GEODEEP
FRENCH GEOTHERMAL CLUSTER FOR HEAT AND POWER

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Association Française des Professionnels de la Géothermie

Deep geothermal energy for district heating network: case histories in Paris Basin and lessons learned since 50 years

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EGPD 16 February 2021 - Webinar

Summary

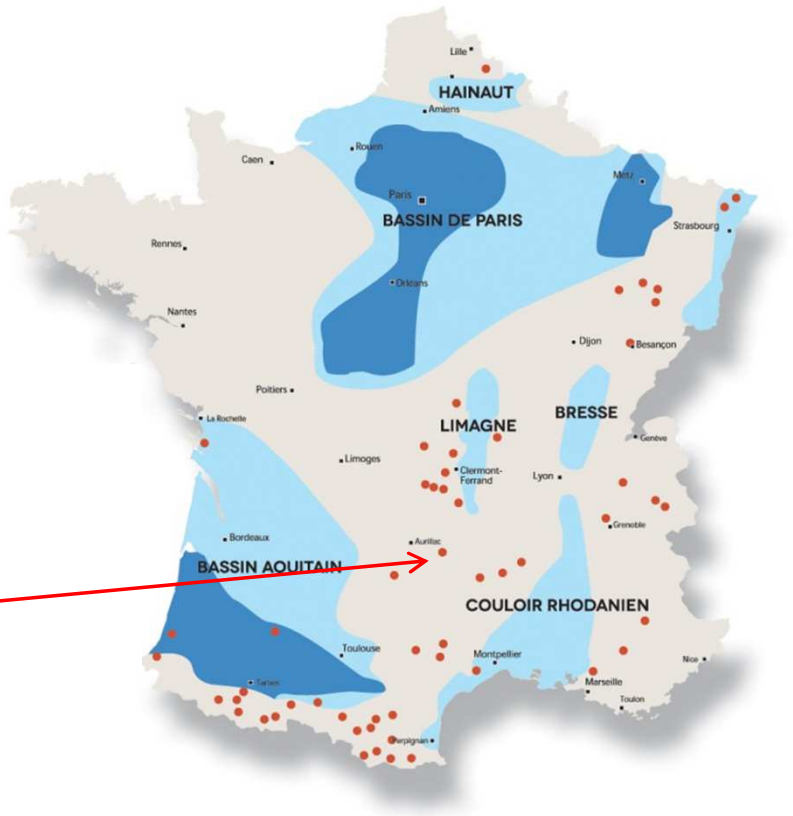
- The deep geothermal resources and the installed capacity in France
- The tools dedicated to geothermal deployment and administrative framework
- High enthalpy for electricity generation
- Geothermal District heating is born 50 years ago with the creation of the doublet architecture in the Dogger limestones in the Paris basin
- Technical development and lessons learnt
- Detrital reservoir targets : Triassic and cretaceous sands and sandstones
- The 3 reasons for success and the RMS existing since 1980
- The Risk Mitigation System (The fund managed by SAF Environment (CDC) is effective since 40 years)
- How to duplicate in EU and abroad, the GEORISK Project managed by EGEC

- **The abundance of various geothermal deep resources with large sedimentary basins**

- 5% of the French territory with high temperature geothermal resources including volcanic (Caribbean islands and La Réunion)

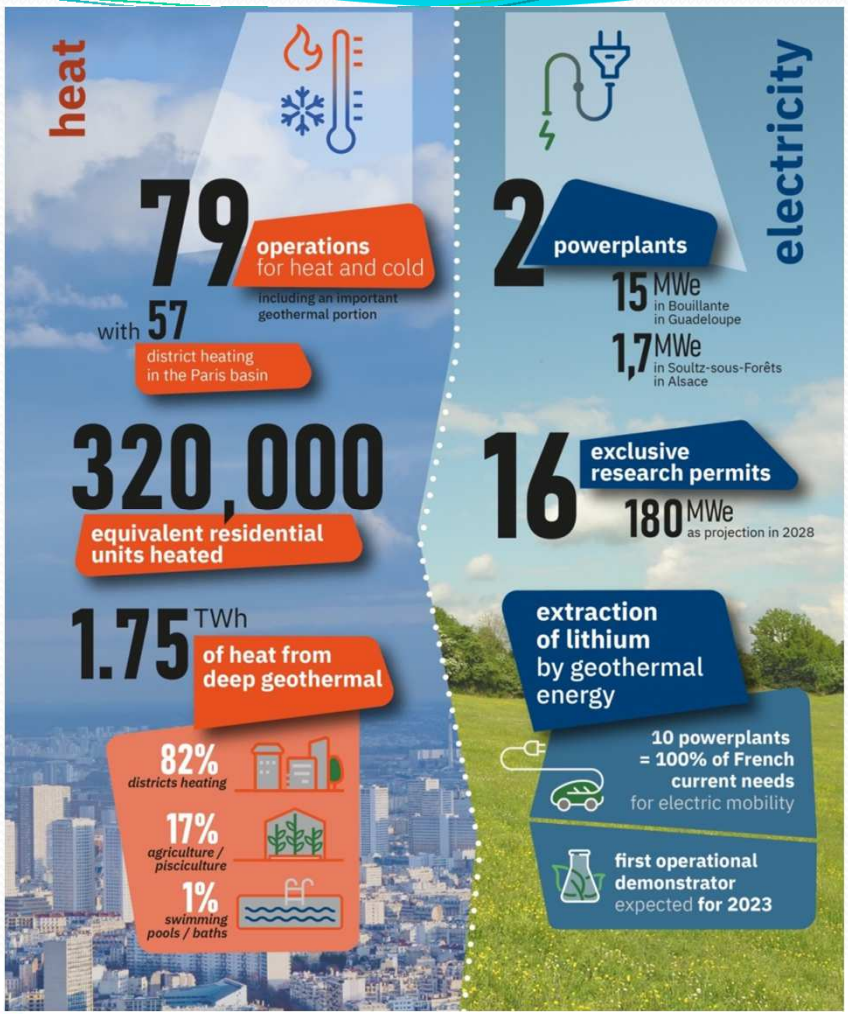
- 40% of the territory with deep resources for heating generation

- In red the thermal springs (Chaudes-Aigues the hottest in EU at 82°C with a geothermal village heating 500 years ago using piping system in wood)



- **The geothermal installed capacity in France (2019)**

- Deep geothermal energy in a nut shell (AFPG)
- Including shallow geothermal energy about 2 millions people in France are using geothermal energy
- The ambition of the National Energy Plan set up for 2030 (PPE) is to multiply by 2,5 the deep geothermal installed capacity



- **The tools for the geothermal deployment**

  - A robust legislative framework included in the Mining Code
  - A risk mitigation system (managed by SAF Environment covering the flowrate and temperature of deep geothermal reservoirs (min 65% reimbursed by the fund in case of failure), to be revamped in 2021
  - A “heat and cold fund” managed by ADEME with 350 M€ in 2020 for biomass, geothermal and solar thermal in order to subsidy the CAPEX for the installations with a capacity over 30 KWth (between 20 - 50% of the investment)
  - End of the tariff for the geothermal electricity at 250 €/Mwe like in Germany . It is maintained for the plants already approved (53 MWe)
  - End of the risk mitigation system GEODEEP SAS (PPP) after the end of the tariff

- **Revamped administrative and regulatory framework in 2020**

FRENCH GEOTHERMAL LEGAL FRAMEWORK (Mining Code)

Depth between 0 and 10m are excluded from the Mining Code

Low Energy

- Exploration and exploitation permits
- Authorization for mining works
- Instruction at Department level

10m – 200m

- GMI (shallow geothermal)
- Tele-declaration system
- 500 kW thermal power,
- T <25° C, Flowrate < 80 m³/h

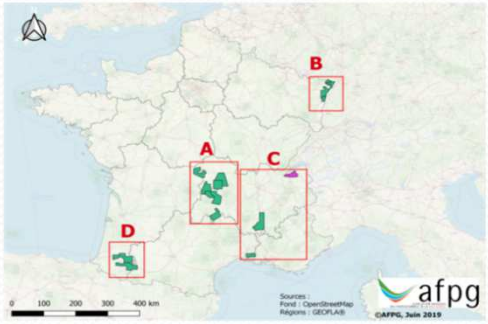
< 20 MW

High Energy

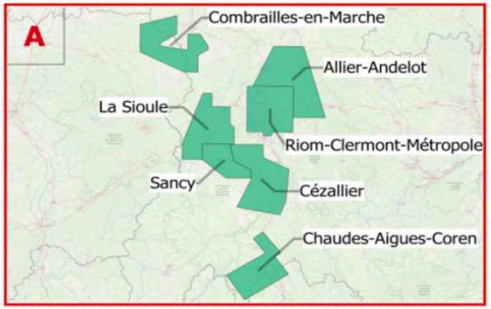
> 20 MW

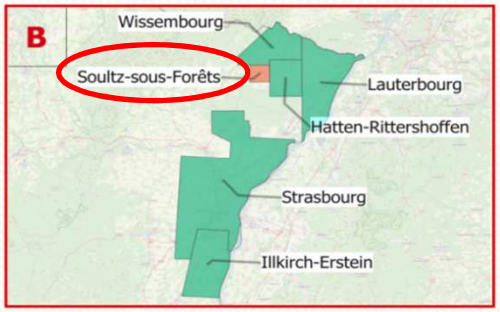
- Exclusive exploration permit
- Exploitation concession
- Instruction at State level (Ministry of Environment)
- Decree by State Council

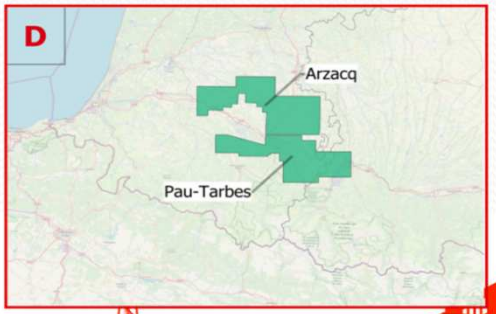
- **Many leases for electricity generation and only two plants producing**

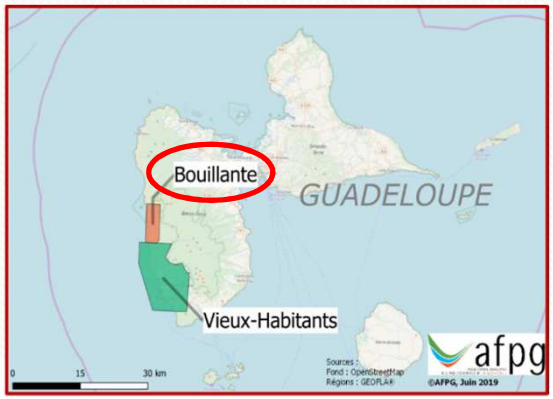


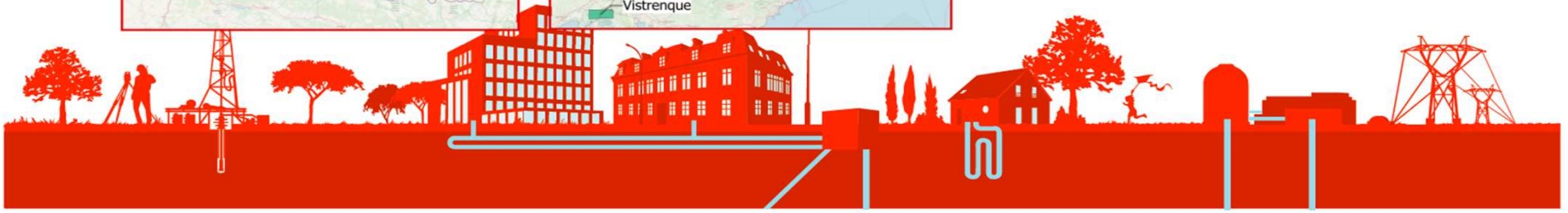
Gîtes géothermiques haute température au 01/02/2018
- Demande de permis
- Permis de recherches
- Concession



