Geothermal contribution on southern Europe climate for energy efficiency of university buildings. Winter season measurements

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COST Action TU1405
Geothermal Applications for Buildings and Infrastructure
Sixth Working Group Meeting, Sofia, Bulgaria, 25-09-2017

OUTLINE

1. Introduction

- Building sector is responsible for over one-third of the global energy consumption and is responsible for one-third of the total greenhouse gas emissions;

- 35% of European $CO_{2\text{-}eq}$ emissions are caused by residential and service buildings;

- Among others, the reduction of the buildings' operational energy is in almost the cases the primary focus of the measures for building energy decrease;

1. Introduction

- EPBD (2010) lead to the achievement of near-zero carbon or energy buildings;

- EPBD strongly encourages buildings energy efficiency, by the reduction of buildings energy consumption and to a very significant extent covered by energy from renewable sources, including renewable energy produced on-site, like geothermal energy.

1. Introduction

Aveiro University Campus: energy efficiency and geothermal systems

- One of the University of Aveiro goals, is the Campus development looking for the sustainability and energy efficiency of the two university campi. To achieve these goals is mandatory the implementation of advanced systems with constant supervision and remote control in the active systems for heating and cooling and in the water systems efficiency: to achieve an exemplar Campus – energy efficient and sustainable.

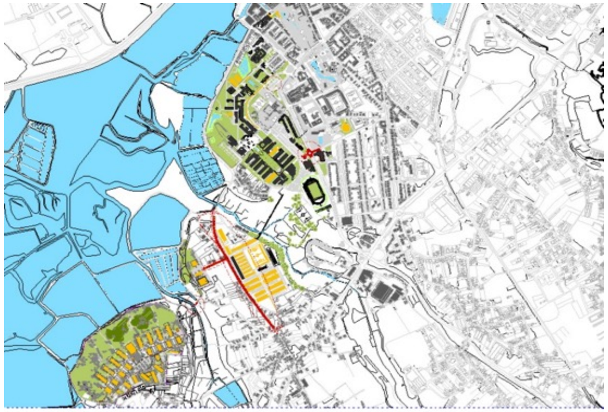
Main campus (Santiago) – 73 ha

Secondary campus (Crasto) – 19 ha

iPark – 35 ha (in current progress)

Approximate 252.000 sqm in 66 buildings

A total of almost 17000 users



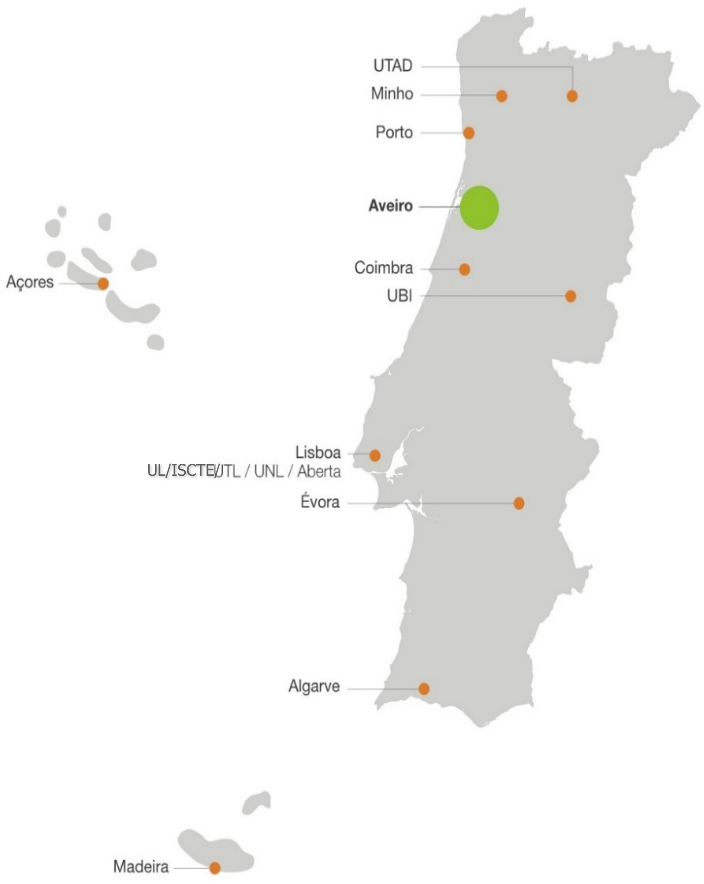
2. Objective

- Despite the great impact of building thermal quality, in university school buildings with high occupancy rates and internal loads, it is unavoidable to use mechanical heating and cooling to provide thermal comfort and wellbeing.

