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Cost and Return on Investment for Geothermal Heat Pump Systems in France

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ABSTRACT

The geothermal sector using heat pump represent 80% of the 0, 5 billion euros geothermal market a year in France. The main part is achieved by close loop systems (CLS) from 5 to 20 kWth adapted to single housing. Due to the crisis the number of installed systems decreased dramatically from 20 000 in 2009 to less than 5 000 in 2013. The actual developing market is based on doublet schemes using mature and improved technologies. This market is focused on residential housing, offices and tertiary buildings using or not cold distribution loops with decentralized heat pumps. The study carried out by AFPG shows that under 100 kWth it is very difficult to get an economical solution using doublet scheme and that vertical closed loop exchanger remains the best system. Over 100 kWth when a water underground resource is available doublet system can provide pay back which is better when the thermal power needed is increasing. A typical ROI for this type of installation is generally below 10 years period following the size of the installation. The pay back is lowered if any cold production by free-cooling or using heat pumps is used. Before 2010, annual COP of 3, 5 was acceptable, performance of 4 to 5 are now common for well-designed installations. Big scale installations using BHE remains marginal because doublet scheme offers better pay back and consequently are installed only if there is no existing productive aquifer. Investment cost for close loop systems is from 1500 to 3000 € and from 750 to 3000 €/kWth for open loop based on water. These systems have been supported the last 4 years by the Heat Fund managed by ADEME, 64 projects has been funded representing an supplementary annual energy saving of 15000 tons of oil equivalent. During the same period the geothermal power installed growth was at 5 to 6% per year giving a total installed power of 2500 MWth in 2013.

1. INTRODUCTION

The geothermal sector using heat pump has been growing strongly in the last ten years. The total installed power estimated for the country is of about 2500 MW. Two third, for individual housing and one third for collective and commercial buildings. The part dedicated to industrial uses is marginal. The cumulative installed power is increasing yearly by 5% even if the market for individual housing as decreased dramatically in the last three years as show on the following diagram. This trend (from French Association of Heat Pumps) is the compilation of heat pumps sales below 50 kW th and represents mainly the market for single houses.

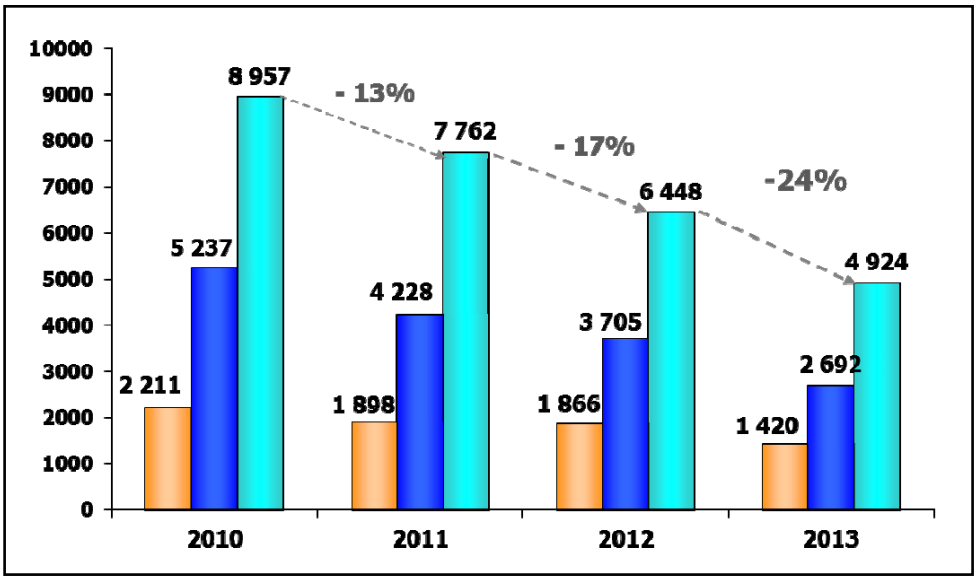

Figure 1: Sales of heat pumps in France below 50 kW (AFPAC 2014)

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Following the "Grenelle de l'Environnement" in 2009 the government has decided that the renewable part in the French energy mix should be 23%. According to this target, a road map for geothermal has been established. The following diagram shows the rather big gap in between the target and the AFPG prognosis which is the red curve close to business as usual. The target 2020 will be missed is no special support for geothermal energy is given to compete with gas which is the main obstacle to invest massively in shallow geothermal.

