

Monitoring of building heating and cooling systems based on geothermal heat pump in Galicia (Spain).

M. Iglesias^{1,a}, J. Rodríguez², D. Franco³

¹ EnergyLab Technology Centre, Alternative Energy Area Manager, 36310 Vigo, Spain

² EnergyLab Technology Centre, Building Area Manager, 36310 Vigo, Spain

³ EnergyLab Technology Centre, Monitoring and Control Area Manager, 36310 Vigo, Spain

Abstract. In November 2009 was signed an agreement between Galicia's Government and EnergyLab to develop a project related with the geothermal heatpumps (hereafter, GSHP) technology. That project consisted in replacing the existing thermal equipment generators (diesel boilers and air-water heat pumps) by GSHP systems in representative public buildings: two nursery schools, a university library, a health centre and a residential building. This new systems will reach the demands of existing heating, cooling and domestic hot water (hereafter, DHW). These buildings can serve as examples of energy and economic savings that can offer this technology. We will show detailed analysis of the GSHP facilities monitored, since the starting-up of them. Which includes: COP's, EER's, energy consumption, operating costs, operation hours of the system, economic and emissions comparative, geothermal exchange evolution graphs, environmental conditions evolution graphs (temperature and demands), etc. The results presented show an example of the important benefits of the GSHP technology and the significant savings that can offer its implementation for heating, cooling and DHW production.

1 Introduction

The energy consumption for heating, cooling and DHW, is a very important part of total consumption of buildings and could be up to 80% for the residential sector. Therefore, measuring to improve the efficiency of air conditioning and DHW has a clear impact on global energy sustainability and efficiency.

Among the different alternatives, using low temperature through GSHP is a well known and widespread technology. It is characterized for using renewable resource, and achieving high efficiency levels. Higher than HVAC conventional equipment, reducing emissions.

In general, Galicia due to their hydro geological characteristics, except some localized areas with geothermal resources of low and medium temperature ($30^{\circ}\text{C} < T < 150^{\circ}\text{C}$) in the provinces of Ourense and Pontevedra, it is characterized by a geological composition of soils predominantly igneous

^a e-mail : mario.iglesias@energylab.es

(granites and granodiorites) and metamorphic (quartzites, slates, schists and gneisses), associated with significant thermal conductivity values.

With this potential for geothermal exploitation of very low temperature (up to 30°C) in the Autonomous Community of Galicia, and the interest and the need to analyze the behavior of the technology in its territory, an agreement was signed in November 2009 between the Consellería de Economía e Industria of the Xunta de Galicia and EnergyLab Technology Center to conduct a Demonstration Project with GSHP systems, and registered within the policies of support of the Consellería de Economía e Industria of renewable energy in Galicia.

This Demonstration Project consists to install GSHP systems and monitoring in some public buildings located in Galicia that can serve as demonstrators energy and economic savings that can offer this technology as well as the establishment of ratios and indicators both installation and operating standards in the region of Galicia. This project may allow a better understanding of the technology at all levels of society and allow, in turn, obtaining clear criteria to ensure minimum quality standards and performance in these facilities. These representative public buildings are: two nursery schools, a university library, a health centre and a residential building,

For the monitoring facility, has been carried out the development of a system for acquiring and processing data by developing specific software for implementing the system and measurement of the necessary field components in each of facilities. Basically: electricity meters, heat meters, temperature sensors and an acquisition system, communication and data processing. So, each of the monitored facilities, may, independently, communicates with a central server located on the EnergyLab headquarter, which makes a daily barrage of data recorded in each of the facilities. The data recorded at intervals of ten minutes of the most important parameters of the system (thermal power and energy, electrical power and energy, flows, temperatures, etc.) obtaining, from the same, technical indicators, environmental, and economic factors that characterize the functioning of each of the monitored premises. In Table I, lists the technical characteristics of each of the installations in the Demonstration Project:

Table I. General data of the facilities.

