GÉOTHERMIE CARAÏBE 2
PRODUIRE NOTRE ÉLECTRICITÉ AUTREMENT

PROGRAMME INTERREG CARAÏBES

Conception of a methodology guide for the successful environmental integration of geothermal energy power projects in an island and/or a tropical context

October 2015

Volet 1 – T.1.1.

Les partenaires du projet :

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Study realized in the framework of the project Caribbean Geothermic Phase 2

CFG Services and Biotope

with the collaboration **BURGEAP, ISOR and VERKIS**

Les partenaires du projet :

Keywords: Caribbean, islands, geothermal power station, electricity production, environmental and societal integration, methodology guide, impact study, environmental management plan, consultation

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Preamble

The geothermal energy in the Caribbean islands, an environmental challenge

The Lesser Antilles shape a volcanic arc from Saba in the North to Granada in the South. Most of these islands own index of existence of geothermal resources linked to their recent volcanic origin. **Some high-temperature geothermal resources have been enhanced in most of these islands and could be accentuated for the electricity production.**

However, a project of geothermal electricity production can be the cause of **negative effects on this environment** presenting substantial patrimonial interests as well as on the living conditions of populations. It is also **crucial to carry out a both environmental and societal approach of integration in the framework of such projects**. It is about evaluating on one hand, reducing and managing the societal and environmental effects and on the other hand creating a dynamics around this new activity based particularly on the consultation with the local players of the concerned territories.

Since the 90s, the **ADEME (Agency for the Environment and Energy Management)** is involved in the development of geothermal energy in the West Indian. It has supported several projects of exploration in Martinique and Guadeloupe. Fort almost 10 years, it has been one the partners of the Caribbean Geothermic Project supported by the European program INTERREG CARAÏBES. It has funded several environmental studies on the geothermic field of the Roseau Valley in Dominica and on the prospects being exploited in Martinique.

Conscious about the importance of environmental aspects in the success of the projects, the ADEME has wished for promoting a **methodology guide** in order to help for the realization of geothermal electricity production projects of good quality, **totally integrated in the natural and societal environment, which are specific in these tropical and island territories**.

The achievement of this guide is perfectly incorporated within the framework of **Program INTERREG IV – Caribbean Geothermic Phase 2**, whose objective is to prepare the necessary conditions for the successful development of geothermal electricity production projects in the Caribbean islands.

Contents of the guide

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1. Introduction

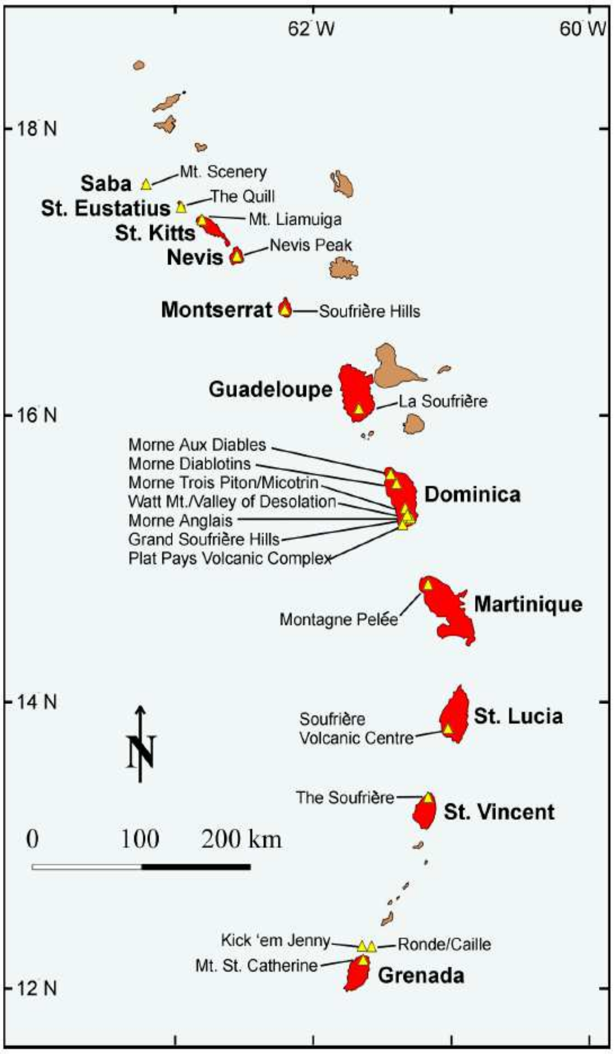
This introductory chapter presents briefly the objectives of this methodology guide, the public to whom it was destined, its content and how using it.

1.1. WHAT ARE THE OBJECTIVES OG THIS GUIDE?

The first objective of this guide is proposing a methodological approach to manage the environmental and societal integration of geothermal electricity production projects in the insular context in the Caribbean islands.

It pursues also providing with some responses to the general questions often came up on these projects, some responses which contribute to a better knowledge and then a better integration of these projects.

This guide has for aim to grant help for the realization of geothermal projects. In the first instance, **it pursues to supervise the realization of new projects of geothermal plants in the Caribbean on blank sites** like in Dominica where the recent exploration drillings have confirmed the existence of a high-temperature reservoir compatible with the electricity production. The preservation of the natural environment particularly rich of this island and the acceptability of such a geothermal project in the Roseau Valley demand an exemplary environmental approach, which will be able to lean on this methodology guide.



The Dominica case is not unique in the Caribbean. Some surface geothermal exploration works and by drilling have been conducted or are ongoing of realization in the islands of Montserrat, of Martinique, of Nevis, of Saint-Vincent (**Erreur ! Référence non valide pour un signet.**). All have the objective to enhance a high-temperature geothermal resource and are susceptible to lead to the new geothermal plants construction. For these islands, such a methodology guide will be also a practical tool and indispensable to succeed the environmental and societal integration of new projects.

Figure 1 : Map of islands shaping the volcanic arc of the Lesser Antilles and localization of active or recent volcanos

Secondly**, this methodology guide can be a diagnostic tool aiming for improving the environmental integration of existing geothermal power stations**. This is the case for example of the power station of Bouillante in Guadeloupe, which has to face up to high environmental constraints linked to the fact that geothermal resource and human establishment are combined there in the same limited space and have to cohabit. This methodology guide can help the different local players (manager, residents, municipality) to find together some solutions facilitating the environmental integration of the existing installations. This is also a tool that can lead the reflection of these different players on the future developments of the exploitation.

1.2. TO WHOM IS ADRESSED THIS GUIDE ?

This guide is created as a practical tool in order to help for the geothermal projects realization in the Caribbean and their integration in their natural and human environment. It is thus addressed to a wide public, specialist or not of the geothermal energy, which is or will be an actor of a geothermal project. This includes the project leaders (industrials, financial backers, territorial collectivities, governments), the designer and producer (design offices, engineering, works companies, administration responsible for the regulation…), and the local players (residents, local associations, municipalities, teachers…).

1.3. HOW DID THIS GUIDE REALIZED ?

The ADEME has entrusted this guide realization to a project team composed with French and Icelander design offices (**CFG Services, Biotope, BURGEAP, ISOR and VERKIS**) working in the field of activity of services and project engineering and having a concrete view of the geothermal energy and of the environmental and societal integration problems. The experts, which have taken part in the redaction of this guide are French and foreign practitioners, which have brought their feedbacks and an expanded view of experienced problems and implemented solutions in the countries where the geothermal electricity production has experienced an important development (Central America, Indonesia, Iceland, Kenya ...). These experiences have been related for this guide in order to do a practical tool.

In order to complete this guide, it is useful to get the **feedback of Costa Rica** in Central America. Indeed this country has developed a real expertise in the environmental and societal integration domain around the geothermal power station of Miravelles, then the ongoing development projects of Las Pailas and of Boriquem, which can serve as an example in many ways. A study mission has allowed to meet all the implicated actors.

The same approach has been undertaken close to the European Economic Interest Grouping « Heat Mining », which exploits the little geothermal power station of **Soultz-Sous-Forêts in Alsace** and which has developed several communication actions to local players (municipality, residents).

Otherwise, in the framework of this guide creation, some surveys has been also carried out in **Martinique and in Guadeloupe** to different interlocutors in order to collect their opinion on the geothermal energy and their expectations concerning this guide.

All this information has been taken into consideration and has largely contributed to the creation of this methodology guide.

1.4. HOW TO READ THIS GUIDE ?

In order to help the reader and several reading levels, this guide has been designed in two distinctive parts: the actual **guide** and a collection of **20 didactic sheets** gathered in appendix.

The Guide part

The guide is composed of 3 parts based on:

- ⇒ The issues presentation;
- ⇒ The presentation of the proposer methodology;
- ⇒ The presentation of societal integration factors.

The first part dedicated to **the issues** presents the aspects of a geothermal plant project pursuing the electricity production and particularly the potential impacts that this type of project involves. It provided also a rapid description of the environmental and societal contexts in the Lesser Antilles islands, volcanic territories particularly favorable to the geothermal resources existence enhanced to produce electricity.

The consideration of all of these things together is the starting point of the reflection on the environmental excellence approach that must be implemented to ensure the good development of a geothermal electricity production project.

The second part proposes a **methodological approach** of societal and environmental integration for the geothermal electricity production projects. The process is based on different realization steps of this type of projects and pursues to provide with some recommendations relying on the feedbacks.

Finally a third and last part insists particularly on the **societal aspects** and on the communication and participation actions around a geothermal electricity production project; determining components in the integration of such a project within a concerned territory and its population.

The redaction of this guide relied on among other things some **feedbacks**, which are illustrated as an insert put in different places in the text. Similarly, important aspects and/or specific to geothermal projects have been brought to light as inserts in order to draw the attention of the reader.

The part Sheets

It is **20 didactic sheets** gathered by themes and which are recapped in the Table 1 below and inserted in the appendix 1. Compared to this guide, they bring to the interesting reader in this or that particular aspect of a geothermal plant project, a further information, which want to be firstly informative and accessible for the wider audience.

Sheet
n°X

These sheets can be the starting point of the deeper reflection for the reader and eventually refer to more exhaustive information sources. Thus they can serve as information supports for a project leader wanting to illustrate the presentation of his project for the authorities or the big public. They can also serve as supports or for technical trainings actions to students and all people called for working in relation with geothermal projects.

1.5. USE OF THIS DOCUMENT

The present document constitutes the preliminary version of the methodology Guide that the ADEME want to avoid. It can be considered as a reflection basis in order to reach a proved methodology. As such, it is thus perfectible and constitutes a starting point rather than a definitive result.

Thematic	*n°*	*Sheets titles*
General presentation of geothermal projects destined to the electricity production	1	The geothermal energy and the electricity production: recaps, situational analysis, perspectives
	2	The key phases of a geothermal project and the geological risk problematic
	3	The costs and the fund of geothermal projects including the Clean Development Mechanism (CDM)
The technologies and basic equipment of a geothermal power station	4	The different components of a geothermal power station: well, pipes and separator, turbine-generator unit
	5	The drillings and associated equipment: the different types of wells, the tests and the wells life duration
	6	The different technologies of turbines used by the geothermal energy
	7	The different cooling systems of the geothermal power stations
The geothermal resource exploitation	8	The geothermal resource management (production, reinjection) and renewability
The regulatory aspects of a geothermal project	9	The geothermal energy and the staffs healthcare/ security
	10	The regulation applicable to geothermal projects
The environmental analysis of geothermal projects	11	The impacts studies within a geothermal project: objectives, chronology an requirements specifications
	12	The description of environment initial state around a geothermal project
	13	The environmental management plans applicable to a geothermal project
	14	The landscape integration of different components of a geothermal plant
	15	The dismantling of geothermal power stations and the rehabilitation of the sites
	16	The treatment and recycling sectors of wastes generated by a geothermal project
	17	The H_2S gas emission treatment of a geothermal power station
The communication around a geothermal project	18	The consultation with populations and associations concerned by a geothermal project
	19	The eco-touristic activities development around a geothermal project
The economic consequences	20	The direct and indirect economic consequences of a geothermal project

Table 1 : List of the concerned themes and recap of the 20 didactic sheets accompanying the guide and provided in Appendix 1.

2. The Issues

The choice of environmental excellence

This part offers firstly a short presentation to the reader of the different aspects of a geothermic power station project aimed at the electricity production and particularly the potential effects caused by this type of project.

It is then question of drawing up a quick environmental and societal portrait of the isles of the volcanic arc of Lesser Antilles that are particularly favorable to the existence of geothermic resources reusable for the electricity production.

Taking in count all of these elements is a starting point of how to implement an environmental excellence to assure the good proceedings of a geothermic power station project in this island and tropical context.

2.1. INTRODUCTION OF THIS PART'S CONTENT

The goal of this section entitled « The Issues » is to present to the reader the necessary elements to comprehend the objectives of this methodologic guide. It contains the following chapters:

- **2.2. General statements about geothermal energy**
- **2.3. Environmental and societal impacts linked to a geothermic project**
- **2.4. Environmental interests and sensibilities of the island and/or tropical territories**
- **2.5. Summary of the environmental and societal issues**
- **2.6. Lesser Antilles and geothermal energy: the choice of the environmental excellence**

2.2. GENERAL STATEMENTS ABOUT GEOTHERMIC

2.2.1. Definition of geothermal energy

Geothermal energy refers to both a science that studies the intern thermic phenomena of the globe and industrial processes that aim at exploiting it, to produce electricity and/or heat. The principal segments that can be distinguished according to the temperature of the geothermal resource are:

- **Very low energy**:
  <86°F (<30°C), <948 feet (<300m) deep, used for individual, service sector and residential community heating, with heat pumps;
- **Low energy**:
  <194°F (<90°C), used for urban heating, generally via heat networks, or for the heating of other work types (greenhouses, fish breeding ponds, pools heating…);
- **Middle energy**:
  194-302°F (90-150°C) used for the production of industrial heat or possibly electric heat;
- **High energy**:
  >302°F (>150°C), used for the electricity production and possibly industrial heat.

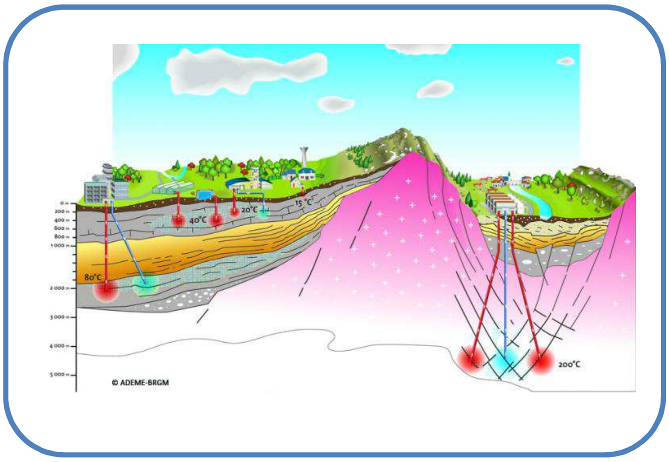


Figure 2: Different forms of geothermal energy from very low energy to high energy.
© Ademe-BRGM.

Currently, the commercial electricity production from geothermal energy is essentially based on the use of geothermal resources of which the temperature is included between **302°F (150°C) and 662°F (350°C)** and having enough fluid production capacities.

Sheet n°1

In the present document, the geothermic segments that are concerned are those of middle energy or high energy and are priority aimed at the production of electricity. This type of project is also qualified sometimes of high energy, high enthalpy or high temperature geothermic project.

2.2.2. Functioning principle of a geothermic power station

Quick review

A brief presentation of the equipment and of the functioning of a geothermic central are given below. For more information, the reader is invited to read the sheets that that come with the guide. Summarily, a geothermic power station includes two distinct groups illustrated on Figure 3.

Sheets n°4 to n°7

⇒ **a set for the production , transportation and reinjection of geothermal fluids after valuation,** and including the wells (or boreholes) located on dedicated platforms, the separators or water / steam pipes;

⇒ **an assembly for the production of electricity** (corresponding to what is commonly called "central" in the strict sense) and including the turbine generator , cooling equipment , and facilities responsible for clearing the energy produced to the mains.

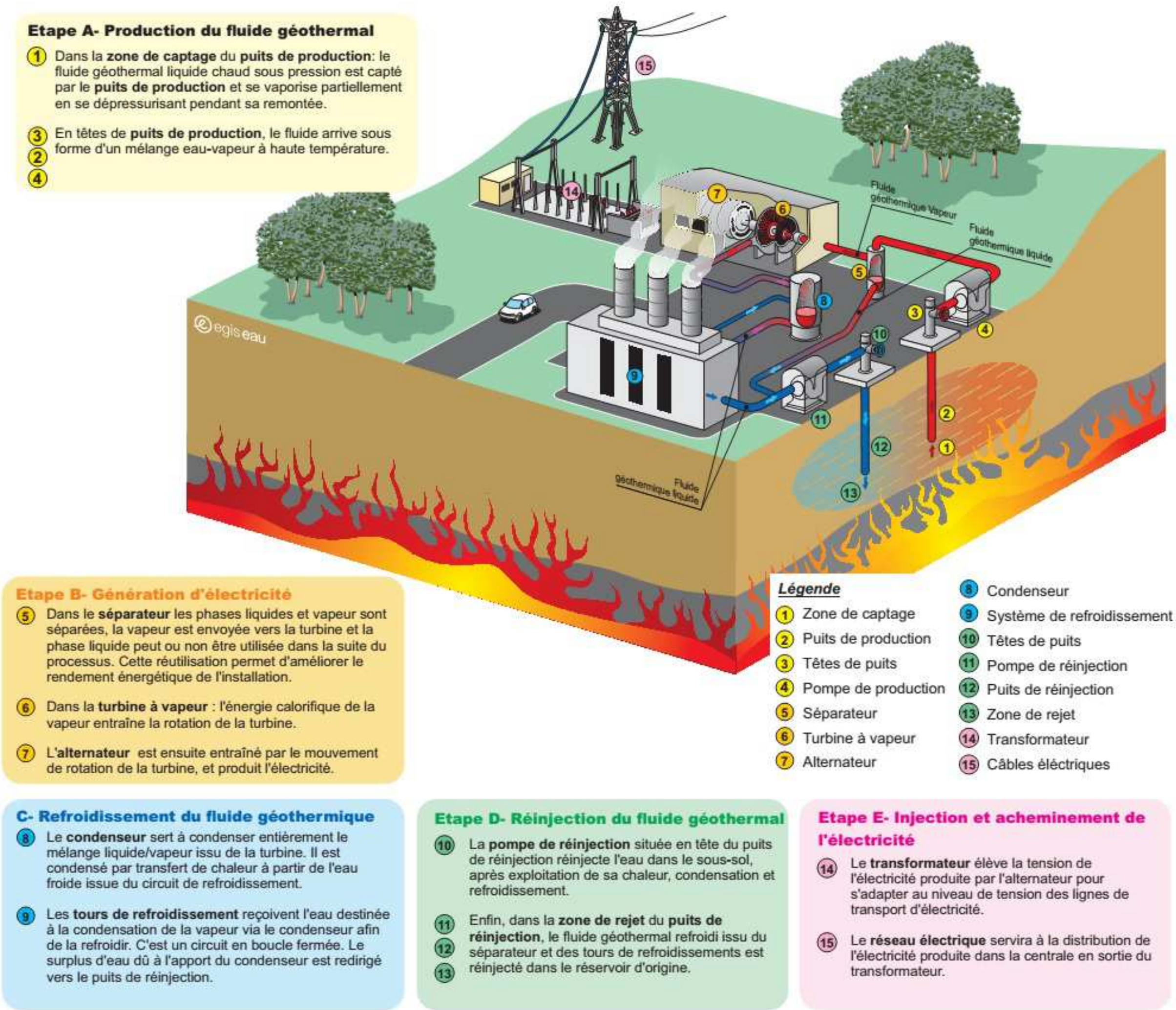


Figure 3: Diagram showing how a geothermic power station works to produce electricity (©Ademe-EGIS Eau).

<u>Diagram translation</u>:

Stage A: Geothermal fluid production.

1. *In the catchment area of the production well: the hot under pressure liquid geothermal fluid is caught by the production well and evaporates partially while depressurising during its raising.*
3. *At the top of the production wells, the fluid arrives as a ware-steam mix at high temperature.*

Stage B: Electricity creation.

5. *In the separator the liquid phases and steam are separated, the steam is sent towards the turbine and the liquid phase can be used or not in the rest of the process. This reuse allows to improve the energetic yield of the installation.*
6. *In the steam turbine: the calorific energy of the steam is then implied by the rotation movement of the turbine, and creates electricity.*

Stage C: Cooling of the geothermal fluid.

8. *The condenser is used to entirely condense the liquid/ steam mix from the turbine. It is condensed by heat transfer from the cold water that comes from the cooling circuit.*
9. *The cooling towers receive water aimed at the condensation of the steam via the condenser to cool it down. It is a closed loop circuit. The extra water due to the input of the condenser is redirected towards the reinjection well.*

Stage D: Geothermal fluid reinjection.

10. *The reinjection pump situated at the top of the reinjection well reinjects water in the underground after exploiting some of its heat, condensation and cooling.*
11. *12. 13. Finally, in the discharging area, the cooled geothermal fluid from the separator and the cooling towers is reinjected in the original reservoir.*

Stage E: electricity injection and transit.
14. The transformer raises the electricity tension produced by the alternator to adapt to the tension level of transmission lines.
15. The electricity network will be used for the distribution of the produced electricity in the power station as it comes out of the transformer.

Key:

1. *Catchment area*
2. *Production well*
3. *Wellhead*
4. *Production pump*
5. *Separator*
6. *Steam turbine*
7. *Alternator*
8. *Condenser*
9. *Cooling system*
10. *Wellhead*
11. *Reinjection pump*
12. *Reinjection well*
13. *Discharging area*
14. *Transformer*
15. *Electric cables*

The functioning principle of a geothermic power station can be summed up the following way:

1. Drilled wells capture the geothermal fluid in depth and at high temperature. The latter evaporates partially as it comes back up to the surface.
2. On the surface, a separation step is necessary to separate the steam phase from the liquid phase.
3. The steam phase is sent to the turbine with an alternator where its energy is transformed in electricity. In some cases, the liquid phase (separated water) is also used for the electricity production via binary cycle turbine (see after)
4. Then, the steam phase is re-condensed in water, re-mixed at the liquid phase and the lot is reinjected in the reservoir via reinjection wells.

The turbine type: one of the key elements of a geothermic power station

There is often a reference made to **two types of turbine** that are rightly mentioned in this guide to supply a few elements for the comprehension of a non-specialist reader. The choice between two types is essentially made on a chemical quality basis of the geothermal fluid and of its temperature. The most common type is the **direct cycle** turbine that, as its name suggests, uses directly geothermal steam. It is suitable for geothermal fluids of which the temperature is above 392-428°F (200-220°C).

Sheet n°6

When their temperature is below, it is preferable to turn to a **binary cycle** or Organic Rankine Cycle (ORC) turbine that uses as working fluid a isopentane type organic fluid for example that has a boiling point below the water's one, to improve the energetic yield. The geothermal fluid (water or steam) is directed towards an exchanger to warm up and spray this organic fluid that is sent to the turbine. When it comes out, it is re-condenses thanks to a cold source (water or air) and the cycle can start again. It is important to notice that the working fluid progresses in a closed circuit.

TO REMEMBER

In a geothermic power station, both turbine types can be coupled, one using directly the geothermal steam (direct cycle), the other using the separated water (Rankine cycle). It is better to add value to the energy contained the geothermal fluid, and to increase the electric production capacity of the power station without increasing the debit of the geothermal fluid extracted from the reservoir.

Figure 4: View of the rotor equipping one of the units of the power station in Larderello in Italy (©Geo-heatcenter).

The cooling systems of a geothermic power station: a key element concerning the environmental impacts

Like for all thermodynamic machine, the yield of the geothermal turbine is clearly improved if a **cold source** is used to condense the geothermal steam or the organic fluid steam at the exit of the turbine. This cold source can be **water on the surface** available in abundance near to the site (river, sea) or **air**. In that last case, air coolers or cooling towers are used.

Sheet n°7

The choice of the cold source will be done considering the establishment of the power station and the available water nearby. It will also be limited by local environmental considerations. Indeed, the water or air use can generate **environmental impacts** (water temperature increase, harmful noise from the air cooler batteries, visual impacts of steam plumes above the cooling towers) that have to be well understood during the stage that determines the feasibility of the project.

Figure 5: Cooling system with cooling towers of the power station in Miravelles, in Costa Rica (©Biotope, 2014).

2.2.3. The different phases of an electricity production geothermic project

One of the distinctive feature of geothermic power station projects for the electricity production compared to other industrial projects, and particularly compared to renewable energy projects like wind or photovoltaics is their duration. Indeed, **there is generally 6 to 8 years between the first studies and the putting into service of a geothermic power station**. This is due to the necessity of doing before an exploration phase, then drilling to confirm the existence of a geothermal resource and evaluate its potential, before being able to size the project and to conceive the power station. Then, the drilling of the production wells and the reinjection have to be done. And it is only when the steam quantity supposed to feed the turbine is available or proven that the construction of the power station can start.

Sheet n°2

A methodology has been progressively organised with successive phases that come one after another. These phases use more important means and require higher financing.

They also correspond "to a progression logic in the knowledge of the geothermal resource than in the conception of a geothermic power station that allows to adapt the project gradually considering the obtained results and to limit the finance risks in case of an abandonment. Each phase finishes generally on a decision to continue or to abandon the project or on a decision concerning the size, the setting up and the type of the power station.

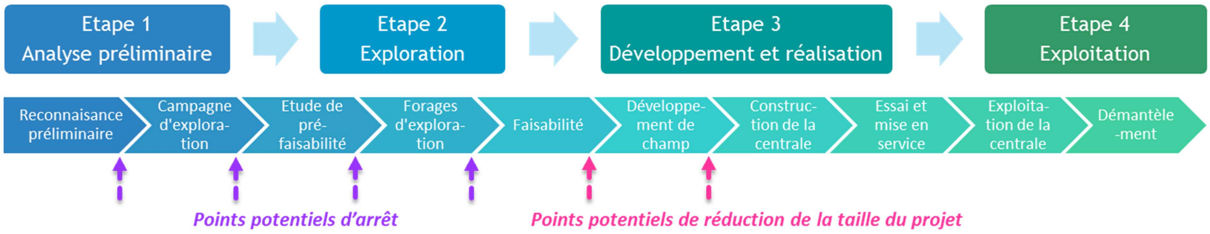


Figure 6: The different phases of a geothermic project of electricity production gathered in four big stages corresponding to particular activities and generating specific environmental impacts (©Biotope, Septembre 2015).

Diagram translation:

Stage 1: preliminary analyse → stage 2: exploration → stage 3: development and realisation → stage 4: exploitation.

Preliminary recognition → exploration campaign → prefeasibility study → exploration drill → feasibility → field development → power station construction → test and putting into service → power station exploitation → dismantling.

Potential stop points

Potential points that can reduce the size of the project

The main phases

The **preliminary recognition** is aimed at selecting the interest areas on an isle scale or a country scale where clues are present and justify the later **exploration** stage. These tasks use different prospection methods (geology, geochemistry, and geophysics) to precise the potential of the geothermal resource. The environmental aspects are also taken in count. The results are synthesized in the form of a prefeasibility study. If the conclusions are positive on a geologic and environmental point of view, exploration drills will be done to confirm the presence or not of the adequate geothermal resource. The project carrier will then be able to evaluate the size of his project or to abandon it.

The **feasibility study** marks the true entry of the project in the development and construction stage that will lead to the power station. The project is defined and planned in detail on the technical, economic and finance plans. The **phase of the field's development** that consists in drilling necessary production and reinjection wells comes before the **construction phase of the power station** or of the first unit if the project is done by stages. The latter can be of a modest size (10-20 MW) and can be planned to test the global capacity of the reservoir during a few years before building bigger units. A **trial and implementation** period of a few months comes before and starts off the **exploitation phase**.

The **lifespan** of a geothermic power station is hard to evaluate. Examples of working power stations for 50 years exist. The lifespan of the power station equipment being generally of 25-30 years, the old and/or obsolete units are progressively dismantled and replaced by new units that often have higher performances. Drilling new production/ reinjection wells can also be done to replace end of life wells or to increase the electricity production capacity of the power station.

Figure 7: Example of unit 1 of the geothermic power station in Bouillante (4,5MW) that is used since 1986 (©CFG Services).

The abandon risks in current project

At the end of each phase and more particularly at the end of each exploitation stage, it is generally decided whether the project should go on or be abandoned. **This a specificity of geothermic projects that can be stopped along the way for multiple reasons**. The brought results of the studies and the exploration drills can be disappointing and the economic yield of the project can be compromised. The environmental limits can also lead to abandoning a project if a part of the resource is situated in a protected area or a national park for instance.

When the project is doable and has reached the right development of the field, a risk on its success still exists, even though it is reduced. It is possibly necessary to reduce the size of the project if the reservoir's potential is smaller than it was predicted.

The geologic risk notion and its financial consequences

The failing risk of ongoing geothermic power stations projects is often qualified of **geological risk**. It illustrates the difficulty of correctly evaluating the potential of an underground reservoir and therefore naturally hard to understand.

A project carrier should thus use significant sums to realise exploration drills with the certitude of finding a geothermal resource that is exploitable and being able to bring the project to fruition and thus get back his initial investment. This geological risks is often **an obstacle to the exploration** of geothermic resources and their exploitation. This is the reason why some countries or international organisations finance or co-finance the exploration drills with the help of public funds. Others organize insurance or geologic risk cover mechanisms that reimburse a more or less significant part of the drill costs if the project fails. That is why the private project carriers are less reluctant to launch drill exploration campaigns if they have the guarantee to recover partially or entirely their investment if the project fails when the exploitable resource is brought to light.

Sheet n°3

The risk can be minimised by giving priority to the camp development by steps and the first unit construction which capacity does not exceed 30 to 50% of the estimated capacity of the tank. During a few years, its exploitation enables to test the real capacity of the tank and in this way size correctly the next units.

TO REMEMBER

✎ An electricity production geothermic project lasts a long time and is done through successive stages, using more and more significant means and financing.

✎ It can stop along the way if the geologic, economic and environmental conditions are not/ not any more favourable.

2.2.4. Regulation aspects of geothermic energy

In France and in many countries, geothermic energy is considered like a **mining resource** belonging to the State. The latter can exploit it directly or delegate its exploitation to an industrial company through the boon of a mining permit or a concession. This activity is subject to a specific regulation that varies from a country to another and that is generally standardised by a "Mining code" or "Geothermal Bill". A quick overview of the practicable regulation for the French islands (Guadeloupe and Martinique) and for the Caribbean English-speaking islands (Dominica, St-Kitts and Nevis, Montserrat, St. Lucia, St Vincent, Grenada) is given below.

Practicable regulation in France (Guadeloupe and Martinique)

The different regulation texts that apply to geothermic electricity production in France are detailed in the attached sheet n°10. The main ones are:

Sheet n°10

⇒ **The mining code** and practicable texts that assimilate geothermic centres to mines (art L112-1). They regulate three big activity types: the Research (or Exploration), the Exploitation and the Work Execution.

⇒ **The environment code** that does not specifically talk about geothermic energy, but applies in the framework of water resource preservation and pollution, risk and harmful substances prevention.

⇒ **The energy code** that defines for the electricity production the authorisation procedures to exploit and declare. It also establishes the obligation principle to buy and the regulated tariffs for the produced electricity from renewable energy sources.

⇒ **The labour code** that sets the general rules practicable to the working conditions and particularly the health and security aspects for the staff.

Sheet n°9

TO REMEMBER

Under French law, the codification is aimed at easing the implementation of the principle that says "ignorance of the law is no excuse" and allowing citizens, elected representatives, civil servants, companies to know better their rights and obligations. The kept method is the one of the codification of the existing right, called "with existing law". The scattered texts are gathered and organised in a coherent way around a plan conceived for the answerable to the law: their writing is, if required, standardized and updated. The rule of law becomes thus more easily accessible.

Practicable regulation in the Caribbean English-speaking islands

The major part of the English-speaking islands of the Lesser Antilles **does not have up to today a precise regulation framing the geothermal resource exploitation**. The constitution of a management document of geothermic resources is in progress in many of them. This document called **Geothermal Bill** is aimed at allowing the development of the resources, their sustainable and beneficial use for the territory.

The regulations in effect or in progress of development ae based on two worldwide recognized concepts framing the development of the geothermal resource:

⇒ Geothermal Exploration agreement : the exploration term includes activities of surface geology, geochemistry, geophysics, the shallow drillings ad the deep explorative drillings

⇒ Geothermal Resource Concession (lease): the duration cannot exceed a 40-year period for Dominica for instance.

The **environmental regulation framework is divergent according to the islands**: when some islands have a special environment right (Montserrat, Dominica), others do not have laws directly linked to the environment.

Nevertheless, during the implementation of significant financing, like the ones that cover the construction of a geothermic power station, **the environmental evaluation** (impact study particularly) **is ordered by the World Bank as well as other international fund backers**, to examine the potential environmental risks and the benefits of bank investment loan transactions.

