D1b E-USE(aq)

Technical performance & monitoring report

Spanish pilot

AICE jtc UNIVERSITAT JAUME•I
Instituto de Tecnología Cerámica

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Climate-KIC is supported by the
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1. Introduction

1.1 Barriers and opportunities for ATES in Spain

Aquifer Thermal Energy Storage (ATES) has proven to be profitable both economically as well as energetically. However, large scale adoption of the technology is limited by several barriers which were identified in the Climate-KIC E-use(aq) project [1]. The use of groundwater heat pump (GWHP) systems results in local temperature anomalies, i.e. cold or warm groundwater plumes. The groundwater is used in many countries as source for drinking water, hence a balance between its use and protection must be found [2] . The ATES well links the heat pump to the underground and allows for extraction of heat from the ground or injection of heat into the ground.

The most common systems in Spain are of low temperature (30 °C to 100 °C). Low temperature geothermal energy estimated in the form of recoverable stored heat in Spain's subsurface amount to a total of 15,862 x 10^5 GWh, of which 160 x 10^5 GWh are located proximal to areas that have a significant direct heat energy demand [3].

This report shows an overview of the gaps and opportunities detected for the ATES development in Spain. Traditionally, geothermal energy in Spain has been ignored due to the scarce information and lack of knowledge available on this topic.
Moreover, the legislation applied to obtain permits for drilling is not harmonized at national level, resulting in different permitting criteria in every Region of Spain [4]. This situation makes the potential market less attractive for the technology providers and for the end users.
In summary, the process to implement ATES technology is complex in Spain due to the administrative barriers and the lack of knowledge discussed above. From the E-Use Pathfinder project [1], the results of the gap analysis are summarized below, identifying the barriers and opportunities of the ATES in Spain:

- The complex administrative process to get permits, which difficult the future development of geothermal energy. The non-harmonized requirements at national level, also limit the number of companies interested in implementing projects with high initial investment costs ATES.
- In Spain there is a lack of knowledge of and trust in the geothermal systems.
- The processing times about environmental and water laws are very long and difficult. - There isn't specific training of this technology
- Public perseverance; the geothermal technology has been criticized in Spain due to electric energy consumption.
- Lack of adequacy of conventional heat pumps to the specific geothermal facilities demanded.
- The water from the aquifer that is used is considered as waste water; hence this water must be treated as such.

ATES system market in Spain is immature, in which the three key barriers to overcome are: 1) Lack of knowledge and experience with implementation of ATES systems, 2) Lack of adequate regulation and 3) Relatively large initial investments with unclear savings. In addition, to guarantee the aquifer quality in order to ensure a good water supply for users (don't contaminate it). Next to barriers the following opportunities are identified:

- There is knowledge of the location of geothermal resources in Spain
- A reference design for adequate regulation of these systems can be obtained to support installers of the geothermal facilities.
- ATES is sustainable and safe use of groundwater, with no net groundwater extraction
- Further knowledge of the ATES systems and more trust in them

The low temperature sustainable heating and cooling systems with use of the subsurface lack research programs that help to develop effective systems. This research project looks beyond: trying to reduce costs and use water needs in a safe and sustainable way and avoiding the water extraction of the soil. In addition, the results from this project help to substantiate and if possible simplify the regulations currently applied to the ATES implementation.

This was important due one of the main barriers in Spain identified in the Pathfinder project, to support the ATES market considered the water extraction from the aquifer (avoiding water extraction from aquifers). Hence, ITC started relations with ITECON in order to develop a new type of well to exchange heat with the subsurface without bringing groundwater to the surface. This information was brought to the coordinator of the project (DELTARES) in order to evaluate the integration of this system into the project.

The pilot has been implemented in the municipality of Nules swimming pool, with the purpose of heating the indoor sports swimming pool.

1.2 Partners involved

Institute of Ceramic Technology

The Institute of Ceramic Technology (ITC), a joint institute set up through the agreement between the Ceramic Industry Research Association (AICE) and the Jaime I University of Castellón de la Plana (UJI), was born in 1969 in response to the needs and requirements of the industries of the Spanish ceramic cluster.

ITC also integrates the ALICER Technology Center, which after the merger becomes ITC's Design and Architecture area. It is worth adding the creation and development of a Ceramic Observatory based on three pillars: the Market Observatory, the Technological and Environmental Observatory and the Habitat Trends Observatory, the first initiative of its kind in the national sphere.

Itecon

Itecon Energy Services is a Spanish engineering company founded in 2001, which has worked in the integration of renewable energies in buildings and industrial processes, thus gaining a valuable experience used to design new renewable energy technologies.

The company experience involves the developing of renewable energy technologies and systems integration in buildings, as well as architectural and urban planning with projects in Latin America, Africa and Europe.

City Council of Nules

The City Council of Nules is the owner of the swimming pool, the collaboration with Council City of Nules (Castellón province) has been very important, because they have allowed us to set up the full system in its municipality and bring us further information about energy consumption during these last years.

1.3 Organizational history

During the development of E-USE(aq) Pathfinder project the partner ITC did look for identifying a technology suitable to be introduced into the project and help to overcome the barriers identified in Spain. Hence ITC contacted with ITECON, which at that moment was developing a new probe named Dynamic Closed Loop (DCL) that skips the water extraction. The City Council of Nules agreed to collaborate in a three-member consortium to participate in the E-Use(aq) project by having installed the pilot in its swimming pool.

2. Pilot description

2.1 Site description and pilot design

The Spanish pilot is located in Avenida Jaume I 1 in Nules, Castellón, it is one of the three largest towns in Castellon de la Plana, which is in Valencia Region. This studied area is in east of the Iberian Peninsula over an expanse of flat land, enclosed between different mountains in the interior on the West side and by the Mediterranean Sea on the East side. The coordinates of the Village are: 39°51’09”N 0°09’02”O, and altitude is about 13 m above sea level.

The Nules city has around 13.500 citizens and its climate is typical of the Mediterranean region. The area is belonging to Hydrographic Sub-basin n ° 171 (*Confederación Hidrográfica del Júcar-CHJ and IGME* -CHJ) [4], figure 1.

The Spanish pilot is a combination of BTES and ATES system, implemented by the name; Dynamic Closed Loop (DCL), created by ITECON. The goal of this pilot is to use the DCL in a coastal aquifer to supply energy to the public swimming pool of this town to achieve the objectives of reducing costs and energy consumption in public buildings (*Plan Ahorro y Eficiencia Energética Edificio-PAEE de la Administración General el Estado-GE*) [4].

The study area covers a surface of 600 m^2 over materials of the Upper Pleistocene of the Quaternary. Moreover, DCL probes are running in the detritus aquifer type multilayer of La Plana de Castellón (Hydrological Unit n ° 8.12 Plana de Castellón) [5,6].

The water body has the reference 080.127: Plana de Catellón. The aquifer belongs to the Exploitation System called Mijares-Plana de Castellón, n ° 2, see figures 1 and 2. The swimming pool has an average of number visits of about 1,150 per week, which adds-up to about 51,000 per year, taking account for a 2 month closing period. The sports facility houses a heated semi-Olympic pool, as well as showers and changing rooms and various offices.

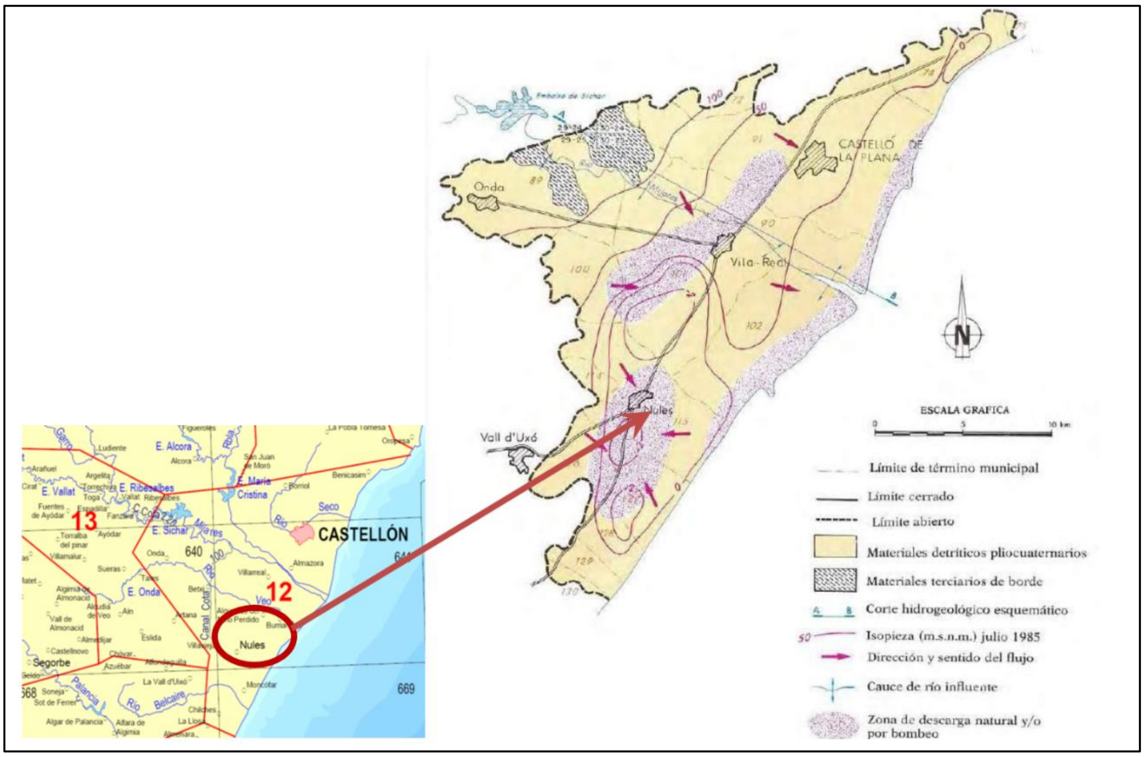


Figure 1. Hydrogeological Unit n ° 8. 12 Castellon de la Plana (Source: IGME and CHJ)

Figure 2. Overview of the study area

Figure 3. aerial view of the swimming pool

The building has a dehumidification system by direct expansion in an Air Treatment Unit, plus a fan coil system for heating and direct expansion split units with outdoor units for air conditioning. Also, the heating system of the pool originally installed has two boilers of 320kW each that use natural gas as a primary energy source.

A geothermal heat pump system has been installed using Dynamic Closed Loop geothermal probes. The four DCL® probes act as a thermal capitation system for a 100 kW Carrier water-to-water heat pump, able to keep the swimming pool's water temperature around 28 °C. The original gas boilers have been kept for domestic hot water production and auxiliary/back-up pool heating purposes.

The system consists of:

- Four DCL® geothermal probes located in the courtyard adjacent to the building, next to the sports field. The perforations to get the water from the aquifer are until 35m deep below soil level, while the perforations for reinjecting the water are in the same drillings
- Four monitoring wells of 25 m depth, with sensors that record water level and temperature.
- A system of pipes buried in trenches for the transport of the water which is used as a medium to transport the heat transport medium between the heat pump and the DCL® probes.
- A circulation pump system, temperature probes, circuit measurement and control elements, thermal exchange with pool water, and power and safety.
- A Carrier geothermal water-water heat pump of 100kW nominal thermal power for pool heating. It has two scroll compressors of 50kW each, which are activated in one or two power stages at the request of the system.

- A monitoring and control system that measures, registers and controls all the operating parameters of the system.

The location and connection of these components are indicated in figures 4 to 7.

The control system activates and deactivates the circulating pumps and the heat pump by means of a thermostat which measures the swimming pool's water temperature, activating the system when it drops below 27,7 °C and stopping it when it goes over 28,3 °C.

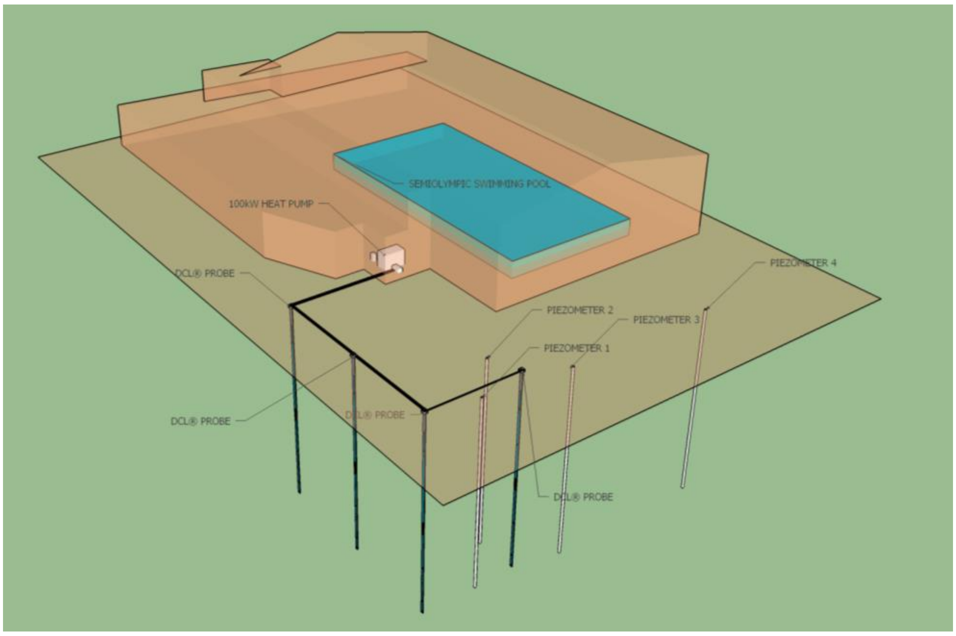


Figure 4. Artist impression of system layout with location of plant room, DCL-probes and monitoring wells.