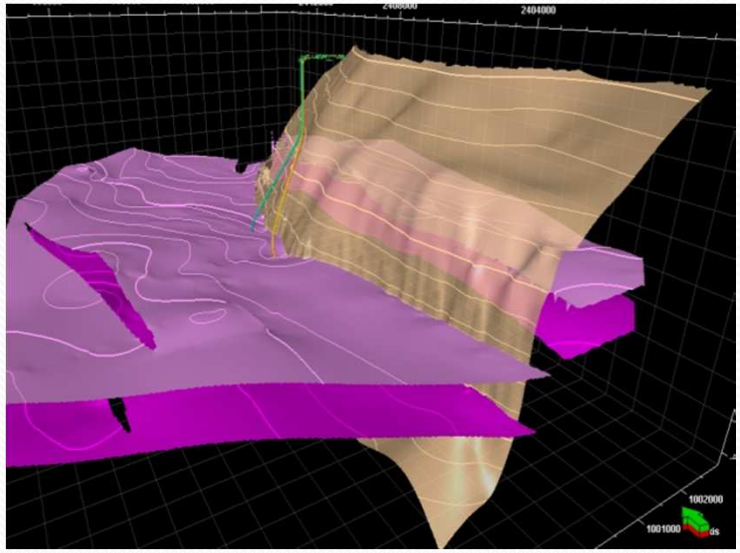


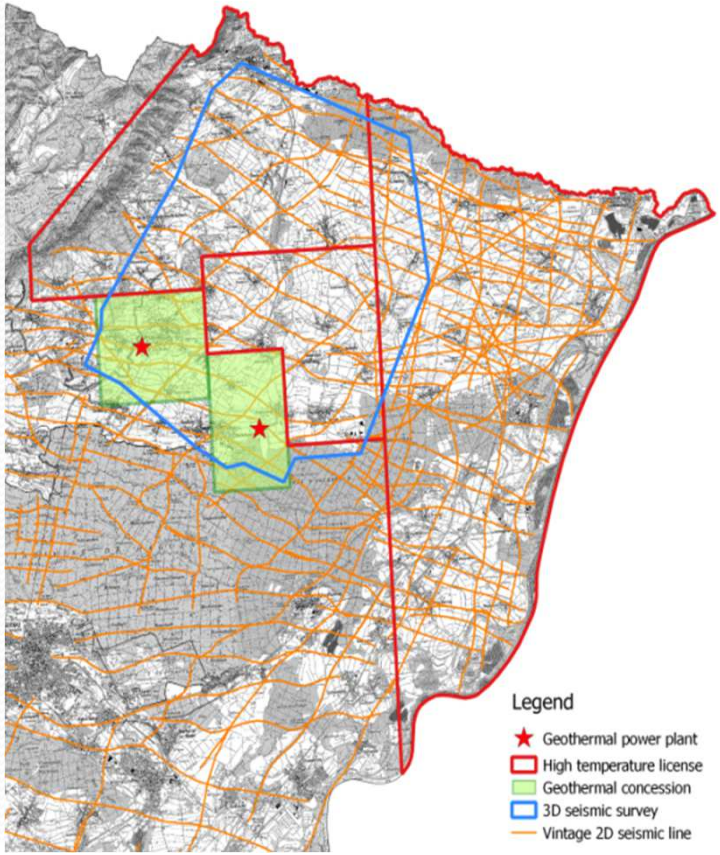






- **For high enthalpy, new technologies and explorations in the last years**



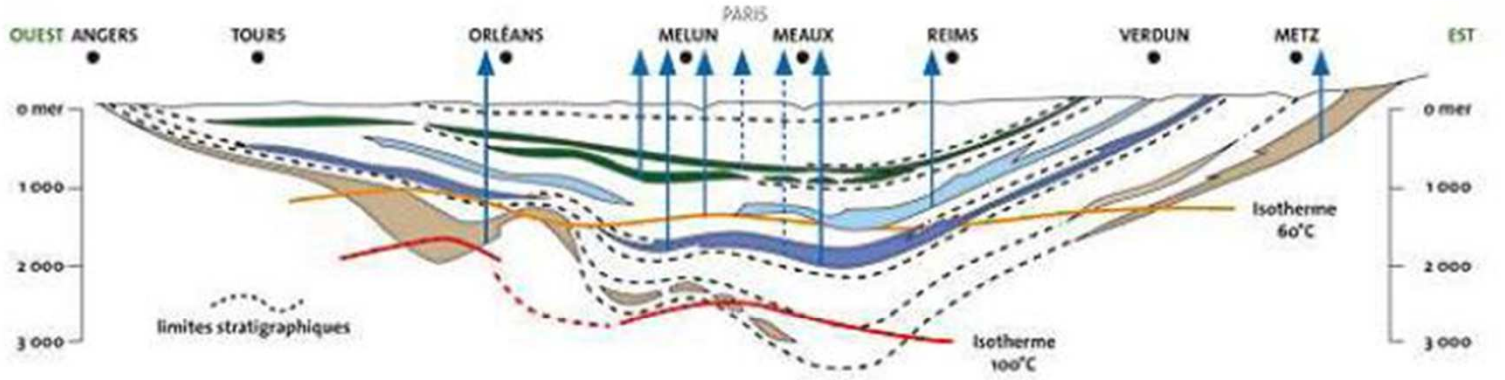


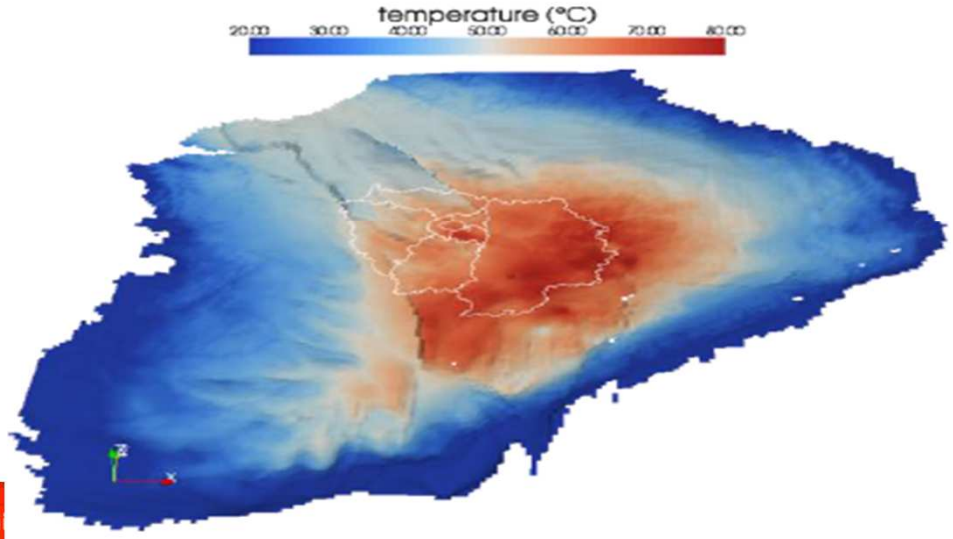
The leases map in Alsace and geographical coverage of the 3D realized in 2018 (blue color). The fault appraisal in the deep reservoirs in Illkirch (South of Strasbourg).

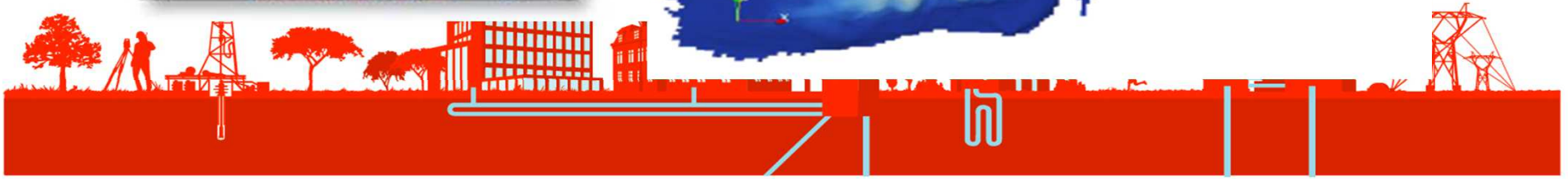
- **Milestones of Dogger exploitation in the Paris basin**

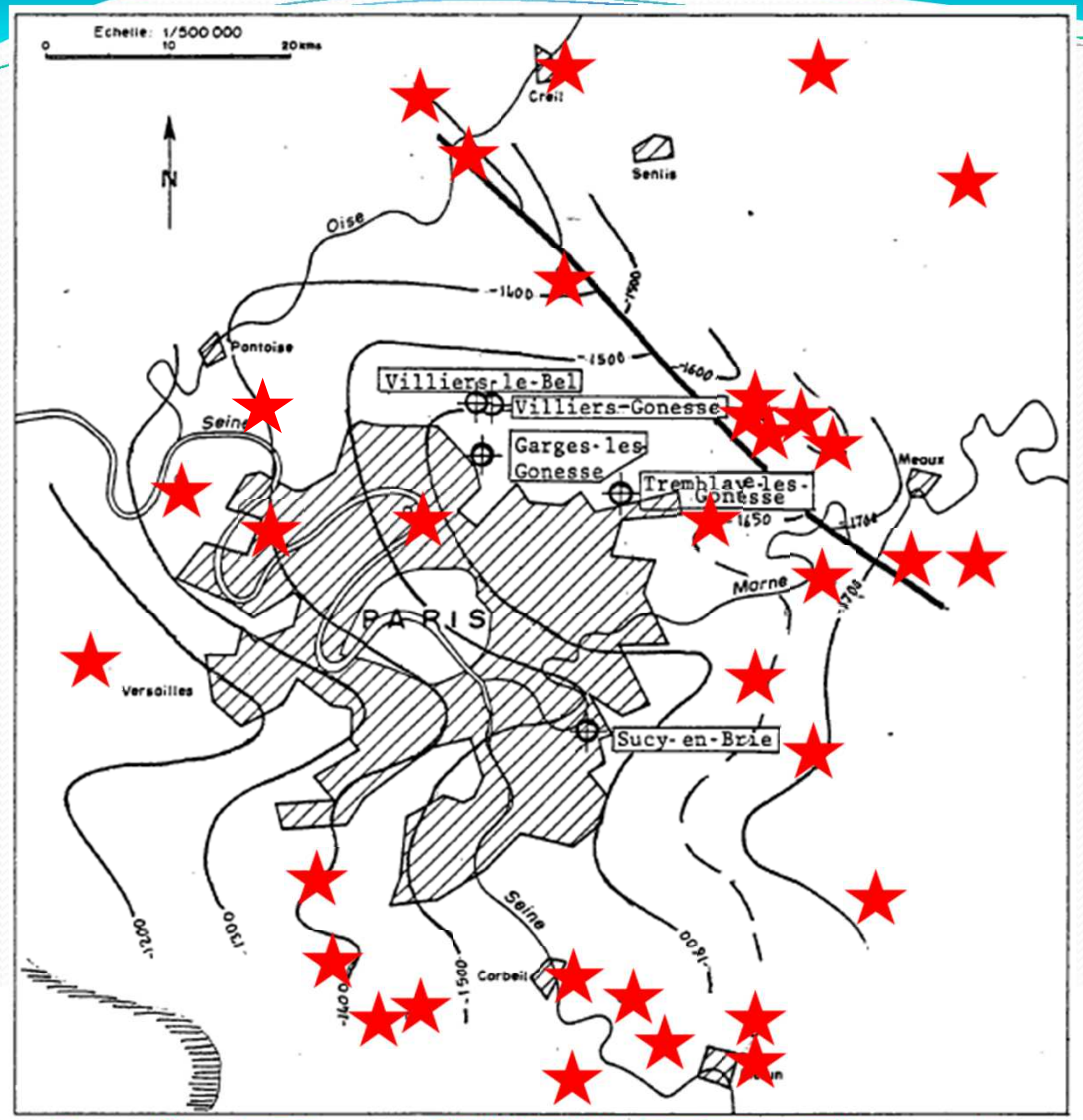
  - **1960's-Pre-oil shock:** First attempt (abandoned and second attempt was successful
  - **1973-1978-Post first oil shock:** Four completed doublets and enforcement of the legal framework
  - **1979-1986-Post second oil shock:** 51 completed doublets with over 90% of success ratio, first well damage symptoms
  - **Late 1980's-Early exploitation stages:** Corrosion/scaling damages and equipment failure (submersible pumps and others)
  - **1990's-Technological and managerial maturation:** technical improvements, with R&D stimuli, debt renegotiation, abandonment of 20 non economic and severely damaged doublets
  - **2008-2015- Restart of the geothermal business:** ADEME geothermal fund support, private investment, new doublets with upgraded production
  - **2015- 2020 New technologies:** First old well equipped with cemented composite casing , first horizontal doublet and first multi-drains wells

- **The favorable geological conditions in the Paris basin and geothermal resource meeting the demand of 11 millions inhabitants**









- **The benefits of extensive oil and gas exploration in the 50's (Dogger map dated 1976)**