Geothermal Bill in Dominica

In Dominica, the Geothermal Bill is currently in progress to be finished. This document defines particularly the general exploitation framework of geothermic resources of the territory and the implementation of a multidisciplinary committee charged of advising the Energy Minister in charge of the resource management.

Dominica has done the choice of an approach aiming at creating a complete and integrated regulation framework specific to the geothermic energy coming to complete the existing regulation. This text ratifies particularly the fact that the geothermal resource is State property.

2.3. THE ENVIRONMENTAL AND SOCIETAL IMPACTS LINKED TO A GEOTHERMAL PROJECT

The following section will present the inherent impacts due to the implementation of a geothermic electricity production plan. The intrinsic potential effects described below do not depend on the context in which the project takes place but are directly linked to their functioning facilities and modes.

The project effects are presented by distinguishing the incidences:

⇒ Of the drilling exploration and exploitation work phases, as well as plant construction.
⇒ Of the plant exploitation phase.

To Remember

During the upstream phase of a project, the surface exploration work which generally implement some geological, geochemical and geophysical prospection resources, do not generate significant impacts.

2.3.1. Environmental and societal impacts linked to the drilling work and plant construction phases

The impacts from drilling work and construction phases are partly similar to any construction site impacts (**generic impacts**) to which are added **specific impacts** linked to a geothermic project particularities.

Working phases generic impacts

The generic impacts correspond to incidences which exist on every construction project, industrial or not. They are listed below:

⇒ **Pollutant emission in the air** having an influence over climate warming and presenting potential effect on health, linked to material and human transport, to the engines use and construction site facilities;

⇒ **Chronic pollution risks** (ground, superficial and underground water): during clearing and levelling work, the sites used for operations will be laid bare and subject to a washout phenomenon during rain period. The effect associated to various construction site activities will consist of water quality and biologic degradation. The inputs of suspended matter (SM) transported by streaming waters will be able to join the nearest natural outflow. The waste production can also be the origin of soils and waters pollution according to the implementation;

⇒ **Accidental pollution risks** (ground, superficial and underground water): the complexity of construction sites (different participants specialised by type of facilities, number of simultaneously present team on the construction site, proximity between men and building sites machines,…) can generate accidental pollution risks which can be the result of a lack of vehicles or material maintenance (hydrocarbon leaks, oil,…), a wrong manoeuver (spilling of a machine) or a bad waste management induced by the building site;

⇒ **Modification of soils stability** joined with erosion risks, landslides and flood, induced by diverse earthwork (creation of roadways, platforms, building implantation,…);

⇒ **Attack of biodiversity,** like it is described in the Table 2;

⇒ **Audible and vibrations nuisances** linked to the machines and facilities operation for the surrounding residents and users, to the roadways circulation,…;

⇒ **Landscape effect**: modification of the landscape structure and soil occupation, reaches; interaction with landscape and cultural patrimony, creation of a new energetic landscape ;

Type of impact	Impact details
Natural and species habitats' destruction	Natural and species habitats' destruction : - changing soil occupation zones - construction sites et network implementation zones
Natural and species habitats' degradation	Natural and species habitats' degradation linked: - to the frequentation linked to the construction (machines, walking) - to the pollution risks with hydrocarbon or other used pollutants on the construction site - to the risk of bringing invasive species
Animal or eggs destruction	Animal destruction on working or access zones
Traveling fauna's corridors degradation	Ecological existing corridor's functionality alteration due to: - the mesh destruction forming natural continuities - Zones' fragmentation due to the project implantation.
Disturbing of animal species	Disturbing caused by the construction site nuisance and more precisely by the noise and the light.

Table 2 : Potential effects of a geothermic project on fauna, flora and natural habitats during the drilling and plant construction phases.

Simultaneously, we must mention a positive impact of this work is the significant **contribution to the local economy** with the involvement of local companies on construction sites (construction, structural works, ... VRD) and local indirect benefits during work (accommodation, hotels, restaurants, shops ...) that are generally consistent to the extent that the cumulative duration of this work is generally high (several years). The improvement or creation of road infrastructure can also be seen as positive aspects of a project

To be complete, it is important to signal that the installation **dismantling sites** occuring during the exploitation phase have incidences which are more like generic impacts observed on the plant construction working phase, with as major preoccupations polluting chronic risks, dangerous waste and other chemical products destruction. Particular sheets (n°15 and n°16) are focusing on this thematic of geothermic central dismantling and site rehabilitation.

Sheet n°15 & 16

Working phase specific impacts

The main incidences of a geothermic project during its working phase are essentially linked with the drilling realisations and are indexed below:

⇒ **The sampling of surface water and fluid rejections and solid material in the natural environment :**

✓ *The sampling of surface water (river, lake, sea) is needed for the fabrication of drilling fluid (drilling mud). It can cause: a decline in flowrate collected water; a modification of the morphology of the water* *collected; a premature drought of harvested sources; a change from Sedimentation Downstream sites of collected water; decreased sediment loads near the mouth of collected of water.*

- ✓ *The releases are represented by the geothermal fluid, debris of rocks from the drilling of the well, dehydrated drilling mud residue. They must be collected, stored and processed. If rejected, the impacts on the receiving environment are considerable: danger of water pollution, changes in sediment dynamics; increase in temperature resulting in the destruction of the flora and a higher mortality of aquatic fauna (fish, crustaceans…).*

- ✓ *The contamination of surface water bodies is also possible during the drilling stage before the well is cased.*

⇒ **Drilling related noise**. The noise levels generated by a drilling site can be high and reach 115 dB (A) during certain phases. They exceed the limit that the World Bank permits, it is to say 85 dB (A) for heavy industrial facilities. Noise pollution is especially present a well site works day and night without interruption. In the lifespan of a project, they are however temporary.

Sheet n°5

⇒ **The risks related to gaseous emissions**: During the drilling of a well and at the end of drilling production tests, accidental discharges geothermal water and gas can occur. Among the gases, hydrogen sulfide (H2S) may present a health risk to personnel working on the site as well as the close proximity to population. It can also represent a risk to wildlife and local flora;

⇒ **The risks related to seismicity**: The actual drilling do not generate earthquakes. Against by the operations of well stimulation low permeability by pressurized injection of water that are usually performed at the end of the drill may under certain conditions cause an induced seismicity. This is in most cases magnitude of micro seismic less than 3 (on the Richter scale) that are not detectable by humans. Only some may be eventually felt ;

⇒ **The effects on the landscape**: interactions drilling equipment with landscape features a large distance because of their height, creating transects related to the passage of piping and electrical infrastructure required by these projects.

Sheet n°14

2.3.2. Environmental and societal impacts linked to the exploitation phase

A number of potential environmental impacts are identified in the operation of a geothermal power plant electricity production. The most significant are:

⇒ **The gaseous emissions in air**: geothermal steam contains a mixture of gases which do not condense at the same pressures and temperature as the water vapor; they are called non-condensable gases (in English: non-condensable gases or NCG). These gases , dominated by carbon dioxide (CO2) and hydrogen sulfur (H2S) , are usually present in small quantities (less than 1% by weight in the vapor phase) ..

These gases are released into the atmosphere at the turbine outlet or at the cooling towers. They generally represent no danger to health. However, in some cases, the gaseous emissions may generate discomfort or risk to the health of the surrounding population if the hydrogen sulfide concentration is high (Table 3).

Concentration	Effets sur l'homme
4 ppm	Moderate smell, easily remarquable (« rotten egg »)
10 ppm	Eyes irritation
27 ppm	Unpleasant smell
100 ppm	Cough , eye irritation , loss of smell after 2-15 minutes
200-300 ppm	Eye inflammation and irritation of the respiratory system after an hour
500-700 ppm	Loss of consciousness and eventual death between 30 to 60 minutes
800-1 000 ppm	Rapid loss of consciousness, breath stop, and death
> 1 000 ppm	Paralysis of diaphragm since the first breath in, quick asphyxia

Hydrogen sulfide (H_2S)

At low concentration, the impact of hydrogen sulfide mainly concerns the living as his "rotten egg " odor is unpleasant and can cause discomfort to the population. When the concentration of hydrogen sulfide rises in the ambient air, the odor fades and then disappears by anesthesia of smell, and the gas becomes lethal.

Special cards are devoted to health aspects and treatment of H_2S gas coming from a central.

Table 2 : Hydrogen sulfur effects on humans, depending on the concentration (source : Ministère de l'Agriculture, de l'Alimentation et des Affaires rurales, France, May 2014)

Sheets n°9 & 17

⇒ **The incidences over water resource** : these effects can be both quantitative and qualitative:

- ***Samples*** :

  The functioning of a plant can require the permanent or punctual sampling of water, especially to power the cooling system. This samples (by pumping) generally concern surface waters (river, lake, sea) but can also be done at an aquifer level, depending on the nearest resources. They can impact the water resource by this manner: diminution of flow, drought of sampled rivers, morphology modification of sampled waters, upstream sedimentation modification; diminution of sediments charges next to the mouth of sampled rivers,…;

- ***Pollutions :***

  ✓ Chronic pollution***:*** the geothermal fluid is preferentially reinject in the geothermic water tank in order to maintain the pressure. It can also be partly thrown back in the natural habitat (as it is the case for the thermal station of Bouillante in Guadeloupe) or totally and can also create a risk of surface waters' pollution. Indeed, the chemical characteristics of the geothermal fluids are generally different from these waters especially regarding their salinity which is generally high. Thus the throw can bring about an alteration of the quality of the surface waters;

  ✓ Accidental pollution: in case of leaks from the shafts or the transport network pf the fluids, the immediate runoff of geothermal fluid can infect the ground, the surface waters as well as the groundwater.

⇒ **The modifications of the natural hydrothermal occurrences :**

The exploitation of the tank can bring about some modifications within the tank as drops in pressure which can have side-effects on the circulation of the fluids in the underground. Among the potential consequences, there is the regression or growth of the surface's hydrothermal occurrences (thermal spring, fumaroles, hot grounds…). These modifications can have a negative economic impact if these natural occurrences are used for the balneotherapy and the tourism. They can also create environmental nuisances or risks if they affect the urbanized areas.

⇒ **The risks regarding the underground**:

- ***Subsidence of the grounds*****:** The exploitation of a geothermic tank can be the origin of a subsidence's phenomenon, that is to say of a slow subsidence of the grounds which can induce material damages. This phenomenon can be consecutive to an important drop in pressure within the tank, caused by the taking of a sample of a big quantity of fluid not compensate by the reinjection nor by a natural reload. The geological context can also be partly responsible. The slow rhythm of this phenomenon can nevertheless allow to minimize the environmental impacts. The reinjection of the geothermal fluid in the tank is one of the most effective corrective measures to fight against the subsidence.

- ***Induced seismicity***: The exploitation of geothermic tank and more particularly the operations of reinjection of the geothermic fluid in the tank can locally create micro seism, usually too weak to be felt by humans. For example, no induced earthquake able to be linked to the exploitation of the geothermic tank of Bouillante was felt since its start in the 80's.

  N.B. : The Caraïb's Islands are volcanic and seismic areas. Therefore it can be difficult to make the distinction between natural seismicity and the one induced by the exploitation of a geothermic field.

⇒ **Harming the environment**: the visual effects result of the presence of the installations ansd of the associated infrastructures (mains, pylons and electric line…), some possible plumes of steam water according to the validate exploitation process, of the creation of a new energetic landscape,…;

⇒ **The noise pollution and the vibrations**: the noise from the geothermic installations is typical from numerous industrial activities (70 to 85 dB(A); Figure 8). It is linked to the functioning of the different equipments of the geothermic station (turbo-alternator, aero-cooler, unloading of steam, maintenance work as the scrapping of the shaft…).

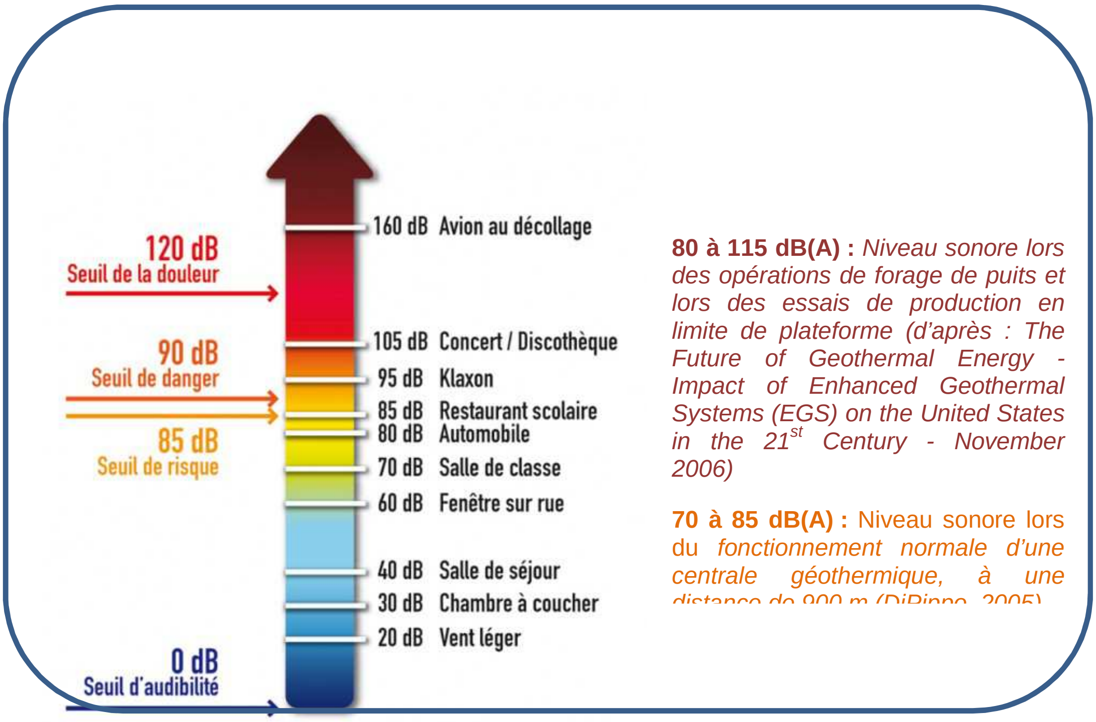


Figure 8: Comparison between noise levels in the every-day's life and noise levels created by a geothermic project during the drilling's operations and during the exploitation of the geothermic station (extracts from the bibliography) © ADEME-BIOTOPE, September 2015.

⇒ **The economic and societal impacts:** The exploitation of a geothermic station contribute generally to the dynamisation of the local economy of the territory where it is located: long-term employment for the exploitation and maintenance of the equipments' site, formation of qualified staff, amelioration of the road network, tax transferred (professional tax…). Nevertheless, the setup of a geothermic project can also go against some ongoing activities. For example, the regression of the surface's thermal manifestations can affect the economy of the thermalism/tourism developed around these manifestations.

To remember

The main environmental and societal effects presented by a project of geothermic station are:

- **The risks of air, water and ground pollutions ;**
- **The noise and visual pollutions ;**
- **The risks of accentuation of some natural risks ;**
- **The use of surface water and of the water resources ;**
- **A globally positive contribution to the local economy but being able to be negative on some points**.

2.4. ENVIRONMENTAL INTEREST AND SENSIBILITY OF THE INSULAR AND/OR TROPICAL TERRITORIES.

The islands of the volcanic arc of the Lesser Antilles are characteristic of insular and tropical habitat. In this way, they have some environmental specificities which is useful to briefly describe in this guide by approaching the natural habitat, the landscapes and the cultural heritage, le human habitat and the natural resources.

Figure 9: From left to right : some examples of the emblematic flora and the fauna of the Lesser Antilles' islands : Tree Fern ©Biotope, Humming bird ©Biotope,, Marbled Anolis ©Biotope.

2.4.1. The natural habitat

The Lesser Antilles are one of the 25 regions of the biosphere **ranked hotspot of the global biodiversity by UNESCO**. They shelter more than 40% of the known biodiversity on less than 1,5% of the continental surface of Earth. Each island owns a **rich tropical biodiversity** (look Figure 9 for example). The geographic isolation and remoteness of the dispersion's focus of the fauna and flora favour the speciation and **numerous species are endemic**. Thus, 27 species are endemic of the Archipelago. The different floras of the islands are very close. The repartition of the habitats is made regarding the stage of altitude of the habitats.

Even though they belong to the same archipelago, all of these islands own some **specific biologic characteristics**. Their biodiversity mainly depends of the spatial organisation, of the altitude and of the pluviometry of each island. Within the different islands of the Antilles, the habitats presenting the highest biodiversity are mainly some series ombrophilous and mangrove swamps.

The notion of hotspot of the biodiversity

A hot point or hotspot of the biodiversity is a geographic area with at least 1500 endemic vegetal species but which has already lost at least 70% of the species originally present. The total surface only represent 2,3% of the surface of Earth. Currently, 34 areas are hot points. More than 50% of the vegetal species and 42% of land vertebrate species live in these hot points.

Endemism

The endemism is a characteristic of the animal or vegetal species which have a limited geographic repartition. In the Lesser Antilles, the insular nature explains their level of endemism. Apart from the rest of emerged lands for hundreds of thousands of years, the life developed itself there in a unique way. These ecosystems are nevertheless very fragile against the alteration of the habitats, the pollutions and the introduction of exotic species.

This profuseness is particularly vulnerable to human activities. The **land pressure** is high. All the faunistic endemic species of the islands are threatened. The biodiversity of islands also suffers from a **general misunderstanding on the habitats**.

The **navy biodiversity od the islands is very profuse as well**. For example, the navy area of the Grand Cul-De-Sac Marin in the north of Guadeloupe constitute a vast reservoir of the biodiversity (255 species of taken fishes). This territory is between other things the object of a reintroduction program of the manatee (endangered animal specie).

2.4.2. Landscape and cultural heritage

In the archipelago of the Lesser Antilles, the eco-climatic diversity is coming with a sociological, cultural, linguistic and economic diversity due mainly to the historical and colonial influences of the islands. The **architectural heritages are highly linked to the colonial past of the islands**.

The **landscapes are multiple on the different islands** (Figure 10) : volcanic landscapes, beaches of white sand, luxurious forest, dried bushes, agricultural landscapes, mangrove swamps … These landscapes are generally under high anthropic pressures (urban spreading, tourism …).

The **archipelagic nature** is fundamental in the identity of the geographic territory, each island being wealthy of its singularities, contributing to the amazing diversity of the landscapes. The islands of the archipelago also maintain some strong visual interrelations which animate the seaside view. The islands between them are landmarks in the area. The sea environment of each island is a strong landscaped limit, but in the same time, the sea is a link between the islands.

Figure 10: Examples of landscapes and west Indian cultural heritage with from left to right: beach of the Arlet's Anses in Martinique ©Biotope, waterfall in tropical forest in Guadeloupe ©Biotope, Typical Architecture of the churches in Martinique ©Biotope.

The **archipelago's landscapes** represent a **major patrimonial and touristic stake** protected especially via the process of registered sites in Guadeloupe and in Martinique (French regulation). The following report is still to underline in the matter of the French islands; the realization of a necessity of preservation of the landscapes is weak and the urbanism's documents doesn't translate enough the measures of protection.

Figure 11 : Some examples of the supports of the economic activity in the Antilles : Banana's farming in Guadeloupe ©Biotope, landscaped footpath in tropical forest, in Guadeloupe ©Biotope, Beachside in Martinique ©Biotope

2.4.3. Climate

The climate of the islands is hot and humid of tropical type. The temperatures diversify between 21°C and 33°C. The trade winds and the sea draughts circulate from East to West. The period of the tropical tempests and cyclones is going from June to November. The islands of the North have a slightly dryer climate.

The volcanic reliefs of these islands have a strong influence on the climate and especially on rainfall pattern and on annual precipitation quantity.

The preoccupation on adaptation to climate change has boomed in the past ten years. The islands of the Lesser Antilles are vulnerable to sea level rise and an increase in cyclone frequency and dry periods.

2.4.4. Natural ressources

The Caribbean's islands are all widely **dependent from the importation of oil which represent 90% of the consumed energy**. Almost all of the electricity is produced in fuel plant. The contribution of renewables energies (solar energy, wind energy, biomass and small hydro power plants) remains moderate.

Most of volcanic islands of Lesser Antilles have geothermal resources. However, Guadeloupe is actually the only one to own a geothermic plant to produce electricity.

With regard to water resources, the situation varies greatly from an island to another. Drinking water supplies comes from rivers or shallow aquifers and are therefore vulnerable to meteorological phenomenon. Lack of other sources, drinking water supply can come from sea water desalination.

2.4.5. Natural risks

The Lesser Antilles have at least **nine active volcanoes** of which the **volcano de la Soufriere** in Guadeloupe culminates at 1467 meters and that constitutes the highest archipelago peak. It's an island arc that comes from the subduction of the American plate and the Caribbean plate. This subduction phenomenon comes from the volcanic activity that gave rise to these islands and those **many earthquakes**.

As a fact, the region is highly exposed to volcanic and seismic risks. The topography generally accentuated of these islands contributes to **land subsidence**.

The meteorological risks such as **hurricanes or tropical waves** are also highly present. They may give rise to important rainfall within a very short period of time and lead to torrential floods, marine submersion (storm surges). They also worsen land subsidence.

Figure 12 : example of volcanic activity in the Lesser Antilles : on the left, the crater of the groundwater explosion of the Boiling Lake in Dominica ; on the right, the stratovolcano of the Pelee mountain in Martinique.

2.4.6. The human environment

Socio-economic aspects

Globally, for the past two decades, natural environments - and especially forest – have been destroyed progressively in favour of urbanized territories. A discontinuous urban fabric appeared on a coastal fringe leading to a **very unequal repartition of populations and to a competition for the ground** between agricultural zones, urban spaces and natural environment.

Islands mainly make a living from **tourism, agriculture (banana and sugar cane),** small industries and financial assets (tax heaven). However, these island territories have a **vulnerable economy**.

Agriculture is an important industry of the island's economy. Agricultural exploitation marked the territories. Moreover, the sector plays a major role for the island's food safety.

The touristic area of the Lesser Antilles is less attractive in terms of number of tourists per year than the Greater Antilles (Dominican Republic, Cuba, Jamaica...). Nevertheless, tourism is one of the dominant economic sectors on the majority of the islands. Saint-Martin Islands, Barbados, Antigua and the British Virgin Islands or Guadeloupe and Martinique dominate the geographical region.

In recent years ecotourism strategies have sprung up on some islands (Dominique, Sainte-Lucy…). They make it possible de reconcile the environment protection and the development of the touristic activity.

Living environment

Regarding the living environment, structural dispositions linked with the waste management sector and sewage treatment are different according to the islands. The organisation of these subsidies is more or less advanced depending on the islands.

The air quality is relatively good. Principal pollutant stem from transports et some industries (power stations using fuel, coal) and so are they concentrated at the most urbanized zone level.

To remember

Interests and sensitivities of the island and tropical context of the Lesser Antilles:

- ✓ **A rich and unique biodiversity;**
- ✓ **Some island vulnerabilities: ground and water ressources;**
- ✓ **An exposition to high natural risks;**
- ✓ **An economic development based on tourism and agriculture;**
- ✓ **An energy dependant concerning the importations.**

2.5. RECAP OF THE ENVIRONMENTAL AND SOCIETAL STAKES

The realisation and exploitation of a geothermic station for the production of electricity is an industrial project likely to generate environmental and societal impacts, which were above presented. These impacts are all the more marked since this type of project integrates into a framework, which presents strong environmental sensitivities. That is precisely the case of the Lesser Antilles.

The chart 4 sums up the link between these two factors and allows us to identify and rapidly order the major environmental and societal stakes with which the projects of geothermic station in the region are - and will be – confronted. Thus it seems clear that these environmental stakes are important or very important for the majority of the regarded thematic.

This chart provides a basis for a consideration when we envisage realising a project of geothermic station in order to promote environmental excellence as soon as preliminary phases.

To remember

The choice of environmental excellence

✓ **The realisation of a project of a geothermic station in the exceptional environmental context of the Lesser Antilles requires taking carefully into account some local societal and environmental stakes. Its successful integration goes naturally through the choice of environmental excellence.**

✓ **The choice of environmental excellence, quality and success guaranty implies a particular engagement from the project initiators from the preliminary phases top the whole project**

	Particular interests and sensitivities of the context	Potential effects of a geothermic project	Stakes	Stake level
Air	Relatively good to very good air quality	Air pollution risk	Maintenance of good air quality	**High**
Grounds and undergrounds	Area can present consequent drops	Modification of the topography, ground erosion, ground pollution risks	Preservation of grounds integrity	**Moderate**
Waters	Vulnerability of freshwater resource	Waters pollution risks, superficial and underground, water consumption	Preservation of freshwater resource	**Major**
Natural risks	Marked natural risks	Landslide, Subsidence phenomenon, Seismicity	Preservation of wares and people Project adaptation to current risks	**High**
Natural environment	Rich and unique biodiversity	Threat for biodiversity Disturbing (noise, luminosity, displacement) Pollution risks (air, waters, grounds)	Preservation of biodiversity	**Major**
Landscape and cultural heritage	Diversified and interesting landscapes	Visual disturbance, creation of a new energetic landscape	Landscape integration, Prevention of the degradation of cultural heritage	**Moderate to high**
Economy	Economic development based on tourism and agriculture, Dependence on oil importations	Freeing regarding current energetic dependence Contribution / Offence against local economy	Development of the project in line with the local economy	**High to Major**
Use of the lands	Limited land availability Pre-existing activities: agriculture, tourism, (balneology)	Consumption of areas, Dispersed grounds occupation (station, canalisations, drilling platforms, power lines)	Consideration of pre-existing activities and uses in the development of the project	**High**
Living conditions	Different living conditions depending on localisation: urban to rural, Local population attachment to their ,natural environment (biodiversity and landscape)	Sound and visual problems Pollution risks (air, water, grounds)	Preservation of living conditions involving protection of natural environment and landscape	**High**

2.6. LESSER ANTILLES ET GEOTHERMIE : LE CHOIX DE L'EXCELLENCE ENVIRONNEMENTALE

Due to their volcanic origin, the Lesser Antilles islands present a geothermal potential which permits to consider electricity production. But, in spite of the numerous prospections and drillings done, the geothermal energy is still not exploited much. The figure 13 summarize the main steps of working and developments achieved in these islands with as a start point the exploitation's drilling achieved in Guadeloupe and Martinique in the 1970's. In 2015, the only geothermal plant in the Caribbean is the one of Bouillante in Guadeloupe with a capacity of production of 15 raw MW.

A recent study of Ademe (2015) has permitted to evaluate the state of advancement in the different geothermal project in these islands, as well as the potential estimated at short-term (2020) and mid-term (2030) in matter of capacity of electric production (Table 5). According to this study, the capacity of production to the scale of the Lesser Antilles could be in the order of 80-100 MW around 2020 and of 200-300 MW around 2030.

In order to illustrate the importance of **the environmental approach** in the projects of geothermal development, three islands have been chosen and their experience feedback are quickly presented hereafter. The first island is the **Guadeloupe** with the geothermal plant of Bouillante which stays the only one in the Caribbean. The second island is the **Dominique** with the recent exploration of the Roseau's valley which has confirmed the presence of a high temperature geothermal tank which could be used for electric production. The third island is the **Martinique** where two areas of interest have been identified but no high temperature resource have yet to be confirmed.

Territory	Geothermal Power installed in 2015	Advancement of the ongoing projects	Short-term potential around 2020	Mid-term potential around 2030
St-Kitts & Nevis	0	3 exploratory drillings in Nevis	**10 MW** (to 30 MW)	**35-40 MW** (interconnection Nevis)
Montserrat	0	2 exploratory drillings achieved	**3 à 5 MW**	**5 MW**
Guadeloupe	15 MW	Bouillante 3 : exploratory drillings in sight Vieux-Habitants : ongoing prefeasibility	Bouillante 3 : **30 MW**	**40 MW of the Dominique**
Dominique	0	3 exploratory drillings, 2 wells of development, Ongoing feasibility study	**7.5 à 10.5 MW**	**100 à 120 MW** (with exportation)
Martinique	0	Identification of the interesting areas, Pre-study of environmental feasibility conducted, Pending exploratory drillings	**0**	**10 à 20 MW + 40 MW of the Dominique**
Ste Lucie	0	2 exploratory drillings achieved, Qualification of the current resource	**10 MW**	**30 MW**
St Vincent	0	Qualification of the current resource	**10 MW**	**20 MW**
Grenade	0	Preliminary study	**0**	**20 à 30 MW**
Total	**15 MW**		**80 to 100 MW**	**200 to 300 MW**

Table 3 : Synthese of the capacity of electric production of geothermal origin installed in 2015 in the Lesser Island, advancement sate of the knowledge and estimation of the short-term potential and mid-term potential (according to Ademe, 2015).

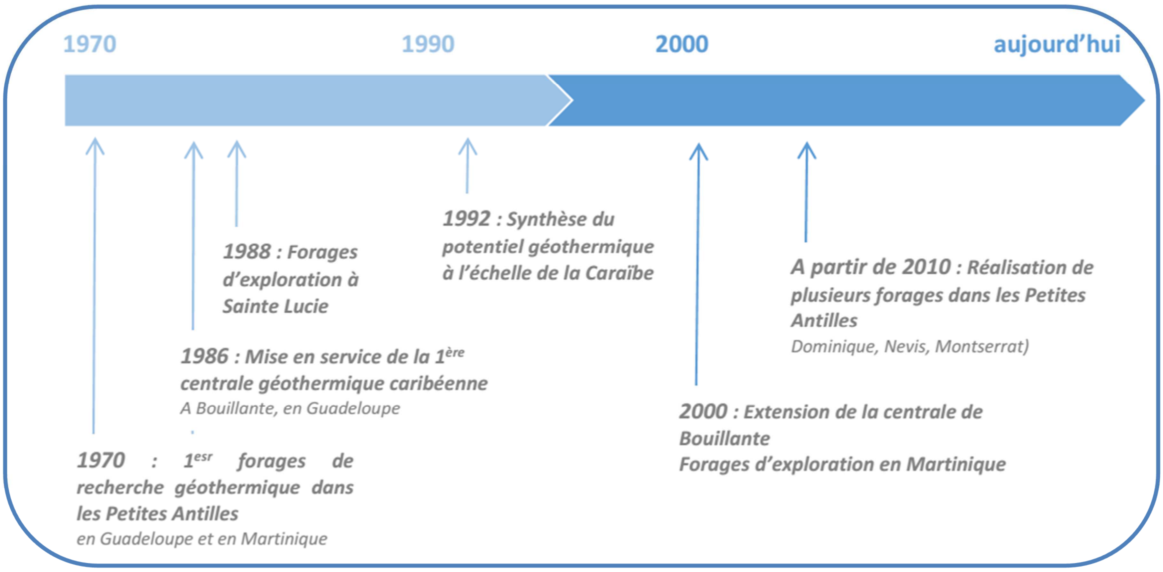


Figure 2 : The main steps of development of the geothermal energy in the Antilles since 1970 (©Biotope).

2.6.1. Bouillante, Guadeloupe : a geothermal plant implanted in urban environment

The first exploration's working are dated from the years 1970 in the south part of Bouillante, whereas the urbanisation was still weak. This area was rich in hot springs and fumarole (in which Bouillante had been named) and four exploration's drillings were realised. One of the wells (BO-2) dispatched a sufficient productivity and EDF decided to build a small geothermal plant in proximity, of a 4,5-MW capacity. It was put in service in 1986.

The particularity of this small power plant is to be implanted in Bouillante (Figure 14). After some arrangements destined to reduce the noise, it has functioned for numerous years without creating any issues for the neighbourhood. One of the solutions adopted to reduce the noise and visual pollution (steam plume) was the utilisation of sea water to condense the stem and cool the geothermal fluids before their ejection in the sea, in the Bouillante's bay.

Figure 3 : View of the geothermal plant of Bouillante, Guadeloupe, implanted in the city of Bouillante (©CFG Services).

In 2000, the new owner of the geothermal filed decided to increases the capacity of production of the plant by drilling three new wells of production and by building a second unit, Bouillante 2, of a 11-MW capacity which was put in service in 2005.Although similar to the ones realised in the 1970's, the drilling and construction's working of this new unit have been harder to realise in term of environmental integration.

The urbanisation had evolved a lot between 1970 and 2000 and the cohabitation between the workings and the neighbours had been become trickier. The surface available for implanting the different equipment (platform of the wells, fluids pipeline, turbine generator unit) had been very diminished. Furthermore, the environmental considerations were becoming more concerning, requiring a different approach from the industrial, with a consideration and a stronger participation from neighbours and the local actors. The necessity to target the societal acceptability of this project has clearly appeared.

2.6.2. The Valley of Roseau in Dominique : a project of a geothermal plant in a preserved natural habitat

The valley of Roseau is famous for a long time for her hydrothermal occurrences and her natural richness, especially thanks to the proximity of the national Park of the Three Pythons, listed as UNESCO World Heritage. The preservation of this exceptional natural habitat has always been a source of concern for the inhabitants of this valley, which takes a benefit from it. The hydrothermal manifestations of Sulphur Springs, of the Boiling Lake and the Valley of Desolation attract numerous tourists and eco-tourists.

