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Geothermal Development in Switzerland – the Case of Geneva Canton

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ABSTRACT

The subject of this paper is to present the case of Geneva canton's approach to develop the use of geothermal resources. The specificity of the approach is its integrated embracing of all aspects concerned with geothermal development. A country with no extractive industry past, Switzerland has very little information about its subsurface set up. The challenge of developing geothermal resources started from scratch. Even worse, geothermal is associated with Basel and St Gallen projects, well known in Switzerland for the seismic activity they were responsible for. In Geneva, a canton amongst the 26 of the country, characterized by massive use of fossil fuel for building heating, and high heating needs density, the option of using geothermal resources to reach the energy transition goals has been identified years ago (Geothermal potential of Geneva Canton, 2011). The government officially launched the GEothermie2020 program in 2013, with the aim to massively and sustainably develop geothermal resources in Geneva. The two main aspects that define the program are:

- A public led approach, where the administration (geological and energy offices mainly) pilots the implementation and the progress, and the public held utility company (Services industriels de Genève, SIG) is in charge of financing and putting the plans into actions;

- A holistic approach, where not only exploration of the geothermal resources is covered, but all aspects that will eventually result in the program's ultimate goal: regulation, environment and sustainability, cross border cooperation, communication and public acceptance, data collection, analysis and management, market development and ultimate use of the resources (decentralized heat pump, district heating systems, primary users like agriculture, etc.).

Switzerland political system and culture is characterized by systematic use of direct democracy. As such, the public's interest in societal matters is high, and population expectations in terms of information and public debates can strongly influence policies decisions making. The GEothermie2020 program was driven from day one by these considerations, and presents an interesting example of agility, collaboration, and progressive de-risking of the use of geothermal resources, to eventually grant success to the development of that resource.

1. INTRODUCTION

As a country, Switzerland presents a number of specificities, in terms of political and administrative organizations, that lead to empowered local communities and local governments. After a brief overview of those specificities, and the local context of geothermal resources development, the specific case of how the development of geothermal resources is being tackled by the Geneva state will be presented. In Geneva, the heat demand sector has been identified as a target to fulfil the CO_2 emission reduction objectives of the energy and environmental transition: heat demand decrease, replacement of imported fossil fuel by local, renewable sources of energy, development of adapted heat distribution infrastructures. Geothermal resources have been formally identified in 2011 as a potentially significant contributor to those objectives. The GEothermie2020 program, led by the state, in collaboration with its public utility provider SIG, has been developed as an integrated approach to kick-start the development of geothermal energy use. The 9 strategic axis of the program will be described, with relevant examples, demonstrating the holistic approach adopted.

2. BACKGROUND AND GENERAL CONTEXT

2.1 Switzerland Organization

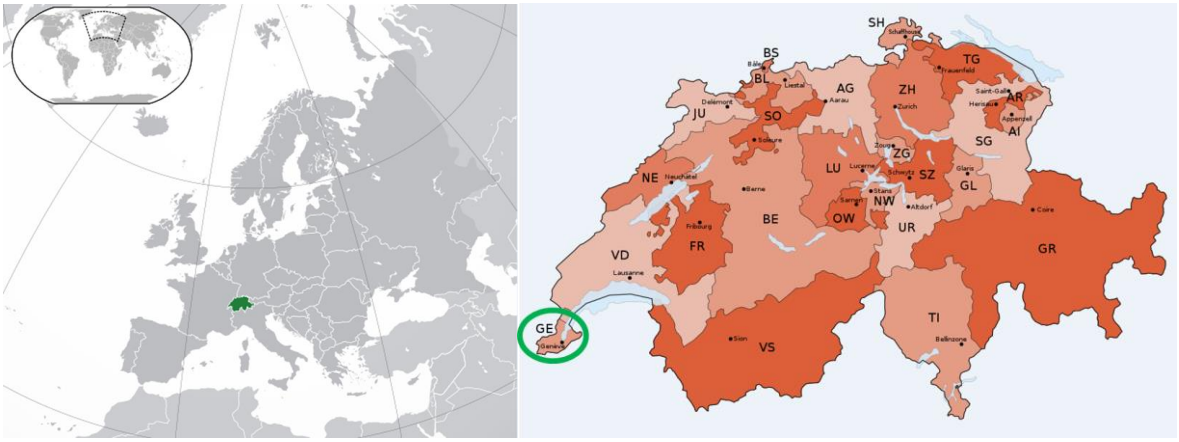
2.1.1 History and Political Organization

The country is constituted of an aggregation of states ("cantons"), 26 in total. The foundation of the country was started by 3 cantons in 1291, cantons and city-states joining gradually through alliances and treaties. The Republic and canton of Geneva joined-in in 1815 and the first federal constitution of the Confederation was eventually adopted in 1848. The federal state is in charge of cross-canton policies like army or trade organization; however, most of the policies are decided, within the guidelines of federal laws and the constitution, at cantonal level, with the cantons being responsible for implementation. Energy and environmental policies are amongst those. As such, the 2018 energy law approved by the voters at federal level in 2017 sets targets for 2050 in terms of energy consumption decrease, renewable energy production increase and nuclear phase-out. This law, along with the CO_2 reduction law updated at the same time, offers the framework in which the cantons have to regulate in order to reach

those targets; as well, the passing of such laws allows the development of subsidy schemes from the federal state to support and kick-start projects along those principles.