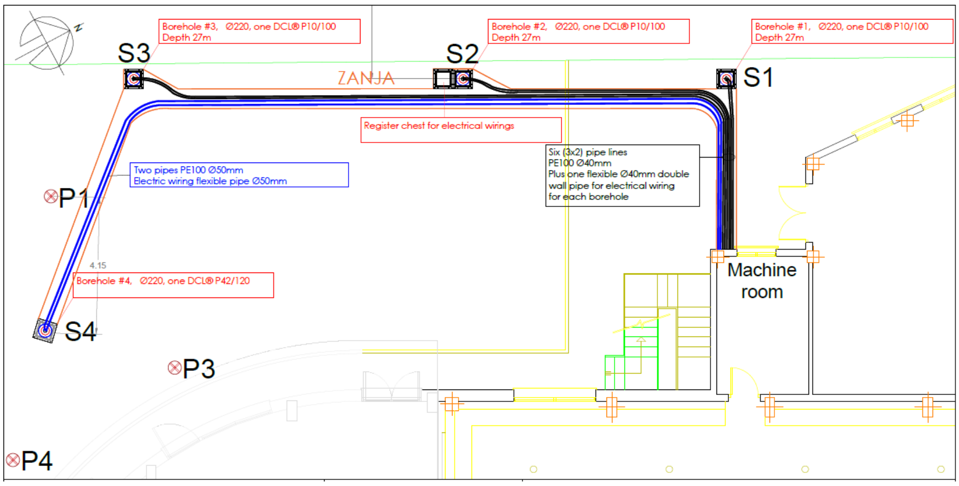


Figure 5. Floor plan of DCL-probes, plant room and connecting pipes.

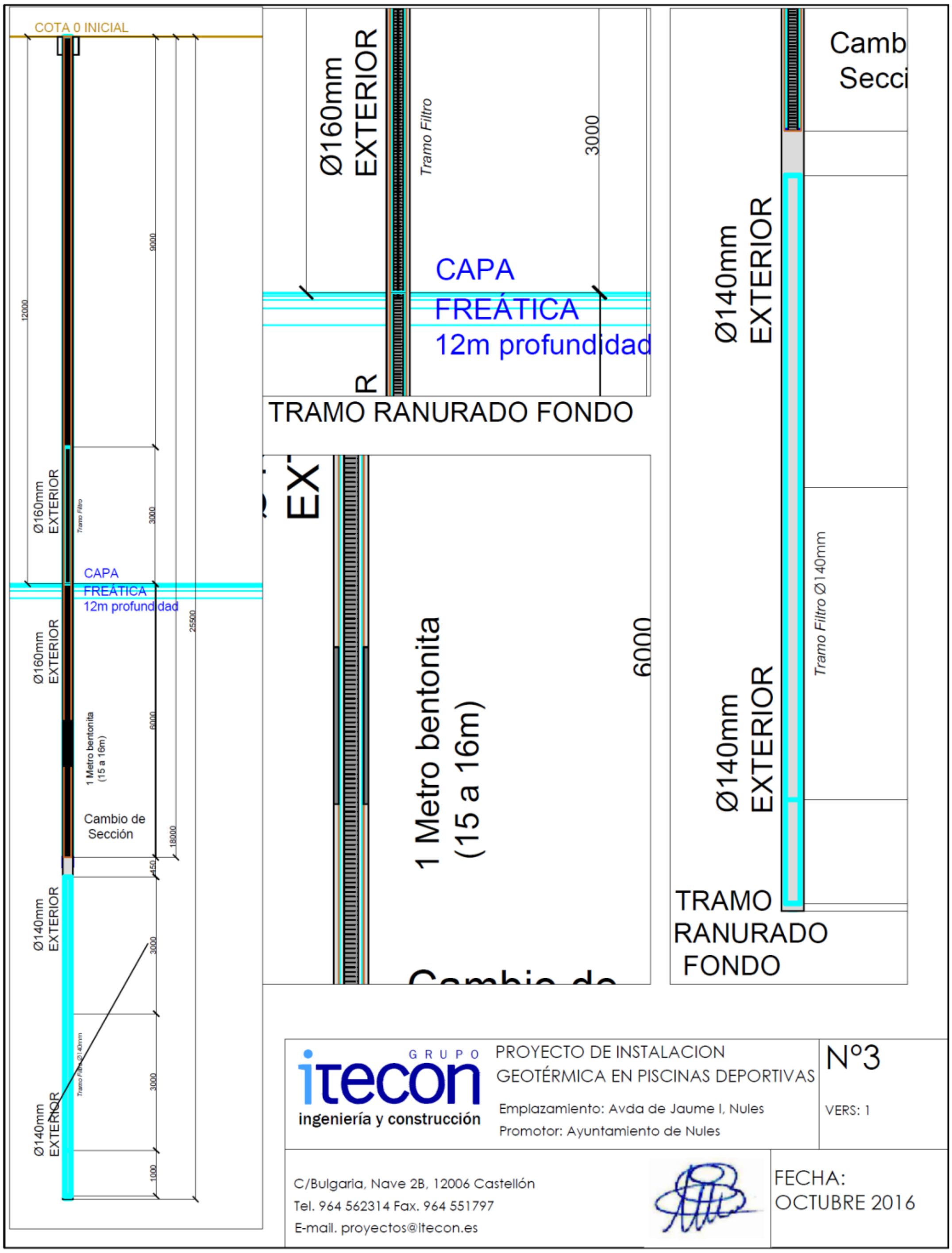


Figure 6. Boreholes and dcl® probes cross-section

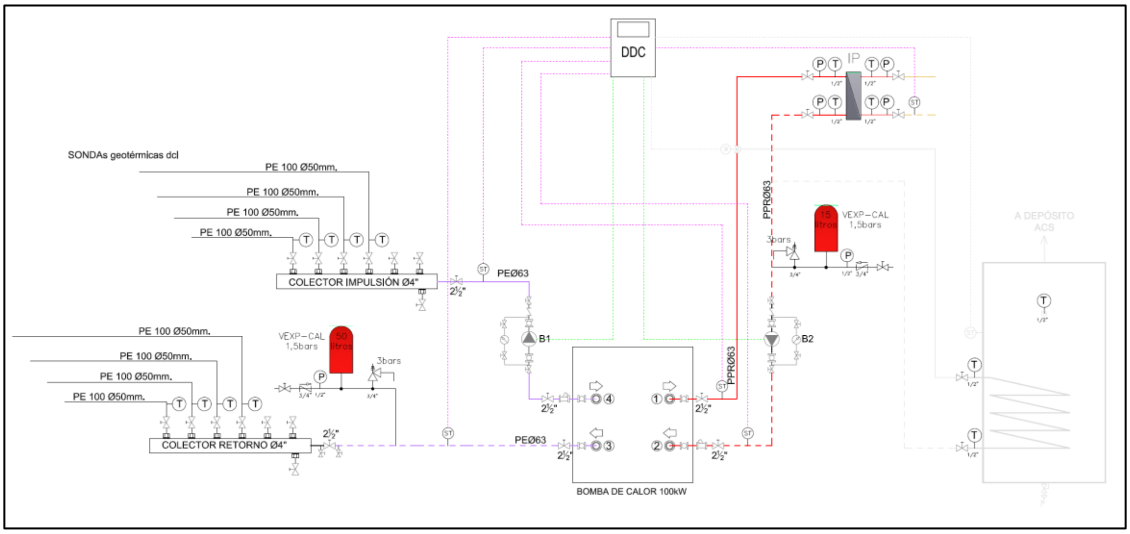


Figure 7. Installation schematics

2.2 System installation

The 4 boreholes were executed by rotopercussion in a period of 8 days, plus 4 monitoring wells in 34 days. The installation work in the plant room was carried out in two weeks, simultaneous with the drilling.

A 3x4m plant room (figure 8) attached to the swimming pool water treatment room was used from which the flow of the heating system is diverted to a 100kW plate heat exchanger that uses the hot water from the heat pump (Between 37 and 45 °C depending on stage of power) to keep the pool temperature at approximately 28 °C. The control system activates the circulation pumps of the evaporator (collection) and condensation (heating) circuits as well as the speed of the pumps of the probes (by means of 4 frequency inverters, see figure 8) so that the use of energy is optimized.

Figure 8. Impression of plant room

Each DCL® probe has a single submersible pump able to make water pass through the probe (which exchanges heat with the heat pump circuit) and its rotating speed is regulated by the control system, thus optimizing the energy use and the capturing system water temperature. They act simultaneously but can, if needed, operate different DCL® probe independently.

The heat exchange in the subsurface is facilitated by pumping water from the bottom along the closed loop tubes inside the DCL to the top of the borehole.

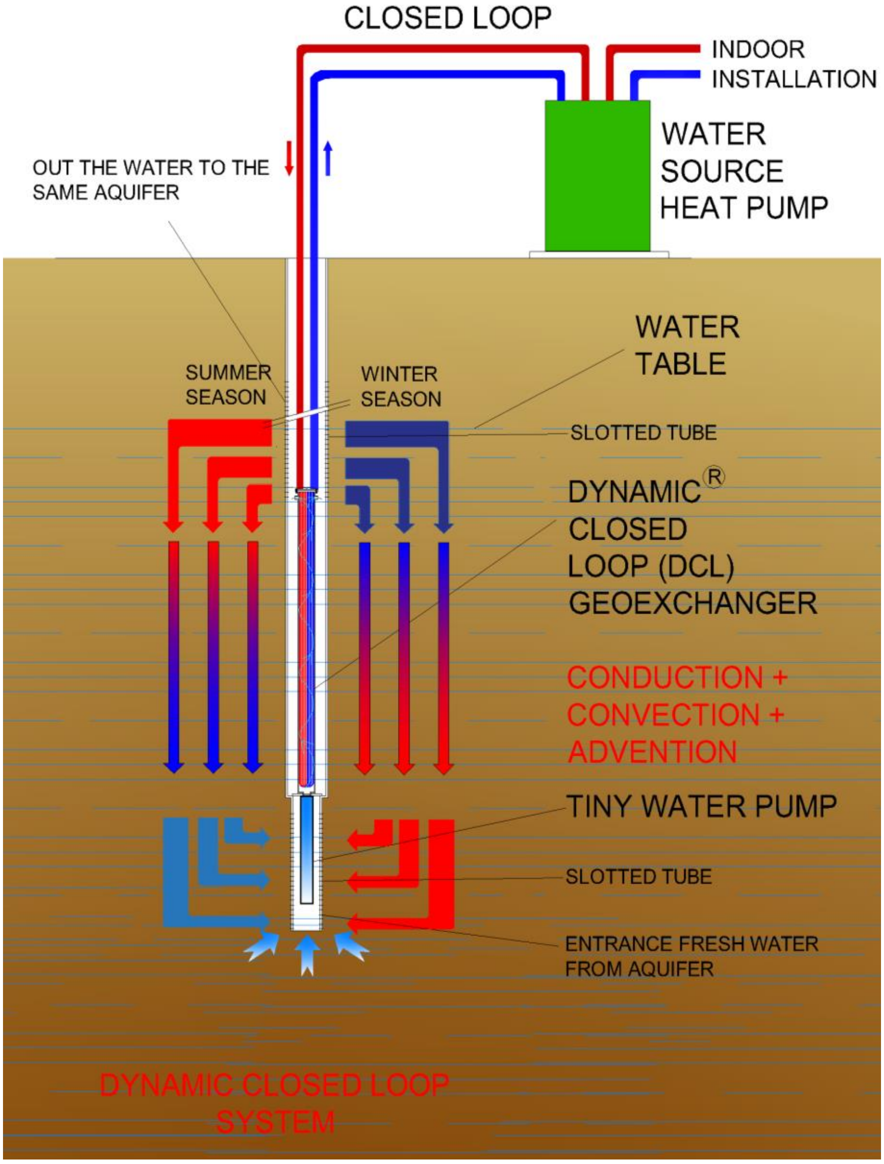


Figure 9. Basic working principle of DCL connected to heat pump

Two external circulating pumps make the water flow in the source side and in the heating side, of which the latter is the hot water circuit which flows through a plate heat exchanger which heats the swimming pool water.

The system layout consists on a geothermal heat carrier medium circuit (source side of the heat pump) which has water plus propylene glycol flowing through each DCL® probe. The probe pump has a power of 370 W, which allow a flow rate of around 3.6 m^3/h for each DCL probe, so 14.4 m^3/h in total. The circulation medium is sent to the DCL-probes at a temperature of 7 to 9 °C and captures heat from the DCL® probes, thus flowing back with a temperature of 4,5 to 5,2 °C higher. A total flow of 14.4 m^3/h, a temperature increase of about 5 °C and a specific heat capacity of the heat carrier medium of about $4x10^6$ J/m^3/°C then results in a power uptake of about 80 kW, which then results in a heat pump COP of about 5.

Each probe can exchange between 26kW and 46kW, being three of them (probes 1,2 and 3) 26kW and the number 4 a 46 kW model, being in testing design phase. So in total there is over 120 kW heat exchange capacity, more than enough to meet the required 80 kW for the evaporator of the heat pump.

A PVC tube jacket with smooth and grooved sections allows the water to move in such a way that it is always obtained from the bottom without affecting its temperature or mixing it with the water that returns to the surrounding subsurface at the upper screen segment (see Fig.9).

A seal of bentonite between the jacket and the perforation short-circuit flow of groundwater between the top and bottom part of the borehole. The reinjected water at the top of the DCL is between 2 °C and 3 °C lower than temperature of the bottom of the borehole. This allows a volume of soil of up to 600m3 to be used in each DCL® probe system with a much higher efficiency than with conventional closed loop systems.

Anticipated system performance ranges from a Coefficient Of Performance of 4.2 to 5.4 depending on the power stage.

Objectives

The technologies of Ground Water Heat Pumps systems (GWHP) were developed at the beginning of 20th century, but its intensive use is recent [4]. The DCL is implemented in the Spanish pilot of the E_USE (aq) project for the interest for promoting the use of renewable energies for the mitigation of climate change, and to assess the potential of the coastal aquifer for heat storage and recovery in the Mediterranean weather and in an area which main water supply is from groundwater bodies.