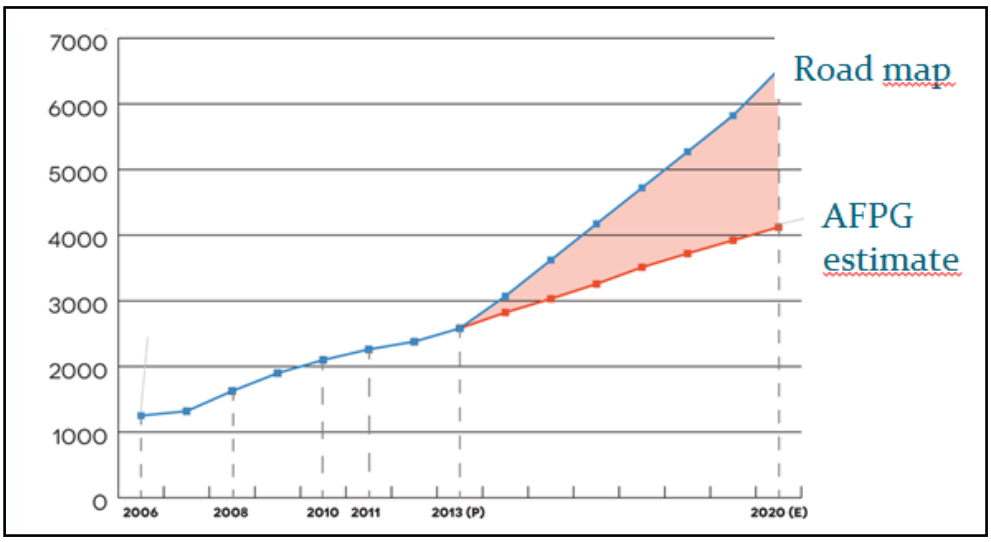

Figure 2: Comparison between the road map target and the prognosis done by professionals

2. ECONOMIC STUDY CARRIED OUT BY AFPG (FRENCH GEOTHERMAL ASSOCIATION FOR PROFESSIONALS)

2.1 Objective of the study

The study aims are to calculate for each main type of shallow geothermal plants the ROI and to compare the final MWh costs for the final consumer. These calculations have been done assuming that geothermal installations, if realised by qualified companies, have a duration life of 50 years, if a proper adapted maintenance is carried out both for the down hole heat exchanger or doublet system if based on aquifer.

The three studied devices are:

- horizontal closed loop (HCL)
- doublet (production and re injection in the same aquifer of 100% of the pumped water: Open loop system (OLS)
- vertical down hole heat exchanger of 100m : Vertical Closed Loop (VCL)

The marked is spitted in the following table:

Table 1: French market for the three main existing technologies

Type of consumer/Systems	HCL	OLS	VCL
Single housing	35%	10%	55%
Collective housing	0%	80%	20%
Offices and commercial buildings	0%	40%	60%

The mining code is expected to change in 2015 with the possibility for geothermal applications to drill down to 200m and up to 500 kW without permit which is actually a strong barrier except for single housing. To obtain a geothermal lease needs at the moment an instruction performed by the administration of Mines with duration of one year as an average. The possibility to drill VCL down to 200m is expected to boost the development of this technology in urban and sub-urban areas where the land surface available for projects is restricted.

2.2 General technical and economic assumptions

The comparison has been done for collective housing and tertiary with natural gas, for single housing the comparison has been extended to propane gas which is utilised in rural areas where the gas distribution network don't exist.

The number of annual working hours for a geothermal system is dependent on the location in the country and the calculation has been done with 2000 hours at full power. Cooling has been considered only for big scale installations and not for collective housing. The thermal and economic assumptions are summarized in the table 2.

Table 2: Thermal and economic hypothesis

Consumer/ numbers	Power (kW)	Heat production (MWh)	Electricity cost (€/kWh)	Gas cost €/kWh)	Subscription for gas (€)	Propane cost (€/kWh)
Single housing	8	16	0,118	0,059	185	0,134
Collective housing	120-300	240-620	0,08	0,051	1093	-
Offices and commercial buildings	1000 to 1200	2170 to 2400	0,08	0,051	1093	-

The investment cost at the surface is not dependent on the sub-surface system built. The annual COP imposed is 4.The heat pump is expected to be changed each 20 years and the corresponding maintenance costs are summarized in the table 3.