From a democratic organization stand-point, Switzerland particularity is that all but one of the executive body in the country is elected by direct elections: all voters are called to elect their local municipalities, cantonal and federal representatives. Only the "Conseil Federal" – the 7 federal state executive members- is not elected directly, but by the federal assembly (parliament and senate). The Swiss also have two powerful means of direct influence on the political decisions of the country at each political level: referendum and popular initiative. Under certain conditions (notably: minimum number of signatures collected within a certain time frame), laws can be contested and suggestions can be submitted for voting. As such, the people of Switzerland are very much used to being consulted, and of being active citizens in the political decisions of the country at every administrative level (local, state, and federal levels).

2.1.2 Geography and Geology



Figures 1 (left) and 2 (right): Location of Switzerland (green) in Europe (dark grey); the Swiss cantons, Geneva canton location (green circle).

Switzerland is located in Western Europe (Figure 1). A rather small country -41,285 km^2, it is surrounded by France, Italy, Lichtenstein, Austria and Germany, and has no access to the sea. The country is characterized by three, mainly east-west trending geographical and geological bodies: The Alps, the Plateau and the Jura (Figure 3).

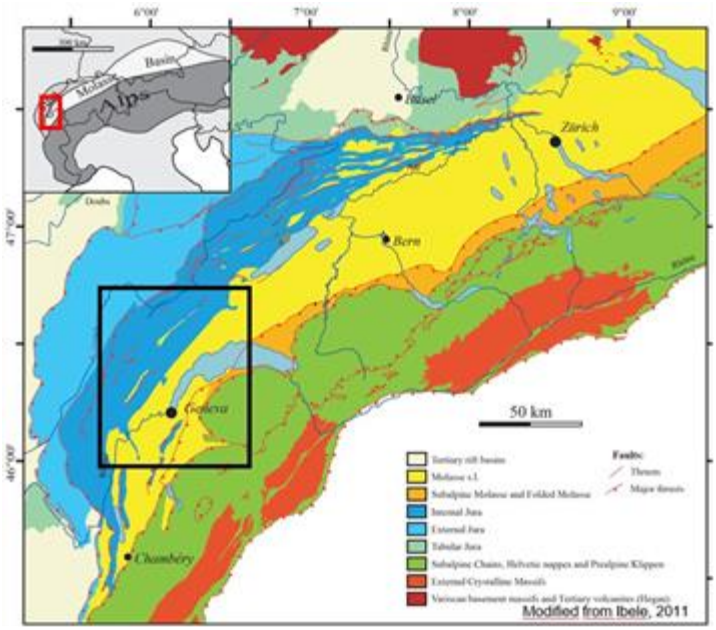


Figure 3: Switzerland geological context, highlighting Geneva area (black square).

Switzerland has little information about its subsurface as it has no extractive industry history. Compared to near-by countries like France, Germany or the Netherland, who have been exploiting mines and oil and gas reservoirs, Switzerland is a virgin province in terms of subsurface exploration. In Geneva canton, the main geological formations that can be found are Quaternary formations from fluvio-glacial depositional environment; Cretaceous and Upper Jurassic formations, mainly limestones from shore-face marine depositional environment; with regressive trend into deeper marine environment limestones in middle and lower Jurassic.

The tectonic history of the Geneva basin has been prone to the development of multiple faulting events, the latest one being a compressive regime associated with the rise of the Alps mountain range. The faults, and the occurrence of brittle geological formations such as limestones, are an interesting target when looking for naturally fractured reservoirs, potentially prone to geothermal fluid circulations.

2.1.3 Geothermal Setting

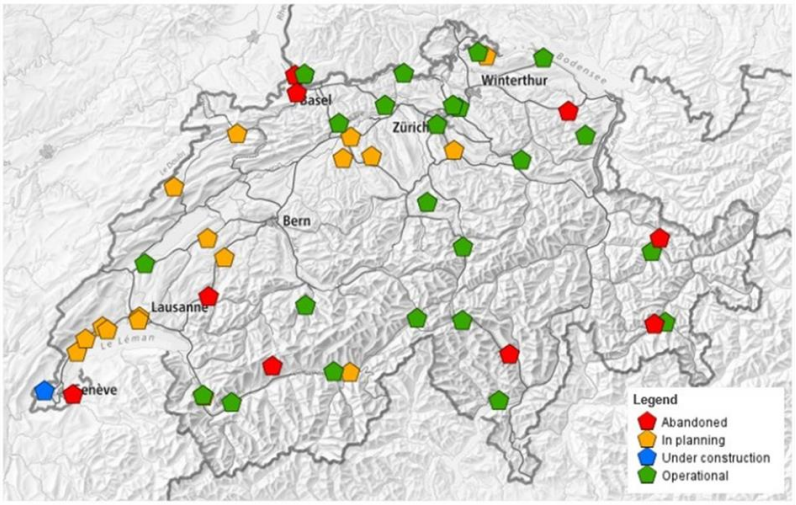


Figure 4: Geothermal projects in Switzerland. Source: Swiss Confederation.

The geothermal gradient is overall rather average (range 30-35 °C/km) with a few anomalies historically identified as the location of hot springs development, like Yverdon-les-Bains or Lavey-les-Bains.

Few projects in the past have looked into developing geothermal resources (Figure 4). A successful one is the exploitation of geothermal resources for district heating in the city of Riehen (Faessler, J. & Lachal, B., 2017) where two 1.6 km deep wells deliver 25 liter/second at 66 °C. It represents a 3.7 MW heat installation connected to a large district heating. About 30 % of the 21,000 inhabitants are deserved by this network.

