IGEIA
Integration of Geothermal Energy into Industrial Applications

DELIVERABLE 10: FEASIBILITY STUDY

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1. INTRODUCTION

The objective of this study is to estimate the feasibility of a geothermal heat pump (GHP) system to meet heating and cooling demands in the new commercial complex « Au Carré d'Or », located in Perpignan.

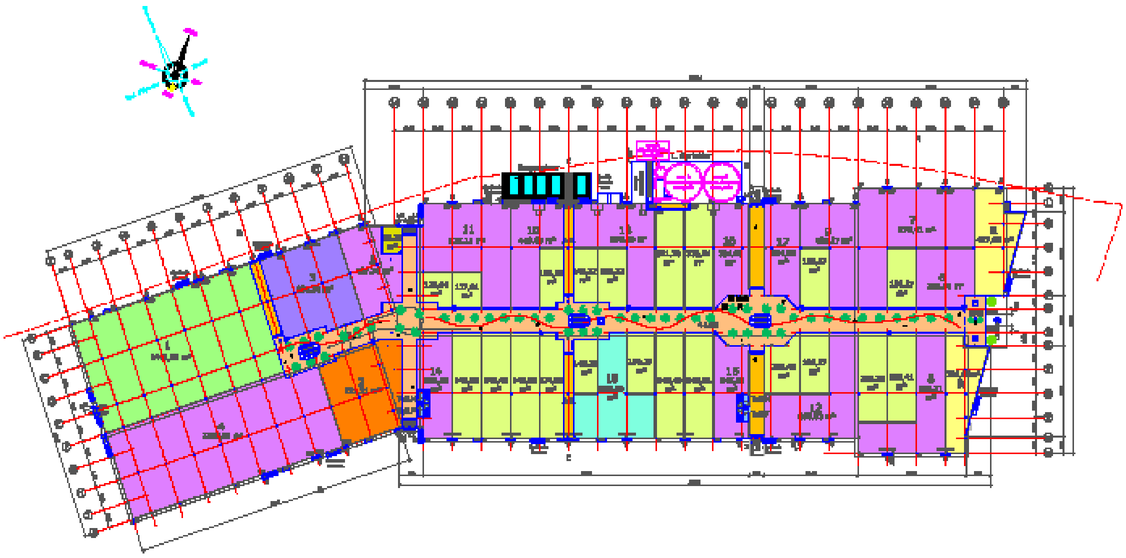


Figure 1 : Project map

The construction of the new commercial complex will involve an area of 25.000 m² dedicated to the world of dwelling: a commercial area of 20.000 m² surrounded by a promenade area 3.000m². Parking areas will also be built around the building.

2. GEOLOGICAL SITUATION

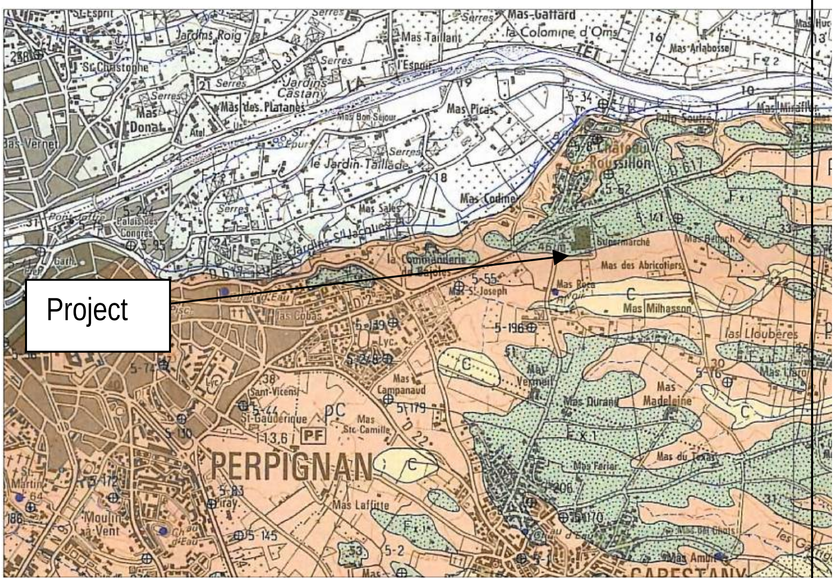
2.1. GENERAL INFORMATION

Perpignan is located in the Roussillon basin, which is a sedimentary basin from the Tertiary, mainly constituted by the piling up of several clayish and sandy layers.

On this particular site the soil is composed of:

- Old alluviums (thickness : 1m)
- Continental Pliocene: stratification of permeable lenticular sandy layers with less permeable clayish layers. The thickness of the continental Pliocene is around 180 m (it increases near the shore).
- Marine Pliocene: mainly formed by mica clays and blue silts. Globally, it is poorly permeable, but the clay formations may laterally and horizontally change into non-consolidated sands, which could represent good aquifers. The basis of the marine Pliocene is impermeable and is formed by black loams

It is difficult to distinguish between these two geological levels. It is impossible to forecast the lithostratigraphic cross-section of the site, in detail, due to many alternations between clay and sand, and the highly varying lateral features.



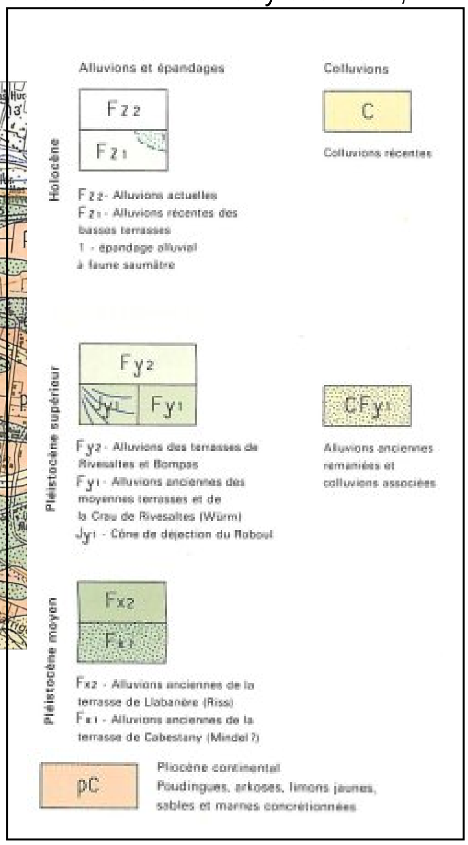


Figure 2 : Geological map

2.2. HYDRO GEOLOGICAL SITUATION

The aquifer of the Pliocene is usually considered as a unique multiple-layer set. This aquifer is intensively exploited in this region; in 1996, it provided 57 % of the collective water production. The groundwater table is confined.

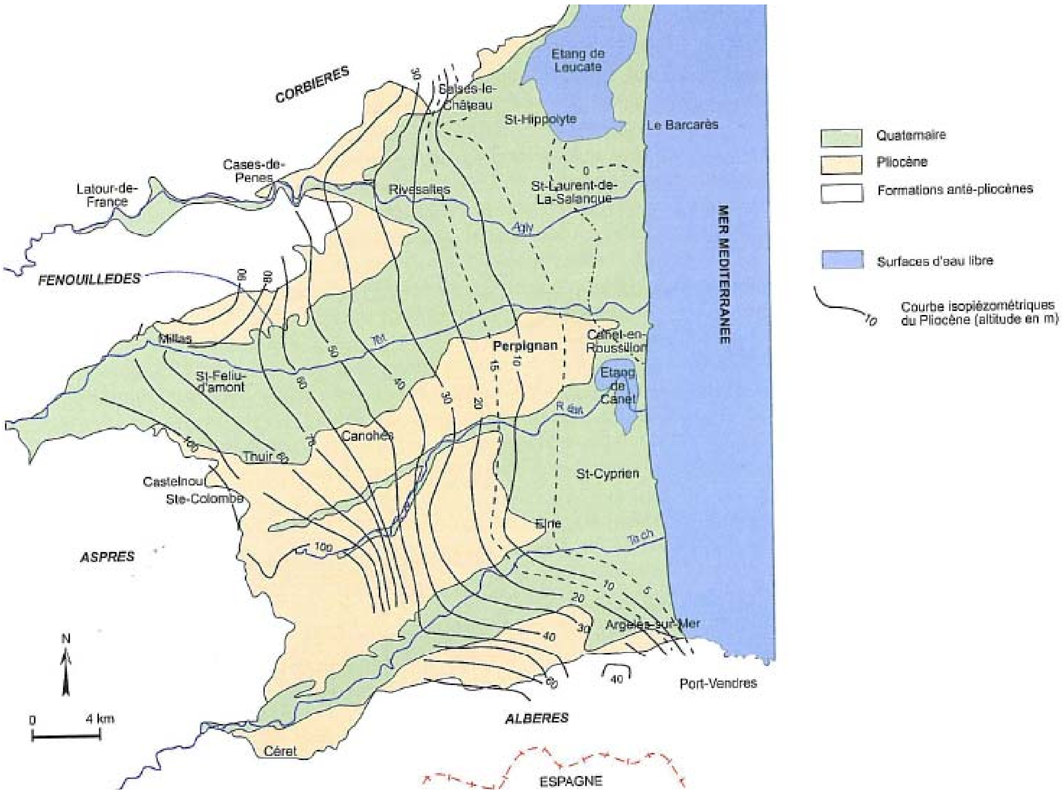


Figure 3 : Simplified hydrogeologic map of the aquifer (Source: BRGM 1997)

2.2.1 Available flow rates

In order to evaluate the hydro-geological potential of the site, all surrounding wells were studied.

