ASSESSMENT OF GEOTHERMAL EXPLOITATIONS RISKS. A CASE STUDY

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ABSTRACT

As many mining venture, geothermal energy shares both exploration and exploitation risks. In the present case study, which addresses a large geothermal district heating (GDH) scheme, the drilling success ration approached 100% (one recorded failure out of ca.100 wells) whereas exploitation of the low temperature deposits showed, in the early stages, severe technical and non technical shortcomings leading to frequent, prolonged, well shutdowns and, ultimately, to their abandonment.

As a result, the ad-hoc mutual benefit insurance fund, setup to mitigate such damages, was asked by the subscribing GDH operators to assess, site wise, the exploitation risks, the remedial procedures and, last but not least re/evaluate the relevant repair/preventing costs and related sinking fund requirements.

Given a five to ten year well monitoring record a deterministic scenario approach was adopted. It consisted of classifying and ranking risk impacts, for each GDH site, according to weight and severity degree for selected technical and non technical criteria, namely:

(i) technical (weighted 1)
- last casing status assessed from residual thickness provided by periodical logging/inspection (three classes);
- corrosion rates, prior to implementing chemical inhibition protocols, inferred from material balances after well cleaning/logging (three classes);
- efficiency of corrosion inhibition practice based on thermochemical monitoring and direct metering of corrosion kinetics and log quantifying (two classes);
- well completion status with respect to damage repair opportunities via casing (re)lining, either total, partial, impossible (three classes);
- the likely dates estimated for drilling/completing new well/doublet (three classes related to early to late deadlines);

(ii) nontechnical (weighted 3). Those were globalised as either favourable or non favourable conditions respective to future sustainable exploitation issues. They address, among other issues, heating grid extension, natural gas competition, operator's managerial, financial and motivation capacities.

The survey enabled to appraise three classes of risks on a representative sample of 18 doublets, further extended to the whole GDH set (i.e. 36 doublets), distributed as follows:
- low risk 12
- fair risk 14
- high risk 10

The ultimate stage led to a cost schedule, estimated from an itemised list of repair works and three scenarios regarding completion dates, projected for each risk level over a 15 year life. It formed the core of the sinking fund and subsequent subscription fees.

Twelve year after its initiation, the exercise proved rewarding since 80% of predicted figures were validated.

The case study addresses the development and management of a large geothermal district heating (GDH) scheme exploiting, since the early 1970s, a dependable carbonate reservoir located in the central part of the Paris Basin.

The geothermal reservoir consists of a hot water aquifer, of regional extent, hosted by Dogger pervious oolithic limestones and dolomites, of mid-Jurassic age, at depths and temperatures ranging from 1450 to 2000 m and 56 to 80°C respectively.

Development of the resource was boosted in the aftermath of the first and second, so-called, oil shocks, in the mid to late 1970s, thanks to a thorough involvement of the French State.

It led to the completion of 54 GDH grids, based on the, mass conservative, well doublet concept of heat extraction, of which 34 remain online to date, achieving a ca 200 MW_t installed capacity, a 1000 GWh_t yearly supply securing the heating of some 120 000 equivalent dwellings and, last but nor least, the savings of 350 000 tons of CO_2 emissions.

Worth mentioning is that, in most instances, GDH had to cope with existing buildings and conventional heating designs so that retrofitting was the rule and GDH operated as base load in combination with, peak rated, fossil fuel (chiefly gas) fired back up/relief boilers.

The rewarding experience, built up from a thirty year exploitation record, reflects the learning curve phases, from infancy to teenage and maturity, inherent to any new technology and energy route. As a result, GDH got soon faced to three major shortcomings, namely:

(i) technical problems : a hostile fluid environment characterised by a thermochemically sensitive (aqueous CO_2/H_2S system) geothermal brine which caused severe, corrosion/ scaling induced, damage to well tubulars and production/injection facilities ; these problems had been clearly overlooked at design/implementation stages;

(ii) financial problems : deemed the most critical, they resulted from a massive debt charge (no equity) aggravated by high inflation and a depleted energy market further to the second oil shock;

(iii) managerial problems: they related to the lack of experience and expertise of geothermal operators, most of them belonging to the public/municipal sector, in handling industrial installations including a significant mining segment; neither did the heating service companies exhibit the required grid operating skills; it led consequently to loose monitoring and maintenance practice.

This bleak outlook could be progressively overcome thanks to innovative, State supported, specifically designed chemical inhibition (continuous, coiled tubing type, downhole injection lines, free annulus fiberglass lined wells) and well restoration (jetting tools, workover waste processing units) technologies, customised monitoring protocols and sound management of GDH plants and grids. Abandonment of the twenty poorly reliable doublets was the tribute to be paid.

