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Geothermal demonstrator project in the Lusitanian layer in the Paris Basin

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ABSTRACT

In the Val-de-Marne area (South-East of Paris), the current exploitation of the Dogger aquifer (middle Jurassic, Bathonian) for heating networks (60 doublets and triplets) is going to significantly increase by the year 2016 thanks to 5 new projects aiming the Dogger aquifer (Cf. Figure 1). This leads to a density of geothermal exploitations aiming at the Dogger aquifer so high in this confined area that the question of conflict of interest acts as an incentive to explore other relevant geothermal resources.

Among them, the Lusitanian reservoir (upper Jurassic, Oxfordian) is studied in this paper as an alternative to the Dogger in the Vitry-sur-Seine project whose goal is to provide the existing heating network with at least 50% of renewable energy.

Despite some uncertainties about the resource tarnishing the results, the study in Vitry-sur-Seine highlights 3 main conclusions:

- the top of the Lusitanian reservoir is expected to be between 1100 and 1150 meters in depth;

- the expected exploitation characteristics are a flow rate of 200 m^3/h, a temperature at the reservoir of 55°C and a minimum reinjection temperature of 25°C,

- the power of a new doublet aiming at the Lusitanian reservoir in Vitry-sur-Seine could be 6.9 MW, which meets the heat demand of the district heating.

In the framework of this innovative project and the scientific hurdles, the economic, technical and regulatory aspects are dealt with in order to demonstrate the feasibility and the reproducibility of such a project within the Paris Basin.

1. FROM GEOTHERMAL DISTRICT HEATING IN THE PARIS BASIN TO THE PROJECT

1.1. Geothermal district heating in the Paris Basin

In the sedimentary Paris Basin, four main continuous reservoirs potentially relevant for geothermal district heating are nested (Cf. Figure 2):

- The Albian-Neocomian (lower Cretaceous)
- The Lusitanian (upper Jurassic)
- The Dogger (middle Jurassic)
- The Trias.

The permeable carbonate rocks of the Dogger limestone reservoir host hot water at an average of 70°C at depths of 1500 to 1800 meters (ADEME, 2012). This geothermal heat is commonly harnessed through a geothermal loop composed of a production well extracting the hot saline brine which is entirely pump back in the Dogger via an injection well.

Owing to the oil crisis, the 1970s and 1980s were a major development period with around one hundred drilled wells aiming at the Dogger. After a downturn in the 1990s due to both financial issues (decreasing oil price) and technical issues (corrosion and scaling), a downturn happened in the 1990s.

Today, the Paris Basin has the world's largest concentration of geothermal district heating exploiting the same aquifer. Moreover, thanks to favourable support policies, numbers of new geothermal projects aiming at the Dogger or work-over of old geothermal loops at the Dogger have come up for 3 years.

As a consequence, in some areas like in the Val-de-Marne Department (Cf. Figure 1), the implementation of new geothermal facilities aiming at the Dogger is hampered or even avoided by existing operations.

As both geothermal resource and heat demand have to be geographically matched, the exploration of new reservoirs, like the Lusitanian, at the bottom of such areas can offer a solution when new projects at the Dogger cannot be implemented anymore.

1.2. Demonstrator project in the Lusitanian reservoir in Vitry-sur-Seine

The demonstrator project in Vitry-sur-Seine is part of a sustainable development project taking place in the southern urban area of Paris in the vicinity of the National Interest Operation named "Orly-Rungis-Seine Amont". This operation will enable the creation of nearly 3 million m² of net gross floor area by 2040 over 300 hectares.

In this context, a 4000-housing existing heating network has to be provided with at least 50% of renewable energy. In this confined area, resorting to the Dogger cannot be considered, so the Lusitanian aquifer was studied as a relevant potential reservoir to supply the existing network with geothermal heat.

Furthermore, the Lusitanian project fits perfectly the urban heating network plan whose goal is also to optimize the networks and keep control of the cost of the final user.

