Planning geothermal district heating projects. Lessons learned from France

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Outline

• The Paris Basin Geothermal District Heating (GDH) system
  • Resource settings
  • Development history
  • Technology
• Innovation: Subhorizontal well architectures
• Innovation: Anticorrosion well concept
• Geothermal District Heating Project Phases and costs
PARIS BASIN RESOURCE SETTING

West East Cross Section

Lithostratigraphic column and target reservoir horizons

- Shallow Tertiary aquifers
- Cower Cretaceous aquifers
- Target Dogger reservoir
- Triassic Target reservoirs
PARIS BASIN GDH
STATUS @JUNE 2021
HISTORY. THE PARIS BASIN GEOTHERMAL LEARNING CURVE

**BIRTH**  
- 1969 1st GDH DOUBLLET @ MELUN L’ALMONTE  
- 1973 1st OIL SHOCK  
- 1977 GEOTHERMAL ACT  
- 1979 2nd OIL SHOCK  
- 1980 ADMINISTRATIVE FRAMEWORK  
- 5 DOUBLETS COMPLETED

**INFANTILE DISEASE**  
(1980-1990)  
- 5 DOUBLETS COMPLETED  
- SEVERE THERMOCHEMICAL DAMAGE  
- REPEATED ESP FAILURES  
- POOR MANAGEMENT PRACTICE  
- LOW EQUITY/HIGH DEBT  
- CRITICAL ECONOMICS  
- 8 TRIAS WELL FAILURES

**TEENAGE LEARNING**  
(1990-2000)  
- 21 DAMAGED/NON ECONOMIC DOUBLETS ABANDONED  
- INNOVATIVE DOWNHOLE THERMOCHEMICAL INHIBITION & WORKOVER TECHNOLOGIES  
- THOROUGH STATE SUPPORT (R&D, DEBT REFINANCING)  
- 1995 COMPLETION OF THE FIBERGLASS LINED ANTICORROSION WELL  
- 17 GAS COGENERATION PLANTS

**SUSTAINABLE DEVELOPMENT**  
(2010-2060?)  
- ACHIEVED (2011-2015)/ 12 NEW DOUBLETS/TRIPLETS  
- PROJECTIONS (2020+)/ 18 NEW DOUBLETS, 6 NEW TRIPLETS  
- 2,000 GW/yr

**MATURITY**  
(2000-2010)  
- OPTIMISED HEAT PLANT & GRID OPERATION  
- 34 GDH SYSTEMS ONLINE  
- IMPROVED MANAGEMENT SKILLS  
- FINANCE STABILISATION  
- DESIGN OF SUSTAINABLE MINING SCHEMES (TRIPLET & WELL ARRAYS)  
- PUBLIC/PRIVATE GDH AGREEMENTS  
- 4 NEW DOUBLETS/TRIPLETS
HISTORY: NO OF WELLS DRILLED
1969-2017
PARIS BASIN. TYPICAL GEOTHERMAL SITES

Parc à la française

High traffic density

Paris intra-muros

Densely populated urban area
PARIS BASIN GDH SCHEME

1. Production well
2. Submersible production pump
3. Injection pump
4. Injection well
5. Geothermal heat exchanger
6. Back-up (peak-load)/relief boiler
7. Heating grid
8. Substation
9. Geothermal reservoir (Dogger limestones)
10. Cooled fluid zone
TYPICAL LOAD DURATION CURVE

64°C WHT, 300 m³/hr, 2 M rated HP at Pump

Yearly RES coverage ratio 66% (assuming a COP=4)

- Geothermal + Heat pump + Natural Gas (100%)
- Geothermal + Heat pump (69%)
- Geothermal alone (56%)
SUSTAINABILITY
MINING COMPATIBILITIES
SUSTAINABILITY - SUSTAINABLE HEAT EXTRACTION SCENARIOS

OBJECTIVE
- Secure well longevities and reservoir life up to 75/100 years

PREREQUISITE
- (Re)Injection of the heat depleted brine into (preferably) the source reservoir

CONSTRAINTS
- Project life = 25 years
- Well life expectation = 20-25 years
- Target thermal breakthrough = 20 years

IS THERE A LIFE AFTER ???
- YES, provided adequate heat mining schemes be designed
GEOTHERMAL ENERGY SYSTEM SYNERGIES
RESERVOIR ENGINEERING AN INTEGRATED APPROACH
TYPICAL GDH WELL ARCHITECTURE
INNOVATION: SUBHORIZONTAL DOUBLET ARCHITECTURE AND OFFSET WELL TRAJECTORIES

a) Well architectures

b) Well trajectories

c) SHW and candidature offset well trajectories
INNOVATION: ANTICORROSION WELL CONCEPT

Present well architecture addresses an artificial lift, pump sustained, production, which implied significant design modifications, chiefly:

(i) an upper, wider (13"3/8OD -11.97" ID) liner section acting as a pumping chamber, sized to accommodate a 500 HP rated ESP, placed under compression between the wellhead and the lower section;

(ii) a lower and slimmer (9"5/8OD –7.74” ID ), freely suspended production liner;

(iii) a (13"3/8x9"5/8) liner connecting system, placed at the (20"x13"3/8) casing interface, allowing for a free annular fluid (a make-up corrosion inhibitor agent) passage, indeed a key issue, and,

(iv) a wellhead expansion spool. The additional capital investment costs (ca 20% compared to a conventional 13"3/8x 9"5/8steel cased well architecture) will get payed back in less than eight years thanks to yearly OM costs savings.