Table 3: Investment and maintenance costs for the heat pump system

Costs/Heat Pump power (kW)	8	120	300	1000	1200
Investment (€)	7500	30000	75000	300000	360000
Maintenance (€)	250	1000	1000	2500	2500

The support and subsidies is different depending on the size and type of the installation. For single housing it is a tax credit which represents 15% of the total investment including the underground heat exchanger and the surface installations. For the other installations, the subsidy is given by the heat Fund managed by ADEME the state agency in charge of the development of Renewables. The average subsidy calculated on the fact five year corresponding to 300 installations subsidized is of 30% for closed loop systems and 20% for open loop systems.

- Vertical closed systems: between 3 and 12 Toe of annual production the subsidy is of 325€/Toe calculated for 20 years and above 25 Toe f 415 €/Toe.
- Open loop systems: the subsidy is of 100 € Toe for an annual production of 6 to 25 Toe and of 120 €/Toe above.

The results are presented by curves on 20 years diagram, nevertheless the cumulative costs have been done for 50 years and the comparative kWh costs do represent the final result.

3. HORIZONTAL CLOSED SYSTEMS

These systems are used only for single housing because they require an important surface to be set up. The average area represent needed is 2, 5 times the surface of the house to be heated. The data has been gathered in the main companies providing this system in France. The heating demand and investment have been calculated for a single house of 13m2 with a n installed heat pump power of 8 kW. The following table summarize the investment and working costs.

Energy/ Costs	Investment (€)	Maintenance (€)	Energy consumption (€)
Geothermal	**11000**	**250**	**470**
Natural gas	**3000**	**685**	**1000**
Propane gas	**3000**	**500**	**2295**

The results demonstrate that with or without tax credit, the solution offers pay back which are under 7 years. The increase of both electricity and gas, even different don't affect the result, because the total power considered is too small.

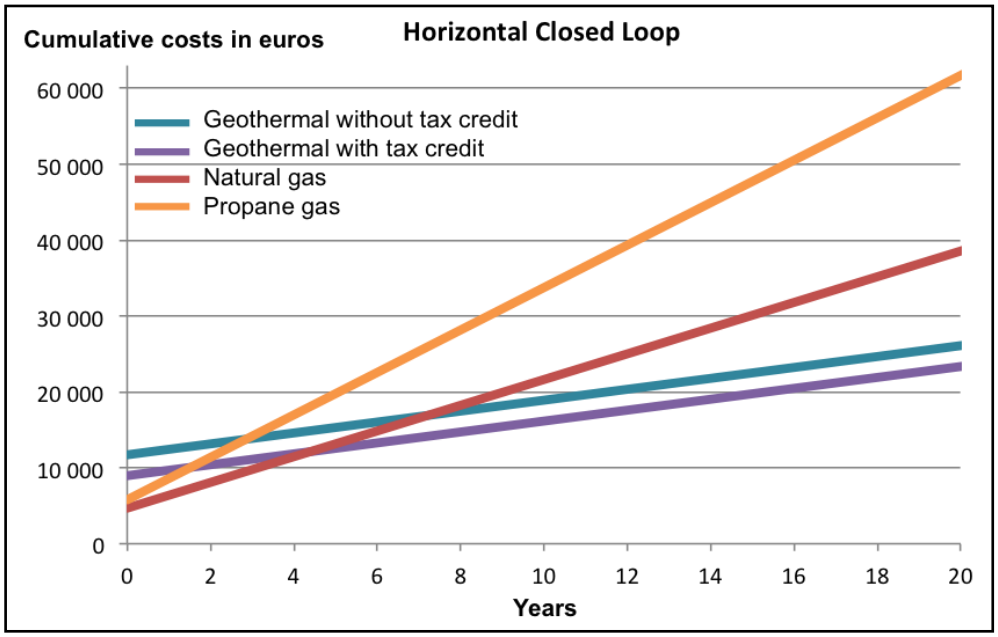

Figure 3: Diagram for single housing with horizontal closed loop

These systems are competitive compared with natural gas from the national network and really attractive if the house is heated by propane. ROI are in every case under 8 years and in the most favourable case around two years. The only obstacle to develop this technology is the space needed which prevent the owner to plant trees and the nature of the underground which as to be soft enough between the surface and 1,5m depth.