2. Objective

Objective and object of the study

- This paper aim to analyse the performance and the contribution of the geothermal system installed in a Research Department of the University of Aveiro, located in the center of mainland Portugal, in a region with mild climate, which goal is the decreasing of the building energy needs both for heating and cooling.

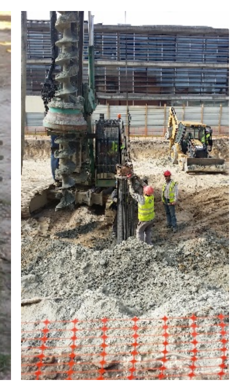


3. Ground Heat Exchangers

The increase development of GSHP (Ground source heat pumps), lead to a continuous development and innovation of GHE (Ground heat exchangers).

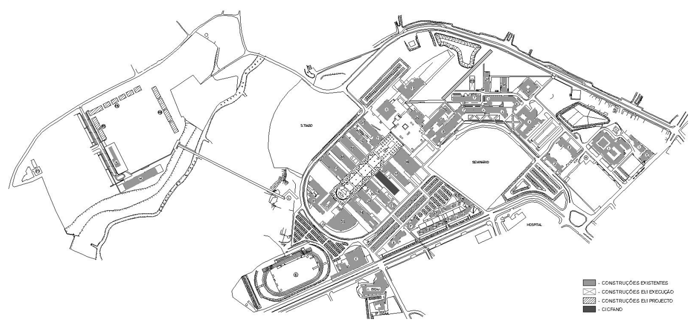
The use of GSHP systems are increasing, because usually offer great advantages at energy efficiency level and at environmental performance, over the traditional systems. The main type of GHE have been the borehole, but in recent years, the building pile foundation structure start to include heat exchange pipes, to act as a new type of GHE known as ''pile foundation GHE" or ''energy pile".



3. Ground Heat Exchangers

In the University of Aveiro until now, five buildings for scholar and research purpose with geothermal systems were constructed. In almost the buildings the geothermal system is composed by both borehole and pile foundation GHEs.
But, in the building under study in this paper the system is composed only by boreholes GHEs.



33 Boreholes ∅150mm with double "U"vertical pipes of ∅ 40 mm with 100m depth.

4. Methodology

To analyse the performance of this geothermal system and its contribute to the building energy efficiency the following approach was followed:

1. Detailed characterization of the building and their systems;

2. Energy audit to collect information about the building use and daily patterns, namely:
   a. occupancy, lighting systems and equipment;
   b. measurements of indoor temperatures and relative humidity;
   c. outdoor climate: temperature, humidity, solar radiation, wind velocity;
   d. measurements of energy consumption.

4. Methodology

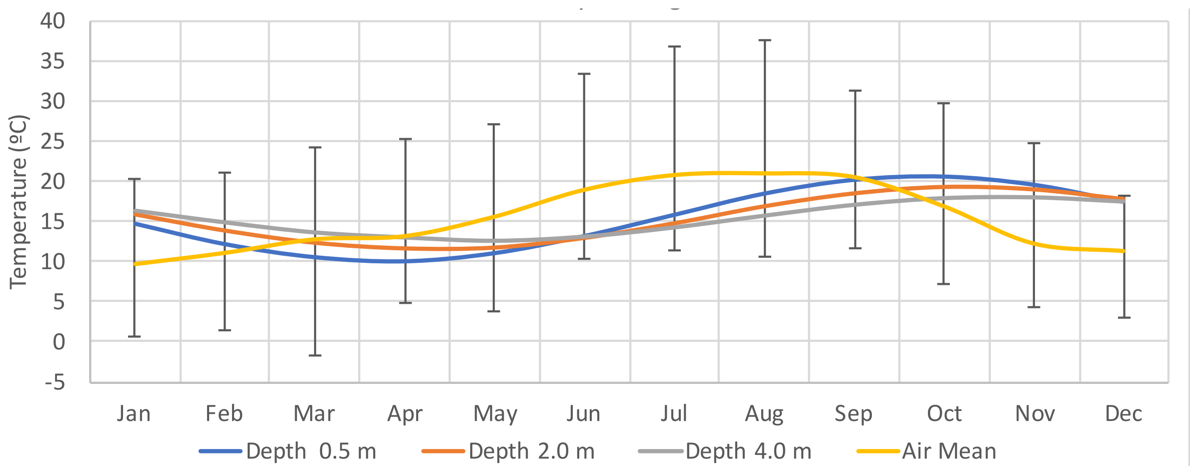
3. The dynamic thermal simulation of the building was carried out with EnergyPlus® 8.6 (EP) software.

