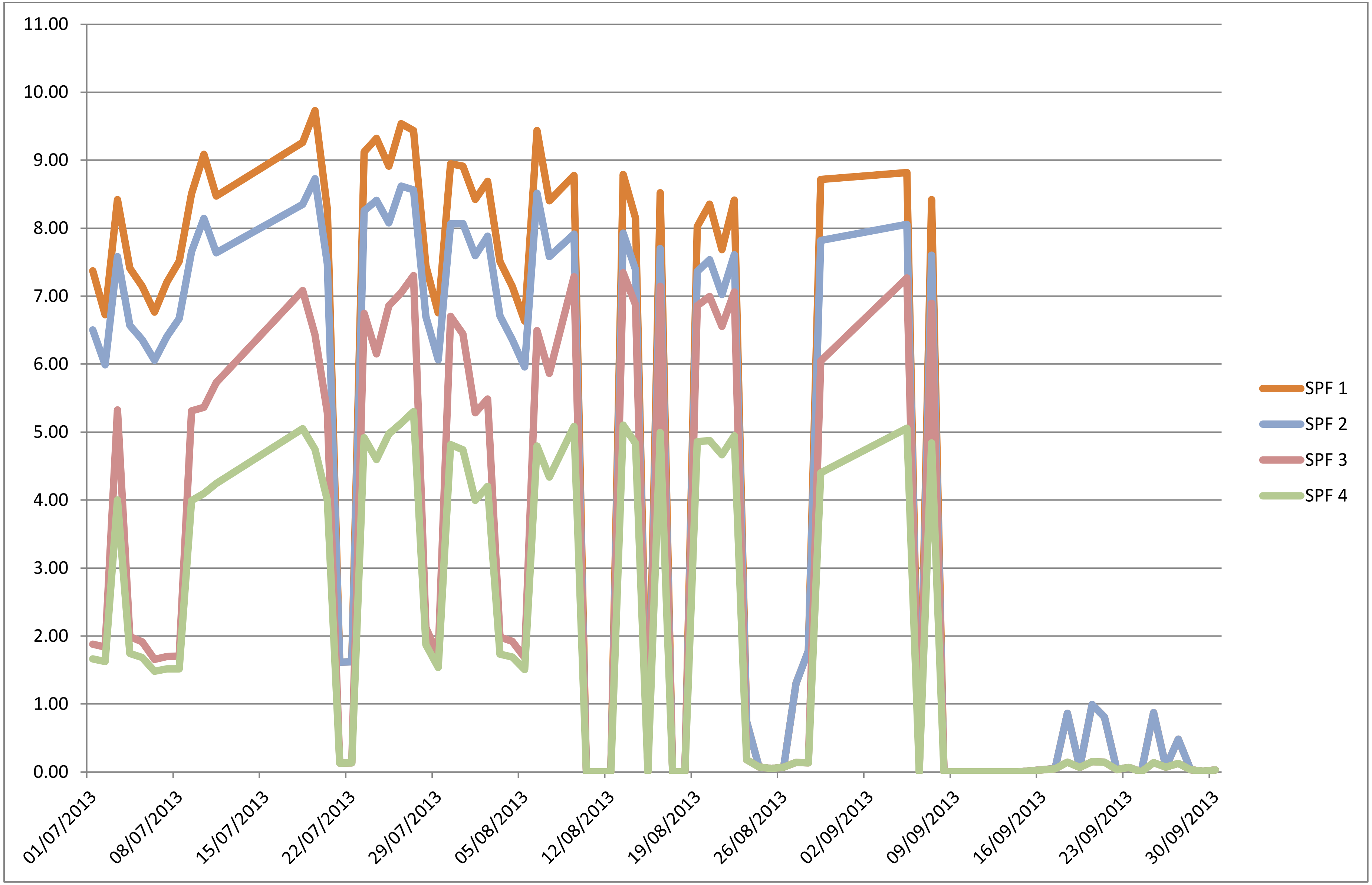
This season has been quiet cool in Barcelona. Therefore the cooling period began in July and finished in September. The following graphs and table summarizes the performance of the system.

Summary	SPF1	SPF2	SPF3	SPF4
Cooling period	8,51	7,70	5,46	4,15
Thermal Energy	HP	External Pump	Internal Pump	Air Handling Unit
6150 kWh	722 kWh	75 kWh	327 kWh	357 kWh

Summer 2014

There has been a very important change in the use of the GSHP. The system is since august 2014 providing also heat and cooling to the first floor. That is the reason why the cooling demand has increased compared to 2013.

Summary	SPF1	SPF2	SPF3	SPF4
Cooling period	7,35	6,72	6,04	4,41
Thermal Energy	HP	External Pump	Internal Pump	Air Handling Unit
8922 kWh	1214 kWh	114 kWh	149 kWh	547 kWh



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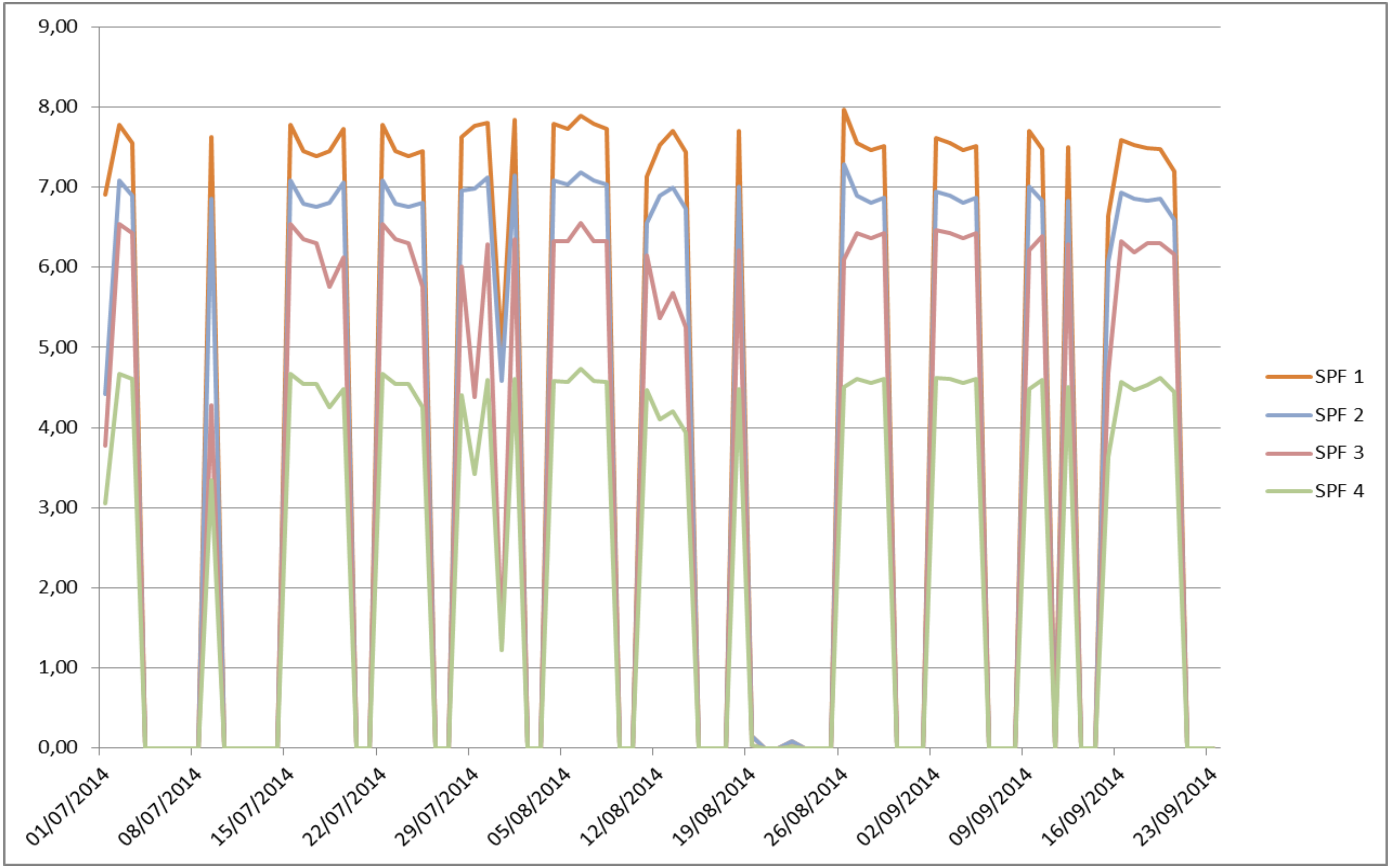
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09/09/2014
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23/09/2014
SPF 1
SPF 2
SPF 3
SPF 4

5. Economic aspects

Installation costs, maintenance costs, electricity consumption costs per season, and seasonal cost savings compared to conventional systems will be analyzed.

The installation cost 101.685€, and since it has been installed the only **maintenance cost has been 300€** due to annual maintenance and the replacement of the expansion valve.

During July, August and September 2013 **the electrical cost has been 161,56€[1].** Considering the same cooling needs and using an air to air HP (COP 2,4) **the cost would be 361,91€.** Therefore, for this 3-month period, **savings are 200€ (55%).**

During the heating season of 2013-14, comprising the months December, January and February, the HP provided 10.476 kWh of thermal energy and **the electrical cost has been 258,76€[1]. That's only 2,47c€/kWh.** Considering the same heating needs and using an air to air HP (COP 2,4) **the cost would be 478€.** Therefore, for this 3-month period, **savings are 220€ (60%).**

During July, August and September 2014 **the electrical cost has been 220,52€[1].** Considering the same cooling needs and using an air to air HP (COP 2,4) **the cost would be 404,89€.** Therefore, for this 3-month period, **savings are 185€ (55%).**

6. Reliability

Reliability: 97%

Some problems appeared during summer 2012 and heating season 2013-14:

- There were condensations in the AHU which caused water leakages in the office.
- The expansion valve and the driver were malfunctioning and they were replaced.
- In heating mode, a little problem appeared regarding a water flow error concerning the external circulation pump which didn't start at time

Above problems were effectively solved and the system reliability reached 100% during summer 2014.

Refrigerant: 100%

No refrigerant leakage has been detected.

Noise: 100%

The HP is placed in the exterior so there are no sound complaints from the employees working inside neither people from outside.

[1] Considering a tariff of 10,8905 c€/kWh

7. Conclusions and recommendations

The results are very interesting; mainly for the change of the strategy controlling the internal circulation pump. During the month of July 2013, the internal circulation pump was always on due to a lack of a controlling system. This problem has been overcome using a manual switch which is used by the employees. They can turn off the internal circulation pump when they leave the office. Whenever they arrive to the office, at the morning, they switch it on back. This simple strategy has improved the final performance (SPF3 and SPF4) even more than expected because, even in winter, they achieved better SPF4 than in summer.

In the future a new starting time will be applied to the HVAC. We noticed that the indoor temperature has inertia of almost 2 hours. Therefore the HP can start 2 hours earlier and take advantage of a cheaper electricity cost. In the other way around, the HP can be turned off also earlier, avoiding the peak tariff.

The above strategy implemented last summer to control the internal circuit pump has proven to work. With this efficiency the municipality decided to shift all HVAC systems to the GSHP. Since August 2014 all floors are heated and cooled using the HVAC. During 2015 the building will be renewed and a new controlling system will be implemented to optimize the use of the Heat Pump and the energy provided by the PV system installed in the roof.

ANNEX: DAY TO DAY MONITORING

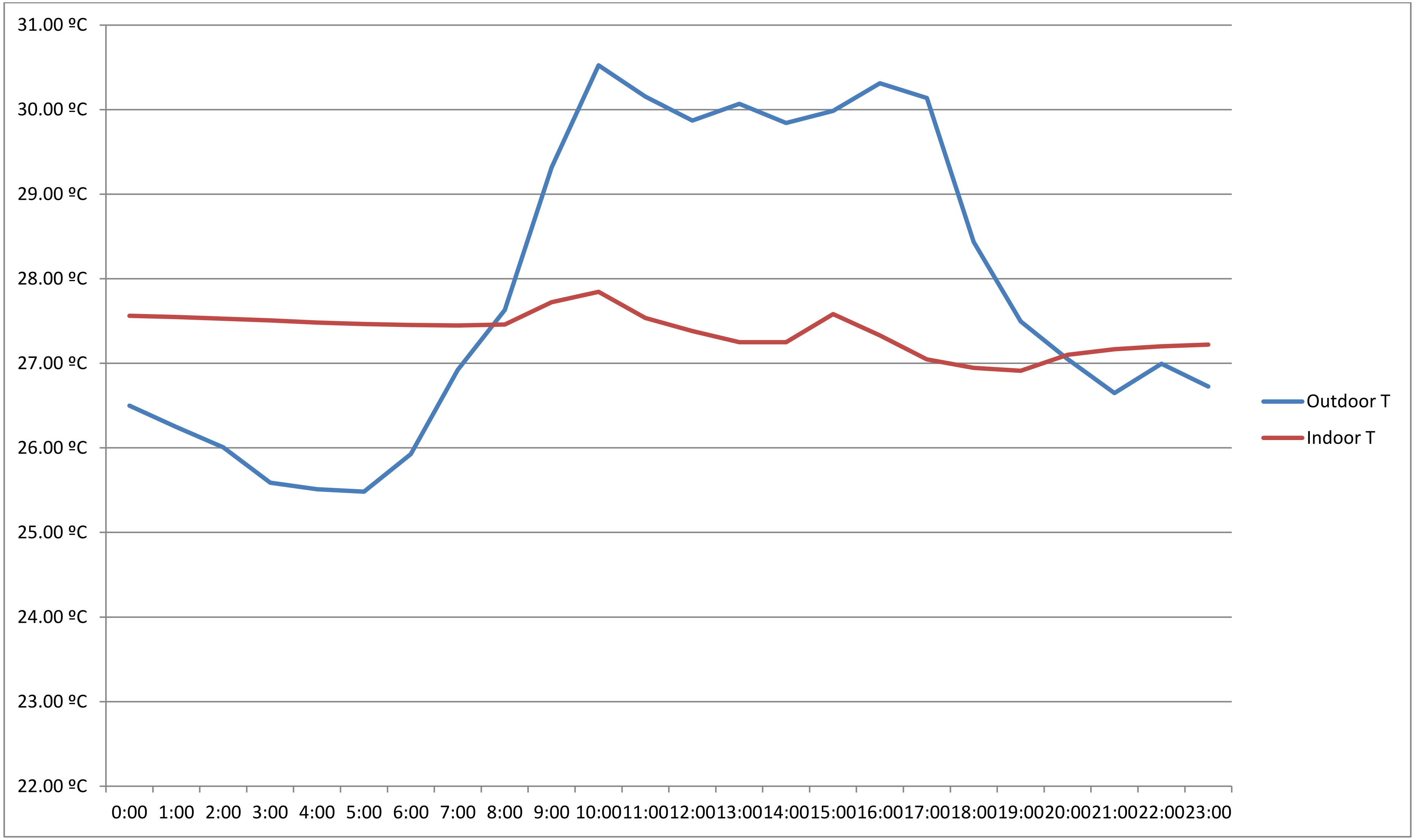
The following graphics are provided for a representative day of each month of the cooling seasons 2013 and 2014, as well as of the heating season of 2013-14:

- Graph1: Ambient Temperature & Indoor Temperature
- Graph2: External circuit (loop) Temperatures In and Out;
  Internal circuit (loop) Temperatures In and Out
- Graph3: External and Internal circuit (loop) flow rates
- Graph4: Thermal Power (heating , cooling & sanitary hot water) delivered to the building;
  Thermal Power to/from the BHE;
  Electrical Power consumption at the compressor (heat pump);
  Electrical Power consumption at the external pump;
  Electrical Power consumption at the internal pumps;
  Electrical Power consumption at the fans (FCUs or AHU)
- Graph5: COP1, COP2, COP3 and COP4 (instantaneous)

ANNEX I

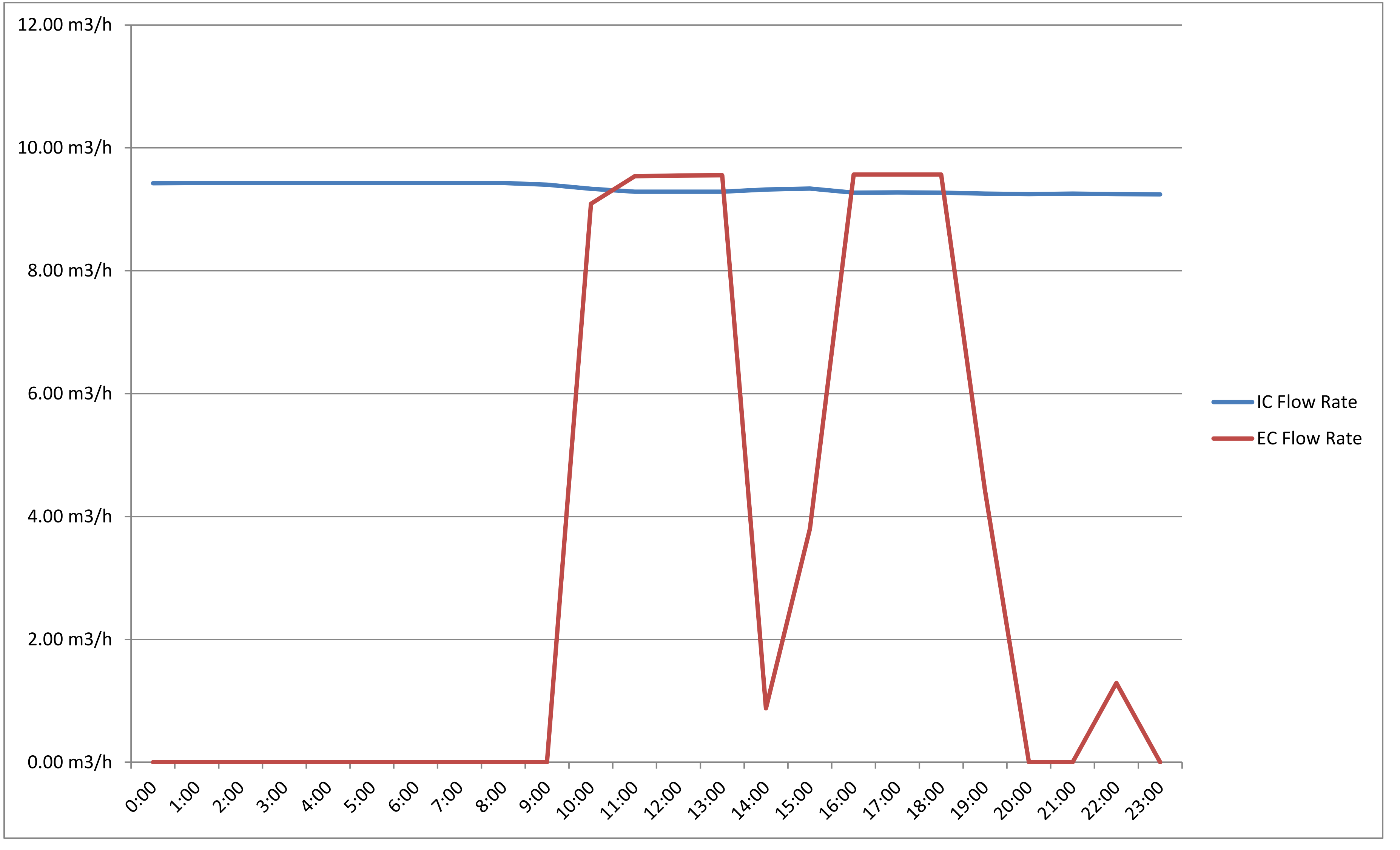
COOLING DURING SUMMER 2013

23/07/2013: Graph1: Ambient Temperature & Indoor Temperature

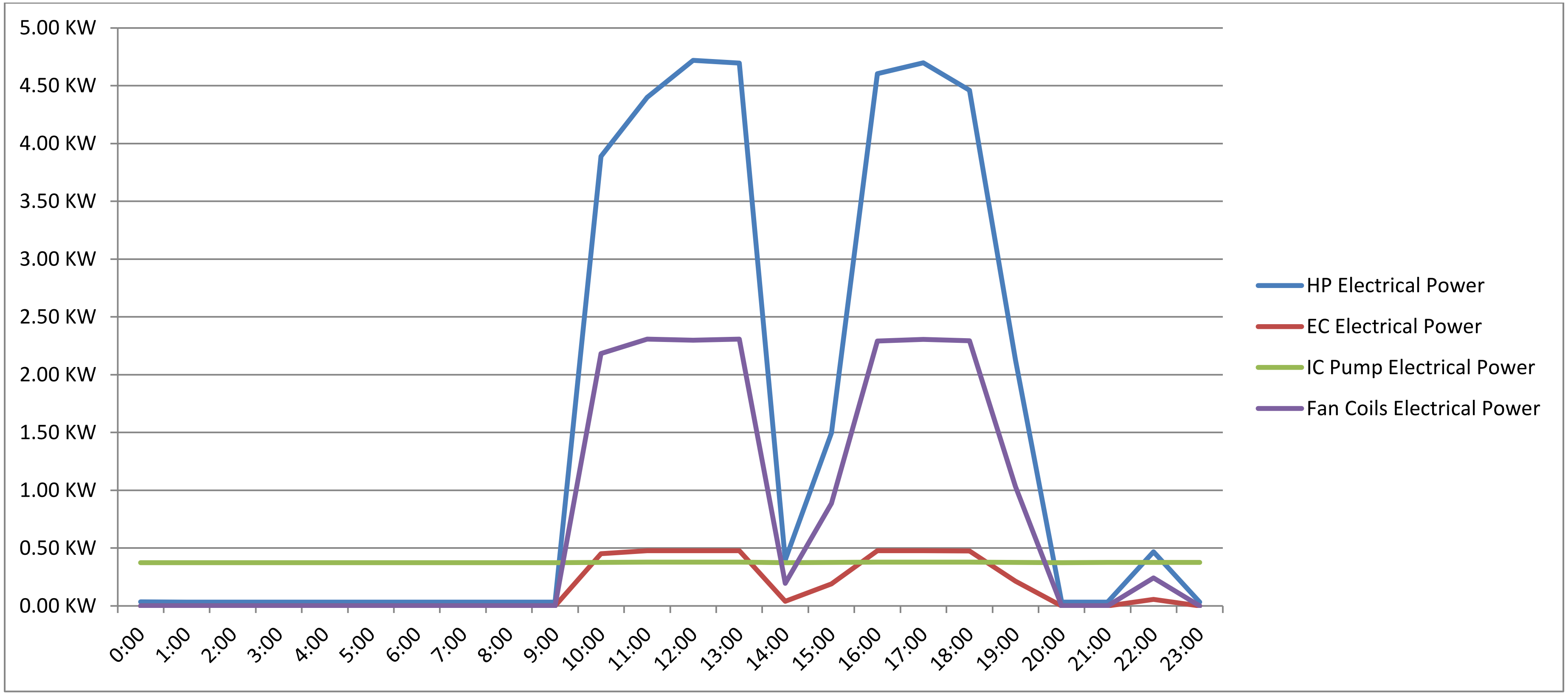


Graph2: External circuit (loop) Temperatures In and Out; Internal circuit (loop) Temperatures In and Out