Installation	m²	Thermal Demand	Previous thermal generator system	Thermal Power GSHP (kW)	Ground heat exchanger	Heating system
Primary School Baiona	800	Heating and DHW	Fuel oil boiler (90 kW)	50	Vertical (5x120 m)	Floor Heating
Primary School Nigran	1.000	Heating	Fuel oil boiler (90 kW)	75	Vertical (10x100 m)	Floor Heating
Library University Vigo	3.300	Heating / Cooling	Fuel boiler (350 kW)+ 2 Air-water HP (350+150kW)	3x60	Vertical (33x100 m)	FanCoils
Health Center As Neves	800	Heating / Cooling	Air-Water HP (50 kW)	40	Vertical (6x100 m)	FanCoils
Resid. Building Ribadumia	1.200	Heating and DHW	Fuel boiler (250 kW)	2x40	Vertical (10x125 m)	Floor Heating

2 Demonstration Project Results

2.1 Primary School Baiona

In this installation, the heating system consists in a heating radiant floor with flow temperatures of 38 ° C, and the production of DHW has chosen a geothermal heat pump equipped with technology "desuperheater" for DHW heating. Which, in combination with a system of instant DHW make this solution, a hygienic solution (by not accumulate consumption water) and energy efficient (through the "desuperheater" and its proper management and control system is obtain high COP's yet to DHW).

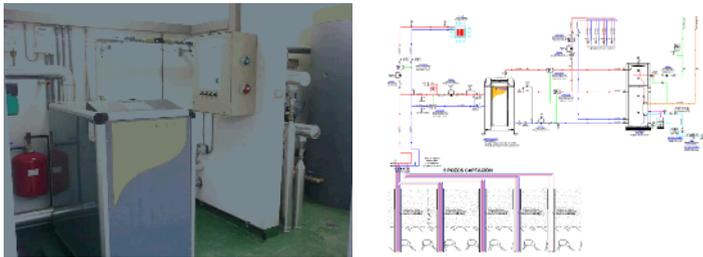


Fig. 1. Detail of GSHP installation in Baiona and hydraulic scheme.

Analyzing the global and the comparative data in this facility corresponding to 2010 and 2011, demonstrate that the facility in general terms:

- It is perfectly sized both in heating power and in number of bore holes, for run times considered standard in Galicia in these facilities (1200-1400 hours/year for heating).
- Use within the parameters estimated and considered normal, while the characteristics of the perforations with working temperatures according to the type of geothermal uptake.
- Compressor start within the parameters estimated by the manufacturers as efficient (these being between 0-5), not exceeding 6 never the average over the two years.
- Energy demand decreased due to greater thermal equilibrium at lower temperatures and the regulation of the system.
- COP stationary are considerably high, improving with time, to stabilize the temperature of the ground.

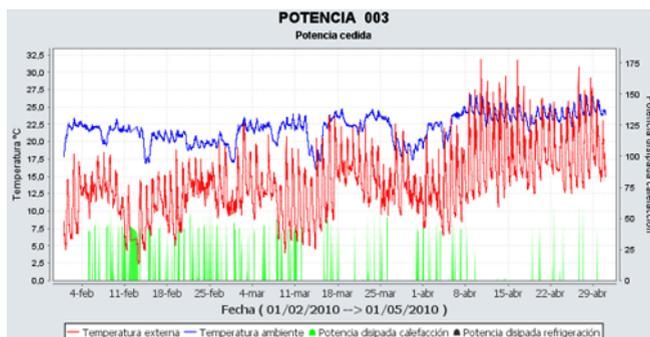


Fig. 2. External temperatures, internal temperatures and heating power supplied from February to May 2010.

2.2 Primary School Nigrán

As for the previous installation, there are recorded data of the operation of the facility since January 2010. In this case, the geothermal pump only works to supply the circuit floor heating with flow temperatures of 40°C.