4. Building energy model with the geothermal HVAC system was validated with the audit measurements.

5. Comparison between the building energy consumption with the geothermal system and with a conventional system (considering a boiler and a chiller).

5. Case Study

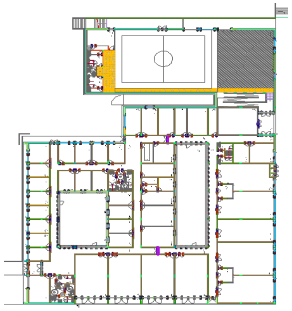
The building under study is located approximately at 10 km of the Atlantic Ocean having a warm-summer Mediterranean climate.
The average annual temperature is 15.3ºC, but the daily ranges can be 15ºC showing that during the day the ground source heat pump could increase the energy efficiency comparing with the conventional air or water-cooled heat pumps.

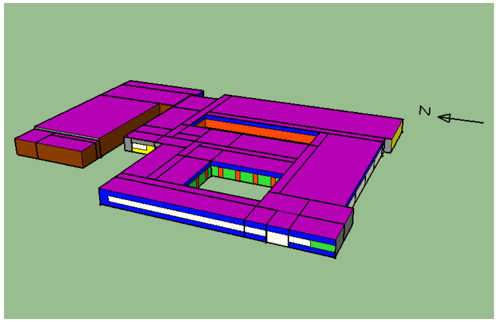


Average monthly values of air temperature and ground temperature

5. Case Study – constructive elements

The building design dates from 2011, and the construction has been finished in 2013. Floor area of ~3200 m^2.
The walls have external thermal insulation, as the flat slab on the roof and the ground floor, being the flat roof a green roof.
Windows have double glazing with low emissivity coating with internal shading system (interior blinds) and external overhangs.





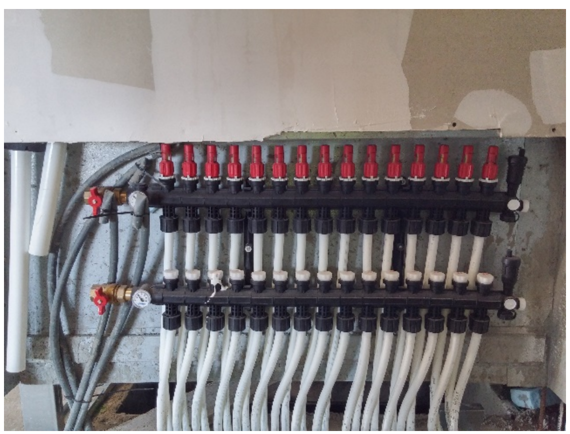
Code of colors	Constructive element	U (W/(m^2.K))
(grey)	External Wall - A	0,52
(yellow)	External Wall - B	0,41
(blue)	External Wall - C	0,54
(green)	External Wall - D	0,44
(brown)	Underground wall	
(magenta)	Green roof	0,35
	Window	3,80
	Internal wall - A	1,30
	Internal wall - B	0,25

5. Case Study - HVAC system

The HVAC system was designed to provide the indoor temperatures of 20ºC in winter and 25ºC in summer. The thermal comfort and the indoor air quality are provided by the HVAC system with a radiant floor system, with pipes connected to the geothermal heat pump.

The geothermal heat pump has a heating power of 272 kW (85 W/m^2) and a cooling power of 245 kW (77 W/m^2) .

Their nominal efficiency is COP=4.7 and EER=4.2.



5. Case Study - HVAC system

The heat pump is connected to 33 geothermal boreholes with 100 m length, composed by polyethylene pipes with 40mm, and a water pump of 5.5 kW/147 kPa drives a water flow of 56.2 m^3/h.

5. Case Study – Energy audit

The main purpose of the energy audit was to identify the energy consumption of each space and assess the indoor environmental comfort and occupant use to allow the development of the building energy model.

Measurements:

- Electricity consumption in several points with data logging devices (uncertainty 0.7%).
- Indoor air temperature and the relative humidity (uncertainty 0.2 ºC and 2%RH).
- Indoor surface temperatures were also measured with a thermography camera.
- Outdoor weather data were collected from the weather station of Aveiro University.