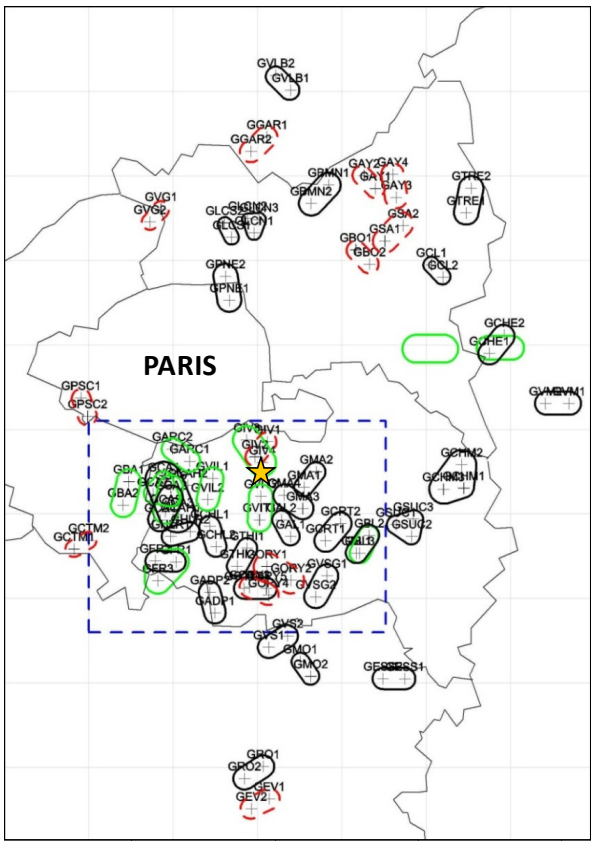


Figure 1: Exploitation permit of geothermal facility aiming at the Dogger, area of the Val-de-Marne and project's location (Hamm, 2013)

The drilling of a geothermal doublet at the Lusitanian is part of a sustainable development project taking place in the South of the Paris urban area in the vicinity of the National Interest Operation "Orly-Rungis-Seine Amont". This project of National Interest Operation will enable the creation of nearly 3 million m2 of SHON (net gross floor area) by 2040 over 300 hectares, among which 600,000 m2 for the Seine-Gare-Vitry area by 2025, including buildings dedicated to activities, offices, shops, housing and equipment.

Figure 1 : The "Seine-Gare-Vitry" National Interest Operation

Furthermore, the completion of the project at the Lusitanian fits perfectly the urban heating network plan of Choisy-le-Roi/Vitry-sur-Seine, whose goal is to reach a renewable energy level greater than 50%, as well as optimize the networks and keep control of the cost to the user. These goals are also part of the leanings of the development programs of VItry-sur-Seine and Choisy-le-Roi and the local territory development organizations.

2. GEOLOGICAL AND HYDROGEOLOGICAL CONTEXTS

As previously mentioned, the Lusitanian aquifer takes place in the sedimentary Paris Basin whose a geological cross section is given herein below (Figure 2).

The Lusitanian (Upper Jurassic, Oxfordian encompassing the Sequanian, the Rauracian and the Argovian) has been slightly explored in the Paris Bassin so far, as it is not a target neither for oil production, neither for drinkable water supply. As a consequence, available data about the Lusitanian are uneven and incomplete.

In addition, its geometry and its characteristics are complicated and intricate within the Paris Basin, even at the local scale, particularly in terms of number of producing levels, thickness and permeability.

The Lusitanian is currently studied by the BRGM (France's leading public institution in Earth science applications) in a project named “Synthesis of the available data regarding the Lusitanian in order to exploit it”.

Synthèse des données disponibles sur le Lusitanien en vue de son exploitabilité

Above the studied area, the Lusitanian layer is expected to be present from 1106 to 1358 meters deep.