Given the foregoing, it is expected this, smart well, material answer to thermochemically hostile corrosive fluid environments, elsewhere securing well longevities and low operation/maintenance (OM) costs, raises due interest among geothermal operators and stakeholders.
FROM COMMISSIONING TO START UP TYPICAL GDH COMPLETION SCHEDULE

<table>
<thead>
<tr>
<th>Task</th>
<th>Start Date</th>
<th>End Date</th>
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<tbody>
<tr>
<td>START</td>
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<tr>
<td>Project Commissioning</td>
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<td>Feasibility study</td>
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<td>Exploration permit</td>
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<td>Land acquisition</td>
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<td>Negotiation of EUR/National support</td>
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<td>Call for tenders (TOR)</td>
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<td>Tendering</td>
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<tr>
<td>Site preparation. Well drilling/completion</td>
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<tr>
<td>Surface works. Heating grid &amp; substations</td>
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<tr>
<td>Geothermal &amp; Back-up/relief heat plant</td>
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<tr>
<td>Start up</td>
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10 MWth heating plant: example of some plants installed in Paris region Ile-de-France, France. In Million €
# TYPICAL COST BREAKDOWN (10^3 €) FOR A GEOTHERMAL DOUBLET

## CAPEX

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<tr>
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<tr>
<td>Well drilling/completion</td>
<td>8500</td>
<td>9000</td>
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<tr>
<td>Primary (geothermal) loop</td>
<td>1200</td>
<td>1300</td>
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<tr>
<td>Geothermal heat exchanger</td>
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<td><strong>Total</strong></td>
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<td><strong>Surface</strong></td>
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<td>Secondary (grid) loop</td>
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<td>Heat plant</td>
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<td>Grid (piping)</td>
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<td>Grid (substations)</td>
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<td><strong>Total</strong></td>
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<td><strong>GRAND TOTAL</strong></td>
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## OPEX

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<td>P1 Power, chemicals, consummables</td>
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<td>250</td>
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<td>P2 Monitoring, light maintenance</td>
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<tr>
<td>Heavy duty maintenance, well workover, on duty call</td>
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<td>300</td>
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<tr>
<td>Miscellaneous</td>
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<td>50</td>
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<td><strong>Total</strong></td>
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<tr>
<td><strong>Surface</strong></td>
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<tr>
<td>P1 Power</td>
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<td>50</td>
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<tr>
<td>P2 Heat plant/grid monitoring/maintenance</td>
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<td>450</td>
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<tr>
<td>P3 Provisions for depreciation</td>
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<td>350</td>
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<tr>
<td>Miscellaneous</td>
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<tr>
<td><strong>Total</strong></td>
<td>730</td>
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<tr>
<td><strong>GRAND TOTAL</strong></td>
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<td>1600</td>
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## BREAKEVEN

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<th>Best Case</th>
<th>Medium Case</th>
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<td><strong>CAPEx (10^3 €)</strong></td>
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<td>22000</td>
<td>23000</td>
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<tr>
<td><strong>OPEX (10^3 €/yr)</strong></td>
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<td>1400</td>
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<tr>
<td><strong>SUBSIDY (% CAPEX)</strong></td>
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<td>35</td>
<td>25</td>
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<tr>
<td><strong>BREAKEVEN (€/MWh t)</strong></td>
<td>81</td>
<td>56</td>
<td>64</td>
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RISK ASSESSMENT
SUCCESS/FAILURE CRITERIA

Numerical application:

CAPEX = 12 \times 10^6 \, €
OPEX = 5 \times 10^5 \, €
n = 20 years
nh = 8256 \, hr/yr
r = 5\% (total failure)
r = 10\% (total success)
Full equity (no debt)
Subsidies = 0 \, ; \, 25\% \, CAPEX
c = 35 \, ; \, 40 \, ; \, 45 \, €/MWht
T_i = 40 \, ; \, 45 \, ; \, 50^°C
2021 - #GeothermalDecade

This decade will be #Geothermal!

• Exponential growth by 2030
• New and diverse applications for geothermal energy

• Geothermal energy is bound to become the bedrock of energy transition. This will be the #GeothermalDecade.
THANK YOU FOR YOUR ATTENTION

Geothermal Energy: 
renewable-sustainable-proven-achievable-realistic

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