The attempt to develop deep geothermal resources for electricity and co-generated heat so far has not been successful. The Basel deep geothermal well was initially drilled to a depth of about 5 km into the basement. The plan was then to stimulate the well by mean of high-pressure water injection, in order to develop a fractured network aimed at circulating the injected water for heating up, then producing it back to surface and extracting the heat primarily for electricity production. However, seismicity was experienced, and the project had to be halted, then eventually stopped. The seismicity experienced and the damage encountered by numerous buildings and public infrastructure resulted in the development of hostile response from the population towards geothermal projects.

The second example attempt at developing deep geothermal project was in St-Gallen. There, the well was aimed at approaching a faulted zone in order to exploit the naturally fractured reservoir. However, gas was encountered and the well experienced a blow-up. After controlling the gas surge, the well was suspended. However, it is rather relevant that despite the tragic events, the population was in majority favorable to continue the project. It was halted for operational and technical concerns more than for a lack of support of the near-by community.

2.2 Geneva Canton

2.2.1 Context

Geneva is the west-most canton of Switzerland, located at the tip of the Geneva Lake (Lac Leman) (figure 2). It is mainly surrounded by France and lays flat between the Jura mountain range and another local famous high: the Saleve. It is constituted of 45 municipalities with the main one being the city of Geneva. With a population of c. half a million and an area of about 280 km^2, it is the second most densely populated canton in Switzerland.

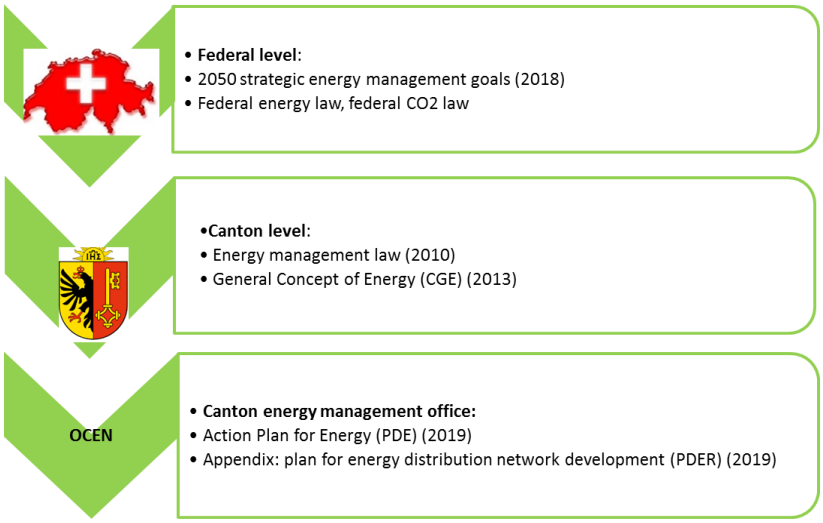


Figure 5: Legal context, energy policies.

In Geneva, the energy law was initially passed in 1986, the last revision occurred in 2010. In its first article, it explicitly states the goals of a rational, sustainable use of energy, and the development of local and renewable energy resources. As per the energy law, a General Concept of Energy ("Conception générale de l'énergie" CGE) was proposed and approved by the parliament in 2013 (Figure 5). This one sets targets for energy consumption use and greenhouse gas emission reduction, following the 2000 Watt society targets (2000 W per person per year, 1ton CO_2 equ. per person per year). Then in 2018-2019, an updated action plan ("Plan directeur de l'énergie", PDE) was put together by the administration to come up with a strategy to reach the objectives of the CGE (Figure 6). This plan, ultimately approved by the Geneva ministers, is organized along 5 main principles:

- Reduction and optimization of energy use;
- Development of local, renewable energy resources;
- Development of infrastructures aimed at exploiting these local resources;
- Support for electric vehicles and electric mobility;
- Development of the "smart-city".

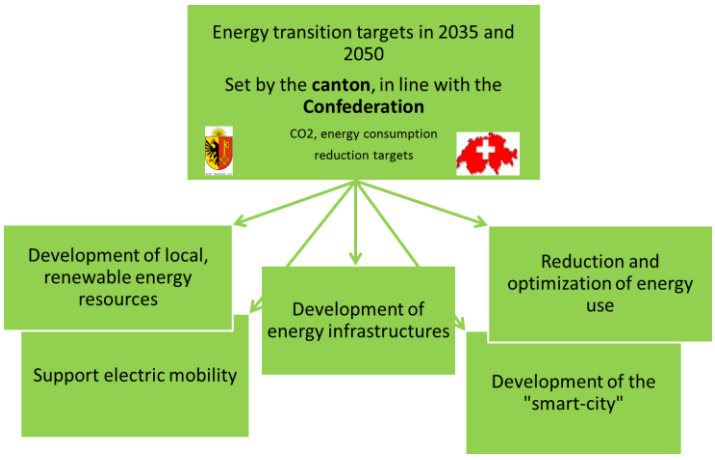


Figure 6: Action plan for energy context and objectives (PDE).

Although the cantonal energy policies office is responsible for kick-starting the projects, it comes obvious that energy transition targets have a direct impact on other policies, amongst which environmental policies, clean air policies, and climate policies.