Sustainability was another key issue. It clearly addressed the longevity of existing, approaching the 25 year deadline assigned by former feasibility assessments, GDH systems and whether or not there was a life after. Reservoir simulation of production well cooling kinetics led to the selection of an optimum doublet-triplet-doublet well scenario, completed from the existing well head platform, securing an overall 75 year reservoir thermal life.

So, everything considered, GDH in the Paris Basin has a good chance. In spite of a technically hostile and economically competitive environment, GDH scored well. It demonstrated so far its technological and entrepreneurial maturity and gained wider social acceptance and credibility.

RISK ASSESSMENT

Paris Basin geothermal district heating projects as one would expect for similar undertakings, faced five levels of risks, exploration (mining, geological), exploitation (technical, managerial), economic/financial (market, institutional, managerial), environmental (regulatory, institutional) and social acceptance (image) respectively.

1 Exploration risk

The mining/geological risk could be minimized here thanks to two favourable factors and incentives. First, the existence of a dependable hot water aquifer (Dogger limestone and dolomite) of regional extent evidenced thanks to previous hydrocarbon exploration/step out/development drilling, which enabled to reliably assess the geothermal source reservoir prior to development. This resulted later in a 95 % geothermal drilling success ratio. Second, the coverage by the State of the geological risk amounting to 80 % of the costs incured by the first, assumed exploratory, drilling.