★ Exploration oil and gas wells

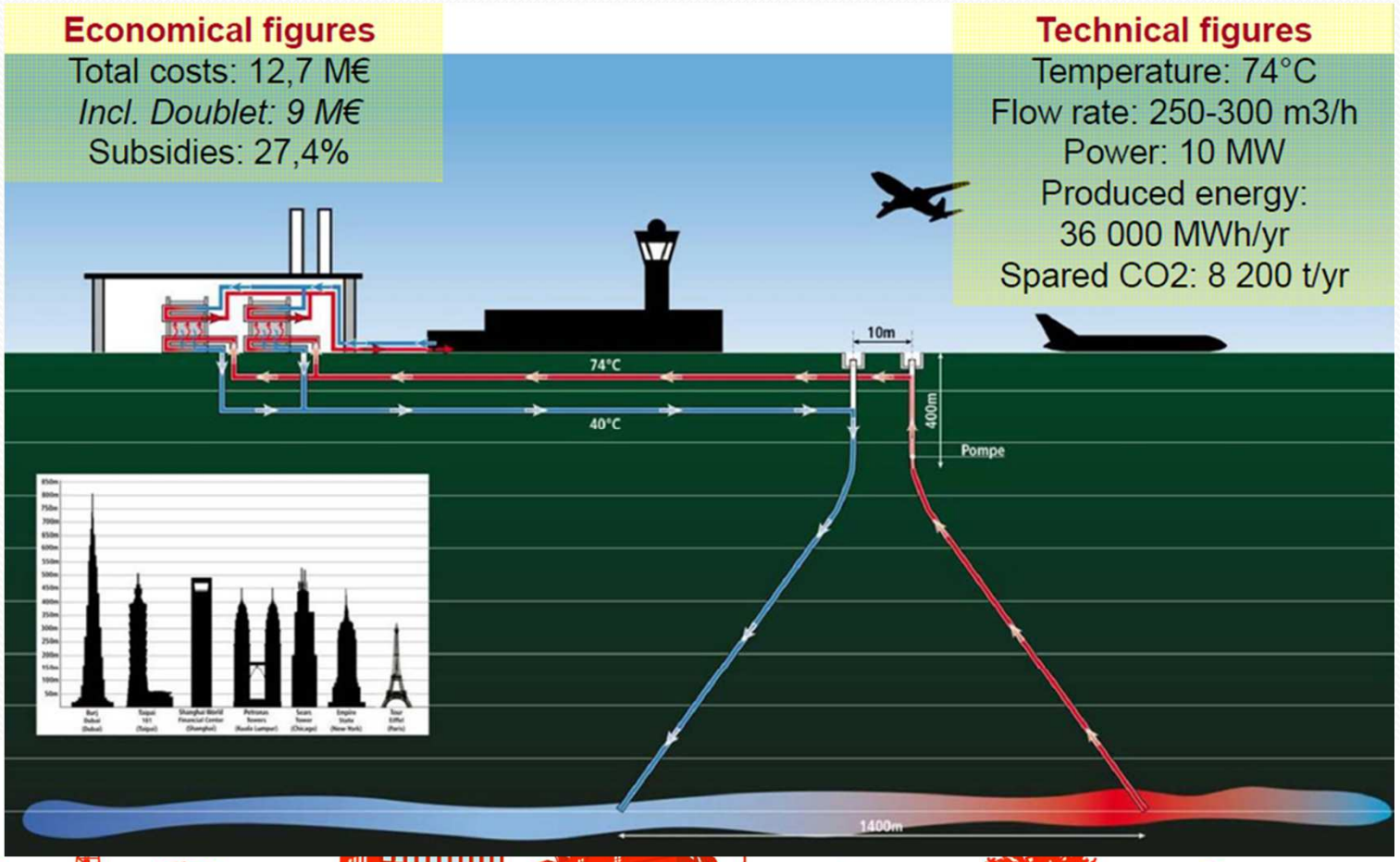
Iso-depth of top Dogger

Expected productive zone for the reservoir

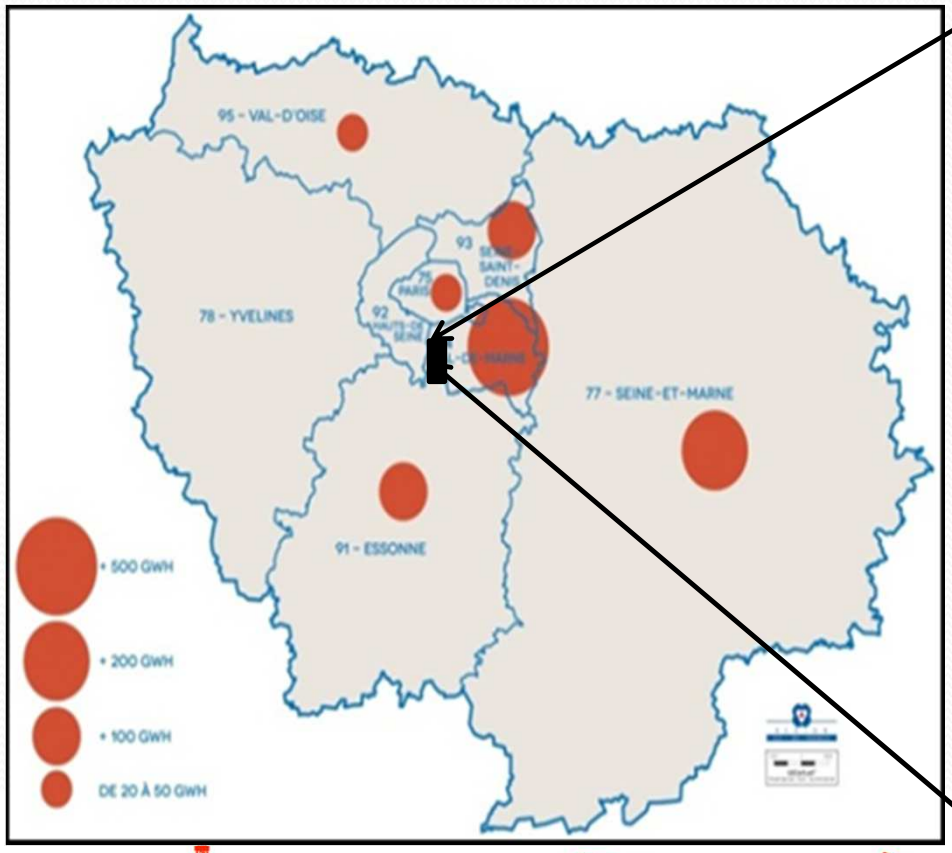
Direct use of deep geothermal resources

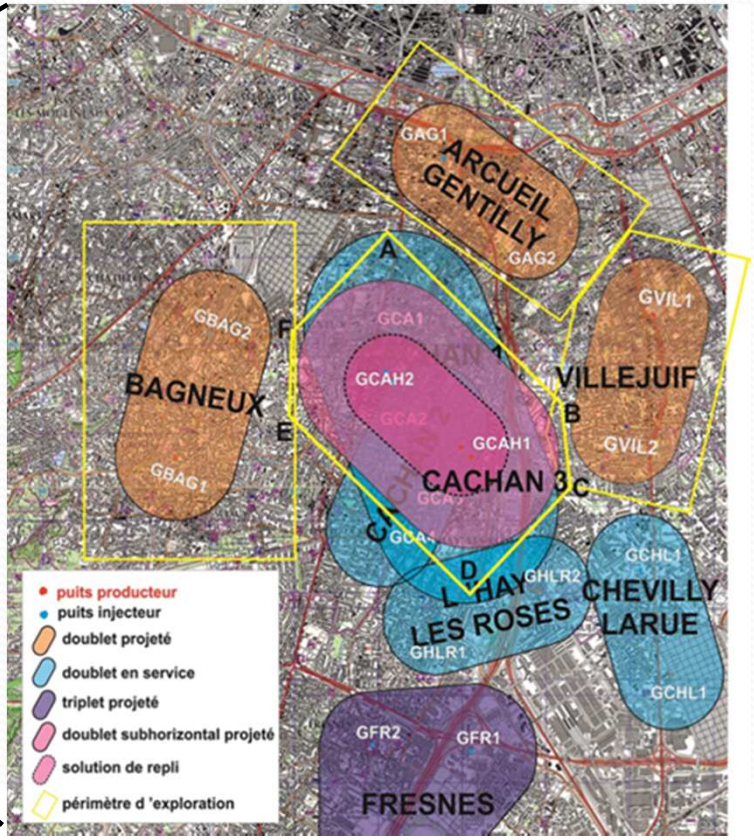
- The direct use at 2100 GWh and represent about 79 plants, mainly located in Ile de France around Paris.
- We celebrated two years ago the 50 th anniversary of the first geothermal doublet drilled in the Dogger geothermal reservoir made of limestones in Melun-l'Almont, 50kms SE of Paris .
- The 3 last years, 7 new doublets have been drilled (5 to Dogger reservoir and 2 to Cretaceous sandstones).
- Due to the fact that some plants are 35 years old, 5 sites have been revamped with the drilling of new production wells in bigger diameter in order to produce each 300 to 350 m^3/h of geothermal water.
- Some others have been relined with new casings.
- Additionally some plants have benefitted of the installation of big power heat pump (2 to 4 MW) to extract additional energy before re-injecting in the reservoir.

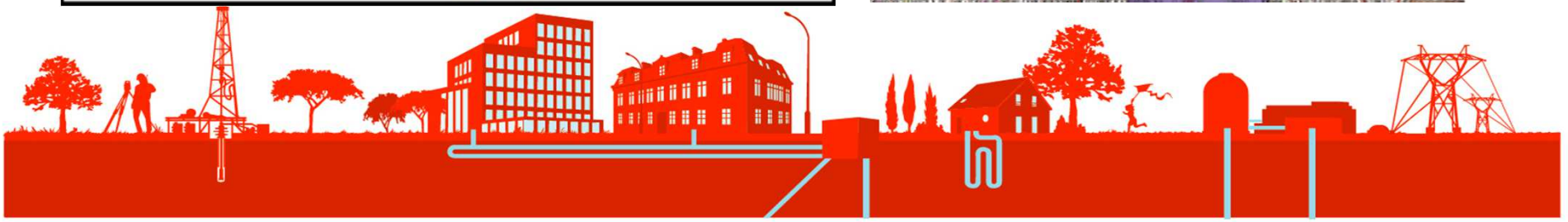
Typical geothermal doublet scheme in Ile de France



- **Concentration in Val de Marne has to be carefully managed**



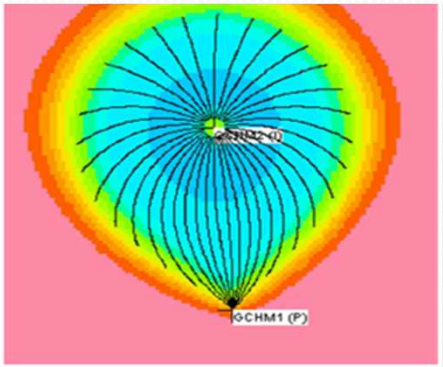


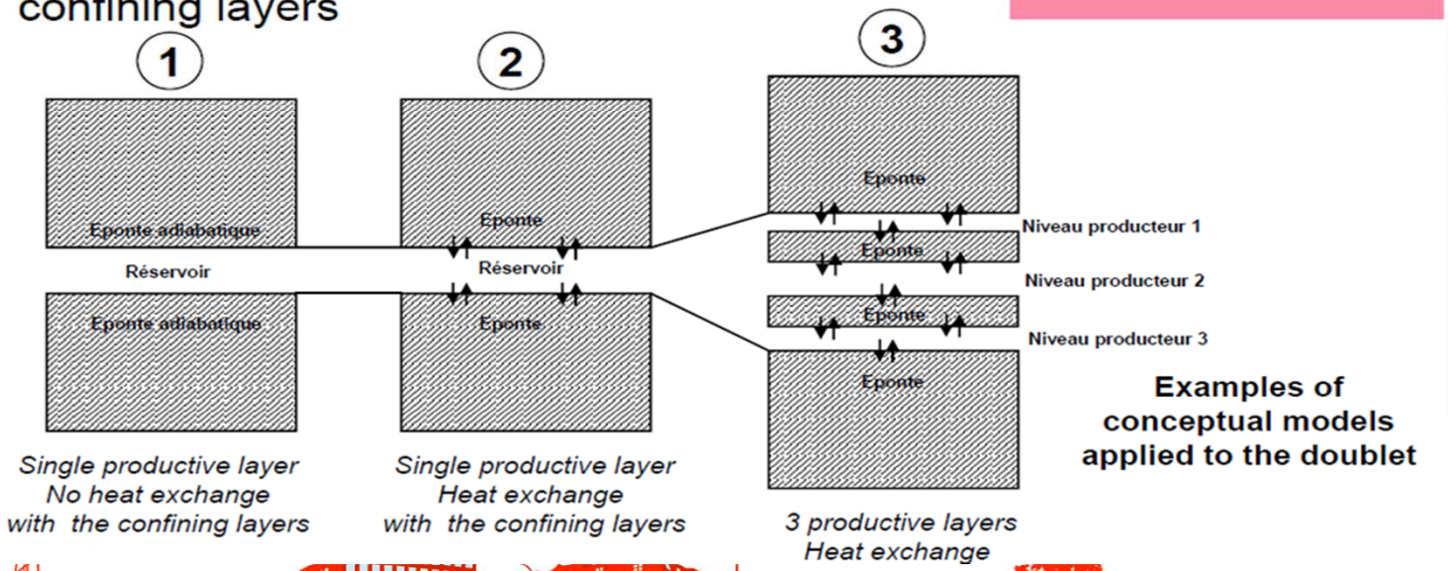


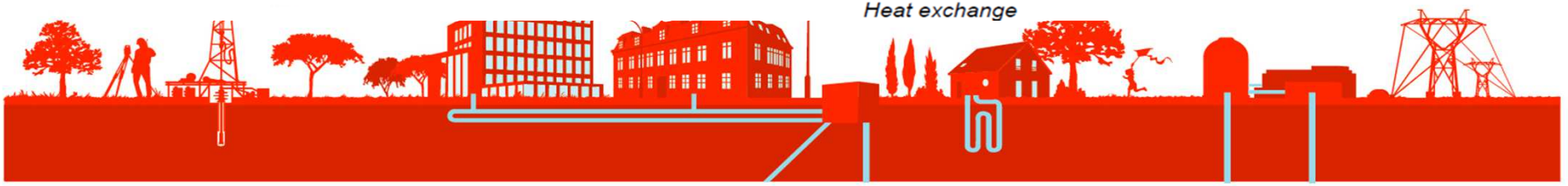
- **Development issues and gained experience:** the thermal breakthrough

> Cold injected water, even if it is heated by the surrounding rock, will at the end cause a drop of temperature in the production well: but when?