An appendix to the PDE, the plan for energy distribution network developments (PDER) comes up with a merit order of energy resources to be used in district heating networks: heat waste and geothermal for direct heat use come respectively first and second.

Another important regulation to mention with impact on the geothermal resources is the subsurface resources management law, passed in 2017 and replacing the old mining law. Noticeably, the law states that the subsurface resources belong to the state,

including geothermal resources. The sound management of the subsurface resources is a state's responsibility. The legal framework for the application of the law is under writing and will give guidelines to the exploration and exploitation of the subsurface resources.

2.2.2 Energy Consumption Profile

In Geneva, the majority of energy consumption is characterized by fossil fuel use (Figure 7). The usage is split between mobility, electricity and heating needs. A detailed study (Quiquerez & al., 2016) was conducted based on 2014 data, looking into energy consumption profiles, distribution, and forecast to 2035. Noticeably, the heating needs account for over 50% of the energy consumption. As such, this sector has long been identified as a target for energy consumption reduction and optimization, and a transition to using local, renewable energy resources.

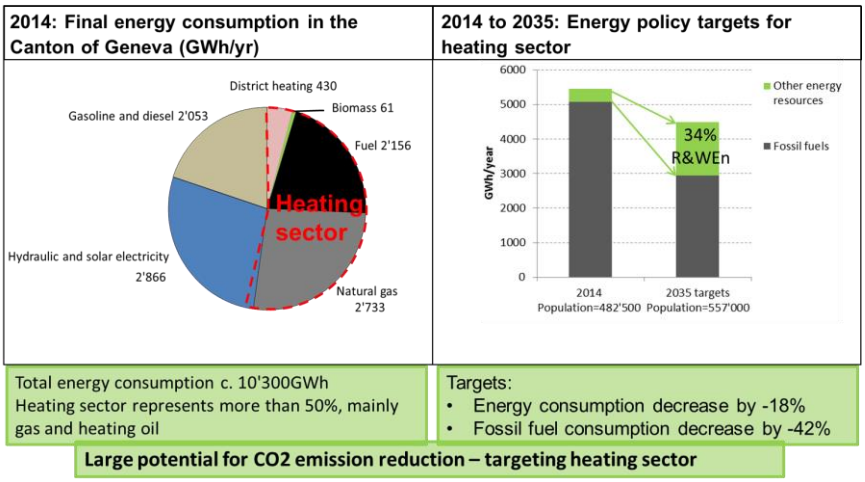


Figure 7: Energy consumption: distribution by sector and forecast for heating.

It should also be noticed that in the Geneva canton more than 70% of the households have a heating needs density higher than 500 MWh per hectare and year (Figure 8). This threshold is often considered as favorable for district heating network development. Despite the efforts in renovation and new buildings standards, the global increase in population means that the heating needs density is forecast to remain high. The transition for local and renewable energy use for heating needs will remain a priority for CO_2 emission reduction. Hence, the canton is, considered to be, a favorable context for district heating network developments, with potential impact on a large majority of households.

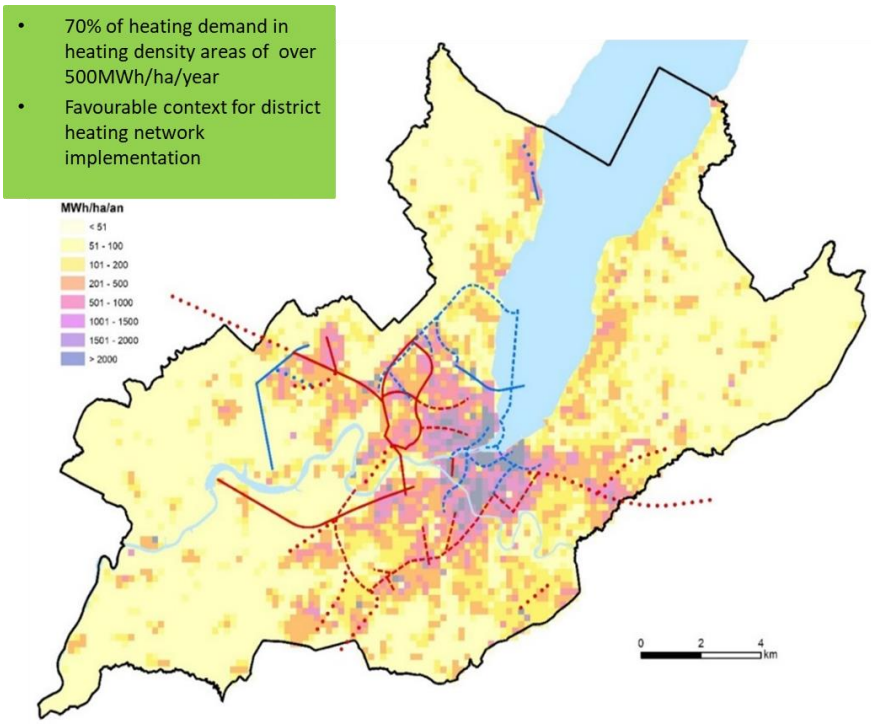


Figure 8: Heat demand distribution, 2014; existing and planned strategic district heating networks (Quiquerez & al., 2016).