The Lusitanian reservoir features oolitic limestone layers that match sedimentary conditions similar to those of the Dogger limestone. These similarities let foresee heterogeneity of the reservoir characteristics which is unpredictable given the lacking knowledge about the Lusitanian.

Thus, the estimated flow rate of 200 m^3/h (for a reservoir transmissivity estimated as 85 D.m and a reservoir drilled in 8’’1/2) and the temperature at the reservoir of 55°C are given with high uncertainty.

The hot brine coming from the Lusitanian at a distance of 5 km from Vitry-sur-Seine has a salinity of 9.81 g/L.

In spite of the uncertainty concerning the forecast in the production capability of the doublet, it seems that the Vitry-sur-Seine area provides an interesting and ideal site as a pilot project at the current state of knowledge.

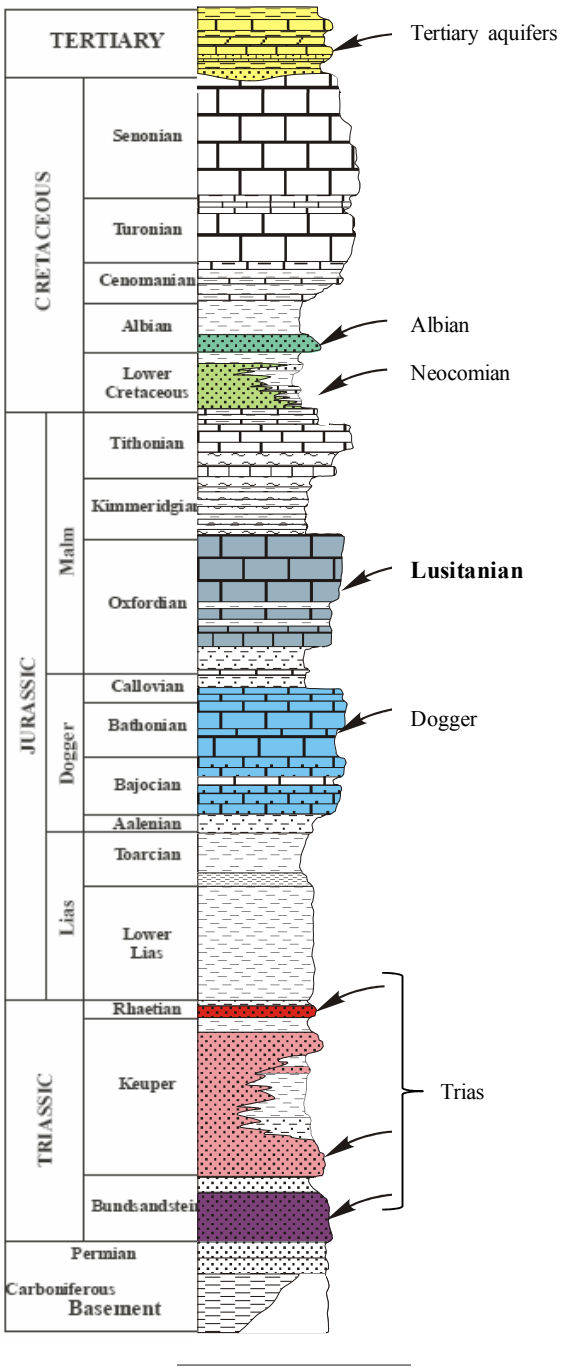


Figure 2: Typical geological cross section of the Paris Basin

3. DESIGN OF THE GEOTHERMAL FACILITY

In order to qualitatively and quantitatively sustain the geothermal resource, the geothermal heat is harnessed by a doublet of wells that spreads apart from a single platform.

The digital hydro-thermal modelling (with the COMSOL Multiphysics software) of the Lusitanian reservoir was conducted to design the bottom hole spacing (spreading apart of the shoe of the two wells) and their optimal implementation.

