Geothermal Energy Use, Country Update for France

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ABSTRACT

The last market study (2016) carried out in France by the French Association of Geothermal Professionals regarding the geothermal domain has demonstrated that the installed power for heating and cooling reaches 2500 MWth. One third is related to the exploitation of the deep Dogger reservoir in the Paris area but the main part is linked to the recent and strong development of shallow geothermal resources in the whole country. The market for single housing using vertical geothermal probes is dramatically decreasing since 2009 due to the economic crisis and tax credit at 30% for geothermal without any bonus compared with efficient gas boiler neither air-air heat pumps. The market for single housing has been divided by 7 in between 2010 and 2016 from more than 20 000 installations to less than 3000. On the contrary, the number of installations to feed collective housing and residential blocks including offices buildings is growing constantly. The direct uses are concentrated mainly in Ile de France, the doublet construction restarted with the support of the Heat funds managed by ADEME and the two last years, more than 20 new deep wells have been drilled in Ile de France. The main barrier remains administrative constraints and delays to get the permission for drilling in one hand and the calculation rules for new buildings (RT2012) which still encourage gas and electricity in the other. In 2023, the market will reach 3000 MWth installed; if ecologically driven, the target objectives at 3500 could be largely attained. For electricity generation no more installations have been commissioned even the Soultz-sous Forêts plant has been revamped. The Bouillante plant has been sold by BRGM to ORMAT mid 2016 and the plant capacity will be upgraded from 15 to 45 MWe in the next years.

1. ELECTRICITY GENERATION

The two power plants are namely the **Bouillante** power plant in Guadeloupe (French West Indies) and the EGS pilot plant in **Soultz-sous-Forêts** (Alsace).

The Bouillante power plant (figure 1) started again in April 2011; a significant part of 2010 and the beginning of 2011 had been previously occupied by technical problems but it is now running again properly. It comprises two units, for a total capacity of 16 MWe, one double-flash 4 MW unit running from 1986 and a single-flash 12 MW unit inaugurated in 2004. In 2010-2011, a partial reinjection has been put in place and improvement works on wells and pipes have been performed. Important events in 2014 included re-commissioning of the B1 unit after renovation, and a clean-out of the BO-5 and BO-6 production wells, and the installation of a treatment plant for atmospheric hydrogen sulphide emissions from the B2 facility.

The plant is run by Geothermie Bouillante, a subsidiary of BRGM (97.8 %) and EDF (2.2 %). Even if this electricity production is negligible compared to the national demand, it is important to notice that the installed capacity in Guadeloupe represents around **6% of the island's electricity supplies in 2015, producing 83 GWh of electricity,** with time functioning close to 90 % at the B2 unit.
The BRGM Group re-launched a process in 2014 to open up the company's capital in order to raise the resources it needs for an ambitious geothermal energy development programme in Guadeloupe, especially in the north of the Bouillante bay ("Bouillante 3" project). It owns two exploration licenses with a total additional potential capacity of up to 30 MW, which could bring the total plant capacity to 46 MWe by 2021-2023.

The plant has been sold to ORMAT in June 2016. The MOU was signed with the owner of GB, Sageos holding a subsidiary of Bureau de Recherches Géologiques et Minières (BRGM).. Upon closing, Ormat will hold approximately 80% of Géothermie Bouillante (GB) which will be increased to 85% within two years by capital investment agreed upon in the MOU.

Figure 1: View of production wells of the Bouillante geothermal plant, (CFG Services)

As a global leader in the geothermal industry, with vast experience in constructing and operating geothermal power plants, Ormat is confident that with its technology and expertise it can optimize the use of the resource and existing facilities and recover its current approximate production of 10 MW to its designed production of 14.75 MW by mid-2017. Additionally, Ormat plans modifications to the existing equipment as well as to further develop the asset, with a potential of reaching a total of 45 MW in phased development, by 2021. Ms. Ségolène Royal stated that the decision of Ormat Technologies, US Company listed on the NYSE and a global player in the field of geothermal energy, to invest in the French island of Guadeloupe for the further development of a clean and renewable energy source is an indication of the French government's policy.

It is in Soultz-sous-Foret where an innovative European research programme based on EGS technology has been initiated since 1987. With a financial support of European Commission and French and German governments, this program led to the drilling of 3 wells with depth of 5 000 m, and the construction in 2008 of the scientific pilot plant, a thermo-electrical conversion ORC unit with a capacity of 2,2 MWe.

This EGS pilot plant, well known worldwide as an important laboratory for European research, went into the power production phase in the autumn of 2010. It is run by the European Economic Interest Grouping "Exploitation Minière de la Chaleur", gathering six French and German companies, among which EDF and ES French ones.
The installations have been fully revamped in 2015 and beginning of 2016, with a Turboden turbine and new cooling systems (figure 2).

Figure 2: Aerial picture of the new revamped plant in Soultz-sous-Forêts *(Courtesy of ES Géothermie)*

For overseas developments, the important activities in 2015 were:

- in the Réunion island (Indian ocean), in order to re-launch the geothermal development, a new project of high-temperature geothermal exploration (EGHERI project) was conducted by BRGM ; its main objectives are to establish the most complete diagnostic of the geothermal potential of this island, and define a preliminary program of exploration well in the most promising areas, taking also into account the environmental aspects and energy needs ,
- in Guadeloupe island (Caribbean area), the first studies of the GEOTREF project (multi-disciplinary platform of innovation and demonstration for high-energy geothermal exploration and development in the fractured reservoirs), focused on the Vieux Habitants volcanic sector has been launched by the Teranov company ,
- the end of the INTERREG IV project "Carribean Geothermal", coordinated by the Guadeloupe region and ADEME will intend to accelerate geothermal development in the entire Caribbean region,

The INTERREG IV project included five items:

- Environmental excellence, including the writing of a guide of recommendations to ensure the successful environmental integration of geothermal energy projects in an insular and/or tropical context ; this guide was based on three concrete cases (Bouillante in Guadeloupe, Wotten Waven in Dominica and Martinique)
- Power production and distribution, with the definition of an MDE-PDE program (Electricity Demand Control-Decentralised Electricity Production) on the scale of the volcanic islands from St Kitts and Nevis in the north, to Grenada, in the south ;
- Caribbean geothermal energy development program, with the production of an inventory of work performed in geothermal energy over the last thirty years in the Caribbean zone, and definition of a detailed program of actions to be led within the next fifteen years ;

- Communication, including the design of generic information tools on geothermal energy for the different publics, and the creation of a Web site dedicated to the project, the definition of a specifications sheet to build Geothermal Energy Houses, the organization of an event on the technical aspects of geothermal energy for the political, technical and administrative leaders in the Caribbean and Central America areas and industrial companies,
- Training: to accompany the prospect of development of geothermal energy on the Caribbean scale, training required in geothermal energy and the associated professions must be analysed to meet these needs, and the creation of a Caribbean Excellence Centre for Geothermal energy located in Guadeloupe will be studied,

In 2015, the geothermal cluster GEODEEP has been founded. It is made of large companies with experience in Research & Development, Studies & project development, power plant equipment, operation and maintenance, engineering firms developers/integrators specialised in geothermal energy, ESCO's and the Geothermal association of professionals

Apart a strong common action to promote the French geothermal offer abroad, the cluster is achieving the creation of 2 different risk mitigation funds:

- One devoted to EGS: in France mainland. The fund is based on public/private financing and aims at mitigating the geological risk of geothermal resource deployment. It will compensate the operator in case of exploration drillings failures. This Fund lowers the financial risk to secure developers and industrials in their investment commitment.
- The second is devoted to volcanic zones**:** in overseas Department and worldwide prospects.

The mechanism covers 60% of exploration costs, assuming fees of 3 to 5% of the CAPEX in volcanic well know zones and 5 to 10% in EGS environment with less deep geological knowledge. These funds are built to be perennial and impose royalties to be negotiated and repaid to the fund in case of success during 15 years

Geothermal electricity is expected to **reach 53 MW** in France in 2030. There are two main issues: the first is to provide French islands (French West Indies and La Réunion) with a decarbonized energy, replacing the actual thermal electricity production, at a reasonable cost; moreover, the 2030 objective for these islands is 50% of renewables instead of 23% at a national level, because the current production is mainly made from fossil fuel. The second objective is to acquire a good experience in EGS projects to develop this energy in a larger way in 2050.
Finally, the feed in tariffs for geothermal energy are disappearing to follow the European Union regulations, AFPG negotiated the new tariff system which is now made of a bonus versus spot electricity price. Normally, the system will ensure for the next years a guaranteed tariff equivalent to about 250€/MWh which is better compared to the former system which was culminating at 130€/MWh in the overseas departments and 200€/MWh in the mainland and close to the price anticipated in Germany.
The more important evolution is the multiplication of many permits allocated to 3 to 4 different companies in order to cogenerate electricity and heat in the next 5 years. At the moment, 12 permits have been awarded by the Ministry of Environment. The potential and numbers are given on the table 1 and sites are located on figure 3.