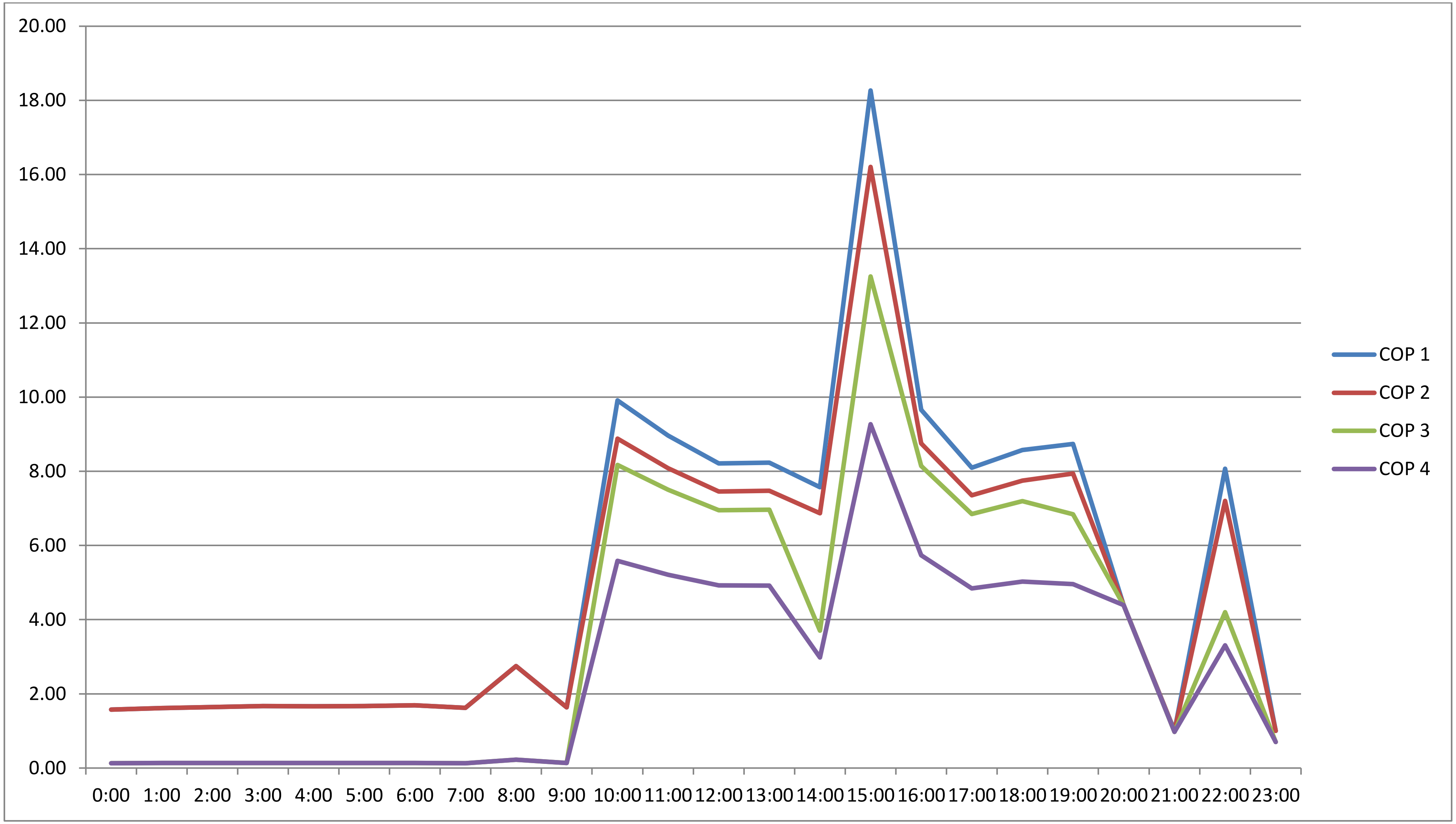
Graph3: External and Internal circuit (loop) flow rates



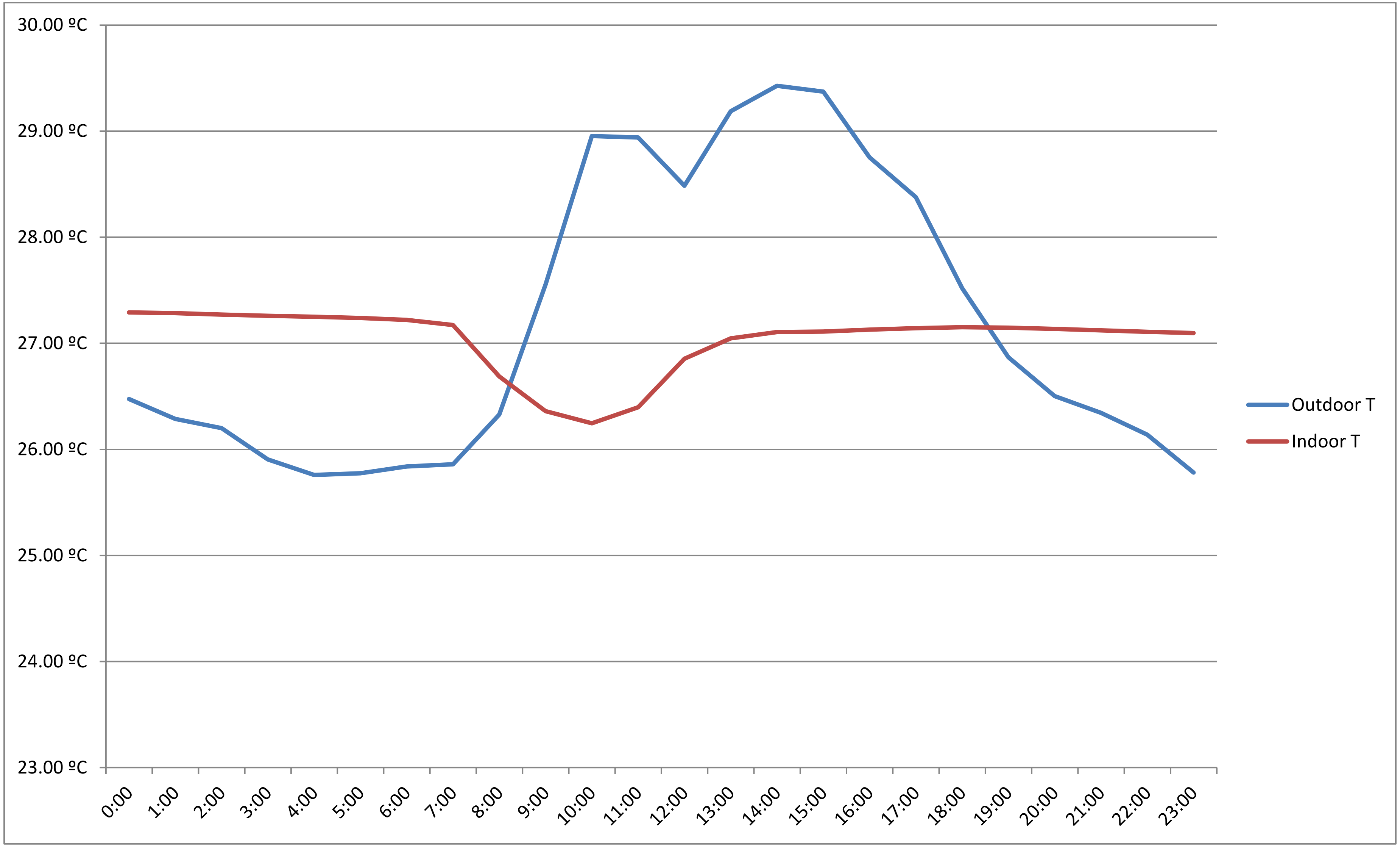
Graph4: Thermal Power (heating , cooling & sanitary hot water) delivered to the building; Thermal Power to/from the BHE; Electrical Power consumption at the compressor (heat pump); Electrical Power consumption at the external pump; Electrical Power consumption at the internal pumps; Electrical Power consumption at the fans (FCUs or AHU)



Graph5: COP1, COP2, COP3 and COP4 (instantaneous) (at 15:00 COP is too high because of the energy stored in the buffer tank)



20/08/2013: Graph1: Ambient Temperature & Indoor Temperature



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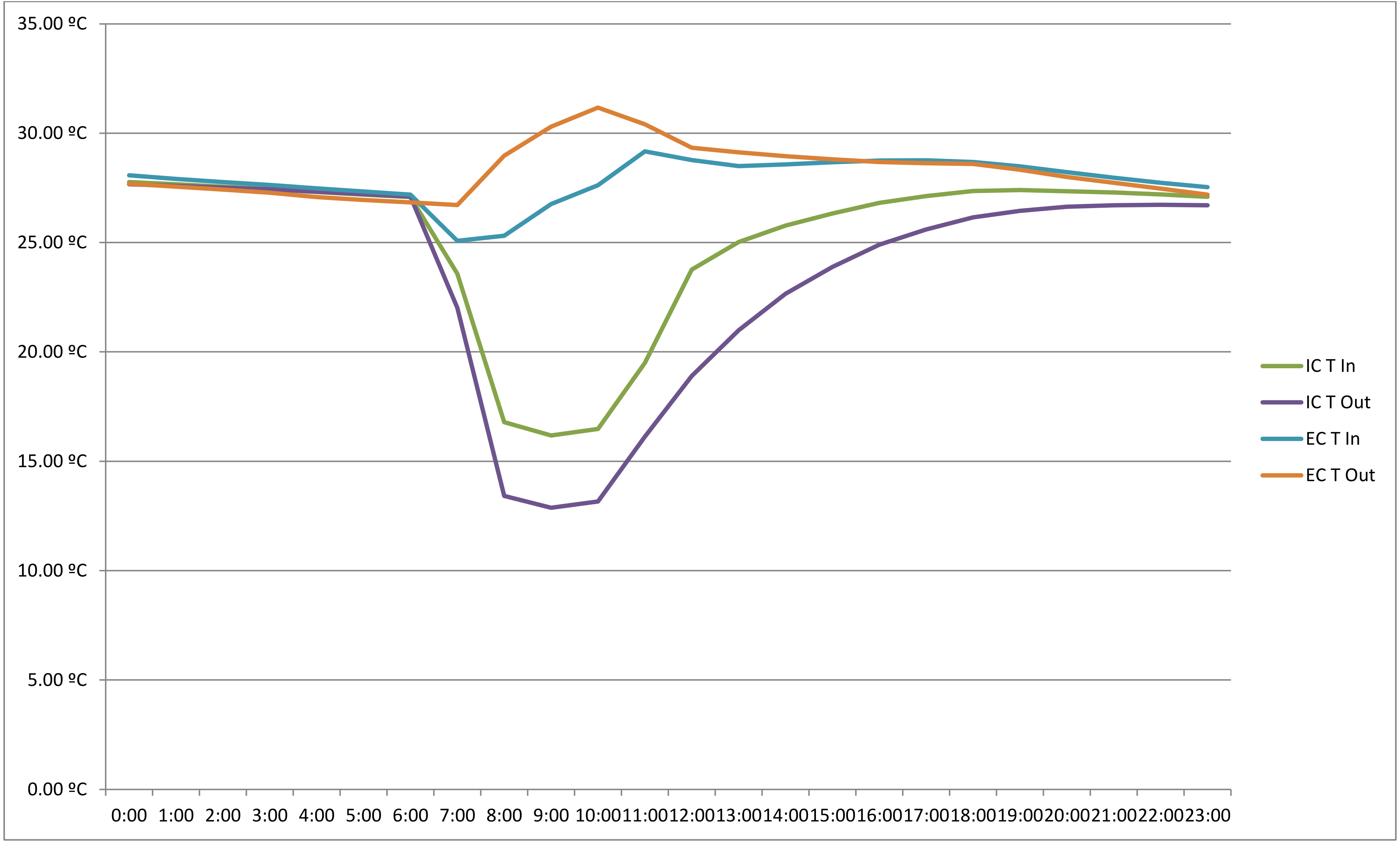
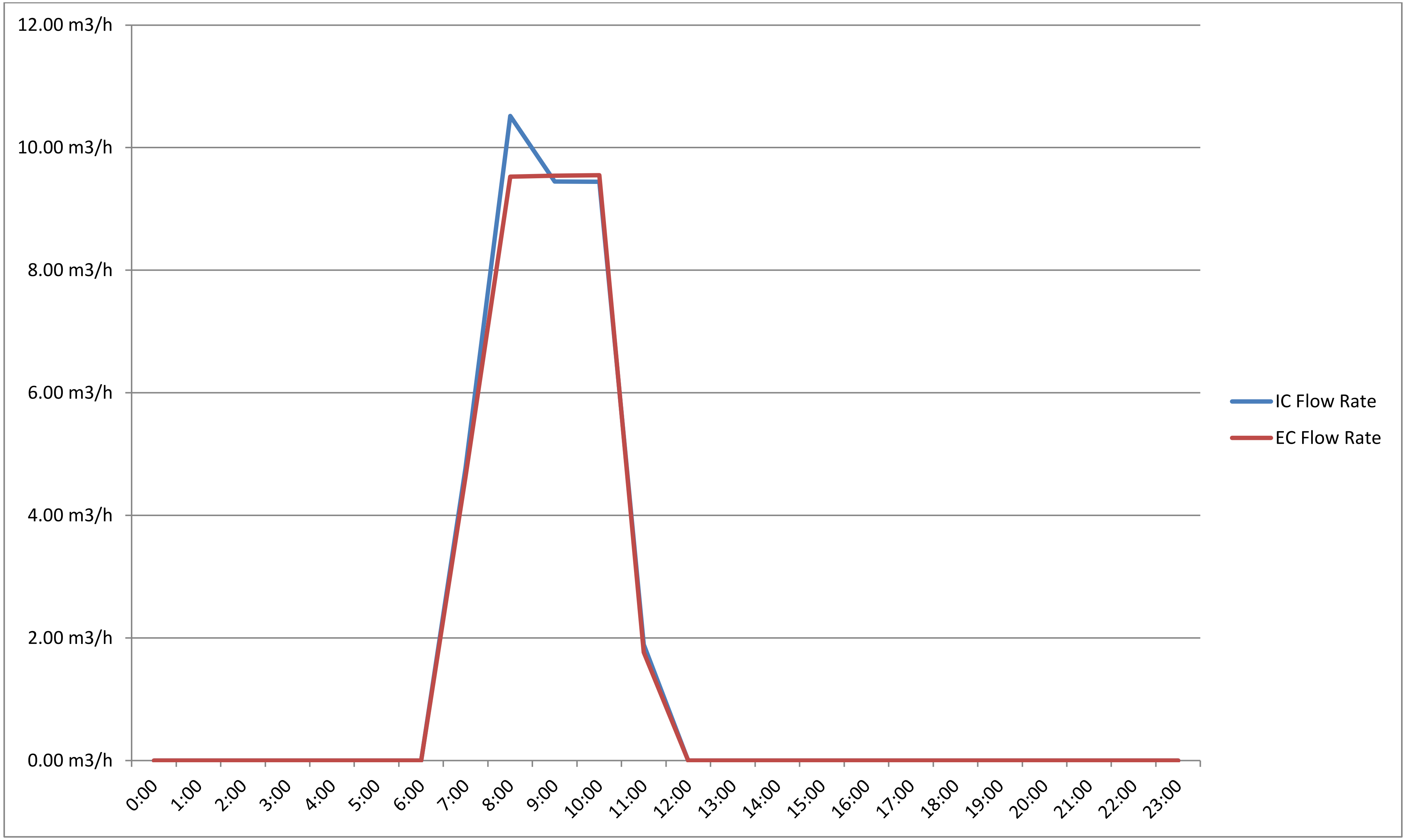


Graph3: External and Internal circuit (loop) flow rates



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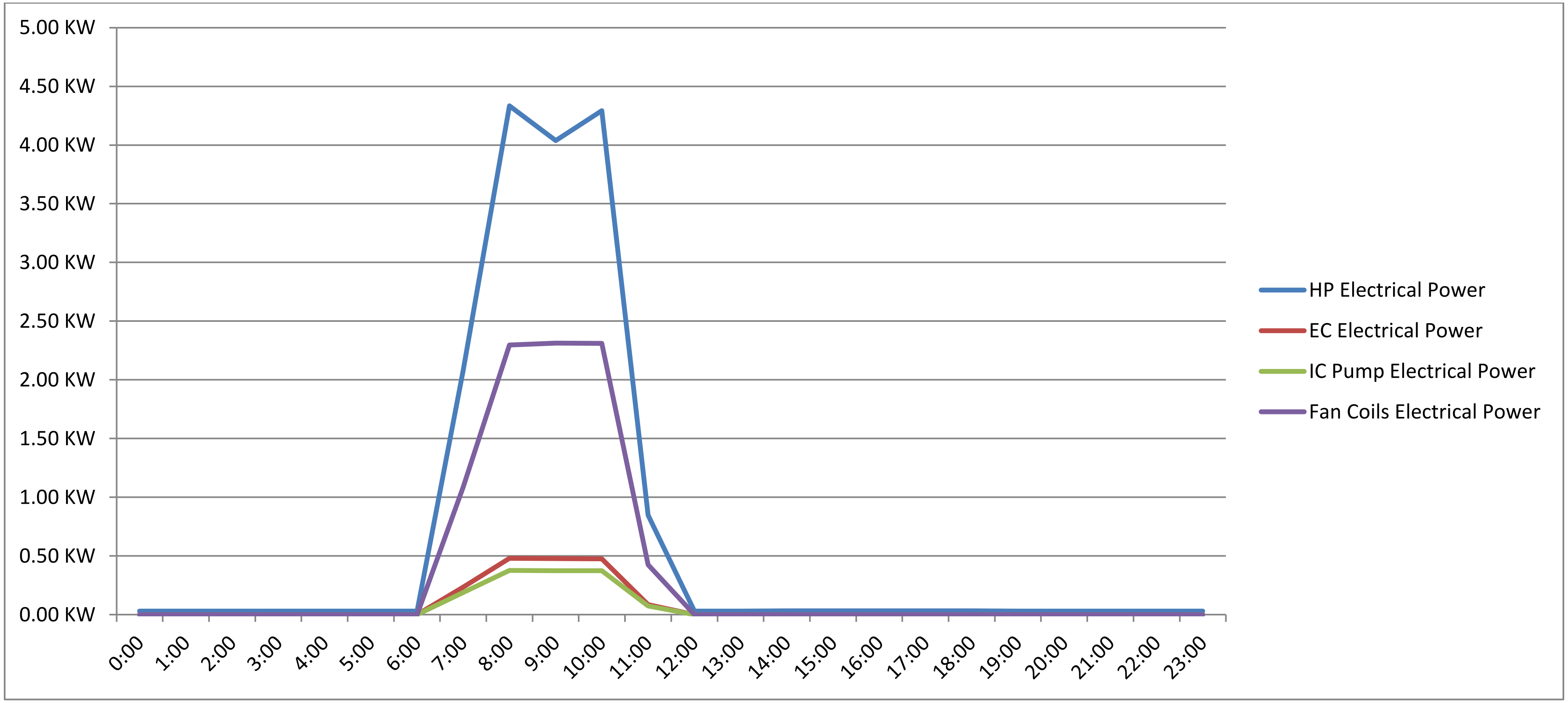