In the same time, the Valley of Roseau owns an outstanding geothermal potential for the production of electricity which has been recently confirmed by the exploratory drillings. The development of this geothermal resource is going to confronted to the necessity of protecting this remarkable natural heritage and is going to induced a deep change for the local community living in this valley. This project has thus to be a model on the plans of environmental and societal integration in order to be accepted and fully beneficial to the Valley of Roseau on the long-term.


Figure 4 : Illustration of the natural habitat in Valley of Roseau in Dominic with the view of the hydrothermal manisfestations in the River Blank (to the left) and a view of the Valley of Roseau (to the right).

Under the program INTERREG CARAÏBES, several environmental studies have been conducted especially to supervise the exploratory drilling's workings on the environmental plan. The more emblematic has been the realisation of an **initial state on the environment** to a global level of the project in order to identify the main environmental and societal sensibilities regarding the Valley of Roseau (Caribbean Environment Development & Coll., 2015). This initial state is vital to define the measures of reduction of the impacts created by the project of geothermal plant. It will also be used as a reference in order to measure the impact of such a project in the time. The realisation of this initial state has been accompanied of **an information and consultation approach** of the local population in the will to associate it to the geothermic project and this, starting the preliminary steps.

Sheet n°12

These workings perfectly illustrate the excellency environmental approach which has to accompany the projects of geothermal plant in these islands of Lesser Antilles.

2.6.3. Martinique: an example of the consideration of the environmental and societal aspects starting from the beginning of the project

Several exploration campaigns of the surface have been conducted in Martinique since the 1960's; the last ones having taken place in 2011-2013. Two interest areas susceptible to possess high temperature geothermal resources for the production of electricity have been identified: the Mountain Pelée in the north and Petite Anse near the Anses-Arlet in the south-west.

At the preliminary step, and before even that the potential resource is confirmed by the exploratory drillings, Ademe has financed the realisation of an environmental pre-diagnosis on these two prospects for a better consideration of the environmental issues (EgisEau, 2014). One of the objectives of this study was to answer to the following questions:

- ⇒ What are the environmental issues that will have to be taken into account in the scope of a future geothermal-plant project on one or the other of these two territories?
- ⇒ What are the necessary and sufficient data to characterise these issues?
- ⇒ What are the detail studies which will have to be conducted in the scope of the environmental impact studies that accompany the drilling workings and the construction of this power plant then the exploitation of the field if the potential of the resource is confirmed?

Figure 5 : Illustrations of the natural habitat in Martinique suceptible to be concerned by te projects of geothermal plant : to the left, view of the bay and of the village of Petite Anseto the Anses-d'Arlet ; to the right, view of a river on the side of the Pelée Mountain.

This environmental pre-diagnosis has been realized along with public meetings in order to inform and consult the population, so as to fully involve them in this process.

This consideration of environmental and societal issues **at the early stages** of a geothermal power station project seems vital in these island and tropical territories where there are major environmental challenges, especially regarding protection of the natural environment and the use of space.

3. The methodology suggested

For the environmental and societal integration of geothermal electricity production projects

This section gives details on the methodological approach suggested to make the environmental and societal integration of geothermal electricity production projects easier.

In a first phase, the tools developed by this methodology are shortly presented. Then, some recommendations indicate the proposed approach. This one is based on the chronology of the various realization phases of this kind of project and draws a distinction between three major steps to take into account: (1) the preliminary phase of studies and prospecting, (2) the drilling and building work phase and at last (3) the operating phase.

3.1. INTRODUCTION ON HE CONTENT OF THE SECTION

This section entitled “Methodology: environmental and societal integration of geothermal electricity generation projects” is divided into several chapters dedicated to:

⇒ **Presentation of the tools used in the environmental approach;**
⇒ **The environmental approach adapted to geothermal projects;**
⇒ **Recommendations for the environmental and societal integration during the project development, with a distinction between:**
  ✓ The preliminary stage of the project;
  ✓ The drilling and construction of the power plant stages;
  ✓ The operating of the power station stage.

3.2. PRESENTATION OF THE TOOLS USED IN THE ENVIRONMENTAL APPROACH

Before demonstrating the methodological approach suggested in order to facilitate the environmental and societal integration of geothermal power plant projects in the islands of the Lesser Antilles, a brief reminder of the various “tools” of the environmental approach that are traditionally used for industrial projects is helpful. These tools are:

⇒ Environmental and societal assessment (impact study);
⇒ Environmental and social management;
⇒ Dialogue and involvement of the public.

The objectives and contents of these tools are summarized in a chart (chart 6) and detailed below.

3.2.1. Environmental and social assessment

The environmental and social assessment is **a formal and legal procedure that is now adopted in over one hundred countries**. Some major financial institutions such as the World Bank also demand it regularly to be part of a project development. Environmental assessment for a project takes the form of an **environmental and societal impact study**. A preliminary environmental assessment can also be conducted in the upstream phase of the project.

Sheet n°11

Objectives

The environmental and societal assessment aims to study the potential environmental impacts of a project at the earliest possible stage of its development. It is based on a good understanding of the environment as a whole (such as natural resources, biodiversity, natural and technological risks, energy, landscape and heritage or social aspects) and of the project throughout its life.
It enables then to make sure that the environmental consequences are properly taken into account in the design of the project. **Thus, there is a strong connection between environmental assessment and design.**

To summarise, the environmental assessment consists in:

⇒ **analysing the potential effects on the environment (positive or negative),**

⇒ **avoiding, minimizing, and counterbalancing residual impacts, if needed, by adjusting the project.**

The purpose of a good environmental understanding of the project must be to optimize the positive effects and to control the negative impacts.

The approach implemented

The approach implemented must be iterative by analysing many variations and alternatives as illustrated in Figure 17. It is a progressive and selective approach since it gains in precision as the iterative reasoning goes. **This iterative approach results in an "optimal" project from an environmental point of view and provides justification for the choices finally made in relation to environmental and social issues.**

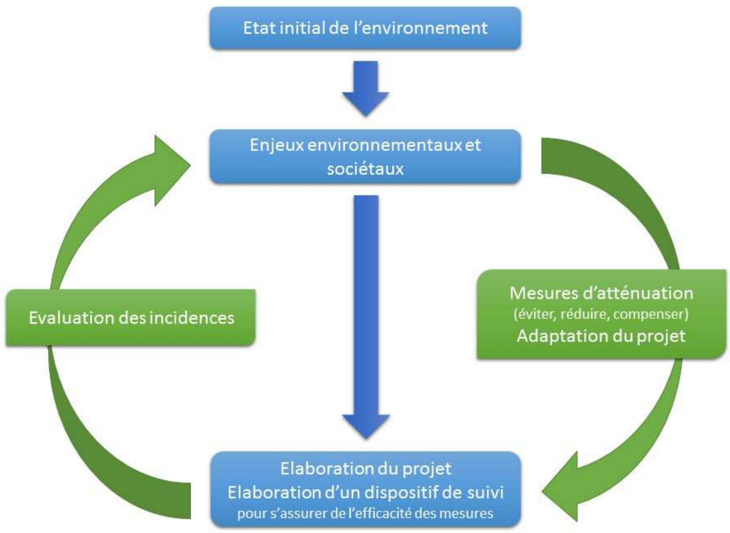


Figure 6 : Organisation chart of the approach used for environmental and societal assessment, illustrating the iterative approach that enables to improve the project design at the environmental level (©Biotope, September 2015).

GRAPHE: flêches bleues = Original state of the environment -> Environmental and societal issues -> Design of the project, Design of a monitoring system to make sure that the measures are efficient.
flêches vertes = repercussions analysis, mitigation measures (avoiding, minimizing, counterbalancing), adjustment of the project.

3.2.2. Environmental and social management

Objectives

Managing and monitoring environmental and societal aspects aim to:

⇒ **check** the initial assessment of the impacts predicted, establish the parameters monitoring the quality of the environmental indicators that have been affected;

⇒ **control** that each of the remedial measures planned are put into practice and define, if there are new impacts, the measures to apply in accordance with the standards and quality parameters established by the current legislation or by international standards.

Sheet n°13

Thus, a continuous monitoring enables to limit impacts thanks to a greater reactivity, and to adjust the measures adequately.

The approach implemented

The approach implemented for the management and monitoring of environmental and social aspects is a process of continuous "in a loop" improvement that can be separated into 5 steps (Figure 18):

⇒ ***Step 1 – commitment***: the analyses carried out during the environmental assessment enable to identify potential impacts and the associated measures, the project developer commits himself in the selected measures;

⇒ ***Step 2 – planning***: direct and indirect indicators need to be defined in order to monitor the impacts and the efficiency of the measures. Information on these indicators must be easily reported thanks to automatically measured data or thanks to manually reported information that follows a defined protocol;

⇒ ***Step 3 – implementation***: this phase applies the approach considered during the analysis phase in a practical manner;

⇒ **Step 4 – environmental monitoring**: the frequency of follow-up must be high enough to get representative variations of the parameters measured;

⇒ **Step 5 – Assessment and improvement**: if impacts are higher than previously estimated, complementary measures must be suggested in order to minimize them.

Preparatory steps – Operational steps

Continuous improvement

⇒ Step 1 – commitment

⇒ Step 2 – planning

⇒ Step 3 – implementation

⇒ Step 4 – environmental monitoring

⇒ Step 5 – Assessment and improvement

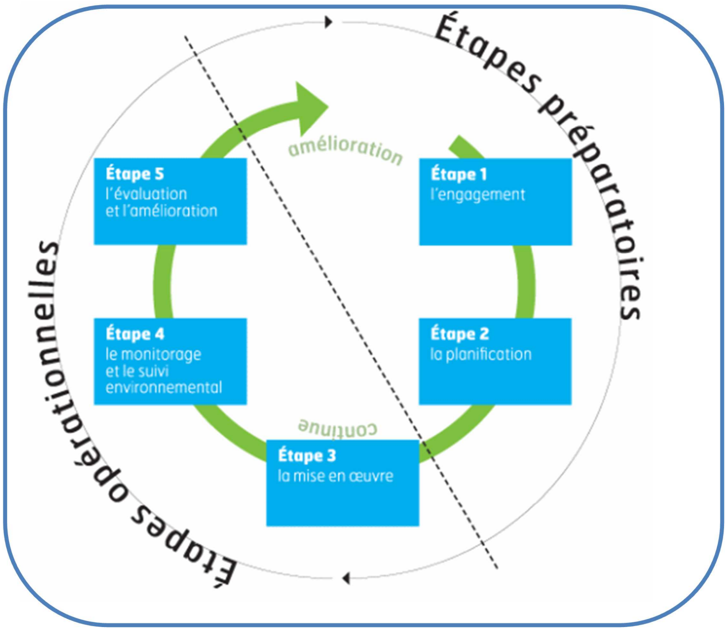


Figure 7 : The general method of environmental and social management (©http://www.gouv.qc.ca)

3.2.3. Consultation and involvement of the public

Objectives

The successful insertion of a geothermal project is managed through a process in which stakeholders **define together the minimum conditions to respect so that the project fits harmoniously** into the environmental and social context of the host territory.

This process aims to improve the quality of the project and to enhance the involvement capacity of citizens, under certain conditions. Although it can't prevent conflicts, it can disclose and explain them.

Consultation is a dialogue process between all stakeholders involved in such a project. Its goal is coming to an informed decision about economic, environmental and social issues. It also leads to:

- ✓ all stakeholders' adherence to the project,
- ✓ developing a common vision of the stakes,
- ✓ identifying compensating measures shared by all.

Thus, **the project is jointly developed by all stakeholders so as to guarantee its success**.

Process of implementation

The approach is based on several axes:

- ⇒ ***Understanding the context in which the project is implemented***: the implementation context of every project is unique. It is of utmost importance to understand these special features, to identify all the stakeholders and how they can be affected by the project;
- ⇒ ***Developing communication and consultation***: An approach based on transparency and on the will of project developers to initiate a dialogue enables to establish the climate of trust necessary for dialogue. However, this consultation must start as soon as possible from the preliminary stage of the project in order to be relevant. To support this process, some

decision-support tools provide structure to dialogue, including prioritizing and analysing the changing perception of stakeholders.

At every stage of the project, **the consultative approach must consider** the expectations from a public consultation that involves:

⇒ **The local and riverside population** during public information meetings that especially allow explaining benefits and drawbacks of geothermal energy and its impacts on the environment and living conditions;

⇒ **The elected members, State services and environmental associations**, in order to refine the choice of project areas depending on environmental impacts and local economic development, in particular.

Consequently the approach of consultation and public participation relies heavily on exchange. The main communication tools and some examples of communication media that can be used are showed in one of the factsheets provided in the appendix.

Sheet n°18

Details about the steps to be taken during the development of a geothermal project will be given later along with its phasing and the major stages of implementation.

Evaluation environnementale et sociétale

Méthode d'intégration des préoccupations environnementales dans l'élaboration du projet

✓ Procédure formelle et légale adoptée dans plus d'une centaine de pays, régulièrement exigée par de grandes institutions financières (Banque Mondiale) : l'ETUDE D'IMPACT

✓ Analyse du contexte et des effets potentiels (positifs et négatifs) du projet sur l'environnement

✓ Proposition de mesures d'atténuation voire de compensation

Gestion environnementale et sociétale

Management en phase de réalisation et d'exploitation du projet

✓ Vérification de l'évaluation initiale des impacts prévus

✓ Contrôle de l'application de chacune des mesures correctives et concrétisation des paramètres de suivi de la qualité des indicateurs environnementaux affectés

✓ Définition et mise en place de nouvelles mesures à cas d'apparition de nouveaux impacts

Concertation et Participation du public

Echanges avec la population et les acteurs locaux tout le long de la vie du projet

✓ Comprendre le contexte sociétal (enquête auprès de la population)

✓ Mise en œuvre d'un processus au cours duquel les parties prenantes (MOA, population, collectivités et services de l'Etat) construisent ensemble les conditions minimales à respecter pour qu'un projet s'intègre harmonieusement, dans son contexte environnemental et sociétal

Chart 6: Summary of the objectives and contents of the three basic tools used for the classic environmental approach that provides guidance for industrial projects development in terms of environmental impacts.

Environmental and social assessment: method of integration of environmental concerns in the project development.
Formal and legal procedure that is adopted in over one hundred countries and regularly demanded by major financial institutions such as the World Bank: THE IMPACT STUDY.
Analysis of the context and of possible effects (negative of positive) of the project on the environment.
Suggestion of mitigation or compensatory measures.

Environmental and social management: management during the implementation phase and the operating phase of the project.
Check of the initial assessment of predicted impacts.
Control of the enforcement of each remedial measure and achievement of the parameters used to monitor the quality of affected environmental indicators.
Definition and creation of new measures in case of occurrence of new impacts.

Public consultation and involvement:
Dialogue with the population and with local actors throughout the life of the project.
Understanding the social context (population survey).
Implementation of a process where stakeholders (the prime contractor, the population, state authorities and services) define together minimum conditions to be met so that the project is harmoniously integrated in its environmental and social context.

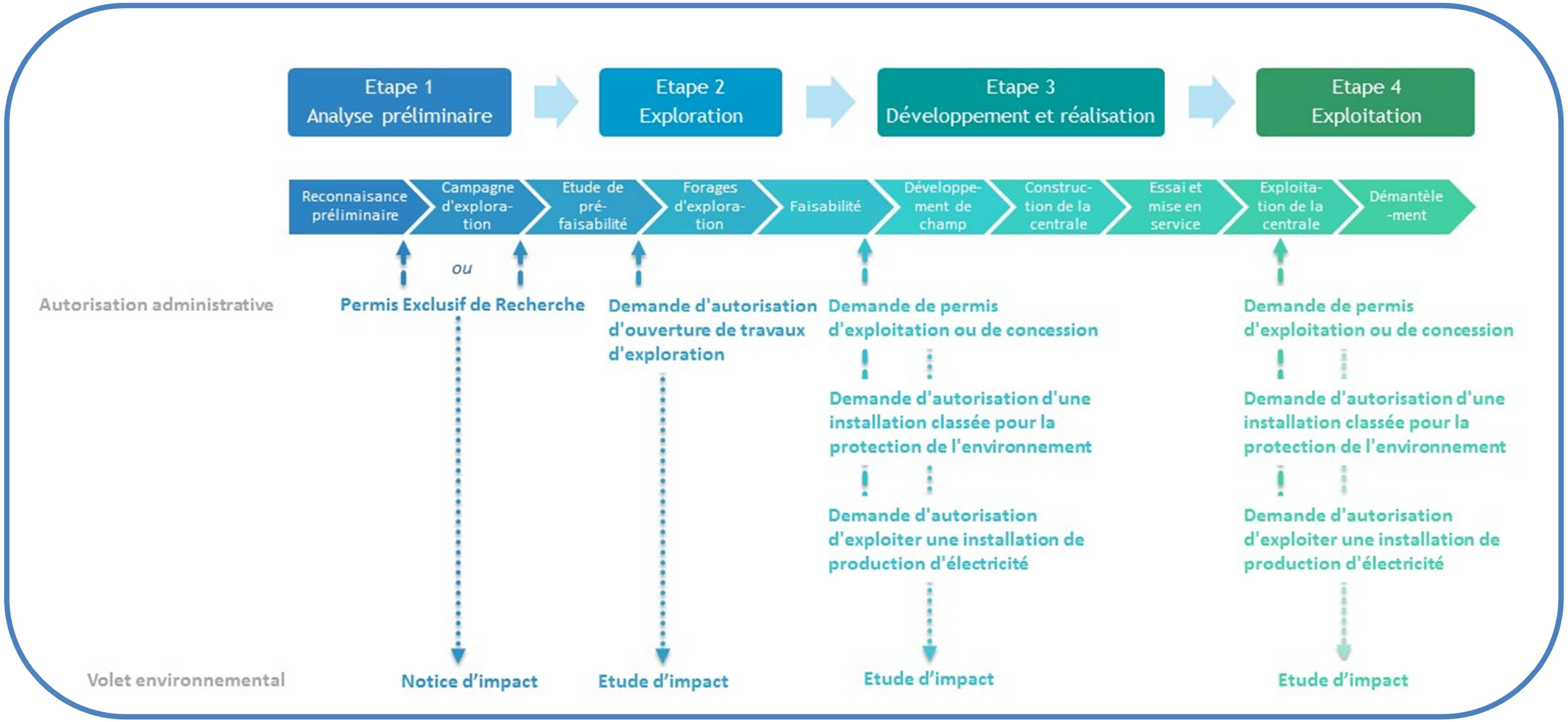


Figure 19: The various stages of a geothermal power plant project for electricity generation and the chronology of the different necessary administrative procedures in France (©Biotope, September 2015).

Comment: There is a complex environmental legislation in France according to which projects are subject to regulatory procedures related to the Mining Code and the Environmental Code, in addition to the basic environmental section of an authorization (file under the Water Act, exemption file in case of ravages on protected species …).

Step 1 : preliminary analysis, step 2 : exploration, step 3: development and implementation, step 4: operation

Preliminary reconnaissance, exploration campaign, pre-feasibility study, exploratory drillings programs, feasibility, field development, construction of the power plant, trial and commissioning, operation of the plant, dismantling

Administrative approval: exclusive licence to prospect, authorization request to initiate exploration work, request for operating or concession permits → request for the authorization of an installation classified for the protection of the environment → application for a licence to operate a power generation facility.

Environmental section: Impact statement, Impact study

3.3. THE ENVIRONMENTAL APPROACH USED FOR GEOTHERMAL PROJECTS

3.3.1. Consideration of the projects duration

A geothermal power station project developed in order to generate electricity presents some special features that have an effect on its environmental impact and on the environmental approach to implement. As a reminder, this is:

⇒ ***A long-term project*** since it usually takes from 6 to 8 years between first studies and the commissioning of a geothermal power station;

⇒ ***A project with successive stages*** that require more and more resources and funds.

⇒ ***A project that can be interrupted before completion*** if geological, economical or environmental conditions are unfavourable or not favourable anymore.

Sheet n°2

In France or abroad, many administrative authorisations punctuate a geothermal project development. Figure 19 shows the moment of the project life when these authorisations are required. On the one hand they are authorisations in order to be able **to explore and then to exploit** the geothermal resource identified as a mineral resource (exploration licence, concession). On the other hand they are authorisations **to begin construction work** (drilling, construction, operation of the plant). All these authorisation application dossiers include an environmental and social section that must legitimate the integration of these themes.

Sheet n°10

The concession duration is usually quite high (50 years long). However, other authorisations must be renewed whenever substantial modifications are made to the project, such as the addition of a new production unit possibly resulting from the dismantling of an old one, or such as new drillings in order to increase the field capacity. That is why new authorisation applications are mentioned during the operating stage in Figure 19.

3.3.2. Key steps of a project and the implementation of the tools for the environmental approach

As reminded previously, a geothermal power plant project is divided into successive stages and its main features are only defined as the project progresses. **Four key steps** in a project development have thus been defined for the implementation of the environmental approach (Figure 19). These steps are:

- Step 1 : The preliminary analysis
- Step 2 : The exploration
- Step 3 : The field development and the implementation
- Step 4 : The operation

What is important is to remember that the environmental approach tools will be implemented **several times** during these key steps, whenever it will be needed according to the work involved, as shown in Table 7. As an example, successive environmental assessments will be needed, first on the creation of access roads and the implementation of exploration drilling (Step 2), then on the implementation of development drilling, the construction of fluid transportation networks and the construction and commissioning of the power plant (Step 3) and finally on possible extension or dismantling projects (Step 4).

	Environmental and social assessment	Environmental and social management	Dialogue and involvement of the public
Etape 1 Analyse préliminaire	Preliminary environmental and social assessment	-	Start of a dialogue
Etape 2 Exploration	Project assessment: creation of access roads and exploration drilling	Monitoring of the work conducted	Consultation and information
Etape 3 Développement et réalisation	Project assessment: development drilling, networks and infrastructure associated, power station	Monitoring of the work conducted	Consultation and information
Etape 4 Exploitation	Project assessment: extension, evolution of the power station and of auxiliary equipment	Monitoring of the operation of the power station Follow-up of the work conducted in case of evolution	Timely dialogue with the public Consultation and information in case of evolution of the power plant, during the dismantling

Table 7: Cross between the major steps of a geothermal power plant project and the implementation of the three environmental approach tools.

Step 1: preliminary analysis, step 2: exploration, step 3: development and implementation, step 4: operation.
LE RESTE EST TRADUIT DANS LE TABLEAU DIRECTEMENT.

3.3.3. Implementation of the methodology suggested

The environmental approach for a geothermal power plant project must address various aspects: choices to make for environmental preservation and for the comfort of local residents during the reflexion of the project; implementation of remarkable practices for the environment during the work; operation; development of a process in order to get the population to accept the project.

The methodology suggested in this guide book is based on **recommendations** made in the previous chapters. These recommendations are made for each of the previously illustrated four key steps of a project, according to the environmental and social issues that have been identified.

First, for each of these stages, there is a summary of all recommendations. Then, the most important recommendations (**key recommendations**) are presented in more detail.

3.4. RECOMMENDATIONS FOR THE PRELIMINARY PHASE OF A PROJECT

3.4.1. Summary of the recommendations made in the preliminary phase

The preliminary stage of a project is based on a review of existing data, which allows selecting the areas of interest (on a regional or national scale) where there are interesting features that legitimate further exploration works. It lasts from several months to one year depending on the availability of baseline data. **This activity doesn't impact the environment.**

However it is recommended for the islands of the Lesser Antilles which are in an exceptional environmental context to anticipate and prepare the environmental and social integration of a project **as early as possible**, so as this preliminary phase starts. The recommendations made are the **key** following ones:

⇒ **Preliminary environmental assessment:** at this preliminary stage of the project, there are still many uncertainties and unknown factors about its size, its exact positioning and the perimeter of area that might be affected, its cost and funding and its future. So it's too soon to start an environmental impact study. Nevertheless the environmental and social aspects of this project must be addressed now, on the basis of the available information. Thus it's recommended to start a preliminary environmental assessment or "environmental pre-diagnosis";

⇒ **Preliminary social analysis:** it is about knowing the public of the implantation area of the project in order to launch an appropriate consultation;

⇒ **Consultation for the launch:** this consultation enables to define and implement a public consultation strategy with all stakeholders (local residents, administrations, local and regional authorities, associations…) which will be implemented by the project developer on his own or with support from local authorities and the agencies in charge of spatial planning and energy planning (in France they are the Regional Council, Ademe…)

⇒ **Environmental management multidisciplinary group:** at this preliminary stage, it is recommended that the project developer set up an environmental management multidisciplinary group in charge of implementing and monitoring the environmental approach and the societal acceptability approach (throughout the entire project).

The three key recommendations written in blue are detailed below.

3.4.2. The preliminary environmental assessment

Phase(s) in question	**Preliminary reconnaissance, Exploration campaign**
Tool(s) in question	Environmental and social assessment, Dialogue and involvement of the public
Theme(s) in question	All themes

N.B: In the table above the phases in question are the phases of an electricity production geothermal project as defined in Figure 6. The tools in question are the one defined in paragraph 3.2. The themes in question are the one shown in Table 4.

Depending on the project, this preliminary environmental assessment will be conducted at the preliminary reconnaissance phase or during the detailed exploration phase, or even during the pre-feasibility study. This last situation will occur if a project is revived after a period of abandon.

This preliminary environmental assessment stage aims to identify from the beginning of the project **the major environmental and social issues** and to make sure that these will be properly taken into account in the project development. In fact, the clear pre-identification of environmental issues:

⇒ enables to give the alarm in extreme situations if the project faces majors issues that can question its feasibility,

⇒ but its goal is also to strengthen/optimize the ability to deal with the repercussions/effects and environmental and social impacts of the project and enable these impacts to be measured, managed and minimized during the duration of the project.

This preliminary environmental assessment must be conducted on the **entire area of interest** likely to be concerned by the project, including access roads.

The brief identification of environmental sensitivities allows the project developer to access information that is complementary to technical and economic parameters so as to be able to take a more informed decision about the future and the features of his project.

This preliminary assessment, as well as being **a tool for decision support**, is a **device for defining the accuracy** of future impact studies and enables to detect needs for gathering additional information and the means to implement in terms of services.

In France, this preliminary environmental assessment can be used for the impact statement that is required in addition to the application file for an exclusive research permit (ERP) in the Mining Code.

The notion of impact statement

In France, the Exclusive Research Permit (ERP) application must include an environmental impact statement that gives indications on potential negative effects of environmental exploration works programs and on the conditions under which the planned operation considers environmental concerns.

Remark: since the reform of impact studies (Decree n°2011-2019 of 29 December 2011), the impact statement previously required for some types of projects has disappeared from the Environmental Code but is still required in the Mining Code.

Table 8 sums up the different steps of this preliminary environmental assessment and suggests a framework of its content.

Sidebar 1 is an example of mapping the regulatory constraints faced during a preliminary environmental assessment on the area of interest of Petite Anse in Guadeloupe (study carried out for the INTERREG CARAÏBES IV Program – Geothermal energy Caribbean Phase 2).

Deconstruction	Proposed content
1- Preliminary description of the project and of its possible variants	A general presentation of the characteristics of the project. Without getting into details, it must address the entire project and not only the initial exploration stages. This description must emphasise the preliminary nature of the information available. The various actors must be aware that the project features are still uncertain when it comes to technical choices, siting of facilities, electricity production capacity of the future power station etc. *As an example, the information that can be given is the following: project background; geothermal resources data obtained from geoscience studies or from a previous preliminary reconnaissance phase; a preliminary drawing of the future establishment; the preliminary and non-definitive delimitation of the area of interest of the project, in other words the area that will eventually concentrate exploration and development drillings and surface facilities that include the buildings of the plant and access roads; the forecast planning of the project and its main deadlines in terms of building works.*
2- Identification of the main environmental and social issues in the territory concerned	The aim is to highlight the main environmental and social issues in the area of interest of the project as defined previously. This inventory will usually rely on a bibliographic study and expert advice. • The bibliographic study will use existing data bases and data available online. Two major types of data can be used: general documents, if available, can provide useful information on the expectations of authorities and local communities, on regional and sub-regional policies and positioning in terms of protection, restoration of environmental quality, energy and climate; local data enable to refine the environmental stakes. • The opinion of one or several experts will be needed in order to identity the environmental and social sensitivities on the field (land use, local residents, rivers, networks, viewpoints, environment and potential to host plant life and the various groups of fauna…). Here to point is not to be exhaustive but to quickly assess and zone the environmental sensitivities of the territory in question.
3- Priorities of the future impact study and organization of the stakes into a hierarchy	A hierarchy of environmental issues should be made in order to: ▪ detect the needs for additional information and define the degree of accuracy of the specific studies that will have to be carried out later and that will be able to constitute terms of reference for an impact assessment; ▪ Possibly identify the need to adjust the proposed project so as to facilitate its integration. ➘ The environment is thus considered, on the same basis as physical and technical parameters, as a component for thinking about the design of the project
4- Preliminary analysis of the potential effects and proposed measures	This stage consists in preliminarily describing the potential environmental effects of a geothermal power station project, based on examples of previous similar cases The analysis will concern the various stages of the project. However, knowing that the work carried out during the preliminary reconnaissance and detailed exploration phases can't affect the environment significantly, the analysis will mainly focus on the drilling, construction of the power plant and operating phases. *This analysis informs the impact statement required for the application file of the exclusive research permit. At this stage it doesn't consists in quantifying the potential effects but in drawing attention to possible impacts and the basic measures to consider. The impact study of drilling operations will be furthered later when the locations will be known.*
5- Analysis of the environmental regulation	Based on the preliminary analysis of environmental issues, the project implementation must be analysed considering the environmental regulation. This analysis enables to define the regulatory procedures that the project developer must follow in order to have official authorisations for his project. It also informs him on the expected content of the file(s) and the related procedures. For a geothermal project, procedures will first and foremost be provided in the Mining Code, as well for the granting of mining rights (Research Permit, Operating Permit and Concession) as for permits for research and operation works (see paragraph 2.2.4 on this subject). ➘ The arc made by the Lesser Antilles is characterised by a remarkable biodiversity, so there are regulations to safeguard it. The reflection upstream of the project phase should consider the procedures related to this regulation, especially in order to best size the specific investigations to conduct.

Table 8: Example of framework and content of a preliminary environmental assessment.

Experience feedback

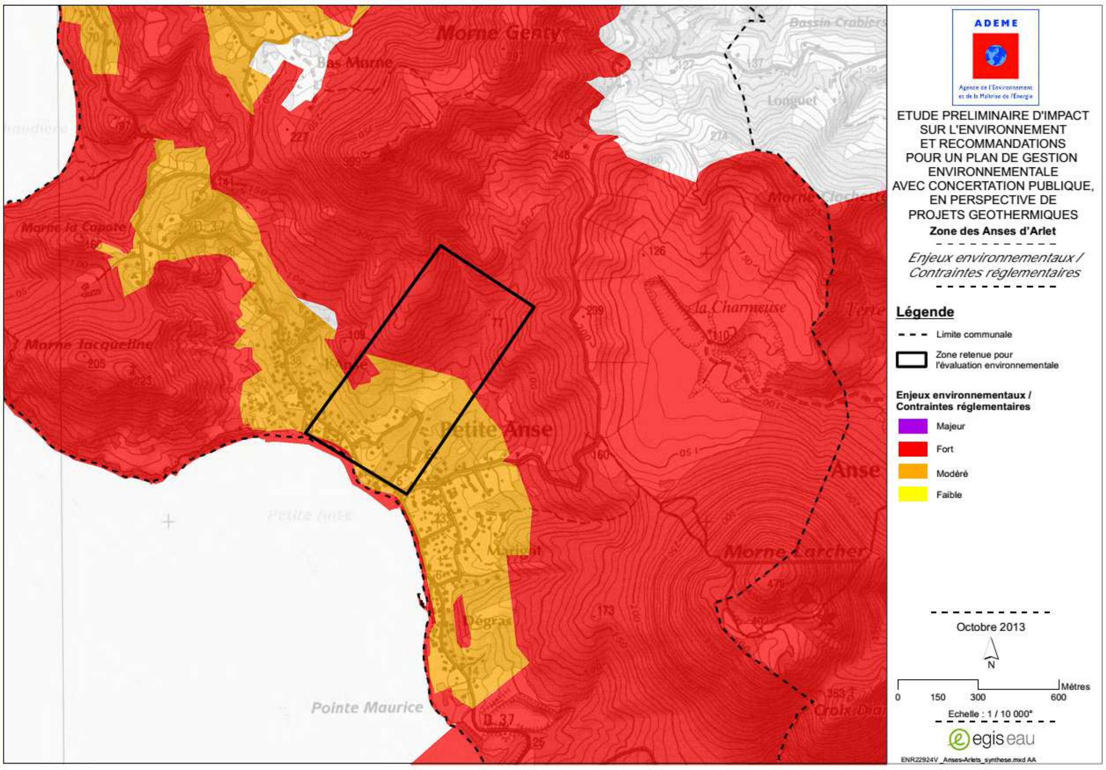
Preliminary study of the impact on the environment in prevision of electricity production geothermal projects on Petite Anse and Mount Pelée in Martinique.