Table 1: Number and size of electricity projects

	Number of projects	Power in MW	Thermal power in MW	Investments in M€
Existing 2016	3	17	37	164
Permits in France	16	60	210	826
Permits in Islands	2	25	0	70
Expected in 2030	23	210	247	<1500

The first drillings will start in Alsace during the first Q1 and Q2 2017.

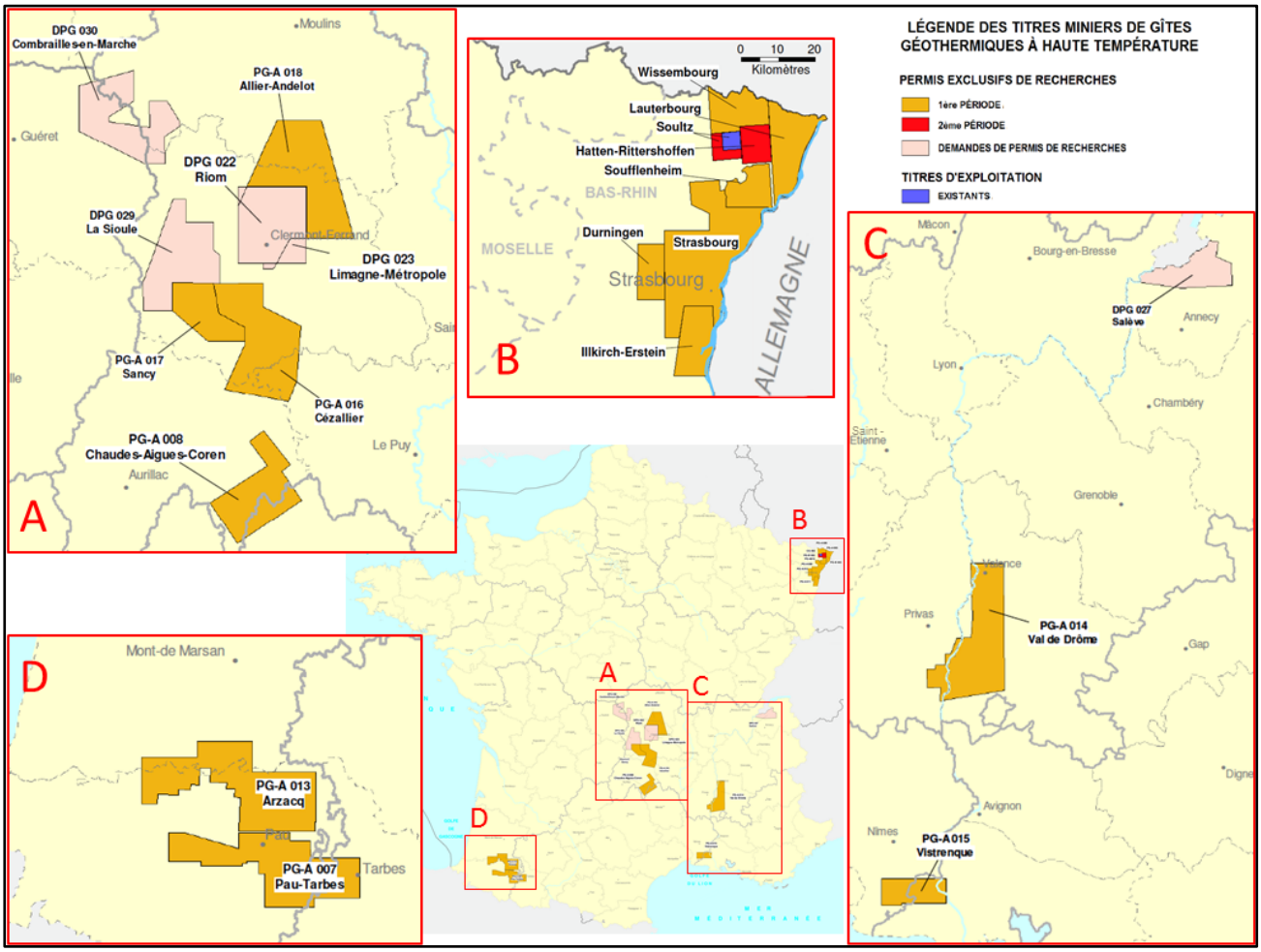

Figure 3: Permit maps (Ministry of Environment January 2016: A : Massif Central and Limagne ; B : Alsace ; C : Couloir Rhodanien et Haute Savoie ; D : Sud-Ouest

2. HEATING AND COOLING PRODUCTION

After the establishment of a strategic geological road map in 2011 by ADEME (the French Agency for Environment and Energy) which is giving 2020 targets for the expectation of a geothermal heat production multiplied by 5 between 2006 and 2020. A new programming named PPE defines new objectives and measures to comply, until 2030.

Two measures are common to both technologies (Direct uses in district heating and Geothermal heat pump):

- The doubling of Renewable Heat Fund and a better promotion and communication plan for the public at large
- The integration of renewable cooling in the Renewable Heat Fund

The figure 4 is showing the increases of heating and cooling production (in kTOE renewables) in 2012, 2018, 2023 and 2030, with and without the PPE additional measures, for collective GSHP, individual GSHP and GeoDH.

If measures are met then the total of kTOE produce by geothermal heat and cold in 2018 will be 622 ; 881 in 2023 and 1269 in 2030.

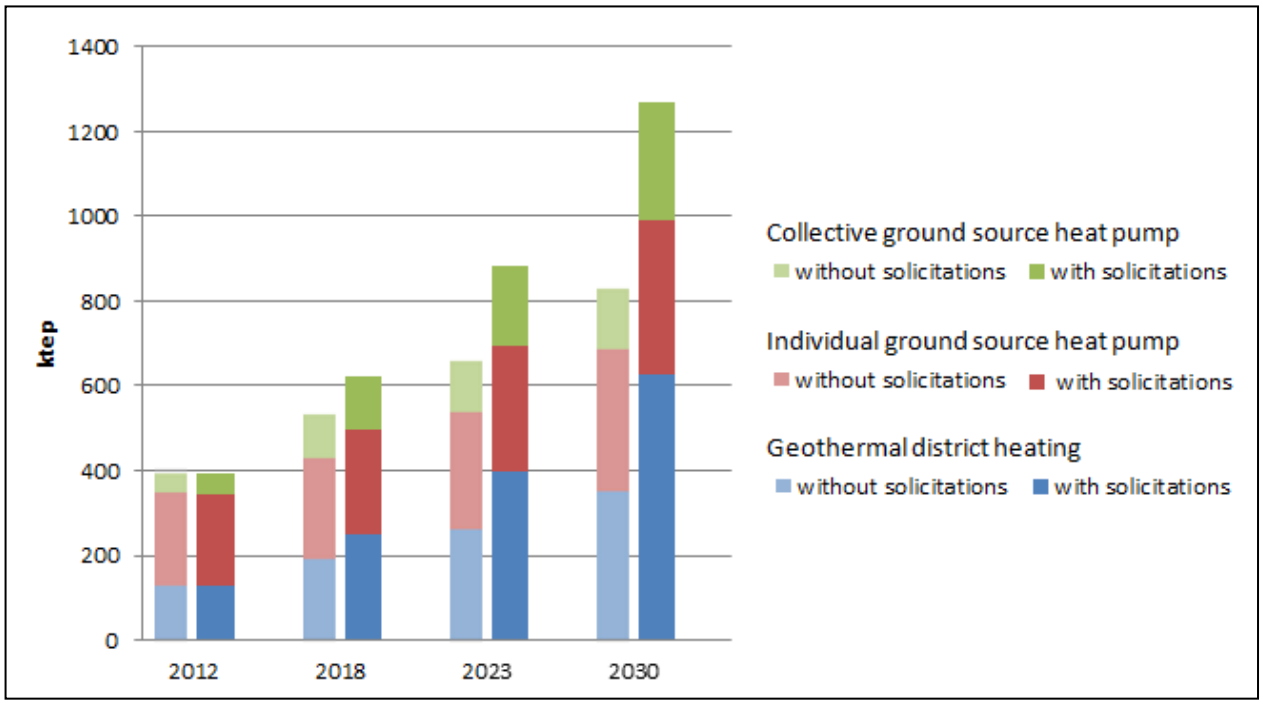

Figure 4: Comparison between expected development for geothermal heating in 2018, 2023 and 2030, with or without additional measures

2.1 Direct uses – Geothermal District heating (GeoDH)

The direct use of geothermal heat is quite well developed in France. The 2015 production is estimated at 1300 GWh and represents about 71 plants in France (details on tables D and D2). Most of them are used for district heating. During years 2015 and 2016, 7 new projects were created, all in the Paris Basin.