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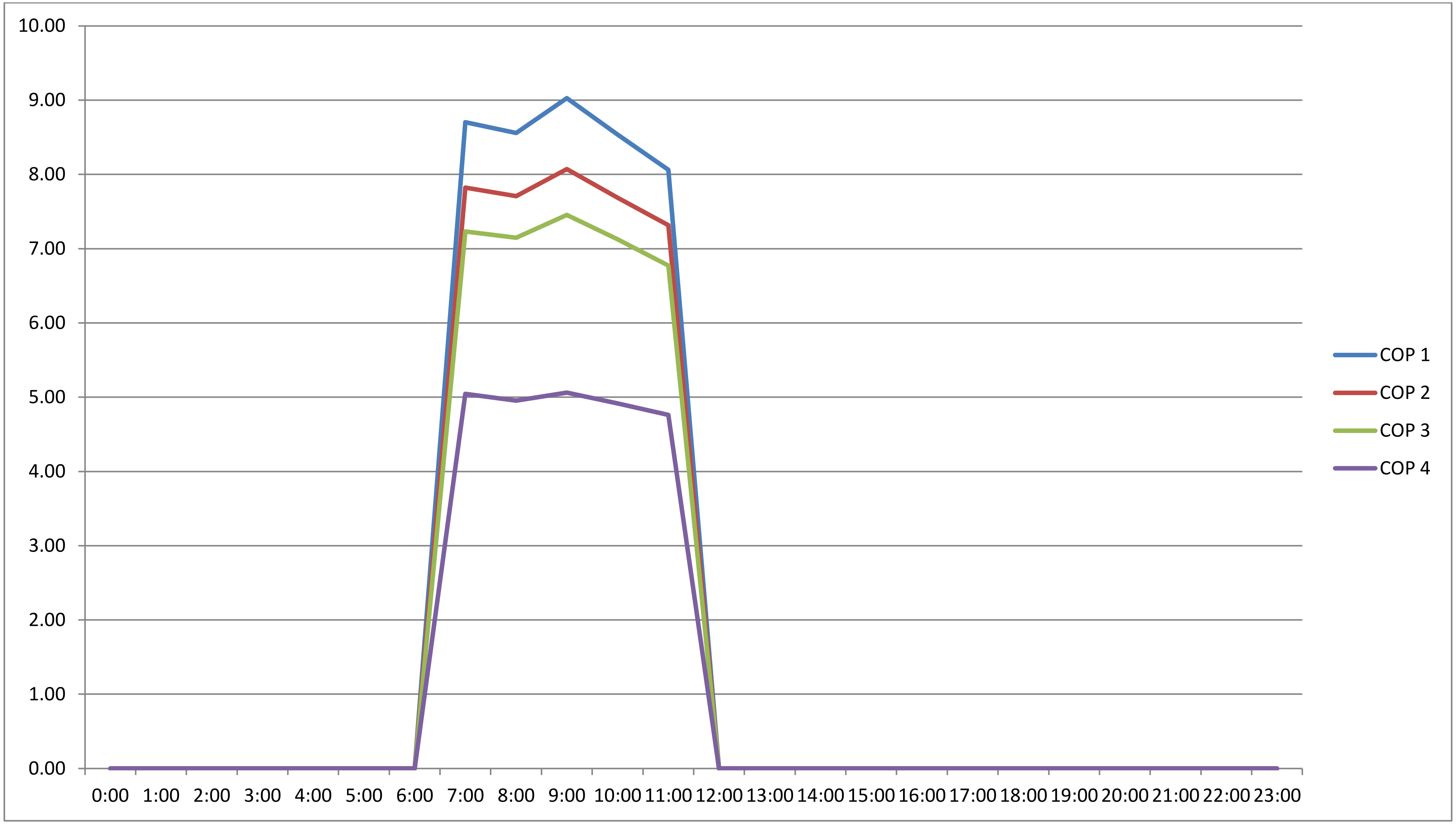
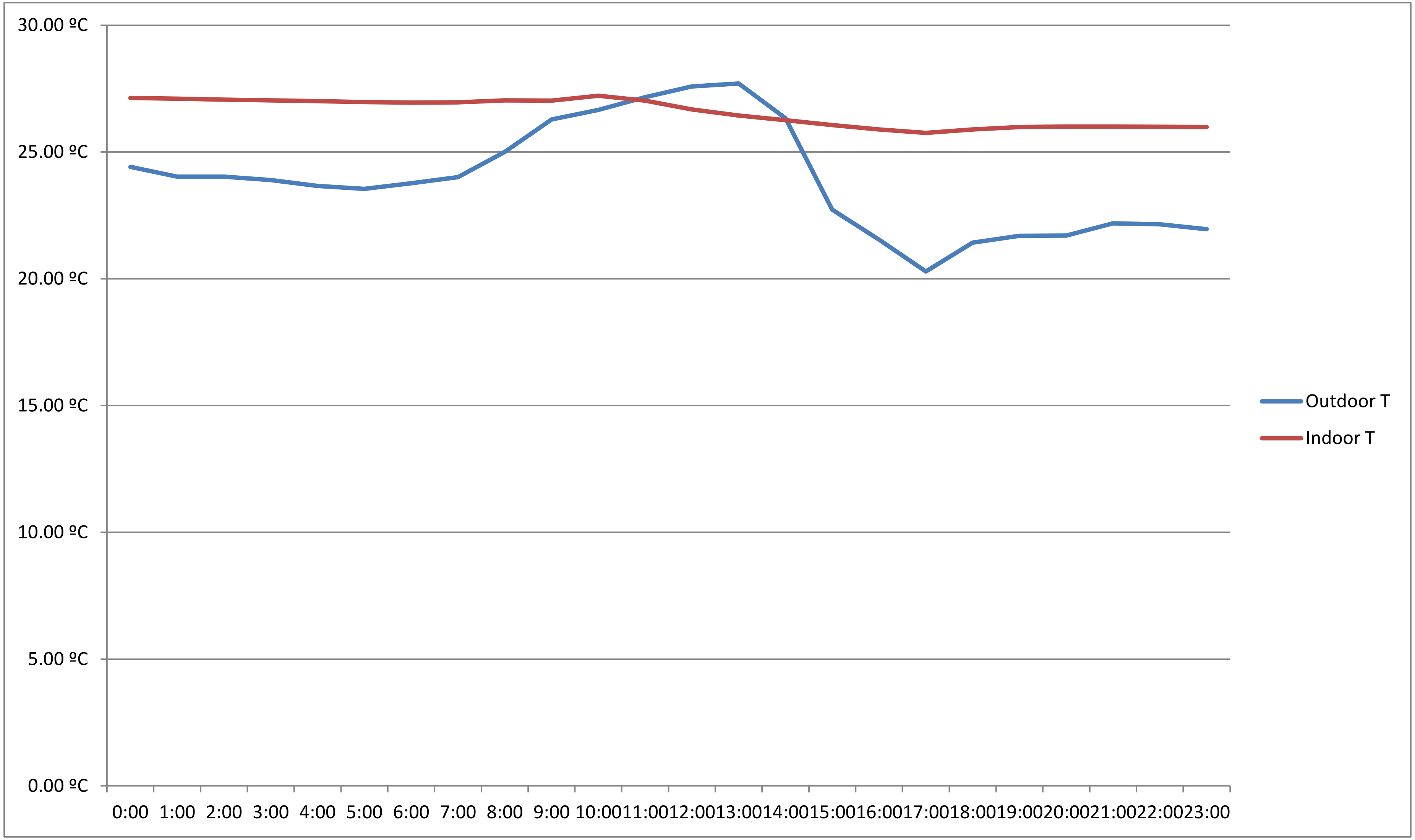
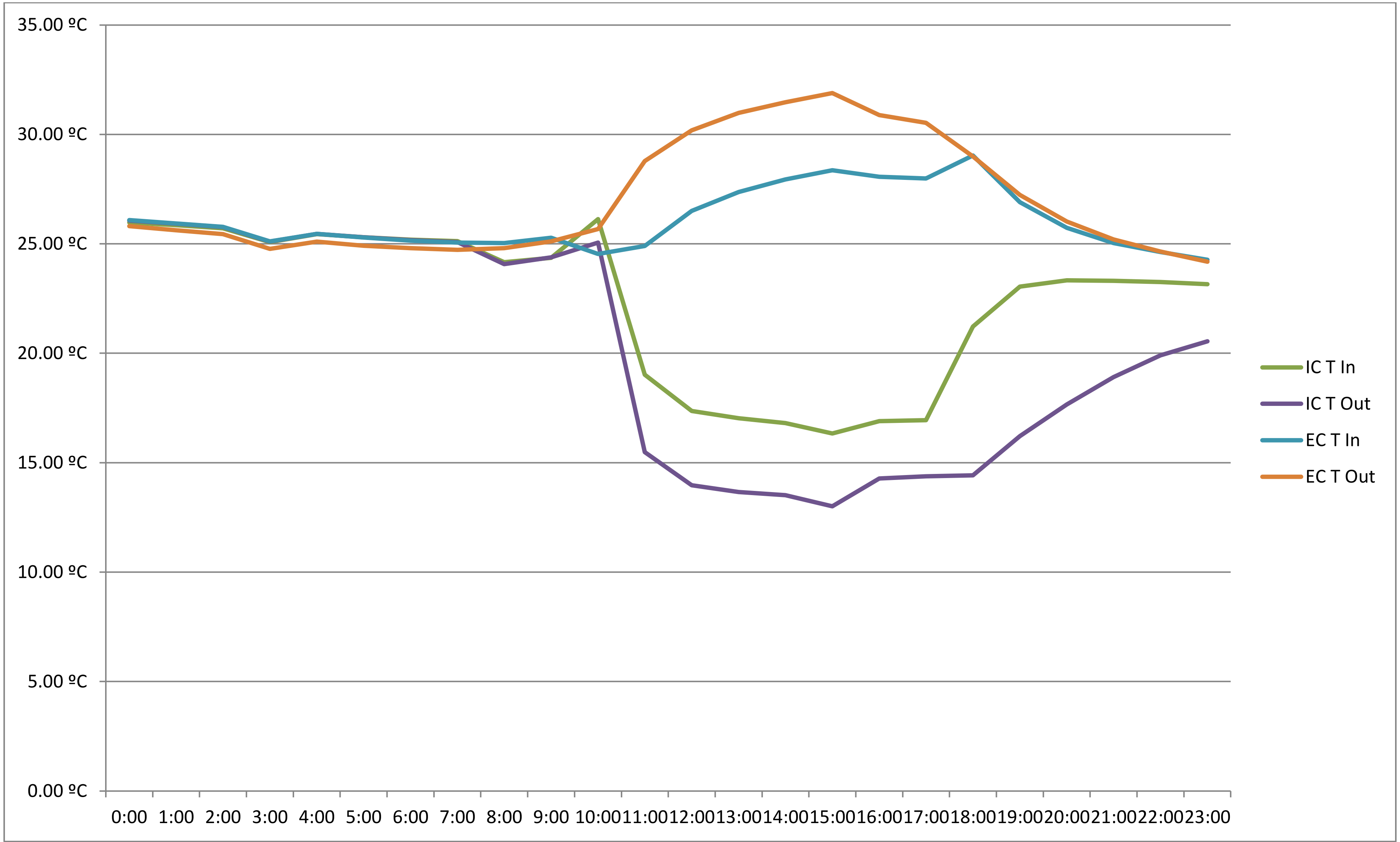


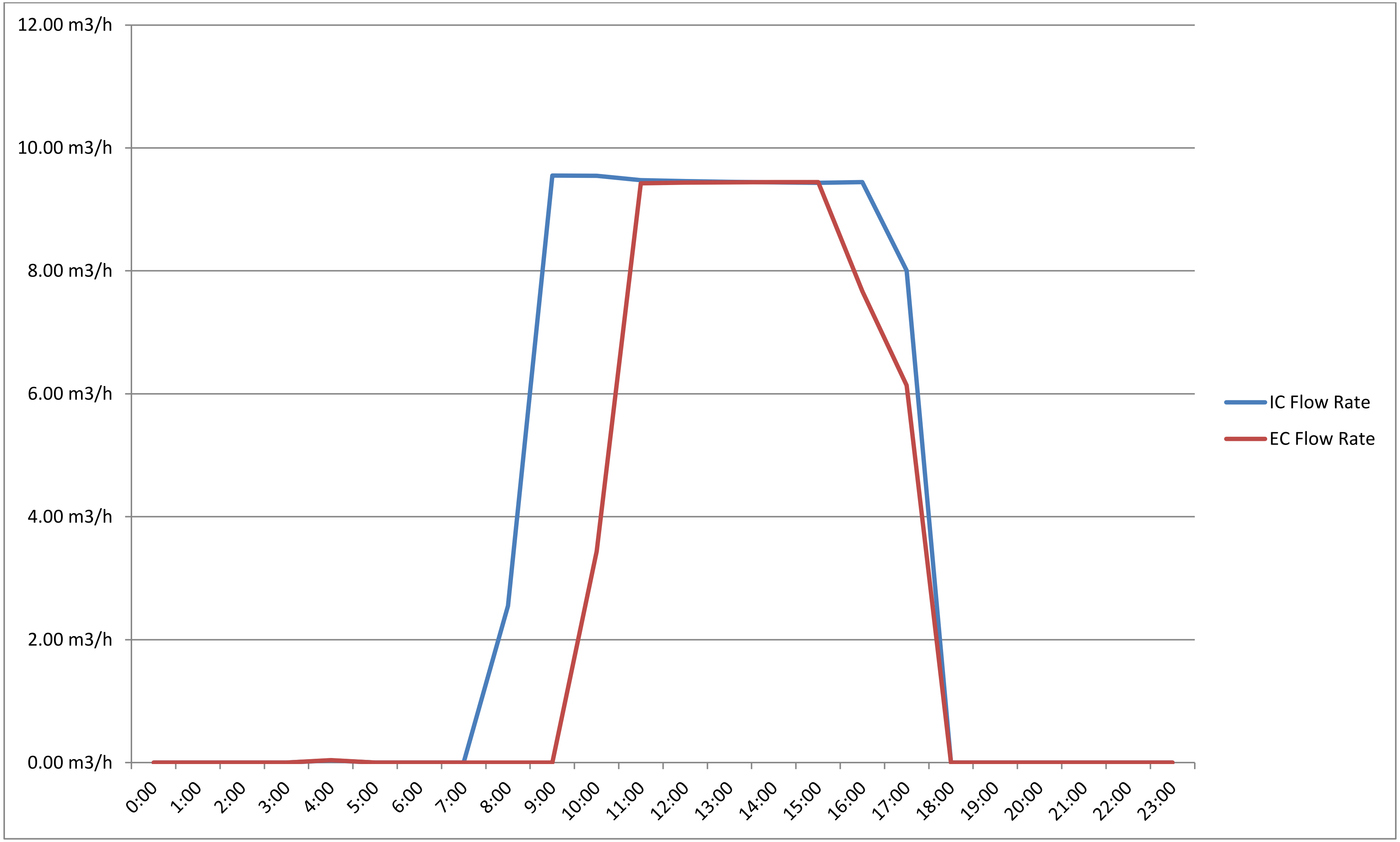
07/09/2013: Graph1: Ambient Temperature & Indoor Temperature



Graph2: External circuit (loop) Temperatures In and Out; Internal circuit (loop) Temperatures In and Out



Graph3: External and Internal circuit (loop) flow rates



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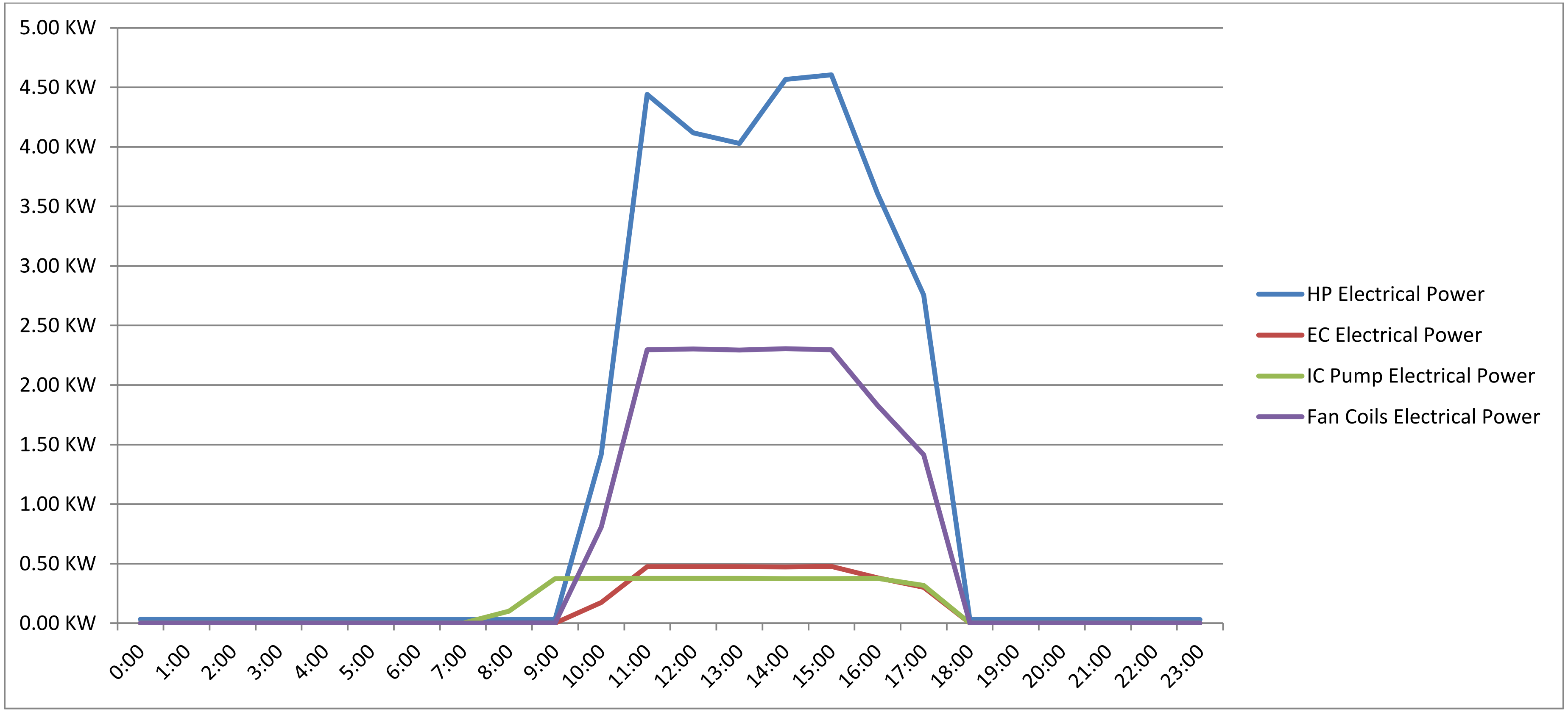

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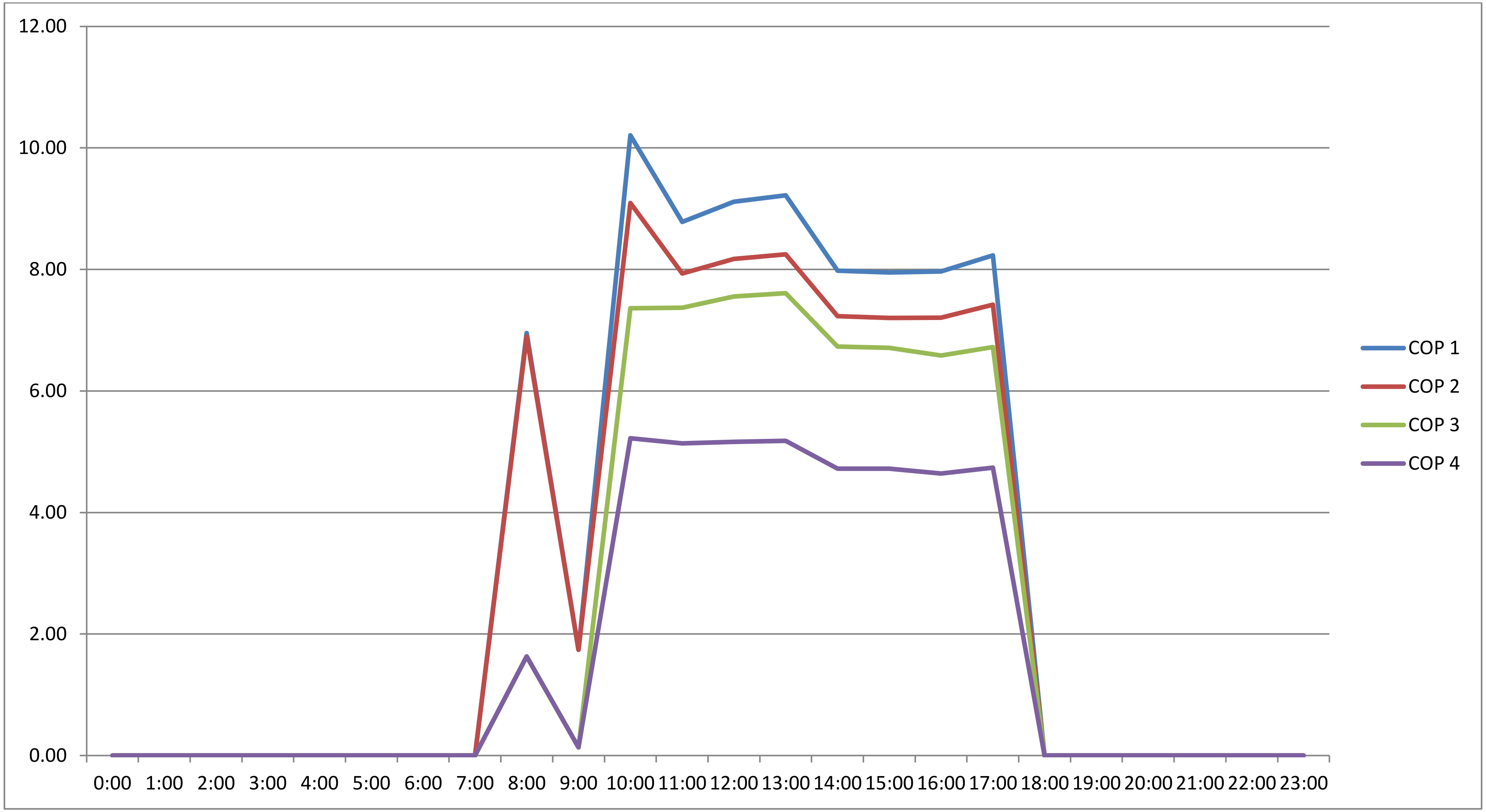
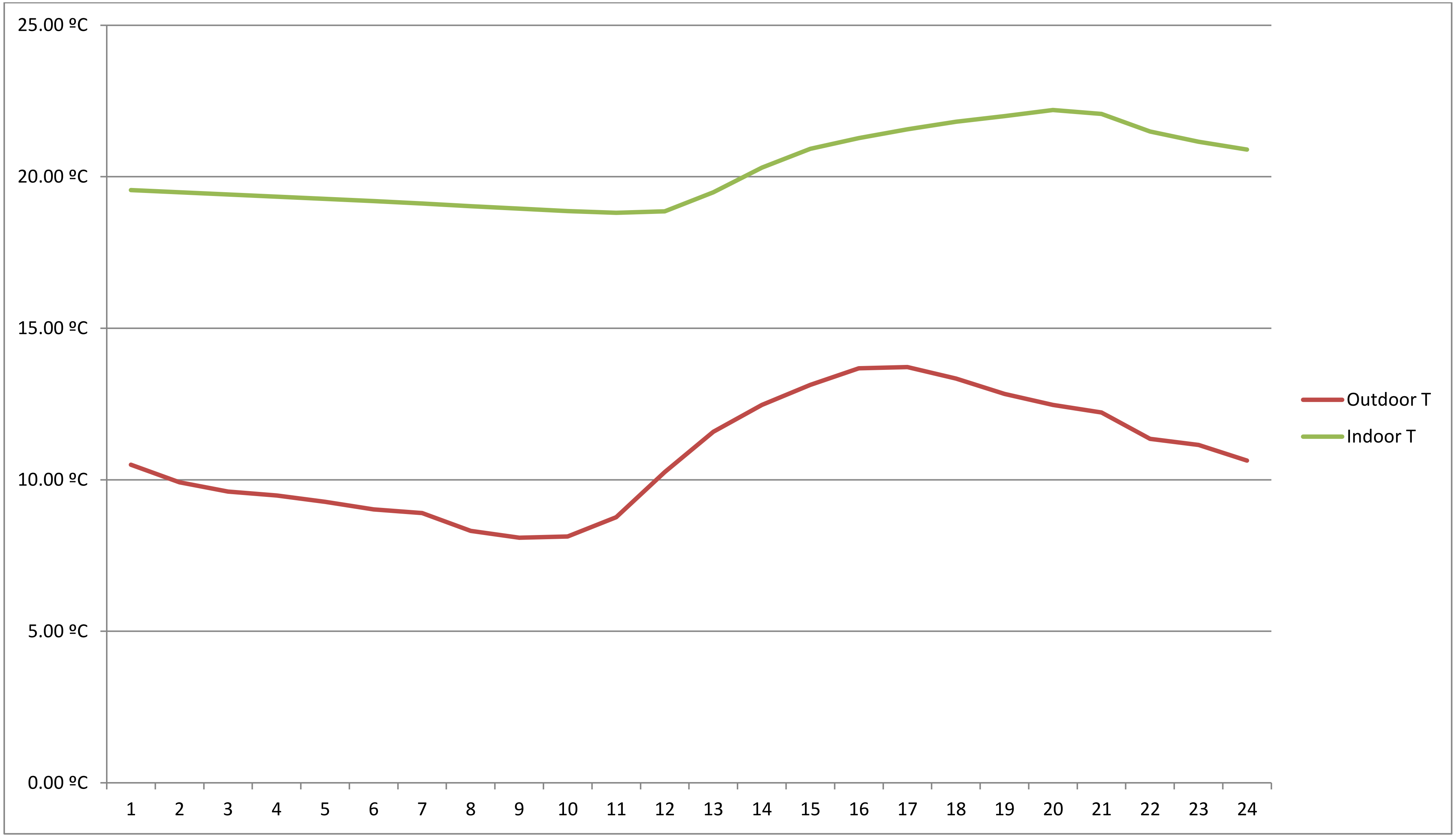