As evoked in the paragraph 2.6.3, two zones of interest susceptible to possess geothermal resources of high temperature for the electricity production were identified in Martinique in Mount Pelée and of Petite Anse (municipality of Anses-d'Arlet).

To understand the environmental and societal issues presented by these two zones of geothermal interest, the ADEME confided to EGIS EAU a mission of environmental pre-evaluation of both sectors. The study carried out is an analysis with multiple criteria gathering the following components:

- Environmental issues (inventoried and protected sites),
- Human issues (living environment, landscape and sites),
- Urban planning constraints (PPRn of Martinique and documents of town planning of the concerned municipalities).

The objective was to supply a **decision-making tool** combining a maximum of information illustrated and presented in a clear way to allow a **hierarchical organization of sites with regard to the global environmental issues**, as shown in the map below which specifies the level of the issues relating to regulatory requirements applying to a future project of geothermal power plant.



Insert 1: example of analysis of regulatory requirements applying to a future project of geothermal power plant at the level of the zone of interest of Petite Anse in Anses-d'Arlet in Martinique, realized within the framework of a preliminary environmental evaluation realized within the framework of the project INTERREG IV - Geothermal science Caribbean Phase 2 (according to Egis Eau, on 2014).

3.4.3. Preliminary societal analysis

Concerned stages	**Preliminary recognition, Campaign of exploration**
Concerned tools	Environmental and societal Evaluation, Dialogue and participation of the public
Targeted themes	Themes connected to human environment (socioeconomics, uses(practices), living environment)

Every territory presents sociological, political, historic or economic characteristics of his/her own and which can influence the good success, or the failure of the implementation of a project. So **the preliminary stage consists, for the carrier of a geothermal project, in knowing as good as possible the territory of setting-up of its project.**

This knowledge of the context and all the present issues in an obvious or latent way comes along with an identification of the public belonging to the territory. This allows to define the social, technical and political limits of the project and to know the future interlocutors on the project.

It is a question of raising the panorama of the actors and their relation with the project to have a good vision of the people or the group of concerned, their degree of knowledge of this type of installation, their level of understanding, support or rejection to the project, the diversity of points of view and expectations. This work is useful to specify the objectives and the strategy to be implemented to communicate in an optimal way on the project.

*It is impossible to know all the nuances of the ground because every person has its perception of things, which comes from their personal knowledge, their biases and preconception which shape their opinion. The addition of these opinions forms what we call the **public opinion**. It is however crucial to encircle it and to make the analysis, to limit the interferences which precede inevitably any communication of a message.*

The realization of an **opinion survey** can be envisaged to encircle better these various aspects. As an example, an opinion survey concerning the perception of the population towards the geothermal science and EnR was recently realized in Guadeloupe, Martinique and Dominique (see Insert 2). Its results can be exploited with profit by a project leader to feed this preliminary societal analysis.

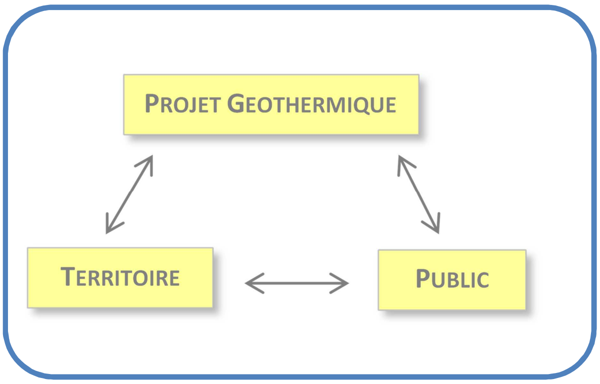


Figure 8 : Interrelations to be taken into account in the preliminary societal analysis (© BIOTOPE, in May, 2015).

Table 9 presents some lines of thought to structure this preliminary societal analysis, to know well the stakeholders and the context in which the setting-up of the geothermal project is envisaged.

Themes	Comments
1- *History of the environment and the project leader*	⟐ What are the other projects and the events which arose in the community of reception? Does the community knows the project leader? What other projects are planned in the region? Are synergies possible between these diverse projects for the profit of the partners and the community? What are needs in resources and municipal infrastructures? ↳ The apprehension of the memory of a territory is a decisive part of the work of anchoring of the project in a given place. It is also important to make sure of the coherence of the project with the regional objectives of territorial development, but also with the projects already planned in the environment, particularly those who benefit from a certain support of the community.
2- *Characteristics of the community (socioeconomics, socio-geography, sociopolitical)*	⟐ Are there particularly vulnerable groups within the community, within an economic or other point of view? What is the economic status of the majority of the population as well as the financial position of the public institutions? ↳ The socioeconomic analysis allows to establish the first characteristics of the stakeholders. ⟐ What are the local stakeholders, but also national and international, and which are their concerns as well as their values? What is the identity and patrimonial character of the affected territories? What environmental, cultural natural and characteristic resources are at stake? ↳ The environmental characterization introduced in the environmental approach in preliminary phase constitutes a tool of analysis allowing to clarify the characteristics and the sensibility of the environment. A mapping of the distribution of the stakeholders with regard to the important geographical elements constitute a considerable assets to understand well their interests, their concerns and their interactions. ⟐ What is the organization of the community? Do the governmental and municipal institutions benefit from the trust of the population? ↳ This trust or non-trust, where necessary, will influence the value and the legitimacy of the statutory steps of the project leader as well as the relevance to obtain from the support of these institutions.
3- *Information and Medias*	⟐ What relevant information to the project is available and conveyed in the community? Is this information exact, is it sufficient, does it explain the risks and the possible consequences of the project in a realistic and understandable way? ↳ The "relevant" information that the community has can include the information relative to similar projects led by other companies in the domain. The community will use these comparable to understand better the possible impacts of the project. From this perspective, it is essential to estimate the available information. ⟐ What are the active media in the community and which are their trends? ↳ The latter can play relay runner's important role of information in the community of reception and thus, it is advisable to know well their positions in diverse cases. The media can fill several functions like to bring back and to amplify the reactions of diverse parties, to convey certain information (good or bad, complete or incomplete), but also to raise problems and to alert the community. It is thus important to understand the role of the active media in the environment. Furthermore, it is important to differentiate the social media, which are directly fed by the real time public from traditional medias.

Table 9: lines of thought allowing to structure the preliminary societal analysis realized during the preliminary stage of a project of geothermal power plant for the prodcution of electricity.

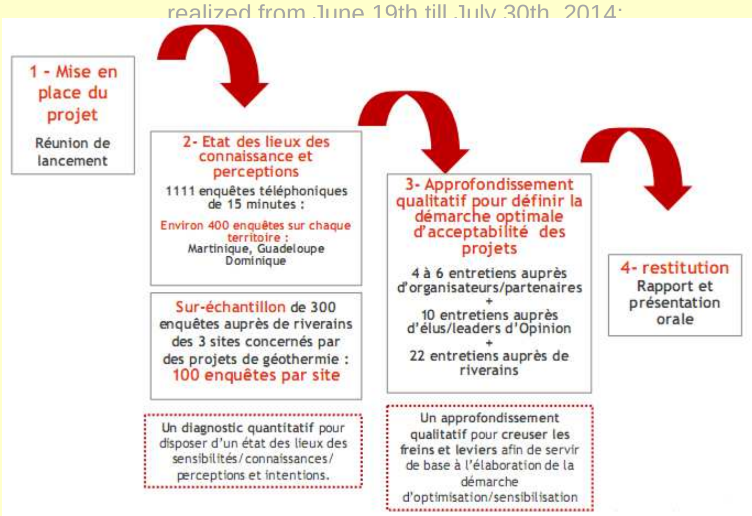
Experience Feedback

Opinion survey in Guadeloupe, Martinique and Dominique

During year 2014, BVA accompanied the ADEME and his(her) partners in the realization of a study to define the approach(initiative) of communication and optimal raising awareness(sensitization) susceptible to favor the acceptance of the projects of energy production thanks to the renewable energies and more particularly from the geothermal science. The study concerned the population of the territories of Guadeloupe, Martinique and Dominique. On every territory, a representative sample was established(constituted), allowing in the end(final) to arrest(dread) exactly the perceptions(collections) according to the sociodemographic characteristics, to the level of knowledge of the energy solutions, the sensibility or the sanitary or environmental commitment, the closeness or not the concerned sites.

The evaluation aimed at 3 objectives:

The approach was made in 4 successive stages and in the end, 1411 phone inquiries of 15 minutes were realized from June 19th till July 30th, 2014:



Insert 2: experience feedback of an opinion survey realized in the Antilles and concerning the perception of the population towards the geothermal science and EnR (according to BVA-Ademe, on 2014).

3.4.4. The dialogue of launch

Concerned stages	**Preliminary recognition, Campaign of exploration**
Concerned tools	Dialogue and participation of the public
Targeted themes	Themes connected to human environment (socioeconomics, uses(practices), living environment)

One of the key-points of the success of the geothermal power plants projects revealed thanks to experience feedback is the implementation of an **active dialogue** with all the actors concerned **from the beginning of the project** to obtain a wide social consensus. It is thus recommended to the bearer of project to prepare and to implement this dialogue within the framework of this preliminary stage.

This phase aims at understanding the context into which fits the project and to begin the dialogue with the stakeholders. It is thus advisable, in this stage, to determine if the project opposes the values or the concerns of the environment, which can vary considerably from a community to another and from a stakeholder to another, both at individual and collective scale.

This dialogue must be led with all the actors susceptible to be concerned by the realization of the project: local and regional population, elected representatives, administrations, associations, etc. … It has to lean on the results of the **preliminary societal analysis** described previously.

In this preliminary stage, this approach includes:

⇒ Exchanges with the public (**meetings**) which can take place before and during the detailed campaigns of exploration which constitute the beginnings of the project where the presence of “foreign” people materializes on the ground;

⇒ The writing of a **document of return** for the work and the obtained results.

Exchange with the public

In this preliminary stage of the project, the meeting of presentation is an effective way of communication. It aims at a simple appropriation of the project by the public. The information, the listening and the dialogue will aim at the understanding of the project. It is thus a question of presenting clearly and simply the project, the following questions can feed the reflection:

- How is your project called?

  It is important that the project has a precise name to be recognized and identified by the largest number from its launch;

- What are its objectives and purpose?

  To arouse the interest of the project facilitates its appropriation; the evocation of the economic fallouts is a track to be studied;

- When was it born and why?

  To return on the genesis of a project allows to register it in its context;

- When will it be finished?

  Within the framework of a project of geothermal power plant, where the steps of time are consequent (between the preliminary phase and the putting into service, several years *pass by). This point is quite important. The presentation of the big stages in a synthetic way with a temporal reference seems essential from the initiation of the project, by insisting on the current stage (preliminary phase).*

The first meeting is the opportunity to collect the first notices, the first expectations, the first questions carried towards the project. A suggestion is to have at arrangement of the first elements of answers on the effects of such installations resting on the impacts noticed on similar units in a general way. It will naturally be specified that particular studies will be led to determine the effects of the project on the environment and the health.

Finally this meeting is the opportunity to present the people who are going to intervene on the ground within the framework of the detailed campaigns of exploration. The project leader will express uncertainties on the outcome of the works, by putting forward the notion of geologic risk.

The first information meeting can be followed by the other meetings during which will be presented the progress and the results of the campaigns of exploration. It is important that the public is informed at the end of the campaigns of exploration of the future of the project (pursuit or abandonment).

Identification of a spokesperson

Throughout the project and beyond its implementation, the project leader and then the developer of the power plant will ideally have to be represented within the community by a spokesman who will insure the link and the communication between the population and the project. The typical profile is the following one:

- ⇒ Because the spokesman has to insure a local presence, he must be easily accessible, not only by telephone and by e-mail, but also on-the-spot physically;
- ⇒ Having preferentially a knowledge of the region in which the project joins and of a basic knowledge regarding geothermal science, he has to be a security of credibility and efficiency;

Ideally, the spokesman arises from the multidisciplinary environmental group of management set up by the project leader.

Handouts

A last action in the approach of societal acceptability which must not be neglected is the writing of a handout recording the results of the preliminary analysis of the societal context and the results of the meetings of presentation in particular the notices and comments of the public on the project.

This guarantees that the information obtained within the framework of this approach of societal acceptability will be taken into account well by the project leader during the later stages.

3.5. RECOMMENDATIONS CONNECTED WITH THE IMPACT OF THE WORKS OF DRILLINGS AND CONSTRUCTION

3.5.1. Introduction

The choice that was made in this guide establish **common recommendations** concerning the impacts of the works of drilling and the building work of the power plant and the related equipments as far as they involves " **works of construction sites** " which present similarity at the level of their impacts which were already described in common (cf. paragraph 2.3.1).

These recommendations thus concern the **Stage 2** (Exploration) and the **Stage 3** (Development of field and realization) such as defined on the Figure 19.

They aim more particularly at framing the following works:

⇒ Forages Exploratory drillings;
⇒ Drillings of development (well of production and reinjection);
⇒ Construction of the transport network and the separation of the fluids;
⇒ Construction of the power plant and its secondary équipemesnts;
⇒ Construction of the electric transport network.

In consideration of the duration of these works in construction sites in the progress of a geothermal project, these recommendations which usually have a temporary nature take here a quasi-permanent character during numerous years.

3.5.2. Summary of the recommendations connected to the impacts of the works

A series of recommendations is proposed on the basis of the stakes defined within the framework of the previous shutter of this guide. These recommendations are presented in the form of a synthetic table (Table 10) containing the following sections:

✓ Concerned Themes;
✓ Potential Effects of the works of drilling and the building work of the power plant;
✓ Identified Stakes;
✓ Recommendations.

This Table 10 contains, among others, the **key recommendations** (underlined in blue) bound in particular to the strong environmental stakes presented by the island territories of the Lesser Antilles, which are the following ones:

1. The Constitution of a Reference state;
2. The realization of a Study of environmental and societal impact (EIES);
3. The application of best practice in phase construction site(work);
4. The realization of an environmental follow-up within the framework of the implementation of an environmental and societal management plan;
5. The Implementation of an adapted dialogue.

These key recommendations are detailed following the Table 10.

	Interests and sensibilities of the context	Potential effects of a geothermal project	Stakes	
Air	**Relatively good to very good air quality**	**Risk of air pollution** In particular CO2 emissions, building machines, rigs of drilling and transport; gas emissions H2S during the drilling, during the tries(essays) of production Remark: the forest ecosystems have the capacity to absorb a part of the present CO2 in the atmosphere. The consequent clearing necessary for the implementation of the installations thus engenders a degradation of this feature, limiting the effect getting of the pollution	**Maintain a high quality of the air**	**Constitution** analysis of the of the air quali **Realization of Environmenta** impacts and th **Best practice** maintenance a construction si Device of closu **Environmenta** concentrations and the neighb Limitation of th
Soil and sub-soil	Zones which can present consequent made uneven	**Risk of destabilization** of grounds, soil erosions, landslides bound(connected) to the opening of access roads, in the deforestation, in the excavations **Modification of the balance of grounds** and the risk of movement of ground due to the modification of the topography **Risk of accidental pollution of the ground**: poor maintenance of building machines, bad operation or mismanagement of waste; mismanagement of the fluids of drilling: muds, additives, geothermal fluid; contamination of the superficial aquifers by the fluids of drilling	**Conserve soil integrity**	**Constitution** geotechnical s **Realization of** Choice of the s of the allocated same platform of conducts Best practice i Fast revegetat necessary

Table 4 : Summary of the recommendations concerning the works of drilling and the building work of the power plant and the related equipments during a geothermal project for the electricity production.

	Interests and sensibilities of the context	Potential effects of a geothermal project	Stakes	
Water	**Vulnerability of the resource in fresh water**	**Water samplings** connected to the preparation of the fluid of drilling, to the tests of injectivity Risk of accidental pollution: poor maintenance of building machines, bad operation or mismanagement of waste **Risk of degradation of the quality of waters in case of accidental releases**: contamination of the superficial aquifers because of leaks of fluids towards the superficial aquifers, the thermal and chemical pollutions of waters of surface from the streaming of rainwaters on the platform and / or the discharge of the geothermal fluid during the trials of production **Risk of degradation of the morphological characteristic**s: disturbance of the transit of sediments, change of the characteristics of flow and hydrological (modification of the debit) of the aquatic environment due to the takings in water and rejections (in particular fluids unloaded during the trials of production)	**Preserve water ressources**	**Constitution** water upstrea setting-up of th ecological stat availability of t **Realization o** Recycling of th water of the pl Installation of forming a barr sensitive aquif Harnessing of temporary stor (cold) reinjecti injectivity, dilu the natural env Management **Best practice** **Environment** the water
Natural risks	**Important natural risks**	**Risk of worsening of the pre-existent natural risks:** landslides Micro-seismicity mainly connected to the injection of water during the operations of stimulation of well	**Conservation of the properties and the people Adaptation of the project to the present risks**	**Realization o** Reflection con basis of the kn specific study **Environment** evolution of th

Table 10 (follow-up): Summary of the recommendations concerning the works of drilling and the building work of the power plant and the related equipments during a geothermal project for the electricity production.

	Interests and sensibilities of the context	Potential effects of a geothermal project	Stakes	Requireme
Natural environment	**Unique and rich biodiversity**	Destruction and degradation of natural housing environment and/or housing environment of species caused by the creation of access roads, the creation of drilling platforms, the pollution Disturbance of the animal species due to the noises, the vibrations and the light inherent to the phase works Risk of destruction of individuals or eggs (in particular those in low capacities of travel) Destruction of the corridors of travelling of the fauna due to forest clearing. Obstacle to the biological continuity in river (according to the type of intake of water) Fragmentation of the environment owed in particular to the presence of access roads	**Preservation of the biodiversity of interest**	**Constituti** inventories concerned seasonality **Realizatio** Reflection from studie of the setti the impact surfaces b platform, t waterproof Adapted ca Protection Measures **Best prac** **Environm** follow-up a
Landscape and cultural heritage	Diversified landscapes of interest	Modification of the landscaped structure and the land use via the creation of tailboards and artificial sectors segmenting the landscape Interactions of drilling rigs with the landscaped elements at a wide distance because of their height (Mast of drilling, panache of vapor during the trials of production) Risk of co-visibility with monuments or protected / remarkable sites Risk of infringement on the cultural, archaeological heritage	**Landscaped integration** **Prevention of the degradation of the cultural heritage**	**Constituti** landscape visibility, la **Realizatio** the tries **Best prac**

Table 10 (follow up) : Summary of the recommendations concerning the works of drilling and the building work of the power plant and the related equipments during a geothermal project for the electricity production.

	Interests and sensibilities of the context	Potential effects of a geothermal project	Stakes	Requirements
Economy	Economic development based on the tourism and the agriculture Dependence towards the oil imports	Contribution / Infringement on the local economy Resort to local companies and job creation Workers' temporary or permanent influx which can cause an imbalance in the domains of the services and modify the traditional lifestyles	**Elaboration of a project in adequacy with the local economy**	**Constitution o** and socioecon **Realization of** **Adapted dialo**
Use	Limited land availability Pre-existent activities: agriculture, tourism (balneology)	Land pressure on grounds which can go to the expropriation, with possibility of reduction of the agricultural surfaces used by the community Risks of incidences on the pre-existent economic activities (tourism, agricultural activities, etc.)	**Consideration of the activities and the uses preexisting in the conception of the project**	**Constitution o** and socioecon **Realization of** Reflection con basis of the inv the uses and t sector Measures of c **Adapted dialo**
Living conditions	Different living environment according to location: urban to countryman Attachment of the local populations to their natural environment (biodiversity and landscape)	Degradation of the air quality Noise pollutions connected to the drilling, to the assembly of tubes and equipment, to the discharge) of vapor during the trials of production, to the activities of building machines and transportation of goods Risk of gene person with a strong visual sense Disturbance of the local residents by the increase of the road traffic around the site (gene and greater risk of accident on roads) Confrontment of the road network Risk of water pollution and grounds	**Conservation of the living environment also involving a protection of the natural environment and the landscape**	**Constitution o** (measures of a closest local re **Realization of** **Environmenta** concentrations and the neighb atmosphere Sound protecti organized by s setting-up of th zones Measures of c **Best practice** **Dialogue adap**

Table 10 (follow-up) : Summary of the recommendations concerning the works of drilling and the building work of the power plant and the related equipments during a geothermal project for the electricity production.

3.5.3. Constitution of a Reference state

Concerned phases	**Campaign of exploration, Study of prefeasibility**
Concerned tools	Environmental and societal evaluation Dialogue and participation of the public
Thematic targeted	Any theme

A "reference situation" (or " reference state " or " initial state ") corresponds to a description of a space (landscape, physical environment, natural housing environment, etc.) at the precise moment. It is with regard to this spatiotemporal reference state that will be quantitatively and geographically estimated the future possible modifications of the local environment. The constitution of reference data seems thus **essential within the framework of the environmental and societal evaluation** of a project.

The reference state is indeed necessary for:

⇒ **Establish a robust base of comparison** (from time - zero, for the naturalistic studies which often require counting of individuals and species for example);
⇒ Allow the wedging of possible modellings;
⇒ **Measure the quantitative and qualitative importance of the evolutions** which could be then noticed, which it is about evolutions of the environment, about the atmosphere (sound, bright, of the temperature), of physical evolutions (movement of ground, turbidity of the water), chemical (water pollutions, grounds), etc.;
⇒ **Estimate** the speed of the changes which will possibly be observed (on various no times, adapted to the species) within the framework of the ecological follow-ups for example.

Sheet n°12

The objectives and the conditions of realization of a reference state are described in the Form n°12 supplied with Appendix. It is interested in the environment in the broad sense. The notion of environment recovers a set of interdependent concerns. With the aim of a relatively wide approach, the environment is cut most of the time in several components: physical environment (ground, air, water), natural environment (housing environments, animal and vegetable species, ecological features), landscape, human environment (socioeconomics, uses, living environment and health).

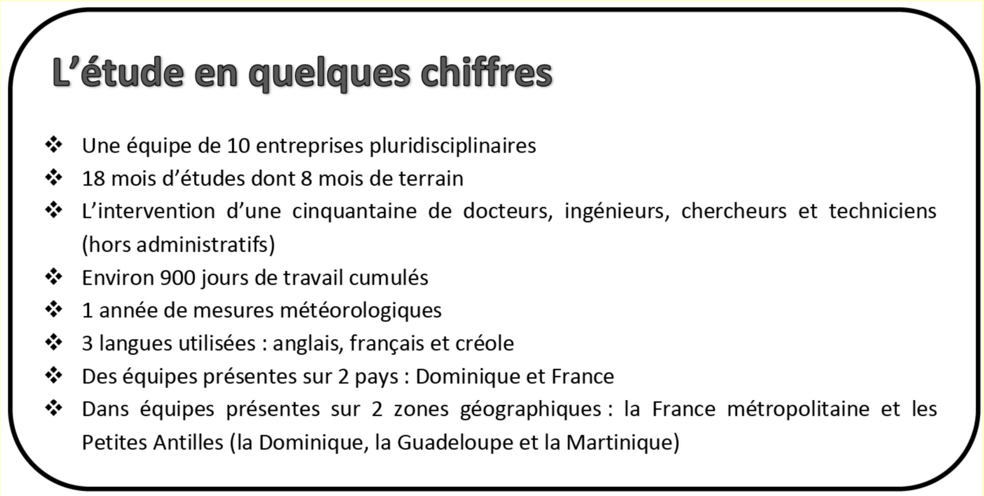
The constitution of this reference state requires of time (regarding ecology, a biological cycle is necessary at least) and particular means (specialists interventions). The Insert 3 illustrates an experience feedback acquired in Dominique during a study financed by Ademe within the framework of the Project Geothermal science Caribbean - Phase 2 supported by the Program CARIBBEAN IV. INTERREG

Experience feedback

Initial state on the environment of the reed valley in Dominique, in anticipation of the development of projects of geothermal electricity production

Since 2005, Dominique introduced a program for the realization of a geothermal project in the reed valley, in cooperation with France, within the framework of the Program CARIBBEAN INTERREG and of the Project Geothermal science Caribbean - Phase 2. In this context, the ADEME financed the realization of a reference state of the environment of the reed valley in Dominique, in anticipation of the construction of a geothermal power plant for the electricity production. The objectives of this study were in particular of:

- Realize a zero state of the state of the environment in the reed valley, being of use as base to the future determination of the impacts and the measures;
- To complete the existing data via reproducible, standard protocols of acquisition in time. The concerned themes are in particular the natural risks (flood, movement of ground and seismic risk), the acoustics, the aerology, the climatology and the hydrography.
- Pay a particular attention carried in the ground and aquatic biodiversity, via the realization of inventories, as well as in the living environment, in the landscape and in the heritage. These elements are particularly sensitive in the eyes of the inhabitants of the reed valley and thus inescapable to engage in a dialogue with the local population.



L'étude en quelques chiffres

- Une équipe de 10 entreprises pluridisciplinaires
- 18 mois d'études dont 8 mois de terrain
- L'intervention d'une cinquantaine de docteurs, ingénieurs, chercheurs et techniciens (hors administratifs)
- Environ 900 jours de travail cumulés
- 1 année de mesures météorologiques
- 3 langues utilisées : anglais, français et créole
- Des équipes présentes sur 2 pays : Dominique et France
- Dans équipes présentes sur 2 zones géographiques : la France métropolitaine et les Petites Antilles (la Dominique, la Guadeloupe et la Martinique)

Insert 3: experience feedback of the realization of a reference state of the environment within the framework of the geothermal project for the electricity production of the Reed valley in Dominique (Caribbean Development environment and Coll. (2015).

3.5.4. Environmental and societal impacts analysis (ESIA)

Concerned phase(s)	**Pre-feasibility study; Feasibility**
Concerned tool(s)	Societal and environmental evaluation Support document to Environmental and societal management and to Consultation and participation of the general public
Targeted topic(s)	All topics

The impact study (abbreviated term for environmental and societal impact analysis) is both the approach and the document formalizing the approach (regulatory dossier). The first one is a careful thought of environmental impacts of a project, carried on by the project owner. It is also an analysis of the technical and economic feasibility of the project. The second one is the document that states how the project owner took in consideration the environment throughout his project development and the principles he adopted in order to attenuate the impacts. This document will be delivered to the administration (of which depends the authorization to carry on the project development) and to the general public.

Point of the impacts analysis

The impacts analysis' objective is threefold:

Help the project owner to design an eco friendly project

The impact analysis must help the project owner to conceive an eco friendly project, by bringing him information likely to improve the quality of his project and to encourage its insertion in the environment.

It is also a way to demonstrate that environmental aspects have been taken into account all along the project planning and the decision making processes.

The impacts analysis is therefore a way to improve the project's planning and to emphasize the efforts made to integrate the project in its environment.

Assist in the administration decision making process

The impacts analysis is part of the public authorities' decision making progress, and therefore is a requisite to the administration's authorization to start electricity production geothermal projects, according to the country's law (it is for instance the case in Caribbean and Dominica oversea departments).

The impact analysis helps the relevant authority in its decision making process, and if the answer is positive, it also helps to define the environmental conditions of the authorization and to set commitment's conditions.

Give account of the negotiation to general public

The impacts analysis is an opportunity for the project owner to dialogue with the population, associations and institutional partners.

Moreover, in France, the impact analysis is a centrepiece of the public inquiry dossier, which is the best way to communicate with general public.

The impacts analysis is therefore a tool of communication and dialogue between the different actors involved.

The general public's participation to the location decision making process, and the consideration of public services' opinion, form transversal steps of the impacts analysis, which are carefully explicated in the chapter devoted to public consultation.

The impacts analysis

The impacts analysis must cover the totality of the project, which is to say both the project and the works necessary to its achievement and/or its operation. The study impact must entirely analyse the various works' environmental impacts, whether these works are achieved simultaneously or sequentially.

Geothermal plant project takes much time, and their main features (size, location, technology used, …) and their impacts will appear as the project will evolve and progress. In order to cover the totality of the project several study impacts must be carried on, for each of the key step defined previously (cf. section 3.3.2). This studies will be completed as the overall impacts of the project will be progressively discussed.

The impact analysis also defines a transversal analytical framework for every thematic expertise. The study must mention all dimensions related to the environment and human health. Indeed, the notion of environment must be broadly interpreted: it includes impacts on physical, biological and human environment.

The elaboration of the impact analysis is divided into several big steps. These steps are successive but going backward is possible if necessary, as it is showed in Figure 21. This elaboration is based on three principles:

- ✓ It is iterative;
- ✓ It is unbiased;
- ✓ It is proportional;

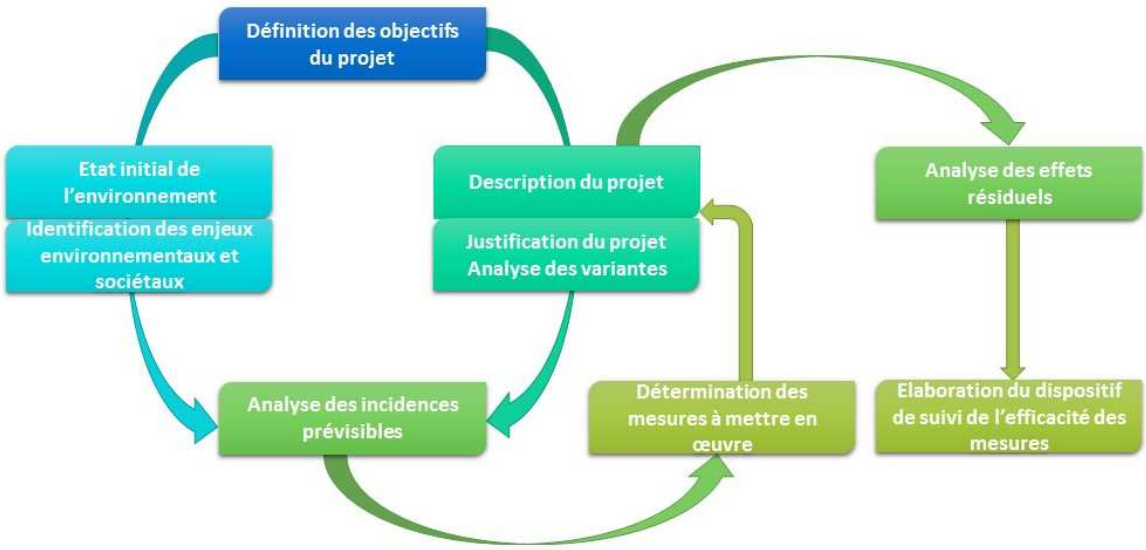


Figure 21: Elaboration of the impact analysis (©BIOTOPE, September 2015).

Itérativité

A study impact is not only an *a posteriori* justification of choices that has been made despite the fact they didn't really contributed to the project. Figure 21 shows that if an incidence is too much emphasized, the adjustment of one of the project's feature is necessary. This can then put into question the relevancy of previous choices and may require a new study.

Objectivité

Since impact analysis are technical and scientific analysis, they must be carried on by experts according to objectivity and transparency principles. Methods employed must be objective, concrete and reproducible. In consequence, methods and criteria used must be listed and explicated mentioning, when it is possible, their reliability, their degree of precision and the limits of their interpretation. The reader must be able to easily understand the redactor's logic and to see the impacts. The impact study must be as clear and concise as possible, and only cover elements necessary to understand the project and its impacts. Every information that may ease the understanding or the interpretation of the data is to be included (diagrams, maps, …).

Proportion-nalité

The content of the impact study must be related to the environmental and socio-economic issues of the project's site, to its size and nature. The proportionality principle encourages the project owner to plan each part of the impact analysis according to the "importance of the project and its foreseeable impacts on the environment".

More concretely, this implies that the more the project is important, the more it tends to have impacts on its environment, and the more the analysis will have to be detailed.

↳ *Consequently, the study impact relative to exploration drillings will be a priori less important than the study linked to development drillings (production and reinjection wells) and the electricity production unit (this unit takes more space and its construction takes much time).*

The project owner must keep in mind the **proportionality** principle when he prepares and plans the impact analysis:

- Proportionality of the initial state's description: if the project's environment has some specific aspects (or is likely to have some), these ones must be studied in detail. It may be necessary to collect data on the spot. Conversely, when a point doesn't have any specific feature, it can be studied briefly (only if the absence of specific features is demonstrated). The reader of the study impact must be able to immediately identify the topics that present some challenges (or are likely to do so), only by noticing the density and length of these topics' sections.

  ↳ In the context of Caribbean environment, which has some biodiversity specific features, challenges related to fauna and flora must be carefully analysed by experts.

- Proportionality of the incidences' analysis: when some environmental issue has potential important incidences, the impact study must be carefully detailed. It may be necessary to use some visualization (photomontage, diagrams…) or effects quantification (modelling, essays…) tools.

↳ Geothermal electricity production projects are likely to produce toxic gases, depending on the processes applied. If the gases are dangerous, a modelling study of their dispersion in air must be achieved, in order to know what proportion of gas is inhaled by people leaving near the plant and to check if there are no sanitary risks.