The **Paris Basin** has the special characteristic of offering a strong overlap in between the geothermal resources and the demand for heating, as numerous cities are located directly above continuous aquifers. Approximately 62% (48 on 78) of GeoDH are exploited in Ile de France region (figure 5). It is 48 operating plants whose 21 are renovated (5 by simple casing replacement, 8 by conversion to triplet and 8 by a new doublet drilled with larger diameter of the production casing).

The 7 new projects which were created in 2015 and the beginning of 2016 are for 6 of them in Dogger aquifer (named Arcueil-Gentilly, Bagneux, Bailly-Romainvilliers, Rosny-sous-bois, Villejuif and Villepinte) and 1 tapping the Albian sands (Clichy-Batignolles).

Furthermore, around 15 projects are on-going in this region. Seven of them are indicated on the following map (clear pink colour and two in blue (Saclay 1 and 2 for Albian projects).

This sedimentary basin has five large aquifers, including the Dogger which has the largest number of low-energy geothermal operations in the world, with 44 operations concentrated in a zone where 12 millions of people are living. The only use collective heating and cooling applications. A conventional operation in the Paris region allows the heating of approximately 4,000 to 5,000 housings. It corresponds to 200 000 housings heated by Dogger representing a population of about 650 000 people.

The Dogger covers an area of over 150,000 km² with the temperature measured directly below the Paris region varying between 56 °C and 85 °C according to the depth of the reservoir (between 1,600 and 1,800 m).

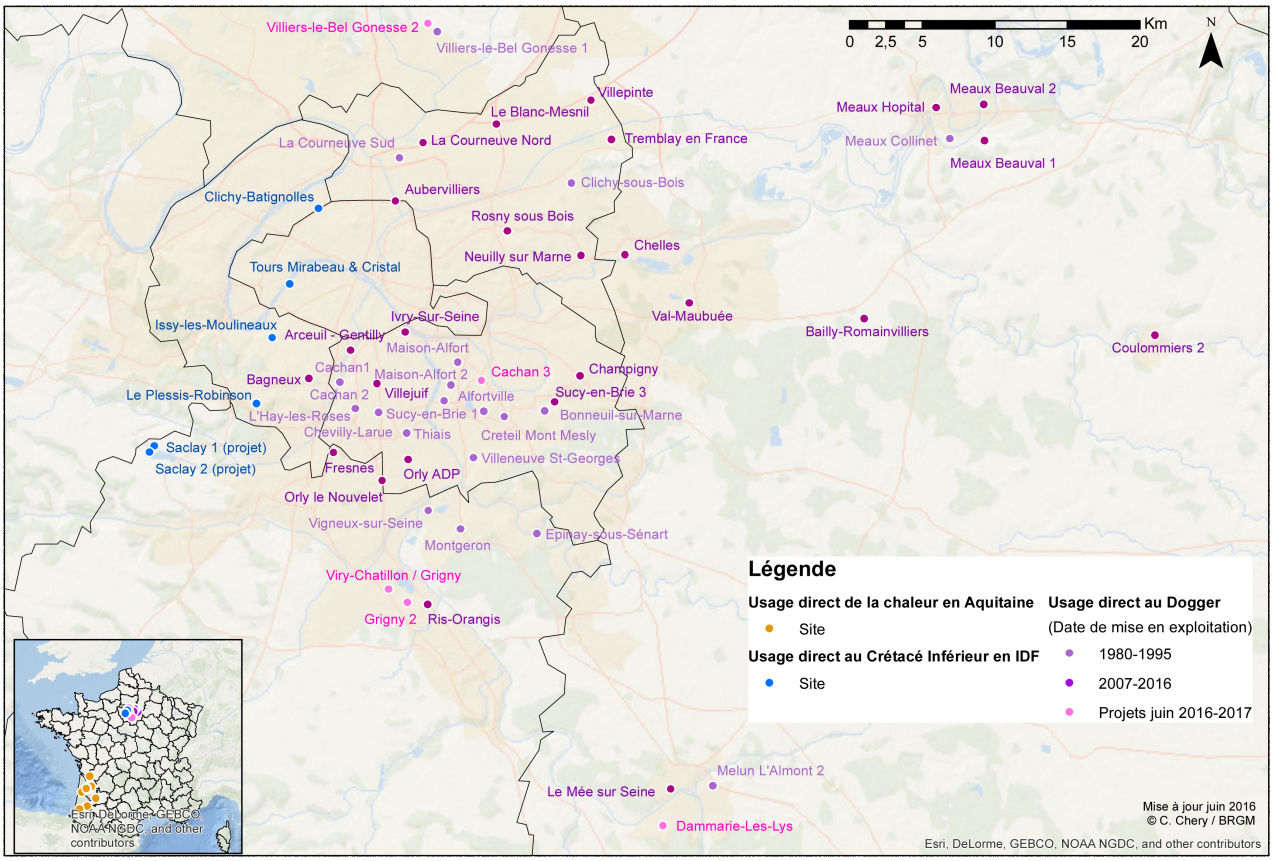

Figure 5: Overview of the geothermal plants running in the Paris basin © BRGM

The district heating networks supplied by the Dogger geothermal resource are mainly exploited by private companies such as Dalkia (EDF Group), Cofely (ENGIE Group), IDEX Energie and Coriance, but also by local public-private ventures (Sociétés d'Economie Mixte). They have been operated for more than thirty years and have thus been fully amortized, with an average availability rate still approaching 95%. The oldest of these installations is located at Melun l'Almont. Commissioned in 1969, it is still into operation (figure 6).

Figure 6: Well head of the Dogger geothermal plant in Melun l'Almont (ADEME)

Recently Albian and Neocomian aquifers (Early Cretaceous) have been used for geothermal district heating and cooling application but with big power heat pumps and for smaller project in term of housings. Four plants are operating and two others are under investigations in Paris Basin (in blue on the map).

The second zone for direct use is **Aquitaine** (south-west of France, figure 7), with around 15 single production wells: these operations have been realised in the beginning of the 1980s and this technical situation was chosen as the pumped is drinking water and can be discharged to the surface. The regional geology is moreover quite complicated and the aquifers to be produced are made of sands and sandstones inter-bedded with clays, in these conditions, reinjection becomes a difficulty which is not easy to solve. In addition, the temperature is lower than in the Paris basin which makes the profitability of a doublet harder to achieve. Nowadays, secondary uses of the resource, as irrigation and agricultural uses are investigated.

Since 2007, a restart of the activity of deep geothermal doublet for district heating purposes has been recorded. Three doublets projects are under investigation in the city of Bordeaux. On the next map 13 of the 15 operations are localised on the new region "New-Aquitania".