3.1. Hydraulic impact of the new doublet

Given the uncertainty about the productivity of the Lusitanian reservoir, two assumptions of transmissivity were simulated as equal to either 42 D.m (pessimistic assumption) or 85 D.m (optimistic assumption).

The flow rate being the same all year long, the influence of the transmissivity is observed only on the groundwater lowering and rising.

The groundwater lowering and rising is about respectively -3.3 bars (production well) and +3.3 bars (injection well) for the optimistic assumption (Cf. Figure 3). These values are doubled in the pessimistic case, which highly impacts the electrical pumping power consumption.

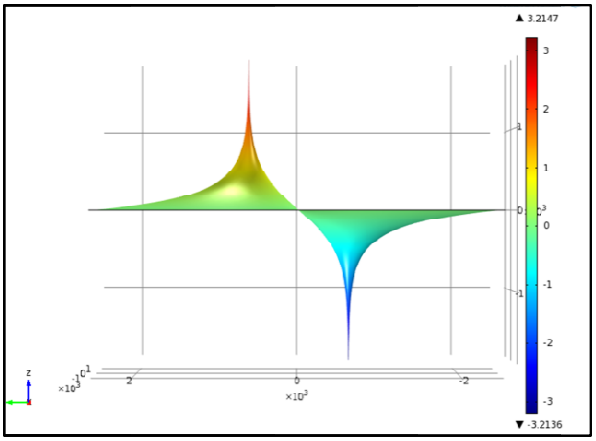
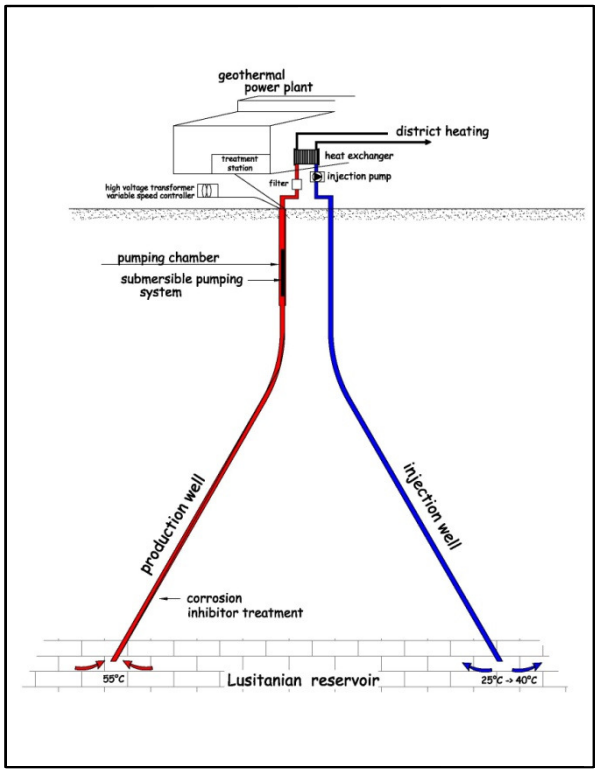


Figure 3: Hydraulic impact simulated with the digital modelling (optimistic assumption)

3.2. Thermal impact of the new doublet

The operating parameters taken into account in the modelling were a flow rate of 200 m^3/h and an injection temperature of 25°C during the winter and of 40°C during the summer.

The spreading apart of the impact points of 1243 meters allows proper operation of the new doublet during 30 years (the lifespan of the exploitation licence) without thermal breakthrough (decrease of the temperature at the production well head of 0.5°C) (Cf. Figure 4).



To pump to surface the hottest geothermal water, the doublet is oriented north to south, with the production well at the south (Cf. Figure 4).