4. VERTICAL CLOSED SYSTEMS

This system can be installed for both single housing and collective dwellings or office and commercial buildings. The underground thermal characteristics are very important and the presence of water which increases the conductivity is of paramount importance. Consequently, a study which depends on the size of the installation is mandatory. The calculations have been carried out with a power of 50 kW/ meter of vertical probe. The technical and economic assumptions are summarized in the table 4.

Table 4: Parameters for the 3 vertical systems studies

Consumer/ numbers	Power (kW)	Meter of drilling	Number of probes	Investment (€)	Maintenance (€)	Energy (€)
Single housing	**8**	**120**	**1,2**	**14700**	**250**	**400**
Collective housing	**120**	**1800**	**18**	**170000**	**2750**	**5540**
Offices and commercial buildings	**1200**	**18000**	**180**	**1540000**	**22900**	**55400**

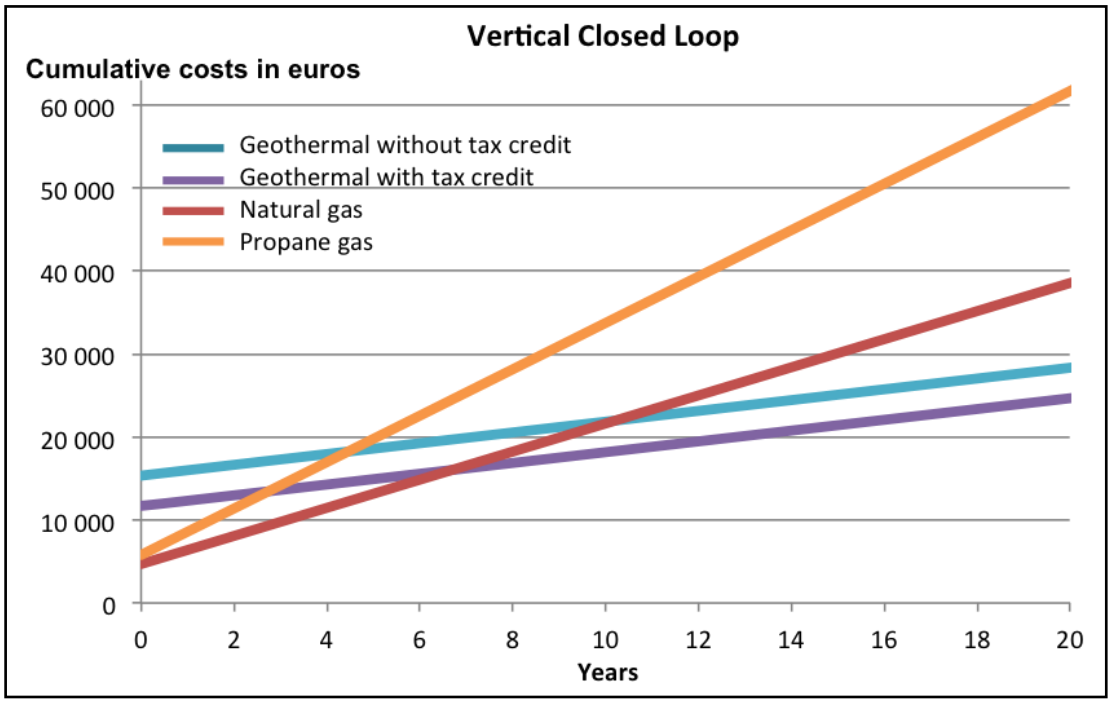

Figure 4: Diagram for vertical closed loop for single housing

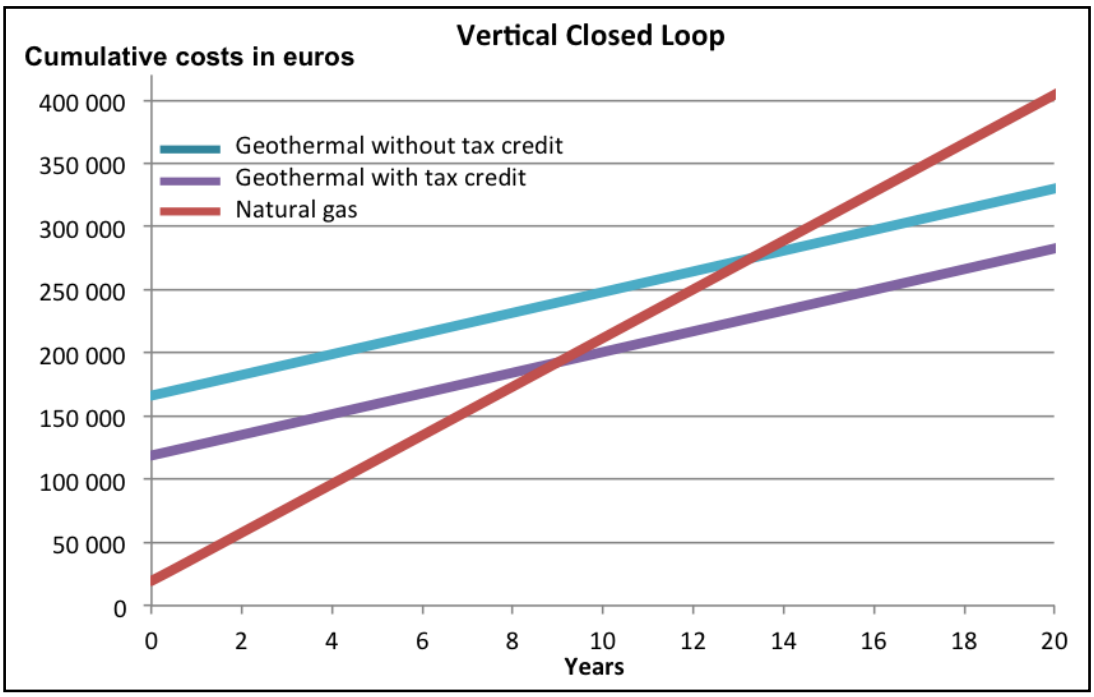

Figure 5: Diagram for vertical closed loop for collective housing

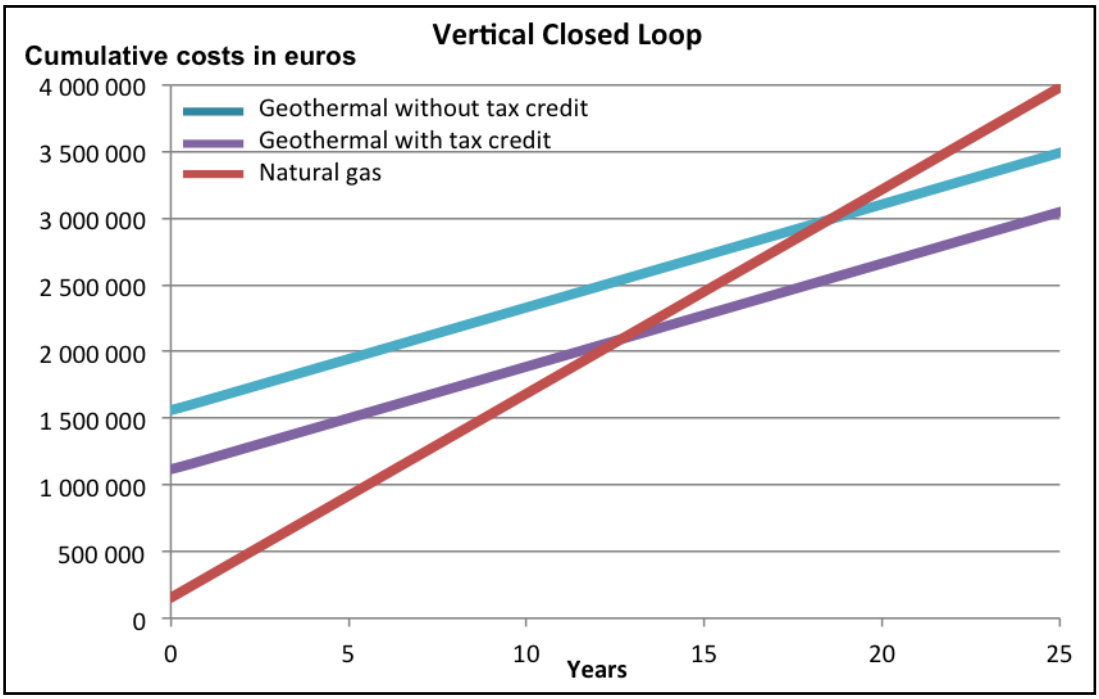

Figure 6: Diagram for vertical closed loop for offices and commercial buildings

The vertical closed loops are more efficient if utilized to generate cold in summer. This technics gives two advantages; one is the injection of heat in the underground with a heat recharge that can be recovered next winter, the second is to maintain a high level of temperature in the underground allowing a longer life time of the installation. The geo-cooling give COP of 40 to 60 which are really the plus of this technology. The payback