> Modeling was initially pessimistic, because it was underestimating the thermal role of the confining layers



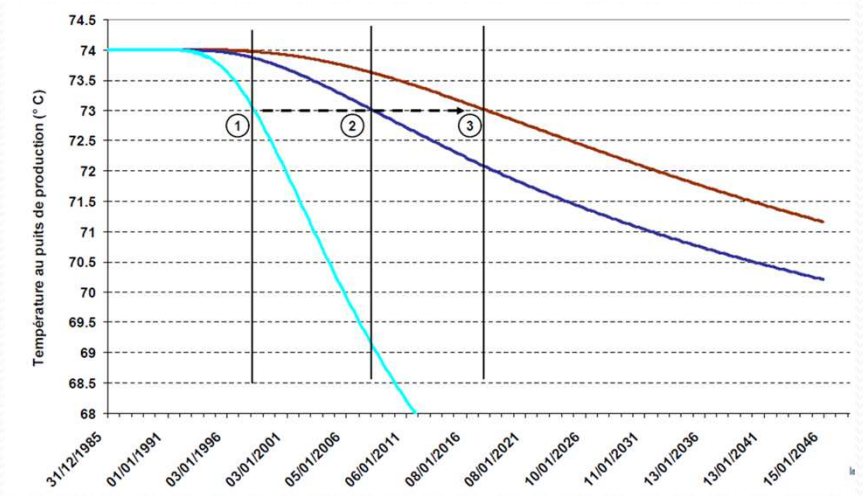


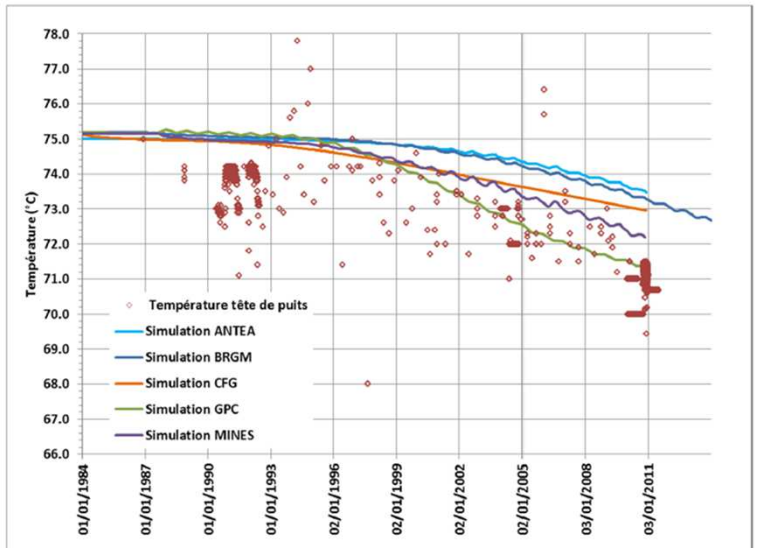


- **Development issues:** thermal breakthrough

The thermal breakthrough which was supposed to happen after 15 years will not happen before 30 to 40 years

Only one problem among 70 plants in Alfortville because the spacing between P and I wells was too small at 1200m





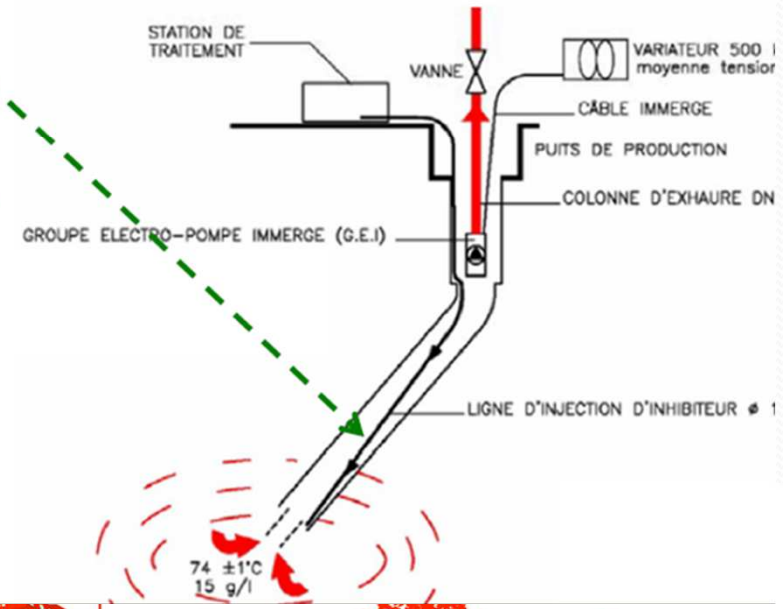
Hamm *et al.*, 2011

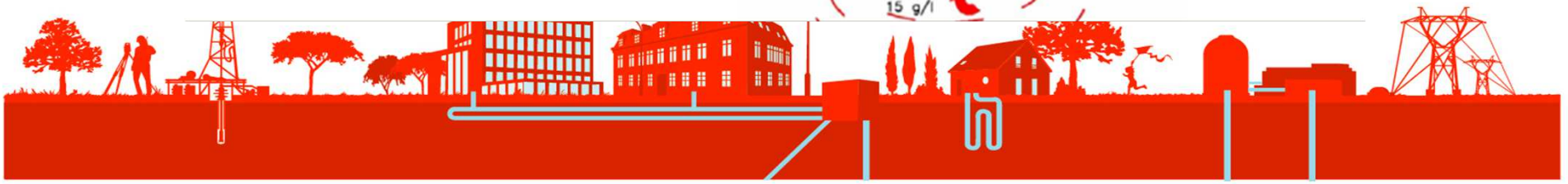
- **Development issues and gained experience:** The corrosion and scaling of wells was the main barrier in the 80's- 90's

> Dogger "water" with a high concentration of salt (10 to 25 g/L) and sulphide
  - Corrosion: risk of casing perforation
  - Deposit: impact on flow rates and under deposit corrosion

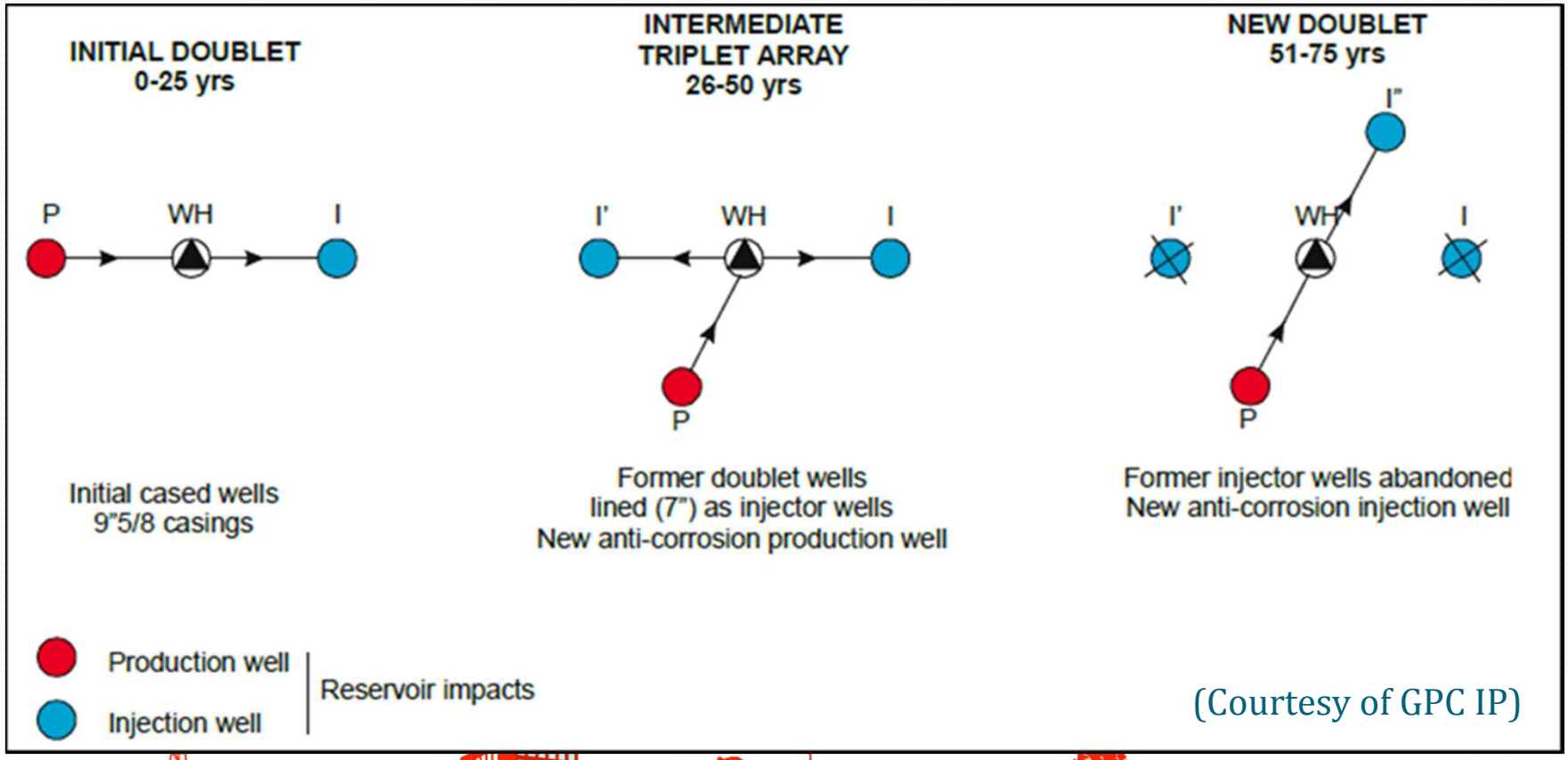
> Preventive solutions
  - **Deposit/corrosion inhibitor**
  - Suitable operating conditions: maintain fluid pressure to avoid degassing
  - Monitoring (geochemical analyses, logging...)

> Curative solutions
  - Cleaning
  - Casing relining
  - New wells (triplet or new doublet)





- **Development issues:** schemes to revamp the old doublets



(Courtesy of GPC IP)

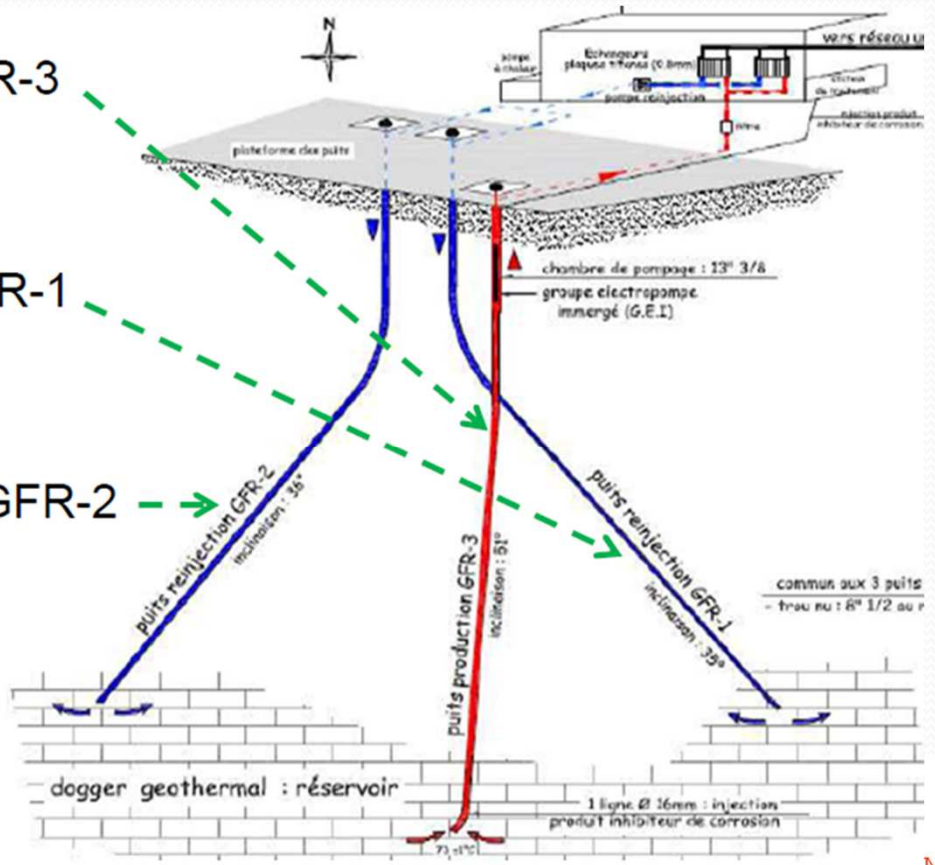
- **Development issues : the “triplet” example in Fresnes**