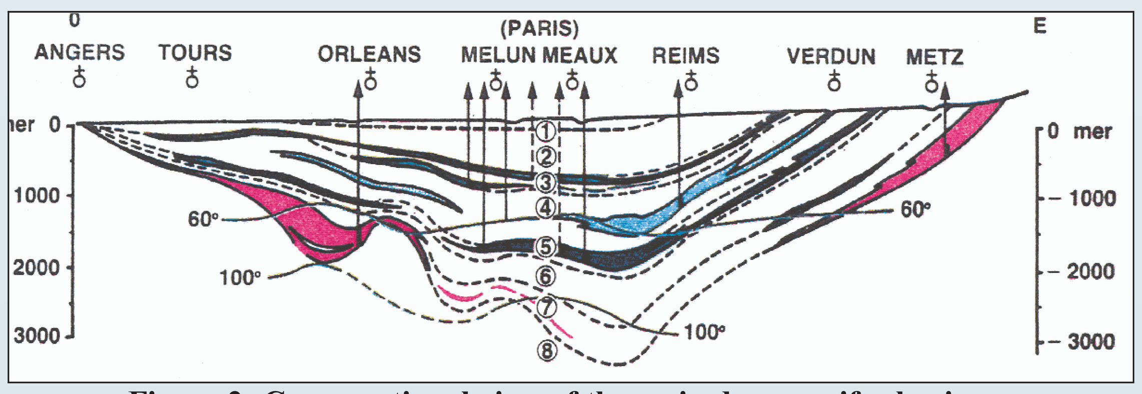

Figure 2: Cross sectional view of the main deep aquifer horizons

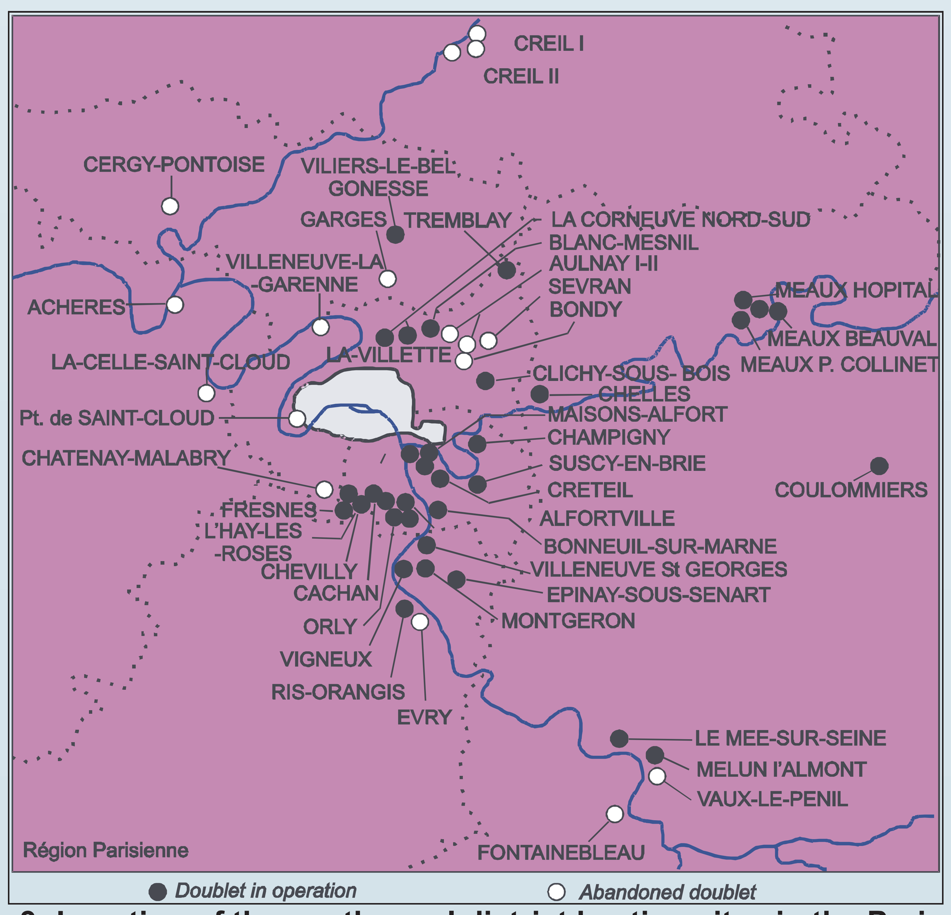

Figure 3: Location of the geothermal district heating sites in the Paris Basin

Table 1: Summary of risk factors

Risk description	Nature weight	Ranking	Status	Remarks
Last known casing status	Technical 1	1	Fine	Residual steel thickness >75% nominal WT before treatment
		2	Fair	Residual steel thickness >50% nominal WT before treatment
		3	Bad	Residual steel thickness <50% nominal WT before treatment
Damaging kinetics	Technical 1	1	Low	Corrosion rate <150µm/an before treatment
		2	Medium	Corrosion rate >150µm/an before treatment
		3	High	Corrosion rate >300µm/an before treatment
Chemical inhibition efficiency	Technical 1	1	High	Provisional statement
		2	Low	Provisional statement
Casing lining opportunities	Technical 1	1	Full	No diameter restrictions
		2	Partial	Some diameter restrictions
		3	None	Total diameter restrictions
New well drilling expectation	Technical 1	1	Long term	> 20 yrs
		2	Medium term	> 10 yrs
		3	Short term	< 10 yrs
Other	Non technical 3	1	favorable	
		2	hostile	

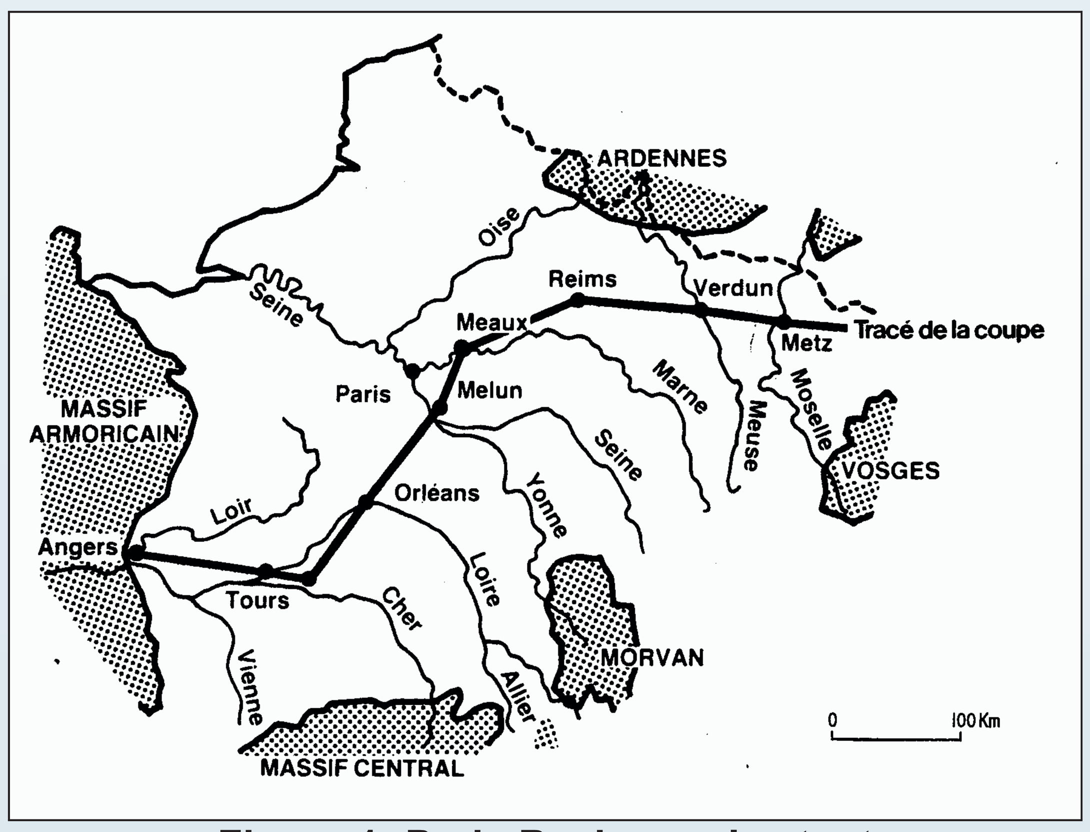

Figure 1: Paris Basin areal extent

Table 2: Recapitulation of provisions (sinking funds) required by heavy duty well workover/repair/ redrilling over 15 years (cost per well/year, 10^3 €)