period, when including a summer free cooling, are lowered in general by 3-4 years which helps in most case to attain an acceptable profitability. The best ROI is obtained for small collective housing representing 30 to 40 dwelling equivalent (9 to 14 years depending of subsidies). For big installations the ROI is higher (14 to 19), in that case if there is a free cooling option to ensure cold production in summer the ROI is lowered at 9 to 10 with subsidies. The most develop size at the moment is the single housing use with about more than 100 000 systems already installed representing average annual heat production of 1,8 GWh. The big installations are rather rare and the biggest plants have a maximum size of 500 KW even if installations at 1 to 2 MW are now planned for the near future.

5. OPEN LOOP SYSTEMS

The geothermal installations based on underground water are in general well adapted to collective housing and commercial buildings. In France only 11% of the OLS are built for single housing. The doublet scheme require a rather big investment except if the house is located in very favourable zones such as river banks or when aquifers are very close to the surface (1 to 15m). Nevertheless one of the main restrictions which limit the development of thes systems is the required land I order to ensure a sufficient spacing in between the production and the injection wells, in order to prevent to pump water with a diminishing temperature.

Two big types of aquifers have been studied. The detrital formations (60%) including alluvium, sand, gravel, sandstone, conglomerate and the carbonaceous (40%) with limestone, dolomite. It has been considered that it is more costly to equip borehole producing from detrital formations (special screens, gravel pack) and also injecting in this type of aquifer. Consequently the investments and maintenance costs for these types of reservoirs are considered to be respectively 10 and 15% up to those for carbonaceous aquifers.

The case studies are based on the water flow-rate produced in the doublet as defined in the table 5.

Table 5: Parameters utilized for open loop systems

Case studies/data	Pump diameter (inches)	Flow-rate in m^3/h)	Thermal power (kW)	Average flow-rate	Average power with a ΔT=5°C	Pumping power (kWe)
1	2	1 to 3	5 to 18	2	12	1,1
2	4	3 to 15	18 to 80	7	40	2,5
3	6	15 to 80	80 to 500	40	232	12
4	8	>80	>500	140	812	40

The investments taken into account includes: the two wells of the doublets, the well heads, the pumping devices including the pump the pumping column, the metrology put in place to control the doublet while running, the piping network and electrical connections in between the wells and the heating room (respectively of 40, 100 and 200m depending on the flow-rate. For the subsurface installations the heat pump and ancillary equipment, the intermediate heat exchanger, all the connections and pumping devices.

A maintenance cost includes an annual checking of the full installation with minor repairs and controls. The heavy maintenance counts the heat pump replacement each 20 years and the down hole pump each 4 years plus replacement of ancillary equipment's each 10 years. The well are supposed to be cleaned, stimulated by air lift and acidized if necessary each ten years. Depending of the case study the total maintenance costs are estimated at 3 to 5% of the investment costs.