The Valencia region has a large potential of geothermal shallow resources, so to promote this renewable energy it is necessary to conduct studies in order to control the impact on the aquifer. This lack of insight is one of the key barriers identified in Spain for growing ATES system.

The geothermal exploitation of aquifers could provide an increase of temperature of these water bodies, and could change the soil conditions and its chemical-physical balance. This work is focused on the evaluation of these aspects during the running time of the pilot. The objectives of this study/pilot are indicated in Table 1.

Table 1. Objectives of Spanish pilot plant

Objectives
1. Gain knowledge about thermal behaviour of “La Plana de Castellón” aquifer, coastal aquifer
2. Identify the impacts in chemical aquifer evolution and soil mineralogy
3. Validate a new probe such as DCL adaptable for Spanish conditions (heat and cooling)
4. Increase the knowledge, reliability and experience on ATES systems by public authorities

5. Promotion of benefits from ATES systems for public buildings
6. Offer a baseline information for an adequate regulation framework for shallow geothermal energy implementation

The achievement of these objectives will help to promote the ATES systems in regional at national level, and they contribute to create a regulatory framework for the exploitation of geothermal resources.

Activities

The activities carried out to monitor the improvements are:

- Monitoring the temperatures of the swimming pool's water
- Register the number of users of swimming pool
- Gas consumption
- Energy production
- Aquifer temperature
- Water level of aquifer
- Evolution of chlorides in the groundwater
- Savings for the Council Town
- CO_2 emission reduction (this is calculated by municipal technician)

There is a full monitoring of the aquifer behaviour since started to run the pilot (at end of 2016) and the full system monitoring started in November 2017. We already started retrieving useful data since January 2017; and we tested the whole dynamic system.

The goal of the test period is to gain insight in the performance/efficiency of the DCL and response of the subsurface conditions under various operating conditions. Therefore, the distribution and total amount of heat we extract from the area is varied.

2.3 Monitoring

Aquifer monitoring

The main tasks carried out focused on the assessment of the impact to the aquifer during the operation of the DCL probes and the evaluation the good performance of ATES systems.

In this line, the tasks have been to correlate the performance of DCL probes with the temperature evolution of the aquifer and the chemical evolution while the system was running.

The main tasks carried out focused on the assessment of the impact to the aquifer during the operation of the DCL probes and the evaluation the good performance of ATES system. In this line the tasks have been to correlate the performance of DCL probes with the temperature evolution of the aquifer and the chemical evolution during the systems was running.

The monitoring of the aquifer was carried out by 4 monitoring wells of 25 m deep with tube-lined and filled with selected gravels, these was implemented on the free surface of study area. The monitoring has been done through two ways:

a) Temperature and water level control by Level SCOUT-LS and BaroScout data loggers
b) Monthly chemical control (conductivity, chlorides, among others)

Temperature and water level control

The physical parameters of the aquifer considered to be monitored in this pilot are: temperature and water level. In each monitoring well, a high-precision data logger 0.05% FS were placed (Level SCOUT-LS). These LS sensors measure temperature and water level, which give us information about aquifer behaviour.

The geothermal wells (S) are separated 10 meters from each other, and three of the monitoring wells (P-1, P-2, P-3) were located near the area of greatest influence of the geothermal wells, covering a volume of soil of 1,256 m^3 between the S-2, S-3 and S-4. Another monitoring well (P-4) was placed away from this area and in the direction of water flow (NW-SE), see the figure 7.

Considering to the nature of the DCL® probe operation (see the figure 11), aquifer typology and the water table, the LS were placed between 14-15 m deep, in the P-1 monitoring well another additional sensor was placed to 6.5 meter of depth (P-1.2), in order to take two temperatures in the water column; the water outflow from DCL about 10 m of depth. In November of 2017, this sensor has been moved to 24 m deep.

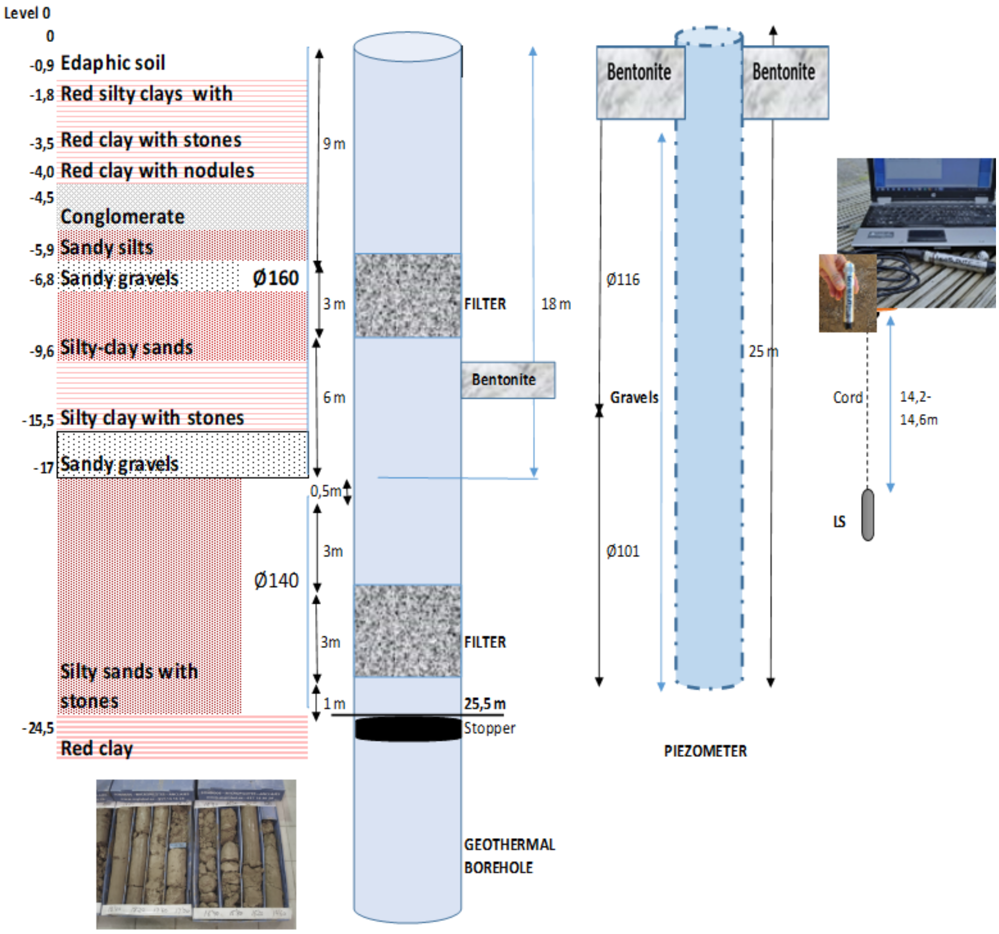


Figure 10 Overview of DCL-well completion scheme

The sensors have been programmed each beginning of the month, ITC visited the pilot at the beginning each month to retrieve the data from sensors and to program a new logging to take data for the next period (monthly). The programming of data sampling in LS was done in different intervals (considered the season, because in winter is when DCL system has worked more:

- Every half hour (1440 records/month) in to winter time (January-April),
- Every 2 hours (350 records/month) in to summer time (May-October)

The data were downloaded monthly.

To complement the thermal study of the aquifer, the City Hall Town gave AICE-ITC access to a meteorological station of the City of Nules located in the Street La Mar n °43, it is less than a kilometre from the study area. We have downloaded the data of precipitations and outside air temperature to integrate with the physical parameters.

Monitoring wells and taking samples	Retrieve the data from sensors and programming (considering the barometric compensation)
	 

Figure 11 Data collection and samples in pilot area

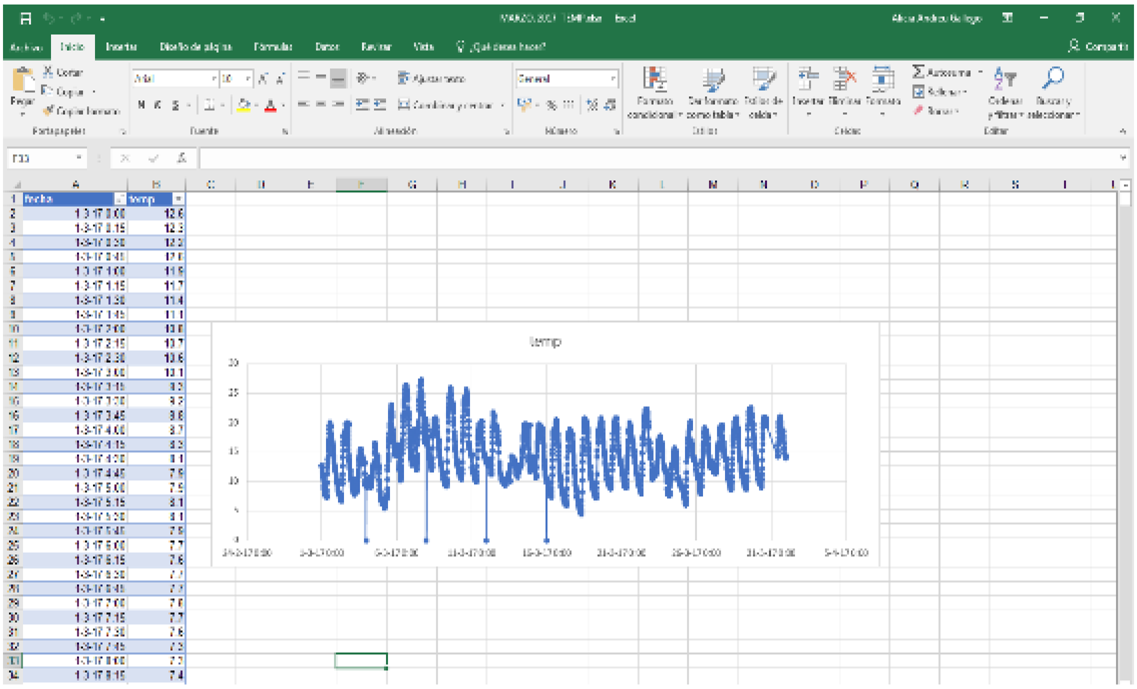


Figure 12 Temperature datasheet from meteorological station of the City of Nules

In addition, each visit to pilot (monthly) the water level has been measured by a level probe of 50 meters of depth, in order to take additional information. When the pilot was implemented the water, level was closely to 10 meter of depth in all monitoring wells.

During the months where DCL probes have worked more hours higher variations of water level-WT have been detected. Due to the pumping of groundwater by the DCL the head in the aquifer changes; increase during injection and a head decrease during extraction of the DCL.

Chemical control

The following chemical parameters have been monitored in the aquifer: pH, conductivity and chloride. The monitoring was carried out by taking water samples in-situ from each monitoring well monthly, and their subsequent analyses were carried out in ITC-AICE laboratories.

The chloride was started to be monitored in May up-to now (in continue way), this parameter was measured in February the first time and from May monthly way, when it was considered to analysis in continue way.

At the beginning of the 2017 (7th February), when the full system starts to run, a full analysis was done to characterize the most relevant ions of the water body in which has implemented ATES system. The main ions analysed in the groundwater are: chlorides, nitrates, nitrites, sulphates, sodium, potassium, magnesium, calcium, manganese and iron. The sample was taken in monitoring well n ° 1.

The determination of chlorides, nitrates, nitrites, and sulphates were carried out by ionic chromatography using a DIONEX model ICS1000 ionic chromatograph; and the determination of sodium, potassium, magnesium, calcium, manganese, and iron was carried out by atomic absorption spectrophotometry using a Perking Elmer model Analyst 400 spectrophotometer.

The most important ions were calcium, sulphates, chlorides and nitrates (see the following table). The full analysis was made in February and in November (3th), the results are in the following table:

Table 2. Results of the chemical analyses at beginning of 2017

	February, 2017
Parameter	**P-1**
Conductividad, µS·cm^{-1}	2200
pH	7.1
Cloruros, mg.L^{1}	215
Nitratos, mg.L^{1}	175
Nitritos, mg.L^{1}	11
Sulfatos, mg.L^{1}	730
Sodio, mg.L^{1}	125
Potasio, mg.L^{1}	1.7
Magnesio, mg.L^{1}	92
Calcio, mg.L^{1}	335
Manganeso	<0.1
Hierro	<0.1

The main idea is to control the annual changes in these more important ions. Hence, these analyses will be carried out into ITC-AICE laboratory, the full results can be seen in the results chapter.

2.3.2 ATES system monitoring

The control and monitoring system operates by means of a Schneider® Modicon®M241 Logic Controller, and by means of a web interface which can be read by a browser in any device, thus making us able to read the system's performance and parameters in real time.