Thermo-hygrometer sensor

Probe Type: Internal NTC Temperature Sensor

Measuring Range: -20°C to 70°C (-4°F to 158°F)

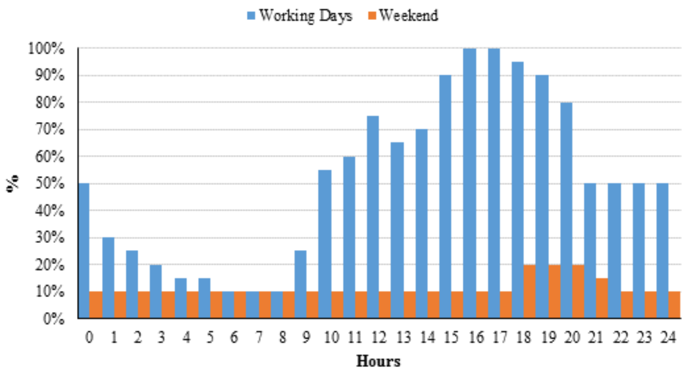
Accuracy: ±0.5°C (-20°C to 70°C)

Resolution: 0.1°C

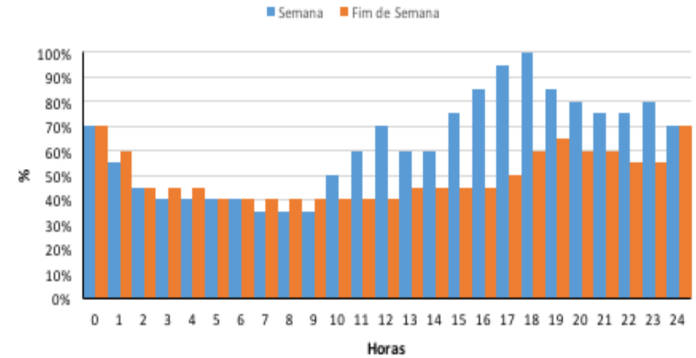
Power & Energy Logger:

- Monitoring period between 27 november to 13 january
- Only for the heating season
- For the cooling season is now on going

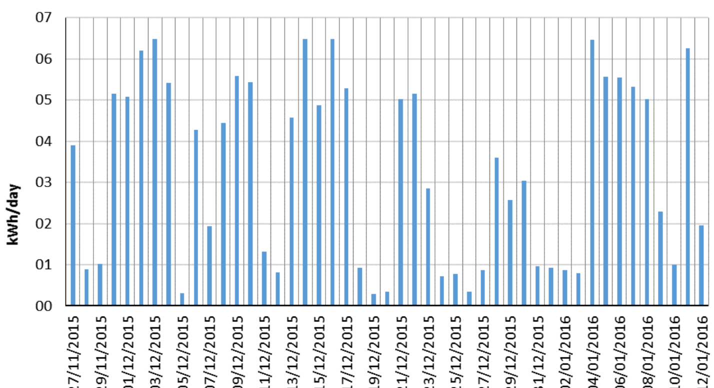
5. Case Study – Energy audit winter



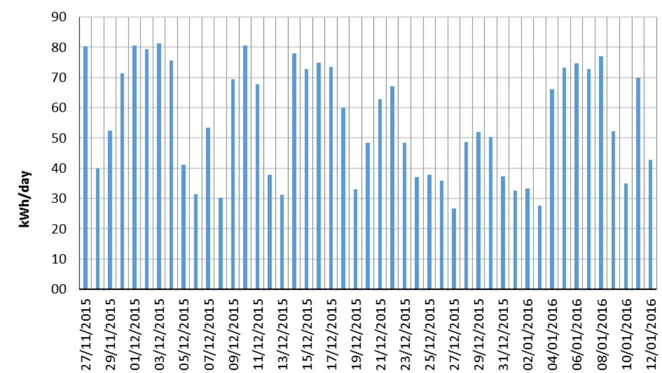
Daily profiles for lighting in scholarships` room