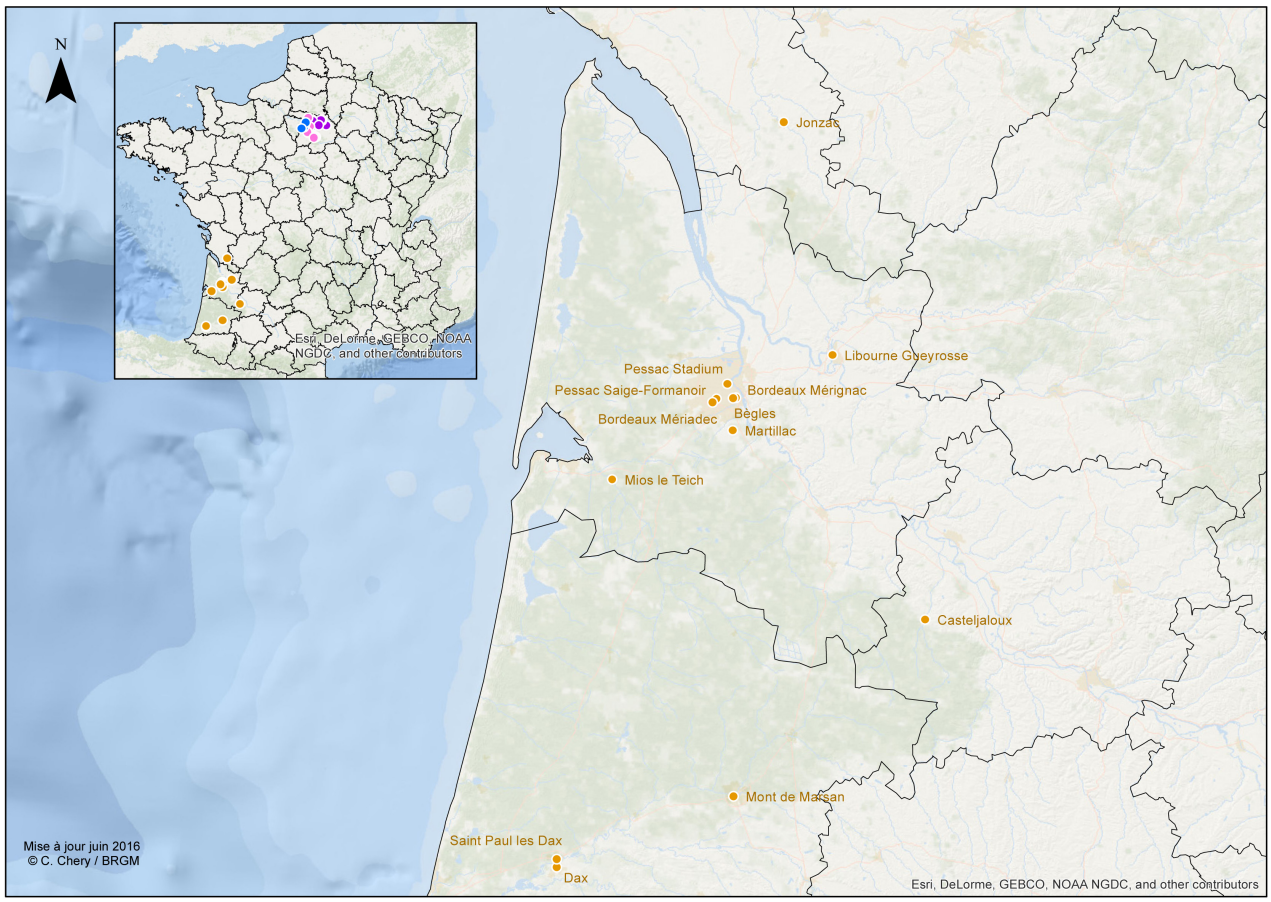

Figure 7: Overview of the geothermal plants running in the Aquitaine Basin © BRGM

Finally **Alsace** region has a very good potential for EGS plants. The Ecogi project in Rittershoffen was inaugurated the 7th of June 2016, it is for industrial process, the water is extracted at 165°C and only heat is used (figure 8). Many projects are under investigation for producing heat and electricity, by cogeneration or coproduction.

Figure 8: The Rittershoffen plant during drilling operations

The figure 9 shows the importance of supporting policy on the number of deep geothermal drilling in France. With PPE programming, this number should increase during the 15 next years.

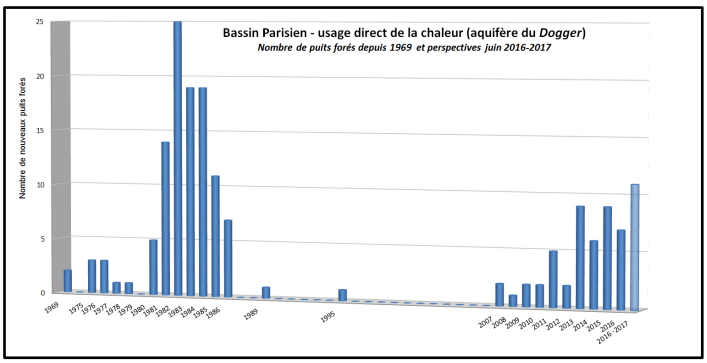

Figure 9: Number of deep geothermal drilling in France from 1969 to 2016 France © BRGM

The three measures specific to GeoDH in the PPE (Puriannual programme for energy of the Ministry of Environment) programing are:

- specific guidance on development projects of new deep aquifers, as the Triassic and Lusitanian aquifer in the Paris Basin or geothermal reservoirs of Aquitaine, Provençal and Rhodanian basins
- support R & D on EGS geothermal energy project and establishment of a geological risk mitigation fund
- development of support for demonstrators using aquifers for energy storage

2.2 Geothermal heat pump

The French geothermal heat pump market shows a decrease since 2009 (Figure 10), when the cumulative installed power for ground heat pump was around 23% per year between 2007 and 2009. It decreased at 10% between 2009 and 2011 and only 4.5% in the last period. For example the number of sold GSHP (Ground source Heat Pump) of a thermal power between 2 and 50 kW, has decreased by 59% between 2013 and 2015 (AFPAC 2014 and 2015)

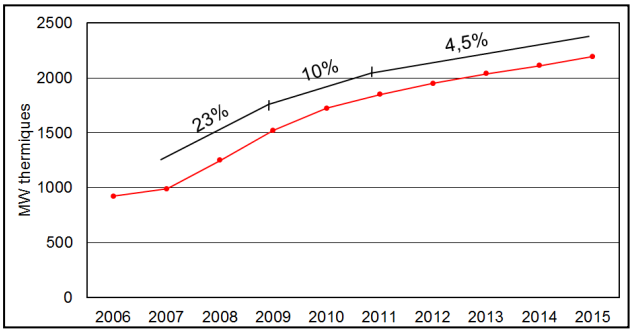

Figure 10: Cumulative installed power for Ground Source heat Pump systems and rate increases

The regions which are leaders in this market of the geothermal installations (individual housing and collectives) except horizontal geothermal are Ile de France, Rhone-Alps, Midi-Pyrenees, Brittany, Alsace and Pays de la Loire. It is shown on figure 11.

The distribution of different techniques at the scale of France is: 3,6% for single housing open loop, 23,8% for collective open loop based on water , 24,6% for individual vertical exchanger and 48% for collective vertical exchanger. Horizontal loops are still representing 26% of the geothermal market for individual housing and thermos-actives foundations remain at the moment largely underdeveloped.

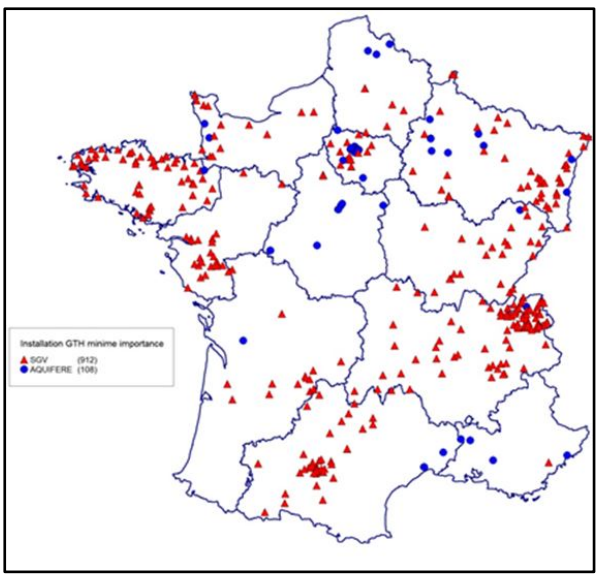

Figure 11: Number of Geothermal wells declared from 07/2015 to 04/2016 © BRGM

For vertical heat exchanger, AFPG determines distributions between installations in new building or renovation. At the scale of France, for private house installations, this is 40% for new and 60% for renovation. For collective installations, this is 53% for new and 47% for renovation.

For the collective buildings (housings, office, hospital, municipality buildings), a study published by Observ'ER in 2015 shows there is a 10% increase in the market of GSHP for this sector. It is around 550 GSHP for 220 facilities installed in France in 2014. The distribution is about 45% of these facilities for offices, 20% for collective housings, 20% for hospital and around 15% for municipality buildings. Only 15% are for renovation and so 85% for new buildings. It is around 55% of these operations made for aquifer and 35% made for closed loop system, the 10% less is about new technics only for specific projects. For 2015 and probably for next years, there is an increase of the part of closed loop system for this type of buildings, and it can be throughout the French territory.

Next figure shows that the geographic distribution of facilities into 7 areas. This map is based on the number recorded in 2014 but not on the thermal power. The Big East and Ile de France areas are the main regions for collective buildings representing half of the total number.