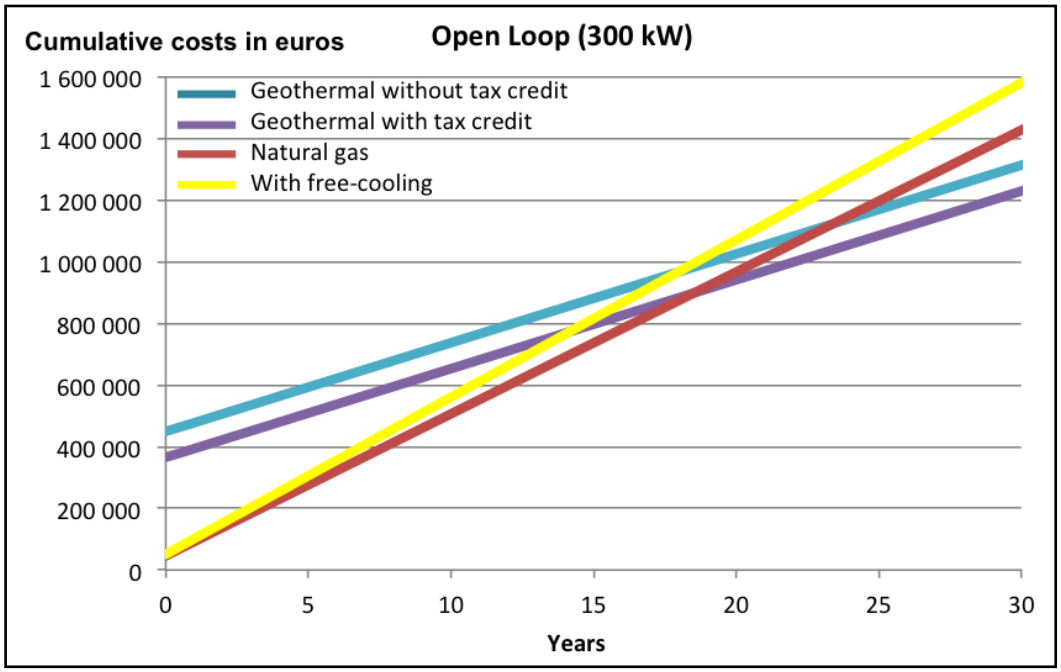

Figure 7: Diagram for open loop systems for collective housing

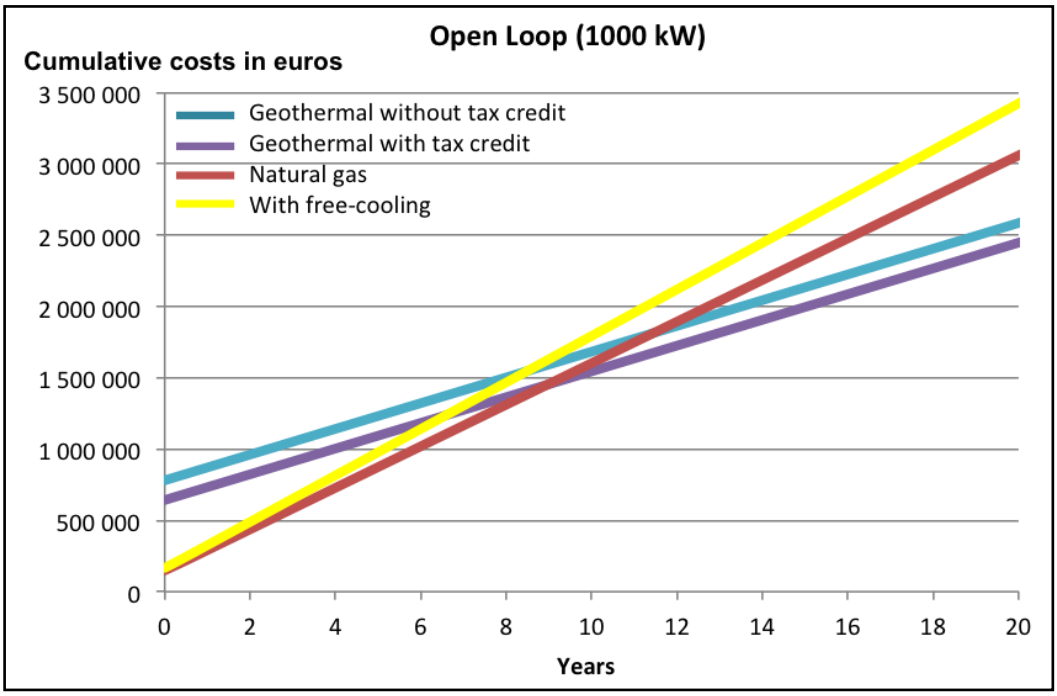

Figure 8: Diagram for open loop systems for offices and commercial buildings

These systems are not well adapted for single housing because the fixed costs to drill proper doublet system are in general too high to offer an acceptable ROI. For collective housing representing around 40 to 50 dwelling equivalent the ROI (15 to 24 years) is worse compare to vertical closed loop. For big installation the ROI is really good (7 to 10 years) and at the moment if the aquifer resource is sufficient to provide the power, this type of plant is now very popular. The quick development of theses installations is connected with the construction of low temperature smart small network to feed new neighbourhoods using centralized or decentralized heat pumps.

6. COMPARISON WITH FOSSIL ENERGIES

The study has been done without taking into account any price evolution of conventional fossil energy to give a fair evaluation of the three main technologies utilized in France. The calculations are done for a time life for each installation of 50 years.