Daily profiles for equipment in scholarships` room

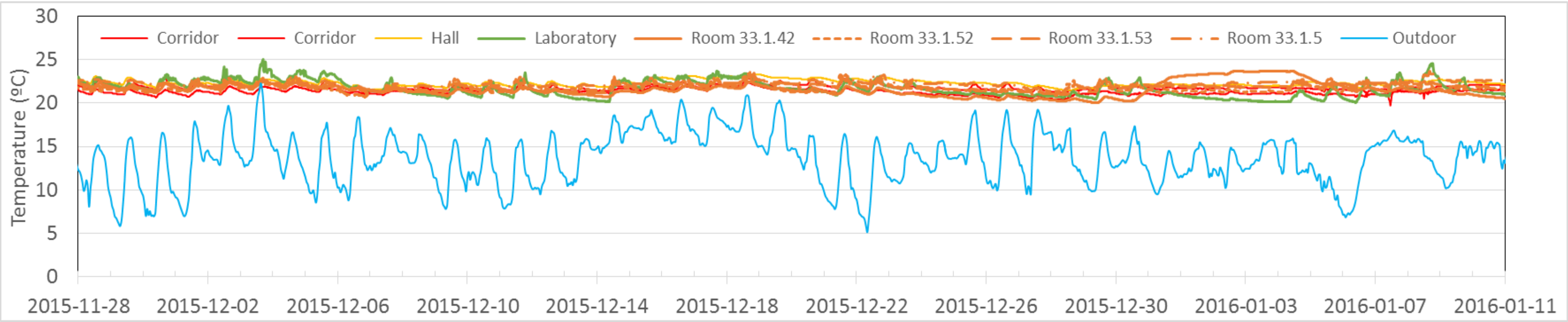


Lighting energy consumption in scholarships` room



Equipment energy consumption in scholarships` room

5. Case Study – Energy audit winter



Indoor and outdoor air temperature measurements

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5. Case Study – Energy audit winter

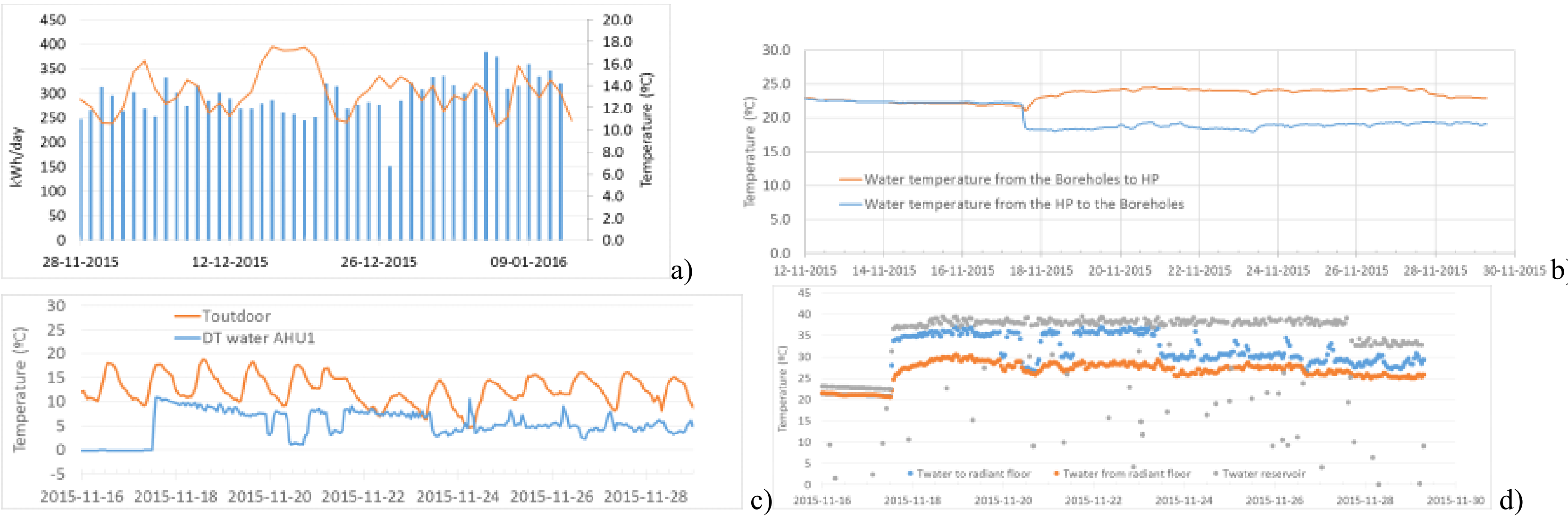
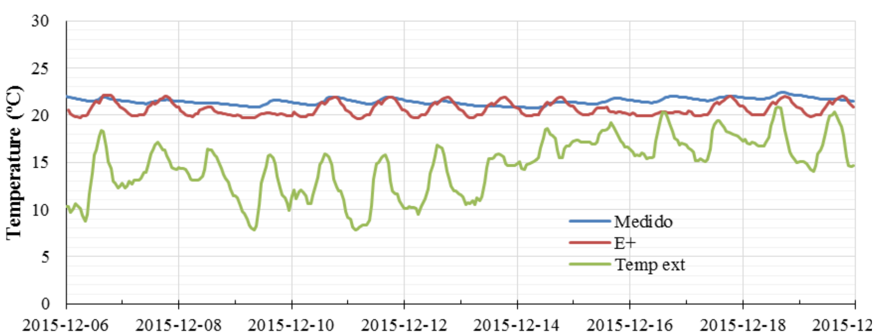