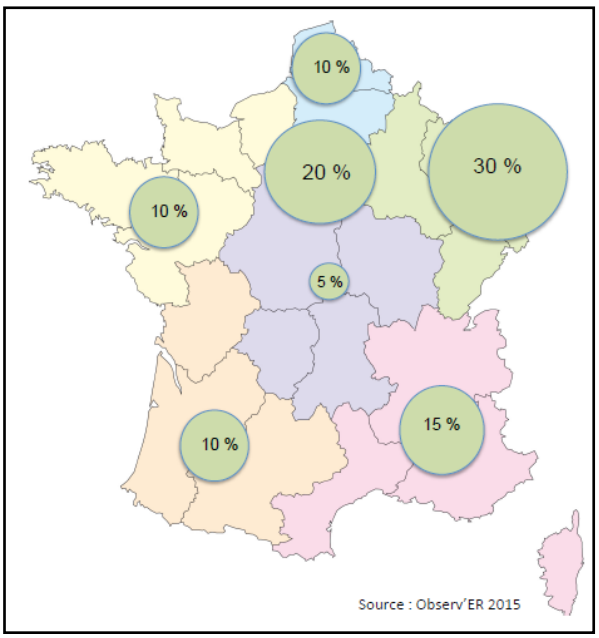

Figure 12: GSHP for collective buildings in 2014: geographical distribution

The three measures specific to Geothermal Heat Pump in the PPE forecast are:

- Establishment of a regulatory label for energy performance. Currently there is no regulatory incentive to exceed the RT (Thermic Regulation) 2012 performances

- Mandatory share of renewable energy in the Thermal Regulations in new buildings in the collective and tertiary sectors. At the moment, it is only the case for new individual buildings

- Establishment of a "Titre V" for "geocooling" it will integrate the cold production into geothermal heat pump performances.

3. GEOTHERMAL SECTOR DEVELOPPING STRUCTURES

3.1 Schemes in supporting geothermal energy industry

France has developed different schemes to help the development of geothermal sectors. One of them is the **mitigation tool fo geological risks**. This risk is linked to the fact that the exploitable geothermal energy resource can only be known after the drilling of the first borehole. This costly operation (more than 5 Million € at 2000m geothermal target) which may result in failure (e.g. due for instance to a lack of resources, to insufficient temperature or exploitable flow rates in relation to the forecasts or to the inability to exploit the geothermal fluid due to aggressive geothermal fluid for example). For electricity generation, the cluster Geodeep is building in cooperation with ADEME, Caisse des Dépots and Consigantions) a double Fund created first for EGS technology and for volcanic projects In a second step.

For deep aquifers used for heating production, the guarantee (SAF Environment) is existing since now 36 years and has proved is efficiency.

For small drilling in between surface and 200m depth, there is the guarantee "Aquapac" (funded by ADEME, EDF and SAF), in place since 30 years, which covers the geological risk of the first drilling and the geothermal production during an exploitation period of 10 years..

Furthermore there is a financial supporting scheme even if the operation is a success. For heating production the **Renewable Heat Fund** (Fonds Chaleur Renouvelable in French) was created in 2009 for collective housing, tertiary, industry and agriculture. At the end of 2014, 342 geothermal installations (for district heating and geothermal heat pump) have been using the Renewable Heat Fund. A total amount of 86 M€ has been given to the geothermal plants and a production of 95 000TOE/year of geothermal heat is the result. On figure 13, the repartition by regions of these subsidies is recorded by the heat production and by the number of facilities supported between 2009 and 2014. On 2015, 52 facilities benefited of this fund (5 for district heating and 47 for installations with GSHP). The doubling of this Renewable Heat Fund is a measure of PPE programme (2015) which is already effective in 2016. Consequently, the yearly budget at 220 M€ devoted to solar, biomass and geothermal heating could reach more than 400 M€ a year.

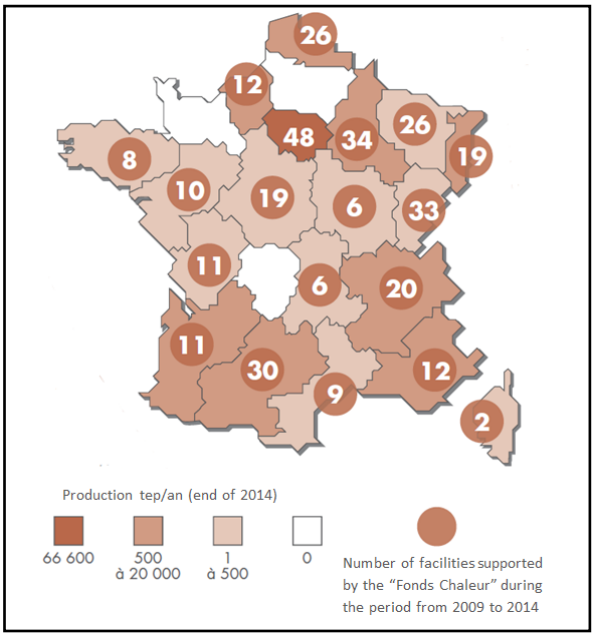

Figure 13: Production and number of geothermal facilities supported by the Renewable Heat Fund between 2009 and 2014 (ADEME, 2015)

For individual housing, the state efforts have been reduced and geothermal GSHP benefits from a tax reduction representing 30% of the CAPEX. The problem is that this tax advantage which is also distributed for the installation of a new and efficient oil and gas boilers, air-air heat pumps, biomass burners etc. The French policy is very supporting the collective housing but neglect the individual housing deployment.

3.2 French regulation

Geothermal energy is ruled by the Mining Code and subject to declaration or authorization in accordance with the figure 14.

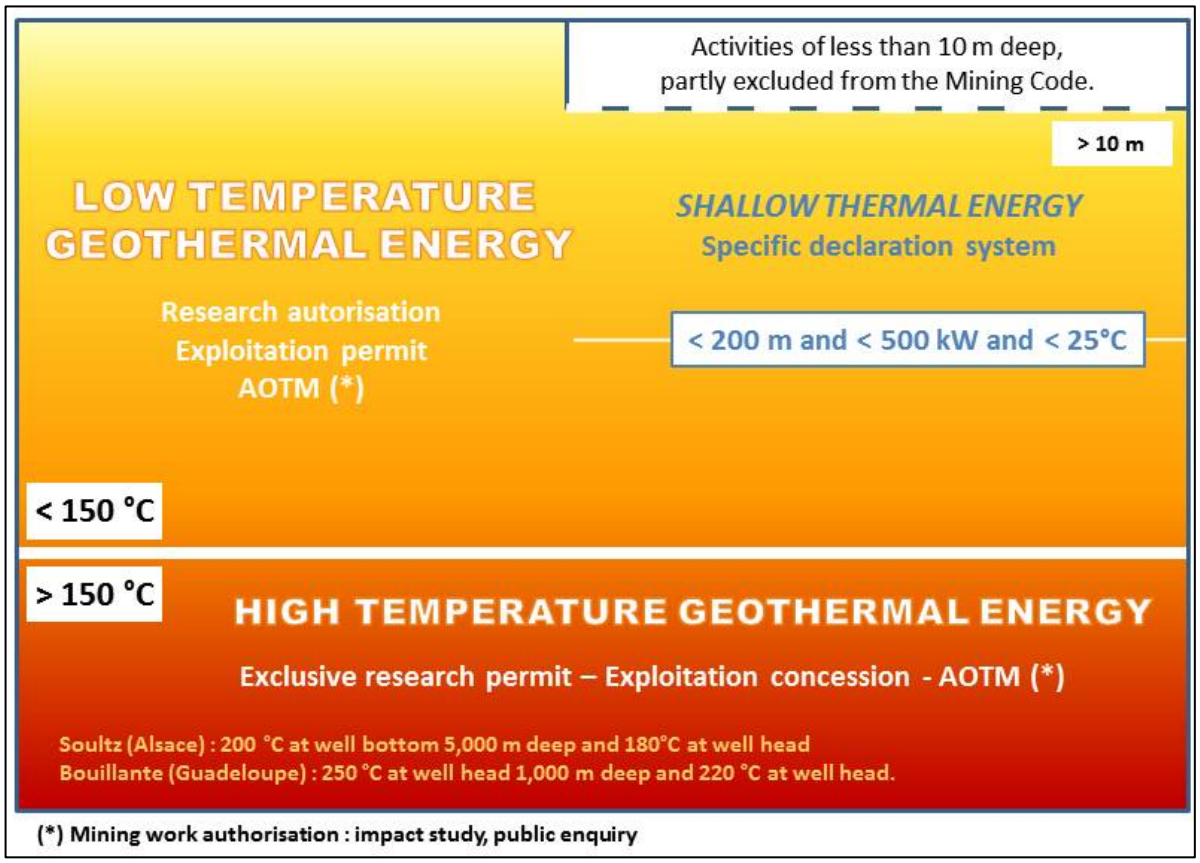

Figure 14: Synthesis of the French regulations for different geothermal exploitations (BRGM, 2015)

About the shallow thermal energy, A new law has been adopted on January 2015 and applications measures orders are now operational since July 2015.

- **general requirements** for shallow geothermal energy activities: conditions relating to the layout of an installation, measures to the implemented on performance, conditions of sale and exploitation as well as the terms of surveillance and maintenance of the installation.