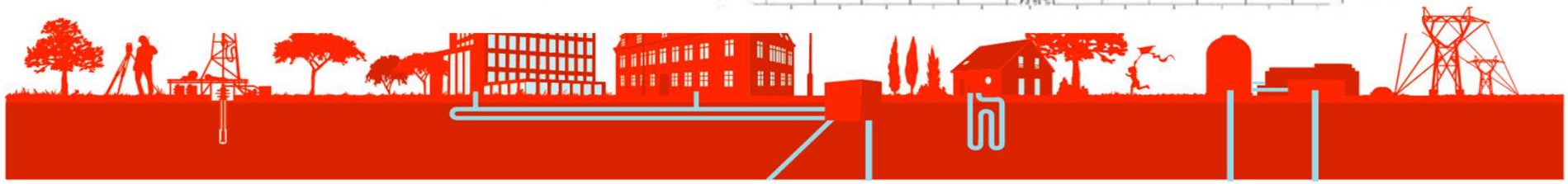
> New production well: GFR-3
  - Highly deviated (51°)
  - Flow rate: 300 m3/h

> Existing injection well GFR-1
  - New 7’’ liner
  - Flow rate: 155m3/h

> Existing production well GFR-2
  - Converted in an injection well
  - New 7’’ liner
  - Flow rate: 145m3/h

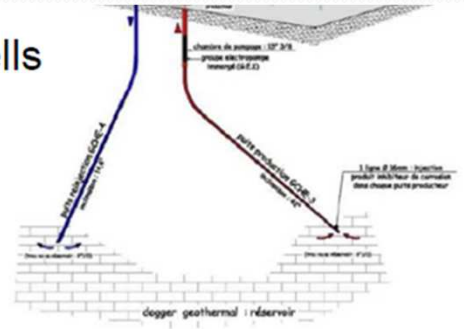
> 30 years without “thermal breaktrough”





• Development issues: example in Chelles

> Closure of existing GCHE-1 and GCHE-2 wells
- "Cold bubble" underneath the existing platform: use of the existing well platform, with two deviated wells

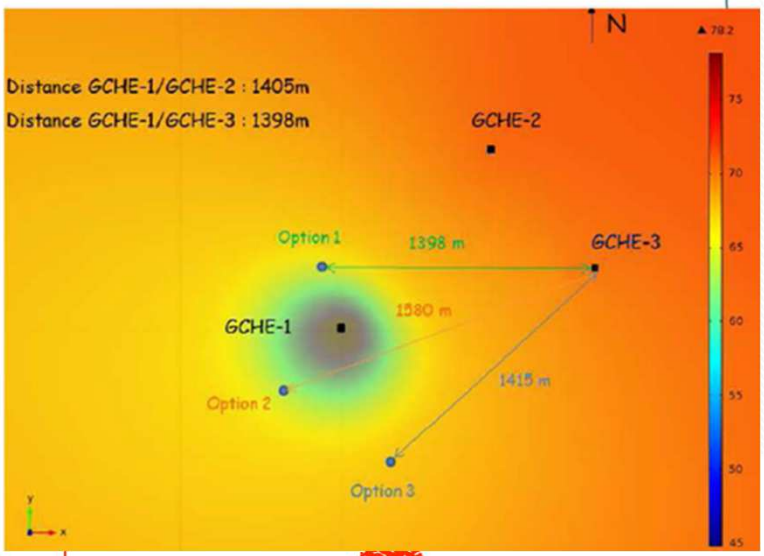


> New generation design
- Open hole: 8''1/2,
- Tubing: 9''5/8,
- Pumping chamber: depth of 250m, 13''3/8
- Flow rate: 300 m3/h

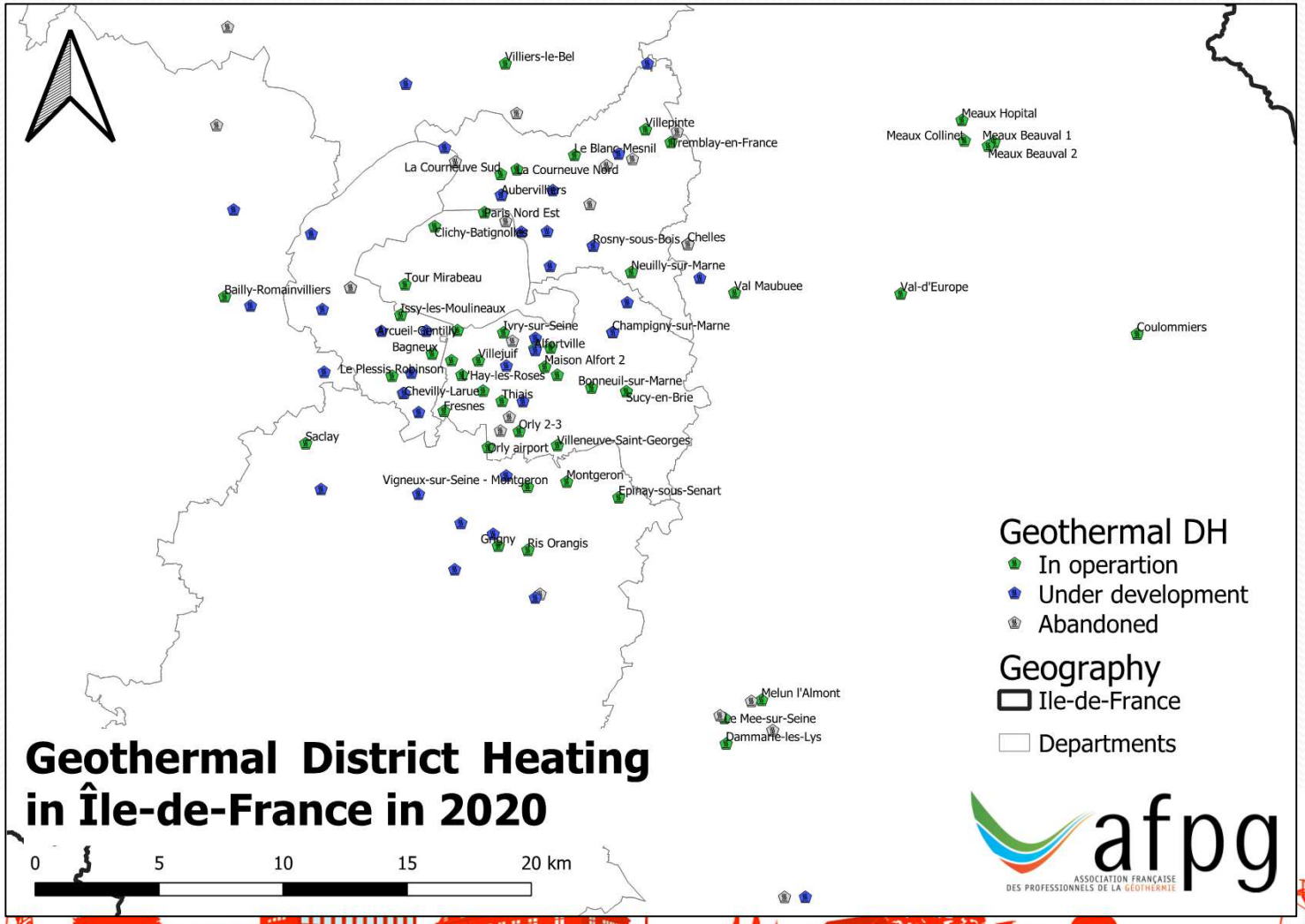
> New production well GCHE-3
- located at the East of the platform to optimize temperature
- Highly deviated (42°)

> New injection well GCHE-4
- Deviated (14°)

> 30 years without "thermal breaktrough"