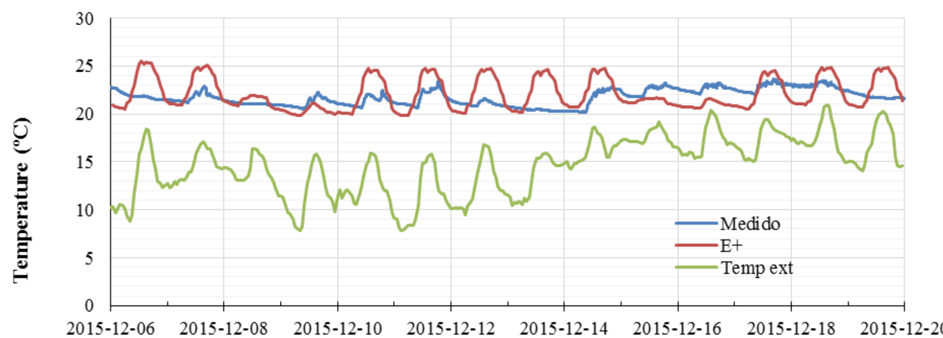
Fig. 9 - Thermal power plant. a) energy consumption; b) Water temperature in boreholes; c) Water temperature difference in AHU1; d) Water temperature in radiant floor

In audit it was measured the energy consumption at the thermal power plant (Fig. 9a), including the energy consumption of the: geothermal heat pump, water pumps, air handling units (AHU1 and AHU2) and control system.

5. Case Study – E+ model Validation winter

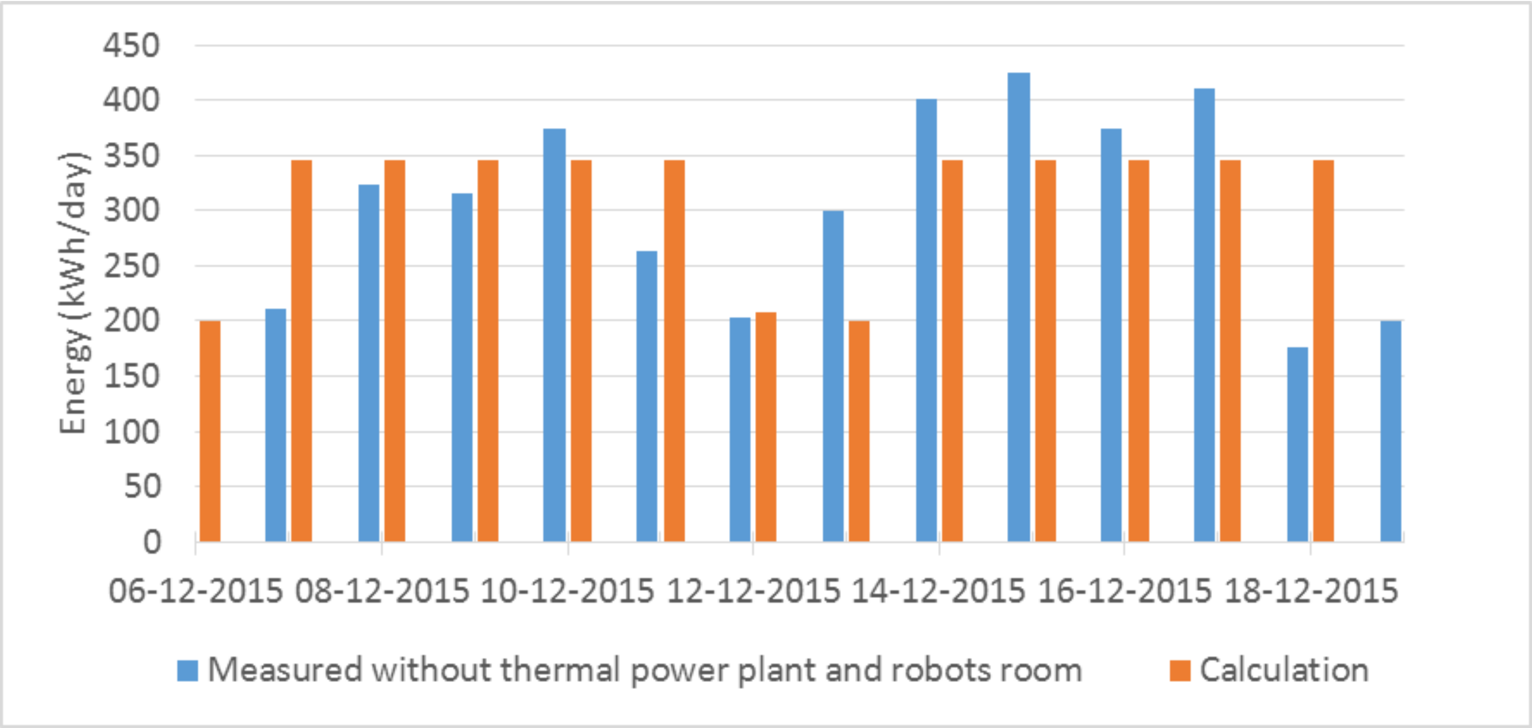
To simulate the heat exchange to the ground, the g-function model was selected. As all the differences between measurements and calculation were lower than 10% the model was considered as representing the real building energy performance.