- **qualification of drilling companies** working on shallow geothermal energy systems: obligation to perform drillings by qualified companies (RGE QualiForage)

- **cartography of statutory zones**. (Figure 15) On a national scale, this relates to two maps, one for closed-loop exchangers and one for open-loop exchangers handling zone 10 at 200 m. These maps may be broken down, on a regional level, for 3 depth intervals: 10-50 m, 10-100 m and 10-200 m. They define 3 distinct statutory zones:

  - "green" zone: the declaration system applies;
  - "orange" zone: the declaration system applies whereby the bidder is required to provide a "certificate of compatibility" from an export to perform the project;
  - "red" zone: the geological risks shown on the cartography of the statutory zones exclude the benefit of the simplified administrative system for shallow thermal energy.

- **expert approval** for shallow geothermal energy systems: lays down the terms of approval of experts and the skills required.

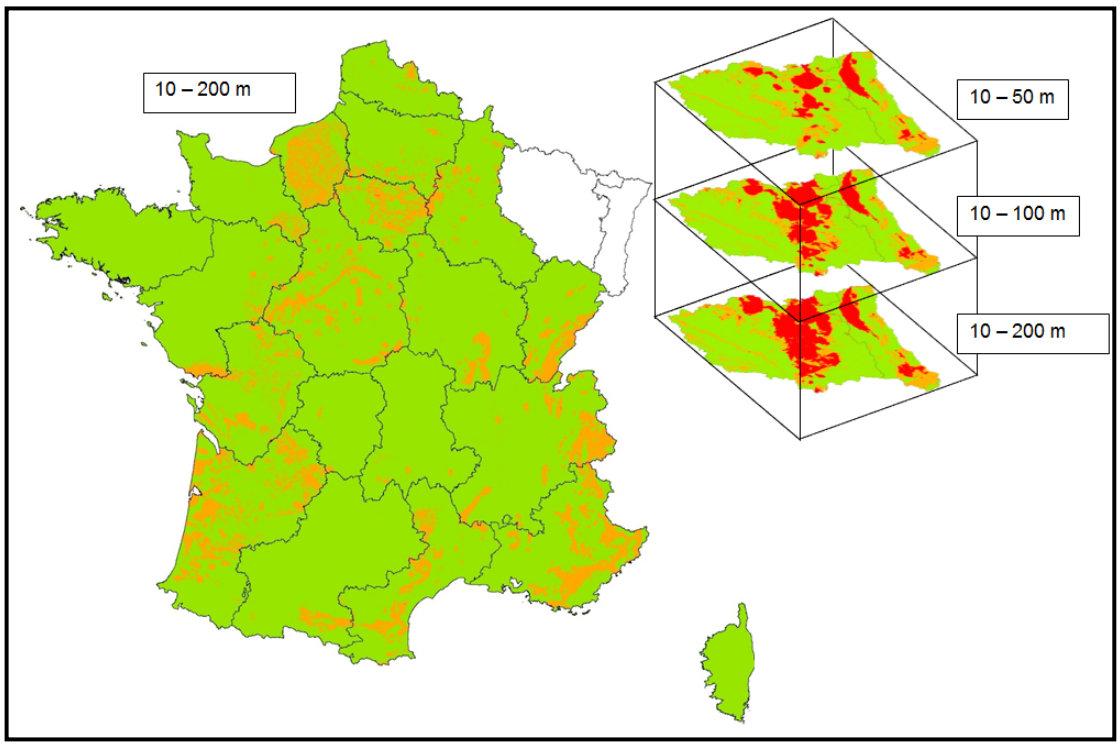

Figure 15: Map of France of statutory zones relating to Shallow geothermal energy for doublets for groundwater, details by depth for regions Lorraine and Alsace (BRGM, 2015)

4. SUPPORT FOR R&D AND INNOVATION

To boost innovation, the French government put in place the "Investments for the Future" program that funds several R&D actions. In 2011, it called for proposals to fund innovative deep geothermal heat and/or power generation demonstration projects. Among the proposals submitted in March 2012, only two about high-temperature geothermal developments were accepted, giving new opportunities to the French industry and opening new perspectives:
- the GEOTREF project in the "Vieux-Habitants area" in Guadeloupe, with the Teranov company as leader ;
- the FONGEOSEC project in the "Pau-Tarbes area" with the Fonroche Géothermie company as leader.

Respectively, these projects have 43 and 82 M€ fundings and started on December 2014 and April 2015.

The main part of the national R&D budget for geothermal energy is managed by ADEME (the French Agency for Environment and Energy). However, some funding can also be associated with a part of the upstream research funded by ANR (national agency for research) and technological innovation funded by FUI (fund for industrial clusters).

After two calls for projects on all research domains in France, 171 Laboratories of Excellence (LabEx) have been awarded. The "G-Eau-Thermie Profonde" Laboratory received its official quality label in March 2012. Based in Alsace, it will focus on deep geothermal energy and receive 33 M€ funding on a 8-year period. It is the first industrial chair of deep geothermal energy, sustained by EDF, Electricité de Strasbourg, Strasbourg University and CNRS which has been inaugurated on April 2014. It illustrates and strengthens the Industry-University partnership engaged in the framework of the "Investments for the Future".

An Institute of Excellence for Carbon-Free Energies, called GeodEnergies, has been also created on July 2015. Based in Orléans, it works on three industrial sectors associated with subsurface levels: CO_2 storage, energy storage and geothermal energy (heat and electricity).
This Scientific Interest Group (GIS) brings together industrial and public research organizations and it benefits from the "Investments for the Future" program to fund industrial research projects.

The objective is to promote the emergence of activities dealing with the underground exploitation and the sustainable management of resources benefiting to carbon-free energies, for example through technological developments and high added values services.

In addition, several national technological clusters have been established to develop collaborative industry and research institute R&D projects, and include:
- Avenia, based in Aquitaine, deals notably with deep geothermal applications ;
- Synergile aims at developing renewable energies in the overseas department ;

- S2E2 (Tours) deals with shallow geothermal and smart buildings.

In June 2014, GEODEEP, the French geothermal Cluster for heat and power, was officially launched. GEODEEP is a cluster of competences in the subsoil and energy sectors that complement each other to cover the entire geothermal value chain and develop full-cycle projects in France and internationally, from subsoil exploration and drilling to power plants and district heating systems through distribution, training, maintenance and technological monitoring.

Carried by AFPG, the cluster comprises a dozen of companies: large energy companies for power construction, for operations and maintenance, and for the integration and development of geothermal energy projects, companies specialized in geothermal energy services, companies specialized in the manufacture of materials and companies for geothermal project integration and development.
Three markets are targeted:
- Geothermal heat and power production in mainland France (Hydrothermal EGS);
- Geothermal power production in the volcanic islands of overseas France;
- Geothermal power production in other volcanic regions in the world.

5. JOBS

Geothermal employment in France is divided into three parts. The first part is about electricity generation and direct uses, EurObeserv'ER in 2015, for 2014 data, estimates 1320 Full Time Equivalents (FTE). In 2015, the activity of those geothermal activities is quite the same, so the employment is stable. The second part is about the geothermal heat pump market included drillers, technical consultants, and administration. It is evaluated at 288 FTE (AFPG, 2016). The third and last part is again for geothermal heat pumps market, but including manufacturing, installation and maintenance of geothermal heat pumps. It is evaluated in 2015 at 712 FTE (AFPG, 2016). It means around 1000 FTE for geothermal heat pumps market and 1320 for direct uses and electricity generation. So French employment for geothermal energy is around 2320 Full Time Equivalents.

6. CONCLUSIONS

During the last 3 years, the existing tool box for geothermal energy deployment has been continuously improved benefiting from a good cooperation between ADEME, BRGM, Ministry of Environment and Caisse des Dépôts et Consignations.

For GSHP, the administrative framework has been revamped and will allow now a fluent development of the technology, in particular for close loop systems. All the actors of the sector (engineering companies, installers and drillers) need to be certified by national label beginning of 2007 to guarantee a top level quality of the installations. However, the sector needs a strong boost in direction of individual housing installations to be competitive with air-air systems (figure 16).

For direct uses, the development is continuous in Ile de France, but new ongoing project are coming also in Aquitaine and Alsace. The sector will also benefits in the next five years from the numerous EGS cogeneration plants to be built in France onshore.

For the electricity generation sector, the work carried out by the professionals under the GEODEEP banner will allow to multiply by 4 the total installed power in at the horizon 2023. The creation of training schools and laboratories of Excellence focused on geothermal research is relatively new and will reinforce the high temperature sector deployment.