The proportionality must be respected in the analysis, but also in measures taken: actions to avoid, reduce or compensate the project's potential impact must be proportionate to the effects they answer to. Following this logic, the monitoring scheme's importance must be proportionate to:

- The importance of foreseeable incidence;
- The predictability of incidence;
- The certainty of avoiding, reducing and compensating measures' efficiency

Content of the impacts analysis

Sheet n°11 presents the conventional content of impact studies. This sheet exposes impact's analysis different parts, bringing explanations concerning expectations and giving some basic advices. This sheet is also a deeper analysis of some methodological points, which are seen as keep points to success.

Sheet n°11

Depending on which step of the project is discussed (cf. Figure 19 page 54), the impact study will include or not the same level of information.

⇒ **The impact study "Exploration"**, achieved during **Step 2 – Exploration** applies to exploration drilling works:

- ✓ It allows the project owner to ensure the exploration drilling works' environmental compatibility before starting them;
- ✓ It is achieved at the end of the pre-feasibility study phase, if this study concluded to the potential existence of a geothermal resource for electricity production, and if it recommended the project continuation. The exploration drilling's location has also to be specified;
- ✓ It is based on the preliminary environmental analysis carried out during step 1 (cf. section 3.4.2), and it contributes to this section;
- ✓ NB: It is not supposed to mention the plant's construction and exploitation since these actions are still hypothetic.

⇒ **The impact study "Project"**, carried out during **Step 3 – Development and Achievement** is much more important since it applies to development drillings (production and reinjection wells), to the plant and its extensions' construction and to its exploitation:

- ✓ It is achieved during the feasibility study phase, when exploration drillings have demonstrated the existence of a viable geothermal resource for electricity production;
- ✓ It is based on the Exploration impact study, in particular when it is linked to drilling works. However, some parts of the study's content will have to be adapted, regarding to the evolutions in term of number and duration of the worksites;
- ✓ It mentions the exploitation phase, which presents potential specific incidences, so as to make sure that impacts generated during this phase are compatible with the plant's environment. If the incidences are too important the project owner will have to make technic choices during the plant's conception to reduce them.

3.5.5. Application of construction site's good practices

Phase(s) concerned	**Drilling works, Field development, Plant’s construction, Tests and commissioning**
Tool(s) concerned	Environmental and societal management
Targeted topic(s)	All topics

The worksites’ code of practice covers two complementary approaches:

⇒ **environmentally friendly building sites;**
⇒ **worksite environmental coordination.**

Environmentally friendly construction sites

The **drilling work** is a phase during which many risks of an impact of the environment are likely to materialize (Figure 22). Indeed, this phase includes infrastructures work (buried networks) that take a lot of space and irremediably modify the use of concerned parcels. Besides, many potentially polluting devices and products (hydraulic binder, hydrocarbon ...) are used. The plant's construction sites may also have impacts similar to the industrial ones on the environment.

An environmentally friendly building site is a natural extension of the efforts made to create an eco-friendly geothermal project. Considering the context (rich and specific tropical biodiversity, concentrated living areas, economy based on tourism and ecotourism), the construction's different phases are likely to have various impacts on the environment. The challenge of an environmentally friendly building site is to reduce these impacts, for the benefit of the surrounding communities, the workers and the environment, while remaining compatible with professional obligations.

In France, the **green construction site charter** is the most used document to define a construction site's environmental operating rules. It takes account the impacts study's conclusions concerning environmental issues and sensible areas to be preserved. The charter can also define some obligations concerning:

⇒ wastes management: wastes sorting, using the nearest and more adapted available waste elimination disposal, incentive to reuse and recycle, interdiction of illegal landfill and open burning prohibition, wastes traceability by returning to the project operator the waste tracking documents;
⇒ limitation of pollution on the site: obligation to build tanks and retention systems, decantation of the waters used during equipment cleaning phases, ...;
⇒ workers' awareness to water and energy savings;
⇒ definition of machineries' noise level limits, to control noise pollution.

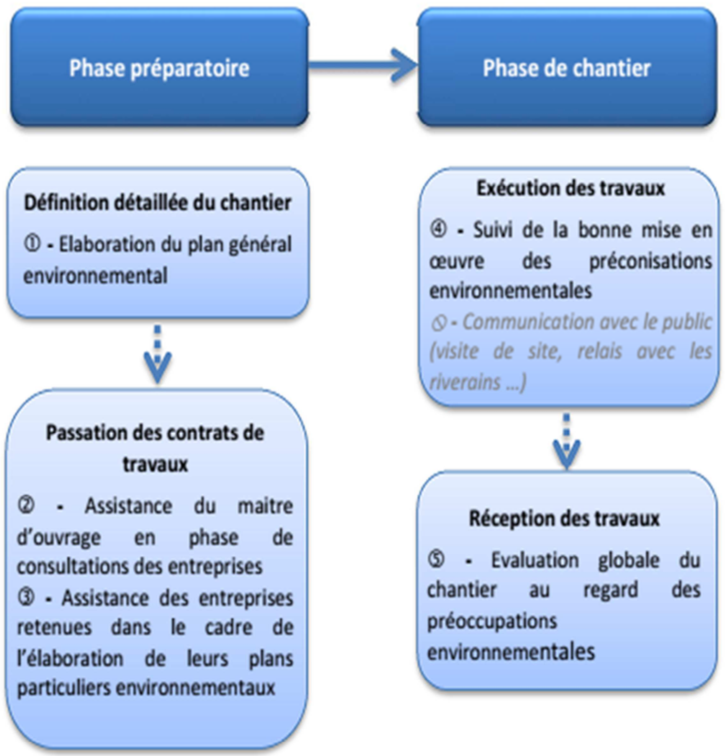
Construction site environmental coordination

Building site environmental coordination is not a duty, but it attests of the geothermal project's initiator willingness to respect the environment. Indeed, this coordination guarantees the application of the measures promulgated during the preparatory phases, mostly defined during impact studies. The building site environmental coordination's objective is twofold:

⇒ ensure the construction site is conforming to high environmental respect standards, which is to say making sure the project's environmental specifications are applied, and that every disturbance caused by the project is minimized, or even compensated;
⇒ advise and sensitize on environmental precautions to follow.

Figure 22: Organisation of a development drilling site, in the lands of Las Paillas, Costa Rica, made by ICE (©Biotope).

In this example, the working platform is delimited by a gutter, wish function is to collect runoff water, to stock it in tanks. These waters are then reused during the drilling and well testing phases.



- **Environmental plan development**

This plan will serve as a reference all along the construction, it will be adapted to every phase of the project. It has been developed conforming to environmental sensibility studies and a critical analysis of the project owner's worksite planning.

- **Support to companies**

This support has a double aspect: during the requirements specification' elaboration, with a transcription of the expected environmental efforts (regulation, studies carried on); during the selection of a company, with an assessment of tenders (considering problems related to environment).

- **Help companies to develop their own environment plan**

The correct consideration of problems related to environment during the construction phase depends on this help. It also meets prevention objectives. This help will be complemented with sensitization meetings during the construction (reminder of the objectives, consideration of how companies distribute their interventions).

- **Monitoring the proper application of the environmental precautions `**

This monitoring is achieved through different controls: common inspections, surprise inspections.

- **Global evaluation of the construction site, in view of the environmental precautions**

This evaluation is also an opportunity to make an assessment of the project's progress, that may be used as tool of comparison in future constructions.

NB: The public consultation mission is developed is the chapter "Adapted Consultation".

Figure 23: diagram of the construction site environmental coordination approach, which can be applied both in drilling worksites and geothermal plants construction sites (©Biotope, may 2015).

3.5.6. Environmental monitoring in environmental and societal plans

Phase(s) concerned	**Exploration drilling, Field development, Plant's construction, Tests and commissioning**
Tool(s) concerned	Environmental and societal management
Targeted topic(s)	All topics

Geothermal plant projects take several years to complete. **Environmental monitoring** is necessary to achieve environmental and societal throughout the different phases of the project. This monitoring can be implemented from Phase 2 - Drilling phase (Figure 19 page 54). It may then evolve and be maintained all along the project's life, so that some continuity in environmental and societal approaches in granted.

This monitoring can have different forms; the most common one is the environmental management plan. Most of the time, this plan is declined into an **Environmental and Societal Management Plan (ESMP)** and **a surveillance plan**. In some countries, the ESMP is systematically included in the impact analysis, in particular in the case of projects that may cause serious damages to the environment. International organization, such as the World Bank, also recommend this inclusion.

Sheet n°13

ESMP's objectives

The ESMP lists the means and procedures that the project owner can apply to meet its environmental and societal project commitments. The management plan is therefore a tool to integrate the environmental aspects bounded to the project during its achievement, while minimizing impacts. The ESMP guarantees the application of principles to minimize geothermal impacts or even to make this impacts positive.

It is a changing evaluation and communication tool, which evolves throughout the life of the project. Its purpose is to ensure the good integration of the geothermal project in its environment and to determine whether corrections made are relevant or not, in order to guarantee the durability and conservation of natural, sanitary, socio economic factors present near the project's site.

ESMP's structure

The ESMP's structure is detailed on Figure 24. The analysis that was carried out during the impact study allow to define the work that will be made during the drilling, construction and operation phases of the project, and to identify the various potential impacts on environment. In order to monitor these impacts, some relevant direct and indirect measuring tools are adopted. These tools have to be easily supplied with automatically measured data and manually collected information, according to a pre-establish protocol. The occurrence of the monitoring must be high enough to collect representative evolutions of the parameters measured.

Figure 24: Classical approach of the environmental and societal Management Plan

If impacts are more important than expected, **complementary actions** must be undertaken to reduce them (Figure 24)

The ESMP can be used as a **communication tool** to local population and institutions. Biannual and annual reports, giving information about the monitoring and its conclusions, can be published.

Most of the time, the coordinator or the project owner's environment manager is in charge of the coordination and animation of the monitoring.

ESMP's content

Basic framework

Table 11 is an example of ESMP elaboration framework, that can be used at the beginning of the project. The ESMP evolves as the project progresses.

The environment analysis, part of the impact study, allows to identify the main environmental and societal issues related to the project, the applicable legal and regulatory obligations, the best environmental practice in this sector, the emergency situations and past accidents which happened in a similar context. This analysis will serve as a documentary basis of the ESMP.

Environmental monitoring documentation

Specific monitoring is effectuated during the work (Exploration phase and Development and achievement phase).

The **environmental monitoring** must be systematically and synthetically evaluated. Environmental monitoring sheets can be redacted and periodically used to do so. Table 12 is an example of such sheets. They may be supplied with pictures or maps if needed.

Surveillance and monitoring programs' conclusions are registered in **periodical reports** (on a monthly basis during the drilling works phase, for instance), which are archived and ensure the environmental monitoring's **traceability** in term of impacts observed and actions undertaken. It may also serve as a communication support. The content of these reports is approximatively the same than the monitoring sheets'; as it includes for instance the following sections:

- ✓ Summary of the monitoring carried out during the period;
- ✓ Observed or measured environmental impacts;
- ✓ Gaps between expectations and reality;
- ✓ Corrective measures undertaken and evaluation of their efficiency;
- ✓ Conclusions.

Sections	Typical content
1- Regulatory point	Political obligations, environmental regulation, including a summary of the authorizations required at the different phases of the project, relevant elements from the exploitations decrees, objectives related to the initial environmental criteria of the project.
2- Summary of the measures undertaken	Attenuation and impact management measures, including every general environmental controls that may allow to prevent and to manage environmental impacts.
3- Resources	Management team, employees and subcontractors' responsibilities and prerogatives, regarding to the application and conservation of the ESMP.
4- Action plan	Detailed surveillance and monitoring plans, parameters to be measured, employed methods, sampling locations, frequency of the measurements, detection limits (if needed), limits beyond which some corrective measures have to be applied, execution schedule and estimated costs.

Table 11: Typical content of the ESMP's basically framework.

Technical agent identification: ……………………,

Date : …./…./…..

Localization of the evaluated sector (GPS landmarks) : …………………….

MINUTES	OBSERVATIONS
Affected environment	Earth, landscape, etc.
Impacts induced on the environment	Those identified in the impact study as well as those detected once the works started
Established corrective measures	Measure description
Progress	Precision if the corrective measures are close to start, are ongoing, are stopped or necessitate an immediate correction
Correction efficiency	Measured quantitatively In the case where the correction has been insufficient, new measures proposition to reduce the impact.
Observations	Observations relating each type of environmental impact

Table 5 : Example content of an environmental monitoring record implemented during the drilling and construction works of the power station.

3.5.7. Implementation of an adapted consultation

Concerned phase(s)	**Prefeasibility study, exploration drilling, feasibility, fields development, plant construction, test and commissioning**
Concerned tool(s)	Consultation and participation of the public
Targeted theme(s)	Themes linked to the human environment (socio-economy, uses, living conditions) even all themes according to populations sensitivity to the different environmental problematic

This adapted consultation approach relies on two types of action conducted by the project leader:

⇒ Some **consultation actions** conducted at the same time as the prefeasibility study and the feasibility phase, and concerning the implemented modes of the exploration and development drilling works, and construction works of the power station. This is the case, for example:

- ✓ Of exchanges with State service;
- ✓ Of exchanges meetings with the public;
- ✓ Of the creation of a partnership between the project leader and the territory players;
- ✓ Of restitution meetings.

⇒ Some **information actions** during this works realization (and aiming especially the public). It is mainly about :

- ✓ The creation of a contract structure ;
- ✓ Information meetings ;
- ✓ Construction site visits during the works.

The implementation of a **multidisciplinary environmental management group** by the project leader responsible for the implementation and the monitoring of the environmental process and the societal acceptability approach all along the project is recommended (cf. paragraph 3.4.1). Although its size and its means will evaluate in accordance with the project steps, this group have a vocation for being **permanent** and will have a major role in the implementation of this adapted consultation during the works phases.

Consultation actions

Exchanges meetings with the public

This meetings aim to broadcast the information concerning the project progress by privileging the listening. This type of meeting takes thus place during the elaboration phases of the project. The process pursues particularly to consult the affected groups on the environmental and societal aspects of the works in the Step 2 – Exploration and of Step 3 – Development and realization. Thus it allows taking into consideration the preoccupations and the expectations of the population concerning the project and integrating them in its proceedings.

A feedback of this type of meeting organized in Costa Rica during the field development of Las pailas is provided in the

Insert 1. The 13 proposes recommendations in order to prepare and conduct this type of meeting.

Exchanges with State services

The State services with an environmental and the project manager on precise questions can consult societal competence as well as the associated public institutions informally and continuously. The consultations can become exchanges meetings with minutes. It is about a preliminary scoping of the impact study (see insert below). The observations received during these consultations allow the geothermal project manager to progressing in the environmental and societal integration of the project, better understand the component, which need to be deepened in the framework of future studies.

Preliminary cropping of the impact study

The preliminary cropping is an opportunity anticipated by the French regulation, pursuing to make precise by the State services the components allowing the project leader to adjust his environmental analysis content to the sensitivity of the environment and of the potential impacts of the project on the environment and/or the human health, particularly the degree of accuracy of the different thematic discussed during the impact study.

It can particularly be organized as an interactive exchange meeting between project manager, instructor service and design office in order to all protagonists can better understand the requests and the needs of everybody. This exchange does not anticipate the decision to allow or not the works. It relies on a specific document, which will be able to preliminary transmitted to the concerned State service. This cropping document is composed by:
- A summary of classed environmental issues;
- A presentation of the main characteristics of the projects;
- A summary description of the potential impacts of the project and the possible mitigation measures.

Initiation of a partnership between the project leader and the concerned territory players

The consultation phase constitutes an occasion to improve the project in order to be a success, not only for the project leader but also for the community. This approach enhances the knowledge of the project-welcoming environment, which contributes to propose mitigation measures or compensation measures according to the environment particularities and optimize the positive effects of the project.

Each project brings changes and the perfect project does not exist. Thus, the project leader cannot promise to implement all modifications that are suggested to him, but it is essential that he promises to take into account the submitted preoccupations and do a monitoring to the community about the taken decisions, implemented measures and preoccupations to whom they respond. A geothermal power station project proposes also different advantages and positive impacts for the community, which have to be enhanced (sheet number 20).

Sheet n°20

With this in mind, the geothermal project leader can, beyond this classic consultation, makes for a real partnership with the community, proposing:

- ✓ Enroll at the resident community's side of the project,
- ✓ To the population, the possibility to enroll in the project.

The community involvement pursues to forge links strong enough so the drilling site and beyond the power station can be perceived as integral part of the collectivity. In a more concrete way, the engagement in the environment is characterized by a presence and a participation in activities, which are specific to targeted speakers in the community. In spite of the engagement has to be done with methodology and rigor in order to avoid the scattering and the waste of the human and financial resources that the company counts invest in the process. There are multiple ways to participate actively in the community development: support to diverse programs (development, education, environment…), associations sponsoring (cultural, sportive…).

The population engagement in the project implies that the project leader includes the community as a territory partner, that he is ready to delegate certain competence fields relative to the elaboration or the environmental management of the project. In return, the population can be led to participate financially in the project.

Restitution meeting

It closes the reflection period linked to the creation works conception phase, in other words here the **prefeasibility study** and the **feasibility study** phases (cf. **Erreur ! Source du renvoi introuvable.** Page **Erreur ! Signet non défini.**). It allows to present the project in its finalized version, to exchange with the public and to take engagements for the rest of the project (presentation of environmental integration measures.

This meeting can be held in a formal setting. In France, this possibility is offered in the framework of the **public investigation**.

Preparation	
Targeting the plublic	⇨ Identifying the concerned public: this identification is carried out during the preliminary analysis (Step 1), a survey among the pubic allows to target the concerned people and to give information about the position concerning the project.
Mobilizing the public	⇨ Writing the invitations: meeting objective, agenda, participants, date, hour, place, plan … ⇨ Distributing the invitations: they will be able to be sent by post in the concerned area (residents of the concerned towns by the geothermal project) or by an announcement in the local newspapers (quite wide area). The hubs of information will have to be privileged.
Defining the content	⇨ Defining an agenda, and a common thread: it can be interesting to announce the results of the environmental and technical expert assessments by presenting the components simply, by using understandable terms. This presentation will be able to enhance the noticed issues and the potential effects and expose the ongoing reflections on the geothermal project in order to better integrate them. ⇨ Anticipating the meeting proceeding by identifying in advance the interventions and questions of the public.
Organization	⇨ The logistic aspects are important: adapted space, disposition, forecasted material.
Animation	
Modalities	⇨ Introducing the meeting: it is necessary to consider from the beginning all the participants at the same knowledge level of the project and the expectations regarding the participation. ⇨ Let speech: a time has to be anticipated to let people who want to speak. ⇨ Close the meeting: summary of the exchanges and presentation of the following steps.
Assessment	
Plan an assessment	⇨ Ensuring the rest of the meeting: making an assessment with hindsight allows to capitalize the components coming from the meeting (feedback public). ⇨ Writing and communicating a minutes.

Table 13 : Recommendations concerning the preparation and the management of exhanges meetings with the public.

Feedback

Consultation meeting in Costa Rica

The CIE (Costa Rica Institute of Electricity), which is the geothermal project leader for the electricity production in Costa Rica, implements in the framework of its projects a communication strategy including different exchanges with the public. This strategy is implemented by a environmental and social management team implemented specifically for each project. The presented example here is the one of the consultation conducted with the communities concerned by the field development project of La Borinquen, which took place in January 2013 in the form of exchanges meetings. This consultation focused on the impacts and measures of the project had for objective:

⇒ To inform the public about the project type and clarify the points of concerns;

⇒ To collect the notices and observations of the public that could conduct to adapt the project and improve its environmental and societal integration.

These exchanges meetings took place in the following manner :

✧ The invitation to the meeting is made by tracts distibuted at home, by posters in the visited places and a diffusion with loudspeakers in the communities ;

✧ The meetings proceedings was the fllowing :
- Participants registration on the attendance sheet ;
- Presentation led by the societal and environmental management team of the project leader of the project general characteritics and steps and preparation of the impact study ont the environment ;
- Presentation of the impacts on the environment and of the considered measures to reduce them ;
- Commentaries and requests of the participants
- Assessment of the commentaries and requests and summary of the meeting.

Insert 1 : Feedback of exchanges meetings with the public in Costa Rica in the framework of the field development of La Boriquen (©ICE).

Information actions

The elements, which have been discussed between the project leader and the different project players for many months, even many years, become true when the exploration drilling works started. It is possible that these elements previously discussed and accepted pose a problem to one or several parties. This results not necessary on an ordinary bad faith, incoherence or incapacity to understand the impacts, but simply the significant gap between the supposition and the reality. It is a matter of maintaining the knowledge pursuing the dialog, doing certain modifications and implementing additional measures if it is necessary.

Three types of action are conceivable: creation of a contact structure, information meetings and work sites visits.

Creation of a contact point

During the drilling and construction works phases of the power station, this structure will ensure the relation with the project residents and will be in charge of collecting their gripes and treating them. It will be also in charge of organizing construction sites visits.

NB : This contact point can be individualized within the environmental management multidisciplinary group implemented by the project leader.

Information meetings

The information of residents and concerned territory users on the works proceeding is an essential condition to the best acceptation of the construction sites. Indeed an explicated harmful substance is better than a suffered harmful substance without explication. It is thus important that the public be informed preliminary about the starting date of the construction sites.

Visits during the works

The visits during the works constitute an opportunity to make discover the construction site reality to an uninformed public, to make meet residents and professionals and to enhance the exemplarity will concerning the environmental and societal integration of the project leader.

Like any exchange with the public, the visits have to be composed by a preparatory phase during which it is necessary to :

- Realize a tracking and prepare the visit : eventual dangers, technical elements and proceedings that has to be enhanced during the visits, … ;
- Forecast a required protection material (for example : hard hat) ;
- To prevent and prepare these visits in coordination with the responsible of the construction site and the environmental coordinator.

The Insert illustrates a feedback of a drilling work site visit in Costa Rica (cf. **Erreur ! Source du renvoi introuvable.**).

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- Presentation of the impacts on the environment and of the considered measures to reduce them;
- Commentaries and requests of the participants
- Assessment of the commentaries and requests and summary of the meeting.

Insert 4 : Feedback of exchanges meetings with the public in Costa Rica in the framework of the field development of La Boriquen (©ICE).

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- Forecast a required protection material (for example : hard hat) ;
- To prevent and prepare these visits in coordination with the responsible of the construction site and the environmental coordinator.

The Insert 5 illustrates a feedback of a drilling work site visit in Costa Rica (cf. Figure 22)

Feedback

Construction site visit in Costa Rica

The CEI (Costarican Institute of Electricity), which is responsible for the geothermal power station projects for the electricity production in Costa Rica, organizes drilling work sites visits associated with the existing installations visits. The implemented process is the following:

⇒ General presentation of the construction site and of the context in which it takes place ;

↳ Forecasting a building to welcome visitors, even the type of Algeco;

- Guided visit of the construction site (drilling platform for example). During this visit, several subjects can be discussed :
- Explaining the issues and the construction site functioning ;
- Showing the measures implemented for the environment protection (waste management, water reception basin) and the reduction of nuisances (means to reduce the noise, dust flight),
- Presenting the personnel and their jobs.

↳ Forecasting a break point at the level of a high point, if it is possible, in order to propose a panoramically view and thus global on all the construction site;

↳ Forecasting and exchange between the visitors and the responsible for the construction site, the environmental coordinator, and a few emblematic jobs of the construction site.

From to bottom and from left to right : presentation of the project in the meeting room ; view overlooking the stocking lagoons of the drilling sludge on the platform ; example of a waste management on the construction site ; exchanges between the responsible for the construction site and the visitors (©Biotope).

Insert 5 : Illustration of a drilling work site visit of the field of Las Pailas in Costa Rica organized by the environmental management multidisciplinary group of the project manager.

3.6. RECOMMENDATIONS LINKED TO THE IMPACTS OF THE PLANT EXPLOITATION

3.6.1. Introduction

The exploitation phase of the power station is the longest in the life of a geothermal project (Step 4 of the figure 19). It generates environmental and societal impacts, which have bee presented in a previous version (cf. paragraph 2.3.2). This chapter presents the recommendations, which are made for facilitating the environmental and societal integration of the geothermal power station in the framework of its exploitation for the electricity production.

It is frequent that the development of a geothermal field happens by successive steps. After a few years or tens exploitations, the project manager can decide to raise the production electricity production capacity by drilling new wells and by installing a new unit. He can also consider the dismantling of the power station or of one of its units. This extension or dismantling works will generate impacts, which will be the same as those described in the paragraph 2.3.1 and the recommendations, which have been delivered before in the chapter 0. will apply to these works and won't be repeated in this chapter.

3.6.2. Recap of recommendations linked to the plant exploitation

A recommendations series is proposed on the base of issues defined in the framework of the previous part (cf. paragraph 2.5). These recommendations are presented in the form of a synthetic table (Table) being composed by the following sections:

- ✓ Concerned thematic ;
- ✓ Potential effects of the drilling works and construction works of the plant ;
- ✓ Identified issues ;
- ✓ Recommendations.

This *Table* is composed among other things by **key recommendations** (underlined in blue) linked particularly to strong environmental issues presented by the island territories of Lesser Antilles, which are the following:

1. The environmental and societal impact study (ESIS) being applied to the exploitation phase ;
2. The environmental monitoring in the exploitation phase ;
3. The prevention of impacts linked to gas emissions ; L
4. The reinjection and the resource sustainable management principle ;
5. Landscape integration ;
6. Consultation and information.

These recommendations are in detail after the Table 14.

	Interests and sensitivity of the context	Potential effects of a geothermal project	Issues	Recommendations
Air	**Air quality relatively good to very good**	**Risk of air pollution** CO_2 and d'H_2S emissions contained in the generated geothermal steam. Other gas can also be present in lower concentration: methane, hydrogen, sulphur dioxide and ammonia. Among these gas, the sulphureted hydrogen, naturally present in the geothermal reservoirs, can have a pronouncing impact on the environmental and health (unpleasant smell ; depending on the quantity, this gas is harmful for the health even lethal) Relative reduction of CO_2 emissions since a geothermal plant produces less CO_2 than other plants using fossil fuel. The geothermal plants produce on average 55g of CO_2 per kWh, around 1O times less than a thermic plant functioning with natural gas. Air temperature rise at the level of cooling towers	**Maintienance of a good quality air**	**Realization (actualization) of an environmental and Societal Impact Study (ESIS)** : impacts appraisal and measures propositions **Prevention of gas emissions** **Environmental monitoring :** gas concentration surveillance at the level of different installations
Soils and undergrounds	Zones that could present substantial differences in level	**Accidental pollution risk** linked to the drilling maintenance (cleaning) and/or to the dysfunction of equipment (well leak), linked to the maintenance and/or the dysfunction of networks and plant equipment (leak in the conveying pipe of the geothermal fluid or transport of the cooling liquid) **Geothermal resource** that could go until its exhaustion particularly in case of non-reinjection Surface hydrothermal demonstrations modifications	**Preservation of ground integrity**	**Realization (actualization) of an environmental and Societal Impact Study (ESIS)** **Reinjection of the geothermal fluid in the reservoir : geothermal resource sustainable management principle**

Table 14 : Recap of the recommendations concerning the exploitation phase of a geothermal plant for the electricity production.

	Interests and sensitivity of the context	Potential effects of a geothermal project	Issues	Recommendations
water	**Freshwater resource vulnerability**	**Receiver environments quality degradation risk** linked to geothermal fluid rejection (if non-reinjected) or water used for the cooling Accidental pollution risk linked to the maintenance and/or dysfunction of equipment (leak in the conveying pipe of the geothermal fluid or transport of the cooling liquid) **Morphological characteristics degradation risk** (disruption of the sediments transit, alteration of the flow faces) and hydrologic (flow modification) of the aquatic environment (disruption of sediments transit, deterioration of flow faces) and hydrological (flow modification) of the aquatic environment due to the water sampling for the geothermal fluid cooling. **Water warming of the receiver environment** in case of the geothermal fluids rejection **Water consumption** (cooling system) that could involve use conflicts	**Preservation of the water resource**	**Realization (actualization) of a ESIS** Choice of the cold source and samplings adapted to available water resources, utilization of steam condensates in the moist refrigeration towers, utilization of air cooler Catchment of storm water of the platform, temporary stocking in the impermeability lagoons, eventual recycling during the drilling operations, dilution and cooling before the rejection in the natural environment if possible **Geothermal fluid reinjection principle in the reservoir : geothermal resource sustainable management** **Environmental monitoring :** punctual quality monitoring of the surface water, temperature and chemical monitoring of the fluids rejections, surveillance program of surface hydrothermal demonstrations
Natural risks	**Pronounced natural risks**	**Risk of worsening of preexisting natural risks** Pressure decrease at the level of the reservoir linked to the extraction/ reinjection of the fluid involving a **subsidence risk** (weakening ground) Involved **micro-seismicity** by the reinjection operation according to the geological context	**Preservation of goods and people Project adaptation to the present risks**	**Realization (actualization) of a ESIS** Reflection concerning the implementation on the base of known elements (bibliography, specific study in case of necessity) **Environmental monitoring :** surveillance of subsidence phenomenon, of micro-seismicity

Table 14 (rest): Recap of the recommendations concerning the exploitation phase of a geothermal power station for the electricity production.

	Interests and sensitivity of the context	Potential effects of a geothermal project	Issues	Recommendations
Natural environment	**Rich and unique biodiversity**	**Risk of deterioration of natural habitat** and/or of species' habitat by a source of accidental pollution linked to the maintenance and/or to the malfunctioning of the equipments **Trouble of animal species** due to noises and light generated by the installations **Risk of perturbation of the aquatic species** due to the taking of water and to the warming of the waters induced by the rejects of geothermal fluids in the aquatic environment Risk of development of certain bacteria and plankton due to the reject of geothermal fluids in the receiving environment Risk of destruction of individuals (risk of collision, trapping in the ponds)	**Preservation of the interest's biodiversity**	**Realisation (updating) of a EIES** **Environmental follow-up :** green follow-up Measures of compensation in case of necessity
Landscape and cultural heritage	**Diversified landscapes and interests**	**Presence of artificialized sectors** segmenting the landscape **Interactions** of the installations with the landscaped elements to a large distance due to the height (buildings, projection of steam) **Risk de co-visibility** with the monuments or protected/remarkable sites	**Landscaped integration** **Prevention of the cultural heritage's deterioration**	**Realisation (updating) of a EIES** **Landscaped Integration** : integrated buildings in the topography, choice of camouflage's colors, limited height …

Table 14 (rest): Recap of the recommendations concerning the exploitation phase of a geothermal power station for the electricity production.

	Interests and sensitivity of the context	Potential effects of a geothermal project	Issues	Recommendations
Economy	Economic development based on tourism and farming Dependence regarding the oil's importations	**Creation of long-term job** for the exploitation of the power station and the subcontracting of maintenance's operations to the local companies Possibility of setting a connected tourism Risk of modification of the flow of hot spring used for tourism **Contribution to energetic independence** of the island even extra economic results if export of the electric surplus	**Elaboration of the project in appropriateness with the local economy**	**Realisation (updating) of a EIES** Favour the local hiring (setting in place of a adapted training **Consultation and information**
Usage	Limited land availability Existing activities : farming, tourism (balneology)	**Land pressure** on the grounds even until the compulsory purchase, with the possibility of réduction of the farming surfaces used by the community **Risks of effect on the existing economic activities** (tourism, farming activities, etc.) **Water consumption** (systems of cooling) which could implies use's conflicts	**Takig in account of the existing activities and usages in conception of the project**	**Realisation (updating) of a EIES** Measures of compensation in case of necessity **Consultation and information**
Lifestyle	Different lifestyle regarding the location : urban to rural Attachment of the locals to their natural environment (biodiversity and landscape)	**Risks of olfactory pollution and deterioration of the air quality** : by emission of polluting products like hydrogen sulphide (H_2S) **Noise pollution** in step of exploitation due to the turbine and to the condenser which le noise level is above around 100dbA at 1m of the source (but isolated inside the infrastructures) **Deterioration of the environment's quality** (natural habitat and landscape), risk of visual pollution **Inconvenience of the residents** by the rise of the traffic near the site (inconvenience and accrued risks of accidents on the roads) **Consolidation of the road network**	**Preservation od the lifestyle implying a protection of the natural habitat and of the landscape**	**Realisation (updating) of a EIES** **Prevention of gas emissions** **Environmental follow-up** : surveillance of the concentrations of gas in and near the power plant, followed by the acoustic atmosphere Prevention of the noise pollution : implantation of the power plant far from the habituated areas, soundproofing of the buildings, phonic isolation of the engines, setting in place of silencers and of rock-muffler, **Consultation and information**

Table 14 (rest): Recap of the recommendations concerning the exploitation phase of a geothermal power station for the electricity production.

3.6.3. The study of environmental and societal impact

Step(s) concerned	**Study of feasibility, Exploitation of the power plant (in case of marked evolution of the equipment implying a modification of the exploitation)**
Tool(s) concerned	Environmental and societal evaluation Support document in the scope of the environmental and societal management and for the consultation and participation of the public
Theme(s) targeted	All themes

The standard content of impact's study is presented in the sheet n°11. This sheet shows the different parts constituting an impact's study by giving the explications concerning the expectations and the first core advises. This sheet also has a part dedicated to the key points of success which presents some methodological points in a more detailed way.