2.2.3 Geothermal Resources

The first, preliminary assessment of geothermal resources was launched in 1979 by the geological survey office of the canton. In 1993, a 2.6 km deep geothermal exploration well was drilled in Thônex, a suburb of Geneva city close to the south-eastern border with France, which did not encounter any significant volume of water. Despite the disappointing technical result, the parliament was since then interested in geothermal resources and regularly challenging the decision makers on the potential of such resource. Their questioning covered aspects from using geothermal for electricity production, to the systematic use of geo-structures in new constructions. In 2011, the report on the Geothermal potential of Geneva canton, conducted by the canton energy office and the public utility company, SIG, was published (Geothermal potential of Geneva Canton, 2011). As such, 2011 could be considered as the kick-off year for geothermal development in Geneva. The main conclusions of the report were that a significant potential exists in Geneva, which could contribute massively to the transition from imported, fossil fuel to local, renewable energy source; it recognized however the need for a strong effort in prospection and exploration campaigns, given the lack of subsurface data available; and made the recommendation to develop a dedicated project with the ultimate goal to massively develop geothermal resources in Geneva. From the beginning, the potential of geothermal energy for multiple uses was recognized, not limiting itself to electricity production.

Following the recommendation of the geothermal assessment report, the GEothermie2020 program was launched in 2013, with the initial aim at improving the understanding of geothermal resource setting in the Canton (Figure 9). From the beginning, the Geo2020 program was led by the environmental and energy offices of Geneva state; and its financing and implementation was the responsibility of the local, public-held utility company, SIG. The SIG owners being the state of Geneva, the city of Geneva, and the 44 local councils, one understands how several levels of the administration and the elected bodies have direct implication in the program.

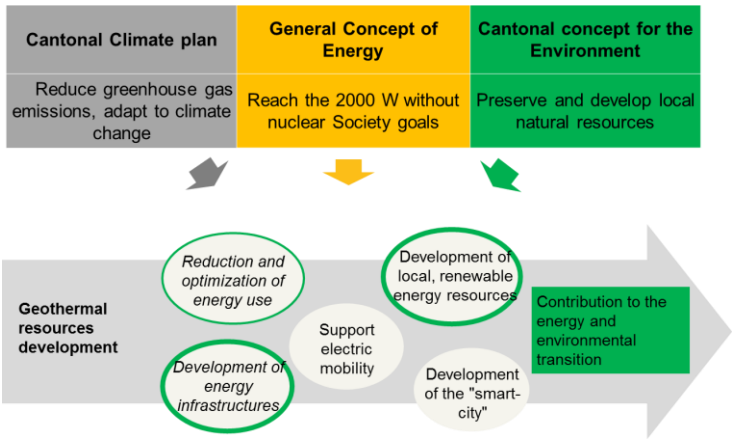


Figure 9: Regulation framework for geothermal resources and its contribution to the action plan for energy objectives

3. THE GEOTHERMIE 2020 PROGRAM

The specificity of the GEothermie2020 (GEo2020) program is its holistic approach to the development of geothermal resources and its optimized contribution to the energy use in Geneva. The "daffodil diagram" (fig. 10) represents the different strategic axis of the program: governance, legal framework, communication, cross-border coordination, environment and sustainability, resource characterization, data management, energy planning, development of the sector (value chain).

Figure 10: The 9 strategic axis of the GEothermie2020 program.

3.1 Governance

The project is overlooked by the state department in charge of the territorial development and management (Departement du Territoire, DT), and by the energy transition department of SIG. More specifically, public policies representatives from the environmental office, specifically the geological and underground management office (GESDEC), the energy office (OCEN), and the communication services, as well as geothermal development and district heating network team members of SIG, are involved in the day-to-day sub-projects associated with the strategic axis. The ultimate authority, to whom all members of the different project teams report, is the minister of territorial development.

The piloting of the project is a three members project team from geological office (GESDEC); energy office (OCEN); and SIG (Figure 11). The technical committee is constituted of c. 15 members. An agile approach to project management is followed, which allows for a maximum of flexibility and supports transversal communication and collaborative decision making across the administrative bodies and departments of SIG. Communication amongst the members is promoted; regular meetings ensure that the findings of the several sub-projects can be passed on to the technical committee and discussed amongst its members, who are also involved or in charge of sub-project teams. The program's interest in all aspects related to geothermal development allow for an early identification of potential challenges, which can then be passed over to decision makers, for continuous progress and adjustment of the project.

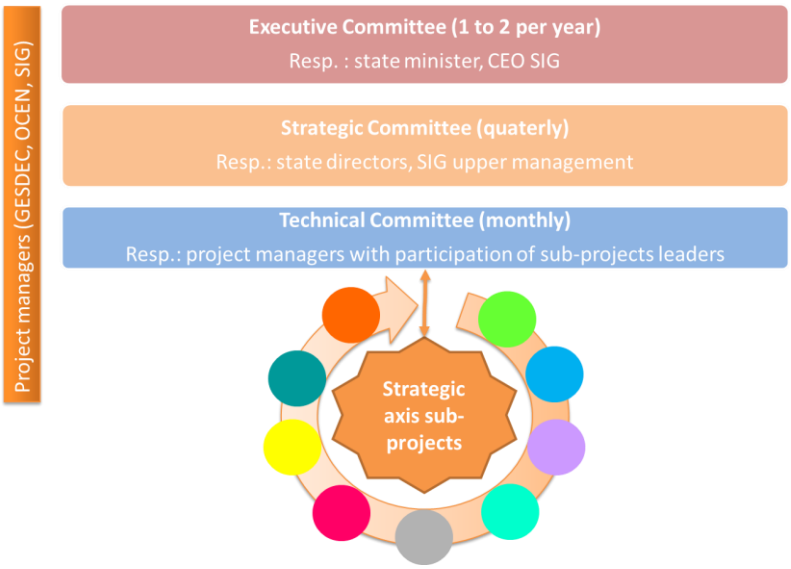


Figure 11: Program GEothermie2020 organizational chart.