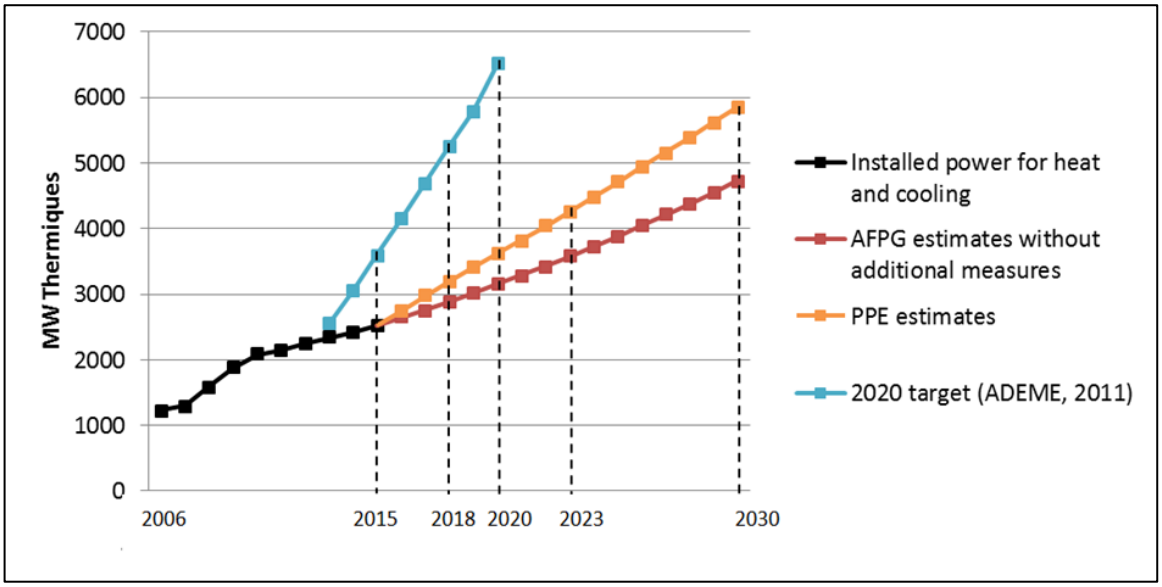

Figure 16: Three scenarios for evolution of installed power for heating and cooling from 2015 to 2030 (AFPG).

REFERENCES

ADEME : Bilan Fonds Chaleur Renouvelables 2009-2014, Relance et nouvelle dynamique (2015), 12 p.

AFPAC : Statistiques des ventes de Pompes à chaleur (P= 2 à 50 kW) en 2015. Lettre d'information n° 28, 1 p., Février 2016

AFPAC : Statistiques des ventes de Pompes à chaleur (P= 2 à 50 kW) en 2014. Lettre d'information n° 18, 1 p., Février 2016

AFPG : Etude du marché français de la géothermie en 2015, (2016), Paris.

CVT ANCRE, ENEA Consulting and BRGM : Les filières de la valorisation énergétique du sous-sol profond. Final report, (2015), 205 p., November 2015.

EurObserv'ER : The State of Renewable Energies in Europe, 2015 edition, December 2015, 210 p.

IRENA : Renewable Energy and Jobs - Annual Review 2016, Abu Dhabi (2016), 300 p.

Observ'ER : Etude sur le marché des installations de pompes à chaleur géothermiques collectives (2016), 64 p.

Observ'ER : Le Baromètre 2015 des énergies renouvelables électriques en France (2016), 168 p.

Vernier, R., Laplaige, Ph., Desplan, A. and Boissavy, Ch.: France Country update, *Proceedings World Geothermal Congress 2015,* 19-25 April 2015 (2015), Melbourne, Australia, 12 p.

WEBSITES

www.geothermie-perspectives.fr/: general geothermal website for France created by ADEME (French Agency for Energy and Environment) and BRGM (French Geological Survey).

www.developpement-durable.gouv.fr/Les-titres-miniers-en-cours-de.html: list of valid high temperature geothermal permits.

http://geothermie-caraibes.org: website of Interreg IV project "Caribbean Geothermal" gathers information about the whole Caribbean region.

www.geothermie-soultz.fr

www.brgm.fr/brgm/le-groupe-brgm/geothermie-bouillante

Tables A-G

Table A: Present and planned geothermal power plants, total numbers

	Geothermal Power Plants		Total Electric Power in the country		Share of geothermal in total electric power generation	
	Capacity (MW_e)	Production (GWh_e/yr)	Capacity (MW_e)	Production (GWh_e/yr)	Capacity (%)	Production (%)
In operation end of 2015 *	18,2	83	130 000	546 000	0,014	0,015
Under construction end of 2015	0					
Total projected by 2018						
Total expected by 2020	25					
In case information on geothermal licenses is available in your country, please specify here the number of licenses in force in 2015 (indicate exploration/exploitation, if applicable):						

* If 2014 numbers need to be used, please identify such numbers using an asterisk

Table B: Existing geothermal power plants, individual sites

Locality	Plant Name	Year commis-sioned	No of units **	Status	Type	Total capacity installed (MW_e)	Total capacity running (MW_e)	2015 pro-duction * (GWh_e/y)
City of Bouillante (Guadeloupe island, French West Indies)	Bouillante	1986 and 2004	2	O	1F and 2F	16,0	15,0	83
Soultz-sous-Forêts (Alsace region)	Soultz-sous-Forêts	2010	1	N	B-ORC	2,2	1,5	0
total						18,2	16,5	83

Key for status:		Key for type:			
O	Operating	D	Dry Steam	B-ORC	Binary (ORC)
N	Not operating (temporarily)	1F	Single Flash	B-Kal	Binary (Kalina)
		2F	Double Flash	O	Other
R	Retired				

* If 2014 numbers need to be used, please identify such numbers using an asterisk

** In case the plant applies re-injection, please indicate with (RI) in this column after number of power generation units

Explanation to tables C, D1 and D2: 'Geothermal district heating or district cooling' (Geothermal DH plants) is defined as the use of one or more production fields as sources of heat to supply thermal energy through a network to multiple buildings or sites, for the use of space or process heating or cooling, including associated domestic hot water supply. If greenhouses, spas or any other category is among the consumers supplied from such network, it should be counted as district heating and not within the category of the individual consumer. In case heat pumps are applied in any part of such a network, the also should be reported as district heating and not as geothermal heat pumps. An exception is for distribution networks from shallow geothermal sources supplying low-temperature water to heat pumps in individual buildings; systems of this kind should be reported in table E. For table D2, please give information on large systems only (>500 KW_{th}); installations with geothermal source temperatures <25 °C and depth <400 m should be reported in table E.

Table C: Present and planned geothermal district heating (DH) plants and other direct uses, total numbers

	Geothermal DH plants		Geothermal heat in agriculture and industry		Geothermal heat for individual buildings		Geothermal heat in balneology and other **	
	Capacity (MW_{th})	Production (GWh_{th}/yr)	Capacity (MW_{th})	Production (GWh_{th}/yr)	Capacity (MW_{th})	Production (GWh_{th}/yr)	Capacity (MW_{th})	Production (GWh_{th}/yr)
In operation end of 2015 *	456	1175		110		0		21
Under construction end 2015	86		24		0		0	
Total projected by 2018	530		30					
Total expected by 2023	790		30					

* If 2014 numbers need to be used, please identify such numbers using an asterisk

** Note: spas and pool are difficult to estimate and are often over-estimated. For calculations of energy use in the pools, be sure to use the inflow and outflow temperature and not the spring or well temperature (unless it is the same as the inflow temperature) for calculating the energy parameters, as some pool need to have the geothermal water cooled before using it in the pools.