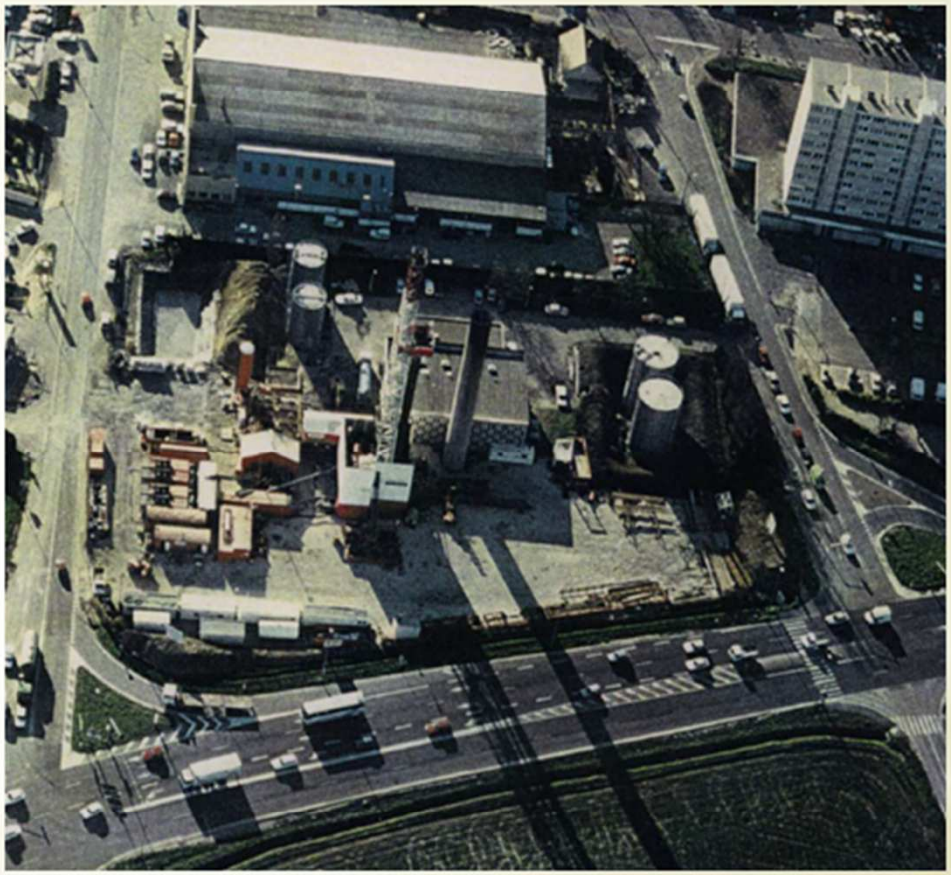


- **District Heating geothermal doublets in Ile de France**



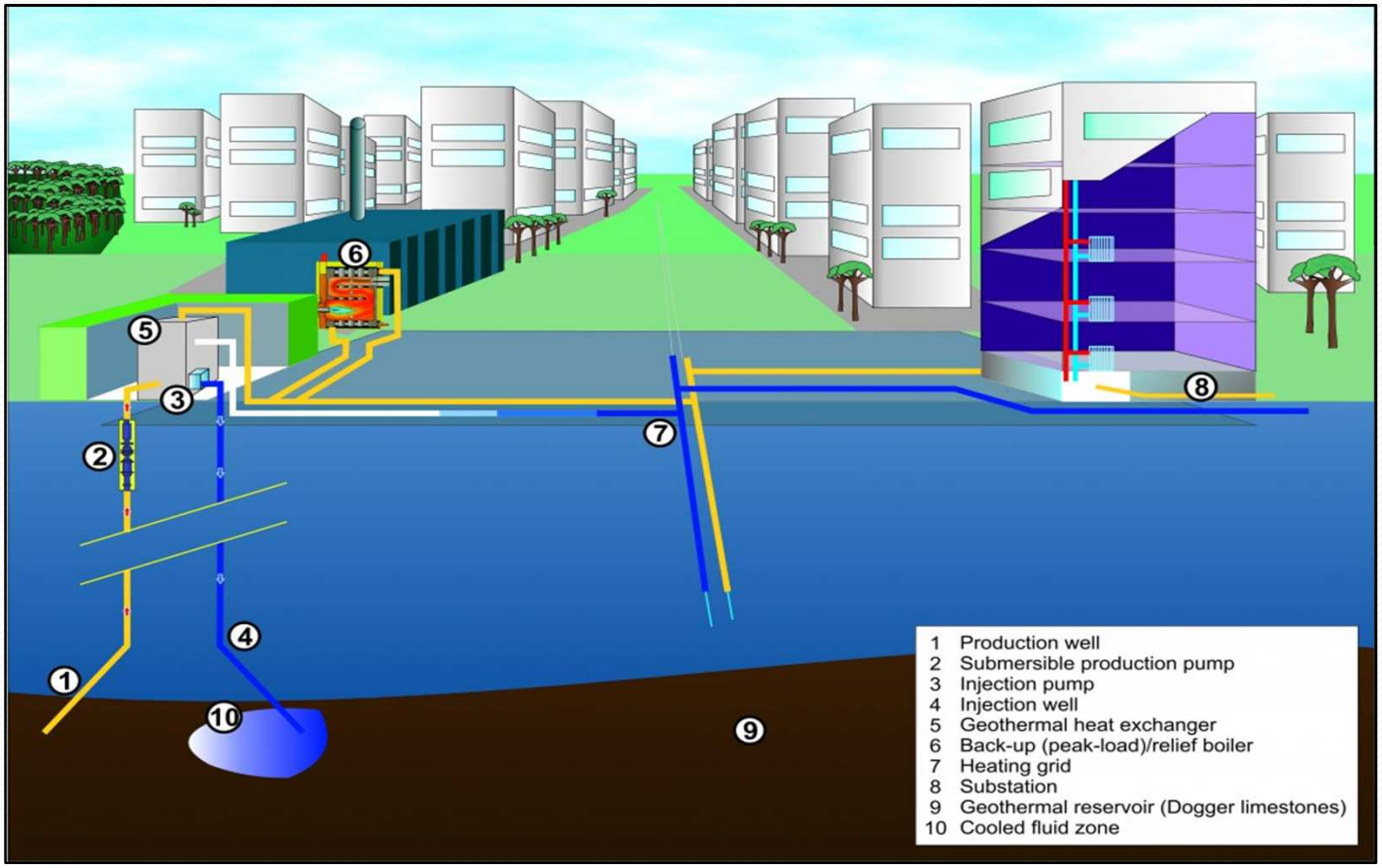
Rig in Torcy (2012)

Melun l'Almont (1983)



(Courtesy of P. Ungemach GPCIP)

- **Diagram of a geothermal district heating in Paris area**



- **Typical cost breakdown for a geothermal doublet (K€)**

CAPEX		
Mining	min	max
Well drilling/completion	8500	9000
Primary (geothermal) loop	1200	1300
Geothermal heat exchanger	300	400
Total	10000	10700
Surface		
Secondary (grid) loop	600	700
Heat plant	800	900
Grid (piping)	8000	10000
Grid (substations)	2500	3000
Total	11900	14600
GRAND TOTAL	21900	25300

OPEX		
Mining	min	max
P1 Power, chemicals, consummables	200	250
P2 Monitoring, light maintenance	75	90
Heavy duty maintenance, well workover, on duty call	250	300
Miscellaneous	30	50
Total	555	690
Surface		
P1 Power, chemicals	40	50
P2 Heat plant/grid monitoring/maintenance	400	450
P3 Provisions for depreciation	250	350
Miscellaneous	40	60
Total	730	910
GRAND TOTAL	1285	1600

	BREAKEVEN		SELLING COST
	WORST CASE	BEST CASE	MEDIUM CASE
CAPEX (10^3€)	25000	22000	23000
OPEX (10^3€/yr)	1600	1285	1400
SUBSIDY (% CAPEX)	0	35	25
BREAKEVEN (€/MWh$_t$)	**81**	**56**	**64**

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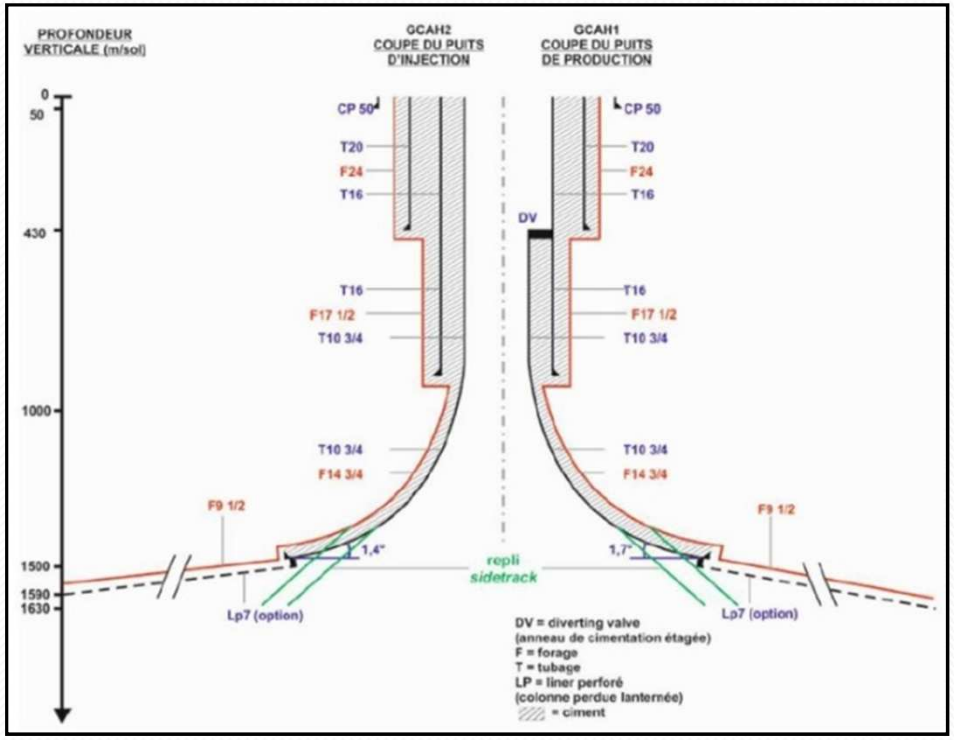
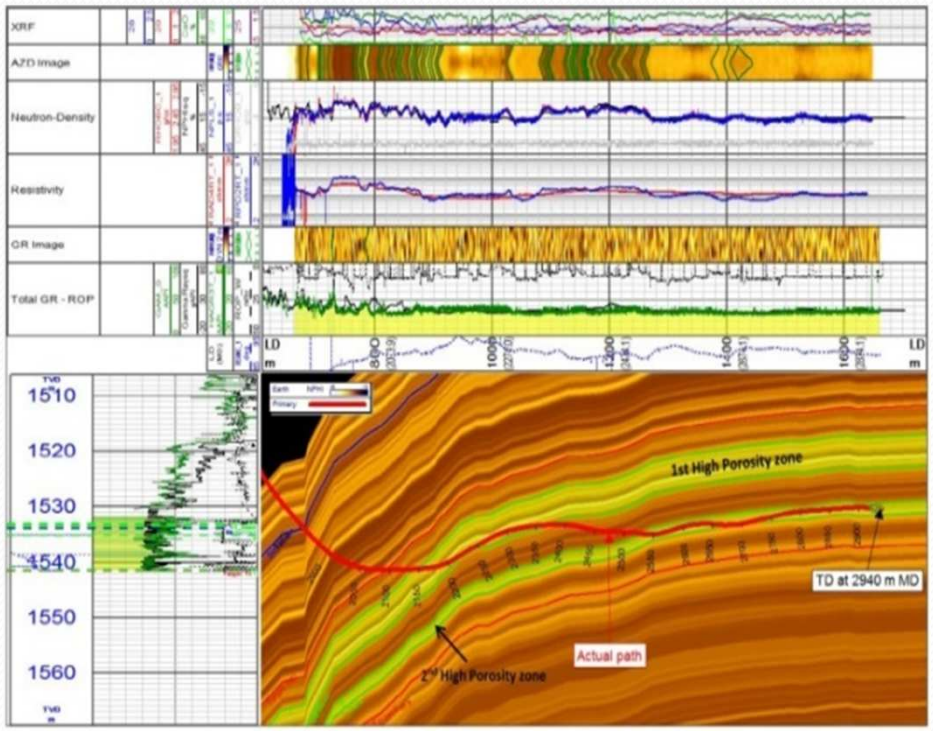
- **New technologies in use: Horizontal drilling**

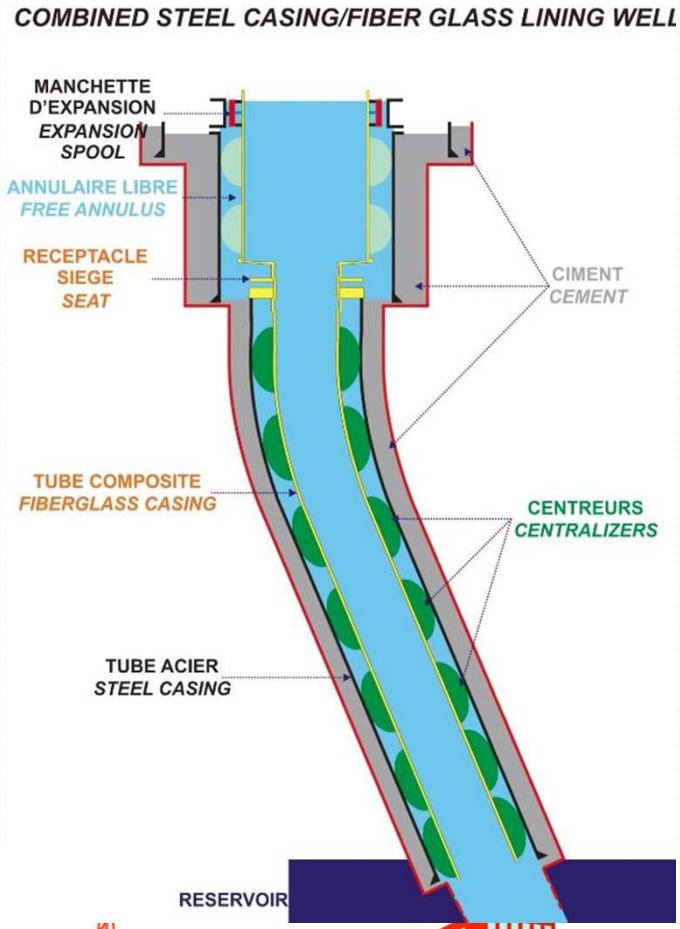


Well concept in Cachan (GPC IP)

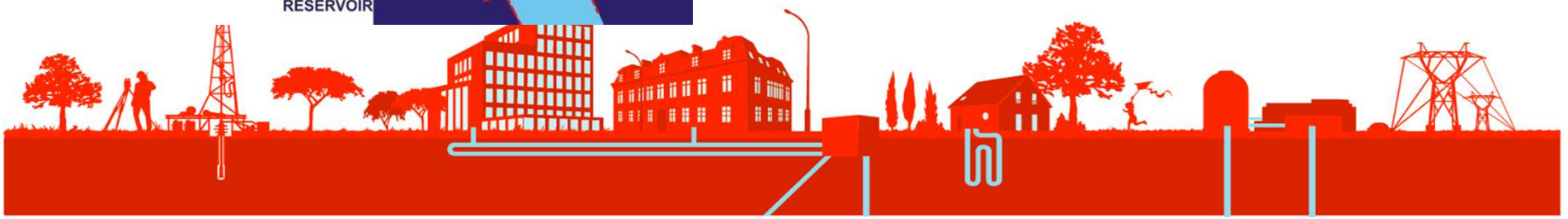


Wireline log (NMR-CMC and Sonic dipole porosity, permeability tools) correlation with drain productive segments (GPC IP)

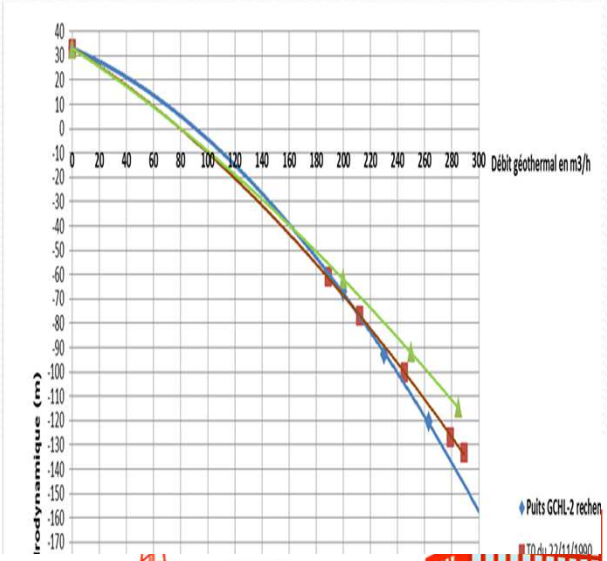
New technologies in use (composite casings)