Sheet n°11

Chronology of the EIES dedicated to the Step of exploitation

In order to anticipate the impacts of the exploitation of the future power plant, the environmental and societal impact's study about this step of the project has to be perfectly conducted during the **feasibility study**. Thus it permits to the industrial to take into account the main environmental and societal issues in the conception of his project in order to keep the technical equipment and the exploitation's process which will minimize the impacts. It is about the **Impact's Study Project** mentioned before in the paragraph 0. This impact's study is based on data acquired during the Exploration impact's study and on the Environmental Preliminary Evaluation.

The impact's Study Project has a core function because it has to approach the three following aspects :

- The drill's working of the production and rejection's wells ;
- The construction's working of the power plant and of the transport network and separation of fluids ;
- The exploitation's working of the power plant.

About the exploitation's working, the impact's study has to deal with more particularly the occurrences of this step as defined in the precedent Table and has to include a timetable of environmental and societal management (look hereafter).

Updating of the EIES

The putting into service of the power plant is preceded of a probationary trial period of a couple of months serving to try the well-functioning of the equipment of the power plant, of the production and rejection's wells. Some tunings can be made if necessary regarding the technical level and in the exploitation's process regarding the first recommendations. Usually, **these tunings don't require the realisation of a new impact's study**. However, this period is used to **adjust and valid the original environment management plan**.

During the exploitation of the power plant, the main modifications can arise as for example the drilling of the new wells and the construction of a new unit. It is also conceivable after 25-30 years to proceed to the dismantling of a former unit and to his replacement by a new unit presenting a technology and different exploitation process. In this case, it will be necessary to conduct a new impact's study taking into account the induced changes by the main modifications of the original project. This move will also include the proposition of a new environmental management plan which will come to complete the precedent.

3.6.4. The PGES and environmental follow-up in step of exploitation

Step(s) concerned	**Feasibility, Exploitation of the power plant (in case of marked evolution of the equipment implying a modification od the exploitation)**
Tool(s) concerned	Environmental and societal management Support document in the scope of the environmental and societal management and for the consultation and participation of the public
Theme(s) targeted	All themes

The PGES approach all the important environmental effects and risks expected due to the particularities of the project as well as the specific measures to take in order to reduce them. It includes a follow-up plan which specifies the indicators to watch out in order to ensure that the project doesn't outline the boundaries of environmental viability. In general, the PGES also suggest a reinforcement program of the institutional capacities of the local execution staff of the project. The costs and budgets of the attenuation and institutional reinforcement's measures have to be made clear.

The environmental follow-up of the exploitation has two main objectives:

⇒ To verify the evaluation of certain identified impacts during the impact study and if needed, to bring the necessary adjustments to their evaluation and to suggest some attenuation measures permitting to minimize the unexpected repercussions on the project's insertion habitat;

⇒ To verify the efficacy of certain attenuation measures suggested and make, if necessary, some adjustments.

Recommendations for an approach of excellence

The environmental follow-up of the exploitation has to be defined in a way to take account all the identified activities in the impact study as having a potential impact on the environment, in the usual conditions of functioning of the installation.

All the sensible themes, especially the atmospheric emissions, the liquid effluents, the noise, the seismic risk, the traffic, are concerned.

The table XX present a example of PGES with some propositions of follow-up and surveillance's measures during the step of exploitation. This plan is built in function of the mode of exploitation of the power plant (reinjection, reject or taking in the superficial waters, etc.).

The program of follow-up has to contain the following points:

- The follow-up's indicators;
- The modalities of follow-up of the measures :
  - Measures of operational control linked to the application of the management plan : verification/evaluation/management of the non-conformities, the recommendations and the plans of corrective actions (if necessary), setting in place of a follow-up/document of traceability of the environmental control plan;

- The measures of environmental follow-up : Some environmental controls will be specifically created for each component of the project in order to watch over the emissions and rejects linked to the project;

➢ The estimation of costs to consider (in first approach);
➢ The staff responsible of the control and/or of the environmental follow-up.

In complement of this environmental follow-up, a complaints' book can be put in place in order to collect the possible remarks and grievances of the local population during the exploitation. A system of collect and of treatment of these information will have to be put in place by the owner, in order to guaranty a transparency of the follow-up of the exploitation and to facilitate the local acceptation of the project.

Characteristic to monitor	Place	Type of reviewing	Indicators	Frequency of reviewing	Responsibility of deployment
Degradation of the tank's quality	Drilling	Follow-up of the pressure inside the tank	Some measures of the pressure will be taken in the tank. A adaptation of the debit of reinjection will be done if needed	Weekly	Manager
	Drilling	Piezo metric follow-up	Level of underground waters	Monthly	Manager
Taking and rejects in the superficial waters	Superficial waters	Follow-up of the quality of the waters in the rejects exit	Factors to measure : debit, temperature, pH, DBO, DCO, MES, bore, mercury, sulphur, salinity, conductivity, hydrobiology	Daily	Manager
	Superficial waters	Follow-up of the debits and taken volumes	Definition of the minimum and maximum starts in order to respect the biology of flowing water.	Daily	Manager
Subsidence risk	Tank	Ground distortion	Annual subsidence rate, Adaption of the reinsertion flow would be executed	Annually	Manager
Seismicity consequence	Place and neighbourhood	Seismic activity monitoring Reservoir pressure monitoring	Seismic activity Reinsertion flow	Monthly	Manager
Climate change	Place	Reviewing of utilization and determining the carbon quantity	Calculation of greenhouse gas rejected and avoided	Annually	Manager

Table 15 : Example of Environmental and societal plan to set up during the running of the exploitation step of a geothermal plant.

Characteristic to monitor	Place	Type of reviewing	Indicators	Frequency of reviewing	Responsibility of deployment
Natural environment	Site	Review of conservation plan for the animal and vegetal worlds with a plan for rare or endangered species or an action plan for the feeding sites	Types of species: rare or endangered animal and vegetal worlds Collar of direction for migration and shelter. Review of special species form the region	Annually	Manager, ecologist
Landscape integration	Site	Review of the plan: systematic visit, summary, suggestions of improvement measures	Type of essence from the trees, bushes… Height of the trees, assessment of the maintenance, phytosanitary assessment of the afforestation	Annually	Manager
Contribution to the local economy	Neighbourhood	Review of actions (employment, touristic activities…)	Number of created jobs	Each 5th year	Manager, cities
Air quality	Site	Review of gases emission (mainly CO_2, H_2S) according to the weather	Review on cold tower and turbines. Parameters to analyse: PM, Nox, Sox, CO_2, O_3, H_2S	Quarterly	Manager, study offices
Noise problem	Site	Measures of noise on the edge of the site and close to the houses welcoming public.	Acoustic level in dB(A) Number of plaint of the neighbourhood	Annually	Manager, study offices
Risk management (employees, neighbour)	Site	Quality review – Health – Security – Environment To apply prevention plan against working risks	Verification of security measures Record of the accidents Plaints of the neighbourhood	Monthly	Manager
Garbage management	Site	Review of the exit of the garbage	Slip for the industrial garbage	Monthly	Manager
Information of the population	Neighbourhood	Review of the communication and information plan	Information meetings Information notes publication Plaints of the neighbourhood	Quarterly	Manager

Table 15 (rest) : Example of Environmental and societal plan to set up during the running of a

3.6.5. Prevent impacts from gas emissions

Stages	Study of possibility, plant exploitation
Tools	Environmental and societal control Document provided in an environmental and societal management for the participation of the public
Topic	Air quality, natural environment, use

Reminder of issues

For a project, in an environmental point of view, the most important issue is to prevent the impacts of gas emissions from a geothermic plant. The main part is about the sulfurized hydrogen (H_2S), which is responsible for bad odours and real risk for human health. Most of the studies show that the impact of a plant on the employees and neighbours' health is a huge issue to all the stakeholders of a project. The **two main issues** are:

⇒ To maintain air quality around the plant;

⇒ No danger for employees and neighbours' health about the plant.

Sheet n°9

Technical aspects

The concentration of H_2S in the geothermal liquid is variable from one plant to another one. It is important to precisely determine this parameter in the preparation stage in order take in account in the technical choices of the future plant. Different solutions could be set up to reduce the presence of H_2S in the air:

⇒ To reject in the atmosphere from the cold tower which insure an efficient dilution and dispersion;

⇒ To catch and treat the gas with chemical procedures in order to reduce its concentration or to erase it;

⇒ To reinsert the gas in the geothermal tank.

Sheet n°17

Advices for a perfect project

The main goal is to remind the specific considerations to prevent the impacts linked to gas emissions in order to improve the environmental excellence:

1. During the EIES: to assess the environmental impacts of gas emissions of the future plant with the characteristic of the geothermal liquid and local conditions (topography of the site, meteorology…) and to assess health risks linked to the H_2S gas;
2. At the study stage, the creation of the plan has to make the choices which reduce the environmental impacts of gas emissions;
3. At the exploitation stage: set up a reviewing of the air quality whom the characteristics are described in the environmental management part (measures frequency, type of tools, measures site…). The management plan describes as well the possible solutions if the maximal values are overtaken.
4. At the exposition stage, communication and transparency on the means to control the emissions of gas H_2S in the atmosphere, on the results of this control, on the risks of the employees' health or on the reducing of this gas concentration.

3.6.6. Reinsertion and management during the whole time of the resource

Stages	Study of possibility, plant exploitation
Tools	Environmental and societal control Document provided in an environmental and societal management for the participation of the public
Topic	Underground, natural environment, natural risk, water

Conclusions from previous experiences

A frequent question is about the **average length of life** of a plant. As it is notified in the introduction of this guide, it is not appropriate to discuss about end of life for a geothermic plant because the geothermic is a renewable energy. However, it has to be a durable management of the exploitation in order to be really renewable, which allow it to be excellent from an environmental point of view. Some of the rules are:

Sheet n°8

- To reinsert the liquid in the tank;
- Normal exploitation of the geothermal resource

To reinsert the liquid

Reinsertion is about to reinsert in the tank thanks to intermediate sinks all or some of the geothermal liquids after to be used. The reinserted liquid is colder than the tank, the reinsertion occurs far from the production zone and on the edge of the tank. This technique provides numerous **environmental advantages**: removing the rejects in the natural environment decreasing the negative impact on superficial waters, the pressure inside the tank does not change which increases the tank length of life and decreases the subsidence risk. Among the negative impacts: possibility of **micro seism** and risk to **decrease the temperature** of the tank which would reduce its power.

Reasonable exploitation of the geothermal energy

The **reasonable exploitation** of the geothermal resource is about fitting the size of the project with the production capacity of the tank in order to avoid an over-exploitation of the resource. This over-exploitation could have negative impacts on the project finance and on the environment. From this point of view, it is advised to create a project step by step, first with the building of a small entity which allows to test the capacity of the tank before building additional entities.

Moreover, this approach allows verifying the measures to decrease the environmental impacts, which are set for this first entity, are efficient and fitted with the local environment.

Advices for a perfect project

1. During the study stage: to include the reinsertion of the liquids in the working of the tank; to prefer a development strategy step by step by building additional entities.
2. During the exploitation stage: to review the parameters of exploitation of the tank and the key indicators of change; to develop tools of durable management based on the numerical simulation of the tank.

3.6.7. Integration in the landscape

Stages	Study of possibility, plant exploitation
Tools	Environmental and societal control Participation of the public: to facilitate the agreement of the population

Topic	Landscape and cultural historic, environment

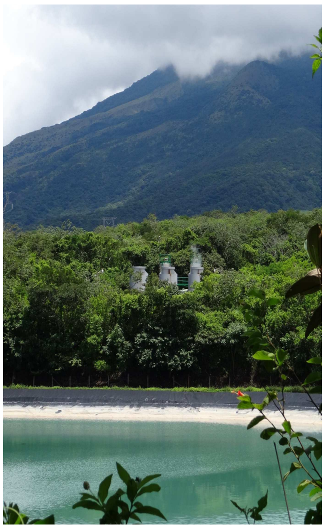
Reminder of issues

The settlement of a geothermic plant in order to produce electricity has consequences on the view and on a physical aspect (change in the topography). So it is needed to take into account this aspect which influences the way of life. After, project managers have to adapt the geothermic project to the different elements of the place (the landscape, the topography, the very near environment, the main goal…), the landscape is becoming one of the main element of the project.

Advices for a perfect project

The appendix n°14 landscape integration explains the different means to set up in a geothermal project.

Sheet n°14



Picture 9 : Examples of integration in the landscape of a plant for separating the liquids in Miravalles (on the left, ©Biotope) and for a geothermic plant in Indonesia (on the right).

3.6.8. Public participation and information

Stages	**Plant exploitation, dismantling**
Tools	Information and public participation
Topic	Topics linked to human environment (social, economic, uses, health). Most of the topics about environment questions.

Discussion with the public

It is important to maintain communication links, to discuss and to keep good relationship with local population of the project. Here, some examples of communication actions:

⇒ Means to interact and to inform the population thanks to brochures about the installation and the geothermic process, a web site;

⇒ To consult population:

- Presentation days inviting population to discover in a real way the new installations
- Open days, site visits: this demonstration shows how you are transparent about the activities of the geothermic plant and allows to demystify some of population’s fears or wrong thoughts created by a lack of information.

Keeping a right working

Once the plant will be built and will work, this activity will be on the territory for decades. So it is important that the manager keeps going to listen population words.

The composition of this community will change along time. So the issue is not only to keep the good existing relationship but also to integrate the new stakeholders and to accept the evolution of population’s desires. Thus, the population has to have the opportunity at any time to know who they have to contact if they want to share their new fears and thoughts. As a result, a contact point has to be developed inside the plant to listen people’s mind about the exploitation (see paragraph 3.5.7)

In the same way, the manager has to implement studies to detect change in people’s mind in order to anticipate their needs. The following sheet presents the opinion of people in Alsace, near the Soultz-Sous-Forêts installation, a geothermic plant producing electricity.

Testimony

Investigation about the acceptability of the deep geothermic

The G.E.I.E. "Exploitation Minière de la Cgaleur" at Soultz-Sous-Forêts, Bas-Rhin, operates the first geothermic plant for the electricity production in France territory. This energy plant has a capacity of 3MW and the production has started since the 13th June of 2008.

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An opinion survey was performed between the 21st of June and the 13th of July 2012 to assess the mind of people who are involved in such project and living in Soultz-Sous-Forêts and Kutzenhausen. With 79 questions, the quiz was brought up with information about the plant and its technical aspect.

There were 6 goals for this opinion survey:

1. To assess the level of knowledge of the local population about deep geothermic.
2. To know whether the population has in mind the danger and risks which it is exposed.
3. To assess the level of information of the population about geothermic.
4. To know if the presence of the plant in Soultz-Sous-Forêts in an advantage for the local population.
5. To know if the presence of the plant is a source of fears for the population.
6. To assess the feeling of the population about the deep geothermic.

Several investigators, staying in different places gathered 203 answers, enough to be representative of the population. Data collected has been analysed in order to have a global understanding about people's mind on the deep geothermic.

Kind of stand set up in public place during the opinion survey in Soultz-Sous-Forêts (© GEIE-EMC).

Appendix 6 : Photo about the opinion poll about people's mind on the deep geothermic in Soultz-Sous-Forêts in Alsace.

3.6.9. Summary of the main advices

The 26th Figure permits to see different advices shown previously and which have to be applied along the entire life of the project in order to make easier the integration from an environmental point of view.

Some of the advices like the review of environment or the questions to the community concerned by the project have to be applied along the whole life of the project.

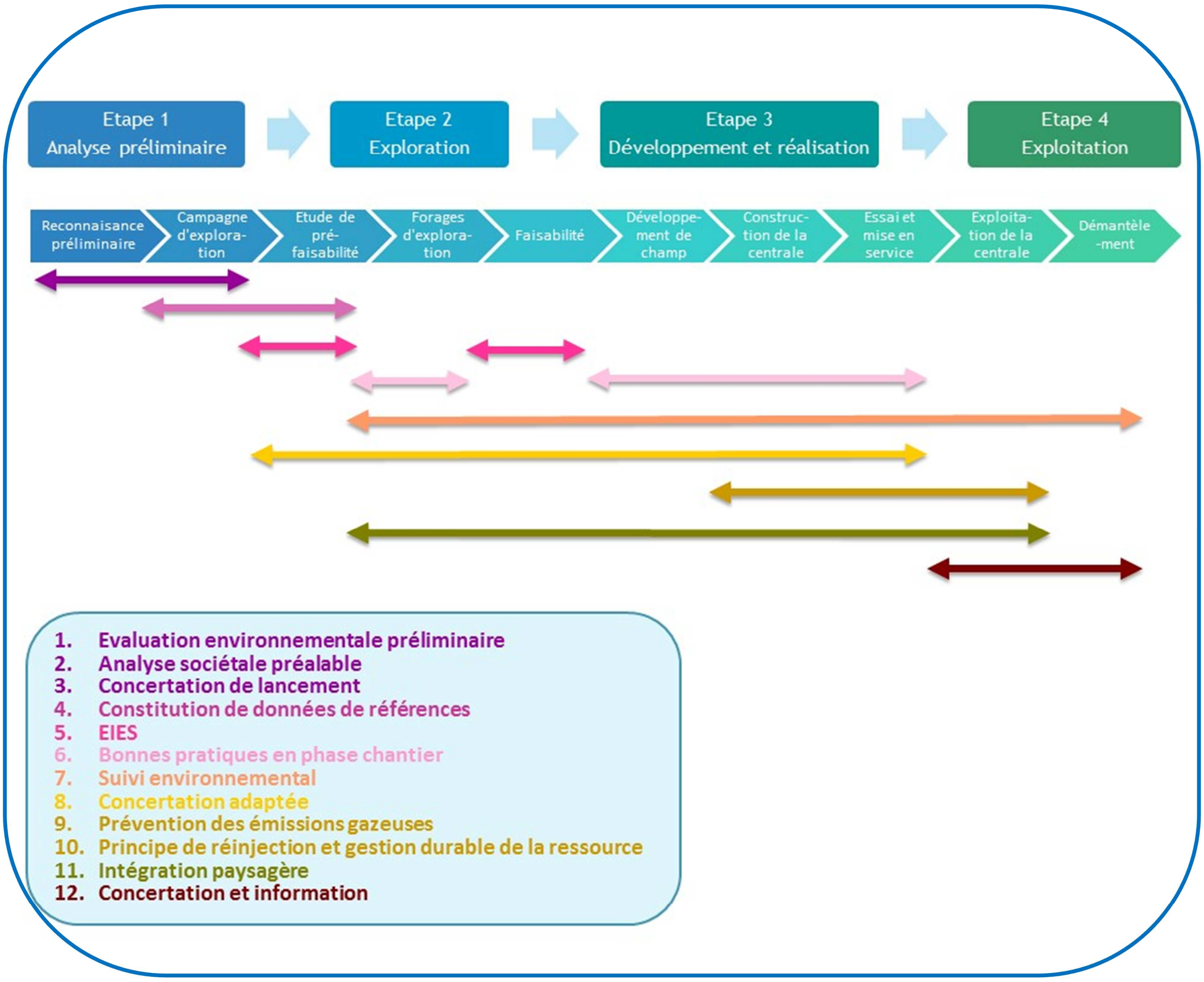

Figure 26 : Sum up of the main advices aiming to facilitate the environmental and societal integration of geothermic project for electricity production

4. Social integration factors

To go further…

This part is more about social and communication aspects around a project of electricity production by geothermic. These aspects are often treated quickly in the environmental studies there are very important in a successful integration. Moreover, communication and sharing with the different stakeholders of the territory involved during all the steps of a project are very important, but putting on the top the advantages of a geothermic project could be gathering elements.

4.1. THE KEY ELEMENTS FOR A SUCCESSFUL INTEGRATION

4.1.1. To share and inform

As all industrial projects, the success of geothermic projects is based partly on the environmental impacts through different tools like the study of environmental impact and the management plan of the environment.

Sheet n°18

This work does not lead to a discussion only focused on the administrative authorities in charge of some agreements. Contrarly, the **questioning** of the widest part of the public (local population, since the beginning and at each stage, is essential for a successful integration.

They have to anticipate the expectations around a project, to go further than only the minimum recommendations. More particularly, the hierarchy of the environmental issues is often very different according to the actors.

The opinion survey of near population from geothermic plants has shown that main people's thoughts were toward the **seismic risks, the noise, the health risk and the odours**.

Thus, it is normal to bring up solutions face to these issues and questions through a **communication** campaign along all the project life. First of all, it has to inform people through the more media (schools, museum, websites, visits…). Information has to be objective because the people's sources of information are multiple now. Transparency is as well a main issue of this communication plan.

However, in order to aim at the project success, it needs to go further with the consultation with people, to involve a discussion with all stakeholders. Project managers have to implement an interactive and long-term relationship aiming to decrease opinion discrepancies.

Through the discussion project managers could identify the main expectations, to share the positive effects, and all the efforts deployed by industrial people. They have to build a real trust, which can be very useful in case of accident.

4.1.2. From the consultation to the building of a territory project

Beyond information and consultation, it is useful to reach a **territory project** around the geothermic project. The principle is to gather the local community in order to multiply the broadcasting. Many tools are available: make easier the access to the market for local suppliers, start to use the geothermic project to develop other projects in relation with eco-tourism…

The building of a territory project needs a total involvement of local actors (neighbourhood, local associations, representatives…). The goal is to implement a new monitoring inside a geothermic project based on an open partnership between different players and stakeholders: governance.

Governance and consultation

The governance and the communication for everyone are two tools used to animate a project.

The governance of a project can be organised around a committee to link all the stakeholders of the geothermic project: public institutions, local workers, associations, scientists…

The strategy of communication toward the whole public has 3 objectives:

- *To inform population*
- *To gather information to make a summary about the local environment, the culture and the history of the place*
- *To assess the view of local population on the project*

This animation can be created by the project manager or delegated to an extern consulting cabinet.

The link committee has a determining role in the consultation because it allows the discussion between all the stakeholders. The consultation has to help people to make the right decision about economics, environmental and social issues.

It allows as well:

- *The involvement of all the stakeholders*
- *To elaborate a mutual view of issues*
- *To identify alternative measures shared by everyone*

Indeed, the project is co-created by players of the territory to guarantee its success.

The involvement of players means to be able:

- ✓ To list the important players to use
- ✓ To involve the population
- ✓ To involve local sources (employment) and to communicate about this
- ✓ To organize information meeting: to move, to be listened, to answer questions
- ✓ To inform population about the completion of the project: done steps and to do ones
- ✓ To give permanent information: to remove wrong ideas

It facilitate the involvement of local players for the project and it allows them to be as stakeholder and to make suggestions to build this project on the territory.

The consultation should to bring up the advantages of the territory and to give value to the geothermic project:

- ✓ To make them want to join both a human and an energetic adventure
- ✓ To make the electric plant not only a "simple plant" but a technopolis to attract tourism, culture and economics
- ✓ To develop tourism around natural water events
- ✓ To bring up the energetic independence
- ✓ To federate around a "Caribbean alliance": to create communication plan in order to promote the Caribbean identity
- ✓ To create a proud feeling about floor wealth.

The manager of the plant must develop a real partnership with the population in order to achieve well the project. The involvement of local representatives and State representatives is very important to make the things going on. With this involvement the manager could enjoy much more space, to use justice and law tools and field to develop linked activities.

Crowd funding could be set up to support the involvement of local players.

The crowdfunding

The crowd funding is a system to fund a project in which you solicit many people, without participation of traditional players.

It allows to hundreds or thousands of people to contribute or invest in very early stage of a project. It reinforces the involvement of the public and local players in the participation to the development of a project and in its governance.

This activity is already used in ecologic transition and more specifically for renewable powers. They were successful funding, for instance with solar panel or windmeel.

This type of funding could be applied to the geothermic, even if the funds are much more consequent in comparison with other renewables power.

The crowd funding could have several forms:

- *Collection of donations*
- *The loan,*
- *Investing in equity*

There are already several websites: Energie partagée, Lumo, Wedogood…

The local players, even more the local governments could be associated by building several companies: Mixed economy companies (MEC), Collective interest cooperative companies (CICC), Simplified stock society (SSS)…

4.2. THE GROWING OF ECO-TOURISTIC PROJECTS

The opinion surveys have shown that Caribbean populations are very protective about their nature and rather agree with the geothermic which is seen as means to gain energetic independence with reasonable costs (BVA-Ademe, 2014)

However, some fears are still present and the lack of information and consultation is often pointed. There is also some worries about the acts of local politicians who are viewed like never take in consideration the local population interests.

The importance of developing a territory project was evocated in the previous chapter in order to foster the consultation and the participation of local players who would like to join local development projects.

Moreover, the managers could find other sources of profit by giving value to the geothermal sources for other uses. Some industrial uses are possible, as the extraction and the using of gases like the CO_2 or H_2S in greenhouse as a motor of growth or to control the temperature or the humidity. These activities can be developed with partnership between managers of the electric plant and local companies. Like this it could have a beneficial impact for the local economy.

Sheet n°20

Another way to value the geothermic resource consists in developing **eco-touristic projects** around the electric plant. Indeed, the plant itself can create an interest for techno-tourism but the geothermal water when it is not reinserted in the process can create interesting points, like thermal centres. The geothermal water is usually rich in mineral salt and is healthy for body and skin, in case of skin diseases. There are already some projects like this, for instance the Blue Lagoon in Island.

Sheet n°19

To build these project, it need the involvement of local politics power, working these centres can be borne by mixed economy companies or private companies.

The local population could beneficiate of a straight access to these installations, but also other infrastructures like restaurants, hotels which are creating jobs.

Other activities could be projected, as centres to discover the geothermic mixing tourism and learning.

This value thanks to the tourism is few developed in Caribbean region. It could be improved along all the other touristic activities. The main goal is to enhance the natural resources of the territory, contributing to the local economic activity.

This development of eco-touristic activities can be built along a geothermic project. It could be the unifying element of the project for the territory project for the local players and population.

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Appendix 1

Notes about geothermic presentation

Summary of the 20 didactic sheets of geothermic presentation

Thematic	*n°*	*Sheets titles*
General presentation of geothermal projects destined to the electricity production	1	The geothermal energy and the electricity production: recaps, situational analysis, perspectives
	2	The key phases of a geothermal project and the geological risk problematic
	3	The costs and the fund of geothermal projects including the Clean Development Mechanism (CDM)
The technologies and basic equipment of a geothermal power station	4	The different components of a geothermal power station: well, pipes and separator, turbine-generator unit
	5	The drillings and associated equipment: the different types of wells, the tests and the wells life duration
	6	The different technologies of turbines used by the geothermal energy
	7	The different cooling systems of the geothermal power stations
The geothermal resource exploitation	8	The geothermal resource management (production, reinjection) and renewability
The regulatory aspects of a geothermal project	9	The geothermal energy and the staffs healthcare/ security
	10	The regulation applicable to geothermal projects
The environmental analysis of geothermal projects	11	The impacts studies within a geothermal project: objectives, chronology an requirements specifications
	12	The description of environment initial state around a geothermal project
	13	The environmental management plans applicable to a geothermal project
	14	The landscape integration of different components of a geothermal plant
	15	The dismantling of geothermal power stations and the rehabilitation of the sites
	16	The treatment and recycling sectors of wastes generated by a geothermal project
	17	The H_2S gas emission treatment of a geothermal power station
The communication around a geothermal project	18	The consultation with populations and associations concerned by a geothermal project
	19	The eco-touristic activities development around a geothermal project
The economic consequences	20	The direct and indirect economic consequences of a geothermal project

Geothermal energy and electricity production: reminder, synopsis and prospects

Sheet n°1

Summary

Geothermal electricity generation started in 1905 in Lardarello, Italy. Today, it's a mature industry established in 27 countries with an installed production capacity of 12, 6 GW (result 2015). Big countries such as the Philippines, Indonesia or New Zealand produce a substantial part of their electricity through their geothermal power plants. Geothermal energy can be competitive with other modes of electricity generation based on fossil fuels or renewable energies, especially in island countries.

Historical reminder

Geothermal electricity generation is an old technique since the first geothermal power plant was built in Lardarello, Italy, in 1905. It only had a capacity of 20 kWe. Then, countries with active volcanic areas such as the US, Japan, New Zealand and Indonesia started to explore their geothermal resources in order to build geothermal power plants. Yet it has been a slow development. The installed production capacity only amounted to 147 MWe (figure 1) in 1947. It reached 400 MWe in 1960, mainly distributed in Italy (Lardarello) and the US (the Geysers). The pace of development quickly increased after the 1973 and 1979 oil shocks. This rapid growth was slowed down around the year 2000 because of the deregulation of the power generation sector in many countries and especially in Central America. Another obstacle to development was the economic breakdown in Asia, which put an end to many projects in Indonesia. In 2015 the installed capacity amounts to 12.6 GWh (sources: Bertrani, 2015).

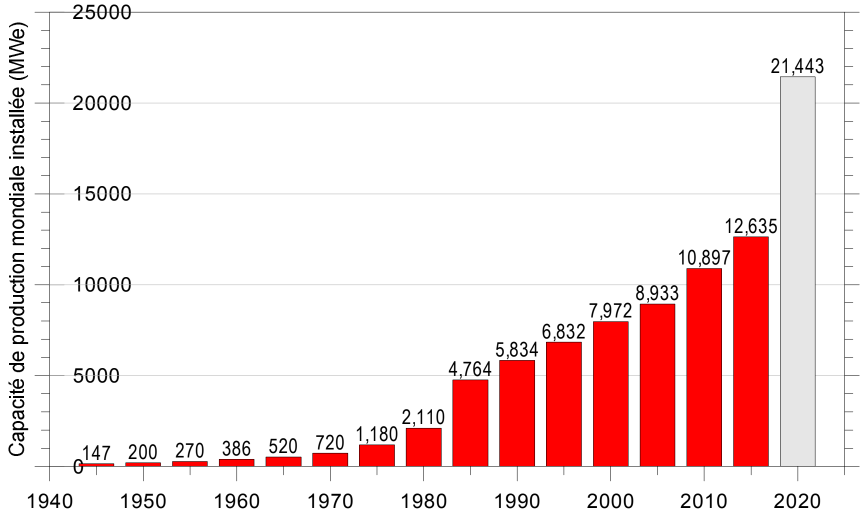


Figure 10: Evolution of the installed production capacity of geothermal power plants at global level since 1940 (Bertani, 2015)

Legend: Global installed production capacity (MWe)

Synopsis

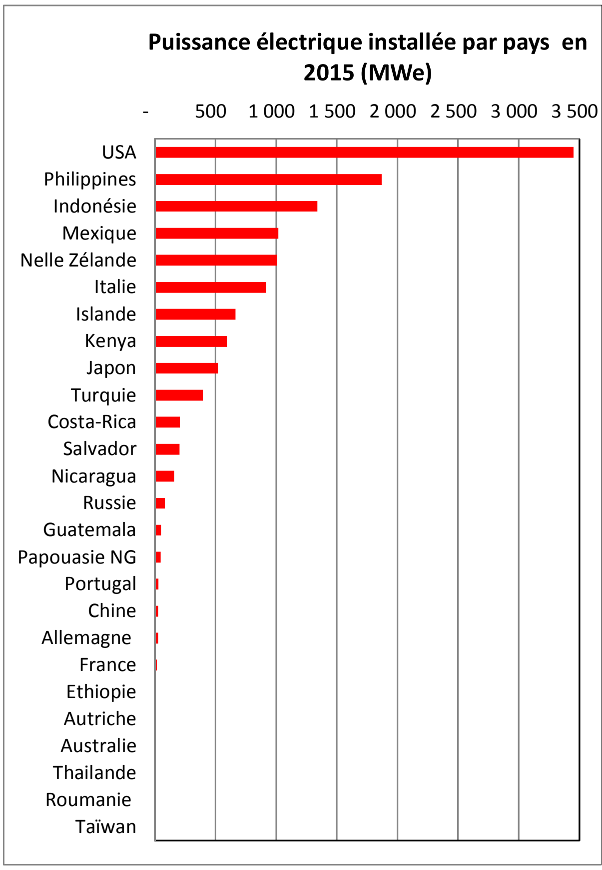
Global distribution of geothermal power plants

According to Bertani (2015), 27 countries have been using geothermal power plants to generate electricity in 2015. Worldwide distribution of geothermal power plants is closely linked to the main active tectonic and volcanic areas on Earth (Figure 2). This explains why the Pacific Ring of Fire focuses the major part of installed production capacity (9.9 GWe of the total capacity of 12.6 GWe, sources: Bertani, 2015). The leader in this sector remains ***the US*** which represents by itself more than 25% of the global capacity (3.45 GWe). ***Southeast Asian*** countries (Indonesia, the Philippines, New Zealand and Japan) have also strongly developed this renewable energy and have often reached installed production capacities above 1 GWe. Many ***Central American*** countries have also counted on geothermal energy to generate electricity, especially Mexico with an installed production capacity of 1 GWe. Smaller countries such as Costa-Rica, Salvador, Nicaragua and Guatemala have also developed their geothermal resources significantly according to their power needs.