Figure 13 schneider modicon® logic controller with dedicated web server

The working data are downloaded periodically in .log files, being imported to any data analysis software. The available parameters measured (each hour) in an extended array of monitoring points are the following:

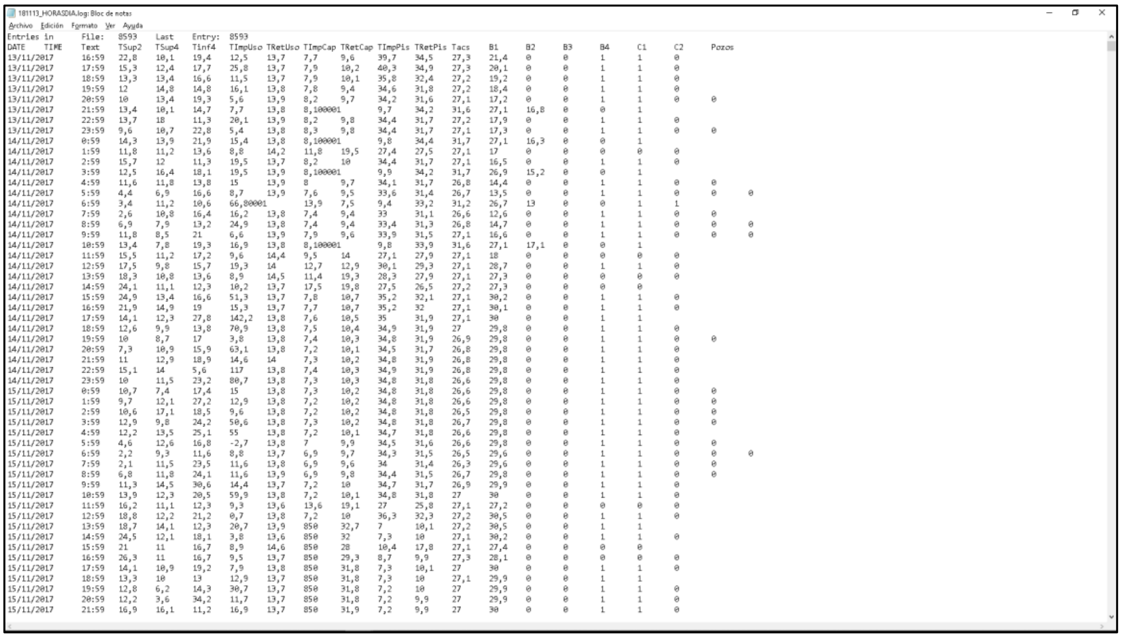
Analog inputs:

- Outside air temperature
- Upper and lower part of Geothermal DCL® Probe number 2
- Upper and lower part of Geothermal DCL® Probe number 4
- Geothermal circuit (Captation) outlet temperature
- Geothermal circuit (Captation) inlet temperature
- Heating circuit outlet temperature
- Heating circuit inlet temperature
- Swimming pool circuit inlet (Actual water temperature)
- Swimming pool circuit outlet (Impulsion water temperature)
- And for the planned hot Water System, both cold and hot water temperatures.

Digital inputs:

- Compressor 1 state (On/Off)
- Compressor 2 state (On/Off)
- Circulating Pump 1 state(On/Off) (heating circuit pump)
- Circulating Pump 2 state(On/Off) (heating circuit pump)
- Inverter 1 state (DCL 1 pump)
- Inverter 2 state (DCL 2 pump)

- Inverter 3 state (DCL 3 pump)
- Inverter 4 state (DCL 4 pump)
- Alarm states (Heat pump, swimming pool filtration system, inverters 1,2,3,4)