3.2 Legal Framework

Two aspects are being treated within this axis.

The first one is regarding the legal framework governing the public policies related to the development of geothermal resources: energy management law, subsurface management law, environmental policies, etc. Each of those comes with a number of application and regulation frameworks, which can be more regularly updated than a law. To that end, the role of the program is to identify regulation gaps or bottlenecks, through real case situations that are experienced by the program in the different sub-projects. As an example, real case situations lately experienced demonstrated the need to regulate where subsurface resources, which are a responsibility of the state, are in the vicinity of district heating network (existing or planed) which can be subject to call for tender, unless specifically stated as being a strategic network.

The second aspect of the legal framework axis is related to the program itself. The collaboration between the state and the SIG is regulated, in particular since SIG is in charge of the investments in its role as a public utility service. As such, a number of tasks are agreed and quantified. The future role of the program, which was defined initially as a transition project, is also discussed as it should ultimately become part of a more global organization looking after all aspects of the energy and environmental transition (canton – SIG project GE2050).

3.3 Communication

Communication is a very important strategic axis of the program. In Switzerland, geothermal is rather unknown. The two examples of the Basel operations, where seismicity was experienced and operations had to be stopped and the project cancelled, and the St-Gallen operations, where despite a gas blow-out, local communities would have supported to continue the operations, show how communication around operational aspects is key to the public acceptance.

In Geneva, the communication strategy around the GEo2020 program not only looks after geothermal operations, but has a broader approach, where geothermal projects are presented in the global context of energy and environmental transitions. Geothermal has a significant role to play and will contribute to the canton becoming greener.

A communication strategy document sets the roles and responsibilities of the institutional communication (the canton) and the operational communication (SIG). Several targeted publics have been identified: the general public, the local councils, the universities and research institutes, the professional organizations, the NGO's, the media, the cross-border institutions. Internal communication towards the other offices that have an interest into geothermal is also considered, like the city planners and building developers. A communication officer from the state is specifically appointed for the GEo2020 program, and regularly attends the project meetings. The goals of the communication are to inform, involve, create awareness, create enthusiasm, help the developers of projects based on the use of geothermal energy, and bring credibility to the program by communicating on the program's actions. Several communication means are used: public-held conferences, public actions around geothermal operations like drilling of the exploration wells or the future 3D seismic campaign, website, social media, newsletter, and a blog animated by the members of the technical committee.

3.4 Cross-border Coordination

Geneva canton is surrounded over 400 km of its border by France, and to a lesser extent, by Vaud canton. However, geothermal resources and energy needs don't stop at borders, and an axis of the program is dedicated to cross border coordination. Regular meetings are organized between the GEo2020 program representatives and the French local councils, to share experience around resource exploration, future development projects, research projects. As well, it should be noted that the French geothermal association and the Swiss geothermal association recently signed a collaboration agreement, acting the will to share learnings and build projects together. However, the coordination also has to take into account different administrative organizations, which is an extra challenge.

3.5 Environment and Sustainability

In 2018, a sustainability assessment of the program was conducted. The goal was to evaluate the sustainability of the program itself. Several key aspects were identified and quantified, then associated with each of the 9 strategic axis of the program. The combination of these factors was then represented by a spider diagram of the sustainability points and the score of the program at the time, for 2014, 2018, and future targets (fig. 12).

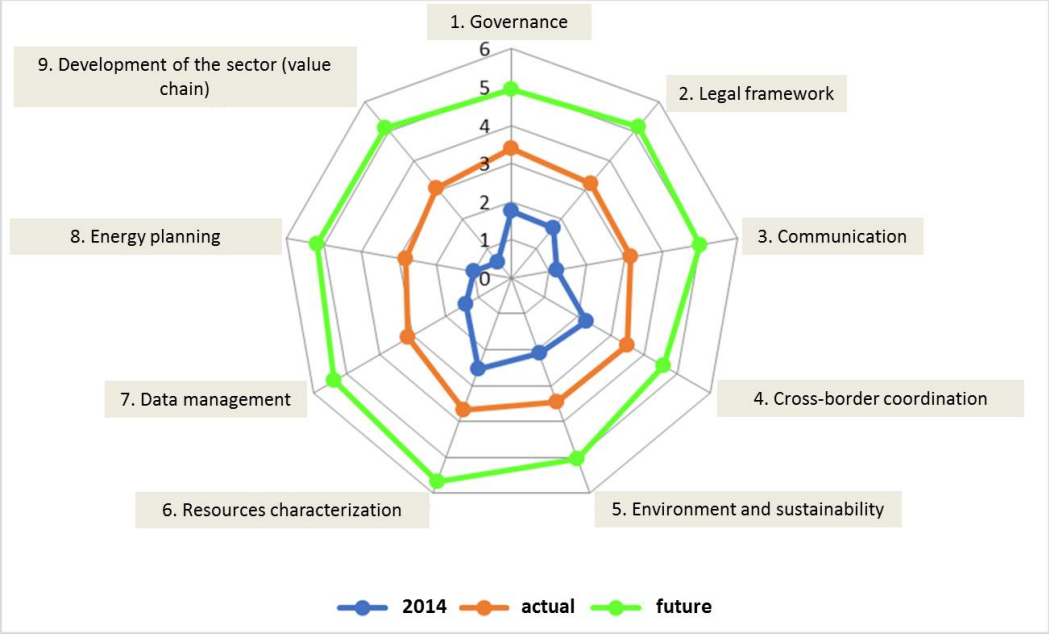


Figure 12: Spider diagram of the GEothermie2020 program sustainability assessment.