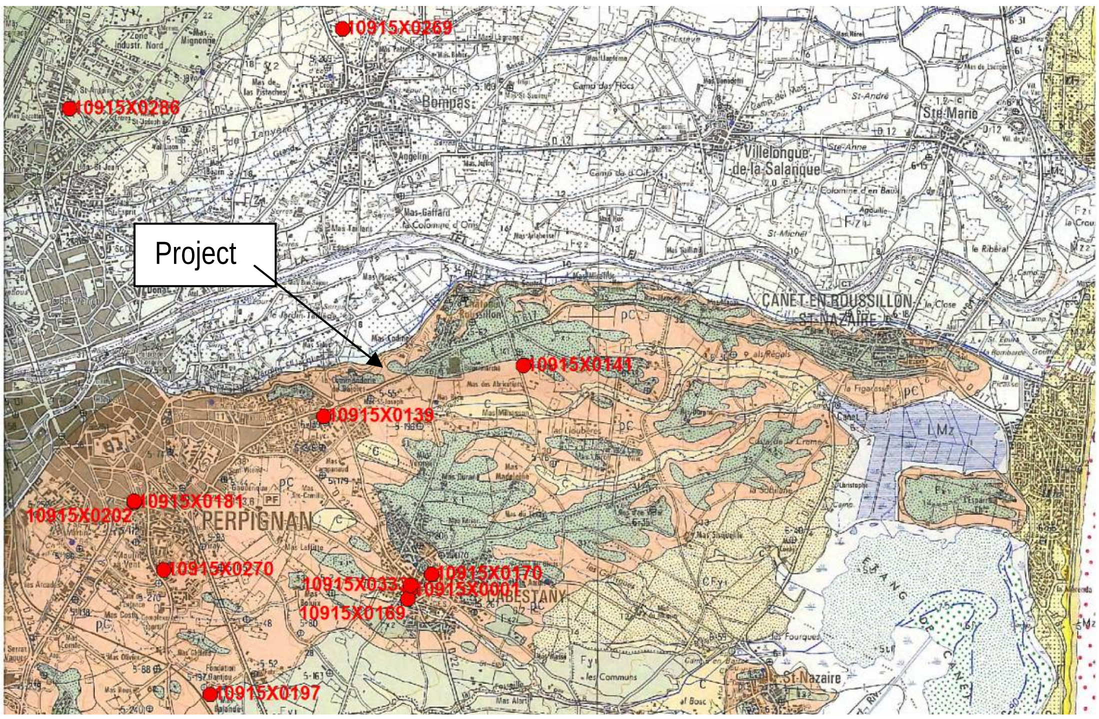


Figure 4 : Localization of reference wells

Drilling BBS index	Depth (m)	Altitude (m MSL)	Flow rate (m^3/h)	Casing diameter (mm)	Static water level (m MSL)	Folding back (m)	Specific flow rate ($m^3/h/m$)	Strainer depth (m/ground level)	Use
10915X0170	204.5	39	106	194	11	26.4	4,0	From 80.5 m to 177.5 m	Water harnessing-drinking water
10915X0333	176	37	120	194	4.3	70	1.7	From 119 m to 170.5 m	Water harnessing-drinking water
10915X0001	205	39	45	208	20.7	18.9	2.4	From 83.1 m to 99.1 m From 110 m to 128.3 m From 145.8 m to 175.9 m	Collective water
10915X0169	139	29.9	20	-	15.4	6.1	3.3	-	-
10915X0141	76.5	37.5	9	-	10.5	2.5	3.6	-	Personal water
10915X0139	150	42	5	132 (upper pipe)	13.7	3,9	4.9	From 121.5 m to 123.5 m	Domestic water
10915X0181	50.1	47	12	159	29.4	9.6	1.2	From 20.7 m to 23.7 m From 40 m to 43 m	Personal water
10915X0269	132	14	120	-	5	36.4	3.3	-	Water harnessing-drinking water
10915X0197	120	33	45	-	15,5	8.5	1.8	-	Irrigation
10915X0202	69.6	47	9.6	114.3	22	2.6	3.7	From 55 m to 68 m	Personal water
10915X0270	156	55	50	-	31.2	21.2	2.3	-	Water harnessing-drinking water
10915X0286	130	32	119.9	-	25.5	25.7	4.6	-	Industrial water-irrigation

Figure 5 : Reference water wells characteristics (Source: BRGM)

The analysis of this data underlines the great lateral variability of the productivity. Thus, both water harnessing 10915 X 0170 and 10915 X 0333 used to provide drinking water have similar characteristics, but the folding back of well 10915 X 0333 is two times high than that of well 10915 X 0170, even though they are separated by only 300m.

It also appears that the deepest wells are the most productive. Generally, many levels are simultaneously harnessed.
Some deep wells (130 m) have low flow rates (example: well 10915 X 0001 – Depth: 205m – Flow rates: 45 m^3/h) but their folding back is not very high, and higher flow rates could certainly be reached (example: well 10915X0333, Folding back: 70 m)

To conclude, the study of the actual wells next to the site shows that a flow rate of approximately $100m^3/h$ could certainly be reached with a 200 m depth well. Such a depth allows the simultaneous harnessing at different levels.

Concerning injection possibilities, there still remains some uncertainty due to a lack of information. In sandy soil, it is sometimes more difficult to inject than to produce. Therefore, the use of one production drilling and two injection drillings cannot be dismissed. No decision can be taken before the first drilling that will allow the testing of the injectivity.

2.2.2 Hydrodynamics data

In order to estimate the hydrodynamic characteristics of the aquifer, data from available literature as well as studies of the surrounding wells have been analyzed. Concerning the studied site, the static water level is evaluated at +10 m MSL (drillings 10915 X 0137, 10915 X 0203). Due to the intensive use of the aquifer, this level tends to decrease.

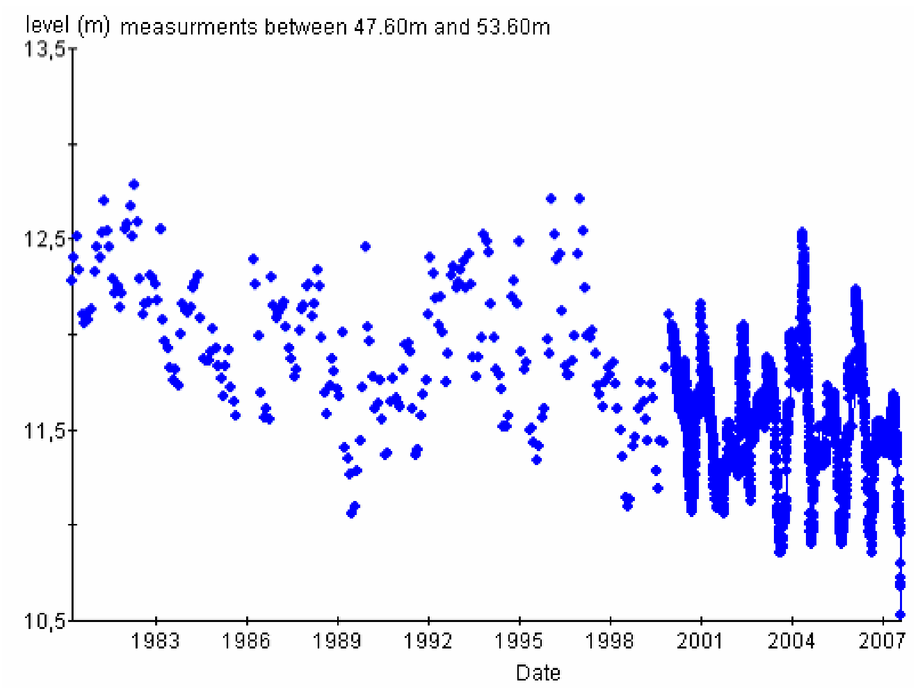


Figure 6 : Change of the piezometric level of the aquifer at Bompas (Source: Ades)

In order to estimate the temperature of the water, results from the well 10915 X 0333 have been used.

September 23 th, 2004	20.6 °C
December 9 th, 2002	20 °C
July 1 th, 1999	21 °C
September 10 th, 1998	20.8 °C
August 28 th, 1997	21 °C
June 26 th, 1997	20.4 °C
April 2nd, 1996	18 °C

Table 1 : Water temperature - drilling 10915X0333 (Cabestany) (Source: ADES)

The annual water temperature is considered to be 20°C.

The groundwater table characteristics considered in the study are:

factors	Values
Temperature (°C)	20°C
Transmissivity for a 200m deeper drilling (m^2/s)	1.10^{-3}
Average permeability of sandbanks (m/s)	4.10^{-5}
Efficient porosity of sand banks	10 %
Storage coefficient	1.10^{-4}
Static water level (m MSL)	10
Hydraulic gradient	0,3 %

The storage coefficient is the ratio between water volume stored or released per unit area (m^2) with the corresponding change of hydraulic load.
The transmitivity is equal to the product of the permeability of the aquifer and its power (thickness).
The hydraulic gradient represents the groundwater slope (without dimension).

2.2.3 Flow direction

The continental Pliocene ground water is flowing in the W-SW / E-NE direction toward the Mediterranean Sea.

2.2.4 Water quality:

The water of the Pliocene is soft; its global mineralization is less than 1 g/l.

3. PRINCIPLE OF GEOTHERMAL SYSTEM

3.1. WATER LOOP

It is crucial to evaluate the energy needs of the shopping center since the legitimacy of a geothermal installation depends on them.

With a constant temperature water loop every tenant, depending on its needs is able to:

- reject calories in order to cool down its space
- take calories in order to heat up its space

The water loop will have a varying flow rate in order to prevent large energy consumption by auxiliaries other than full load operations.

This facility will work during the working hours of the commercial mall defined by its manager.

The main purpose of the facility, achieved by the lessor, is to regulate the temperature of the water loop, allowing:

- The evacuation of calorie excess during summer periods ;
- The supply of calories during winter periods

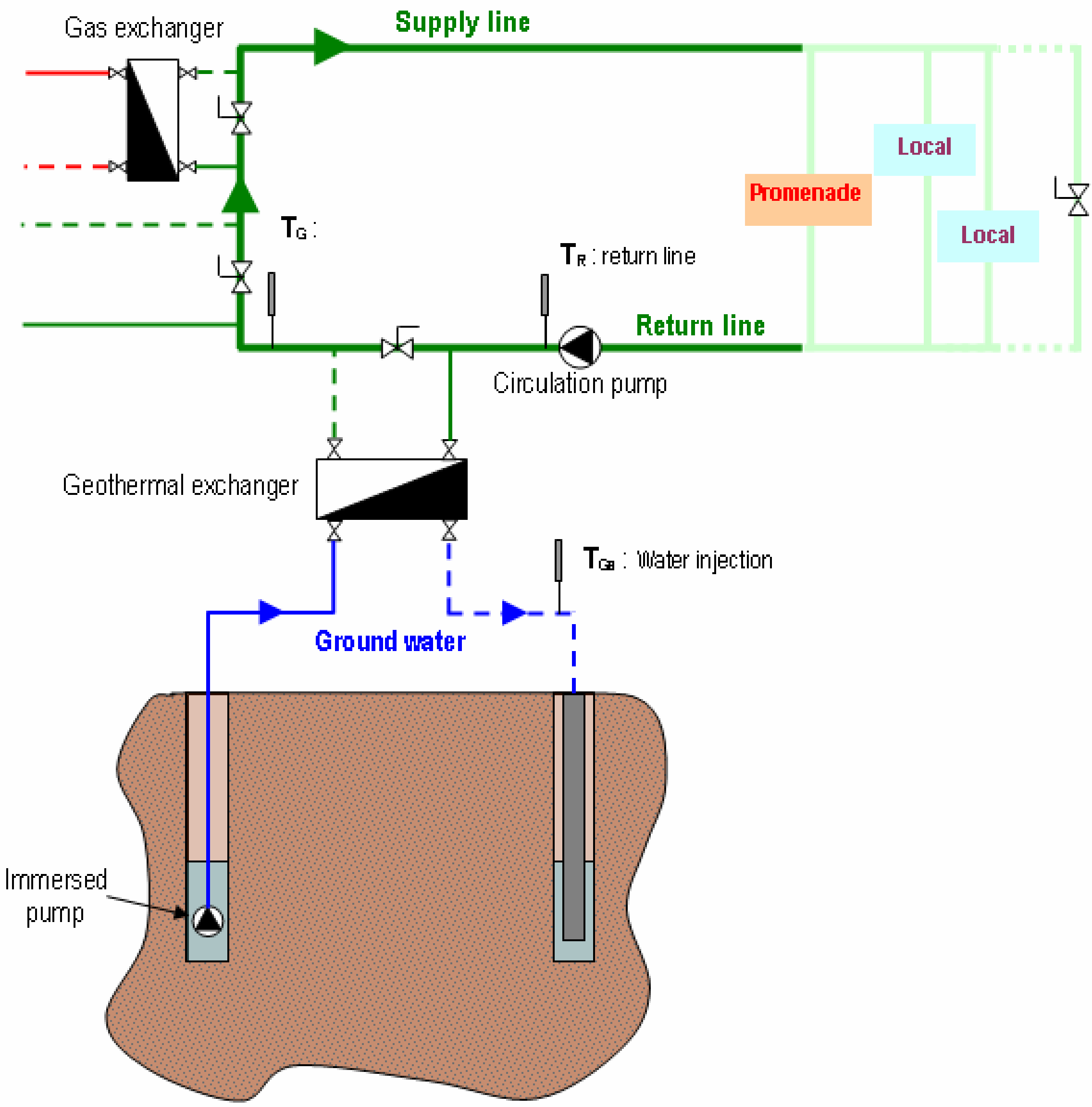
All tenants will have to connect a heat pump linked to the water loop inside their locale.