In ***Europe***, the three countries with substantial production capacities are Italy (916 MWe), where geothermal science was born, Island (605 MWe) and Turkey (397 MWe), which experienced a recent progression. In ***Africa***, Kenya is the leading country with an installed capacity of 594 MWe.

Apart from those countries with large production capacities, there are a number of countries such as China, Portugal, Ethiopia and France, which have developed geothermal power to a limited extent, either for lack of high temperature geothermal resources or because of technological or economical motives. Finally, this last category of countries includes Germany that has recently increased the use of geothermal resources of medium enthalpy with low-capacity geothermal power plants equipped with ORC turbines. As regards France, the geothermal production capacity amounts to 17 MWe with the Bouillante power plant in Guadeloupe (15 MWe) and the Soultz-Sous-Forêts power plant in Alsace (2 MWe).

In **the Caribbean** the only achievement so far is the Bouillante geothermal power plant in Guadeloupe.



Pays	Capacité installée (MWe)	Besoins couverts (%)
USA	3 450	0,5%
Philippines	1 870	14%
Indonésie	1 340	5%
Mexique	1 017	2,4%
Nelle Zélande	1 005	16%
Italie	916	
Islande	665	29%
Kenya	594	
Japon	519	
Turquie	397	
Costa-Rica	207	15%
Salvador	204	24%
Nicaragua	159	10%
Russie	82	
Guatemala	52	
Papouasie NG	50	
Portugal (Açores)	29	22%
Chine	27	
Allemagne	27	
France	17	
Ethiopie	7,3	
Autriche	1,2	
Australie	1,1	
Thailande	0,3	
Roumanie	0,1	
Taïwan	0,1	

Translation of the board: First line: Countries, installed capacity (MWe), electricity demand covered (%)

1st Column: USA, the Philippines, Indonesia, Mexico, New Zealand, Italy, Island, Kenya, Japan, Turkey, Costa Rica, Salvador, Nicaragua, Russia, Guatemala, Papua-New-Guinea, Portugal (the Azores), China, Germany, France, Ethiopia, Austria, Australia, Thailand, Romania, Taiwan.

Title of the graphe: Installed electrical generation per country in 2015 (MWe)

Figure 2: Geothermal electricity generation capacity per country in 2015 and percentage of the electricity demand covered by geothermal when available (sources: Bertani, 2015).

The contribution of geothermal science to the satisfaction of a country's electricity

needs

Geothermal electricity generation is a mature industry now. Besides, it doesn't depend on climatic conditions contrary to other sources of renewable energy such as solar or wind power, and offers high levels of availability. That explains why it can cover a substantial proportion of a country's electricity demand, provided that the latter holds important geothermal resources. For instance, figure 2 shows the percentage of the electricity demand met by geothermal for countries where this information is available. Big countries such as the Philippines, Indonesia or New Zealand produce a substantial part of their electricity through their geothermal power plants. This is a good illustration of the reliability of this industry and it also shows that geothermal energy can compete with other modes of electricity generation based on fossil fuels or renewable energies, especially in island countries.

Table 1 shows the installed production capacities of the twelve major geothermal fields in the world, for information purposes. Those capacities are generally obtained through setting up new production units gradually as the field expands. They are similar to the capacities of classic power plants using fossil fuels (coal and gas) or to a type of nuclear power plants. It shows how mature and industrial this sector is.

Pays	*Nom du champ*	*Capacité installée (MWe)*
Etats-Unis	Les Geysers	1 585
Mexique	Cerro Prieto	727
Philippines	Tongonan	726
Italie	Larderello	595
Kenya	Olkaria	592
Philippines	Mak-Ban	458
Nelle Zélande	Wairakei	399
Etats-Unis	Salton Sea	388
Indonésie	Salak	377
Islande	Hellisheidi	303
Etats-Unis	Coso	292
Indonésie	Darajat	260

First line: Countries, Field name, Installed capacity (MWe).

Column 1: Unites states, Mexico, the Philippines, Italy, Kenya, the Philippines, New Zealand, Unites States, Indonesia, Island, Unites states, Indonesia.

Column 2: the Geysers, then same names.

Board 6 : Capacity of electricity production of the twelve main global geothermal fields (according to Bertani, 2015).

Still in relation to the possible contribution of geothermal energy to the electricity generation at national scale, the average size of the geothermal turbines that have been installed throughout the world until now is interesting. This capacity varies from 6 to 91 MWe (Bertani, 2015) according to the type of turbine. The most common type is the conventional steam turbine that has a medium size of 30 MWe.

The geothermal market

Figure 2 shows the countries that have developed geothermal power plants for electricity supply purposes. Among these countries, some have acquired an expertize that allows them to be actors on the global geothermal market. In that market there are two complementary types of activities in the realisation of geothermal power plant projects. These types are project engineering and equipment suppliers.

- As for project engineering, the countries that have an expertise and that benefit commercially from it are the one with a domestic geothermal market that has enabled them to develop these skills, such as the Unites-States, New Zealand, Island, and to a lesser extent, Italy and Japan;

- As for the provision of equipment of a power plant and especially of the turbine, which is the key element of the installation, the top three suppliers are Japanese (Toshiba, Mitsubishi, Fuji). The ORMAT Company, which is specialised in providing ORC turbines, ranks 4th and is followed by an Italian company (Ansaldo-Franco Tosi). These five suppliers account for almost 95% of the market.

Figure 3: Berlin's geothermal power plant in Salvador, with a capacity of 109 MWe (sources: Verkis).

Prospects

Figure 1 illustrates installed production capacity growth for geothermal electricity over the past 80 years. If the pace of growth observed over the last 10 years is maintained, the installed production capacity will be about 15 GWe in 2020. However, many projects of geothermal power plants have started or will start in countries such as Island, Indonesia, Kenya, the US, the Philippines, Mexico… Kenya plans to triple its capacity by 2020. Indonesia plans to increase its production capacity from 1,340 MWe to 3,500 MWe. In 2020, optimistic forecasts anticipate an installed capacity of 21.5 GWe, which is almost twice the 2015 existing capacity.

Over a longer time frame up to 2050, the projected production capacity amounts to 140 GWe, including the use of conventional geothermal resources and of non-conventional resources of EGS type (Enhances Geothermal Systems). Geothermal energy would then be able to meet from 5% to 10% of electricity needs at global level and about 40 countries could be fully supplied with electricity by geothermal power plants! The amount of carbon dioxide that would be avoided would reach about 1 billion tons per year.

The key phases of a geothermal project and the problem of the geological risk

Sheet n°2

Summary

A particularity of geothermal power plants projects for electricity generation purposes is their duration. Generally, it takes from 6 to 8 years between first studies and the establishment of a geothermal power plant. Another particularity is the risk of failure in exploring the resource, which can conduct the project to be abandoned.

This form illustrates the key phases of a geothermal power plant project and brings to light this notion of geothermal risk.

Introduction

Compared to other industrial projects, a particularity of geothermal power plants projects for electricity generation purposes is their duration. In fact, it takes generally **from 6 to 8 years** between first studies and the establishment of a geothermal power plant. This duration is due to the need to carry out a preliminary exploration phase and then undertake drilling in order to confirm that the geothermal resource exists and to assess its potential. Then it's possible to size the project, conceive the power plant and start its construction.

Another particularity of these projects is that they can be abandoned before completion when the potential of the geothermal resource is considered too low or when the resource has unfavourable features. This risk of failure in the process of geothermal power plants projects is often called **a geological risk.**

The key phases of a geothermal power plant project

Since the 1950s, many construction projects of geothermal power plants have been carried out successfully. A methodology has been implemented gradually with successive phases that follow one another. Table 1 identifies the different phases of a typical geothermal power plant project. It also sums up the average duration of each phase, the goals and the nature of the work conducted. These phases follow a clear progression in knowledge of geothermal resources and then in the design of a geothermal power plant that we can illustrate as follows:

- the identification and the selection of areas of interest;
- the exploration of the geothermal resource;
- the design of the power plant project;
- the drilling of wells and the construction of the facility;
- the operation of the facility.

These key phases follow a clear progression in knowledge of geothermal resources and then in the design of a geothermal facility. They generally end on deciding whether to pursue a project or on deciding the establishment, the size and the type of power plant.

The ***identification*** of areas of interest is based on a review of existing data. It enables to select areas of interest (regionally or nationally) where there are interesting indications that justify further exploration work.

Tableau 1 : Récapitulatif des différentes phases d'un projet-type de centrale géothermique pour la production d'électricité.

	Phases	*Durée moyenne*	*Objectifs*	*Nature des travaux*
1	**Reconnaissance préliminaire**	0,5 à1 an	Sélectionner les zones présentant un intérêt et pouvant faire l'objet de travaux ultérieurs d'exploration détaillés	Analyses bibliographiques des données existantes, visites de sites et sélection des zones d'intérêts, évaluation environnemantale préliminaire (notice d'impact)
2	**Campagnes d'exploration de surface**	1 à 2 ans	Réaliser des campagnes de prospection géologiques, géochimiques et géophysiques sur la ou les zones sélectionnées	Prospection de terrain, mesures, prélèvements de roches et de sources thermales
3	**Etude de préfaisabilité**	0,5 à 1 an	Evaluer la taille et la température du réservoir géothermique, faire une première estimation de sa capacité de production électrique, évaluer l'intérêt du projet et décider la poursuite ou l'abandon, établir un plan de financement des forages d'exploration	Etudes, Synthèse des prospections géologiques, géochimiques et géophysiques, Elaboration d'un modèle conceptuel, Implantation des forages d'exploration, étude d'impact exploration
4	**Forages d'exploration et de confirmation**	1 à 2 ans	Confirmer la présence d'un réservoir géothermique haute température (>160°C) apte à alimenter une centrale géothermique, préciser sa capacité de production électrique, décider la poursuite ou l'abandon du projet	Préparation de plateformes de forages, aménagement de voies d'accès, forage, tests de puits, essais de production
5	**Etude de faisabilité**	1 an	Choix de la taille et de la technologie de la future centrale, choix de l'implantation des puits et de la centrale, calcul du coût global du projet, négociation du contrat de vente de l'électricité produite	Etudes d'ingénierie, conception technique de la centrale, modèle numérique du réservoir, tracé des plans d'implantation, élaboration des plannings , étude d'impact du projet
6	**Développement du champ**	2ans	Forer le nombre de puits nécessaires pour assurer les besoins en vapeur de la future centrale et permettre la réinjection des fluides dans le réservoir	Aménagement de voies d'accès, génie civil pour la préparation de plateformes de forages, forage des puits de production et de réinjection, tests de puits, essais de production,
7	**Construction de la centrale**	1 à 2 ans	Construire l'ensemble des infrastructures et équipements qui constitueront la centrale géothermique	Construction de la centrale, construction des lignes de transport électrique, construction des conduites de transport des fluides entre les puits et la centrale, construction des routes d'accès
8	**Période d'essai et mise en service de la centrale**	0,5 an	S'assurer que les procédés et équipements qui ont été mis en place fonctionnent correctement d'un point de vue technique et respectent l'environnement	Tests de fonctionnement des équipements, tests des puits de production et de réinjection, contrôles et mesures des impacts environnementaux
9	**Exploitation de la centrale**	25-30 ans	Assurer la production de vapeur et la production d'électricité, assurer une bonne gestion de la ressource géothermale, assurer la maintenance des installations,	Travaux d'entretien de la centrale et des puits, forage éventuel de nouveaux puits pour augmenter la production de vapeur ou la capacité de réinjection, installation de nouvelles unités pour augmenter la capacité de production ou en remplacement d'unités anciennes ou obsolètres,
10	**Démantèlement/ mise en place de nouvelles unités**	0,5 an	En fin de vie du projet/des unités, procéder au démantèlement des installations, au recyclage des matériaux et à la remise en état des sites	Génie civil, déconstruction des bâtiments, retrait des conduites de transport, évacuation des matériaux et recyclage

Table 1: Recap chart of the different steps of a typical geothermal power plant project for electricity generation.

Phases, average length, objectives, nature of the work.

1. Preliminary recognition: from 0.5 to 1 year
- Selecting the areas that have special value and that are subject to further exploration work.
- Literature reviews of existing data, site visits and selection of zones of interest, preliminary environmental assessment (impact statement)
2. Surface exploration campaigns: from 1 to 2 years
- Carrying out geological, geochemical and geophysical prospecting campaigns on selected areas.
- Field prospecting, measurements, collection of rock samples and water abstraction from thermal springs
3. Pre-feasibility study: from 0.5 to 1 year
- Assessing the size and the temperature of the geothermal reservoir, making a first estimate of its electricity production capacity, deciding the merits of the project and whether to pursue or abandon it, establishing a financing plan for exploratory drillings.
- Studies, summary of geological, geochemical and geophysical prospecting programs, development of a conceptual model, exploratory drilling programs, impact study of the exploration (TRADUIT COMME ETUDE D'IMPACT DE L'EXPLORATION)
4. Exploration and confirmation drillings: from 1 to 2 years
- Confirming the existence of a high temperature geothermal reservoir (>160°C) that can supply a geothermal power plant, clarifying its electricity generation capacity, deciding whether to pursue or abandon the project.
- Preparation of drilling platforms, construction of access roads, drilling, well tests, production tests.
5. Feasibility study: 1 year
- Deciding the size and the technology of the future power plant, choosing where to implement wells and the facility, calculating the overall cost of the project, negotiating the sales agreement of the electricity produced.
- Engineering studies, technical design of the power plant, numerical model of the reservoir, preparation of installation plans, elaboration of schedules, impact study of the project
6. Field development: 2 years
- Drilling the right number of wells to meet the steam needs of the future power plant and to enable the fluid reinjection into the reservoir.
- Construction of access roads, civil engineering preparation of drilling rigs, drilling of production and reinjection wells, well tests, production tests.
7. Construction of the power plant: from 1 to 2 years
- Building all the infrastructure facilities and all equipment that will constitute the geothermal power plant.
- Construction of the power plant, construction of power distribution lines, construction of fluid conducting conducts between the wells and the power station, construction of the access roads.
8. Trial period and commissioning of the power station: 0.5 year
- Making sure that the processes and equipment built function well in a technical sense and are environmentally friendly.
- Functional checks of equipment, tests of production and reinjection wells, control and measurement of the environmental impacts.
9. Operation of the plant: from 25 to 30 years
- Ensuring steam and electricity production, ensuring good management of geothermal resources, ensuring the maintenance of installations
- maintenance work of the power station and wells, possible drilling of new wells in order to increase steam production or reinjection capacity, installation of new units in order to increase generating capacity or to replace old or obsolete units.
10. Dismantling / installation of new units: 0.5 year
- At the end of the project/units life, proceeding to dismantle installations, to recycle materials and to rehabilitate sites.
- Civil engineering, demolition of buildings, removal of fluid conducting conducts, disposal of materials and recycling.

The ***exploration*** of the geothermal resource first consists in implementing different surface prospecting methods in the selected areas of interest in order to get detailed information on the geothermal resource and enable to make a first estimation of its potential. If the results are positive, it will be decided to conduct exploratory drilling programs. If these first drillings are positive, the project developer can decide to put an end to the exploratory phase by digging 2 or 3 additional wells called confirmation wells. This stage represents a major milestone for the project for two reasons. According to the results, the project developer can decide to pursue or abandon the project. Moreover, in this first case, he would also be able to identify the size of his project.

The ***feasibility study*** is the primary entry point of the project in the phases leading to the construction of the power plant. Its goal is ***designing*** and planning in detail on the technical, economic and financial levels the drilling of production or reinjection wells and the power station itself. The total project cost is computed and its economic profitability is estimated. The project is often conceived by steps by implementing gradually medium-sized units rather than a single, large sized unit. If the project developer is an industrialist or an investor, this one starts negotiations on the purchase price of electricity generated with the local or national electricity company and concludes a power sales contract that enables him to develop a financing plan of the project and to approach banks for the necessary loans.

Drilling of production and reinjection wells comes usually before the construction of the power plant, which allows adapting the size and type of turbine to the results achieved. Once the production and reinjection capacity of wells is confirmed, the project is secure and the developer can launch the ***building of the power station*** phase or the building of the first unit, if the project is carried out in stages. This includes all the surface equipment (in opposition to wells). On one hand this consists in constructing the geothermal fluid conducting conducts (water and steam) that will connect wellhead platforms to the power plant and in constructing separation stations where water and steam are separated. (Sens de la phrase ambigü: relier les stations de separation ou les construire ?). On the other hand it consists in constructing the power station itself, which is composed of a turbine, an alternator and various auxiliary equipment such as the steam cooling system and the treatment of gazes.

Finally, after a trial and commissioning period, the ***operating of the geothermal power plant*** can start. This phase consists in ensuring proper management of the geothermal reservoir with the extraction of fluids from the reservoir and their reinjection after use. It also consists in ensuring the operating and maintenance of electricity generation facilities. Although the equipment life is usually 25 to 30 years, the operating phase can be much longer. Old and/or obsolete units are replaced by new ones.

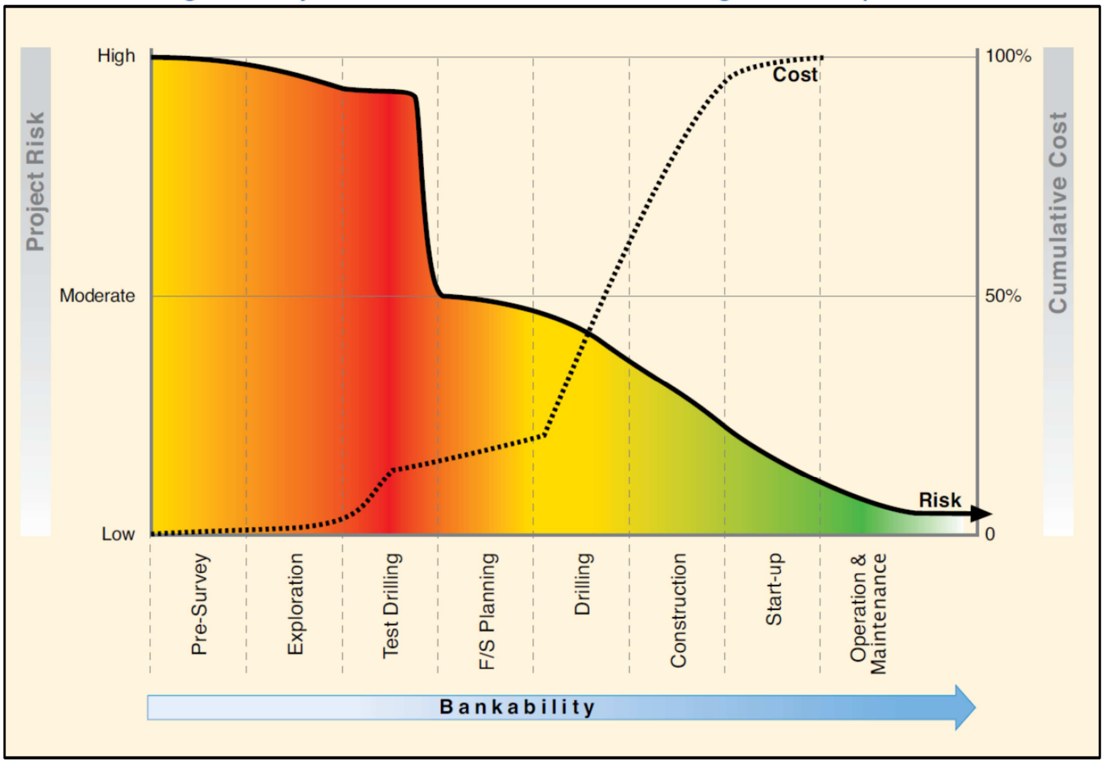
The problem of the geological risk

The success of a geothermal power plant project strongly depends on the results of **the exploration phase of the geothermal resource**. Results from surface exploration campaigns and then from exploration drillings can be deceiving and lead to project being abandoned if the temperature of the geothermal resource is too low, if the reservoir has a poor permeability or if it's too small to launch a project (and so on).

This risk of abandoning the geothermal power station project before completion is often called **a geological risk.** It shows how hard it is to correctly assess the quality and capacity of a geothermal reservoir situated at a certain depth. Thus a project developer has to spend significant amounts of money for exploration drillings (from several millions to tens of millions of euros) without being sure to find an exploitable geothermal resource and to be able to complete the project and then recover his investment.

Once the project is at the operating phase, the risk of failure still remains even if it is minimized. The production capacity of the reservoir can be compromised by a too low natural recharge rate or by difficulties in the fluid reinjection. Overexploitation of the reservoir in order to meet the needs of an oversize power plant can lead to the early exhaustion of the resource and put at risk the financial balance of the project because of proceeds from electricity sales lower than expected and that can't meet financial costs anymore.

Figure 1 : Evolution of the risk of failure and of costs incurred during the development of a typical geothermal power station project (according to Gehringer and Losksha, 2012).



This geological risk is often ***a hindrance*** to the exploration and exploitation of geothermal resources because it leads to substantial financial risks for a project developer. That is why some solutions have been implemented gradually in order to limit those risks and to make the development of geothermal for electricity generation purposes easier.

- As regards the risk of failure during the exploration phase, some countries or international organizations choose to fund or co-fund exploration drillings with ***public money***. Others establish insurance mechanisms or geological risk coverage mechanisms that repay a more or less significant part of drilling costs in case of failure. Consequently, developers of private projects are less reluctant to start geothermal power plant projects if they are sure to recover partly or totally the money spent for exploration drillings programs;

- As regards the risk of overexploiting the reservoir, it can be minimized by favouring a **field development step by step** and the building of a first unit with a capacity below 30 to 50% of the estimated capacity of the reservoir. Exploiting it for few years enables to test the real capacity of the reservoir and then to size the next units correctly.
- Figure 1 shows graphically the evolution of the risk of failure and of costs incurred during a project life. During the early stages, there is a high risk of failure but the costs incurred remain low. On the contrary, during the phases of field development and of the construction of the power station there are much higher costs but the risk of failure turns low.

The phasing of a geothermal project as presented previously, with regular decision-making milestones about pursuing of not the project, enables to reduce the financial risk in case of abandon while the project is in progress.

The costs and funding of geothermal projects including the Clean Development Mechanism (CDM)

Sheet n°3

Summary

A geothermal power station project presents some very specific technical features. It also has specificities regarding its costs and its method of financing.
The point of this form is to concisely present some key elements in relation to these aspects.

The costs of a geothermal project

The investment cost

On one hand, a geothermal power plant project is characterised by a high investment cost and a very long payback period. Indicative costs for the various phases of a 50 MWe power station project are detailed in Table 1 and Figure 1 shows the costs accumulated as the project proceeds. Because of the project duration, it can take from 6 to 8 years for the first revenues from electricity sales to be received and to enable first repayments.

Stages	***Average costs (In US$ millions)***	***Cost accumulation (in US$ millions)***
Preliminary reconnaissance	2	2
Detailed exploration campaigns, pre-feasibility	3	5
Exploration and confirmation drilling programs	18	23
Feasibility study	7	30
Field development (20 wells)	70	100
Construction of the plant	91	191
Testing and commissioning	5	196
Total	**196**	
Cost per MW of installed capacity	3,9	

Table 1: The average indicative costs of a 50 MWe geothermal power station project (according to Gehringer and Loksha, 2012)

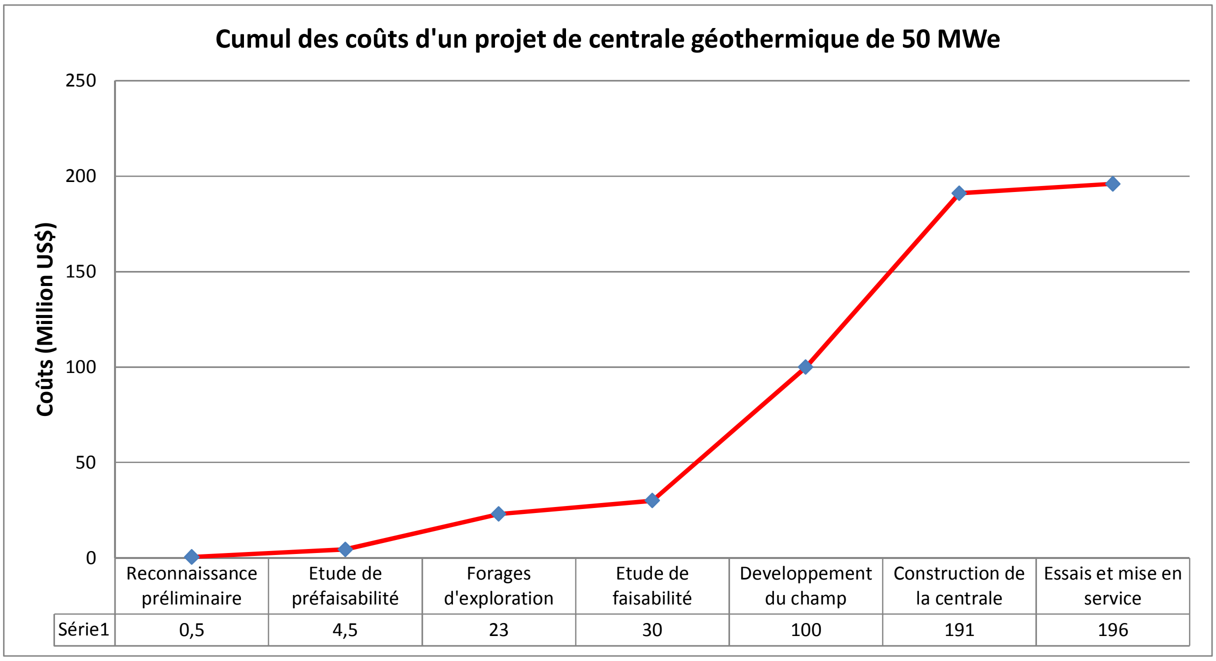
On the other hand, this type of project presents a high financial risk since it can be interrupted after disappointing exploration drilling results, even though a significant amount has already been committed (from 10 to 15% of the global amount). The phases of field development and construction of the power station present much higher costs but the risk of abandoning the project before completion has turned low.

This investment cost of a geothermal power plant, defined per MWe of installed capacity, can vary from a project to another. Table 2 recaps the main parameters that can affect this cost and Table 3 shows the values usually observed according to the characteristics of the project.

⇒ Quality of the deposit (depth and temperature) ⇒ Location of the deposit in comparison to the needs/distribution networks of electric transportation ⇒ Size of the power plant (scale effect) ⇒ Method of funding the project (self-financing, loans,

Table 2: Main factors affecting the investment cost of a geothermal power plant per MWe of installed capacity

mechanisms covering the geological risk)
⇒ Tax incentives and other public aids



Cost accumulation of a 50 MWe power station project

Costs (in US$ millions)

Preliminary reconnaissance, Pre-feasibility study, Exploration drilling programs, Feasibility study, Field development, Construction of the plant, Testing and commissioning

Series 1

Figure 1: Cost accumulation as the 50 MWe geothermal power plant project proceeds.

The cost of production and the competitiveness of geothermal energy

The updated generating cost per kWh of geothermal energy is the sum of the investment cost including the financial expenses of the project, and the maintenance and operating cost, divided by the number of kWh produced during the project life (for example 25 years).

In compensation for high investment costs, a geothermal power station benefits from very low and stable operating costs since it doesn't require the purchase of energy (gas, coal, fuel oil) whose price can fluctuate over time. It also offers a great availability (90 to 95%) that enables it to function as a basic energy.

Thus, thanks to these very low operating costs, a geothermal power plant is competitive compared to other means of electricity generation based on fossil fuels or on variable renewable energy sources (wind power, solar energy). Table 3 gives the values usually observed according to the characteristics of the project.

	Investment cost (MUS$/MWe of installed capacity)	*Updated production cost (US$/kWh)*
High-temperature deposit and/or large power plant (greater than or equal to 50 MWe)	2 à 4	0.05 to 0.09
Medium-temperature deposit and/or power plant with a small/medium capacity (less than 50 MWe)	3 à 6	0.10 to 0.20

Table 3: Investment costs and electricity generation costs usually observed for a geothermal power plant, according to the characteristics of the project.

Funding a geothermal project

The financing of a geothermal project is specific because of the project duration and the risky preliminary exploration stage. There are several financing models for each country and stage of development of a project.

⇒ It can be totally funded by the public sector. For example, the national power company can build and operate the power plant. Funding is provided by the national company and/or the government and can be completed by donations or loans from international organisations such as the World Bank.

⇒ The project can be implemented as a public-private partnership between the government or the national power company and one or several private partners. The public sector will usually fund the risky exploration phase. The private sector will invest money in the development phase and in the construction of the power station.

⇒ Finally, the project can be totally funded by one or several private companies that agree to take on the risk involved in exploration. Once the project is implemented; the private sector can operate the plant and resell the electricity to the company managing distribution networks. It can also resell the power station to the national power company.

In parallel with these various means of financing, Table 4 sums up the main financial instruments commonly used to support a geothermal power station project. They all aim to limiting the financial risk of the project, whatever the method of funding is. They are useful especially for promoting the development of new geothermal fields in order to generate electricity ("Green fields") in countries where geothermal energy is not yet a mature sector and private operators are missing.

Phases	*Financial instruments*
Preliminary reconnaissance, surface exploration	Publicly funded studies (Regions, State, European Union, Ademe)
Exploration drilling,	Hedge funds to cover the geological risk in case of failure

development drilling	(Geodeep), institutional support funds (ArGeo)
Operation	Preferential buy-back rate, obligation of repurchase at a price set by the regulator

Table 4: The main financial instruments commonly used to support a geothermal power station project.

The Clean Development Mechanism (CDM)

The Clean Development Mechanism (CDM) established by the Kyoto Protocol can be an interesting tool for funding a geothermal power plant project while committing to environmental excellence. CDM is intended to boosting efforts to tackle global warming while encouraging industrialised countries to invest in the greenhouse gas emission reduction projects (GHG) launched by developing countries. In return, they get carbon emission credits that enable them to observe the GHG emission quotas attributed to them. Thus, CDM projects have a triple interest:

- an ***environmental interest*** at local and global level by reducing the GHG emissions generated;
- an interest for ***the social and economic development*** of the host country that benefits from the project implementation and a complementary source of funding;
- an ***economic interest***, by improving clean technologies having low GHG emissions.

Consequently CDM can apply to a geothermal power plant project carried out by a developing country. For now, 31 geothermal projects have been registered by the UNCCC (United Nations agency that coordinates the CDM at global level) in countries such as Indonesia, the Philippines, Malaysia, Guatemala and Nicaragua. In principle, these projects are eligible since CO2 emissions per kWh are much lower than those of power plants using fossil fuels (Figure 2) and therefore enable to globally reduce GHG emissions.

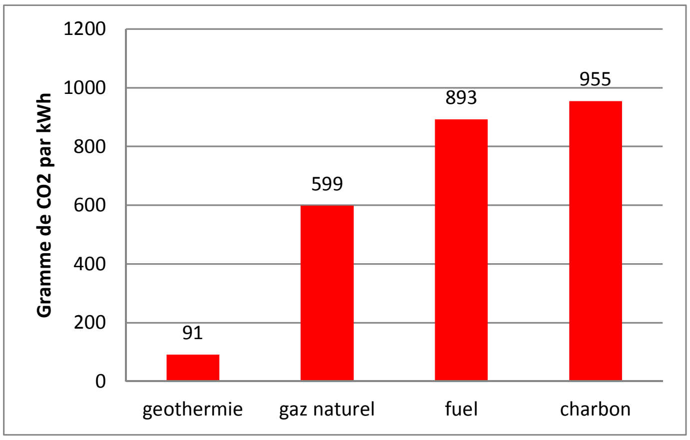


Figure 11: Comparison of CO2 emissions for each energy source used for electricity production (according to Gehringer and Loksha, 2012)

Geothermal energy, natural gas, Fuel oil, Coal

Grams of CO2 per kWh

The table below illustrates, on a simplified basis, how to preliminarily asses CDM support to a geothermal project with a 25 MWe gross capacity in a developing country:

Investment cost of the project outside the CDM framework	€100,000,000
GHG gas reductions generated by the project (CERs)	80,000 teqCO_2/an
Gross income resulting from the sale of CERs over a 10-year period (Hypothesis: 1 teqCO2 = €5)	€4,000,000

Information sources

A high number of reports or documents on the subject were published by international institutions and can provide a more complete approach of the topic to interested readers. In particular, a document recently issued by the World Bank can be quoted: *Geothermal*

Handbook - Planning and financing power generation, by M. Gehringer et V. Loksha, ESMAP Technical Report 002/12, 2012).

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The various components of a geothermal power plant: wells, conducts, separators and turbine-generator unit

Sheet n°4

Summary

A geothermal power plant is made of various components which have for function to collect the geothermal in-depth fluid, to insure its transport, to convert its energy in electricity and finally to evacuate this electricity towards the distribution network.
The object of this sheet is to present briefly the nature and the role of these various components.

Introduction

The geothermal power plants are different from conventional steam thermal power plants for many reasons. They are powered by a geothermal fluid, taken directly in a reservoir that can be extended under the power plant or in its direct neighborhood. The operation of a geothermal reservoir distant is thus strongly dependent of the nature of the geothermal fluid and the topography of the neighborhood of the power plant, among other things. The geothermal fluid can be used directly, or indirectly, through heat exchangers by means of selected, binary or flash turbines.