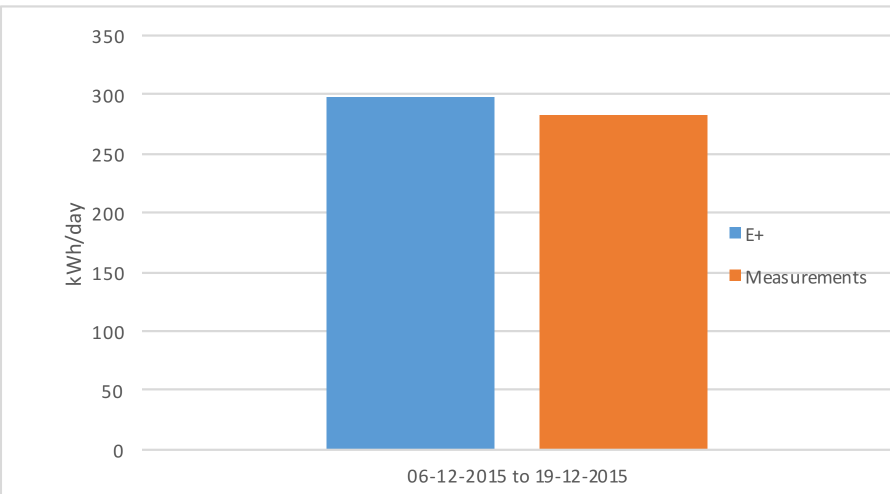
Comparison of temperature measured and calculated with Energy Plus.
a) Scholarship room, b) Laboratory

5. Case Study – E+ model Validation winter

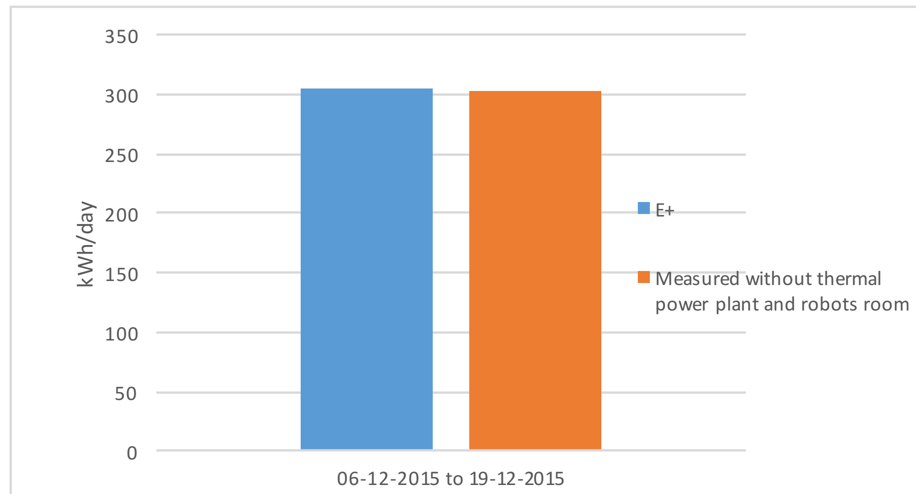


Comparison of building total energy consumption (without HVAC) measurements and calculation