Heating demands are low since large heat gains are available from lighting, people and sunshine.

Obviously, cooling demands are much higher than heating demands since there are many gains.

3.2. GEOTHERMAL FACILITY PRINCIPLE

The following scheme shows the technical layout of the facility.



The geothermal facility is installed upstream of the gas boilers and dry air coolers since it will supply the base load demands

The geothermal facility includes:

- Two drillings (production and injection),
- One immersed pump,
- One geothermal exchanger.

In order to upgrade the geothermal source potential, emitters of the promenades (Rooftop hot water battery + cooling system) will be replaced by new ones (rooftop air/water HP) directly plugged in the water loop. Thus, all emitters will be plugged into the water loop.

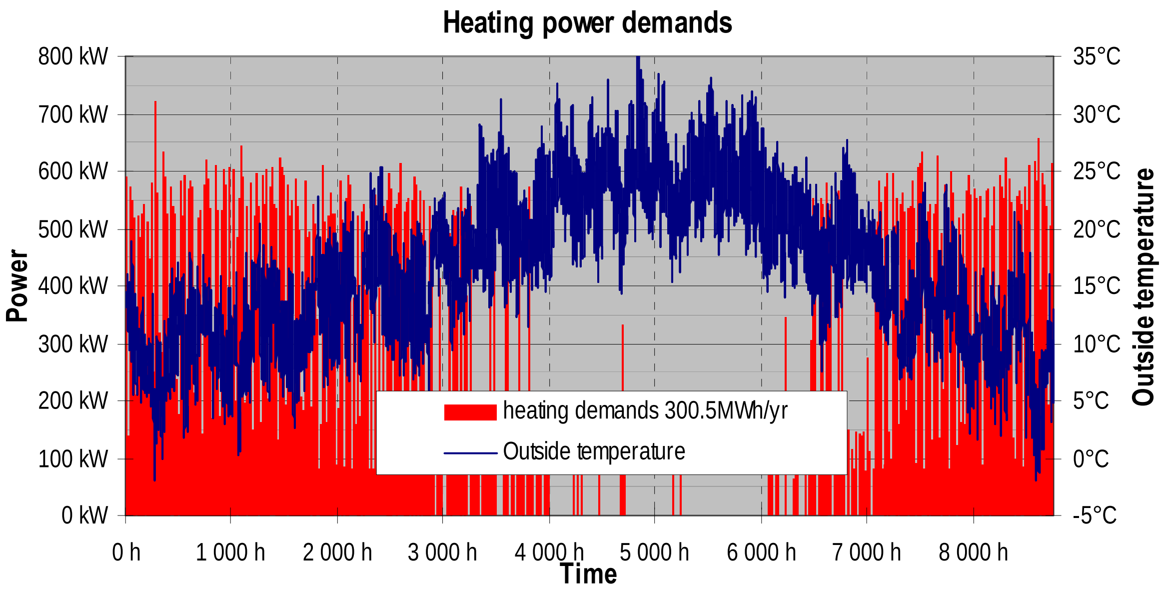
According to hypotheses, the new flow rate will be equal to **290 m^3/h**, with a minimal value of **57 m^3/h** (20% of the maximal flow rate). The water volume will also increase to **40 m^3** to take into account the promenade area.

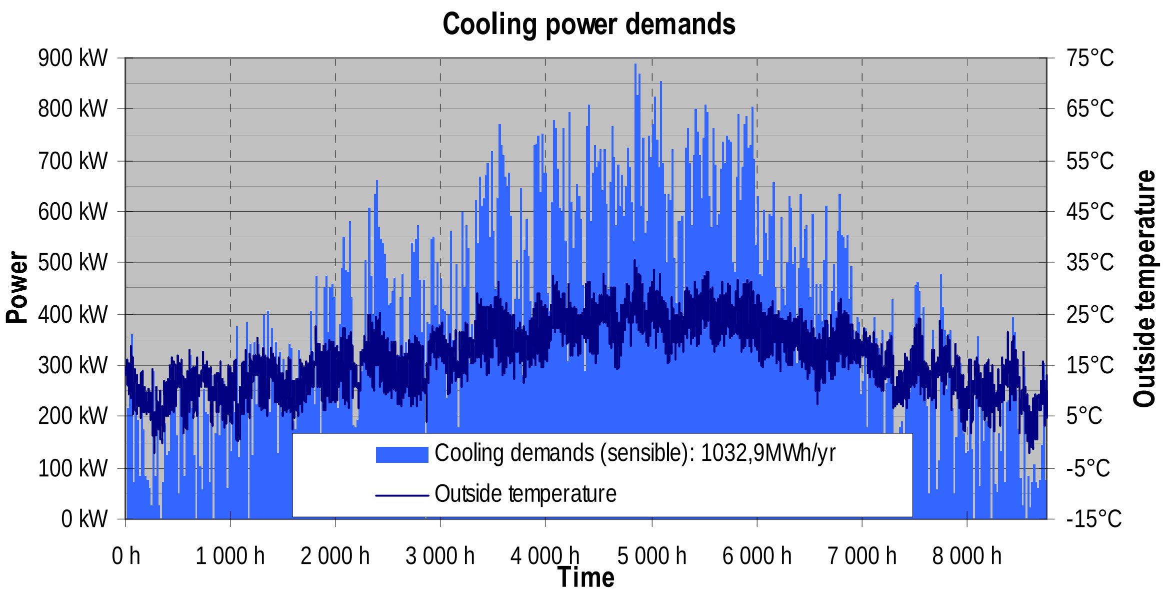
4. Performance of the system

4.1. Energy demand

4.1.1.1 Power demands:

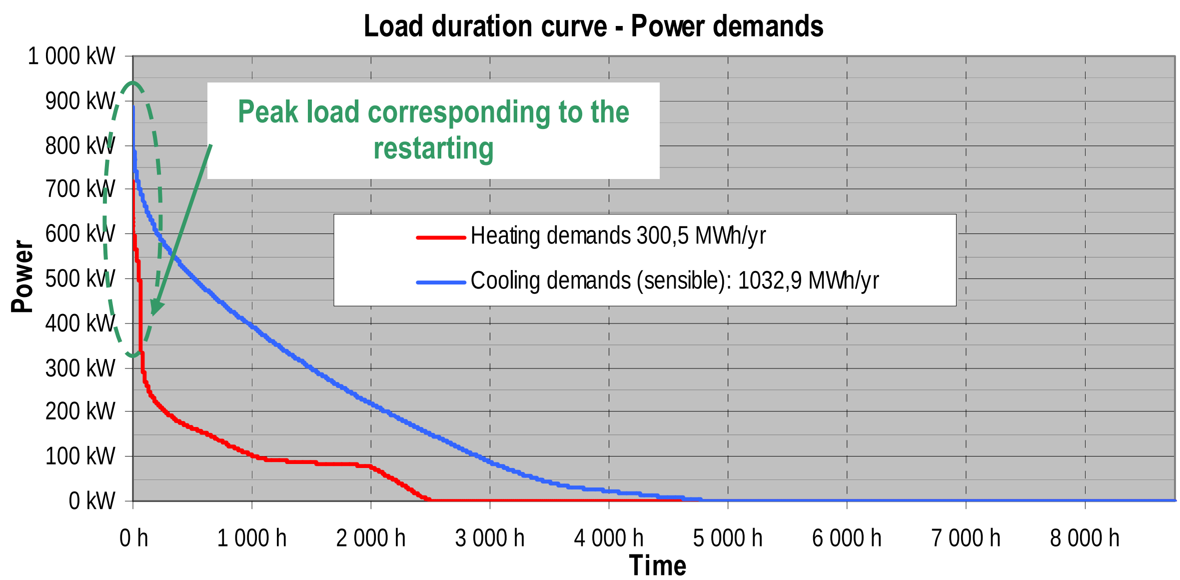
The following graphs represent the dynamic power demands of the shops zone, restaurants and day nursery zone and the outside temperature. Those graphs stem from the dynamic thermal simulation of the shopping center, achieved according previous hypotheses.





Concerning the heating power demands, the pick load corresponds to the morning restarting.

The following graphs represent the load duration curve for power needs (heating and cooling) of the shops, restaurants and day nursery zones as well as the promenade zone.
This curve has been drawn according to the dynamic simulation.

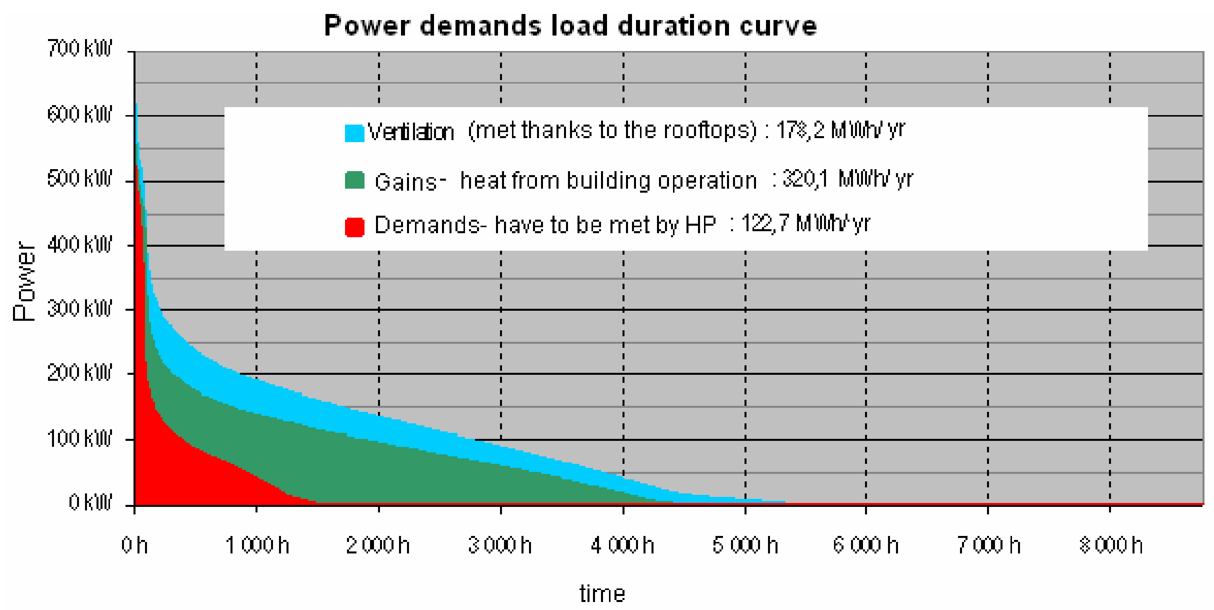


Energy demands to achieve heating and cooling in the shopping centre are:

- **Energy demands - heating purpose : 122,7 MWh$_h$/yr**
- **Energy demands - cooling purpose : 860,3 MWh$_c$/yr (sensible)**

Heating demands are low since large heat gains are available from lighting, people and sunshine.