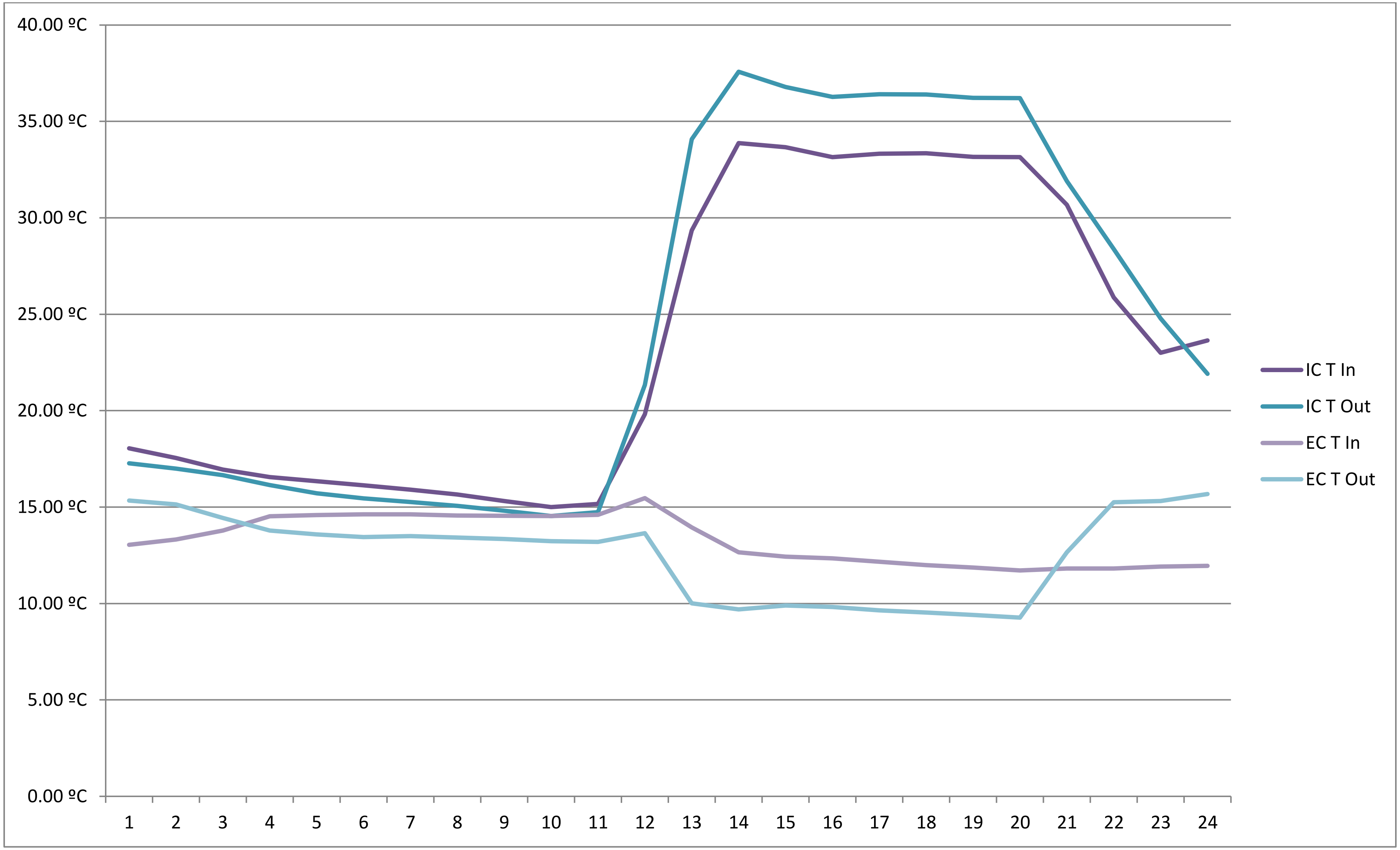
ANNEX II

HEATING DURING WINTER 2013-14

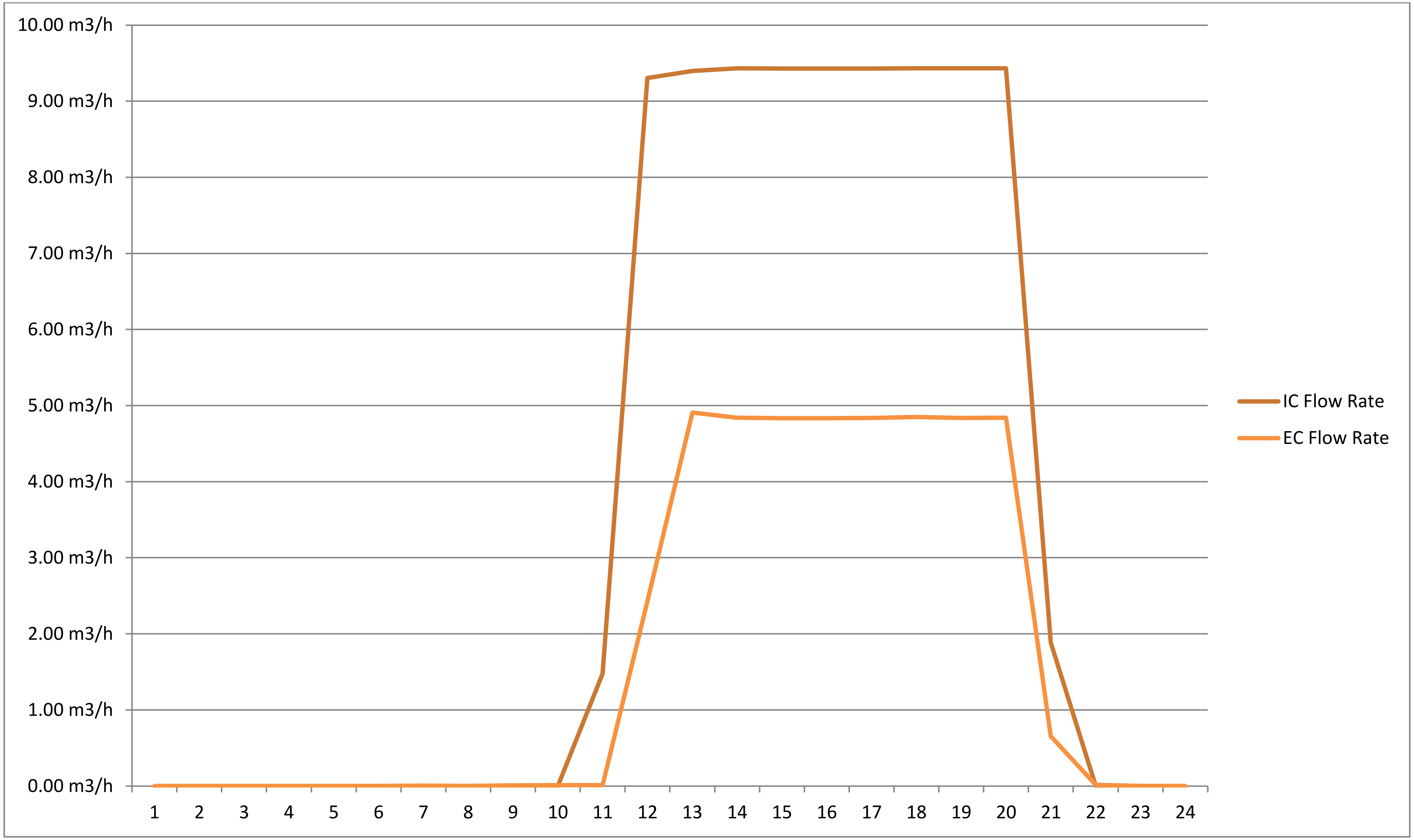
07/12/2013: Graph1: Ambient Temperature & Indoor Temperature



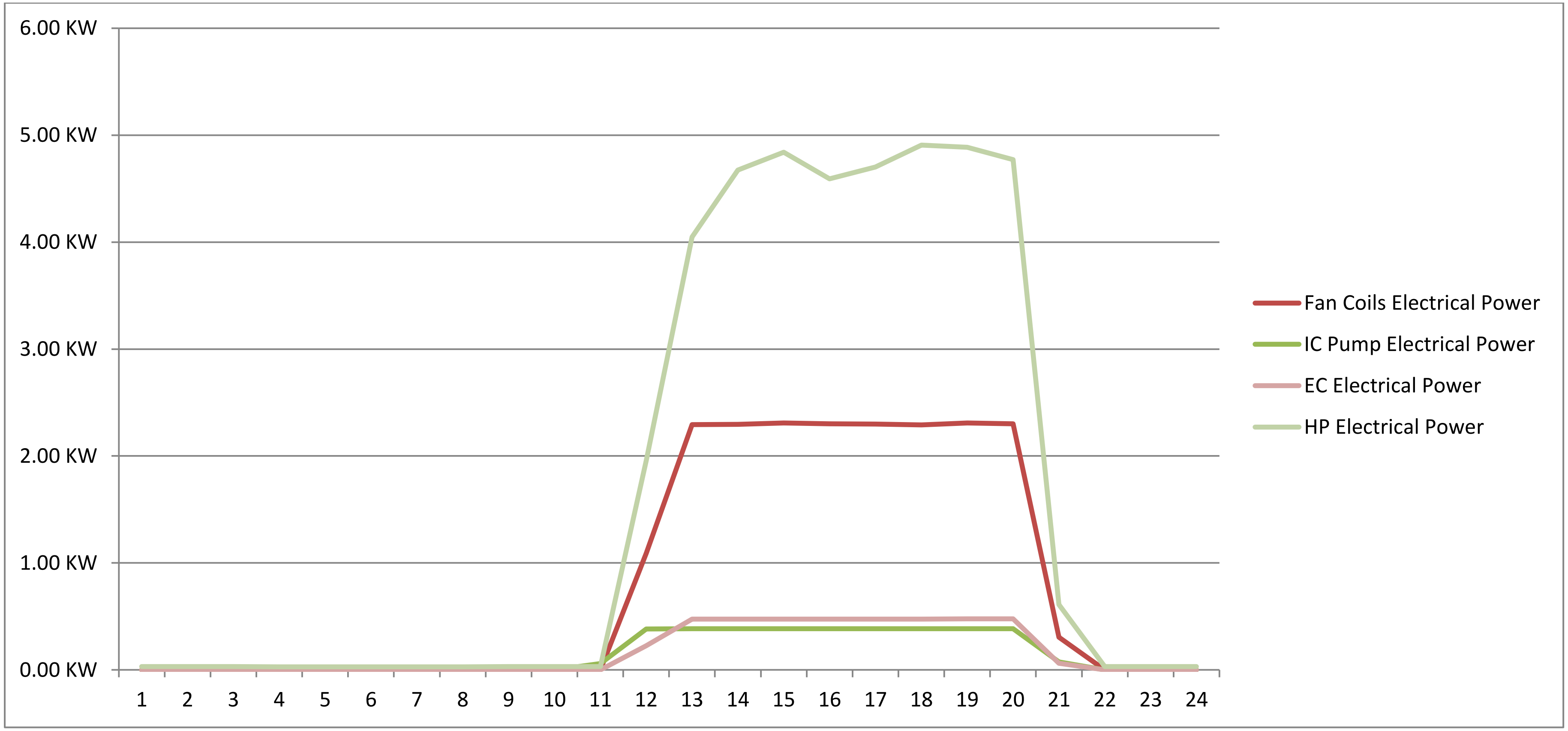
Graph2: External circuit (loop) Temperatures In and Out; Internal circuit (loop) Temperatures In and Out



Graph3: External and Internal circuit (loop) flow rates



Graph4: Thermal Power (heating , cooling & sanitary hot water) delivered to the building; Thermal Power to/from the BHE; Electrical Power consumption at the compressor (heat pump); Electrical Power consumption at the external pump; Electrical Power consumption at the internal pumps; Electrical Power consumption at the fans (FCUs or AHU)



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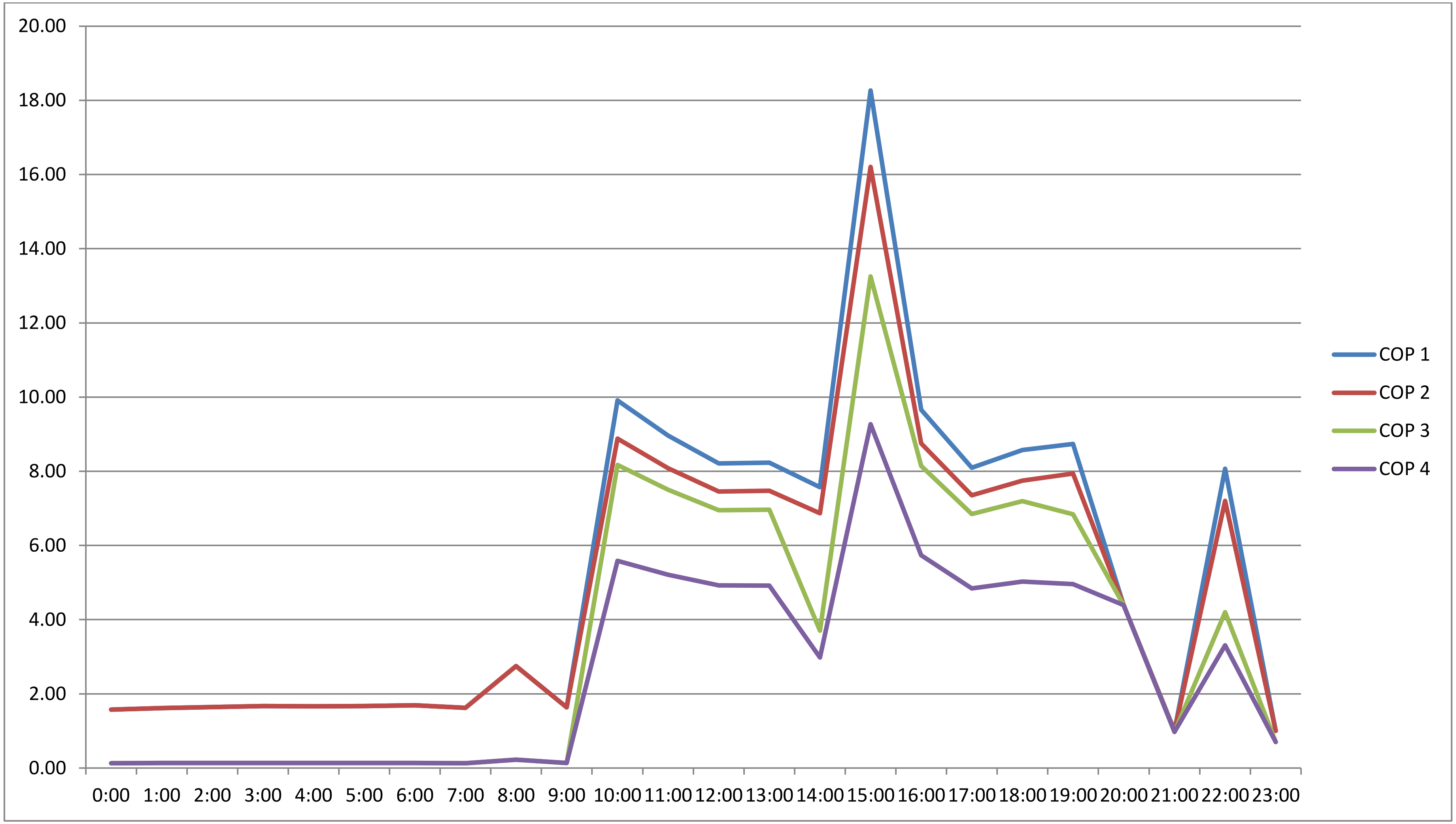
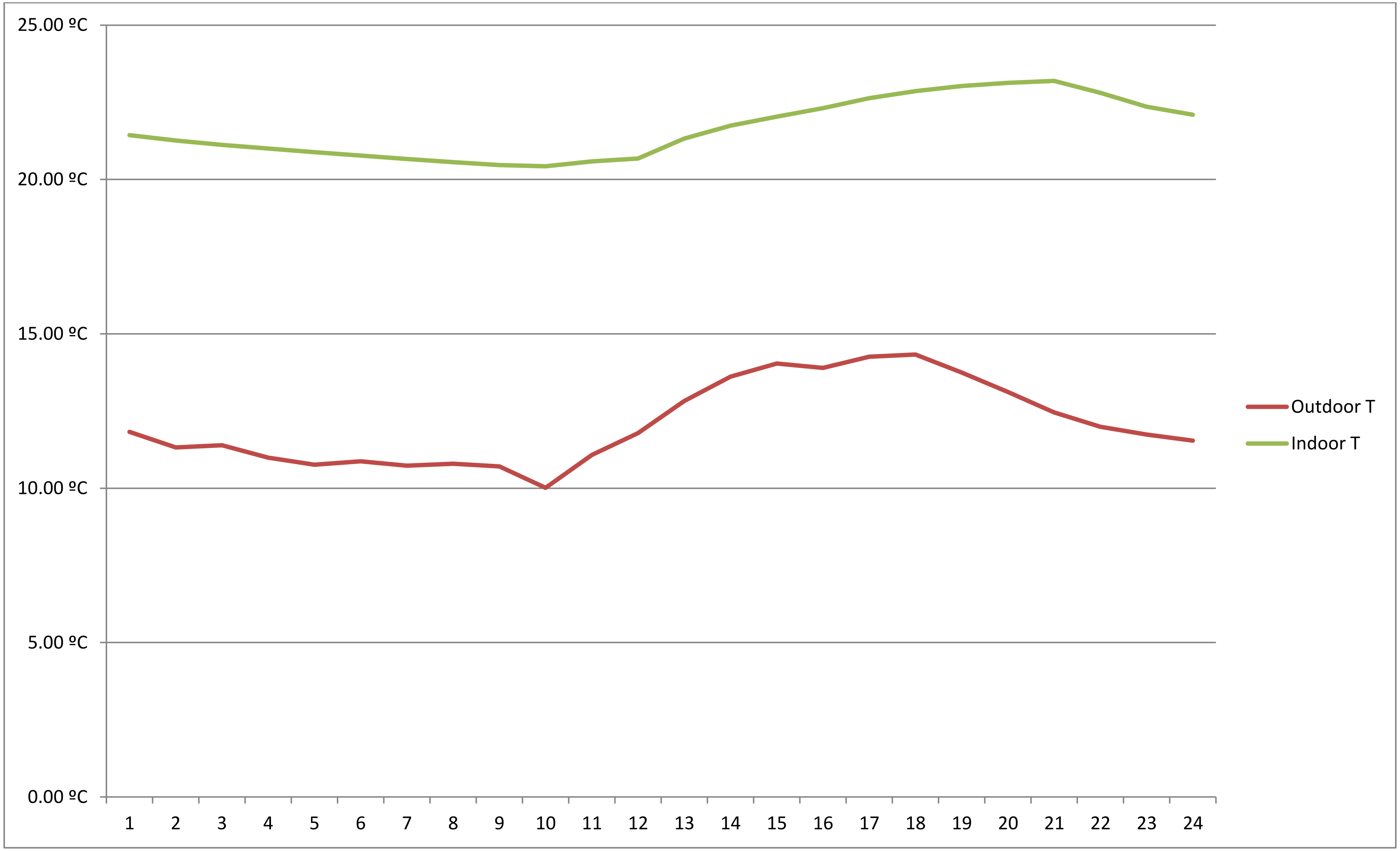
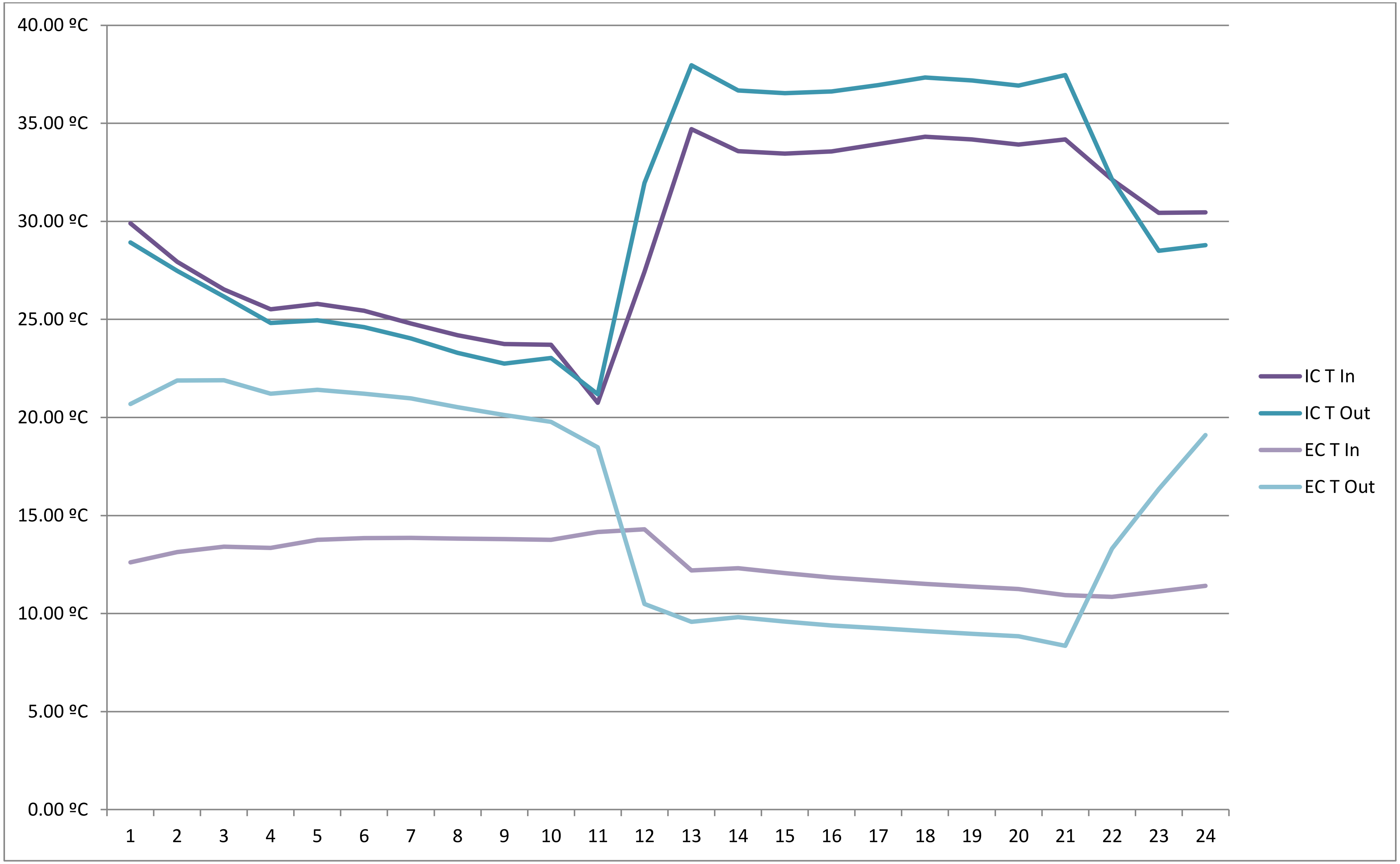