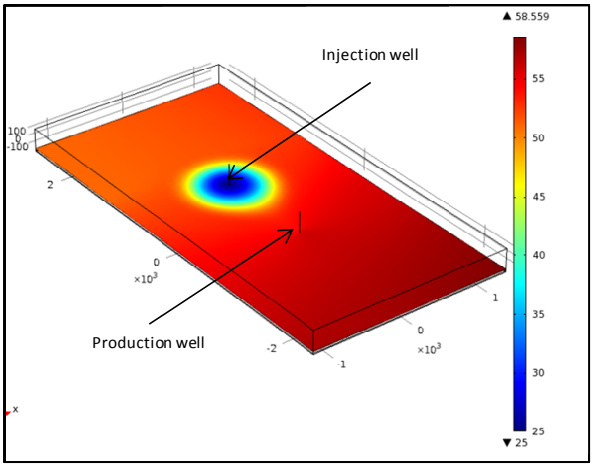


Figure 4: Thermal impact simulated with the digital modelling

As this project is the first aiming at the Lusitanian in the Paris Basin, it was not necessary to study the interference with other geothermal operation.

3.3. Schematic drawing of the geothermal loop

The hot saline water of the Lusitanian reservoir including a solution gas phase needs to be pumped thanks to an electrical submersible pumping system placed in the pumping chamber in the production well. The heat depleted brine is pumped back to the reservoir in the injection well thanks to an injection pump.

The two wells are highly slanted (about 50° at the top of the reservoir) with the aim of reaching:

- an horizontal displacement of about 645m at 1152m in depth for the production well,
- To a horizontal displacement of about 598m at 1106m in depth for the injection well.

The expected salinity of the geothermal water, the possible bacteria activity and the sulphur content could lead to scaling and corrosion issues, which represents a risk for the well casing integrity.

To avoid scaling and corrosion issues in hostile thermochemical environment, a corrosion inhibitor treatment is injected in a continuous downhole lines going to the shoe of the production well. In addition, the geothermal water is filtered at the production well-head.

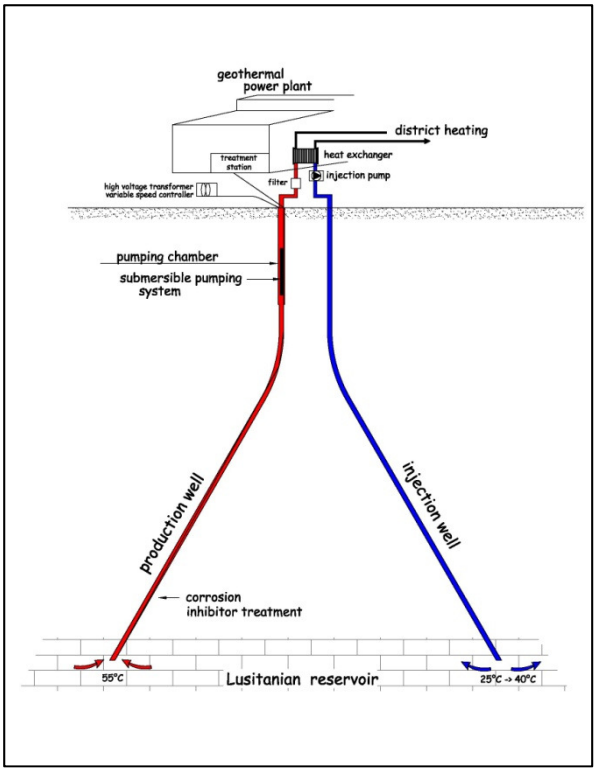


Figure 5: Vitry-sur-Seine geothermal loop aiming at the Lusitanian reservoir

3.4. Heat recovering

The facility aiming at recovering the geothermal heat is expected to feature plate heat exchangers and a novel magnetic bearing heat pump (high fidelity and extended lifetime), allowing increasing the energy power of the whole set-up.

The installation aiming at recovering the heat from the geothermal fluid is expected to feature plate heat exchangers and a novel magnetic bearing heat pump (high fidelity and extended lifetime), allowing to increase the energy power of the whole set-up.