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14/11/2017      5:59    4,4     6,9     16,6    8,7     13,9    7,6     9,5     33,6    31,4    26,7    13,5    0       0       1       1       0       0       0
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14/11/2017      7:59    2,6     10,8    16,4    16,2    13,8    7,4     9,4     33      31,1    26,6    12,6    0       0       1       1       0       0
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14/11/2017      10:59   13,4    7,8     19,3    16,9    13,8    8,100001        9,8     33,9    31,6    27,1    17,1    0       0       1
14/11/2017      11:59   15,5    11,2    17,2    9,6     14,4    9,5     14      27,1    27,9    27,1    18      0       0       0       0       0
14/11/2017      12:59   17,5    9,8     15,7    19,3    14      12,7    12,9    30,1    29,3    27,1    28,7    0       0       1       1       0
14/11/2017      13:59   18,3    10,8    13,6    8,9     14,5    11,4    19,3    28,3    27,9    27,1    27,3    0       0       0       0       0
14/11/2017      14:59   24,1    11,1    12,3    10,2    13,7    17,5    19,8    27,5    26,5    27,2    27,3    0       0       0       0
14/11/2017      15:59   24,9    13,4    16,6    51,3    13,7    7,8     10,7    35,2    32,1    27,1    30,2    0       0       1       1       0
14/11/2017      16:59   21,9    14,9    19      15,3    13,7    7,7     10,7    35,2    32      27,1    30,1    0       0       1       1       0
14/11/2017      17:59   14,1    12,3    27,8    142,2   13,8    7,6     10,5    35      31,9    27,1    30      0       0       1       1
14/11/2017      18:59   12,6    9,9     13,8    70,9    13,8    7,5     10,4    34,9    31,9    27      29,8    0       0       1       1       0
14/11/2017      19:59   10      8,7     17      3,8     13,8    7,4     10,3    34,8    31,9    26,9    29,8    0       0       1       1       0       0
14/11/2017      20:59   7,3     10,9    15,9    63,1    13,8    7,2     10,1    34,5    31,7    26,8    29,8    0       0       1       1       0
14/11/2017      21:59   11      12,9    18,9    14,6    14      7,3     10,2    34,8    31,9    26,8    29,8    0       0       1       1       0
14/11/2017      22:59   15,1    14      5,6     117     13,8    7,4     10,3    34,9    31,9    26,8    29,8    0       0       1       1       0
14/11/2017      23:59   10      11,5    23,2    80,7    13,8    7,3     10,3    34,8    31,8    26,6    29,8    0       0       1       1       0
15/11/2017      0:59    10,7    7,4     17,4    15      13,8    7,3     10,2    34,8    31,8    26,6    29,8    0       0       1       1       0       0
15/11/2017      1:59    9,7     12,1    27,2    12,9    13,8    7,2     10,2    34,8    31,8    26,6    29,8    0       0       1       1       0       0
15/11/2017      2:59    10,6    17,1    18,5    9,6     13,8    7,2     10,2    34,8    31,8    26,5    29,8    0       0       1       1       0       0
15/11/2017      3:59    12,9    9,8     24,2    50,6    13,8    7,3     10,2    34,8    31,8    26,7    29,8    0       0       1       1       0       0
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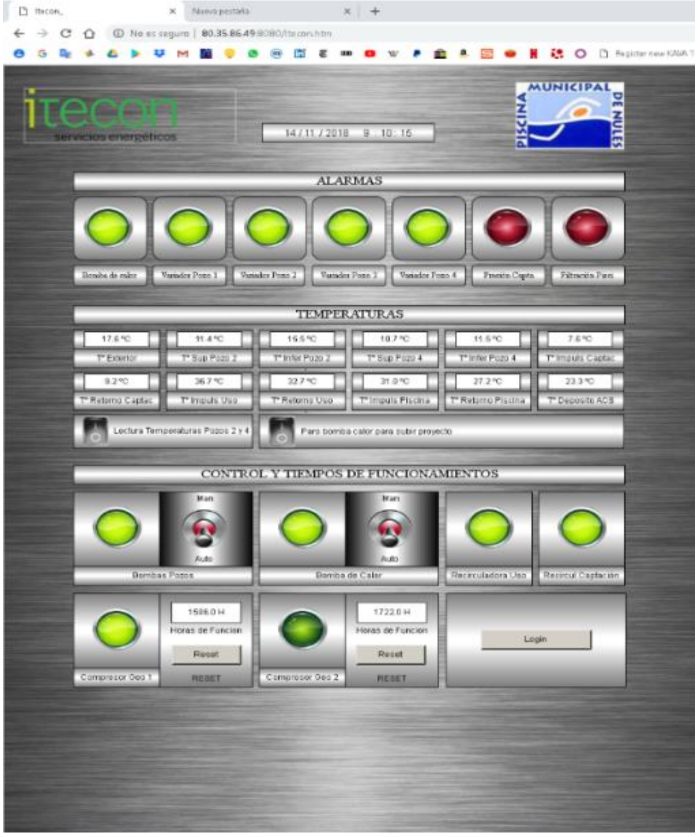
15/11/2017      5:59    4,6     12,6    16,8    -2,7    13,8    7       9,9     34,5    31,6    26,6    29,8    0       0       1       1       0       0
15/11/2017      6:59    2,2     9,3     11,6    8,8     13,7    6,9     9,7     34,3    31,5    26,5    29,6    0       0       1       1       0       0       0
15/11/2017      7:59    2,1     11,5    23,5    11,6    13,8    6,9     9,6     34      31,4    26,3    29,6    0       0       1       1       0       0
15/11/2017      8:59    6,8     11,8    24,1    11,6    13,9    6,9     9,8     34,4    31,5    26,7    29,8    0       0       1       1       0       0
15/11/2017      9:59    11,3    14,5    30,6    14,4    13,7    7,2     10      34,7    31,7    26,9    29,9    0       0       1       1       0
15/11/2017      10:59   13,9    12,3    20,5    59,9    13,8    7,2     10,1    34,8    31,8    27      30      0       0       1       1       0
15/11/2017      11:59   16,2    11,1    12,3    9,3     13,6    13,6    19,1    27      25,8    27,1    27,2    0       0       0       0       0
15/11/2017      12:59   18,8    12,2    21,2    0,7     13,8    7,2     10      36,3    32,3    27,2    30,5    0       0       1       1       0
15/11/2017      13:59   18,7    14,1    12,3    20,7    13,9    850     32,7    7       10,1    27,2    30,5    0       0       1       1
15/11/2017      14:59   24,5    12,1    18,1    3,8     13,6    850     32      7,3     10      27,1    30,2    0       0       1       1       0
15/11/2017      15:59   21      11      16,7    8,9     14,6    850     28      10,4    17,8    27,1    27,4    0       0       0       0
15/11/2017      16:59   26,3    11      16,7    9,5     13,7    850     29,3    8,7     9,9     27,3    28,1    0       0       0       0       0
15/11/2017      17:59   14,1    10,9    19,2    7,9     13,8    850     31,8    7,3     10,1    27      30      0       0       1       1       0
15/11/2017      18:59   13,3    10      13      12,9    13,7    850     31,8    7,3     10      27,1    29,9    0       0       1       1
15/11/2017      19:59   12,8    6,2     14,3    30,7    13,7    850     31,8    7,2     10      27      29,9    0       0       1       1       0
15/11/2017      20:59   12,2    3,6     34,2    11,7    13,7    850     31,8    7,2     9,9     27      29,9    0       0       1       1       0
15/11/2017      21:59   16,9    16,1    11,2    16,9    13,7    850     31,9    7,2     9,9     27      30      0       0       1       1       0
```

Figure 14 log file with data array



14 / 11 / 2018   9 : 10 : 16

17.6 ºC
Tª Exterior
11.4 ºC
Tª Sup Pozo 2
16.5 ºC
Tª Infer Pozo 2
10.7 ºC
Tª Sup Pozo 4
11.5 ºC
Tª Infer Pozo 4
7.6 ºC
Tª Impuls Captac
8.2 ºC
Tª Retorno Captac
36.7 ºC
Tª Impuls Uso
32.7 ºC
Tª Retorno Uso
31.0 ºC
Tª Impuls Piscina
27.2 ºC
Tª Retorno Piscina
23.3 ºC
Tª Deposito ACS

Lectura Temperaturas Pozos 2 y 4
Paro bomba calor para subir proyecto

1586.0 H
Horas de Funcion
1722.0 H
Horas de Funcion

Figure 15 web system interface screen shot

The web interface can be seen in any browser by using the following URL:
http://80.35.86.49:8080/ltecon.htm

The pumps, heat pump, alarms, temperaturas and working hours can be checked out in real time. Additionaly, several subsystems can be deactivated remotely (protected with a password).

The web interface itself can show the last 100 rows of data available; and up to 2 years of data are stored in the SD-card supported memory. This control and interface system has become the DCL® system standard for any new installation made.

3. Results and discussion

3.1 Aquifer behaviour / response

Temperature evolution analysis

One of the main objectives of this work is the evaluation of behaviour (the main impacts) on regional aquifer of an ATES system operation with a new probe DCL®. These probe pumps water from the bottom trough along the probe for heat exchange, and after which is returned at soil trough the upper part of the probe and the water returns to the aquifer and descends again into the aquifer by gravity. In this way, the heat exchange takes place with a large volume of subsurface space, which covers the whole extension of the system in vertical and with a diameter of several meters. In this way, an effective heat exchange is performed with the subsurface using groundwater as transport medium. The volume of subsurface with which the heat exchange takes place is 2,400 m^3, and the pump rate is 1 litre/minute.

This generates an effective heat exchange is performed with the subsurface using groundwater as transport medium. Hence, this work mainly is focuses on evaluating the thermal impact on the aquifer.

This system leads to aquifer thermal affection heat and cool, this study has been focused on cool season (introducing cool into aquifer). The initial situation of the aquifer, before to start running the system, was water level about 11 m deep and the water temperature about 21 °C. This is an aquifer multilayer with sedimentary materials (gravels, clay, sands, slits), these materials are mixing with different thickness, the permeability analysed in the silty sands (by in situ test) has been determined a hydraulic permeability (K) of 3.3 x10^{-07} cm/s.