14/01/2014: Graph1: Ambient Temperature & Indoor Temperature



Graph2: External circuit (loop) Temperatures In and Out; Internal circuit (loop) Temperatures In and Out



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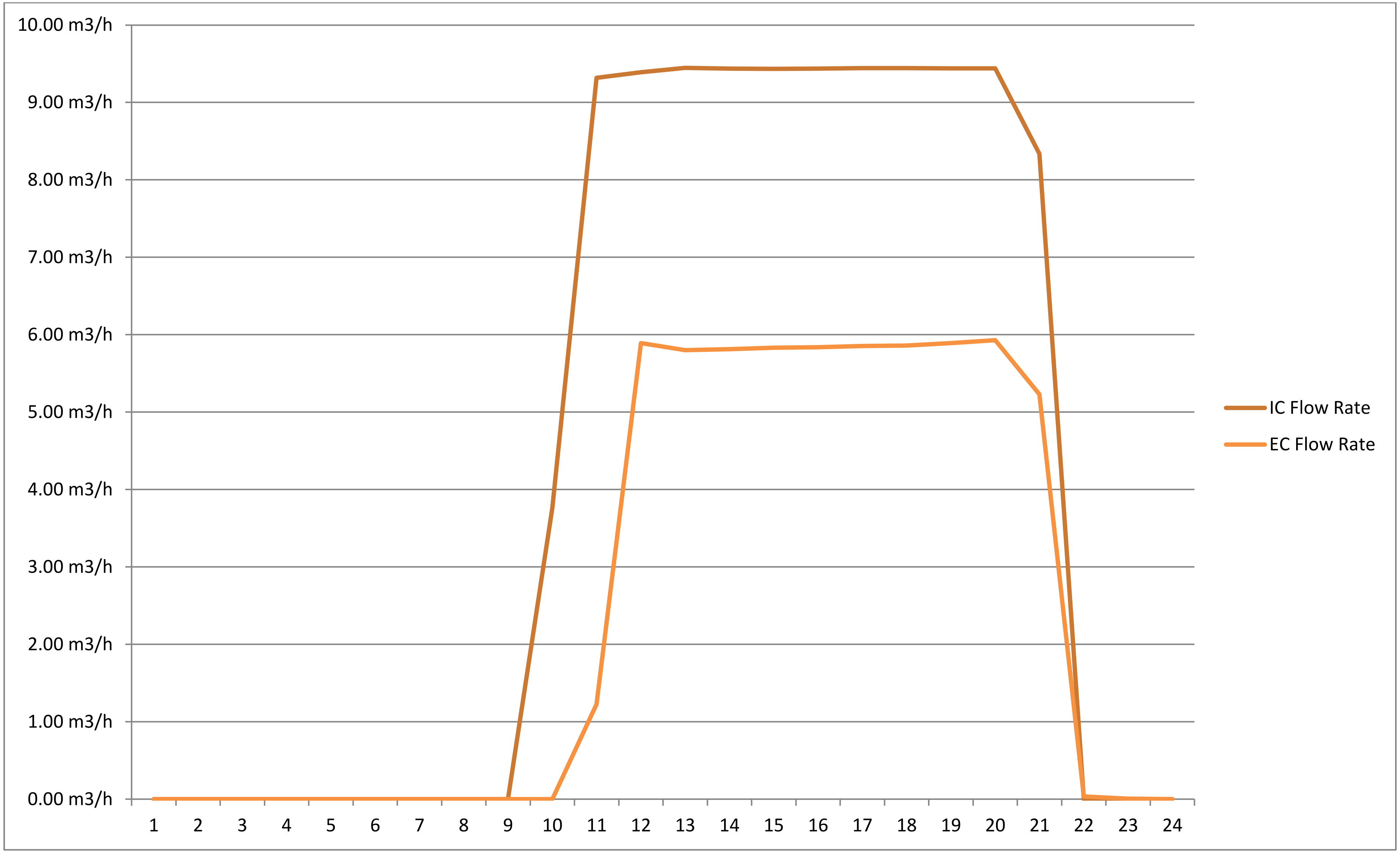

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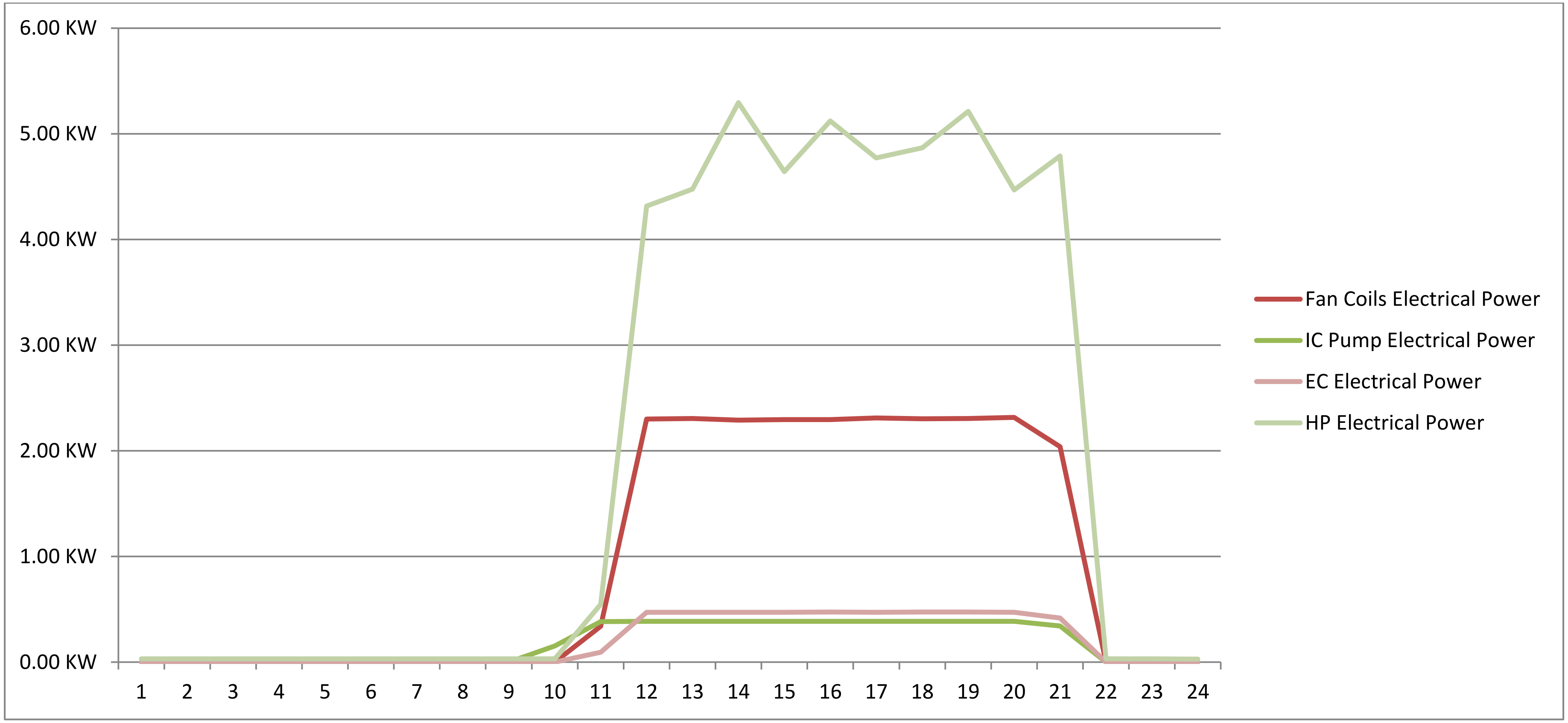

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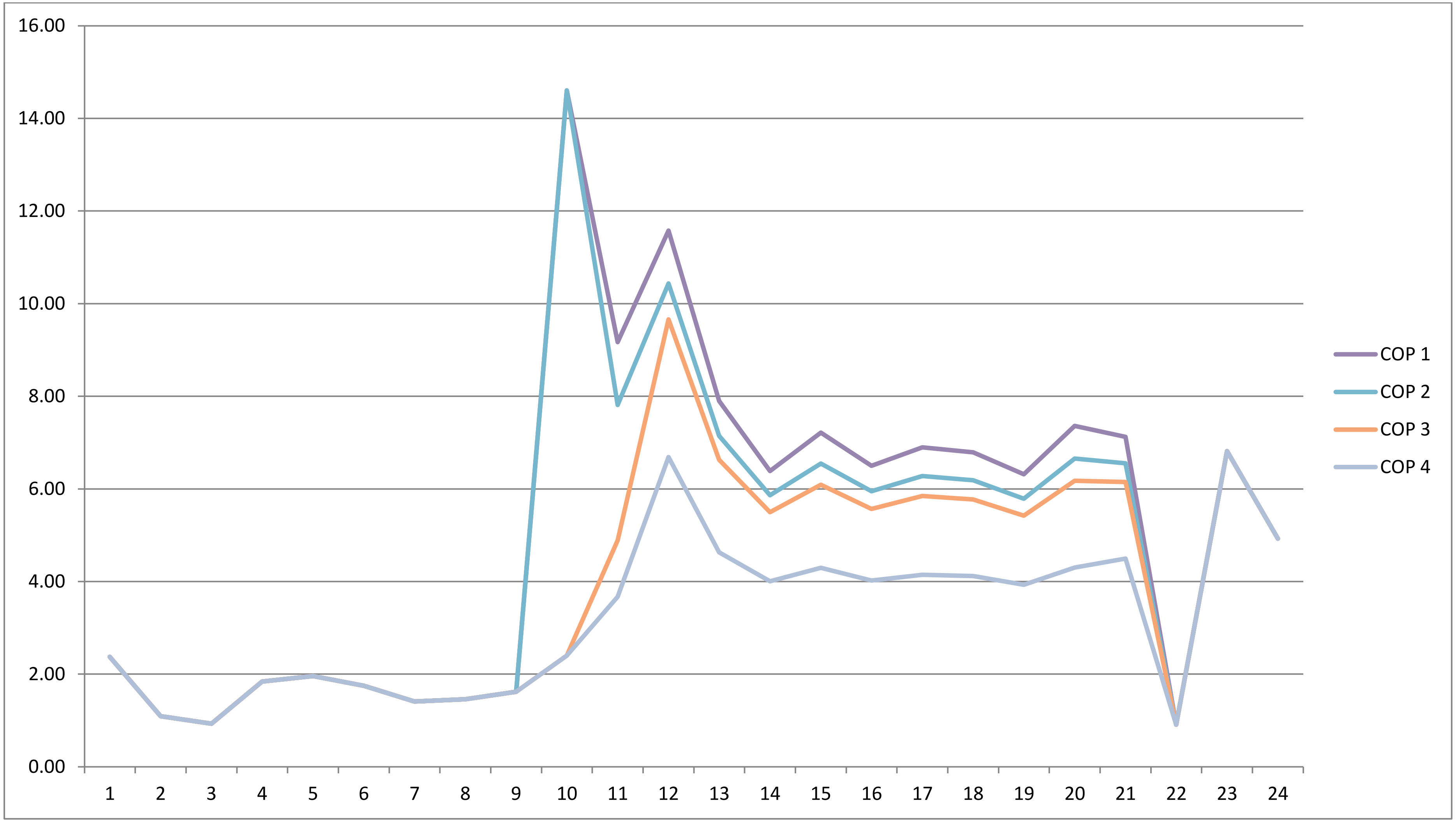
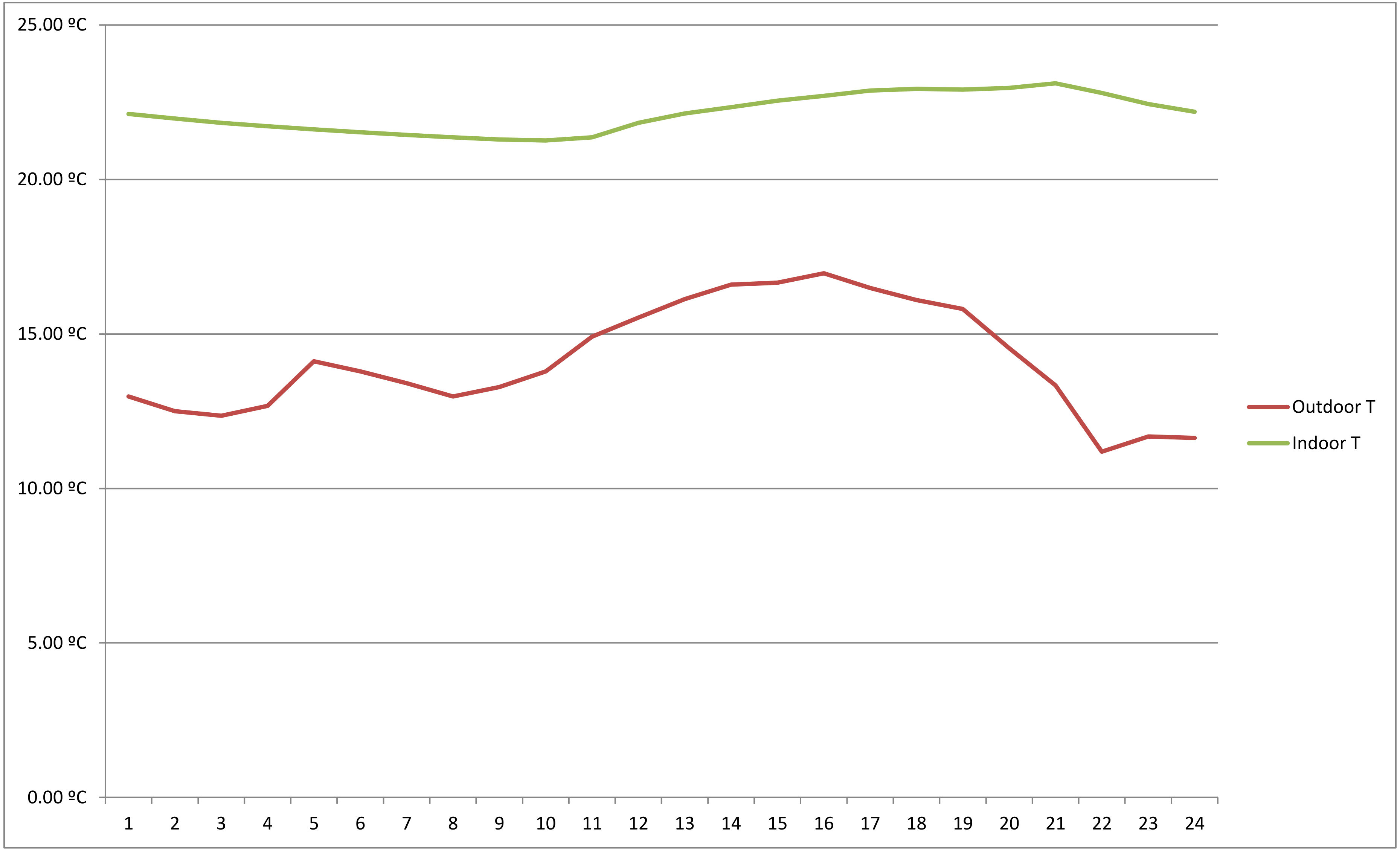


21/02/2014: Graph1: Ambient Temperature & Indoor Temperature



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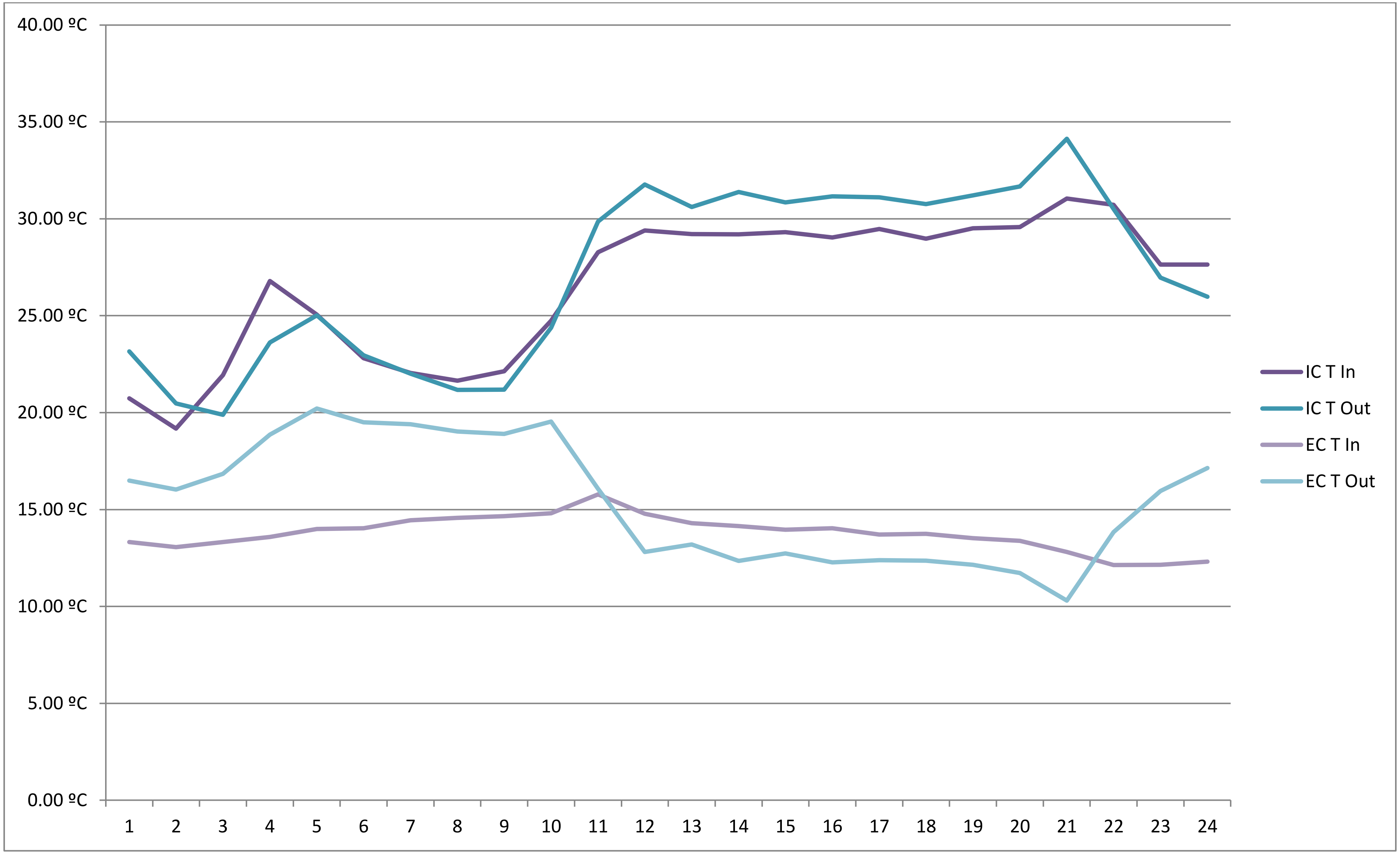