Fig. 3. Detail of bore holes works and the hydraulic installation in Nigrán.

Analyzing the global and the comparative data in this facility corresponding to 2010 and 2011, demonstrate that the facility in general terms:

- The installation according to the number of hours is oversized, to observe a lower number of operating hours of work required. This oversize can reach up to 30% of power.
- It also means a system oversize pickup, so the temperatures return to the machine are very high, providing large specific COP.
- But if one takes into account the ground sources pumps, the COP drops sharply because of the invested return hydraulic system implemented.
- Compressor star within the parameters estimated by the manufacturers as efficient (these being between 0-5), surpassing that record and finding time point up to 15 starts/hour.

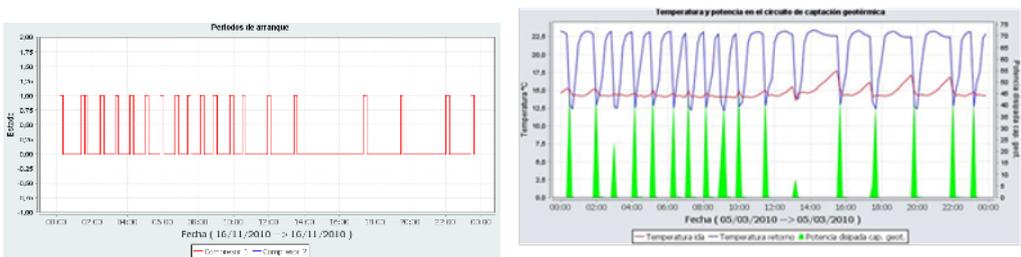


Fig. 4. ON/OFF of the system and groundsource heat exchanger behavior in one day operation in Nigrán.

2.3 Library University of Vigo

As for the Central Library of the University of Vigo, where the above heat-generating system consisting of two air - water heat pumps (with support for peak demand times of a fuel oil boiler). The air conditioning system consists in fan coil units and air ducts where the flow temperatures are 52°C for heating and 7-9°C for cooling. In this building, are installed 3 GHP that allow the generation of cold and heat in the same time, with 33 boreholes.



Fig. 5. Detail of building and geothermal heat pump and heat exchangers.

Analyzing the global and the comparative data in this facility corresponding to 2010 and 2011, as representative to demonstrate the installation, in general:

- This installation is characterized by very high production, but to avoid oversizing has been chosen with the installation sized to cover 80% of energy demands, leaving the old installation to cover 20% of peak demand.
- The production of heating is 43% of needs, while the production of refrigeration is the rest, allowing to have a thermal equilibrium in the ground and in the performance of the installation.
- Use within the parameters estimated and considered normal in power and temperature.
- Compressor start within the parameters estimated by the manufacturers as efficient (these being between 0-5), not exceeding 6 never average over the two years
- Energy demand decreased due to greater thermal equilibrium at lower temperatures and the regulation of work in the same installed.
- The cost of energy consumption of the prior system was 20,000 €/year, and with the GSHP system is being 9,900 €/year.

2.4 Health Center As Neves

In this installation differences between the power generation and power use existed, so it was necessary to properly size a function of the internal thermal demands, improving comfort of the rooms. For this reason, will increase thermal power within the centre, and designs the flow temperature of 45°C, for heating, and 10°C, for cooling.

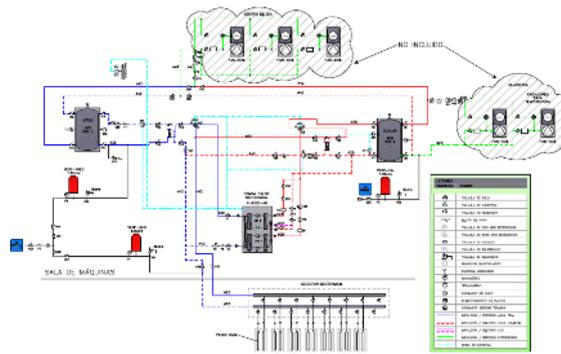


Fig. 6. Health Centre As Neves GSHP hydraulic scheme.