SCENARIO	A	B	C
Risk level		1	
Yearly provision	74	100	120
Risk level		2	
Yearly provision	203 (229)	193 (221)	255 (277)
Risk level		3	
Yearly provision	222 (241)	201 (213)	206 (216)
TOTAL (Weighted average)		173 (186)	

2 Exploitation risks

Those could not be estimated from scratch. It soon became obvious that the, initially overlooked, hostile thermochemistry of the geothermal fluid provoked severe corrosion and scaling damage to casing and equipment integrities resulting in significant production losses. A prospective survey, commissioned in 1995, aimed at assessing the exploitation risks and related restoration costs, projected over a fifteen year well life. The results of this exercise, applied to thirty three doublets, are presented in [13]. The governing rationale consisted of (i) listing potential and actual, technical and non technical, risks ranked and weighted as shown in table 1, and (ii) classifying risks according to three levels (1 : low, 2 : medium, 3 : high), each subdivided in three scenario colourings (A : pink, B : grey, C : dark) regarding projected workovers deadlines and expenditure. This analysis led to a symmetric distribution, i.e. eleven sampled sites per risk level, each split into three (A), five (B) and three (C) scenario colourings.

The next step applied the workover/repair unit costs to concerned wells, required works and forecasted schedules, thus leading to the synthetic expenditure breakdown summarized in table 2. This evaluation illustrates the paradox between competing (if not conflicting) well heavy duty maintenance strategies, i.e. repeated repair of damaged infrastructures, vs redrilling/recompletion of new wells, reflected by scenarios 2 (A, B, C) and 3 (A, B, C). Here the optimum, in terms of investments but not necessarily cash flows, is represented by scenarios 2B and 3B, case 2C displaying definitely the worst profile.

In conclusion, an average provision (fiscally deductible) of ca 186,000 €/yr has been recommended to cope with future exploitation hazards resulting in a 12 % increase of initially anticipated OM costs. Loose management remaining the exception, managerial risks can be reliably regarded as minimized, starting from year 2000.

3 Economic/financial risks

They represent a major uncertainty owing to a somewhat unpredictable, if no chaotic, energy market and pricing context in which geothermal heat must prove competitive. This is indeed a difficult challenge, bearing in mind that geothermal district heating grids are structurally, especially under Paris Basin conditions, strongly capital intensive and financially exposed, in case of low equity/high debt ratios, a distinctive attribute of Paris Basin loan policies.

At the time, in the wake of the second oil shock, most geothermal district heating doublets were commissioned, oil prices, dollar exchange and inflation rates stood high and accordingly feasibility projections shaped very optimistic, in spite of their fragilised financial planning. A few years later, these trends were totally reversed. This, added to the dramatic technical, financial and managerial problems undergone by most geothermal doublets, endangered grid operation to a stage the abandonment of the geothermal district heating route was envisaged. These difficulties could be overcome at the expense of the shut in of technically irreparable/economically non feasible doublets and rationalizing exploitation technologies and management of the remaining thirty four doublets operated to date.

The economic/financial risks were controlled thanks to debt renegociation, technological/managerial improvements and stable heat selling prices agreed in long term and users subscription contracts.

Since year 2002, both a sharp increase of oil prices and natural gas tariffs and growing environmental concerns (global warming and related climatic disasters) modify again the energy panorama. Taxation of greenhouse gases becomes a realistic working hypothesis for the future, limiting the uncertainty margin of geothermal heating prices. In this perspective a 40 €/MWht selling price appears a reasonable threshold safeguarding the economic feasibility of most operating grids.

4 Environmental risks

Damages caused to the environment by casing leaks, uncontrolled well head blowouts and workover operations have been minimized. Limitation of the environmental risks is to be credited to the periodical (quaterly) doublet monitoring and casing inspection logging imposed by the competent mining/environmental authority and blowout control/waste processing equipments currently operated by the industry.

5 Social acceptance

Geothermal energy, particularly direct uses of low grade heat, has a structural image problem. The product and the recovery (heat exchange) process remain somewhat mysterious or esoteric to the public as opposed to obvious, visible, competing solar, wind and fuel sources. For many years indifference, at the best, was the prevailing attitude. In the early days of geothermal development (the infancy stage), it was regarded as a poorly reliable and costly, occasionally, environmentally hazardous, technology. Nowadays mature engineering and management and growing environmental (clean air) concerns have gained wider acceptance by the public of the geothermal district heating alternative. Still, image building efforts need to be persued to popularize the technology.