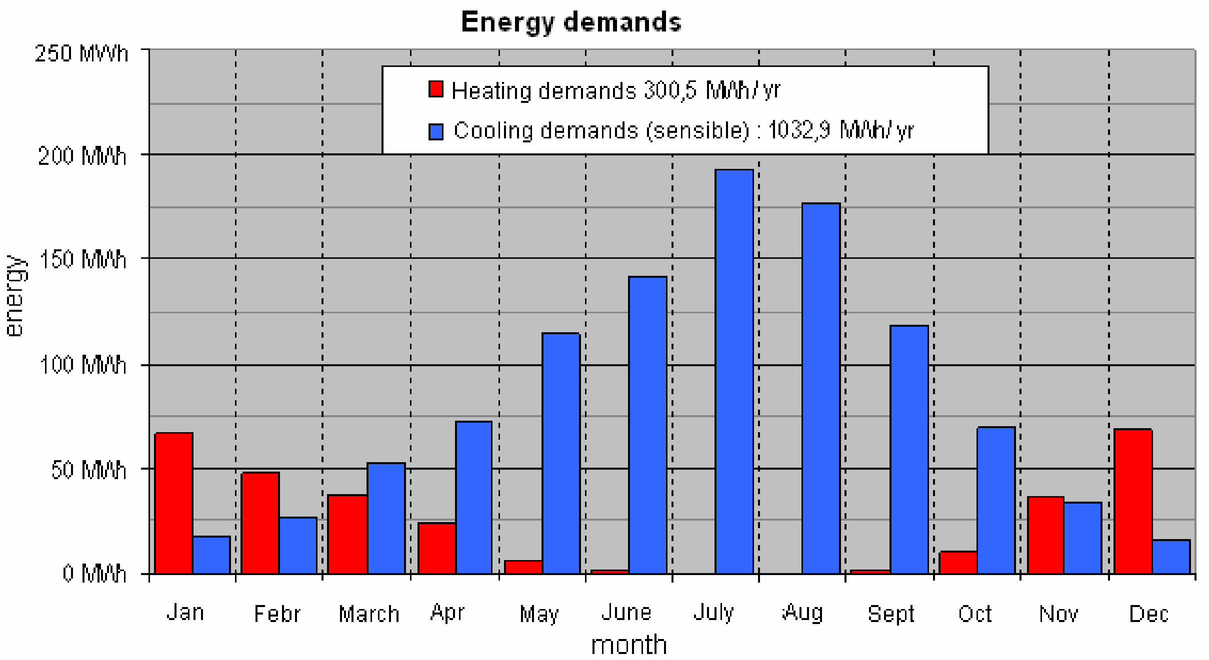
The following graph represent the total demands distribution between actual demands (met by locales HP), heat gains and demands linked to the ventilation (met thanks to the promenade zone).



4.1.1.2 *Energy demands:*

▪ Global energy demands:

The following graph represents the energy demands for each month.



It is obvious that the cooling demands are much higher than heating demands due to important heat gains.

4.2. SYSTEM DESIGN

4.2.1.1 Technical description

The design of both wells (injection and production) will be similar. According to the soil composition and to the forecasted wells depth, a mud rotary drilling is highly recommended.
The inner diameter of the harnessing part of the wells will be 265mm.

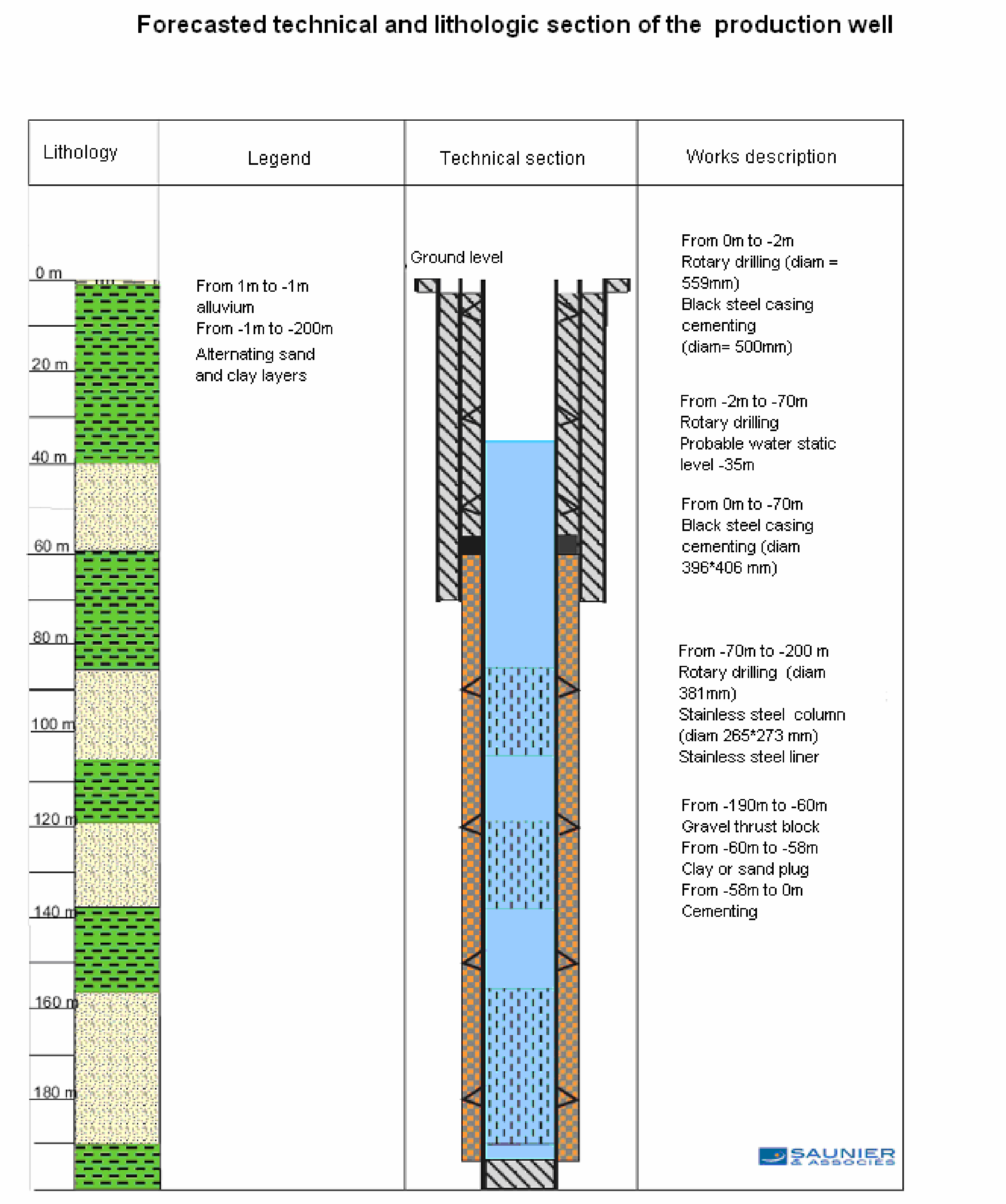


Figure 7 : Forecasted technical and lithologic section of the production well

4.2.1.2 *Facilities equipments*

Drill head premises

Both drill heads will be located in closed cellars which will be accessible in case of necessary works. Thus, they will not be deep, and they have to be quite large and long, in order to make working easier.

Production well

The production well will be equipped with pumping equipments to allow a nominal production of approximately 100 m^3/h.
Based on different data, such as the folding back, the static water level etc, the pump depth will be 90 m
The pump diameter will be 9''; its power will be 55 kW. The manometric head has to be at least equal to 120 m of water column, in order to get an available pressure of 3 to 4 bars.
The pump control will be automated.

Injection well :

The injection well equipments will be comprised of a watertight head with a pickup tube, down to 10m in order to avoid any kind of oxygenation of the re-injected water. The drilling head will also be watertight.

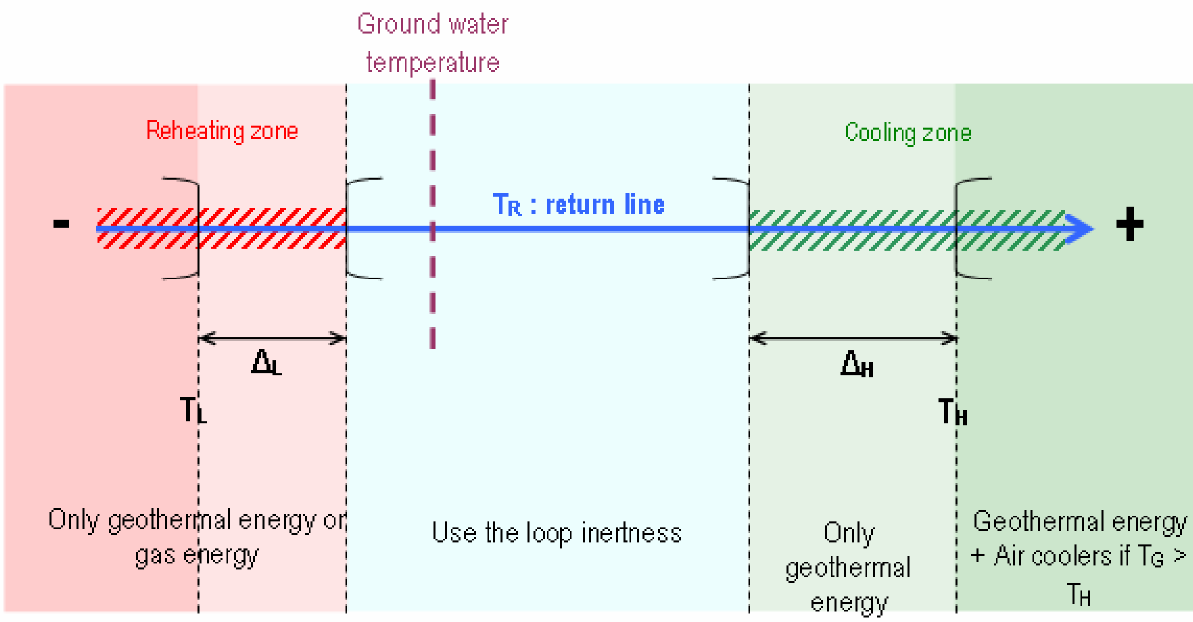
Control devices:

On the control board of the main cabinet, they will display data about the functioning of the immersed pump (amperage, voltage, dysfunctions, horometer, and pressure) and about water-levels in the wells.
It would be preferable that the production flowmeter, initially intended to be in the drilling head, be placed in the plant, or otherwise comprise a means to send data to the control board (flow and total counter)
In order to avoid water hammers, which would be detrimental to the system, a launching ramp must be added upstream of the power supply for the immersed pump

4.2.1.3 *Working principle.*

The water loop temperature is regulated and maintained between two temperatures defining a temperature interval of operation.
Low temperature limit: $\mathbf{T_L}$,
High temperature limit: $\mathbf{T_H}$.