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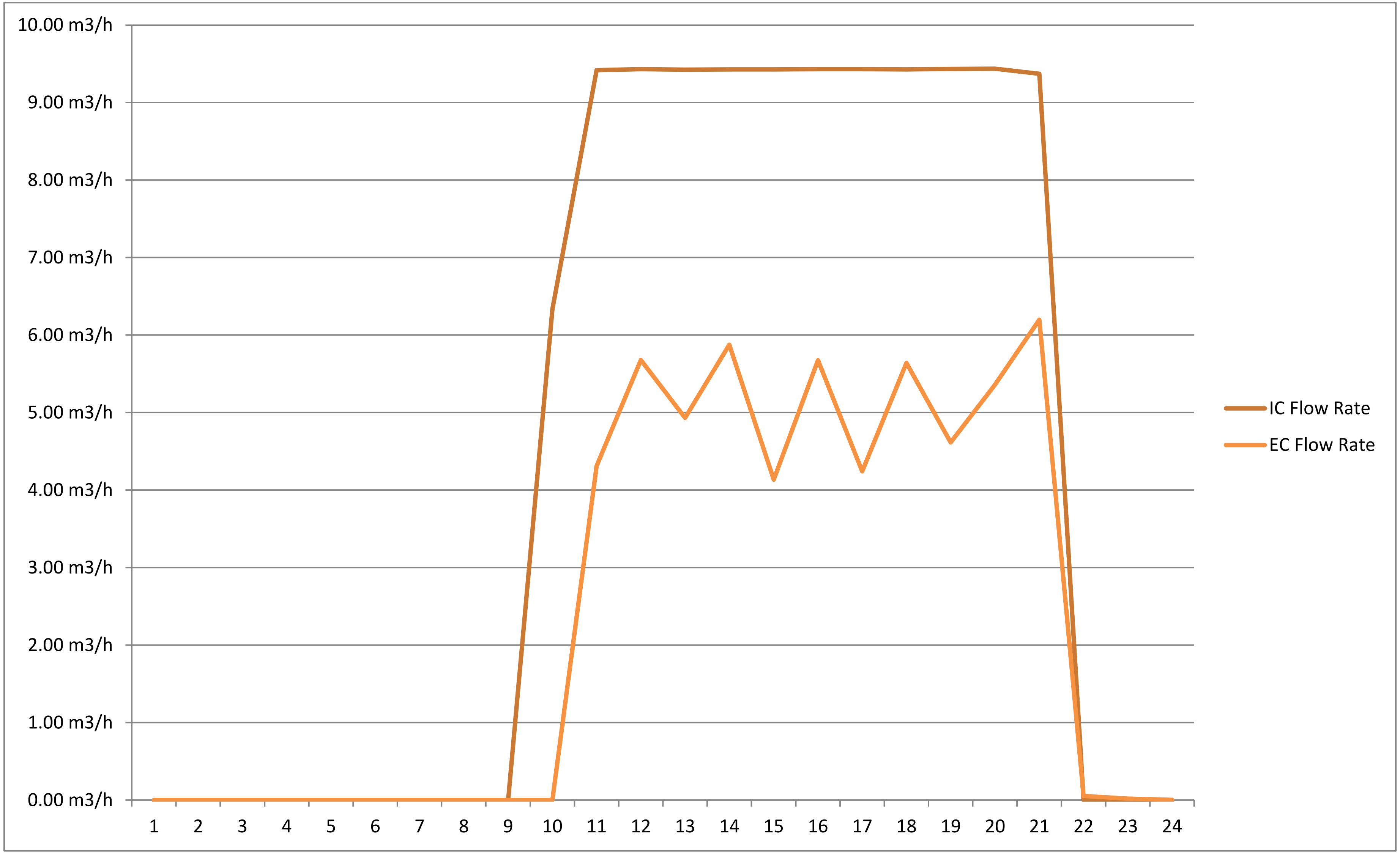

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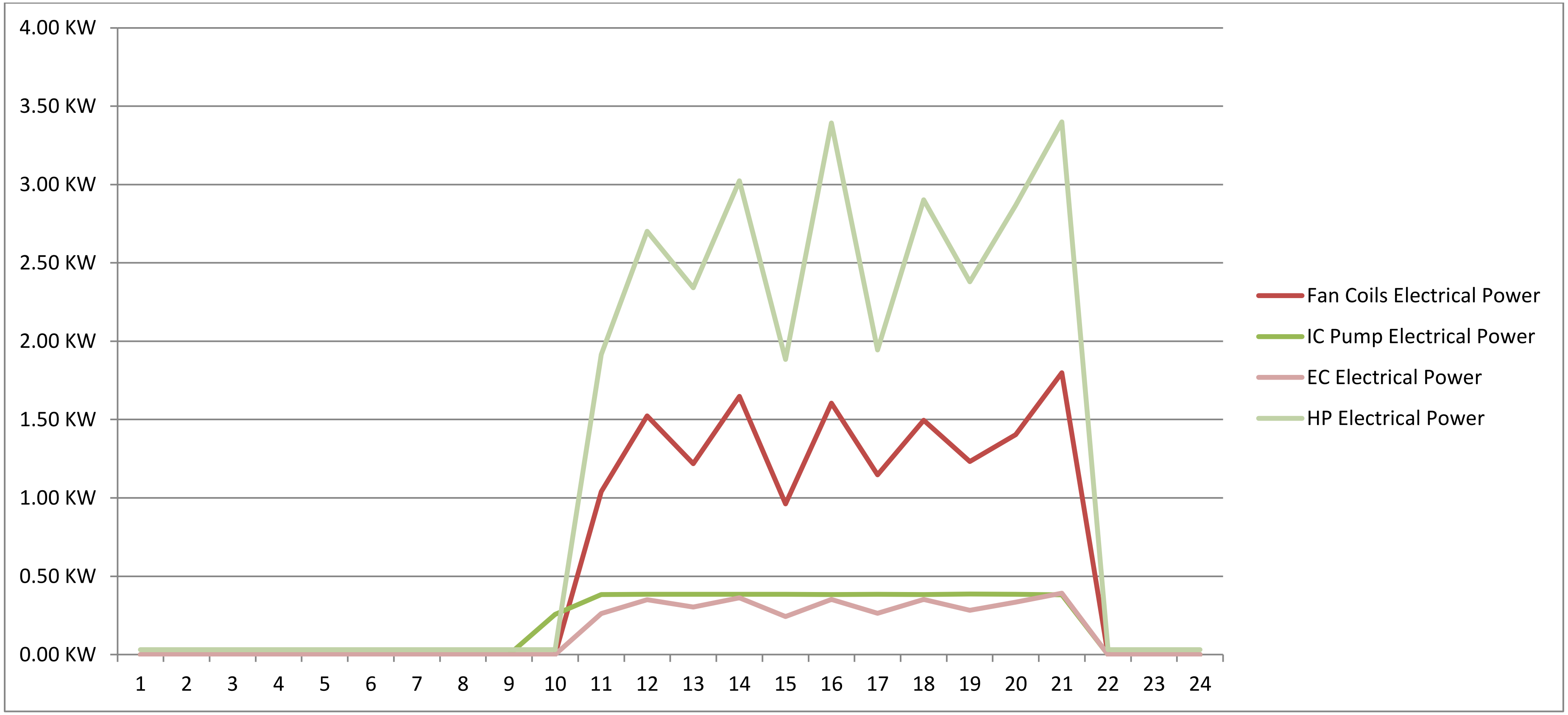

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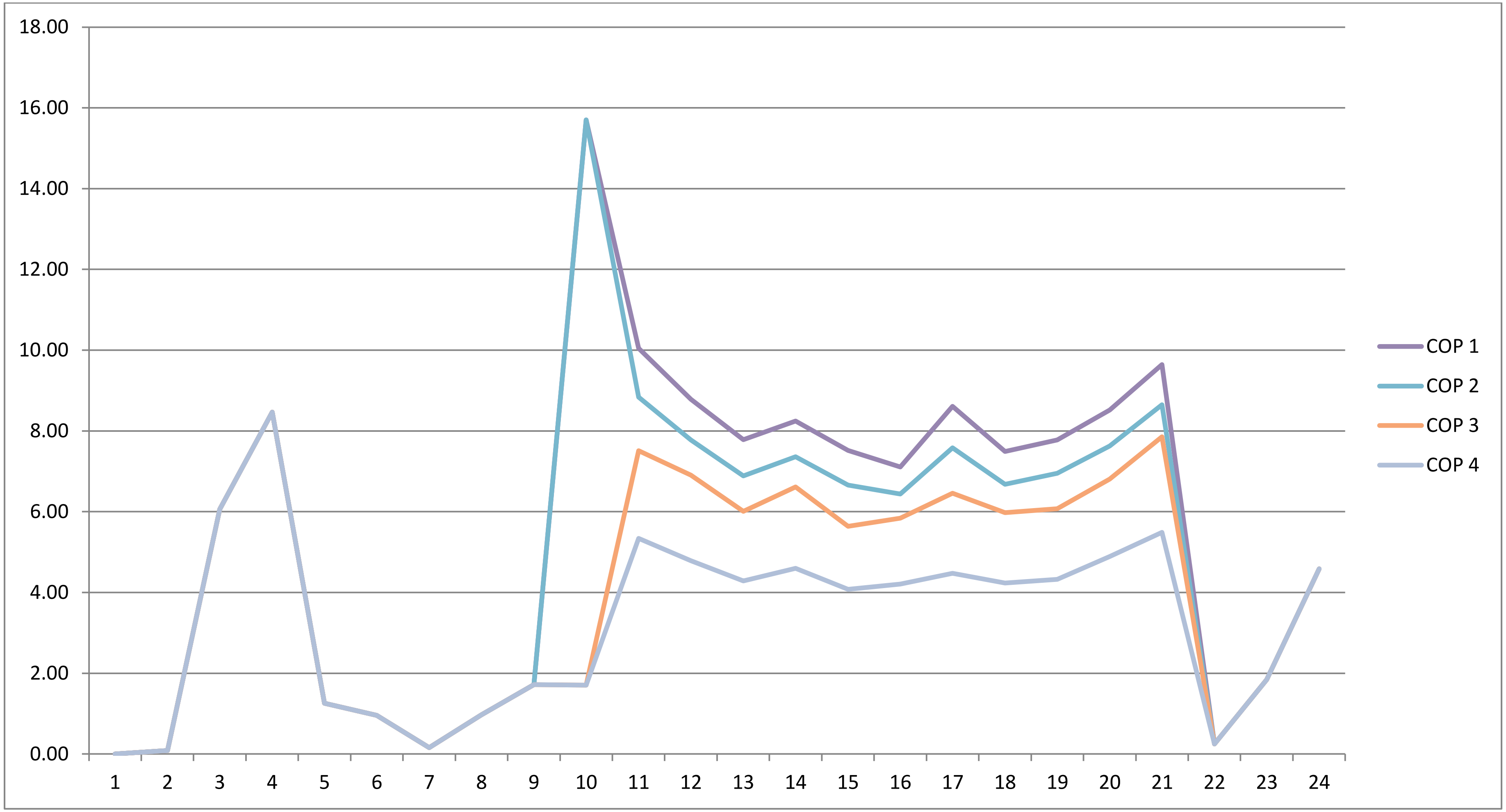
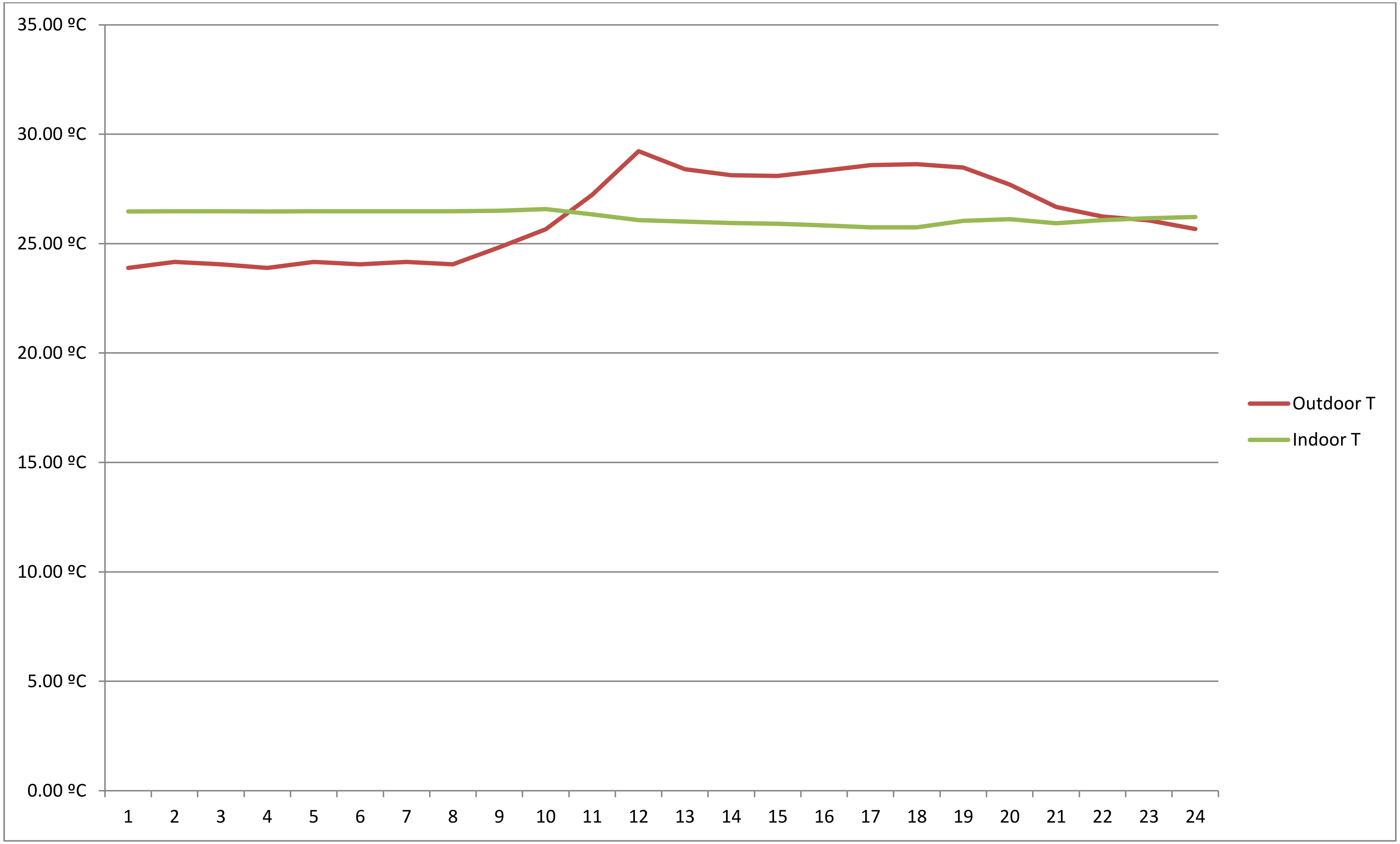


ANNEX III

COOLING DURING SUMMER 2014

16/07/2014: Graph1: Ambient Temperature & Indoor Temperature



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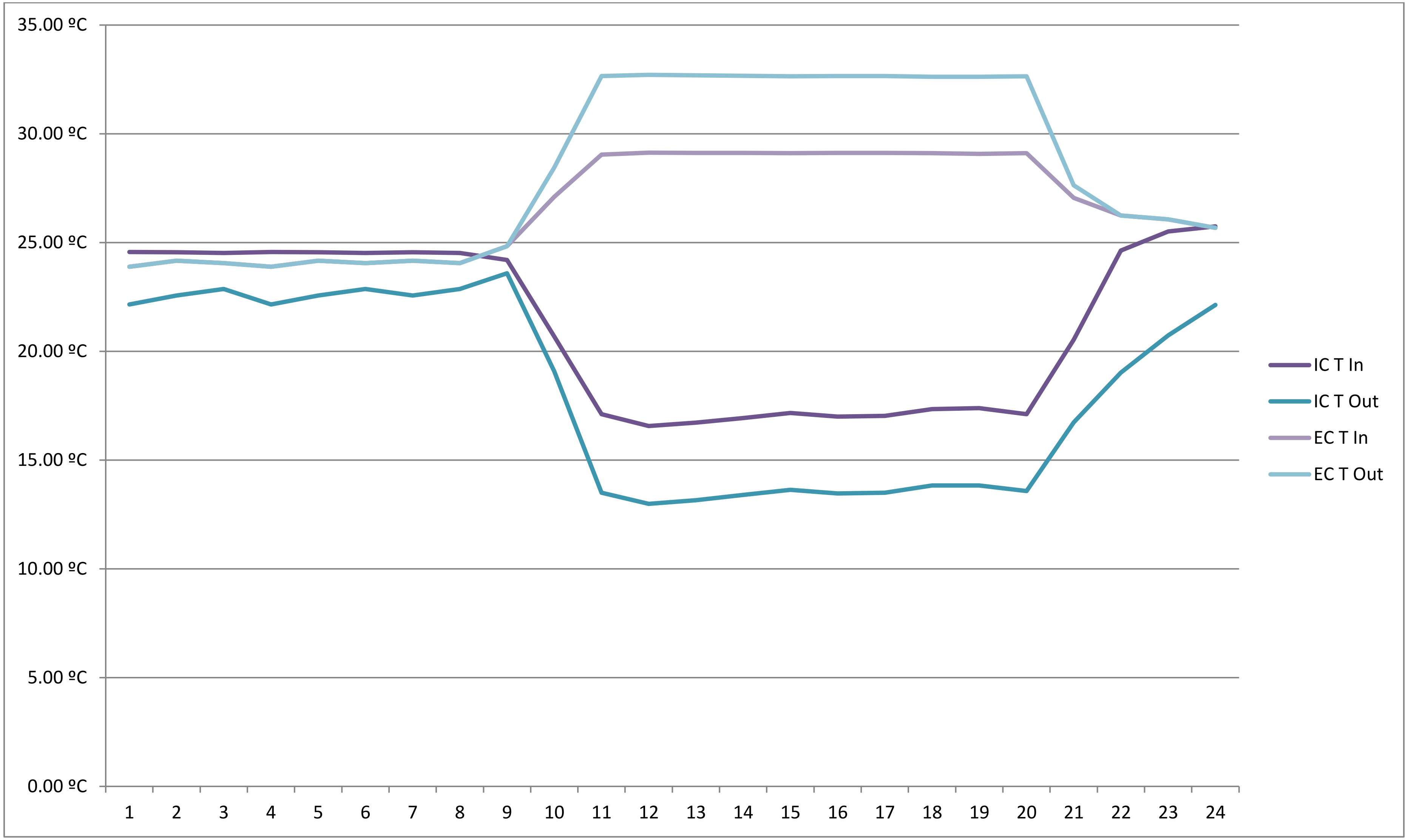