Table D1: Existing geothermal district heating (DH) plants, individual sites

Locality	Plant Name	Year commis-sioned	CHP **	Cooling ***	Geoth. capacity installed (MW_{th})	Geoth. 2015 production * (MW_{th}/y)	Total 2015 production * (MW_{th}/y)	Geoth. share in total prod. (%)
Ile de France (75)	Paris Nord-Est (CPCU)	2010	N	O	6,5	8777	20457	43%
IDF (75)	Paris Tour Mirabeau Cristal	1989	N	O	3,19	3712*	7424*	50%
IDF (75)	Paris Batignolles	2016	N	N	5	0	0	
IDF (77)	Chelles	1987	N	N	7,4	29488	52913	56%
IDF (77)	Coulommiers	1981	N	N	11,3	31326	32118	98%
IDF (77)	La Mée sur Seine	1978	N	N	10,8	46395	58867	79%
IDF (77)	Lognes-Torcy (Val Maubuée)	2012	N	N	13,5	41339	48363	85%

IDF (77)	Meaux Beauval Collinet (8 wells)	1983	N	N	14	79739	86108	93%
IDF (77)	Meaux Hopital	1983	N	N	5,3	28150	39334	72%
IDF (77)	Melun l'Almont	1969	N	N	9	55721	78976	71%
IDF (77)	Val d'Europe, Village Nature	2016	N	N	19,5	0	0	
IDF (91)	Epinay sous Sénart	1984	N	N	9,8	40000*	50000*	80%
IDF (91)	Montgeron	1981	N	N	7	10000*	17000*	59%
IDF (91)	Orly airport	2010	N	N	8	35000*	40000*	88%
IDF (91)	Ris-Orangis	1983	N	N	4,9	12991	18445	70%
IDF (91)	Vigneux-sur-Seine/ ZUP Croix Blanche	1985	N	N	7	8096	36497	22%
IDF (92)	Bagneux	2016	N	N	10	0	0	
IDF (92)	Issy-les-Moulineaux (Albian)	2013	N	N	5	3480*	5800*	60%
IDF (92)	Plessis-Robinson (Albian)	2013	N	O	5,7	10440*	17400*	60%
IDF (93)	Blanc-Mesnil Nord	1983	N	N	4,13	0	24531	0%
IDF (93)	Clichy-sous-Bois	1982	N	N	2,5	definitively stop	definitively stop	
IDF (93)	La Courneuve Nord	1983	N	N	6	productor well stop in april 2016	29625	
IDF (93)	La Courneuve Sud	1982	N	N	1,8	5268	26394	20%
IDF (93)	Neuilly-sur-Marne	2013	N	N	9,4	14558	41786	35%
IDF (93)	Tremblay-en-France	1984	N	N	13,9	32910	50814	65%
IDF (93)	Villepinte	dec. 2015	N	N	18,1	773	40317	2%
IDF (94)	Alfortville	1986	N	N	9,5	43000*	50000*	86%
IDF (94)	Arcueil-Gentilly	oct. 2015	N	N	13,5	3143	16282	19%
IDF (94)	Bonneuil-sur-Marne	1986	N	N	13	28690	35579	81%
IDF (94)	Cachan	1986	N	N	12	50592	62265	81%
IDF (94)	Champigny sur Marne	1985	N	N	14,7	53564	80277	67%
IDF (94)	Chevilly Larue & L'Haÿ les Roses (4 wells)	1985	N	N	24	60000*	73000*	82%
IDF (94)	Créteil	1985	N	N	11,5	58369	291578	20%
IDF (94)	Fresnes	1986	N	N	6	43410	66444	65%
IDF (94)	Ivry	2016	N	N	12,5	0	50831	0%
IDF (94)	Maison Alfort 1	1984	N	N	7,8	37000*	45000*	82%
IDF (94)	Maison Alfort 2	1985	N	N	7,8	21000*	30000*	70%
IDF (94)	Orly 2 et 3 Le Nouvelet (4 wells)	1986	N	N	21	68000*	80000*	85%

IDF (94)	Sucy-en-Brie	1983	N	N	13,5	17165	31946	54%
IDF (94)	Thiais	1986	N	N	11,6	32311	33874	95%
IDF (94)	Villejuif	2016	N	N	10	0	0	
IDF (94)	Villeneuve Saint Georges	1987	N	N	15	25418	47389	54%
IDF (95)	Villiers-le-Bel	1985	N	N	4,6	24555	42545	58%
Aquitaine (33)	Bordeaux Benauge	1981	N	N		400*	400*	100%
Aquitaine (33)	Bordeaux Mériadeck	1981	N	N	2,5	16000*	20000*	80%
Aquitaine (33)	Mérignac Base aérienne 106	1987	N	N	3,4	17000*	20000*	85%
Aquitaine (33)	Mont de Marsan 1	1976	N	N	1,8	16000*	20000*	80%
Aquitaine (33)	Mont de Marsan 2	1984	N	N	0,9			
Aquitaine (33)	Pessac - Saige Formanoir	1984	N	N	6	16200*	20000*	81%
Aquitaine (40)	Hagetmau	1986/ 1991	N	N	0,8	2800*	3200*	88%
Centre (36)	Châteauroux	1986	N	N	4	10600	12700	83%
Charente-Maritime (17)	Jonzac 1	1980	N	N	1,1	5500*	7000*	78%
Charente-Maritime (17)	Jonzac 2	2002	N	N	2	14475	16744	86%
Lorraine (54)	Nancy 2 - Caserne Kellerman	?	N	N	1,7	1900*	2200*	87%
Midi-Pyrénées (31)	Blagnac 1	1975	N	N	2	3200*	4000*	80%
Midi-Pyrénées (31)	Blagnac 2	1981	N	N	3,2	7000*	10000*	70%
Total	56 operations				456,12	1175455	1870629	63%

* If 2014 numbers need to be used, please identify such numbers using an asterisk

** If the geothermal heat used in the DH plant is also used for power production (either in parallel or as a first step with DH using the residual heat in the brine/water), please mark with Y (for yes) or N (for no) in this column.

*** If cold for space cooling in buildings or process cooling is provided from geothermal heat (e.g. by absorption chillers), please mark with Y (for yes) or N (for no) in this column. In case the plant applies re-injection, please indicate with (RI) in this column after Y or N.

Table D2: Existing geothermal direct use other than DH, individual sites

Locality	Plant Name	Year commis-sioned	Cooling **	Geoth. capacity installed (MW_{th})	Total capacity installed (MW_{th})	2012 produc-tion * (MWh_{th}/y)	Geoth. share in total prod. (%)
Midi-Pyrenees (32)	Nogaro	1986	N			18494	
Aquitaine (33)	Bordeaux Pessac Stadium	1985	N			1092	

Aquitaine (33)	Mios-le-Tech	1983	N			21440	
Languedoc-Roussillon (34)	Lodève 1		N			8770	
Languedoc-Roussillon (34)	Lodève 2		N			6280	
Languedoc-Roussillon (34)	Montagnac		N			7850	
Languedoc-Roussillon (34)	Pézenas		N			11576	
Aquitaine (40)	Argelouse / Sore	2001	N			16492	
Aquitaine (40)	Saint Paul lès Dax Sebastopol	1979	N	4,4		13775	
Aquitaine (40)	Saint Paul lès Dax Christus		N			4299	
Lorraine (54)	Lunéville		N			827	
Lorraine (54)	Nancy 1 Thermes		N			3134	
Lorraine (57)	Dieuze		N			5233	
Auvergne (63)	Aigueperse		N			11512	
Alsace (67)	ECOGI	2016	N	24	90	0	27%
total	15 operations					130774	

* If 2014 numbers need to be used, please identify such numbers using an asterisk

** If cold for space cooling in buildings or process cooling is provided from geothermal heat (e.g. by absorption chillers), please mark with Y (for yes) or N (for no) in this column. In case the plant applies re-injection, please indicate with (RI) in this column after Y or N.

Explanation to table E: 'Shallow geothermal' installations are considered as not exceeding a depth of 400 m and (natural) geothermal source temperatures of 25 °C. Installations with geothermal source temperatures >25 °C and depth >400 m should be reported in table D1 or D2, respectively. Distribution networks from shallow geothermal sources supplying low-temperature water to heat pumps in individual buildings are not considered geothermal DH *sensu strictu*, and should be reported in table E also.

Table E: Shallow geothermal energy, ground source heat pumps (GSHP)

	Geothermal Heat Pumps (GSHP), total			New (additional) GSHP in 2015 *		
	Number	Capacity (MW_{th})	Production (GWh_{th}/yr)	Number	Capacity (MW_{th})	Share in new constr. (%)
In operation end of 2015 *	200 000	1800	3060	3700	105,4	53
Projected total by 2018	330 000	2640	4 488			

* If 2014 numbers need to be used, please identify such numbers using an asterisk

Table F: Investment and Employment in geothermal energy

	in 2015 *		Expected in 2018	
	Expenditures ** (million €)	Personnel *** (number)	Expenditures ** (million €)	Personnel *** (number)
Geothermal electric power	25	1320	30	1520
Geothermal direct uses	125		145	
Shallow geothermal	150	1000	170	1150
total	**300**	**2320**	345	2670

* If 2014 numbers need to be used, please identify such numbers using an asterisk

** Expenditures in installation, operation and maintenance, decommissioning

*** Personnel, only direct jobs: Direct jobs – associated with core activities of the geothermal industry – include "jobs created in the manufacturing, delivery, construction, installation, project management and operation and maintenance of the different components of the technology, or power plant, under consideration". For instance, in the geothermal sector, employment created to manufacture or operate turbines is measured as direct jobs.

Table G: Incentives, Information, Education (Not applicable)