For several reasons developed through this paper, geothermal resources have a strong link with environmental policies and ultimately have the potential to significantly contribute to the energy and environmental transition of the canton. Being under the responsibility of the canton, geothermal resources have to be sustainably managed. Underground water resources also have to fulfil the local needs in terms of drinking water, irrigation, and natural environment preservation for fauna and flora. A resources management plan (PGR), owned by the geological and underground management office (GESDEC), allows to combine these different aspects of underground water management, and specifically identifies geothermal resources location, their potential, the risk associated (data white spot; conflict with other resources like drinking water; etc.). It also provides didactic "user manuals" on what geothermal resources are, their possible use, and the administrative procedures to submit demands based on the use of geothermal resources, from exploration to exploitation, monitoring, and abandonment of such projects.

3.6 Resource Characterization

The most visible axis of the program so far has been the resource prospection and exploration. In Geneva, a portfolio based approach has been followed: a step-by-step prospection and exploration campaign is currently on-going under the responsibility of the SIG, covering most of the canton. Noticeably, the de-risking is looking into all geothermal targets from shallow, quaternary aquifers, to deeper, Cretaceous and Jurassic aquifers, driven by the primary aim of direct or indirect heat generation. Indeed, the geological setting of the Geneva basin is not favorable for sole electricity production in the current state of commercial technics available. However, co-generation of electricity alongside a main heat production facility is not ruled out and prospection and exploration data acquisition cover depth range from surface to c. 5500 m depth. The most noticeable operational activities to be mentioned are:

- Shallow aquifers: mapping and hydrogeological evaluation of shallow aquifers, de-risking in white spots area;
- Drilling of first medium depth geothermal exploration well; 744 m (TVD), encountering 33°C water with flow rate of 50 l/sec.
- On-going drilling of second medium depth geothermal exploration well, targeted final depth of 1130 m (TVD), expected final temperature of c. 48°C.
- Planned for summer 2020: 3D geophysical acquisition campaign covering 180 km^2, primarily targeting the areas within a buffer zone of c. 3 km around the main district heating networks (existing and planned), with the aim to also include the strategic high heating needs areas in nearby France.

3.7 Data Management

Data management was identified at an early stage as being a critical issue. As the program makes progress, the amount of raw data being acquired, data interpretations and studies increases tremendously. The technical committee soon identified the need to make those data available for all, through a shared GIS based tool. The maps bring together various sources of information, such as quaternary aquifers contours, wells location and status, heat distribution networks, areas for aquifer studies, location of urban development projects involving geothermal aspects, etc. This geo-portal is primarily for restricted access because of the confidentiality of the data and the on-going interpretations. However, some of the maps will eventually be made publicly available, as a source of information for opportunity assessment through geo-analysis. It will also be compulsory to make publicly available the data acquired through subsidy schemes from the federal government.

In parallel to the work dedicated to the program's data management, other data management projects are also linked, like the development of a geo-analysis tool for subsurface assessment and planning by the geological and subsurface management state office (PGR, see "environment and sustainability" section), the linking with several databases and tools used for energy transition policies, and the integration with the databases and monitoring performed by the SIG (state – SIG project GE2050).

3.8 Energy Planning

The, portfolio based, approach of the resource evaluation from the subsurface standpoint is linked with the will to massively develop and make optimal use of geothermal resources over the whole canton. Geothermal can be used for local heating and cooling needs, at the individual house scale, through open systems with surface heat exchanger or closed systems within geo-structures; up to the drilling of deep geothermal doublets to feed into district heating networks or to supply high demand consumers, like greenhouse farmers.