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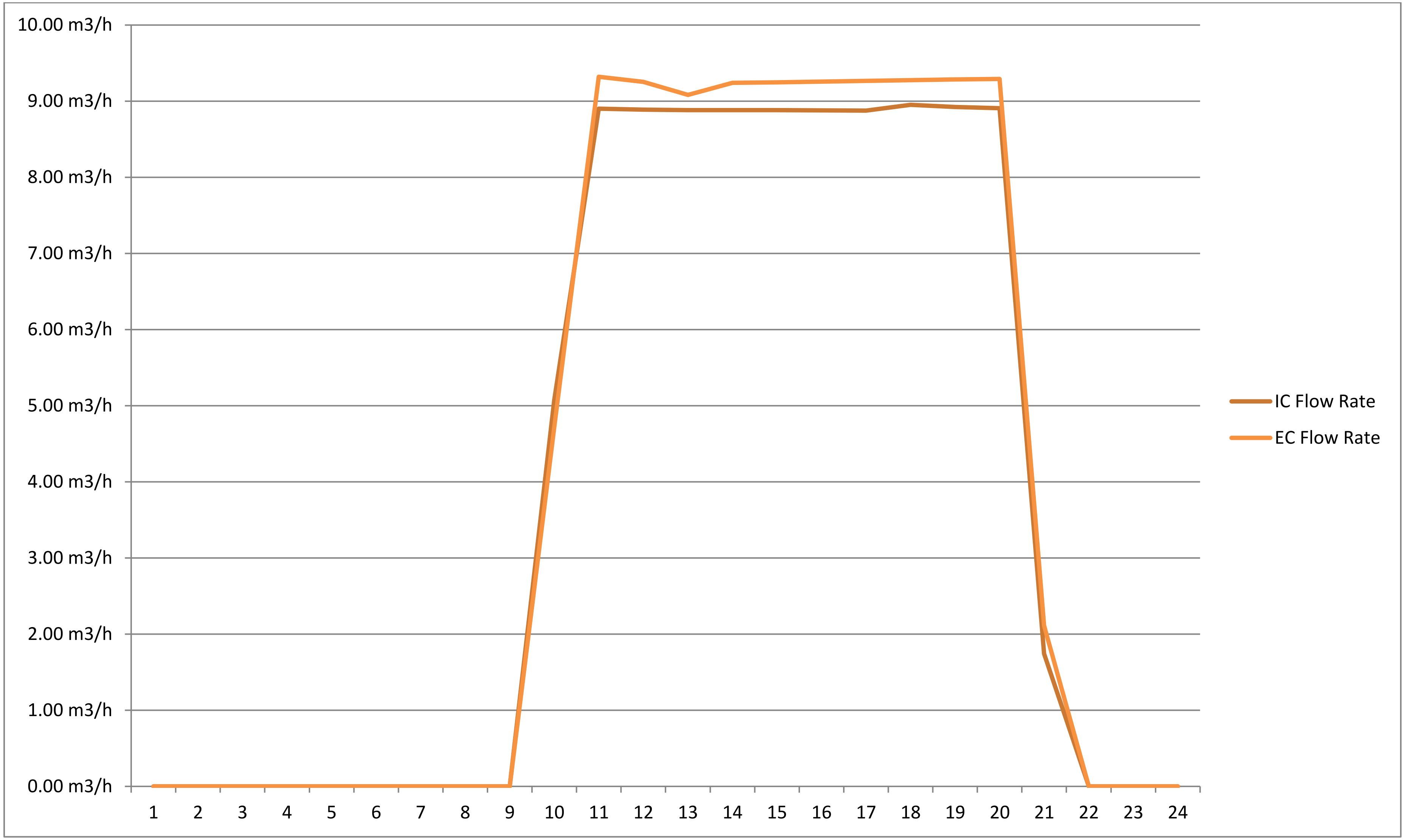
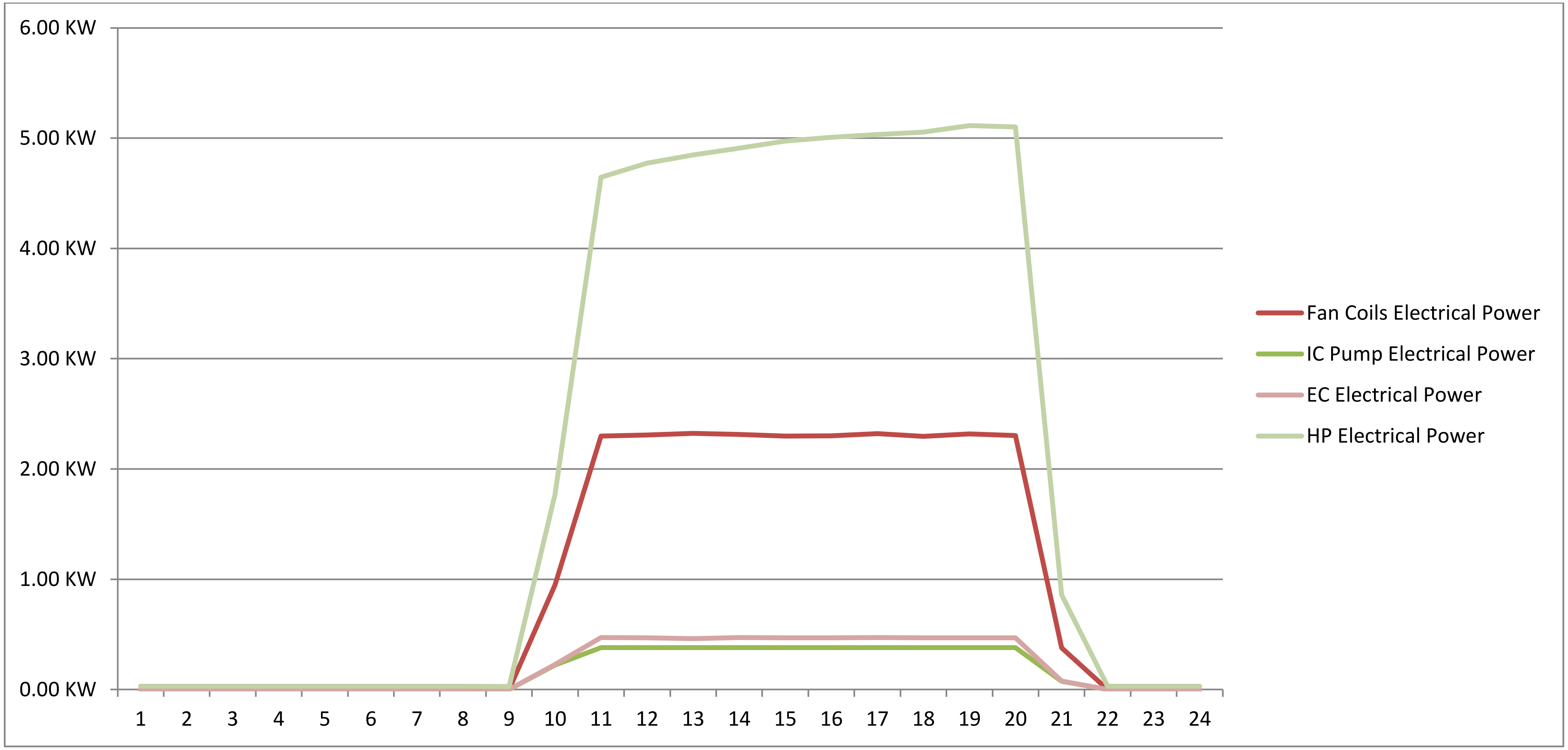
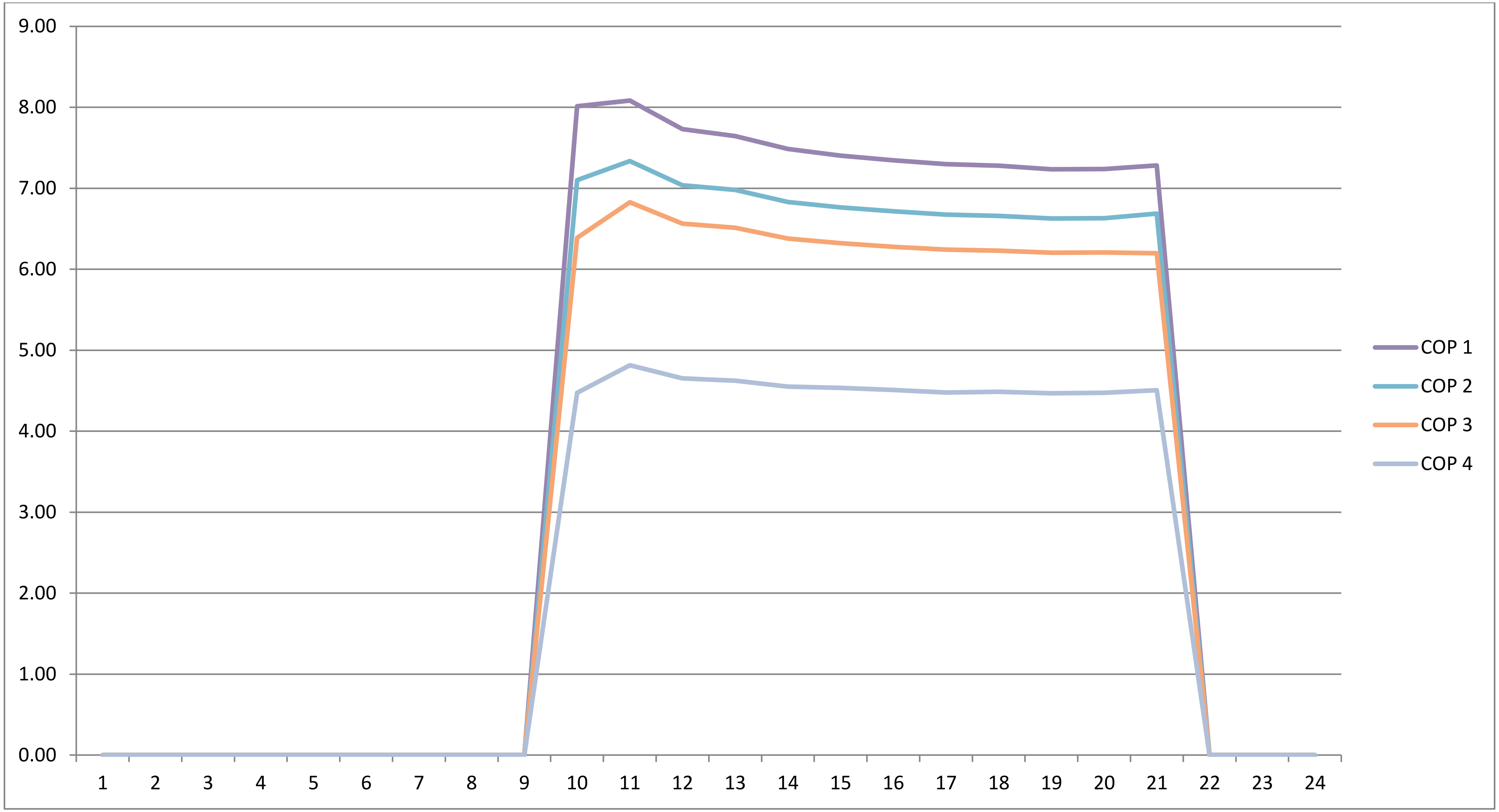


Graph4: Thermal Power (heating , cooling & sanitary hot water) delivered to the building; Thermal Power to/from the BHE; Electrical Power consumption at the compressor (heat pump); Electrical Power consumption at the external pump; Electrical Power consumption at the internal pumps; Electrical Power consumption at the fans (FCUs or AHU)

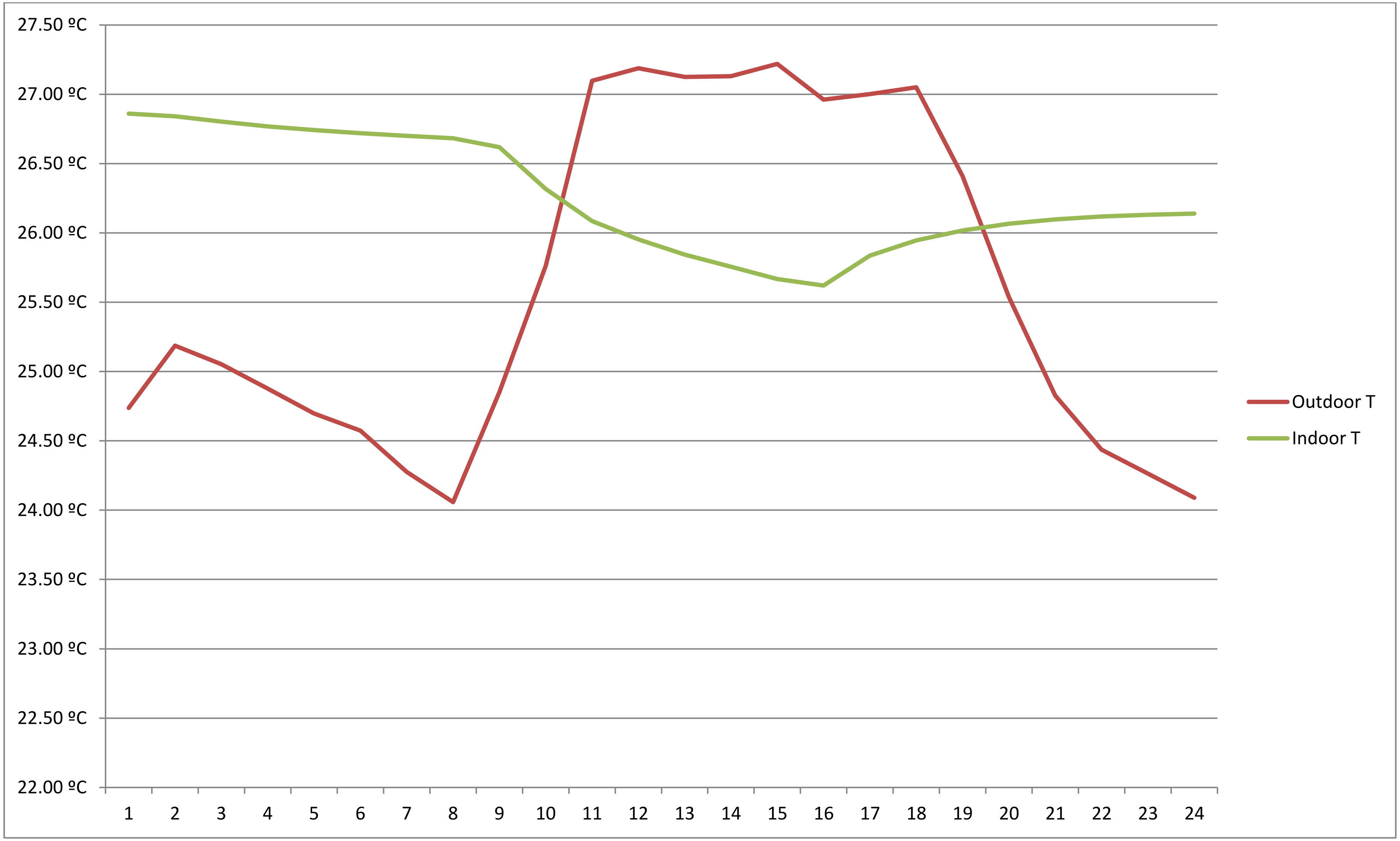


Graph5: COP1, COP2, COP3 and COP4 (instantaneous)

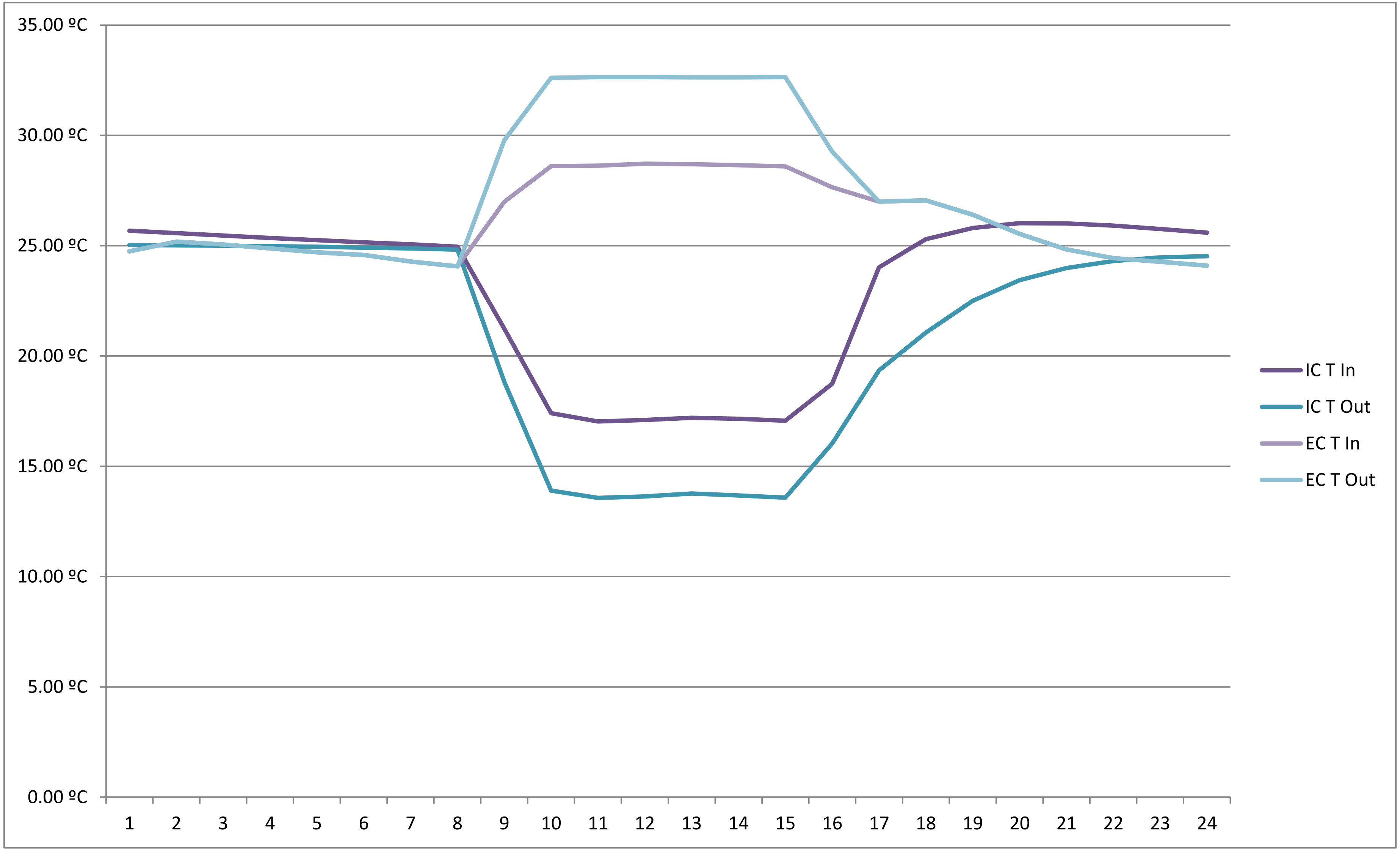


9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
COP 1
COP 2
COP 3
COP 4

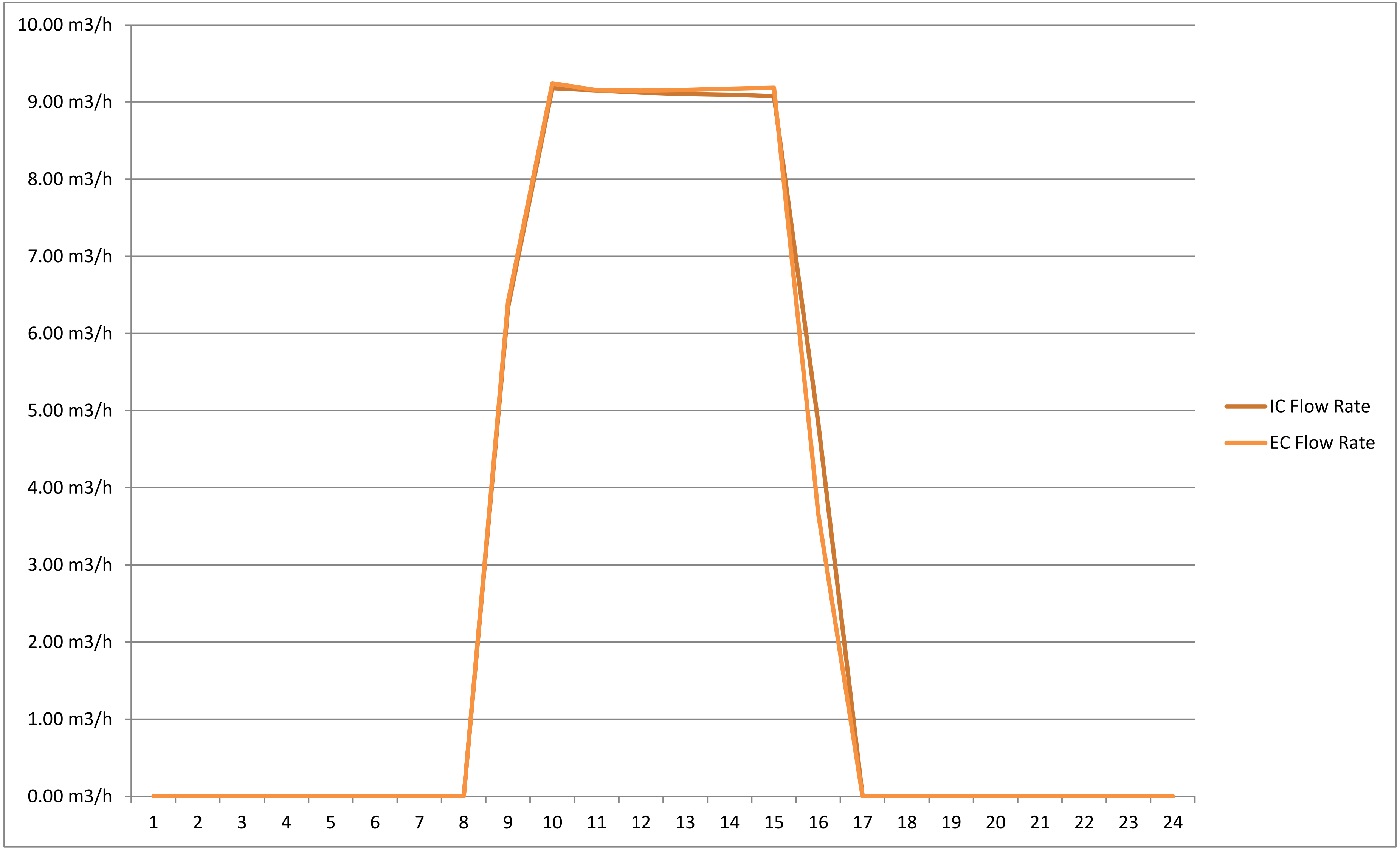
27/08/2014: Graph1: Ambient Temperature & Indoor Temperature