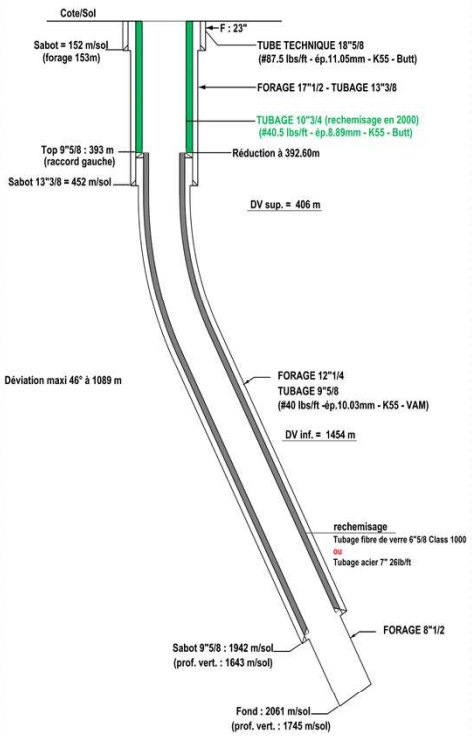


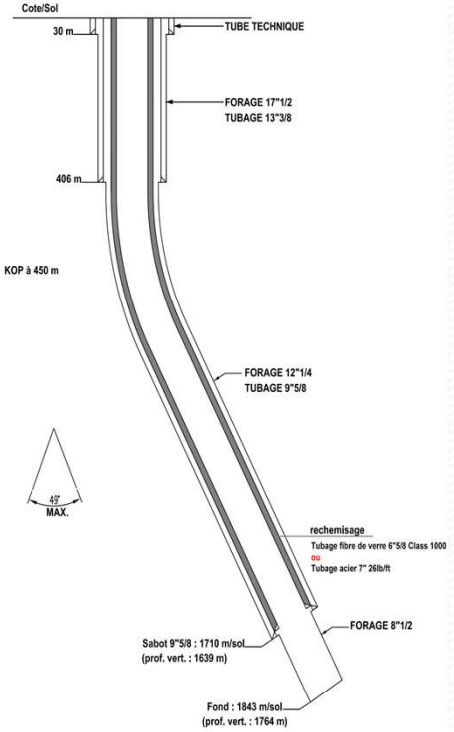
Concept of composite casing installed in Bonneuil and picture of the casing on the site (GPC IP)



- **New technologies: lining in an old doublet (9”5/8) using composite casing (6”5/8)**



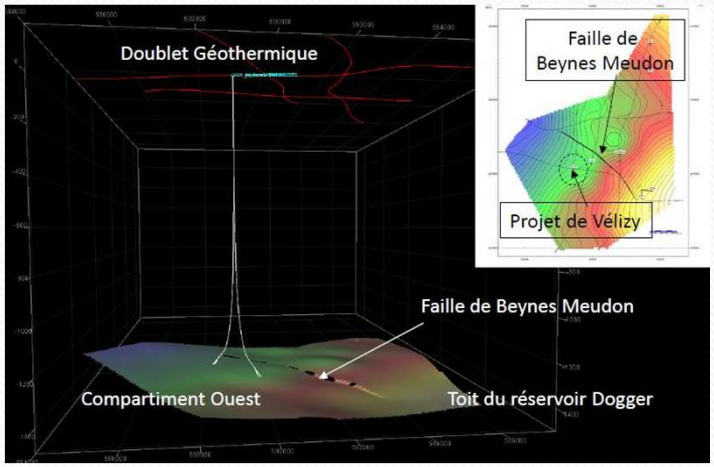


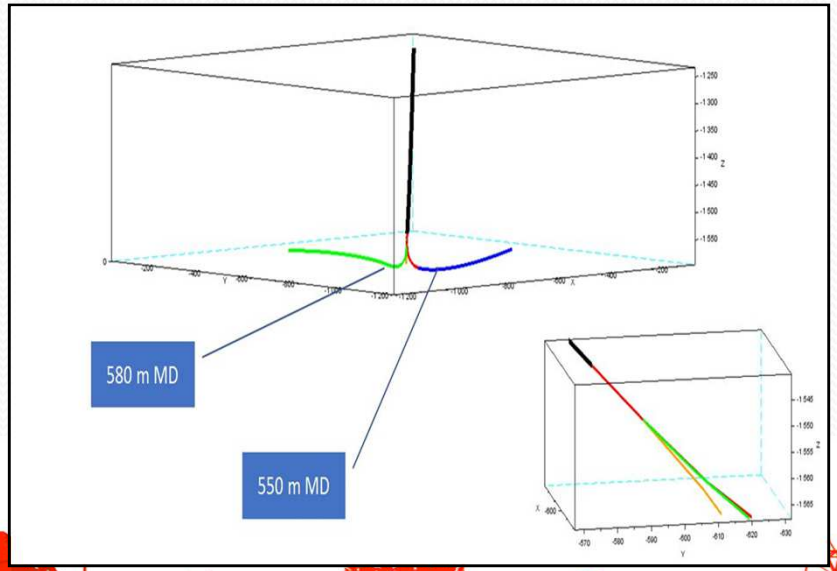


(Courtesy of CFG Services)

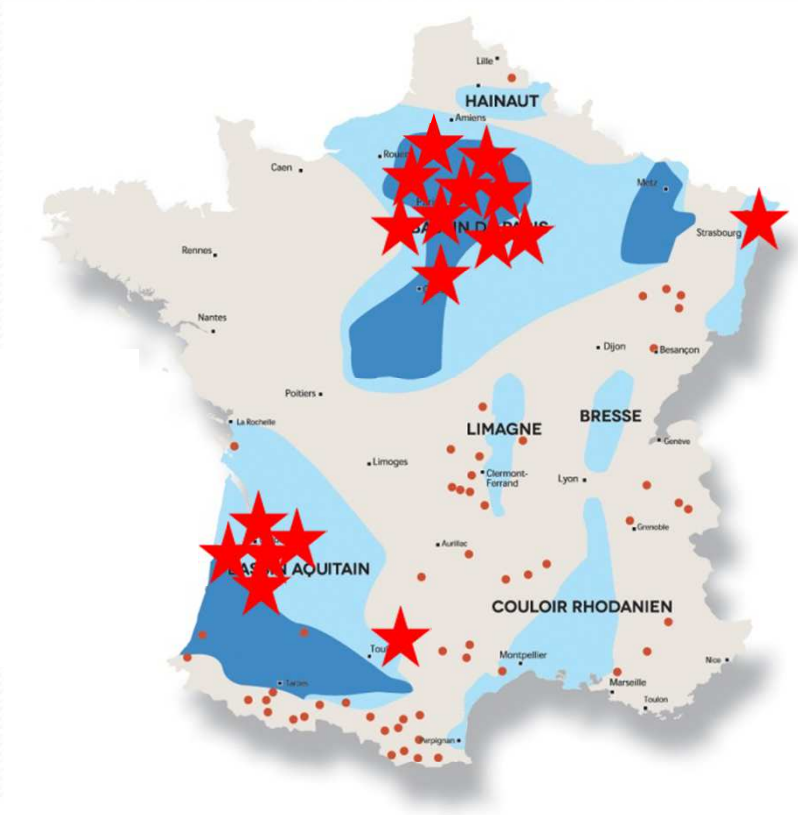
- **New technologies in use (multi-drains)**

The latest experimentation to develop the Dogger geothermal reservoir has been carried out by ENGIE Solutions in Vélizy-Villacoublay utilizing the multi drain technology (realization Schlumberger Services in 2020-2021). The production well has been drilled and tested successfully with 3 legs for a total length of about (600 - 450 - 60m). The flowrate is up to 400m^3/h which is 30% above the productivity of one standard doublet with a correlative 15% increase of the CAPEX.



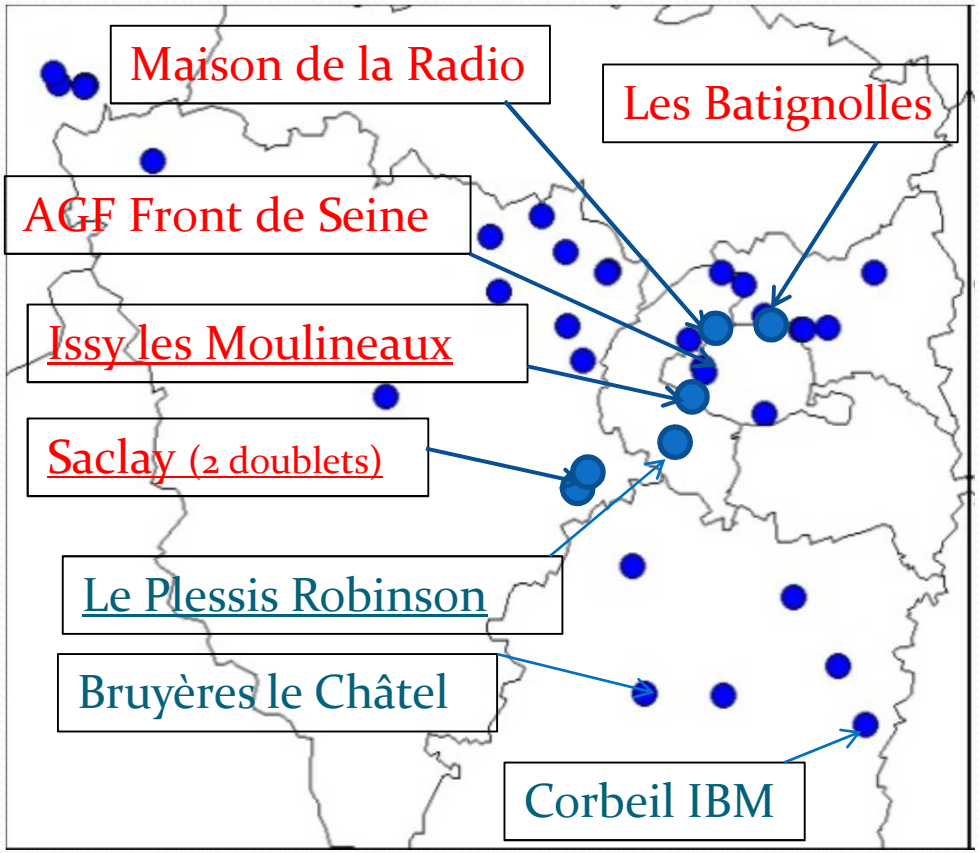


Wells drilled into detrital formations



Various experiments carried out in the 80's: Melleray, Achères, Cergy Pontoise tapping Triassic sandstones as reservoir target.
Production is fine but injection appears very difficult using normal pressures. No clear solutions at the moment except triplet array with one production well and one injection well or production well producing from Triassic formation and injection well in Dogger.
The last attempt in 2019 in Bobigny failed to test the triassic sandstones.
In Ritershoffen drilled in 2014 no injection problems in the reservoir made of Bundsandstein sandstones and granite.

Wells drilled into the cretaceous sandstones



39 existing wells drilled to the Albian sandstones of which 22 for tap water and 11 for geothermal purposes. The Neocomian sandstones are tapped by 2 industrial uses with single well and one doublet in Le Plessis Robinson.

The re-injection in sands and sandstones formations remains a challenge for high flowrate

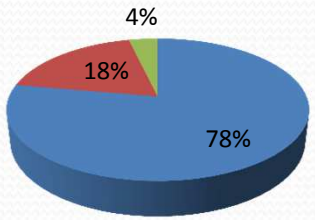
- The injection index in detrital formations is usually smaller to production index
- The last doublet have been in big diameter and oversize gravel packs and some wells have been also equipped using pre-gravel-packed screen with glass ball to optimize the filtration
- The 4 last doublets drilled in the cretaceous formations experimented decrease of injection rate from some months to some years
- The problem has been solved in general partly using high filtration down to 2 microns in Saclay for example
- The best method to recover the injection index is achieved by pumping back of the injection well to eliminate particles plugging the reservoir close to the well.
- The recommendation is to exploit at about 60% of the full potential of the aquifer in order to maintain a manageable injection pressure
- The triplet solution is also a possibility (1 Production and 2 Injection wells) but with a lower pay back time because CAPEX higher

- **The 3 reasons of success for GeoDH systems in Ile de France**

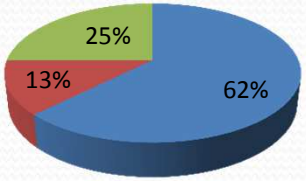
  - The geothermal resource of the Dogger is just under the main French urban area
  - Since the 80's, there are pro-renewable energy policies tailored for geothermal energy, even if the efforts could be upgraded
  - A short and long term geothermal risk mitigation fund is running since 40 years and should be revamped in 2021 to boost the geothermal deployment outside of Ile de France region