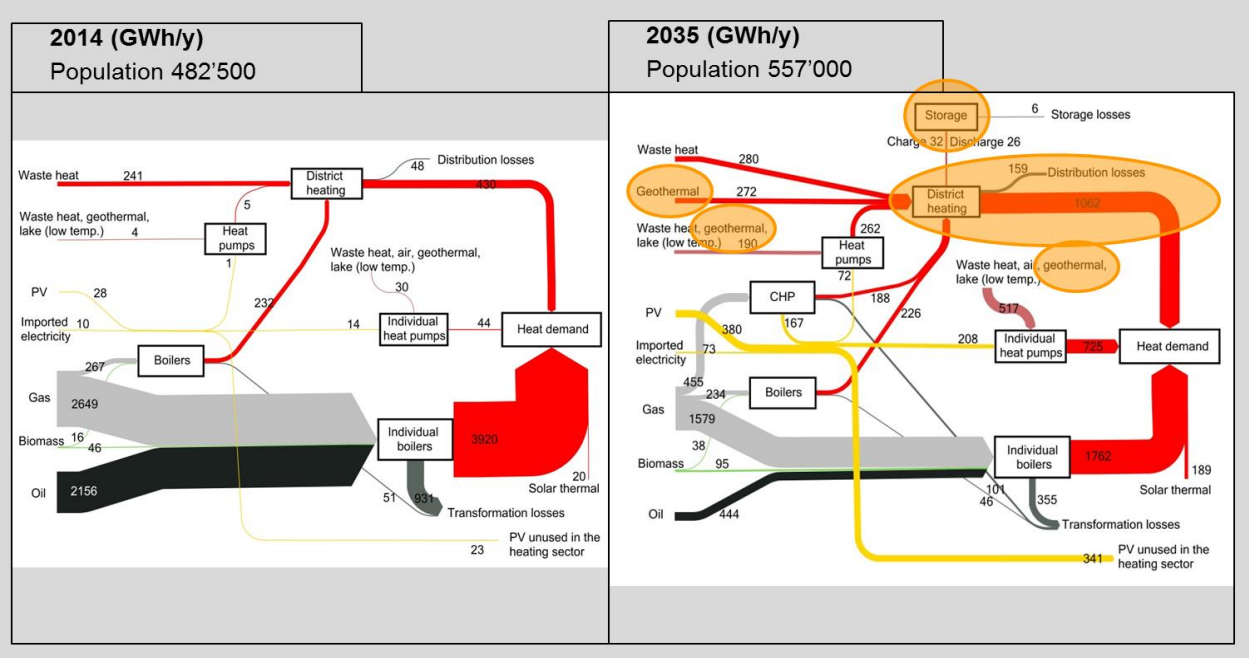


Figure 13: 2014 situation and forecast scenario for 2035 showing geothermal energy integration in the Geneva canton energy use (Quiquerez & al., 2016).

The energy planning axis works on actual situations to bring together resources and energy needs. When significant geothermal resources are identified, in parallel with the assessment of heating and cooling needs for a specific area or project, the challenges faced are to bring together multiple actors, with multiple demands, each following their specific agenda. The inherent silos-like organization of the administration means that a robust coordination effort is necessary between the geological management office (GESDEC) and the energy management office (OCEN), as well as with the public utility actor, SIG.

SIG has a dual role to play:

- Regarding the geothermal resources management, it acts on behalf of the state in areas of identified risks or strategic resources to bring to surface and monitor the resource usage.
- Regarding the development of district heating networks, it is in charge of developing the main strategic district heating networks (described in the PDER), but is under open-market regulation (call for tender base) in the case of non-strategic heating network developments.

The complexity of the situation between in one hand, the resource management from the subsurface stand-point; and in the other hand, the optimized use of all renewable resources available, in addition to geothermal, can be tested through real life cases that are brought to the energy planning group of the Geo2020 program. This group allows identifying these complexities and bringing them for discussions and eventual call for decisions from the decision makers of both the state and the SIG.

3.9 Development of the Sector (Value Chain)

The final axis is looking into developing local knowledge and skills in relation to geothermal projects, from the subsurface evaluation to the use of geothermal as energy resource. Collaboration exists with the local universities and schools of engineers like UniGE or HEPIA. Numerous thesis and papers have been sponsored and are on-going in various domains related to geothermal, from geological studies to the social impact of geothermal projects. Most recently, a collaboration agreement on a data exchange basis was signed with the CERN (European Organization for Nuclear Research) and the academic partners. Specialists are being brought from abroad, and work together with local companies, to share experience and increase the local competencies. Finally, GEo2020 has been the leader in testing a first "REX PEX" experience: return of experience (REX) and sharing of experience (PEX), on the subject of the challenges faced by mid-depth geothermal wells drilling. This platform brought together administrations from Geneva, Vaud, and Valais cantons; local companies involved in drilling and operations; and utility companies.

The success of that first trial was recognized by the confederation at the federal energy management office (OFEN). The Swiss geothermal association has been identified to host such REX PEX subjects, with the aim to run two to four such exercises per year, over the next 5 years.

4. CONCLUSION

Switzerland is a country with a history and culture of strong implication of the citizens in public policies, at all administrative levels (municipalities, state, federal levels). The challenge of the energy and environmental transition, driven by the CO_2 emissions reduction, is amongst those.

From an energy consumption profile, the state of Geneva is characterized by an energy consumption profile mostly covered by imported fossil fuel, of which over 50% is for heat demand. It is also characterized by high heat demand density. As such, the heat sector was identified as a key target for energy transition and development of adapted infrastructures (district heating networks).

In Geneva, the potential to develop and use geothermal resources, alongside other renewable resources, was formally identified by the state in 2011. In 2018, geothermal energy was put second in the merit order to provide heat source through district heating networks of the canton (after waste heat). The development of geothermal resources presents specific challenges:

- Located in the subsurface, geothermal reservoirs have an inherent risk associated, which has to be taken into account alongside the whole life cycle of any subsurface based project; in Geneva, the state is responsible for the sustainable use of subsurface resources.

- At such immature stage, an integrated approach covering the full life cycle of geothermal projects, where outputs use are guaranteed, is necessary to carry the risk of exploration and early development; the business models integrating the full life cycle are still immature.

The specificity of the GEothermie2020 approach adopted by the Canton and its public-utility partner, SIG, is to take into account all key factors to make that potential become reality. The GEo2020 program plays the kick-starting role for developing a whole new industry in Geneva. The holistic approach allows identifying and bringing solutions at an early stage to the challenges of geothermal resources development. Geneva, because of its small but densely populated configuration, its demanding citizens, and it readiness to put into actions the ideals of the energy and environmental transition, can be considered as a very inspirational live-lab for other places facing similar challenges.

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