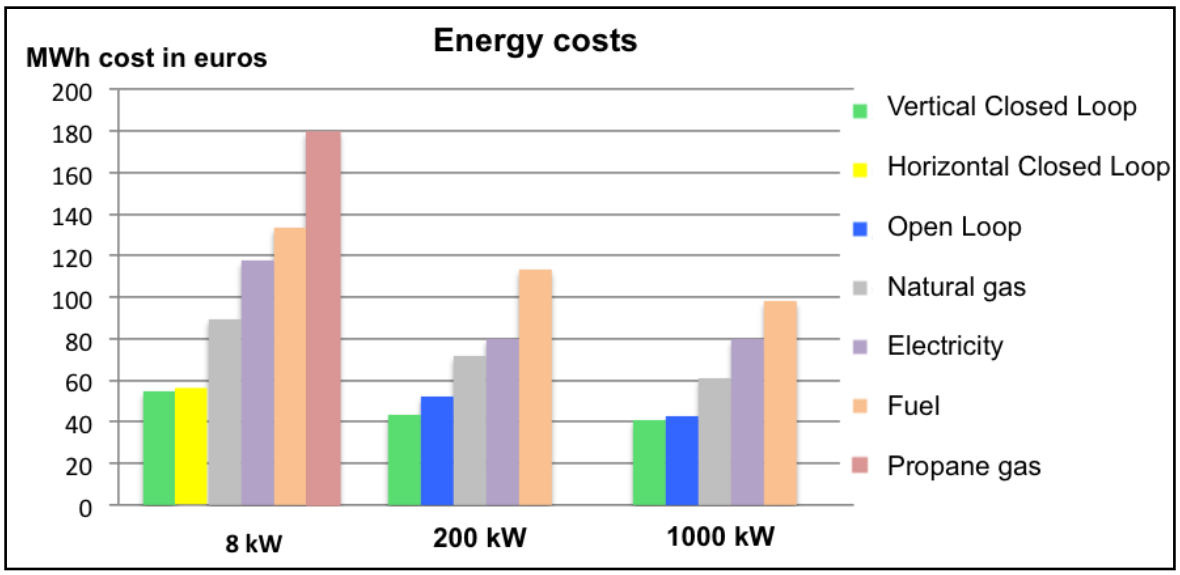

Figure 9: Comparative costs of energy with geothermal with subsidies from ADEME (heat fund)

Table 6: Recapitulative table with ROI and CAPEX per KW thermal installed

Consumer/ numbers	Type of system	ROI without subsidies (years)	ROI with subsidies (years)	Investment per KW installed (€)without subsidies	Investment per KW installed (€) with subsidies
Single housing	**Horizontal closed loop**	**7**	**4**	**1380**	**1170**
Single housing	**Vertical closed loop**	**10**	**7**	**1840**	**1560**
Collective housing	**Vertical closed loop**	**14**	**9**	**1410**	**980**
Collective housing	**Open loop system**	**24**	**19**	**1400**	**1120**
Commercial buildings	**Vertical closed loop**	**18**	**15**	**1200**	**840**
Commercial buildings	**Open loop system**	**12**	**9**	**1200**	**1090**
Commercial buildings	**OLS with cooling**	**9**	**7**	**690**	**550**

The diagram shows the average MWh cost in euros for the different plant size compared with natural gas, propane, electricity and fuel oil. The best cost is for big installations with both technology (open or closed loop). It can be underlined that the average best price of thermal energy is obtained with vertical closed loop because on the long term the very low maintenance (OPEX) costs compensate a bigger CAPEX. The average cost of 55 to 40 €/MWh is considered as low in France and Europe. The cost comparisons are done with natural gas and at the moment geothermal remain very attractive for medium to large geothermal installations. The diagram has been done taking into account the subsidies. Without the impact on the final costs is of around only 2,5 €.

The recapitulative table shows that the CAPEX per KW installed is comprised between 1840 and 550 €. To collective housing, the best ROI is given by the vertical closed loop system. The best ratio is for commercial buildings equipped with doublet systems on aquifers. On reverse for smaller installations devoted to collective housing, the best ROI is given by the vertical closed loop system. For single housing the ROI are attractive compared with conventional fossil fuel, but the competition of this type of installations is with air heat pump which necessitate smaller CAPEX even if on the long term (after break-even) the air solution with a lower COP is not the best energetic solution.

The competition of geothermal heat pump is also difficult to compete with biomass solutions which need also lower CAPEX. The new legislation on buildings (RT 2012) in force since 2 years will lead on short term to the disappearance of electricity for heating purposes.

Nevertheless, geothermal heat pumps represent a significant market for new buildings construction but the main work to come is the renovation of old buildings which represent more than 5 million targets for geothermal applications.

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