4. COSTS, SUBSIDIES AND INSURANCES

4.1. Costs

Considering the operating parameters given herein before (200 m^3/h and minimum injection temperature of 25°C), the thermal power of the new doublet of Vitry-sur-Seine is expected to be 6.9 MW.

The investment encompassing the implementation and the commissioning of the geothermal loop is expected to be under 9 M€ at a global cost of 15.8 M€ for the whole project (including the scientific experimentations: testing of the aquifer, core samples, etc.).

4.2. Subsidies

Public authorities employ support policy like the "Fonds Chaleur" (Renewable Heat fund) subsidies for which the Lusitanian project is eligible. This financial support is raised by the French Environment and Energy Agency (ADEME), the Ile-de-France Region and the European Regional Development Fund (ERDF) which would reach a proportion of the investment cost linked to the drilling works of the doublet wells of Vitry-sur-Seine.

4.3. Insurances

Geothermal projects are subjected to geological risks due to the drilling works and to the exploited geothermal resource. ADEME and SAF-Environnement (a subsidiary of the French Consignments and Loans Fund - Caisse des Dépôts et Consignations) allows general contractors to cover these risks in adhering to their insurance policy divided in two guarantee funds.

The short-term guarantee fund covers the risk of drilling failure (i.e. in the case temperature and/or flow rate are lower than expected), and the long-term guarantee fund covers the risk linked to the sustainability of the resource in terms of flow rate and temperature and the geological or geothermal damages to the wells.

5. CONCLUSION AND PROSPECTS

The feasibility study has underlined the relevancy of the Lusitanian reservoir to be exploited for heating the existing heating network of Vitry-sur-Seine.

The planning of the project, based on optimistic forecast, suggests that the wells may be drilled in the course of the first quarter of 2016, commissioned during the third quarter of 2017 and delivered heat for the first new constructions.

Considering the lack of available data, the geological risk is pretty high (particularly concerning the flow rate) and the drilling of wells aiming at the Lusitanian will significantly improve the knowledge of this aquifer and allow considering duplicating this project on other site.

Thus, taking into account the denser and even denser concentration of geothermal projects aiming at the

Dogger, in the Val-de-Marne for instance, the purpose of this project in a broadened prospect is to provide operators with another geothermal resource meeting their heat demand for 3000 to 4000 housings.

Moreover, the technological advances in the field of heat pumps and the development of low-energy houses, sustainable building projects and thus low temperature heating networks, now lead to consider the exploitation of deep geothermal resources whose temperature are in the range 30°C to 60°C, like the Lusitanian.

As the Vitry-sur-Seine's geothermal operation is currently the only project targeting the Lusitanian resource, it is a matter of major importance to the acknowledgment of this reservoir as a resource technically conceivable and economically sustainable.

That is why it could be worth carrying out additional scientific experimentations in addition to the common investigations during the drilling works:

- An axial core sample throughout the Lusitanian reservoir;
- Lateral core sample in the producing layers shown on the production logs;
- Additional logging (electric resistivity, sonic, gamma ray, …);
- Bottomhole water samplings at the reservoir level.

On the other hand, for 40 years of geothermal exploitation in the Paris Basin, more than one hundred and twenty wells have been drilled in order to exploit the Dogger reservoir but only two hydraulic tests have been performed on the Lusitanian reservoir which was drilled through.

To enhance the knowledge about the Lusitanian reservoir and reduce the geological risk, scientific support for exploration on the Lusitanian reservoir would be conducted on numerous new projects targeting the Dogger.

This investigation on the Lusitanian reservoir aims at providing reliable characteristics of the reservoir to cope with the feasibility and the reproducibility of the exploitation of this aquifer thanks to a geothermal doublet. It could be carried out as followed:

- A complete wireline logging program in order to characterize the reservoir properties (Neutron porosity, resistivity, sonic, magnetic nuclear resonance and borehole imagery)
- The use of LWD (Logging While Drilling) tools to assess the same parameters,
- And a hydrodynamic test program as DrillStem Test (DST).

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