A small test of aquifer heating has been done in August 2018 for 8 days, but only in one of the DCL probe (see figure 32 thermal test temperature) and don't is representative to analyse the aquifer heating behaviour.

The P-1, P-3 and P-4 are in the direction of the water flow and P-2 is not in line with the flow direction.

The LS were placed about 14.5 m deep, in the P-1 monitoring well another additional sensor was placed to 6.5 m of depth, from May (P-1.2) and at the end of 2017 this sensor has been moved at 24.5 ms of depth, in order to take two temperatures in the water column; also, atmosphere compensation has been done by baro (Baro Scout datalogger).

The evolution data from each monitoring well (P-1, P-1, P-3 and P-4) can see in the following graphs by year (2017, 2018 and in together) and the environment temperature, where in the axis show the degrees temperature (°C):

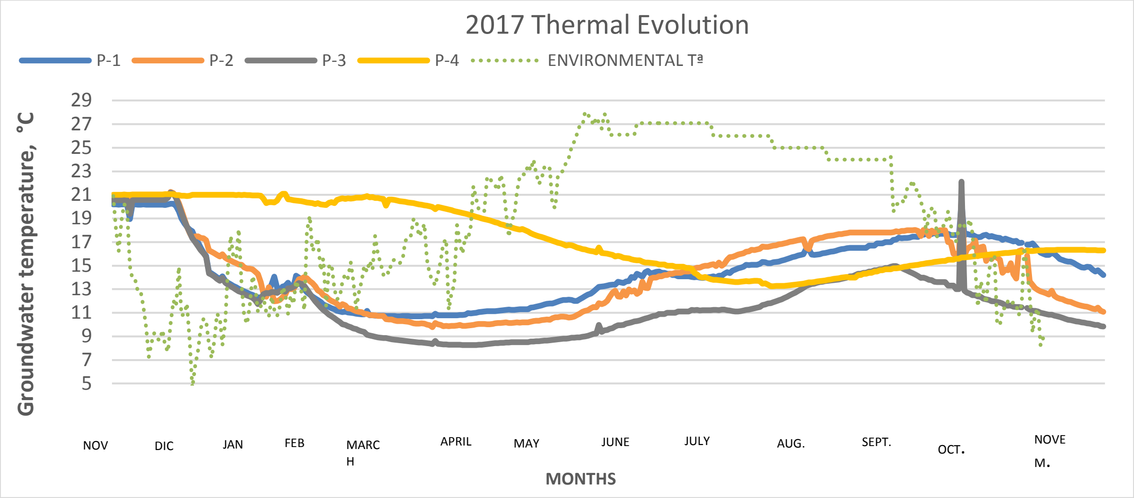


Figure 16. Thermal evolution in 2017

This parameter suffers the most adverse effects; a progressive decrease in the water temperature of the aquifer is clearly observed, leading to a cooling of the aquifer, especially in the winter months. There is a quick drop in temperature from the beginning of the system start-up (end of 2016) to February, dropping from the initial 21 °C to 13 °C. From February to March, the temperature remains constant due to operation stop of the system (February month). From March the temperature drops more gradually and less markedly up to 10 °C. The temperature starts to settle down in April and it tends to go back gradually.

It is noted that the evolution of the thermal plume, as expected, is moving in the direction of groundwater flow (NW-SE) towards the P-4. The P-1 starts its thermal recovery in April, while the P-2 and P-3 start it in May. On the other hand, from March onwards, the P-4 will begin to suffer from the thermal condition of the feather, progressively lowering its temperature. The insensitive of the cool plume arrived on P-4 in June/July and starts to recover the temperature at the end of August. This means a flow rate of the 0, 059 m/d (P-3 to P-4 distance is 9.5 m and the time needed 160 days). However, for a right operation of the thermal store the ground water velocity should be less than 0.05 m/d, to avoid subtracts the heat or cool from the store [9]. This work is not focusing on the recovery curve.

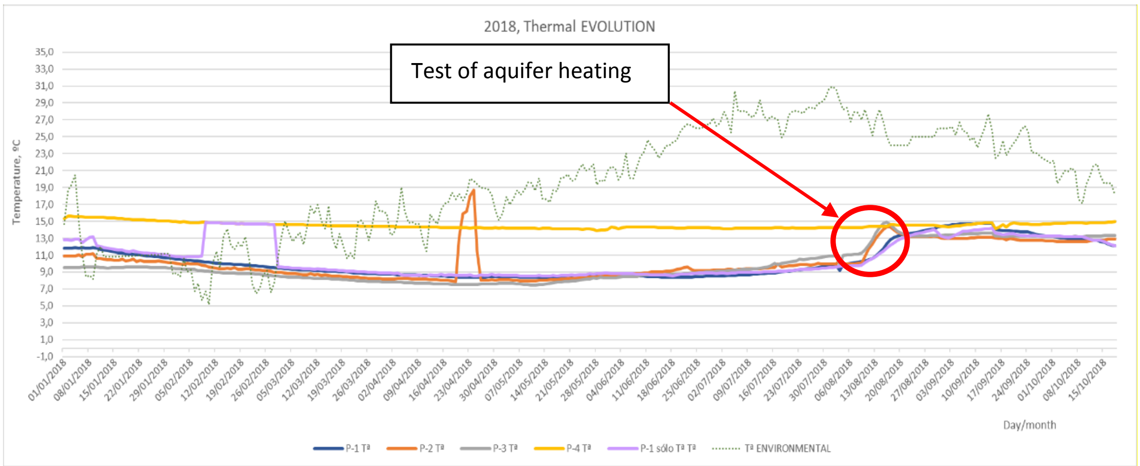


Figure 17. Thermal evolution 2018

In this year the evolution of the aquifer temperature has been less dramatically than 2017. During this year the temperature is keeping slightly constant, but the trend is decreasing the temperature. In 2018 start about 15 degrees and finished the year in 13 degrees. In general, we can see that the natural trend is to reduce the temperature in this area, hence to ensure the good performance the ATES system in the time, we should be doing a heat injection to the ground.

In August a small temperature recuperation is done, this due a heating test made for 8 days for analysing the aquifer behaviour when it is introducing heat. In August the temperature increases up to 13 degrees, and at the end of September, when ATES system start to work, the temperature decreases again.

In figure 18 we can see a global analyse, from aquifer temperature evolution in each monitoring well and the environmental temperature.

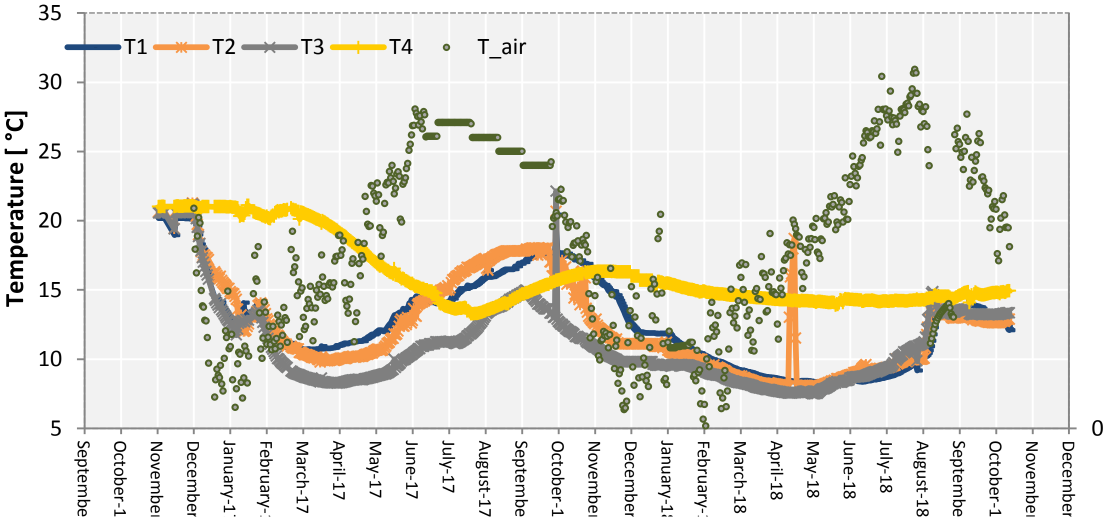


Figure 18. Temperature evolution over 2017 and 2018

The yellow line is the aquifer temperature evolution in monitoring well number 4, far away of the affection area. The aquifer temperature initial was about 20 °C and currently is about 15

°C. This graph shows a decreasing trend of the aquifer temperature in the area in which ATES system is working.

Water Level evolution analysis

The evolution of the water table and the rain can be seen in figures 19 and 20.

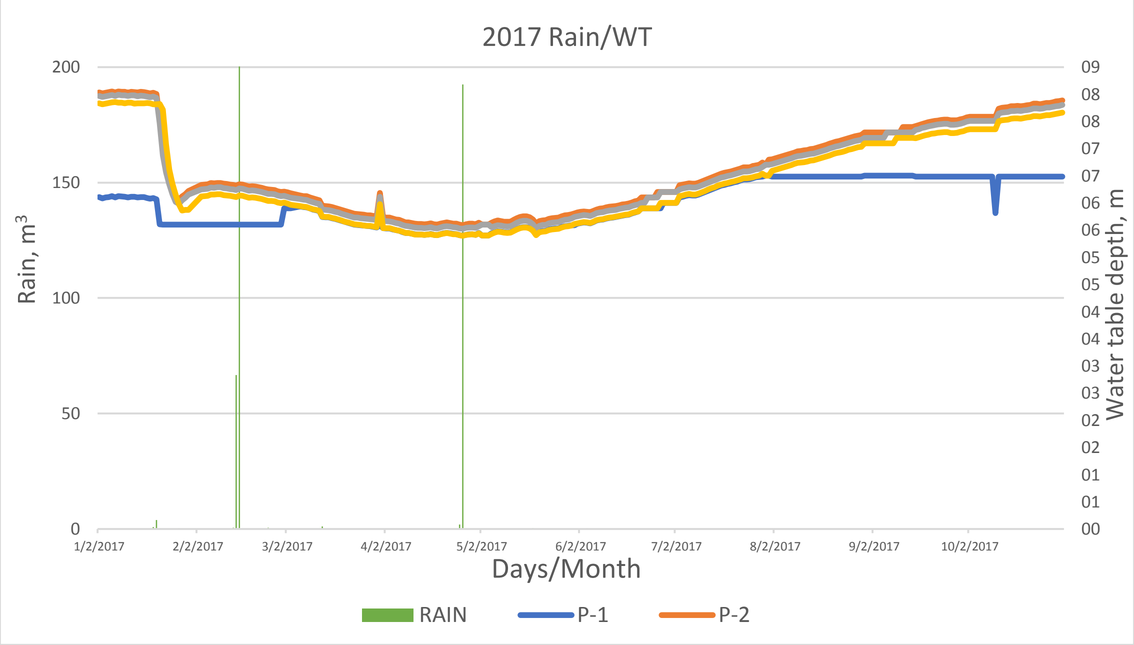


Figure 19 Water table evolution 2017 and rain

During the months when ATES system has worked more hours higher variations of water table-WT have been detected, because the pumping of groundwater by the probes modified slightly the WT of the aquifer. This can see in P-1, because it is more influenced from wells' S-1 and S-2; while in the P-2, P-3 and P-4 the WT remains constant and the same for all three of them.

In general, it is observed that the WT is highest in the months of March to June, months in which the the probes have worked more hours, hence more pumped water over the water level. According the DCL® probe operation, these months are the ones in which the system works best, with levels beginning to fall during the summer season.

The rain did not have a high influence on water table, as no major rain episodes have been registered during this year.

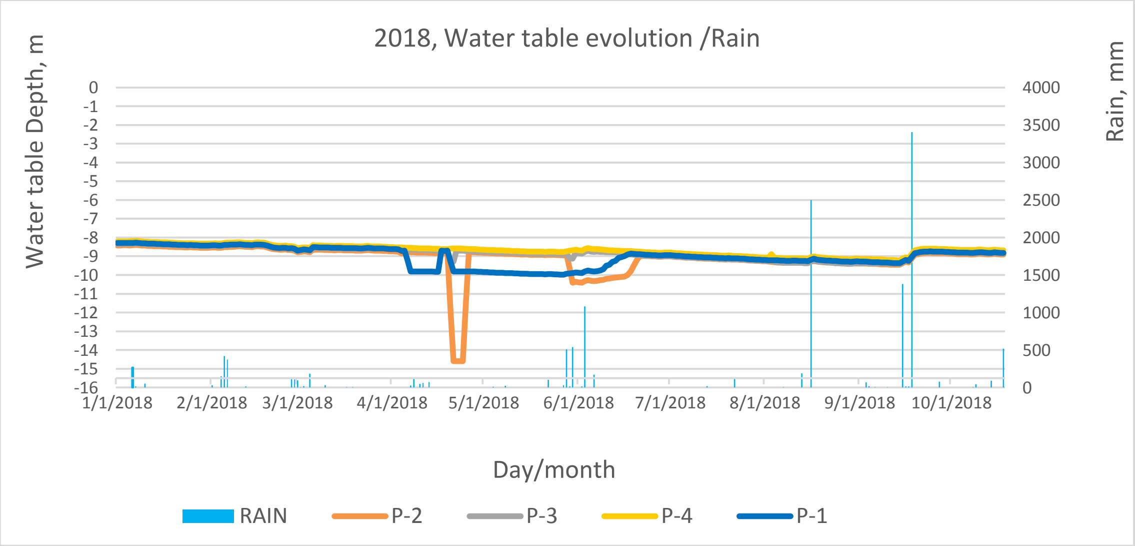


Figure 20 Water table evolution 2018 and rain

The water table evolution in 2018 has been very stable, as show the graph, with negligible influence of the rain precipitation. Only in the monitoring well number 1 suffers dramatically variations from April until July. Also, the graph shows some spot fluctuations on water table, these are regarding to technical problems. But, in a general overview the water level is keeping constant between 8-9 meters of depth.

Chemical evolution analysis

To determine this evolution, the basic parameters of temperature, conductivity, pH and chloride concentration in the monitoring wells have been analysed. The initial data are: 2200 µS/cm of the conductivity and chlorides concentration of the 215 mg/l. The results are indicated in figure 21-23.

1. <u>Chlorides:</u>

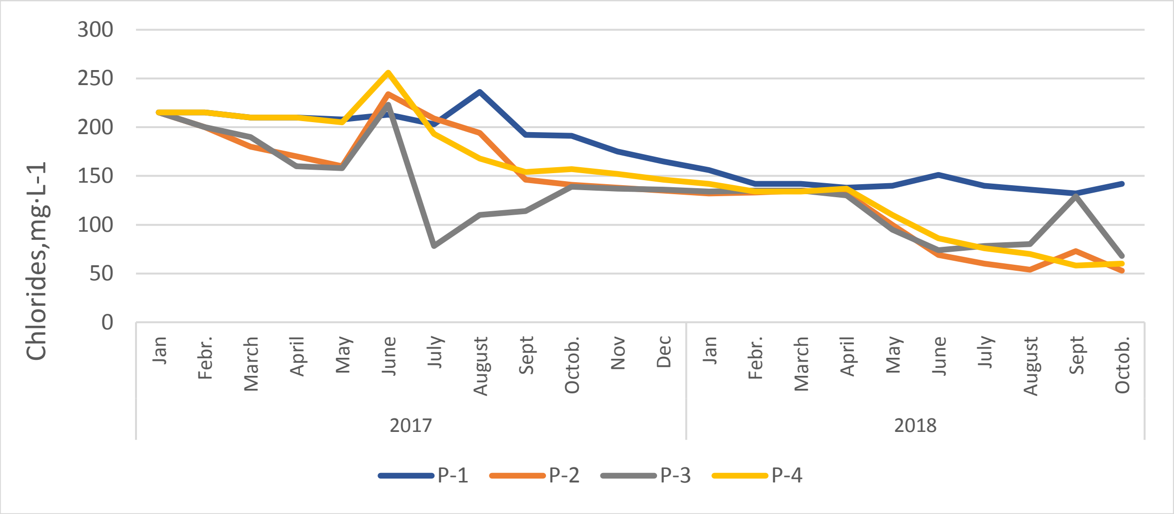


Figure 21. Chloride concentration evolution

The chlorides trend to increase modestly in the months in which the aquifer temperature is higher (from 215 mg/l up to 256 mg/l in June 2017).

In general, the trend is to decrease the chlorides concentration with the drop temperature, due the aquifer temperature is decreasing also the concentration of chlorides.

Also, the graph shows that in P-1 the concentration is slightly higher than the rest monitoring wells due the cool plume is moving in the flow direction. In addition, it is observed that with the recovery of the temperature (temperature increases) the concentration of chlorides in the 4 monitoring wells decreases (P-4 decrease up to 168 mg/l in August and September).

2. Conductivity:

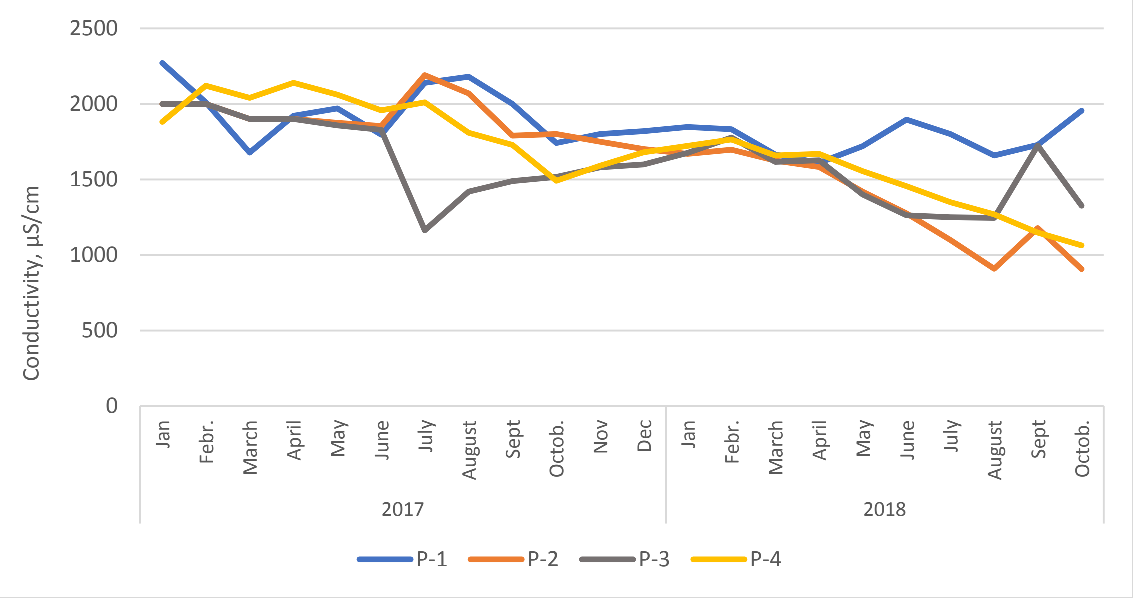


Figure 22. The conductivity evolution during the pilot was running

Regarding the conductivity, it is observed a decrease in the months of greater operation of the system, in which there is a greater temperature reduction; as shown in the data of P-1 and P-4.

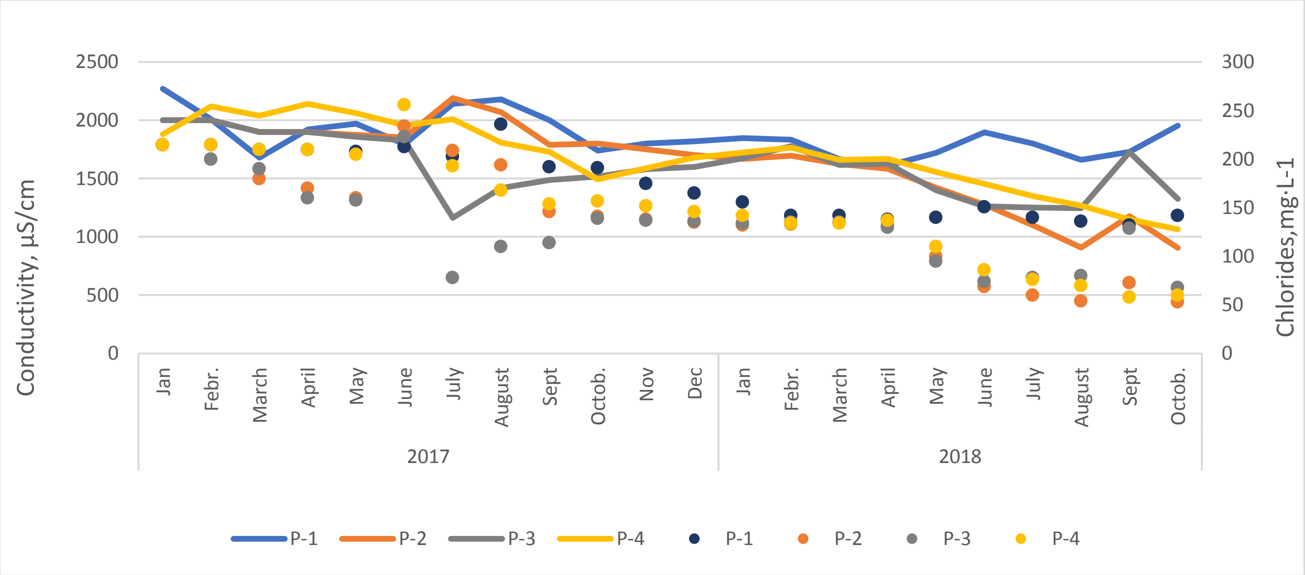


Figure 23. The evolution of conductivity versus chloride

3. pH:

At the beginning to start the system to work the pH identified was about 7.3. In table 3 can see the evolution of the pH.

Table 3. PH evolution in monitoring wells

	P-1	P-4	P-2	P-3
January	7.1	7.28		
February	7.06	7.02		
March	7.25	7.16		
April	7.18	7.21		
May	7.84	7.73	8.06	7.92
June	7.62	7.76	7.92	7.89
July	7.72	8.08	8.11	8.21
August	7.24	7.51	7.83	7.6
September	7.3	7.4	7.8	7.6
October	7.2	7.45	7.6	7.5

The pH did not change significantly (between 7-8) but suffers a bit increase closely to basic pH, thus could facilitate the $CaCO_3$ dissolution. The aquifer contains a high concentration of Ca^{+2} and Mg^{+2} ion (427 mg/l), due to the aquifer is fed by the western limit of a carbonated aquifer. This is a carbonate aquifer and considering that the temperature of the water affects the dissolution of the carbonates (at 25 °C the dissolution is 7mg/l, Le Chatelier's principle) could be occurs a modify the conductivity, i.e. at lower temperatures a higher dissolution of the carbonates [10]. This has not been discussed in this study.

4. Chemical parameters:

A further chemical analysis of the most relevant ions of this aquifer was performed, before starting to run the system: chlorides, nitrates, nitrites, sulphates, sodium, potassium, magnesium, calcium, manganese and iron; the most relevant being calcium (335 mg/l), sulphates (730 mg/l) and chlorides (215 mg/l). During operation, another complete analysis has been carried out to evaluate possible changes, the main idea is to control the annual changes in these more important ions (see table 4).