The interval between $\mathbf{T_L}$ and $\mathbf{T_H}$ has to match the working temperature of the emitters.
The following scheme shows the regulation principle of the water loop used to maintain its temperature.



▪Geothermal facility operation

The regulation is done according to different measured values.

- Water loop return line temperature $\mathbf{T_R}$,
- Injection water temperature $\mathbf{T_{GS}}$,
- Water loop flow rate $\mathbf{Qv_{BE}}$.

When the temperature $\mathbf{T_R}$ is outside of the interval defined by $\mathbf{T_L}$ and $\mathbf{T_H}$, the geothermal facility starts. Actually, if no system (heating or cooling systems) linked to the water loop is working the supply line temperature is equal to the return line temperature $\mathbf{T_R}$.
If $\mathbf{T_R}$ changes and comes out of the interval allowed for the supply line temperature, the geothermal facility is activated.

The geothermal facility is shut down when the return line temperature $\mathbf{T_R}$ reaches a value between $\mathbf{T_B+\Delta_B}$ and $\mathbf{T_L-\Delta_L}$. However, the geothermal facility cannot be shut down if the minimal working time has not been reached

The minimal working period as well as the minimal shutting down period are both defined according to the constraints of the immersed pump and drilling constraints. This results from the numerous start-ups and shutdowns that can damage the immersed pump as well as the production and injection wells.

There are also some constraints on the injection water; it must be between **7°C and 25°C**

In order to keep the injection temperature in this interval regulation of the flow rate through the geothermal exchanger is needed.

- If the temperature deviates out of the interval, the flow rate across the geothermal exchange decreases. Heat exchanges drop and the injection temperature returns into the interval. The regulation is achieved by a valve.
- If the water loop flow rate is higher than the immersed pump flow rate, the flow rate across the geothermal heat exchange is limited by the immersed pump flow rate. This regulation is done using a control valve.

The possibility to install a speed controller on the pump will be considered. The main purpose of this controller is to adapt the flow rate to the needs. Thus, when the heating or cooling demands are low the flow rate could be decreased instead of be kept to the nominal value. Thereby electricity consumption could be reduced.

▪ Peak load conditions.

The geothermal energy resource available cannot supply enough energy to recover all the cooling and heating demands.

- Heating peak loads: peak load gas boiler connected to the water loop through a gas heat exchanger.
- Cooling peak loads: dry air coolers.

Water loop and peak load systems are connected downstream the geothermal facility.
Peak load systems are switched off or switched on depending on the water loop temperature $\mathbf{T_G}$ after the geothermal facility.

If $\mathbf{T_G} < \mathbf{T_L}$, the peak load gas boiler is activated in order to guarantee a supply line temperature higher than the low temperature limit $\mathbf{T_L}$.
If $\mathbf{T_G} > \mathbf{T_H}$, dry air coolers are activated in order to guarantee a supply line temperature lower than the high limit temperature.

4.3. ENERGETIC PERFORMANCE

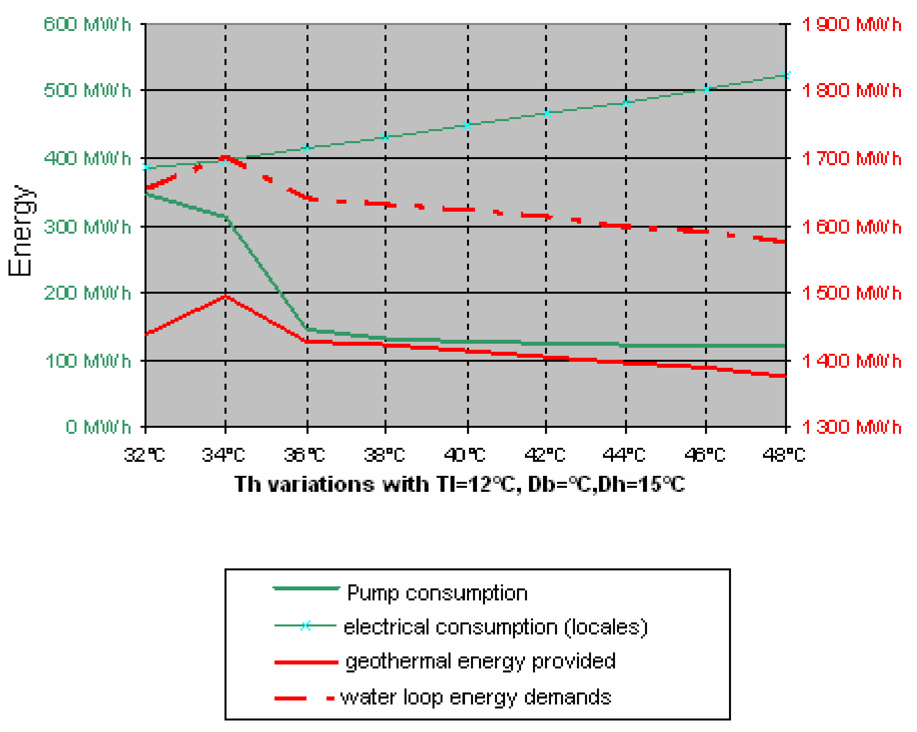
Some characteristics are already known:

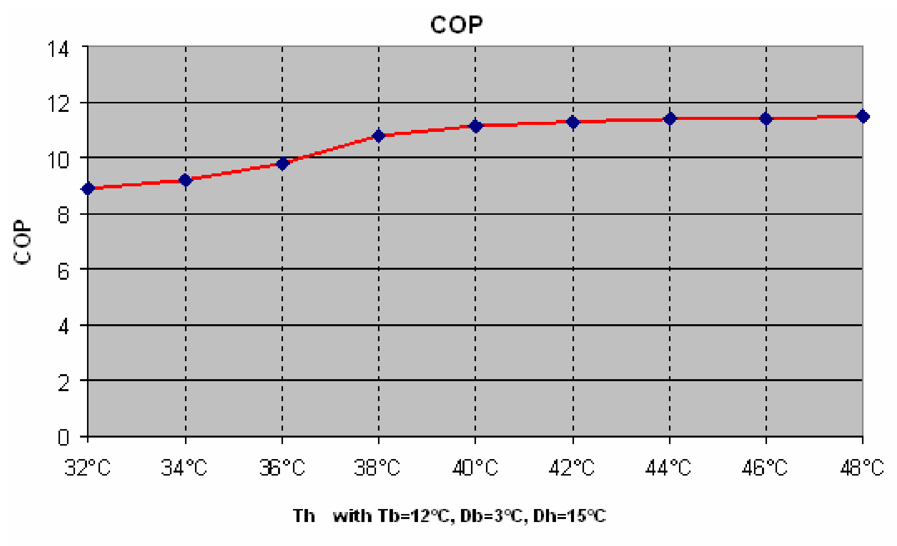
- Immersed pump flow rate: (maximum value with a controller) **100 m^3/h**. It is the available flow rate of the geothermal resource.
- The geothermal heat exchanger is characterized by a minimum heat capacity of **285 000 W/K**. Heat exchanger characteristics:
    - Plate heat exchanger- Stainless steel,
    - Power 580 kW,
    - Primary and secondary fluid : water
    - Variable flow rate, with a maximum value : **100 m^3/h**
- Geothermal water temperature : **20°C**,
- Minimum injection water temperature, maximum injection temperature : **25°C**,
- Maximum water loop flow rate: **290 m^3/h** , minimum water loop flow rate : **57 m^3/h** (20% of the maximum value),
- Water loop volume **40 m^3**,
- Minimum operating time of the immersed pump: **30 minutes**, minimum stopping time: **30 minutes**.

4.3.1.1 Regulation characteristics:

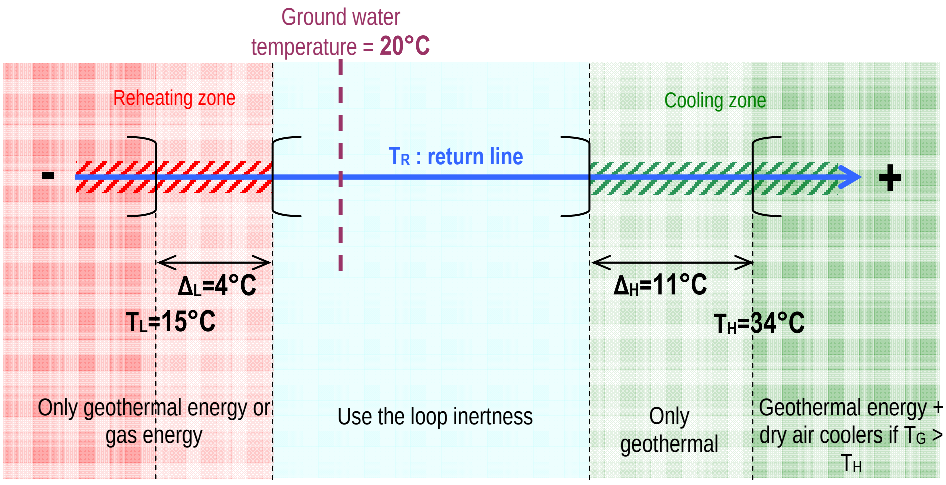
Regulation parameters still have to be specified. These values have to be determined in order to optimize the facility.
To compare various options, simulations have been run using different regulation parameters values.
The following graphs show the influence of different parameters on the facility. For example, the change of the high temperature limit has a great influence on the energetic parameters. Thus, it has to be noticed that HP electrical consumptions change significantly with this high temperature limit.

Actually, HP efficiencies vary with temperature levels of the water loop. (Cf- 2.1.1.3 Emitters characteristics) The lower the low temperature limit is the lower the HP consumptions are.