Analyzing the global and the comparative data in this facility corresponding to 2010 and 2011, as representative to demonstrate the installation, in general:

- Compressor start within the parameters estimated by the manufacturers as efficient (these being between 0-5), not exceeding 6 never average over the two years.
- Energy demand decreased due to greater thermal equilibrium at temperatures down the job and installed the same regulation.

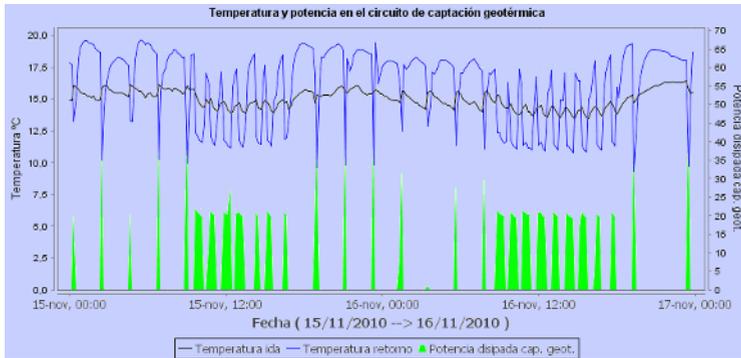


Fig. 7. Heat exchanger behavior in one day operation in As Neves.

2.5 Residential Building Ribadumia

Ribadumia residential building, which consists of 15 homes, had a boiler and a heating radiant floor system with heat exchange stations for each house. This configuration allowed the GSHP installation although had to reduce the flow temperature in the stations from 65°C with the boiler to 50°C with de GSHP, for producing DHW and heating. Also this installation has a solar heating system for support.

Another difficult was the existence of sandy soil which led to the use of a double head borehole machine for soil instability in the first 25 meters.



Fig. 8. Drilling works and GSHP in Ribadumia.

Analyzing the global and comparative data from the 2011 installation, the installation is shown that, in general:

- The installation according to the number of hours is perfectly dimensioned with respect to power consumption.
- This means it is able to cover 80% of demand from the planned project, this reflects the large number of hours under a quarter and continuing in the first quarter of 2012.
- Compressor start within the parameters estimated by the manufacturers as efficient (these being between 0-5), surpassing that record and finding time point up to 15 starts/hour.
- The temperatures of the uptake system also indicate the perfect functioning of the system.

- All the major problems associated with consumption of the building, are related to the installation of high demand, and making the comparison with the boiler, based on demand, the percentage of savings, remains considerable.

3 Conclusions

3.1 Economic Savings

- Monitored on site with only heat demand (heating and/or ACS), compared to previous thermal generating system (oil boiler), the average cost savings obtained are between 60 and 70%.
- In the facilities monitored with heating and cooling demand, compared to previous thermal generating system (air heatpumps), the economic savings are between 40 and 55%

3.2 CO₂ Savings

- Monitored on site with only heat demand (heating and/or ACS), compared to previous thermal generating system (oil boiler), the reduction in CO₂ emissions obtained are between 70 and 80%
- In the facilities monitored with heating and cooling demand, compared to previous thermal generating system (air heatpumps), the reduction in CO₂ emissions obtained are between 40 and 55%

It is observed from data recorded that operating temperatures of the heat transfer fluid in each and every one of the monitored facilities correspond to geothermal heat pump properly sized.

In addition, thermal demands for heat and cold are being met with low operating costs, which affects the major owners and users satisfaction.

The results presented are good examples of the important benefits of the GSHP technology and the significant savings that can go as far in heating, cooling and DHW production.

However, it is necessary to continue monitoring and analyzing the recorded data and behavioral development of facilities along successive cycles of thermal demand, to confirm their current and future performance.