Table 4. Results of chemical analysis

	February 2017	**November 2017**				**October 2018**			
Parameter	**P-1**	**P-1**	**P-2**	**P-3**	**P-4**	**P-1**	**P-2**	**P-3**	**P-4**
Conductivity, µS/cm	2200	1740	1627	1517	1492	1954	906	1326	1064
Chlorides, mg/L	215	191	141	139	157	142	53	68	60
Nitrates, mg/L	175	187	-	152	135	157	28	49	39

Nitrites, mg/L	11	<1	-	<1	<1	<1	<1	<1	<1
Sulfphates, mg/L	730	580	-	433	417	602	268	354	336
Sodium, mg/L	125	96	-	81	80	82	51	51	53
Potasium, mg/L	1.7	5.6	-	4.1	4	3.5	2.7	3	2.8
Magnesium,mg/L	92	68	-	57	54	64	31	38	36
Calcium, mg/L	335	290	-	243	213	223	103	125	120
Manganesse	<0.1	<0.1	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Iron	<0.1	<0.1	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

Table 4 shows important results at chemical level, in general we can see that the aquifer suffers a slightly improvement of the water quality, because the ATES system reduce the sulphates, nitrates and chlorides concentration. This aquifer is a coastal aquifer in environment of high agriculture production; hence with a problem about nitrates, sulphates and chlorides concentrations, therefore the ATES system could help to improve the groundwater quality.

Aquifer impact:

In 2017, although the aquifer cools down in the winter months, the tendency is to recover its temperature from June, when the ambient temperature also rises, and the energy demand of the pool drops; thus, giving a rapid recovery of the aquifer that allows us to extract heat again for the next winter season, for ensuring the correct functioning of the ATES system. The presence of the groundwater allows accelerating the soil thermal regeneration [9]. But in 2018 the trend to recover the temperature is low; hence we should introduce heat into the soil in order to ensure us the good performance of ATES system in the time.

The decrease of the temperature of the aquifer occurs in a small area of the aquifer, the cool plume is moving in the flow direction, from P-1 to P-4 (about 14 m distance), and the cool plume is dissipating through the surrounding ground; while in P-1 it descends up to 10 °C in the P-4 the lower temperature was 14 °C; this means there is a trend to dissipate the cold plume and not to alter the aquifer as a whole.

Regarding to chemical evolution, the water cooling affects the $CaCO_3$ dissolution present in water and soil; considering that at 25 °C is generated 7 mg/l, we would estimate the generation about 14 mg/l at 10 °C for our case [10], (*Química* de las *aguas naturales, U. Granada*). This effect and its prolongation over time should be studied. We have seen the need to scale up to provide us with data for possible future operating systems.

The results observed show the dilution of the chlorides and sulfates, this show an opportunity to improve the groundwater quality by ATES systems. This should be analyzed in deep, using the ATES system and groundwater remediation. The current studies on ATES systems are focusing on temperature evolution but not on processes of diluted contaminant [11]. This knowledge gap in water quality development could be a severe constraint in ATES application in many urban aquifers.

3.2 ATES performance

During the months August-September we worked to prepare a full project for public Industrial and Miner Register; moreover, of the documents that Nules Town Hall required us such as: A agreement of the collaboration between Nules and ITC-AICE, a recap of the E-USE project with our obligations and the requirements to Nules Town Hall. These documents were needed for the Extraordinary assembly of the city council, in which was approved the project (5th September). During this month of September, we had to wait the administrative times of the Nules Town Hall. But, during this time we worked in the collection of material and the purchase of equipment.

The agreement was signed by the Mayor of Nules and the Manager of ITC-AICE on 7th October, at the same time that was registered the project in the Miner Register for the license. This project should have the full description of each borehole.

Also, during this time and before the start of the operation a **plan** was developed regarding **security conditions,** according to: *Reglamento General para el Régimen de la Minería R.D.2857/1978 de 25 de Agosto [12]*.

Also, a full project was defined for obtain the licenses for the drilling and the registering of each borehole. This was done in "*Registro Industrial and Minero*" (on 7th October).

The heat pump has been producing heat since its starting phase, and the estimated daily energy production is shown in figure 24.

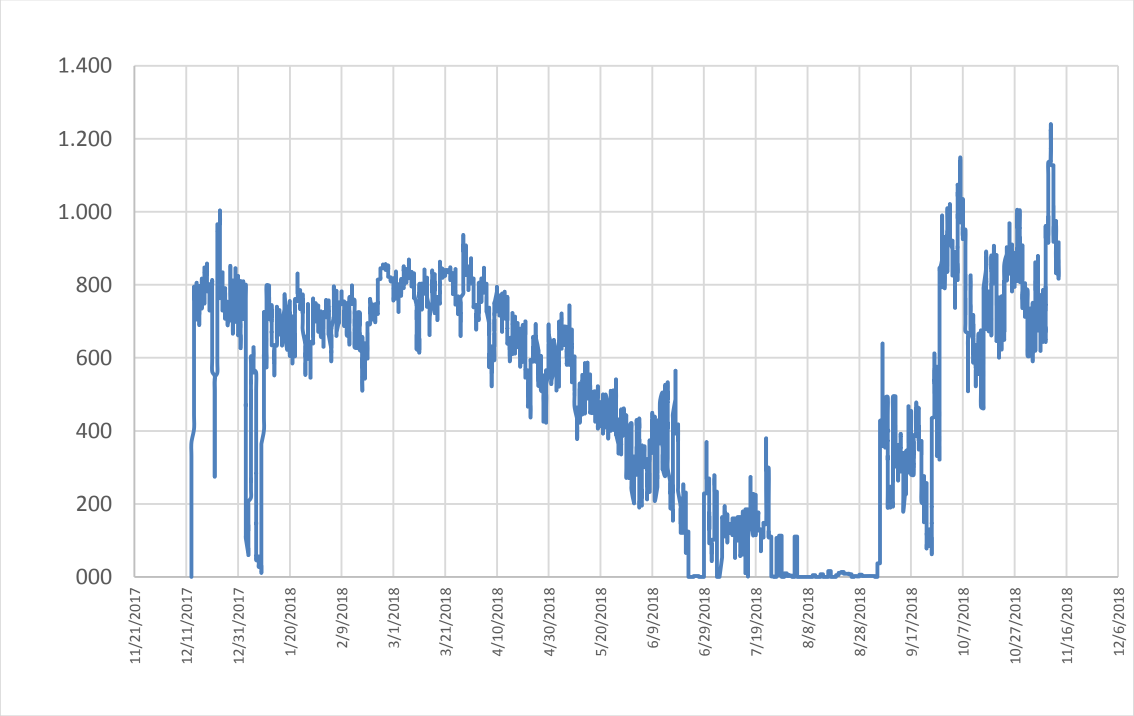


Figure 24. Daily thermal energy production, kWh

The monitoring system allows us to register each of the previously listed parameters, thus given the amount of energy the system produces by hour; since the water flow is fixed in each circuit and it has been measured, the instantaneous power of both heat pump circuits (Heating and capturing) can be determined with accuracy by calculating it from the waterflow and the thermal difference between inlet and outlet.

Our data stored gives us these temperatures each hour, so by integrating it in 24-hour periods we can obtain the total amount of thermal energy the DCL® geothermal probes have captured.

Our first thorough energy analysis can be done in the monitoring system full performance period, i.e. since the first of January, 2018 until the last measured date.

First of all, we can compare the amount of energy captured with the HDD (Heating Degrees Day) and external temperature, which can show the influence of the needs of heating on the system amount of heat capturing necessary.

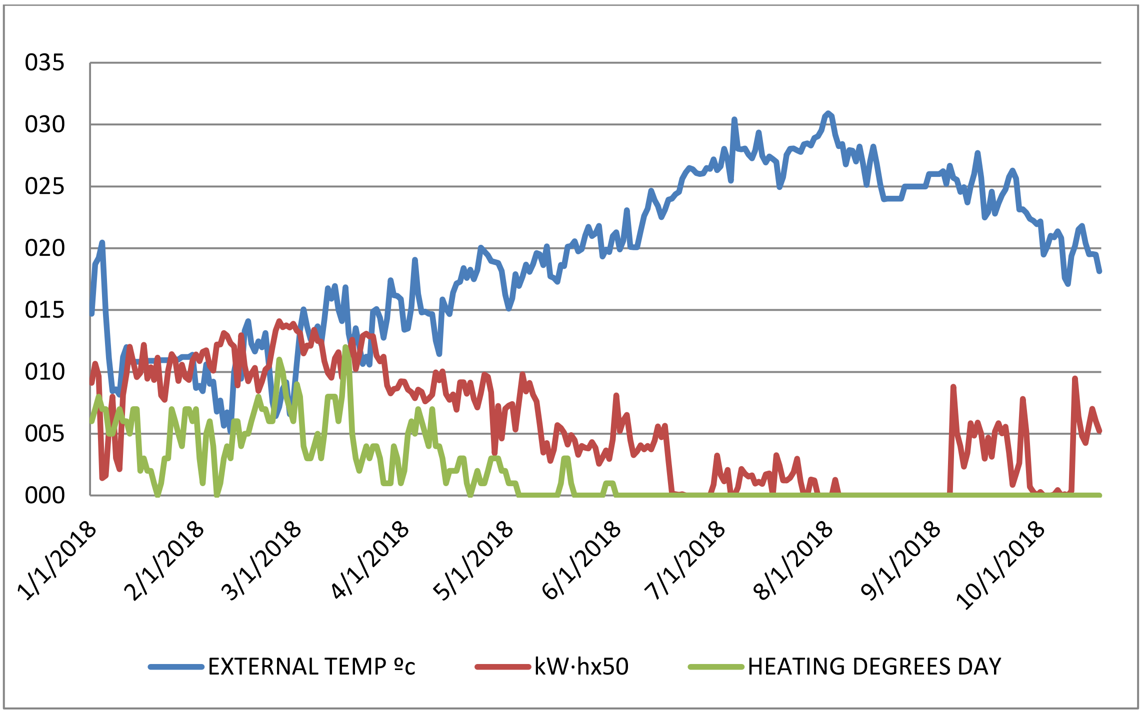


Figure 25 Daily energy captured vs external temperature °c

We scaled the heat captured so that we can compare both profiles and see its correlation, with the HDD graph that shows a tendency following the amount of energy graph. The swimming pool has thermal demands slightly over the usual Mediterranean building, given the temperature of the pool's water (around 28 °C) which makes it more demanding than other indoor facilities.

The Town Council provided us with information of the annual evolution on gas consumption, from the comparative of kW/h used in 2016 - 2018 for swimming pool (data given by owner). The energy use is compared to the Heating degree days (HDD) that have occurred during these years, HHD are a measure for the heating demand, depends on outside air temperature. The HDD for these 3 years were: 335, 428, 420 for 2016, 2017 and 2018 respectively, excluding the HDD contribution of October, November and December [13]. Table 5 shows that the HDD for 2017 and 2018 are almost the same, but for 2016 are much less. So heating demand in 2017 and 2018 was about 60% higher compared to 2016, however, despite the 28% larger heating demand, in 2017 the gas consumption was 53% lower, compared to 2016. In 2017 and 2018 the heating demand was about the same (2% difference), but as a result of improved control of the DCL system, the saving went even further down by 37%.

Table 5. Gas kWh consumption comparative and saves to Council Town of Nules

Month	**2016**	**2017**	**2018**	**DIFERENCE 16-17**	**SAVINGS 16-17**	**DIFERENCE 17-18**	**SAVINGS 17-18**
January	80,024	52,997	42,064	-27,027	-34%	-10,933	-21%
February	67,027	48,719	40,318	-18,308	-27%	-8,401	-17%
March	82,055	33,554	22,090	-48,501	-59%	-11,464	-34%
April	60,304	22,090	4,677	-38,214	-63%	-17,413	-79%
May	40,898	12,679	2,000	-28,219	-69%	-10,679	-84%
June	23,059	3,662	1,279	-19,397	-84%	-2,383	-65%
July	11,114	1,843	0	-9,271	-83%	-1,843	-100%
***August (closed)**	4,715	0	0	-	-	-	-
September	21,532	4,691	1,480	-16,841	-78%	-3,211	-68%
Total	**386,013**	**180,235**	**113,908**	**-205,778**	**-53%**	**-66,327**	**-37%**
HDD (measure for heating demand):	**335**	**428**	**420**	**93**	**28%**	**-8**	**-2%**

The DCL was running, mainly, in the winter and spring season (from January to June), hence if we compare the gas consumption in these months, in which the environmental temperature was more low (January to March).