Values which make the facility the most efficient are as follow
:

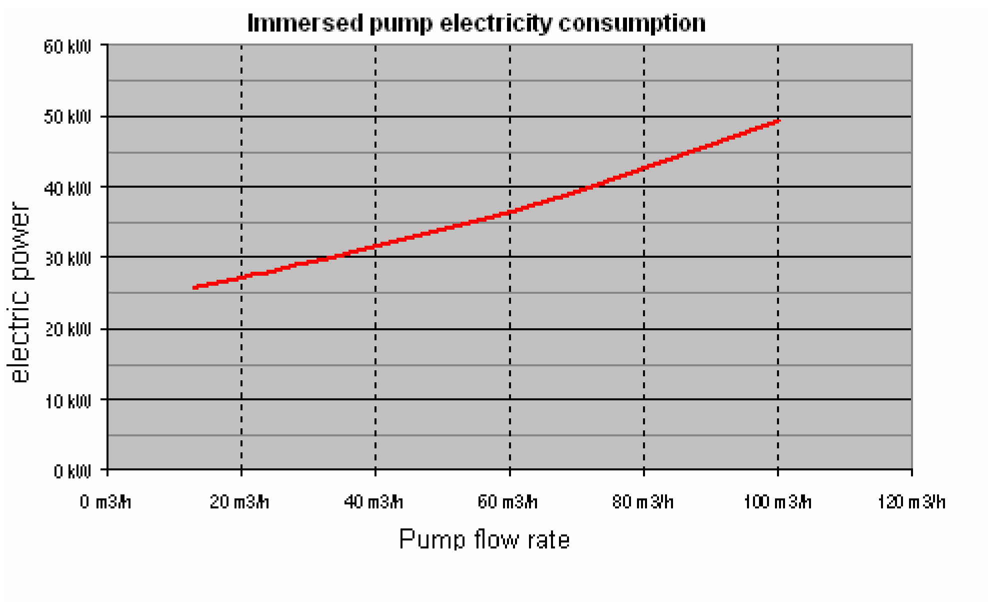


- Low temperature limit **T_L :** **15°C**
- Low shut down temperature difference **Δ_B : 4°C**
- High temperature limit **T_H :** **34°C**
- High shut down temperature difference **Δ_H : 11°C**

4.3.1.2 Immersed pump operation – with or without a speed controller.

A speed controller could be added to the pump in order to decrease its speed when the demands decrease. A speed controller would allow the decrease of electricity consumption by the pump.

Simulations including a speed controller have been run.
With a speed controller, the pump can run from 13% to 100% of its maximal flow rate (from 13 to 100 m^3/h).
The following graph shows the electricity consumption changes with the operating flow rate.

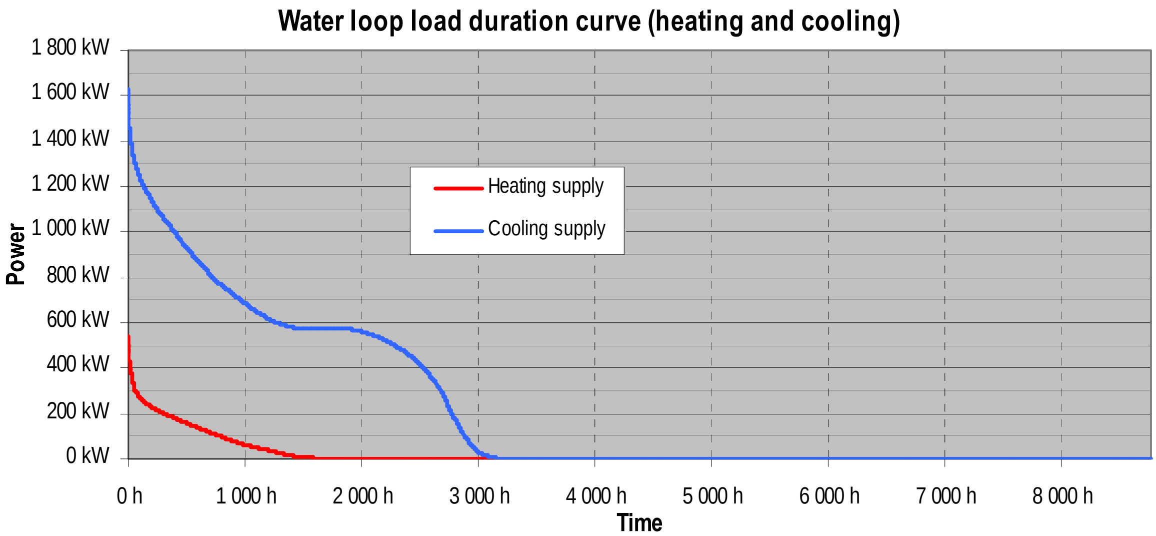


It has to be noticed that when the pump is operating at 13% of its maximal flow rate electricity consumptions drop by around 50% (in comparison with the maximal flow rate electricity consumptions). Calculations show that a speed controller allows an electricity consumption drop of 4% which represents **6 MWh_e** in one year.

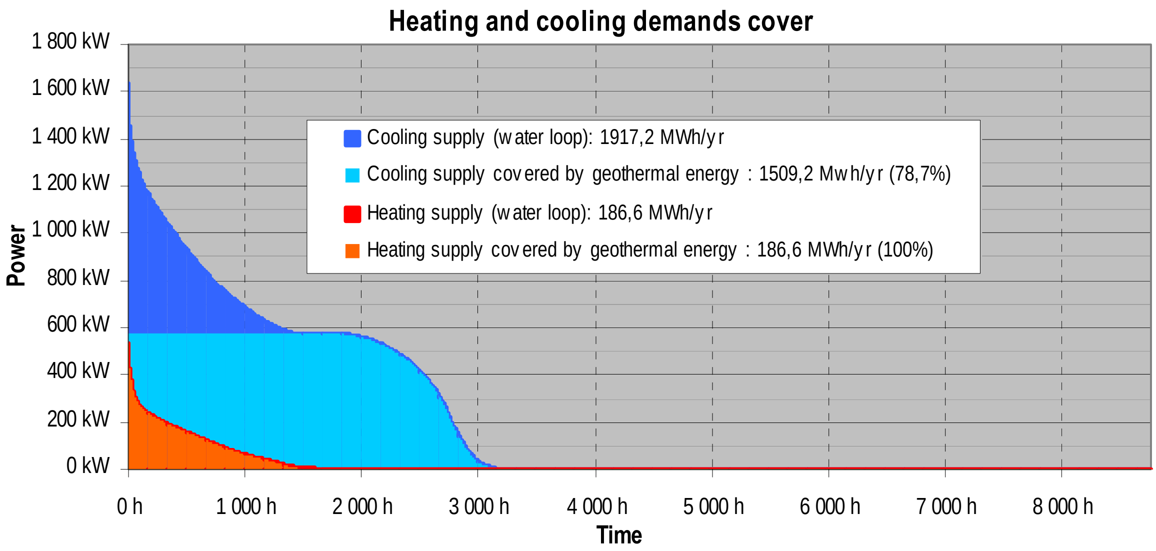
This energy savings is quite low and basically does not justify the investment in a controller which is somewhat expensive.

4.3.1.3 Water loop energy balance.

Energy demands on the consumption side have been previously characterized. Heating and cooling demands that have to be provided to the water loop on the production side need to be defined.
Operation and regulation parameters, previously defined, have allowed the characterization of cooling and heating demands that have to be supplied in order to keep the water loop temperature constant.
The following graph show the load duration curve (heating and cooling) in order to maintain the constant water loop temperature.

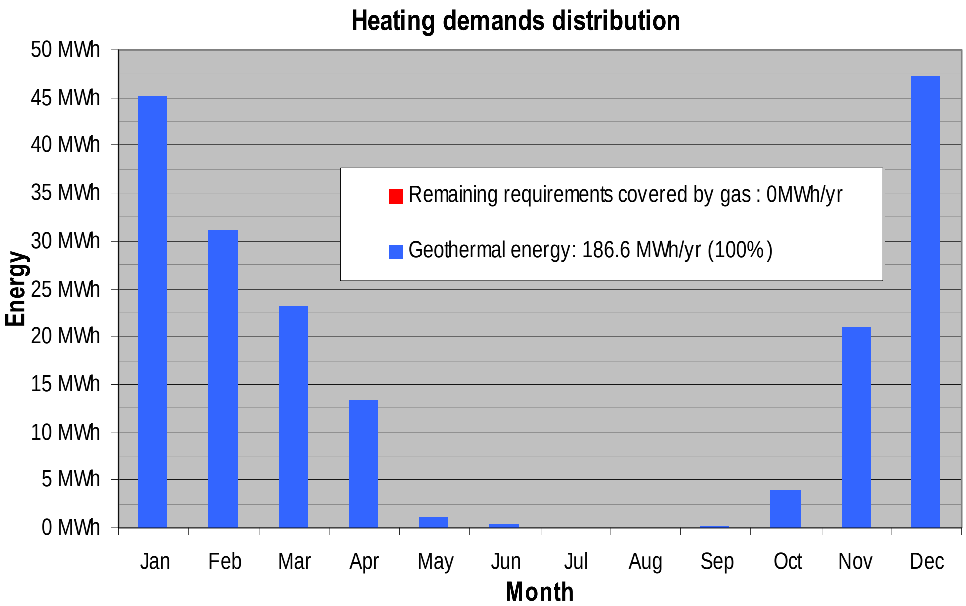


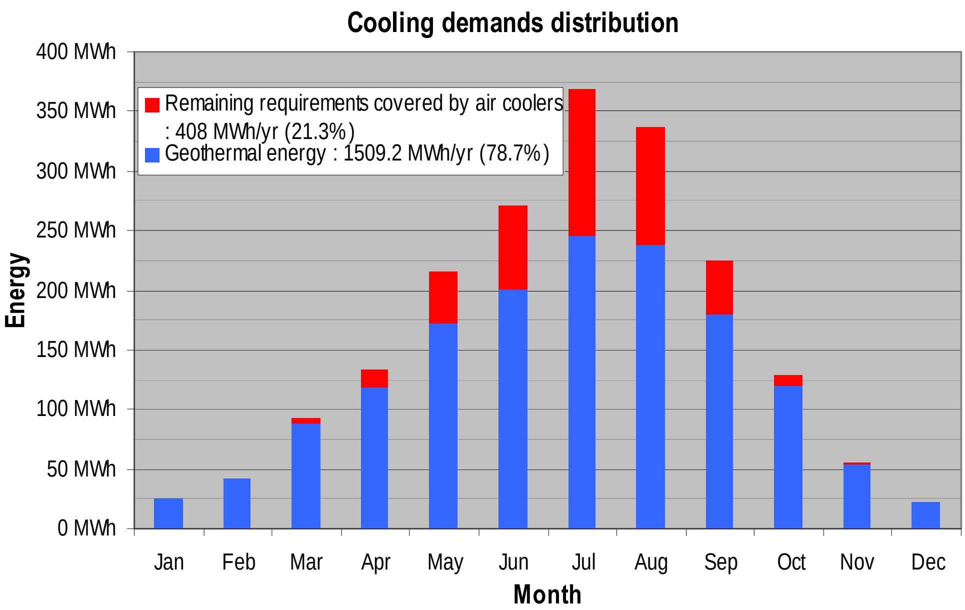
The following graph shows the distribution of the heating and cooling demands covered by geothermal energy.