5. Case Study – E+ model Validation winter



Comparison of HVAC energy consumption simulation (E+) and measurements (5% deviation)



Comparison of non-HVAC energy consumption simulation (E+) and measurements

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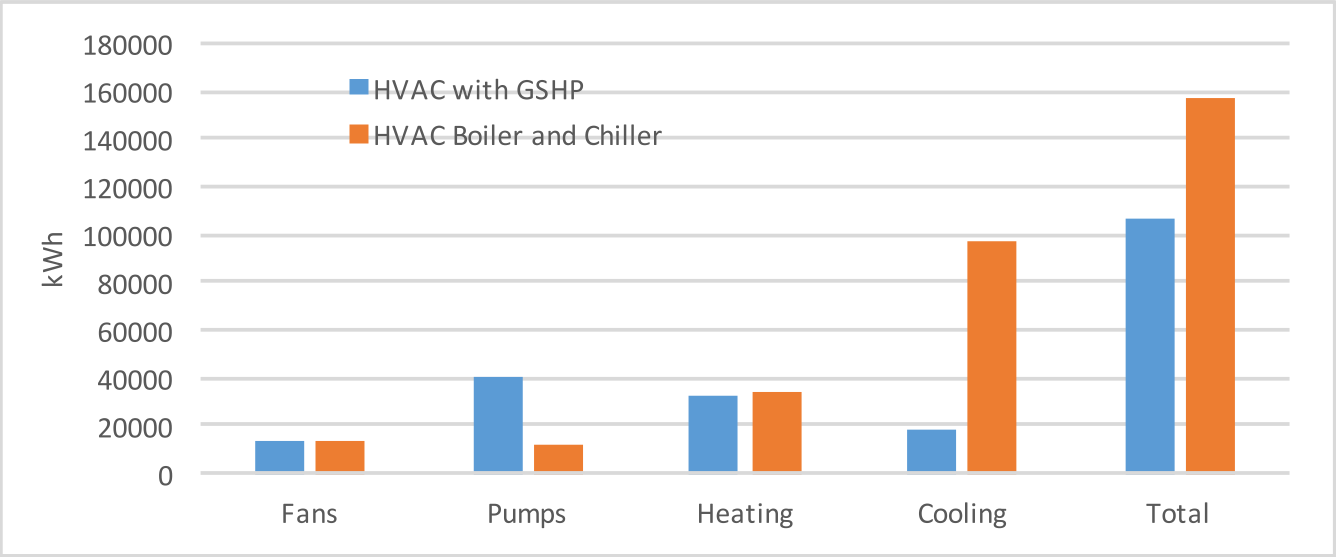
6. Results: energy efficiency analysis

To assess the energy performance of the geothermal system, it was compared with a traditional HVAC system, with a boiler (90% efficiency) and a chiller (EER=3.0).
The geothermal system presents higher pump energy consumption, but a much lower cooling energy demand, showing an annual primary energy consumption 34% lower than a traditional system. Regarding the winter season, during which the Energy Plus model of the building with the geothermal system was validated, shows that the energy efficiency is almost the same as conventional system with a boiler.



Comparison of geothermal and conventional HVAC system – Primary energy

7. Conclusions

The energy performance and energy efficiency, during the winter season, of a research department of the University of Aveiro, located in a warm climate region was analysed.

EnergyPlus® 8.6 (EP) software, allows to simulated the energy performance of this building in winter, with heated floors and GSHP.

In winter, the geothermal system is only slightly more efficient than a conventional boiler.

It seems that GSHP is more efficient than a conventional HVAC system with boiler and chiller, mainly in the summer period.

7. Conclusions

During the audit, the building heating load was low and it was not possible to assess the performance of the systems in peak heating demand conditions.

The average indoor air temperature is relatively high 22.2ºC and the system runs 24h per day. Changing behaviors can save energy.

This measurements in the summer period finished in September and is being analyzed.

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Many thanks for your attention!

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