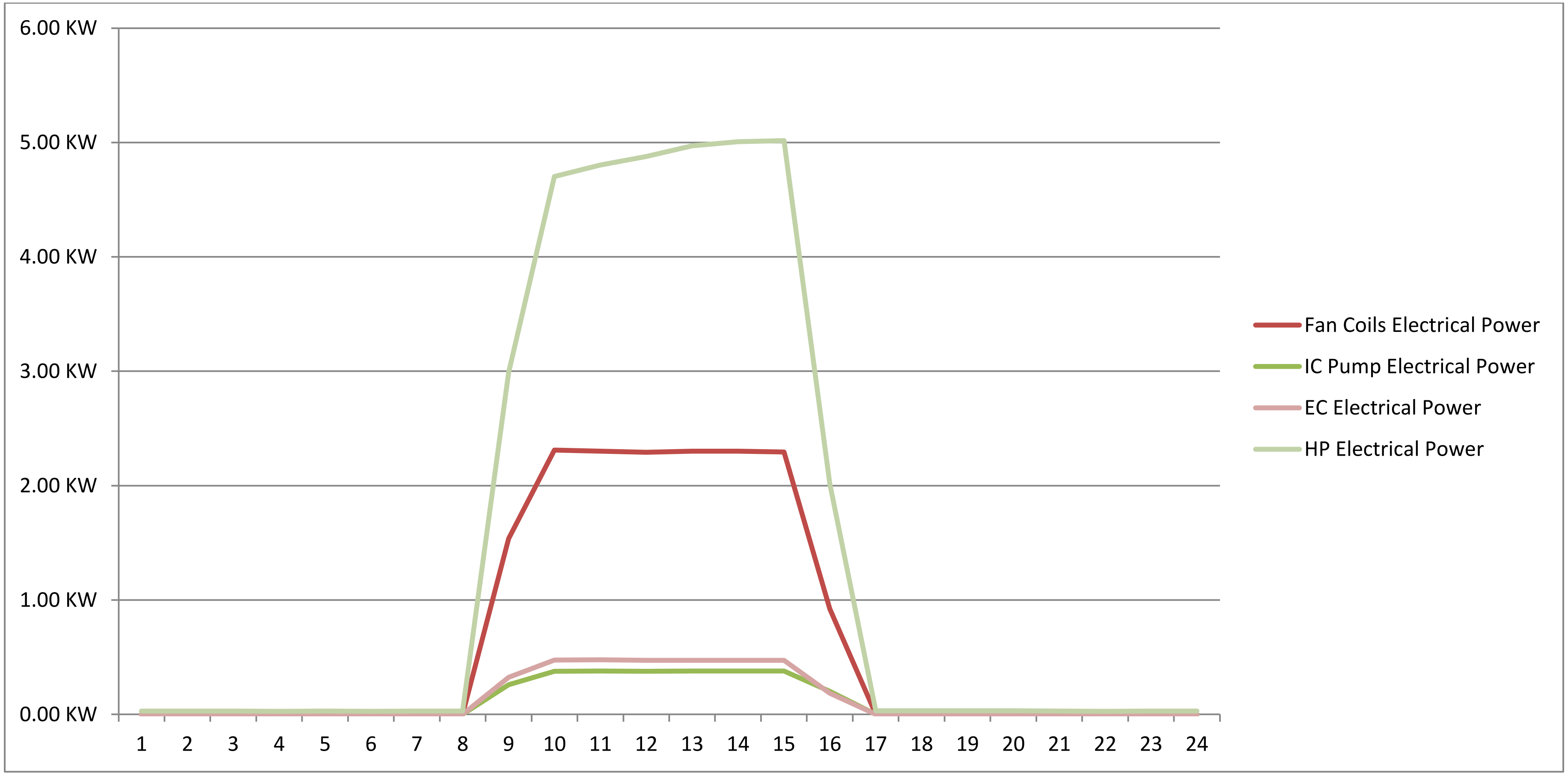
Graph2: External circuit (loop) Temperatures In and Out; Internal circuit (loop) Temperatures In and Out



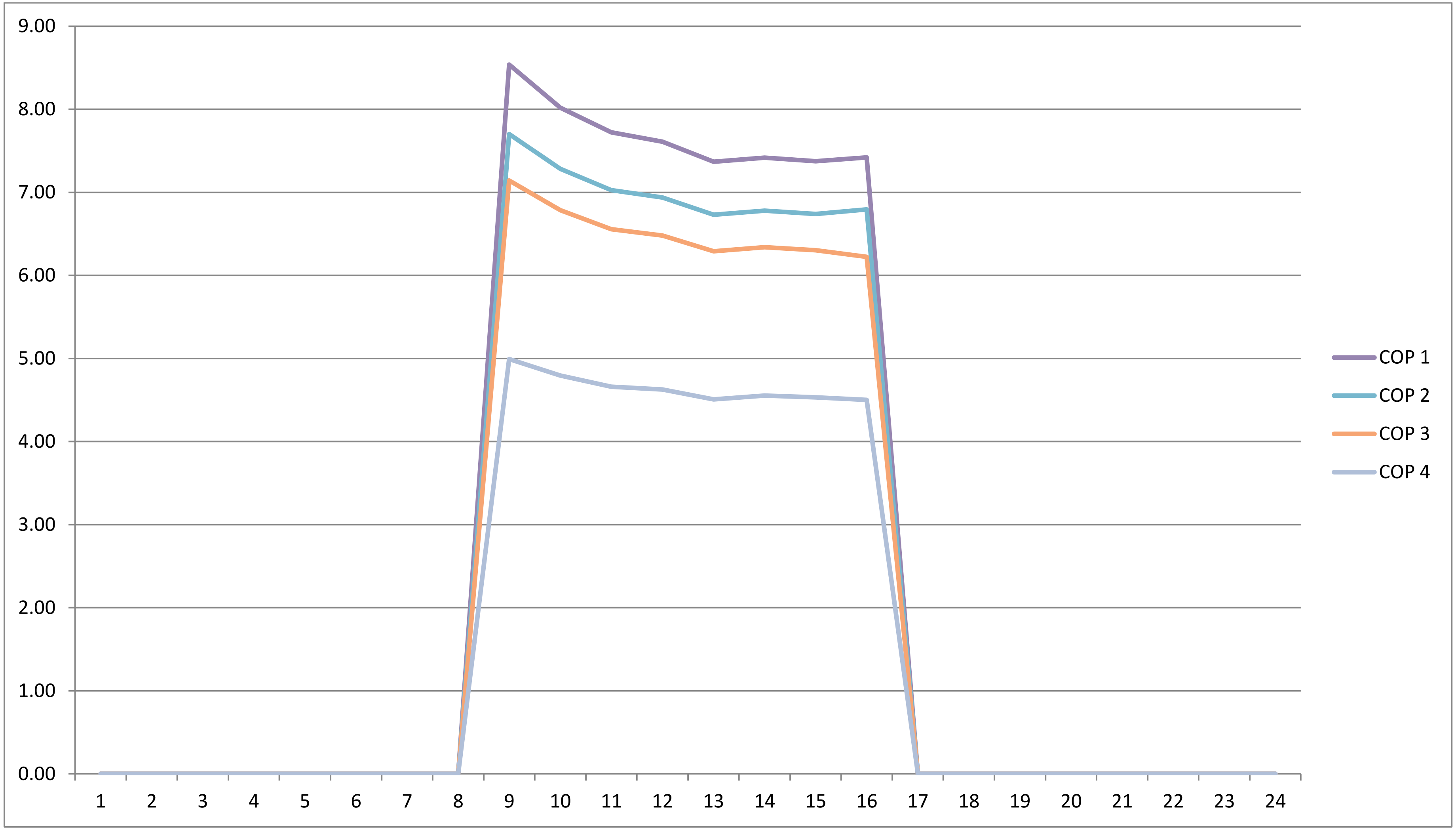
Graph3: External and Internal circuit (loop) flow rates



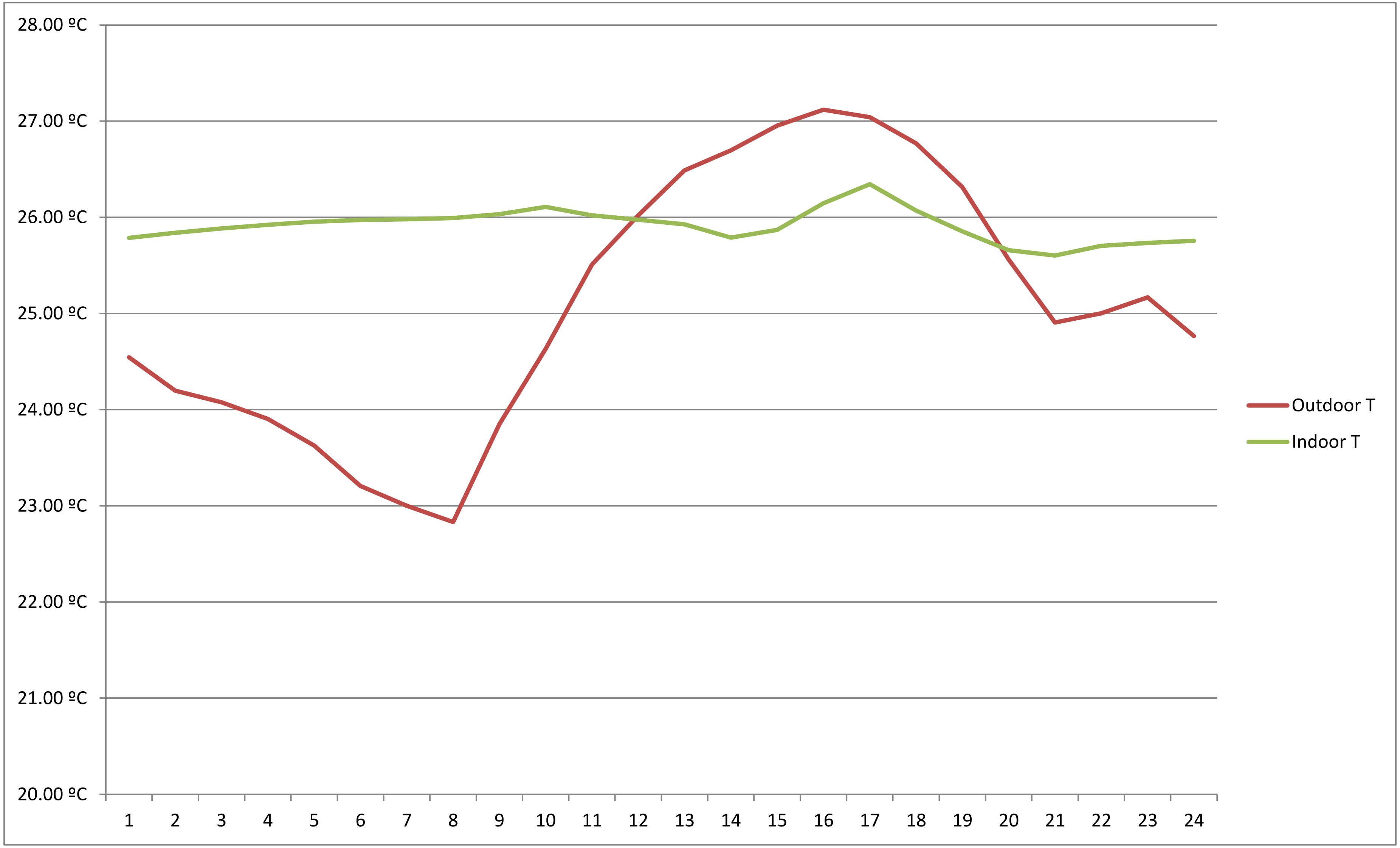
Graph4: Thermal Power (heating , cooling & sanitary hot water) delivered to the building; Thermal Power to/from the BHE; Electrical Power consumption at the compressor (heat pump); Electrical Power consumption at the external pump; Electrical Power consumption at the internal pumps; Electrical Power consumption at the fans (FCUs or AHU)



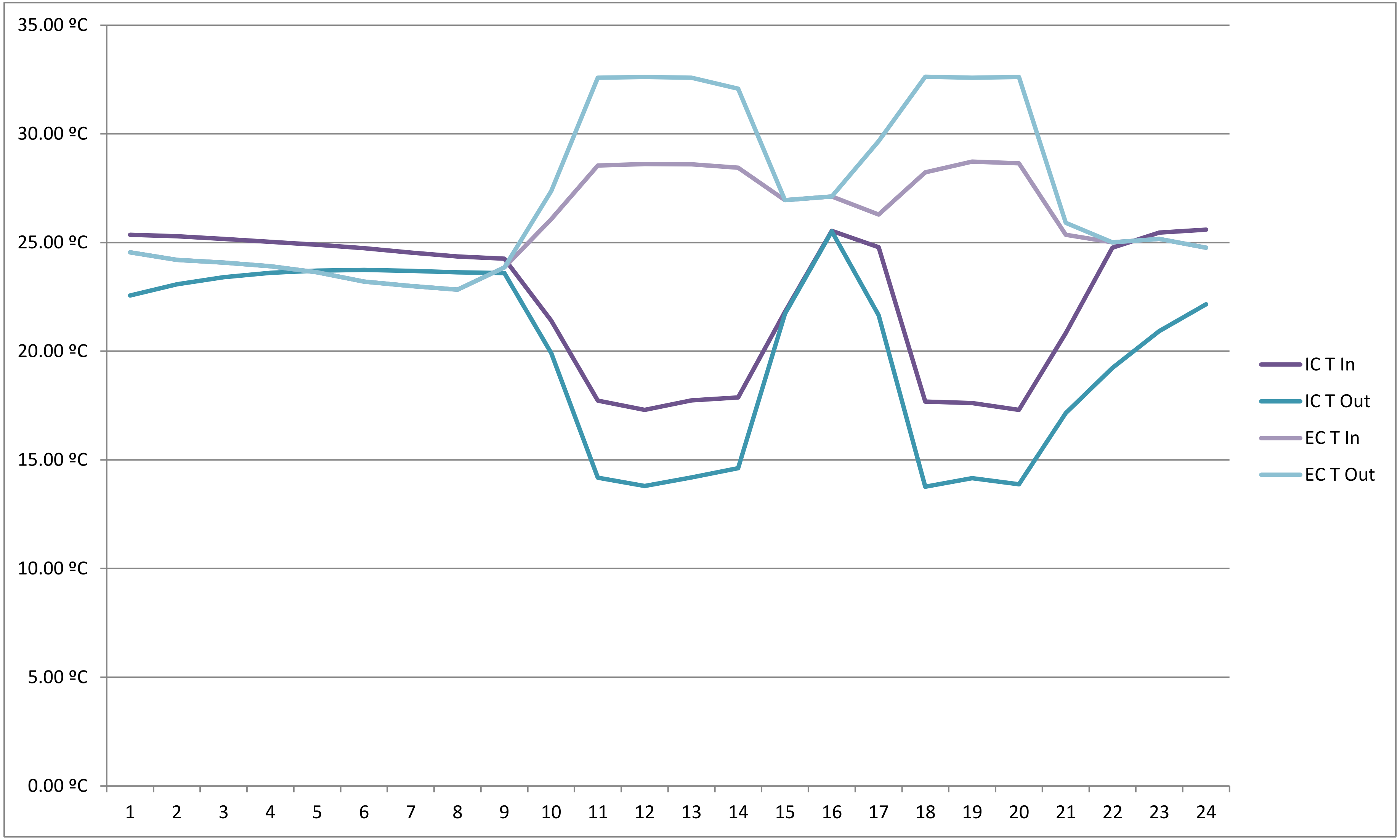
Graph5: COP1, COP2, COP3 and COP4 (instantaneous) (at 15:00 COP is too high because of the energy stored in the buffer tank)



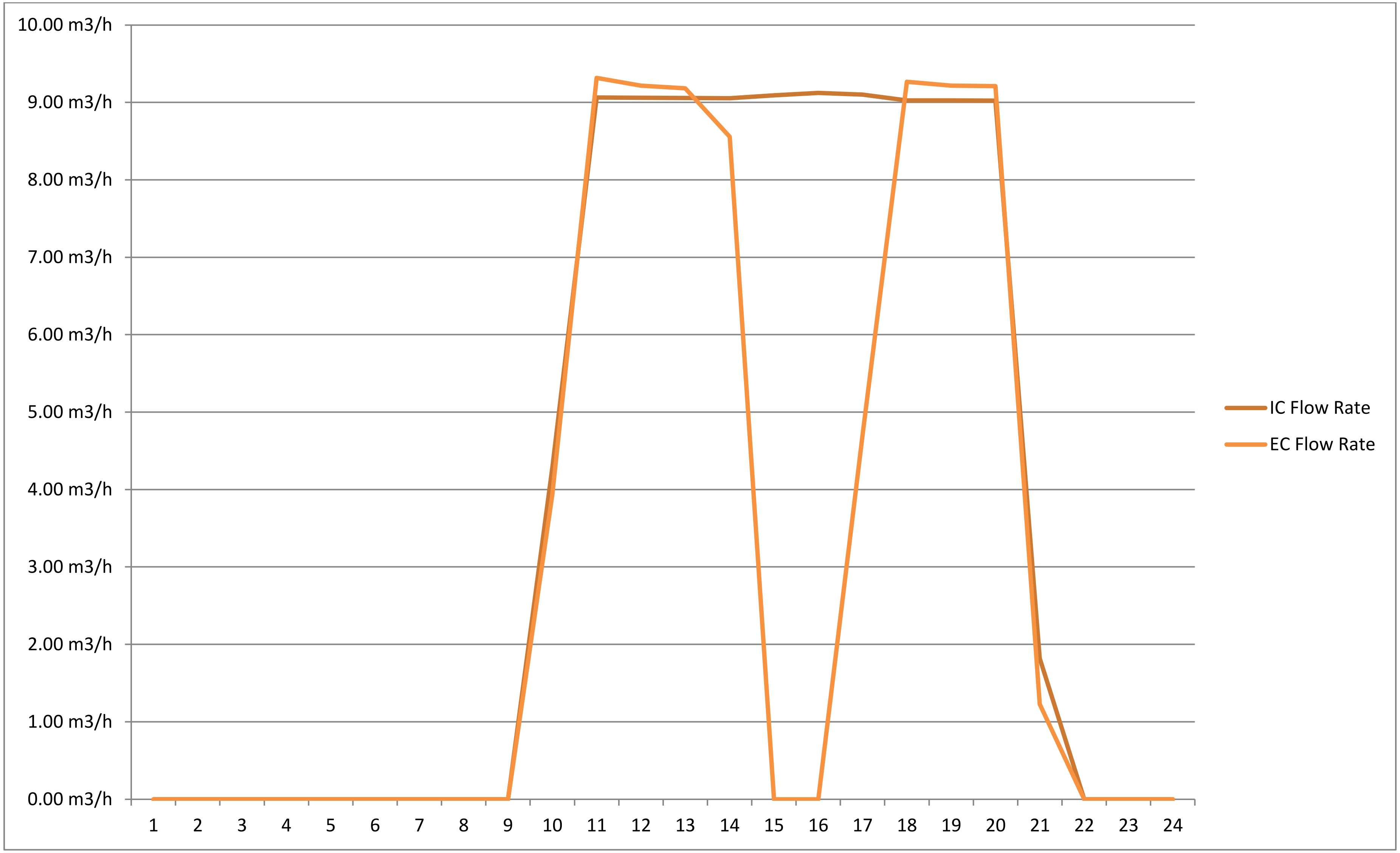
19/09/2014: Graph1: Ambient Temperature & Indoor Temperature



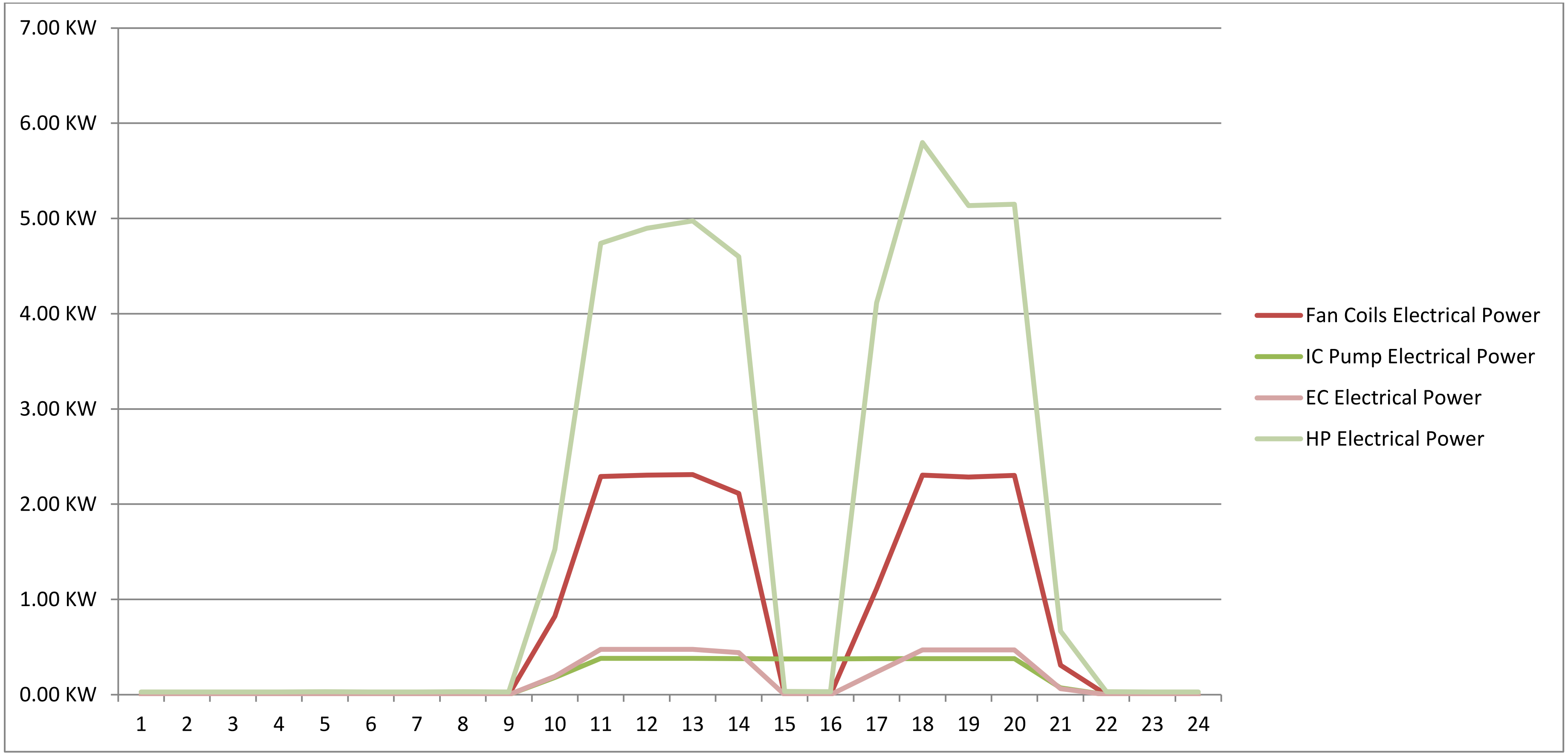
Graph2: External circuit (loop) Temperatures In and Out; Internal circuit (loop) Temperatures In and Out



Graph3: External and Internal circuit (loop) flow rates



Graph4: Thermal Power (heating , cooling & sanitary hot water) delivered to the building; Thermal Power to/from the BHE; Electrical Power consumption at the compressor (heat pump); Electrical Power consumption at the external pump; Electrical Power consumption at the internal pumps; Electrical Power consumption at the fans (FCUs or AHU)



Graph5: COP1, COP2, COP3 and COP4 (instantaneous)