The influence of the amount of energy captured in the DCL® system has been tested by comparing its variation with the four monitoring wells temperature sensors, thus showing the variations in between probes and the influence at a distance radius of 10 m, which is the distance the #4 monitoring well from the boreholes. Also that #4 monitoring well is placed downstream of the ambient groundwater flow, so that the delay of thermal changes can be shown on it.

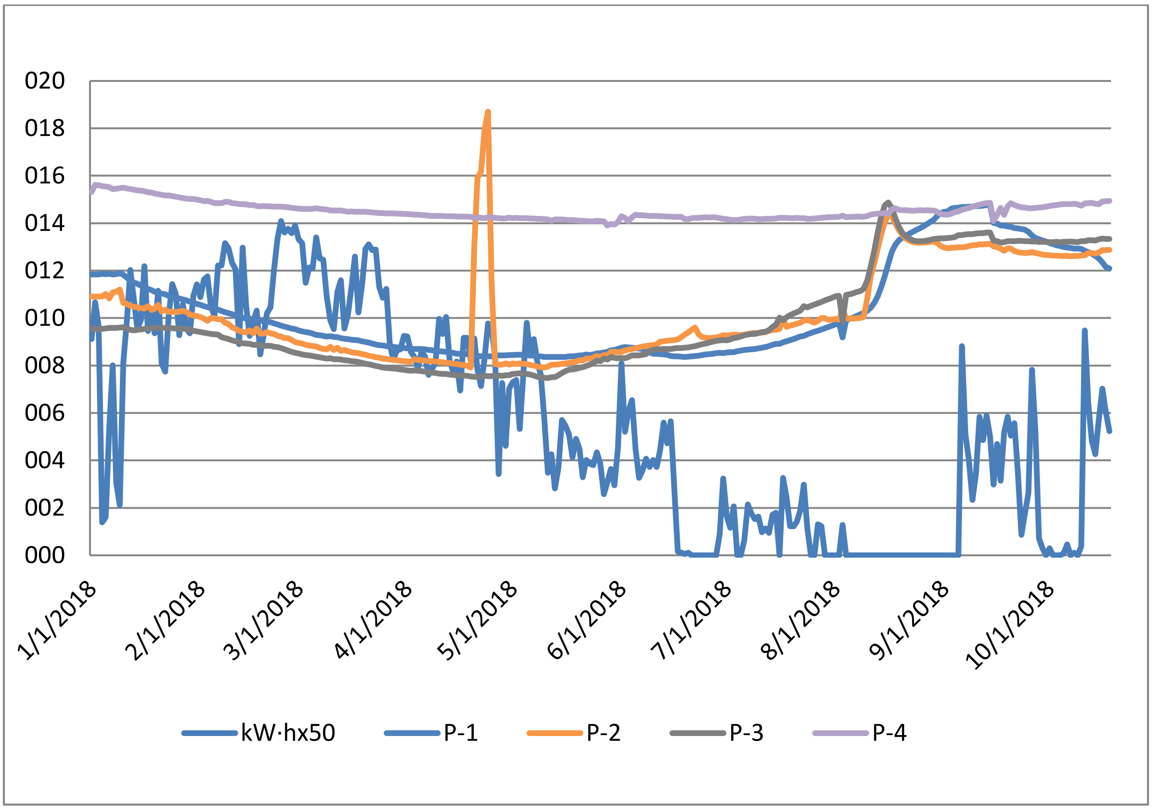


Figure 26 Well temperature vs daily energy captured

When a 10-month period is displayed, we can observe the thermal influence of the energy capturing process and the changes in the two temperature sensor groups: The three monitoring drillings (number 1,2 and 3) which experience the same changes with little variations, thus recovering its temperature as the amount of heat captured decreases in the month of July, and the #4 monitoring well in which its sensor measures a more steady tendency and slighter variations. The radius of influence, about ten meters, changes the subsurface temperature only 1,5 °C overall, following the tendency of the other temperature measurements. The peak measured in the #4 monitoring well is explained by a single water spilling from the surface.

The temperature in the first period of the system started by between 20,2 °C and 20,5 °C in the three monitoring wells between the probes (#8; #1,#2 and #3) and 21 °C in the #4 monitoring well (The most distant one). After the first stage of testing, the temperature dropped to a more steady value of 8 °C to 10 °C; notwithstanding the #4 registers a temperature drop with a delay of approximately two months (56 days).

Average temperature changes in monitoring wells

The average temperature difference in this period has been:

- 1: 3,5 °C
- 2: 3,6 °C
- 3: 1,3 °C
- 4: 2,5 °C

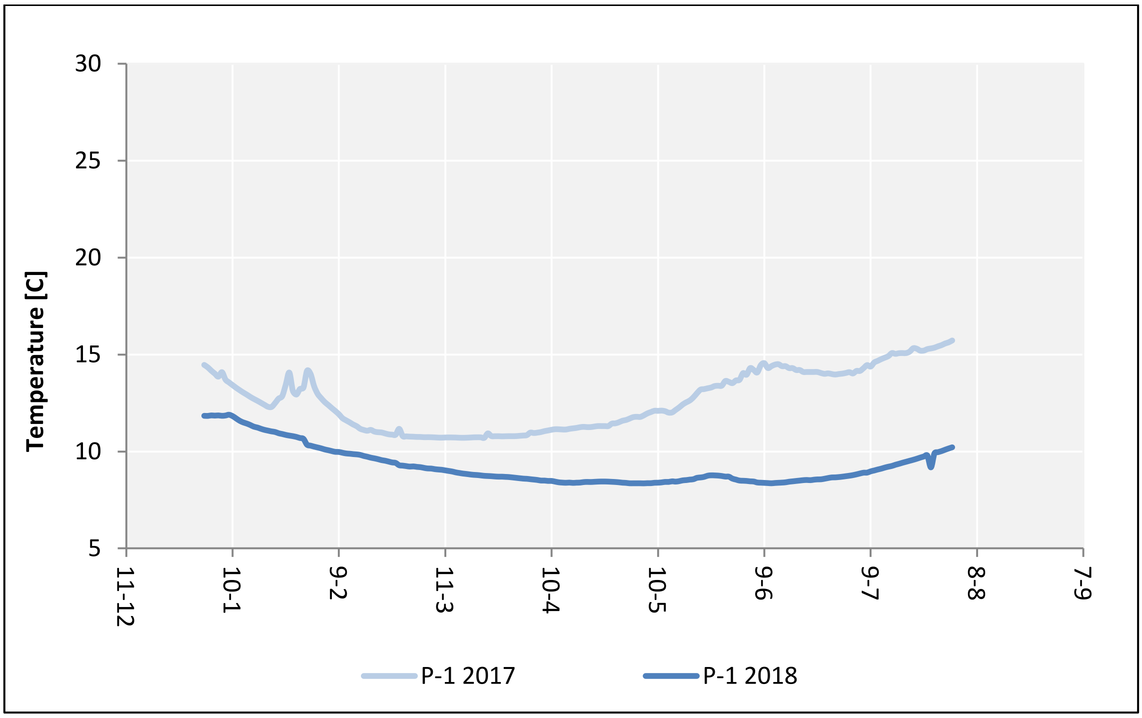


FIGURE 27 TEMPERATURE VARIATION P-1 2017-2018

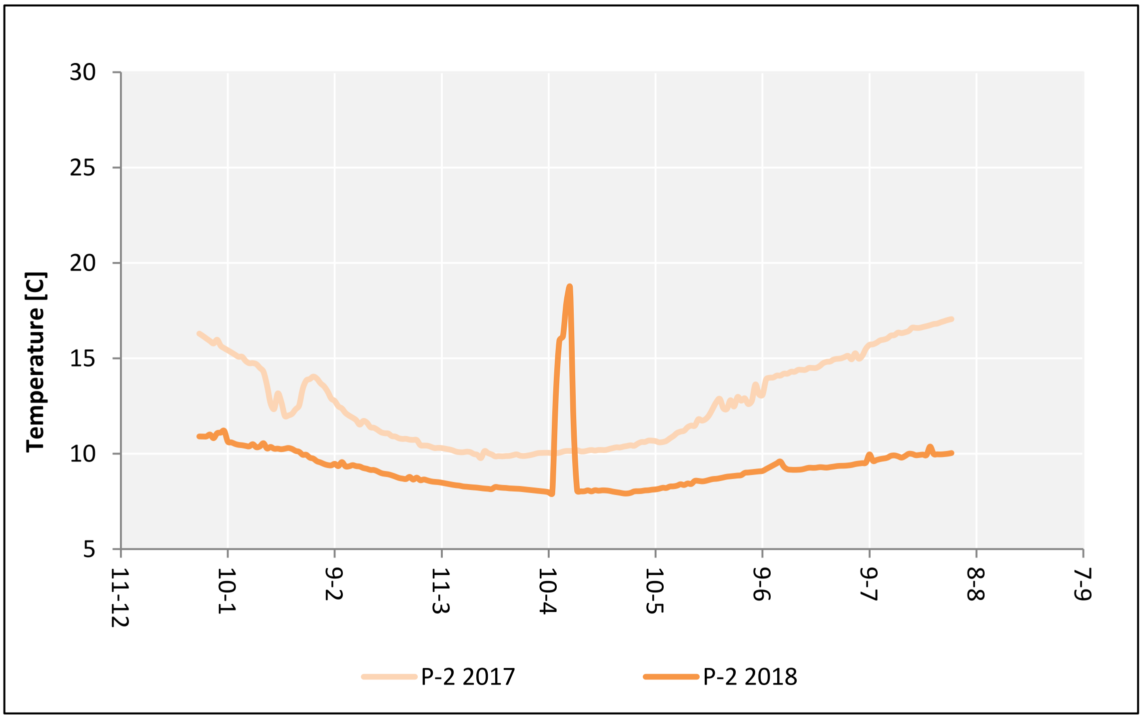


FIGURE 28 TEMPERATURE VARIATION P-2 2017-2018

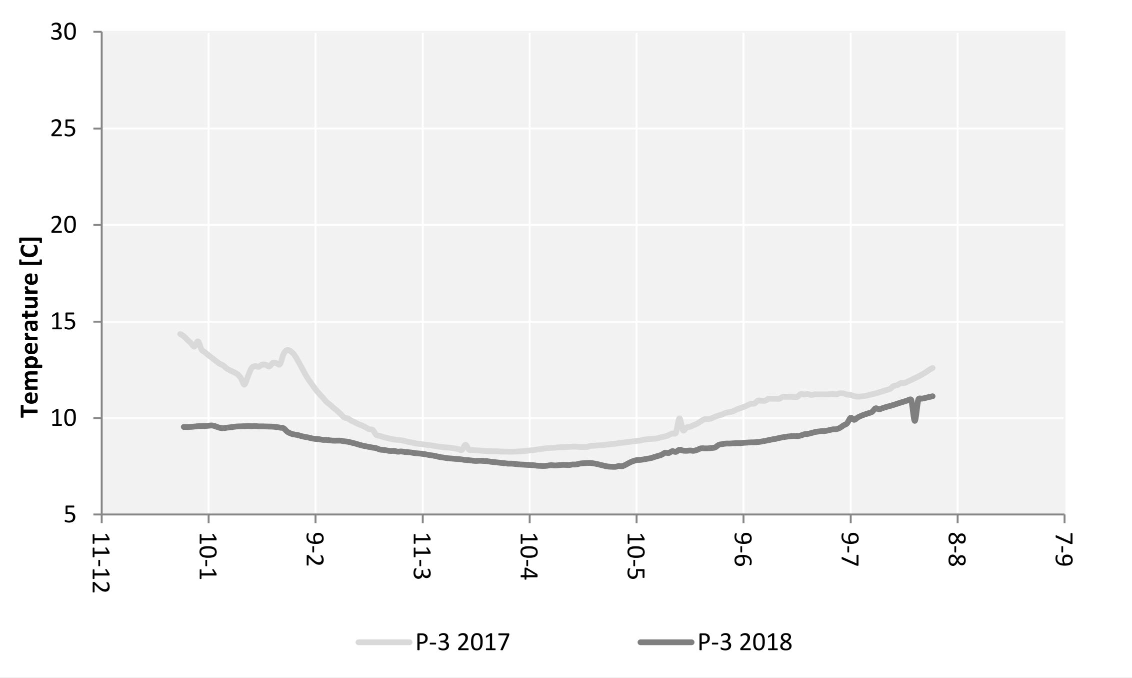


FIGURE 29 TEMPERATURE VARIATION P-3 2017-2018

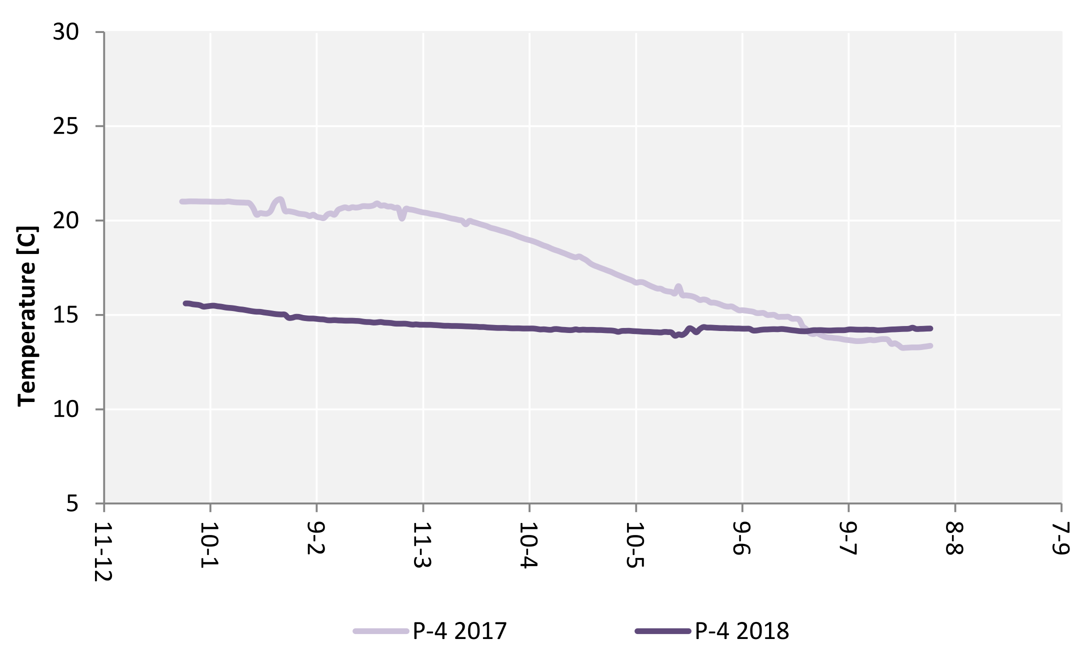


FIGURE 30 TEMPERATURE VARIATION P-4 2017-2018

It is not possible to establish if the temperature drop will continue in the following cycles, so that further periods' data analysis would show the tendency.

Given the P-4 (The control monitoring) it is possible to establish that the temperature changes in the subsurface in the affection radius are not going to be affected in the long term, given that its variation is lower and without major changes or influence from changes in the amount of heat captured.

Thermal stress and dynamic tests

The testing of the thermal dynamics has been made following the programmed activities:

- A six-week period of full stopping the probe number 4 in order to test the thermal influence between probes. This way we can obtain data about the natural heat retrieval rate of the volume of soil used and compare it with the aquifer flow effect.
- A four weeks working phase with the whole system working (The four DCL® probes in full operation).
- After analysing the monitoring results, we've been able to reverse the ATES system and starting the heat injection in the DCL® system. The distribution in time will be arranged by using the thermal testing data from the previously described tests.
- An air-to-water thermal exchanger has been connected in the 4th probe circuit in order to start injecting heat into the subsurface and obtaining the readings of the thermal dynamics of the subsurface. This test simulates the effect of a heat pump system working in reverse way, i.e. injecting heat by using the DCL® system as cooling systems do.
- We have stopped the whole system during the last week of first week of august in order to install the heat injection system.
- The heat injection system has been working in a period of 8 days.
- The municipality has the swimming pool closed for that month (august) so no thermal extraction will be done, thus creating a chance to observe the thermal storage dynamics.
- The next three weeks the whole system has been stopped (in coincidence with the swimming facilities holiday period) and thermal recovery data have been retrieved.
- The first week of September the system has returned to nominal operation and results of the performance and thermal dynamics have been retrieved for overlapping and comparing them with the previous year same period.

The heat injection results show the way the subsurface reacts to a period of heat injection and the influence in time on the other areas. Note that it is the probe #4 the one receiving heat, so that we can observe the thermal influence in the surrounding and distant monitoring probes:

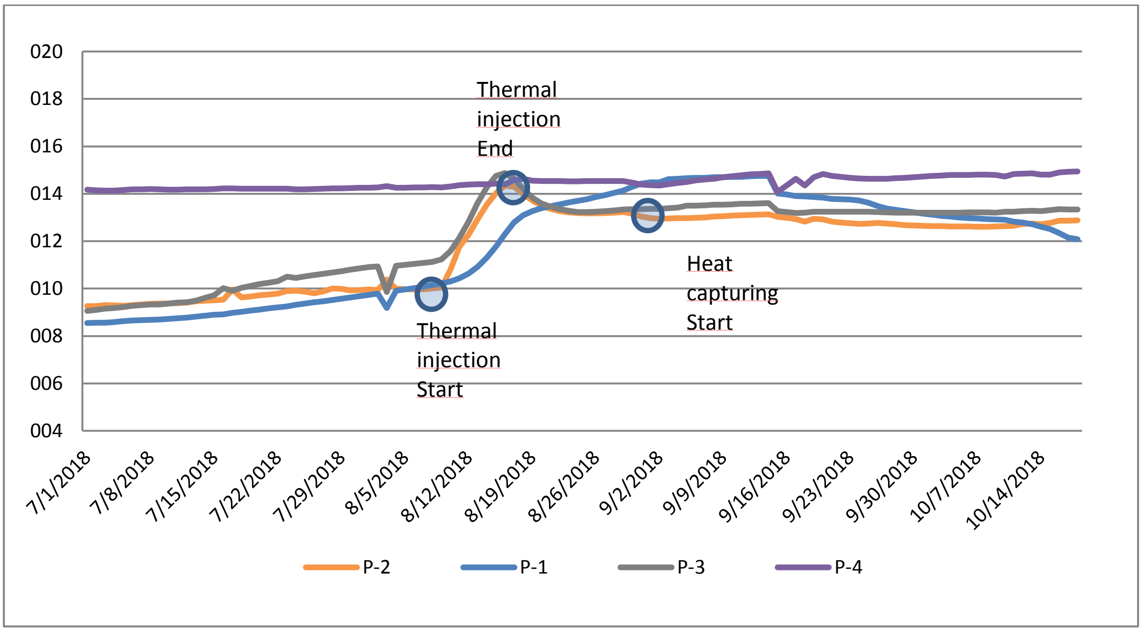


Figure 31 Thermal test temperatures

The delay between the heat injection and the monitoring wells temperature rise is less than one day in the #4 and #3 (The ones which are downstream from the #4 borehole). The influence in the #1 is slower, given that it is upstream (And at the same 4m distance).

The #4 monitoring wells temperature probe doesn’t register major changes, and remains almost constant.

The temperature rise in the 8-day heat injection period has been of 3,3 °C in the two downstream monitoring wells, and 2,4 °C in the upstream one.

Thermal recovery is very quick and can be related to the aquifer’s movement, even though the amount of heat the subsurface stores is still the main component of the long term thermal behaviour.

4. Conclusions and recommendations

Conclusions

The results of this pilot indicate that:

- It is possible to successfully implement an energy saving DCL system in an existing swimming pool and evaluate the thermal balance limits in different environments.
- Spreading of cold groundwater around the DCL probes is limited, but higher density of monitoring wells and/or detailed subsurface simulation can improve insight on thermal distribution in the subsurface
- Slightly improvement of the groundwater quality. The implementation of the DCL has improved the water quality because the concentration of sulphate, nitrate and chloride reduced. In this aquifer is common have these values high.
- Given the different needs of heating/cooling, there may be a limit (in latitude and climate) that make feasible and economically viable a DCL® based ATES system.

Barriers that were overcome:

- The thermal behaviour can be evaluated from a two-dimensional perspective, but further research with more extensive 3d arrays would offer more information about those phenomena and its relevance in the heat storage of a DCL®based ATES. Such information has shown to be of vital importance on a future design phase. Exporting the results and learnings to different environments is an obstacle to tackle with that information.
- Despite the successful implementation of the DCL in Nules, it is still hard and time-consuming to legalise a DCL® based ATES system in several areas of Spain given the technology is still in an introductory phase. The lack of knowledge on funding calls makes it hard to classify the technology. And without systems in operation data about DCL system performance is also not possible.

Recommendations:

- Continue monitoring the aquifer behaviour and DCL performance. Also closely monitor heat pump power conspumption.
- The pilot site has several decades ahead to work and offer valuable data, given the importance of the long-term thermal behaviour and the possibilities it has since the building is undergoing a refurbishment, the options include to work with a reversible system for both heating and cooling.
- Given the energy savings in Nules, similar swimming pool may also benefit from implementing a DCL heat pump system. We recommend integrating the results and experience into the existing public funding schemes.
- A DCL® based ATES system, even with one probe can be integrated in the other pilot sites, giving an opportunity to tests its performance in different aquifers and to act as a backup in cases of water extracting limitations.
- Promotion of ATES systems in Valencia region, The Spanish pilot could be a showroom to public administrations and technicians

- Data base from which we could start to elaborate a regional programme/legislation to implement DCL for Mediterranean swimming pools in similar conditions

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