Differences between locales and promenade needs as well as demands to maintain the water loop at a constant temperature are due to the inertness of the water loop stemming from its large volume.

The following graphs show the distribution of heating and cooling demands that have to be provided to the water loop.





Tanks to the simulation, energy demands to maintain the water loop temperature are known.

- Heating demands: **186.6 MWh/yr**
- Heating demands covered by geothermal energy: **186.6 MWh/yr (100%)**
- Cooling demands : **1917.2 MWh/yr**
- Cooling demands covered by geothermal energy: **1509.2 MWh/yr (78.7%)**

4.4. ENVIRONMENTAL BALANCE

4.4.1 Environmental impact of the geothermal facility.

4.4.1.1 Pumping impact.

This part deals with the folding back that can be expected due to the aquifer exploitation.
The production well operations could induce a decrease of the ground water table level, whereas the injection well operations could induce an increase of this level.
The theoretical impact of the production and injection wells has been evaluated according to the expression (C.E Jacob):

$$s = \frac{0{,}183Q}{T} \ . \log \frac{2{,}25Tt}{x^2 S}$$

With : s :: folding back (m)
Q : flow rate (m^3/s)
T : transmitivity (m^2/s)
t : time passed since the pumping start-up (s)
x : distance between the piezometer and the well axe (m)
S : storage coefficient.

Annual mean flow rate (m^3/h) [1]	57
Folding back m (1 year) at 100 m from the well	14
Folding back m (1 year) at 1000 m from the well	8
Current static water level (without pumping) (m MSL))	10
Forecasted dynamic water level (m MSL) [2]	-17
Terrain (m MSL)	45

Table 2: Forecasted folding back evaluated with Jacob approximation

[1] This flow rate corresponds to a facility with a nominal flow rate of 100 m^3/h, working 5 000 h a year
[2] The specific flow rate used is 3.8 $m^3/h/m$ (calculated with data from the wells 10915X0141 and 10915X0170)

Induced folding backs are high. However sandy formations are not inevitably continuous, since they are sandy shoals, stemming from a riparian sedimentation.
According to this, folding backs will probably be lower than those calculated. During pumping test, achieved on the well 10915X0001, folding backs that have been observed were 0.45m and 0.34 (50m and 1500m depth) for a flow rate of 25 m^3/h. This is significantly lower than results that could be forecasted. In addition, folding backs are attenuated thanks to injection.

4.4.1.2 *Influence on nearby wells.*

Impact of both injection and production wells on nearby wells have been evaluated over a one year period. The annual mean flow rate is 57 m^3/h. Injection and production wells Lambert coordinates have been calculated in order to keep a distance of 200m between them.

Well	Distance from the production well	Distance from the injection well	Folding back due to production (m)	Folding back due to injection (m)	Global folding back (m)	Depth (m)
10915X0008	988	811	8.29	-8.79	-0.50	103
10915X0014	863	1057	8.63	-8.12	0.51	40.3
10915X0055	734	931	9.04	-8.44	0.60	35
10915X0057	1372	1196	7.46	-7.81	-0.35	30
10915X0062	763	573	8.94	-9.66	-0.72	154.9
10915X0065	1217	1413	7.77	-7.39	0.38	9
10915X0076	1885	1836	6.66	-6.73	-0.07	62
10915X0084	1213	1412	7.78	-7.39	0.38	70
10915X0086	1315	1488	7.57	-7.26	0.31	70
10915X0137	656	726	9.32	-9.07	0.26	63
10915X0139	1365	1561	7.48	-7.14	0.34	150
10915X0141	1256	1091	7.69	-8.04	-0.36	135
10915X0143	1459	1656	7.31	-6.99	0.32	55
10915X0148	816	1015	8.77	-8.22	0.55	28
10915X0149	1664	1512	6.98	-7.22	-0.24	120
10915X0150	1720	1685	6.90	-6.95	-0.05	30.6
10915X0160	1775	1788	6.82	-6.80	0.02	50
10915X0161	1372	1478	7.47	-7.28	0.19	60
10915X0168	1332	1159	7.54	-7.89	-0.35	130.5
10915X0179	1747	1945	6.86	-6.59	0.27	117.0
10915X0180	832	877	8.72	-8.59	013	74
10915X0196	613	761	9.49	-8.95	0.54	125
10915X0199	1202	1184	7.80	-7.84	-0.04	80
10915X0203	716	821	9.10	-8.76	0.35	74

10915X0213	1325	1489	7.55	-7.26	0.29	62
10915X0217	*1333*	*1182*	7.54	-7.84	-0.30	65
10915X0229	446	247	10.29	-11.78	-1.49	79.5
10915X0237	1137	1335	7.94	-7.53	0.40	67
10915X0248	1495	1695	7.25	-6.93	0.32	160
10915X0260	772	616	8.91	-9.48	-0.57	63
10915X0261	1396	1219	7.42	-7.76	-0.34	67
10915X0279	1776	1577	6.81	-7.11	-0.30	84
10915X0283	174	361	12.66	-10.82	1.84	12
10915X0305	1331	1524	7.54	-7.20	0.34	72
10915X0338	784	656	8.87	-9.32	-0.45	40
10915X0341	1142	1106	7.93	-8.01	-0.08	-
10915X0342	1390	1521	7.43	-7.20	0.23	-
10915X0344	1421	1602	7.38	-7.07	0.30	72
10915X0350	1017	970	8.22	-8.34	-0.12	-
10915X0356	1230	1390	7.74	-7.43	0.31	-
10915X0357	1230	1390	7.74	-7.43	0.31	-
10915X0362	1230	1390	7.74	-7.43	0.31	-
10915X0363	1230	1390	7.74	-7.43	0.31	-
10915X0364	1230	1390	7.74	-7.43	0.31	-

Table 3 : Calculated folding back - nearby wells

Global folding back that will be induced on nearby wells is tolerable.

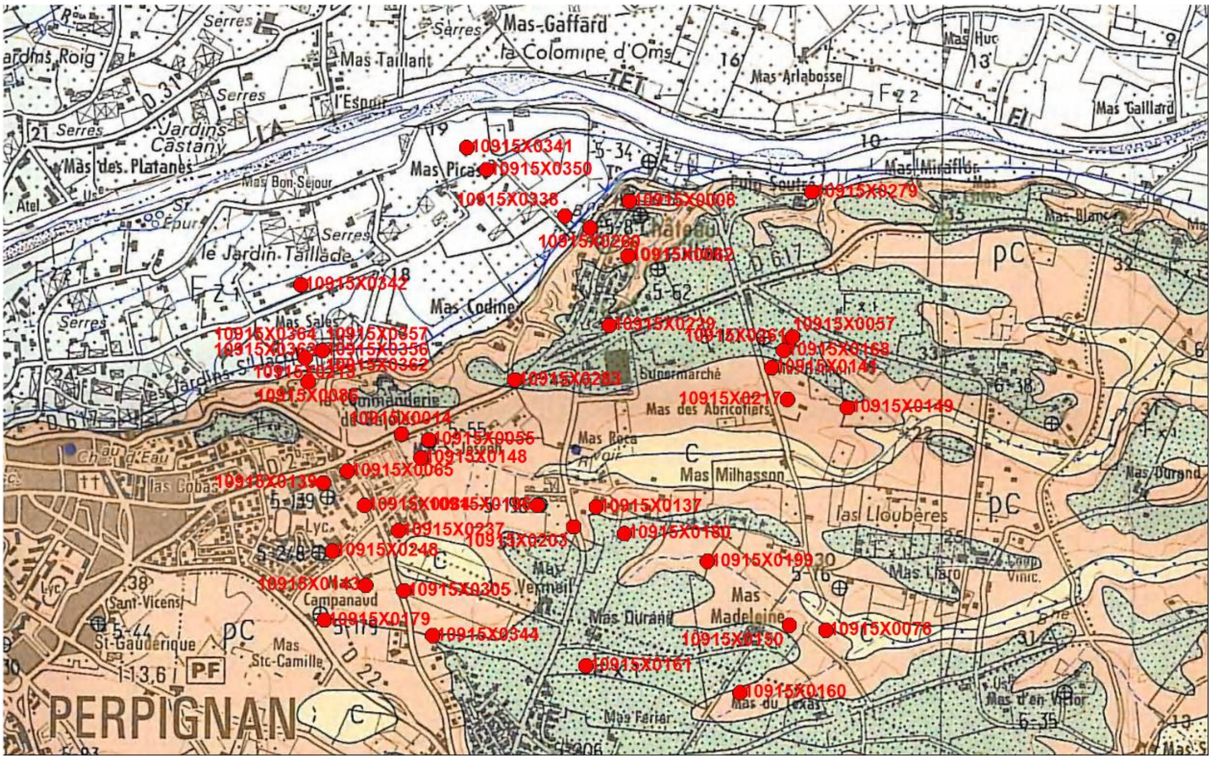


Figure 8 : Nearby wells

4.4.1.3 *Injection*

According to environmental reasons, injection is required. Injection and production wells have to be far enough apart in order to prevent thermal recycling that can lead to the degradation of the facility potential.
The minimum distance, to fulfill these constraints is 200m (calculated with abacus).
Legislation does not set the injection temperature. However the temperature of water harnessing dedicated to drinkable water has to be lower than 25°C. Since there are water harnessing wells dedicated to drinkable water production near Cabestany, it is likely not allowable to inject water with higher temperature than 25°C. A temperature difference of 5°C between production and injection could be harnessed for cooling production (it is equivalent to a cooling power of 580 kW, with a flow rate of 100 m^3/h).

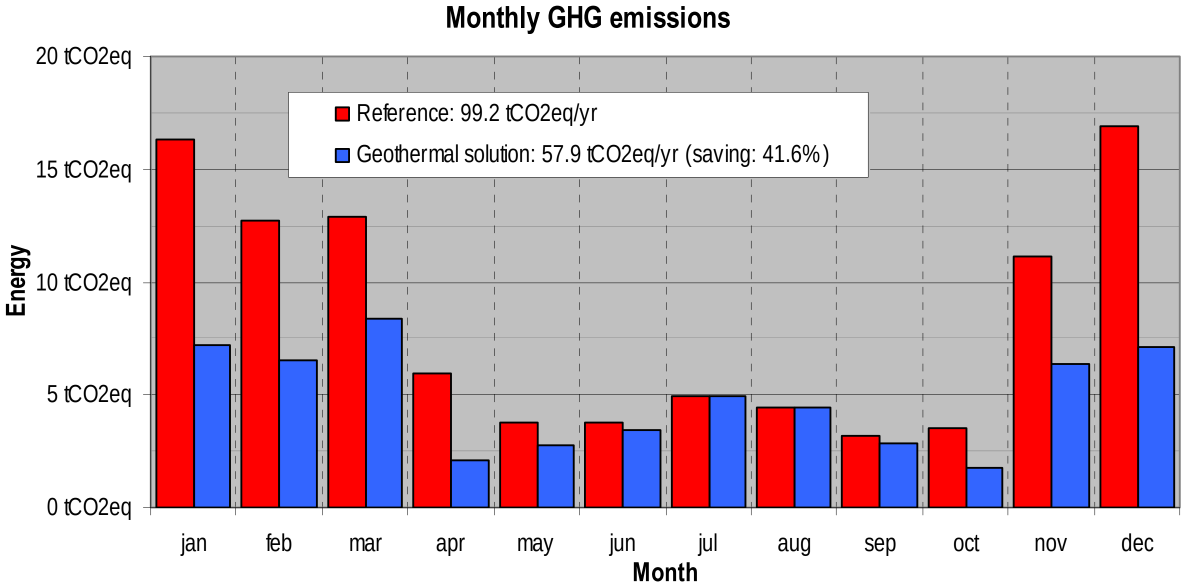
4.4.2 Environmental balance

A CO2 emission balance has been achieved for both solutions (geothermal and reference), in order to quantify the reduction realized.