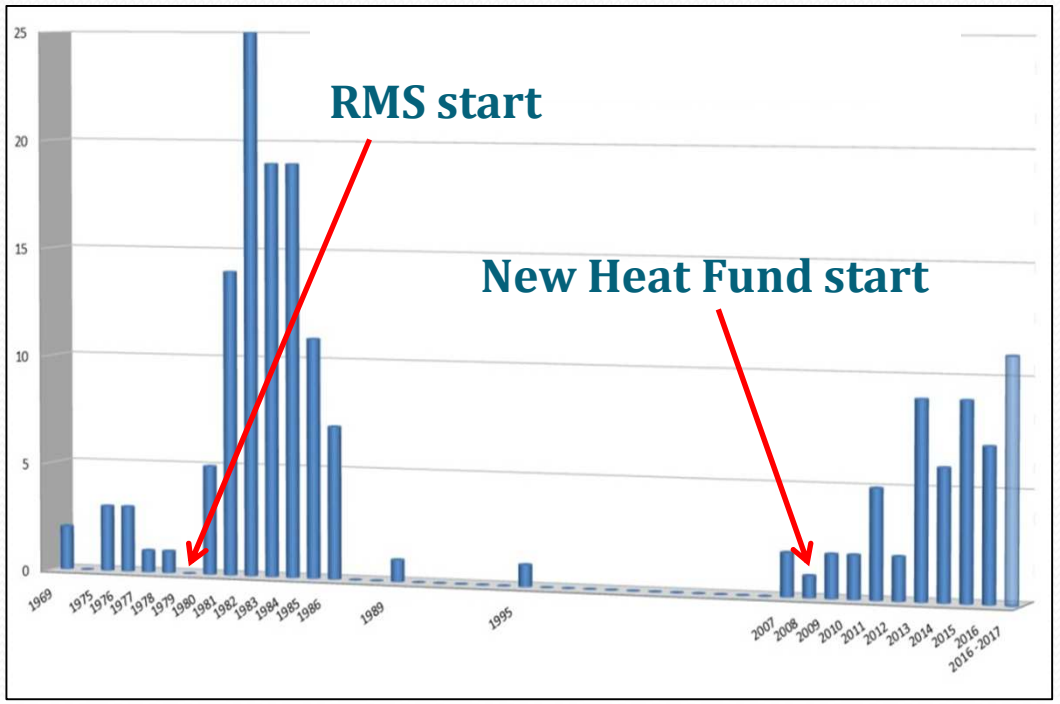
RSM system is an obligation but subsidies are also a booster for the geothermal deployment

Opérations in the Paris basin



Opérations the rest of France





Blue is successful
Green a failure
Red a partial success

- **The Short Term Risk: Conditions to subscript to the insurance**

  - Acceptance of the project by a technical committee after a detailed expertise including, technical ,economical, financial and juridical aspects

  - Payment of 3 to 5% of the covered cost depending on the zone (for a Dogger doublet of 10 M€ the insurance cost is of 350K€)

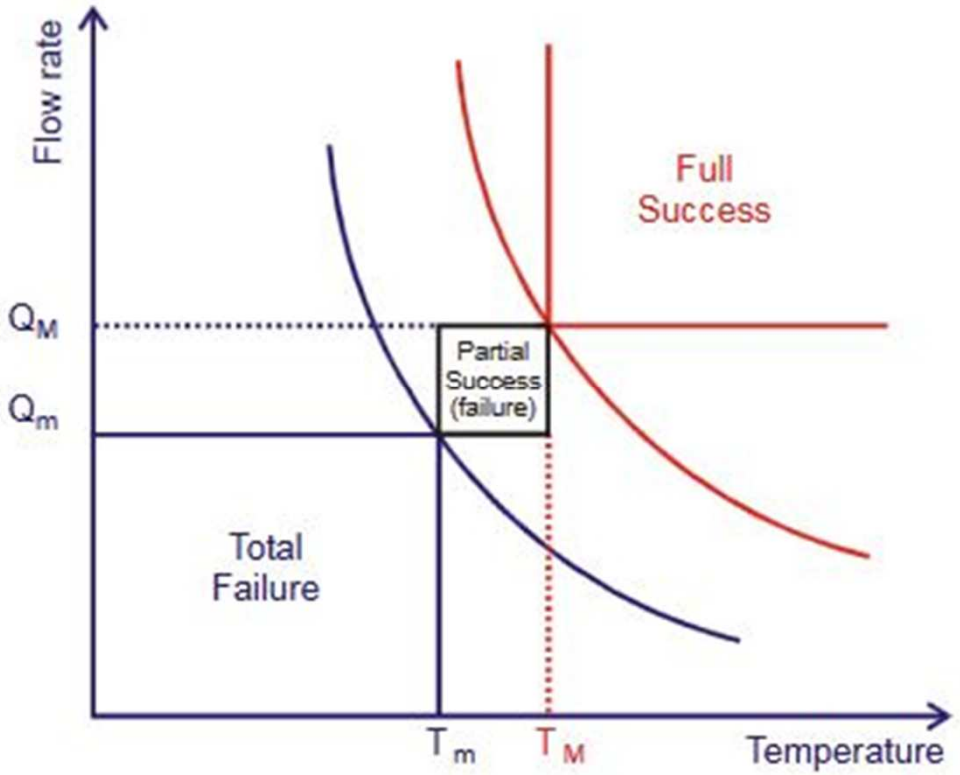
    - Maximum compensation reach 65% of the eligible cost

    - The regional authority add a complementary compensation (25%) to reach 90% in Ile de France

    - The final sum granted in case of failure is calculated according to the degree of success of the project based on a pre-established curve negotiate between the fund and the developer (insurance cap is 4,8 M€ at the moment)

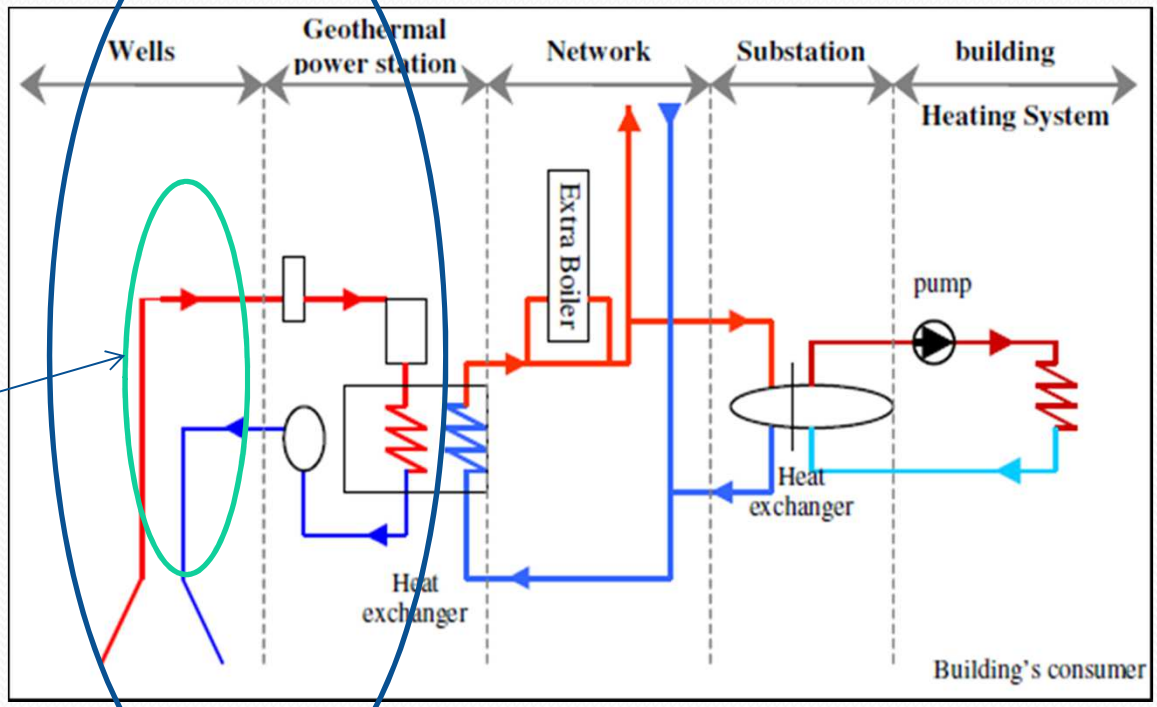
- **Success appraisal based on temperature and flowrate**

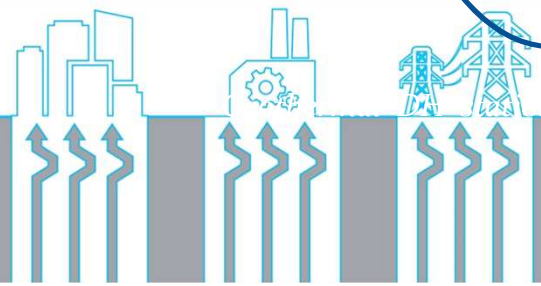
Partial success is defined by a real power below 85% of the expected power and failure by a real power below 60% The developer is reimbursed by a lump sum corresponding to a percentage of the power obtained applied to the guaranteed provisional costs.



- **The Long Term Risk: insurance system**

Covering repairable incidents on equipment's in direct contact with the geothermal fluid (casings, pumps, heat exchanger, anti scaling and inhibitors systems, piping systems)





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- **The Long Term Risk: a French exception**

  - Covering repairable incidents on equipment's in direct contact with the geothermal fluid (casings, pumps, heat exchanger, anti scaling and inhibitors systems, piping systems)
  - Covering also the potential decrease of the thermal power extracted from the geothermal reservoir during a 20 year period
  - The premium paid by the developer is 15 K€ per year for a geothermal doublet
  - The guarantee cap is at 1,4 M€ (there is a franchise at 130K€) and defined by the technical committee
  - To benefit there is the obligation to have ensured the doublet using the Short term fund, to have in place a downhole inhibitor system and and to transmit each year to the fund an exploitation report

- **Result of the short and Long Term Funds 35 years of life**

Amounts paid by the government	8 500 000
Fees paid by the operators	9 790 000
Fees paid for the guarantee extension of 10 years	3 000 000
Financial products generated by cash in bank	3 320 000
Total resources of the fun in €	24 610 000

Sums repaid to the operators	19 500 000
Personnel and management of the fun	4 600 000
Total expenses of the fund in €	24 100 000

Final balance of the fund in €	+510 000

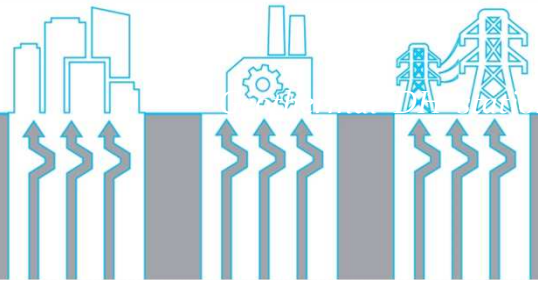
During the 20 years of the fund, 1,7 Billion € investment with a leverage effect of 1€ of public money for 30€ of investment guaranteed during 25 years

Amounts paid by the government	2 630 000
Fees paid by the operators	3 350 000
Financial products generated by cash in bank	2 700 000
Total resources of the fun in €	8 680 000

Research and technological programmes	3 450 000
Sums repaid to the operators	3 000 000
Personnel and management of the fun	830 000
Total expenses of the fund in €	7 280 000

Final balance of the fund in €	+1 400 000

During the 20 years of the fund, 1,3 Billion € guaranteed with a leverage effect of 1€ of public money for 42€ investment



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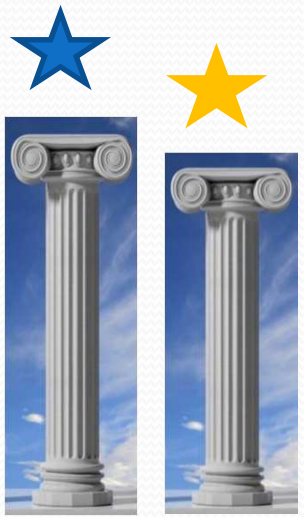
Last result of the running funds (Short + Long term) from 2008 to 2020

- **End of 2020 the resources of the fund were at 31 M€**
  - Subsidies from ADEME (French Government) + 16M€
  - Subsidies from Ile de France Region +1,50 M€
  - Fees from developers: 13,5 M€
- **Expenses of the fund** 53% payment for failures, 15% expertise and management (0,4 M€ per year), reserves in cash 32% (8M€)
- **Short term fund:** 80 wells covered (33 doublets and triplets + 13 single wells with 7 partial or total failures and 4 overheads due to geological conditions)
- **Long term fund:** 34 contract signed for 180 years of cumulated years of exploitation and 6 failures declared and reimbursed



Public 56% **Private 44%**

- **GEORISK project to replicate the existing RMS systems developed in France, Germany, The Netherlands and recently in Switzerland and Turkey (www.georisk.com)**

The GEORISK main achievements at the moment are:

- Establishment of a GEORISK register unique at world level
- Inventory of every tested or existing RMS worldwide and presentation of Pros and Cons
- Creation of a CRI (Commercial Readiness Index) for geothermal energy in the consortium countries
- Creation of a robust tool in order to model a RMS taking into account, equity, premiums, existing geothermal risk and level of coverage
- Presentation of the DoubletCalc software built for The Netherlands by TNO in order to evaluate and benchmark the geothermal doublet in sedimentary basin context

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Thanks for your attention

Don't be shy… and feel free to contact if questions

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