GHG emissions have been calculated according to ratios from ADEME for each type of energy. The following table shows type ratios for each type of energy

	Electricity (kg.MWh)	Gas (kg/MWh (LHV)
Winter	180	230.8
Summer	40	230.8

According to these ratios and to energy consumptions of each solution, monthly GHG emissions have been determined.
The following graph shows the comparison of monthly GHG emissions between solutions



The reference solution produces **99.1 Tons $C0_2$ equivalent a year.**
The geothermal solution emits only **57.9 Tons $C0_2$ equivalent a year**. It represents an annual saving of **41.2 Tons CO_2 equivalent** (41.6% in comparison with the reference solution).

5. FINANCIAL BALANCE

5.1. INVESTMENT COSTS

Costs induced by the geothermal facility have been evaluated:

The following table shows the results:

Drilling + junctions	
Site preparation	2 360 € exclusive VAT
Production well	126 750 € exclusive VAT
injection well	126 750 € exclusive VAT
Drill head premises	15 750 € exclusive VAT
Drill head	10 610 € exclusive VAT
immersed pump, pumping equipments	24 620 € exclusive VAT
Circuit box, casing, flow meter and sensor,	8 930 € exclusive VAT
Pipeline and surface cables	33 500 € exclusive VAT
TOTAL drillings + junctions	**349 270 € exclusive VAT**
Boiler room	
Geothermal heat exchanger (1+1 emergency)	21 000 € exclusive VAT
Surplus - Promenade emitters + loop pump	28 622 € exclusive VAT
Depreciation gas boilers (-1)	-20 000 € exclusive VAT
Depreciation air coolers (-1)	-36 000 € exclusive VAT
Régulation / Others	10 000 € exclusive VAT
TOTAL Boiler room	**3 622 € exclusive VAT**
TOTAL Overinvestment	**352 892 € exclusive VAT**

Table 4: Budgetary envelop

The overinvestment for the geothermal facility is **352 892 € exclusive VAT**.

The investment depreciation, from the gas boilers are due to the fact that only two boilers are needed instead of three. Gas boilers will be used in case of emergency; when the geothermal facility does not work properly during the winter period.

The investment depreciation from the air coolers stems from the fact that there is one air cooler less than for the reference solution. Air coolers will be used during peak loads.

It has to be noticed that the investment costs concerning the construction works, do not include:

- Engineering costs (conception /implementation)
- Potential costs for teleprocessing

5.2. OPERATING COSTS

5.2.1 Energy costs

The following table shows the energetic costs for the chosen solution (geothermal facility+ peak load units) and those for the reference solution.

		Geothermal facility + Peak load units		
			Energy	Cost
Electricity (EDF price list 15/08/2007)	Green tariff A5 LU	Immersed pump	186 MWhe	10 080 €/yr
		Promenade HP	110 MWhe	4 076 €/yr
		Air coolers	25 MWhe	660 €/yr
	Blu or yellow tariff	PAC Preneurs	435 MWhe	26 812 €/yr
		Cost		**41 627 €/yr**
		GHG emissions :		57,9 tCO2eq/yr

		Reference (gas+air coolers)		
			Energy	Cost
Electricity (EDF price list 15/08/2007)	Green tariff A5 LU	Air coolers	11 MWhe	323 €/yr
		Promenade cooling	53 MWhe	1 383 €/yr
	Blu or yellow tariff	Tenants HP	594 MWhe	36 453 €/yr
Gas (GDF price list)	Tariff B2S	Loop heating	25 MWh HHV	1 636 €/yr
		Promenade rooftops	250 MWh HHV	8 699 €/yr
		Cost		**48 495 €/yr**
		GHG emissions :		99,1 tCO2eq/yr

The geothermal facility leads to a decrease of the energetic expenditure of **6 868 €exclusive VAT/yr** (14%).
It also induces a GHG emissions reduction of **41.2 teqCO_2** per year (41.6%).

5.2.2 Maintenance expenditures forecast.

The following table shows the difference between the geothermal solution and the reference solution according to their maintenance expenditures.

P2 - Maintenance	
Fdry air coolers	-1 440 € exclusive VAT
Gas boilers Geothermal heat exchangers	-1 500 € exclusive VAT
Wells	1 200 € exclusive VAT
TOTAL P2	**-1 740 € exclusive VAT**

P3 - Repairing works	
Dry air coolers (-1)	-2 700 € exclusive VAT
Gas boilers (-1)	-1 938 € exclusive VAT
Geothermal heat exchangers	525 € exclusive VAT
Wells	2 900 € exclusive VAT
TOTAL P3	**-1 213 € exclusive VAT**

TOTAL P2+P3	**-2 953 € exclusive VAT**

Expenditure forecasts are based on following hypotheses:

- « minimum » current maintenance

- Concerning wells :
  Maintenance expenditures include:
  - Bi annual site visit ,
  - Annual physicochemical measurements and interpretation of the results,
  - Bi annual data monitoring report: well data compiling, interpretation and advices concerning the facility operation.

  Repairing works include:

  Over ten years term:
  - Replacement of the immersed pump and its electric wiring,
  - Sensors and meter replacement or repair.

- Concerning dry air coolers :
  Costs include the implementation of only 4 dry air coolers instead of 5. Their lifetime can be considered longer since they are used as peak load units.

- Concerning gas boilers :
  Costs include the implementation of 2 gas boilers instead of three. Since they are used as emergency units, they need less control visits and their lifetimes are longer.

- Concerning geothermal heat exchangers :
  Costs include the implementation of two exchangers with the same nominal power (P_N).

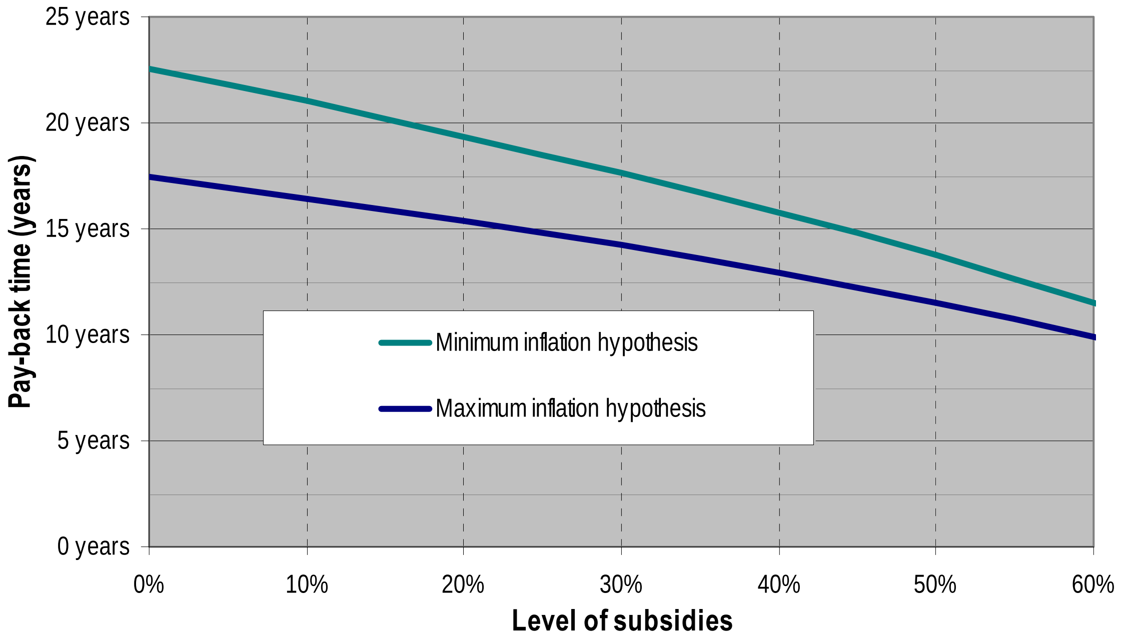
5.3. PAY-BACK TIME

The pay-back time is equal to the ratio of overinvestment costs linked to the geothermal facility implementation (after potential subsidies) over the annual operation savings.

In order to get accurate results calculations have to be done according to hypotheses on energy costs and maintenance costs inflation
Two hypotheses have been done:

- Minimum inflation hypothesis :
  - Gas price : +4% / yr
  - Electricity price : +2% / yr
  - Maintenance : +2% / yr
- Maximum inflation hypothesis :
  - Gas price : +8% / an
  - Electricity price : +4% / an
  - Maintenance : +4% / an

The following graph shows the pay-back time on the overinvestment compared to the reference solution depending on the level of subsidies.



With a subsidy covering 30 % of the overinvestment, the pay-back time of the geothermal facility would be around 16 years (depending on the inflation hypotheses).

6. CONCLUSION

This feasibility study is conclusive and its results are acceptable.

- Concerning geothermal resource :

An aquifer with a temperature of **20°C** and a flow rate around **100 m3/h** can be upgraded with a well whose depth is around 200m, provided that several levels are harnessed

- From a regulation point of view :

The entire Roussillon basin is classified as a water distribution zone. Thus, in order to follow the legislation and to not damage the Continental Pliocene water ground, the injection is necessary.

- Concerning the thermal use :

The geothermal energy covers 100% of the heating demands and 79% of the cooling demands of the water loop. Nevertheless, an emergency system is required for heating production (2 gas boilers). Peak load units are needed to cover all the cooling demands (4 dry air coolers).
It is strongly recommended to add a teleprocessing system in order to manage the installation and to optimize the system.

- Concerning the energy and environmental balances :

The geothermal installation **avoids any gas consumption on site** and induces energy savings up to 7 000€ exclusive VAT/year. This solution also reduces GHG emissions, with an annual decrease of **41,2 t_{CO2eq}** (41,6%).

- From an economical point of view :

Considering subsidies equal to around 30% of the overinvestment, the pay back time is around **16years.**

To conclude, the technical feasibility of a geothermal solution using HP on groundwater is proven. The economic feasibility depends on Public authorities' subsidies. They might accept to financially support this kind of pilot project in order to stimulate investments in renewable energies.