Contrary to the steam which is used in the classic steam turbines, the geothermal fluid requires a specific treatment in order to clear the different gases and other dissolved substances contained in it and in order to insure a good quality of the steam or of the mixture vapor and liquid. This process is usually directly made in the well-head or at the level of a station connected through pipelines to the wells.

The power plant in itself is made of components that we also find in the classic steam thermal power plants: turbine and generator; processing aids; cooling system specially designed to bear operational conditions inflicted by the nature of the source of energy. Finally, a complete system of reinjection in the reservoir is necessary to recycle the geothermal fluid after it was used.

The wells

The geothermal wells have typically a depth from 1,000 to 3,000m. They are conceived with steel intubations to isolate the superficial aquifers and insure stability to the ground. Floodgates and other components are fixed to the top of the steel intubations to form the well-head.

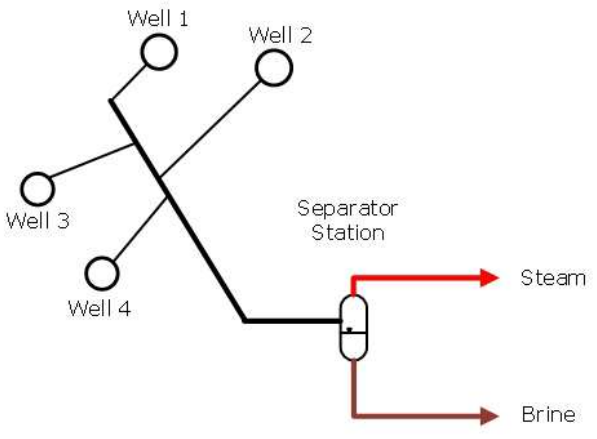

Figure 12: Schematic representation of the wells, the collectors, the main conduct and the station of separation.

The pipelines

The pipes insure the transport of the geothermal fluid from the wells up to the power plant. The system of transport of the fluid is generally made of a main conduct and collectors. The collectors are connected with wellheads and ensure the transport of the fluid to the main conduct at the end of which is generally connected a separator liquid / steam. The Figure 1 shows the possible connections between the wells and a station of separation. Different architectural configurations can be adopted for the system transporting the fluids in order to obtain better economic and technical results depending in the topography, the distribution of the wells, etc.

Figure 13 : System of transport of the fluids to the power plant of Pico Vermelho in the Azores (© CFG Services).

The separator water/steam

The separator is used to separate the steam and gases on one hand and the water in liquid state on the other hand. One or several separators can be located at the level of the power plant, at the level of satellite stations or directly in the well-head.

The most common type of separator is a vertical cyclone. The water arrives in the separator at high speed and tangentially, creating a whirlwind in the separator. Droplets are "thrown" on the walls of the cyclone while the steam concentrates in the center. The droplets of water fall at the bottom; the steam escapes from the top and is then conducted towards the turbine.

The separator can also be a horizontal balloon. The separation between water and steam is then simply made by gravity. The lighter steam escapes from the top. The denser water occupies the bottom of the balloon and is evacuated by a well.

Figure 3: Horizontal separator water/steam in the power plant of Boiling, Guadeloupe (© CFG Services)

The turbine and the alternator

The turbine and the alternator constitute the heart of geothermal power plants. The steam is received in the turbine where it’s relaxed and makes the shaft of the turbine turn. The rotation of the turbine’s shaft pulls the alternator which converts the mechanical energy in electrical energy.

The steam penetrates into the high-pressure turbine and leaves the turbine more or less at the atmospheric pressure, ~~0,1 bar-abs (±0, 03 bar)~~. The steam going out of the turbine is conducted towards a condenser where it’s transformed in liquid form.

Turbines can also have no condenser at all. In this case, the steam going out of the turbine at atmospheric pressure is released through a chimney. This is called a back pressure turbine. This type of turbine is much less efficient and produces approximately twice less power than a condensation unit with the same amount of steam.

ORC's turbines (also called binary turbines) use a secondary fluid, like pentane or ammoniac, which is vaporized in the contact of the geothermal fluid in a heat exchanger. It is this vaporized secondary fluid which is sent towards the turbine (and not the geothermal steam). At the exit of the turbine, it is sent towards a condenser where it is condensed again and the cycle starts once again.

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Figure 14 : Picture of a Fuji steam turbine with a capacity of 50 MWe in the geothermal power plant of Reykjanes in Iceland (© Verkis).

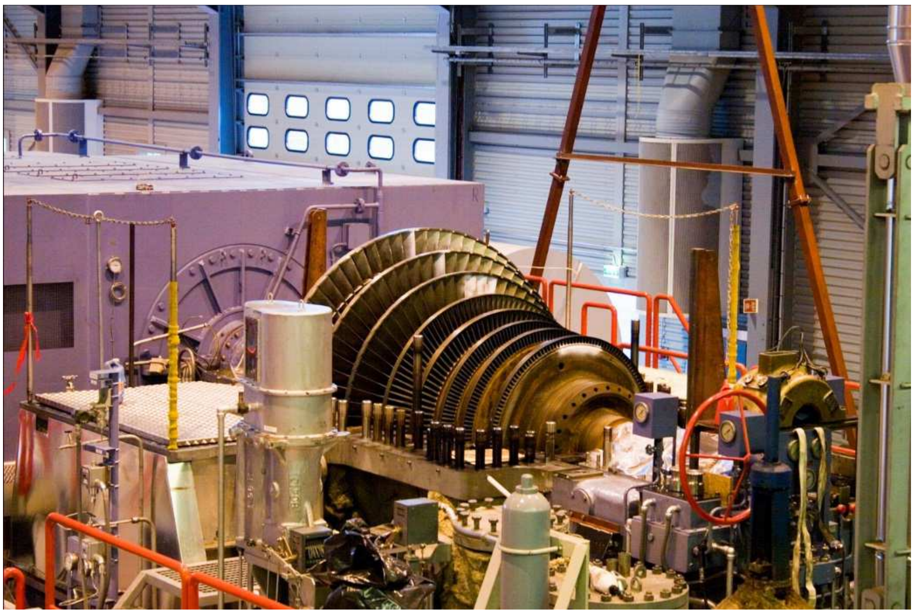


Figure 15 : Picture of the rotor of one of the steam turbines in the power plant of Hellisheidi in Iceland during its construction (© Verkis).

The cooling system

The cooling of the steam at the exit of the turbine is an important factor to improve the efficiency of the turbine. The cooling system of a geothermal power plant includes a condenser, one or several cooling towers, water transmission lines and pumps. Furthermore, it contains auxiliary elements such as the system of extraction of gases, the cooling system of the alternator and the lubrication oil cooling system of the turbine.

The cooling system of a geothermal power plant can use the water or the air. Among the frequent sources of cooling, we count in particular superficial waters (river, lake, sea) and groundwater. The selection of the appropriate technology is often an optimization matter which depends strongly on available resources and on the environmental impact.

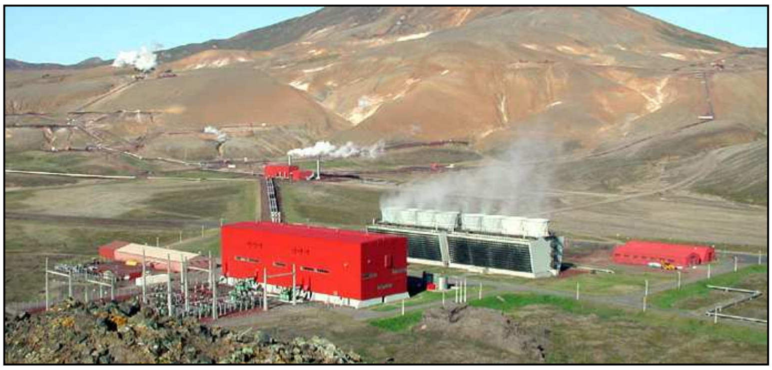


Figure 16 : Cooling towers on the geothermal power plant of Krafla in Iceland with a capacity of 60 MWe (© Verkis).

Electrical equipment and protection

The electric arrangement of a geothermal power plant generally consists of:

- the alternator for the conversion of the mechanical work into electrical energy;
- transformers to adapt the frequency of the current to the same frequency as the electrical grid;
- direct current to feed the system of command;
- controls and protections to make sure that the turbine, the alternator and the other components are protected against overloads the power breakdowns.

Figure 17 : Picture of an electric substation and a room for electrical equipment in the power plant of Pamukören in Turkey (© Verkis).

Reinjection equipments

The reinjection is the ultimate step when running a geothermal resource. Following the process of separation, the liquid phase and the vapor phase are reinjected in dedicated wells. The purpose of the reinjection is to maintain the pressure in the reservoir and to reduce the environmental impact of the power plant.

The wells of reinjection can be specifically drilled to this purpose or they might be low efficiency wells. A separate pipeline network is necessary to insure the reinjection. It is normally made far from the wells of production to avoid short circuits between the zone of production and the zone of reinjection and minimize the risk of temperature dropping in the wells of production.

Although the gravitating flow is usually used to insure the reinjection in a well, the topography and the degree of mixture between the liquid and vapor phases can sometimes impose to use pumping means.

Les forages et les équipements associés : les différents types de puits, les essais et la durée de vie des puits

Fiche n°5

Résumé

Cette fiche décrit les procédures mises en œuvre lors de la conception et de la réalisation de forages géothermiques. Elle tente aussi de répondre aux préoccupations que peut avoir le grand public sur la sécurité et les impacts environnementaux de ces opérations. La production d'électricité géothermique s'est développée de façon importante au cours des cinquante dernières années et l'expertise dans le domaine des forages géothermique est maintenant très importante.

Les puits géothermiques

En général, les premiers puits réalisés dans un nouveau champ géothermique sont des puits d'exploration, c'est-à-dire qu'ils servent à confirmer l'existence d'une ressource géothermique viable. Ils font suite à une phase d'exploration de surface. Les premiers puits d'exploration peuvent être forés en petit diamètre (76-150 mm) jusqu'à 1200 m ou moins. Les puits d'exploration profonds sont semblables aux puits de production et sont forés à des profondeurs de 1500-3000 m. Les puits géothermiques ne sont pas uniquement dédiés à la production, ils peuvent également être utilisés pour la réinjection des fluides.

Le débit et la pression d'un puits dépendent fortement de sa température maximale. Les fluides doivent généralement avoir une température supérieure à 180° C pour pouvoir fournir de la vapeur à une pression supérieure à 6 bars-a, pression d'entrée requise pour les turbines à vapeur. La quantité d'électricité que l'on peut produire à partir d'un puits peut varier de 2 à 15 MW, la moyenne mondiale est d'environ 5 MW.

Les puits sont soit verticaux, soit déviés (fig. 1). Dans le cas des forages déviés, plusieurs puits peuvent être forés à partir d'une même plateforme de forage. Les forages déviés peuvent avoir un déplacement latéral d'environ 1 km ce qui est très utile dans les zones d'accès difficile. Les forages déviés sont très répandus, bien que plus coûteux, car ils permettent notamment de réduire l'impact en termes de surface des plateformes de forage mais aussi des routes d'accès et conduites. Une fois qu'un puits a été foré et équipé la seule partie visible de l'ouvrage reste la « tête de puits », qui comprends plusieurs vannes afin d'assurer l'ouverture et la fermeture du puit. Les puits peuvent être conçus pour durer 40-60 ans.

Environ deux-tiers des puits géothermiques sont déviés, en général à partir de 300-400 m de profondeur. Les forages déviés nécessitent des outils spéciaux (moteur en fond de puits) afin d'augmenter très progressivement l'angle d'inclinaison au cours du forage. Des outils mesurent l'inclinaison et la direction du puits (azimut) et servent à guider le forage directionnel.

Les forages géothermiques

Le forage consiste à broyer la roche et à ramener les déblais à la surface, créant le trou de forage ou puits. L'énergie mécanique est fournie par la double action de la rotation des tiges de forage et dans le même temps, par la pression exercée par l'outil de forage en fond de trou. Le nettoyage du trou est assuré par la circulation d'un fluide de forage. Le fluide de forage est pompé au travers des tiges de forage, puis au travers de l'outil de forage, puis enfin remonte vers la surface via l'espace annulaire entre les tiges de forage et le trou, en entrainant les déblais de forage. Les principales fonctions d'un appareil de forage (rig) sont de lever/abaisser les tiges de forage (100-200 t), d'assurer la rotation des tiges de forage (50 à 80 tr/min) et la circulation du fluide de forage (30-60 L/s). Les appareils de forage possèdent des obturateurs anti- éruption ou «blow-out-preventer » aussi appelés BOP, qui permettent de fermer complètement le puit à n'importe quel moment en cas d'urgence.

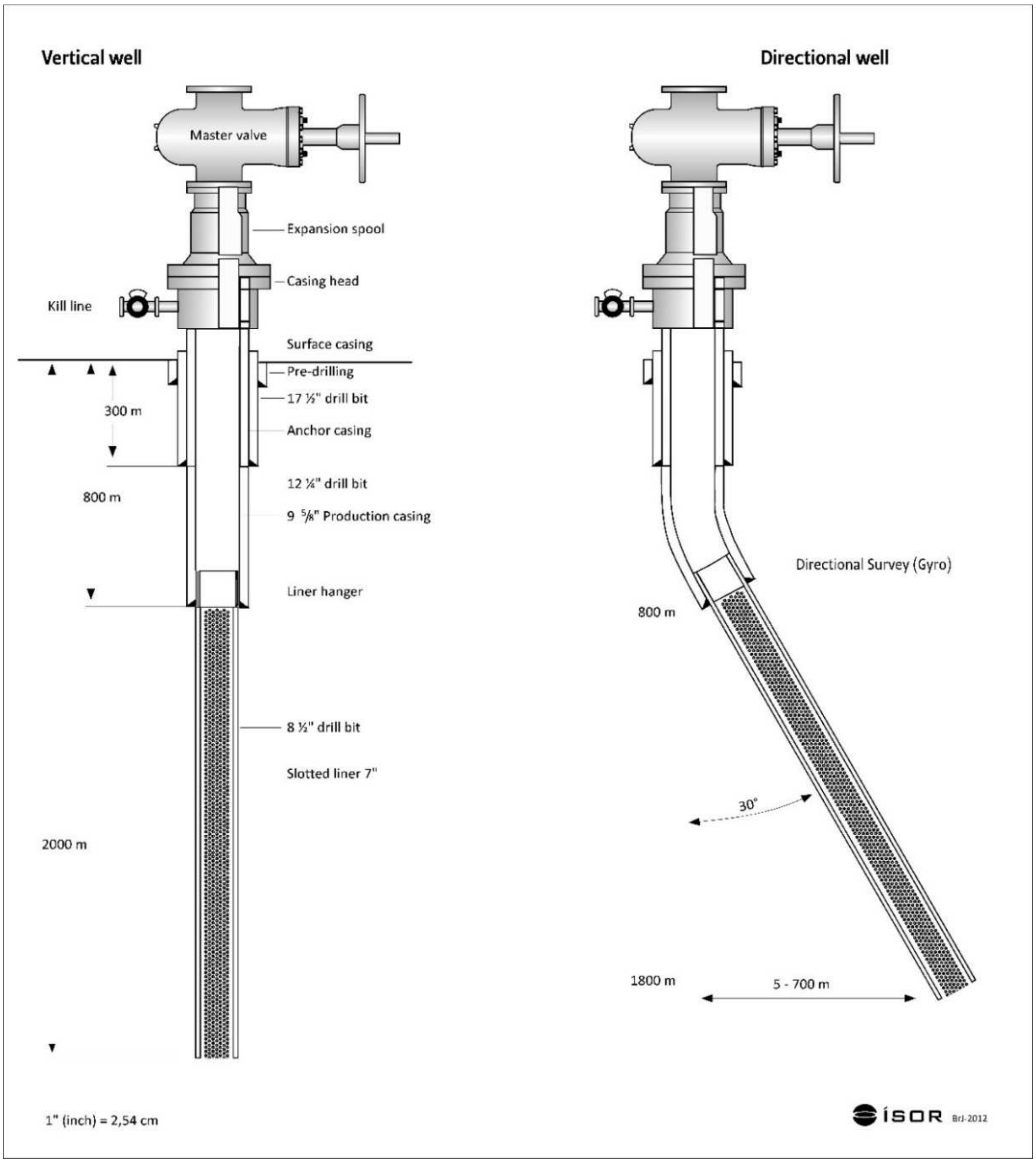


Figure 1. Comparaison entre un puits vertical et un puits dévié. Notez que les tubages sont identiques, seules les trajectoires des forages diffèrent.

Au niveau du réservoir géothermique, le fluide de forage idéal pour évacuer les déblais de forage est l'eau douce. La boue est utilisée lors du forage depuis la surface jusqu'au réservoir. Elle a une viscosité élevée qui facilite l'évacuation des déblais de forage. La boue de forage est obtenue simplement en mélangeant de l'eau avec environ 5 % de bentonite, une argile naturelle. Afin de maintenir les propriétés de la boue, de la soude caustique peut être utilisée pour augmenter le pH du fluide jusqu'à pH 9. Des polymères naturels ou synthétiques peuvent être utilisés pour améliorer la viscosité de la boue. Lorsqu'elle retourne à la surface et après le tamisage des déblais de forage, la boue de forage est recyclée puis pompée à nouveau dans le puits.

Les déchets solides sont composés principalement de fragments de roche et seulement d'une faible quantité de boue de forage. L'ensemble est déposé dans un « bourbier » qui doit être imperméabilisé afin d'éviter l'infiltration de la boue dans la nappe phréatique (fig. 2). Une part importante de la boue de forage peut aussi être perdue dans la formation lorsque des zones perméables sont rencontrées lors du forage. Une opération de forage géothermique nécessite généralement l'accès à des quantités importantes d'eau pour compenser les pertes et assurer le contrôle du puits.

Une des phases les plus importantes pendant une opération de forage est la cimentation de chaque tubage. Le laitier pour la cimentation est un mélange de ciment et d'eau qui est pompé dans l'espace annulaire entre le trou et le tubage en acier. Pour des puits géothermiques, il y a normalement trois tubages emboités et donc trois étapes de cimentation. Une bonne cimentation assure l'isolation des niveaux producteurs et garantit une plus longue durée de vie du puits.

Figure 2. Photo d'un site de forage d'exploration dans le Commonwealth de la Dominique. Au premier plan, le bassin (bourbier) destiné à stocker les boues de forage. Photo : Sigurdur Sveinn Jonsson.

La surveillance et l'enregistrement des données de forage

Une partie importante des opérations de forage consiste à recueillir des informations sur la ressource géothermique. Par exemple les déblais de roches ramenés à la surface sont analysés par un géologue qui identifie les formations géologiques et les différents minéraux qui peuvent renseigner sur la température actuelle ou passée du réservoir. Selon la nature du projet des diagraphies peuvent aussi être réalisées au moyen d'instruments spécialisés, afin notamment d'identifier les formations avant l'installation de chaque tubage. Les paramètres de forages sont également enregistrés au fur et à mesure des opérations de forage. Toutes ces données sont interprétées conjointement afin d'en déduire des informations sur les zones perméables qui contribueront à la réussite du puits et aussi afin d'estimer la température de la formation. Une fois que les données provenant de plusieurs puits ont été collectées et interprétées, des modèles sont construits pour mieux comprendre la ressource géothermique dans son ensemble et fournir un aide à la décision pour la sélection de cibles pour de futurs puits.

Les essais de puits

Bien que des indications sur la capacité de production future d'un puits soient obtenues lors du forage, le succès final ne peut être confirmé que par des essais de puits. De façon simplifiée, ils consistent à mettre le puits en décharge et à mesurer son débit. Un réservoir géothermique contient généralement de l'eau liquide sous haute pression. Cette eau est partiellement vaporisée lors de sa remontée vers la surface. La figure 3 montre une installation typique et l'équipement nécessaire pour des essais de puits.

Au début des essais, des mesures de pression et température sont réalisées dans le puits afin d'obtenir des informations sur les zones perméables et sur la température de la formation. Des mesures des propriétés physiques du réservoir sont également faites et pourront être utilisés plus tard pour la construction d'un modèle du réservoir. Pendant les essais, des échantillons d'eau, de vapeur et de phases gazeuses sont prélevés. Cela permet de connaitre la composition chimique du fluide géothermal et déterminer la quantité de gaz présente.

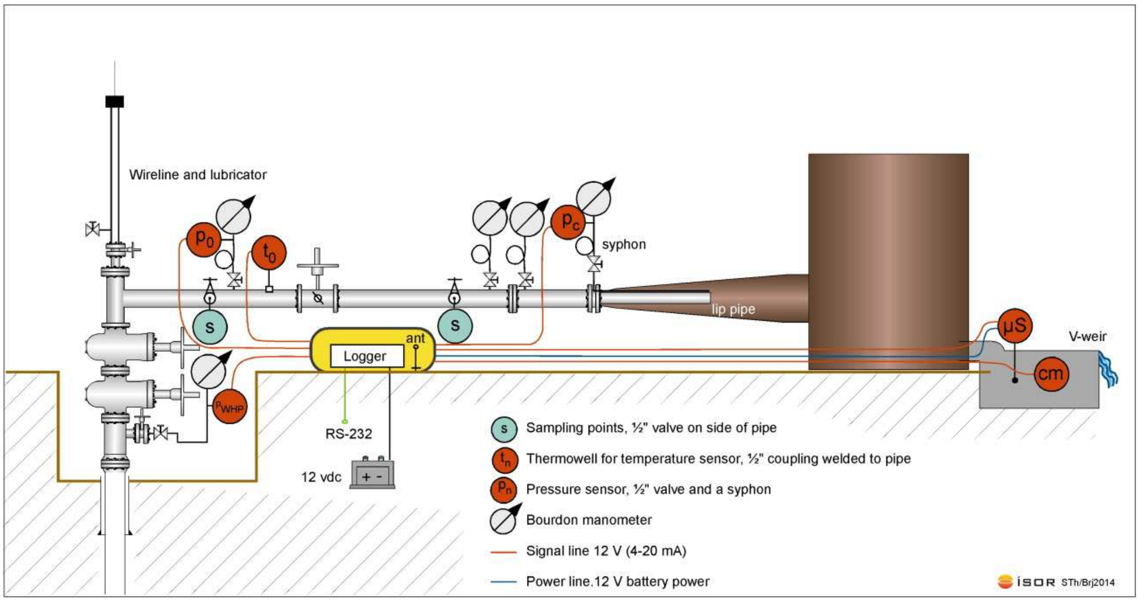


Figure 3. Installation typique d'équipements pour des essais de puit.

Les essais de puits durent environ une semaine (essai à court terme) mais peuvent nécessiter jusqu'à trois semaines pour obtenir des informations plus détaillées sur la ressource (essai à long terme). Ces opérations sont très bruyantes et nécessitent l'utilisation d'un silencieux/séparateur. De grandes quantités d'eau sont produites au cours des essais (100-200 m3/heure), ce qui a pour effet de rapidement remplir le bourbier de la plate-forme de forage (1000-2000 m3). Si les normes environnementales et la composition chimique du fluide le permettent, il peut être rejeté dans le milieu naturel. Lorsque plusieurs puits ont été forés, la réinjection de l'eau peut être une option.

Lors des essais, la phase vapeur s'échappe dans l'atmosphère et forme un panache. Il contient principalement de la vapeur d'eau et des traces de gaz, principalement du dioxyde de carbone et certains gaz comme le sulfure d'hydrogène H2S. L'impact environnemental au niveau des zones éloignées de l'essai est quasiment nul. Au niveau du puits, les personnels sont formés et dotés de détecteurs multi-gaz. Ces précautions font partie des bonnes pratiques de sécurité et ne doivent pas être une source de préoccupation pour le grand public, même si des odeurs peuvent parfois se faire sentir en dehors du chantier de forage, en particulier pour le sulfure d'hydrogène auquel le nez humain est extrêmement sensible.

Des milliers de puits géothermiques, haute température, ont été forés dans le monde entier et l'expérience a montré qu'ils peuvent être réalisés en toute sécurité. Les statistiques sur les résultats des forages géothermiques le montre bien.

The various technologies of turbine used in geothermal science

Sheet n°6

Summary

The turbine is the heart of the geothermal power plant. Various technologies are available and can be selected according to the characteristics of the geothermal fluid. Environmental requirements can also influence the choice of the turbine. This index card quickly presents these various technologies and their main characteristics.

Introduction

The turbine is the heart of the geothermal power plant. It converts the heat energy of the geothermal fluid in electrical energy. The minimal temperature of the geotermal fluids used for the electricity production can in theory be lower than 100 ° C. However, we consider that the projects using fluids under 120°C are not profitable.

Various technologies of turbine are used in geothermal science and are presented here:

- Backpressure turbines;
- Steam turbines;
- ORC turbines;
- Combined cycle gas turbines / ORC.

Backpressure turbine

It is the simplest type of steam turbine (Figure 1). The high-temperature geothermal fluid (> 200 ° C) is vaporized then separated at the level of the separator. The vapor is admitted in the turbine where it pulls the generator to produce some electricity.

The peculiarity of this type of turbine is that the vapor is not condensed at the exit of the turbine. It is expelled by means of a fireplace at the atmospheric pressure. The back pressure units constitute a simple and cheap solution. However, their efficiency is not as optimal as that the condensation turbines because of the low pressure drop through the turbine resulting at the atmospheric pressure at the end.

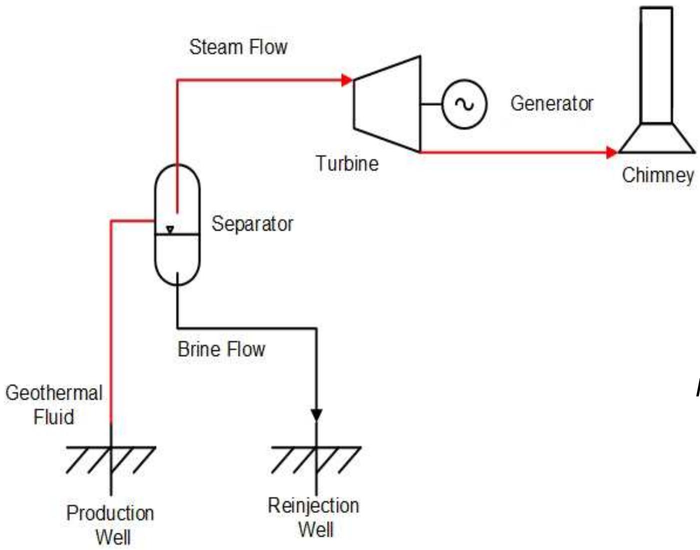


Figure 18 : Principal plan of a backpressure turbine.

Steam turbine

A simplified scheme of a condensed steam turbine is presented in the Figure 2. The process is similar to the one of the back pressure turbines until the exit of the turbine. A system of condensation is added at the exit of the turbine to optimize the extraction of the energy by using a condenser. As mentioned in another index card, the cooling system can vary according to the available cold sources. The system presented here is a condenser with direct cooling connected with cooling towers. In the condenser, the vapor resulting from the turbine is cooled by spraying of water resulting from the cooling tower. The mixture is then redirected towards the cooling tower where a part of the fluid is recycled in the circuit of cooling water and the other part intended to be reinjected.

This type of turbine can be fed by a single flow of vapor. It is then called a simple floor turbine (or simple flash). It can also be fed by two flows of vapor: a flow of high-pressure vapor and a flow of low-pressure vapor for example. We speak then of a double floor turbine (or double flash).

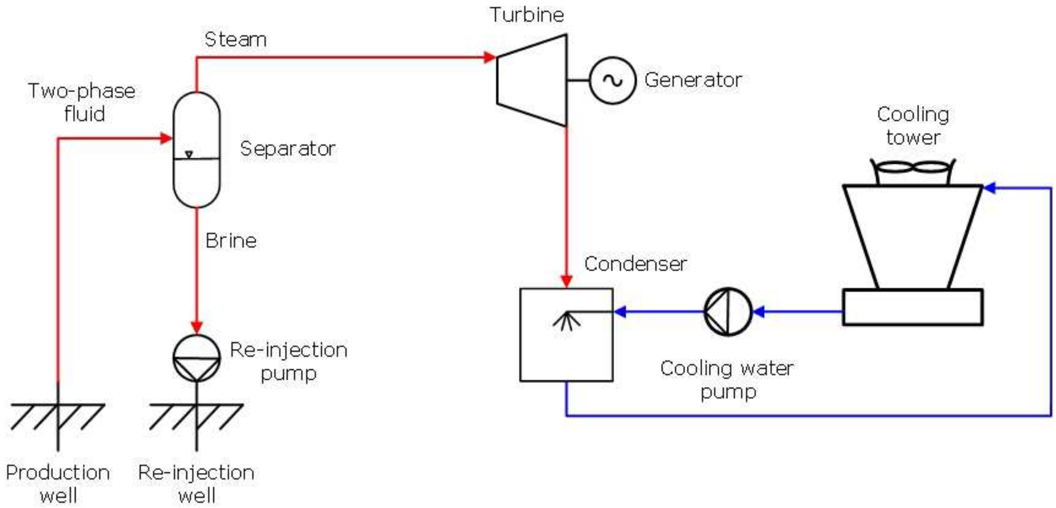


Figure 19 : Main scheme of a condensed steam turbine.

Figure 20 : The geothermal power plant of Krafla in Iceland (60 MWe) equipped with a steam turbine with double flash (© Verkis).

ORC turbine (or binary cycle turbine)

In the geothermal fields where the geothermal fluid is at a temperature between 120 and 220 ° C, it is currently economically viable to use the Organic Rankine Cycle (ORC). In theory, ORC turbine can exploit fluid in much lower temperatures but for very low power levels and without profitability. The principal plan of an ORC turbine is presented in the Figure 4. The geothermal fluid is used to exchange its heat with a secondary organic fluid (isopentane, isobutane, R134a) having a boiling point lower than water, which is the working fluid.

The working fluid in liquid phase is pre-warmed at first then vaporized and then sent towards the turbine. At the exit of turbine, it is managed towards a condenser cooled by air where it is condensed to liquid form. The cycle can then restart.

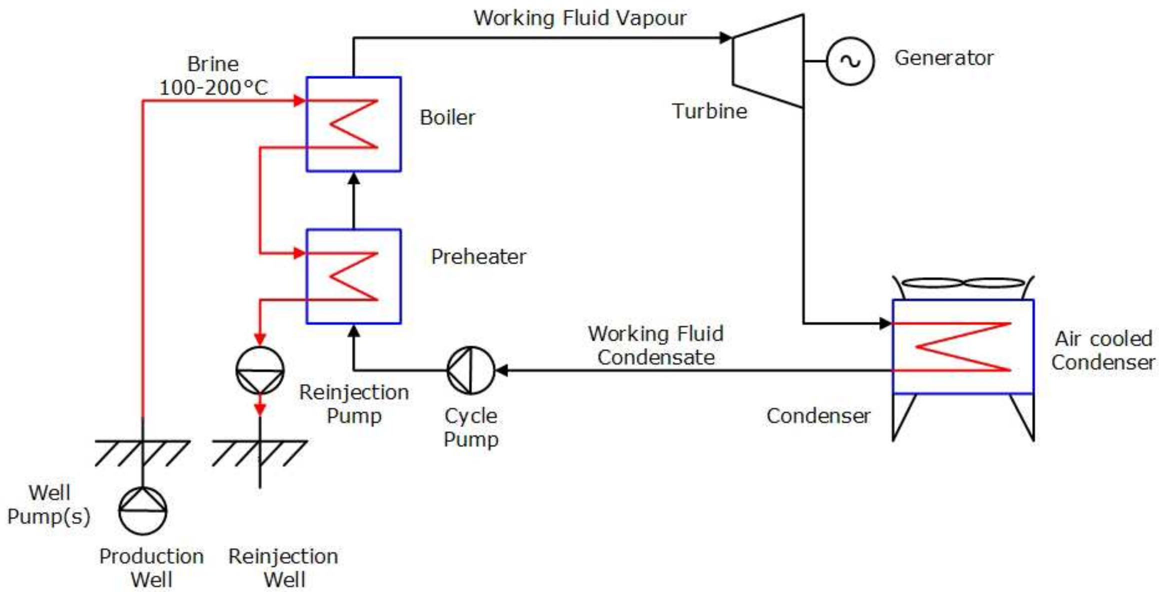


Figure 21 : Principal plan of an ORC turbine.

Figure 22 : Sight of the geothermal power plant of Pamukören in Turkey equipped with two ORC turbines of 25 MWe atlas Copco Energas (© Verkis). To the left, we distinguish the drum kits of ventilators for the cooling by air.

Combined cycle gas turbines

The combined cycle is the combination of several types of turbines. It allows to extract better the energy of the geothermal resource and so to optimize the thermodynamic cycle. It can also avoid the implementation of a system of capture of gases having a high capital cost. A main plan of such cycle is illustrated on the Figure 6 and an example of power plant of this type is given in the Figure 7. In this example, the first cycle is a backpressure turbine. It uses the vapor and the incondensable gases of a first stage of high-pressure separation. The latter are then expelled in the atmosphere via a fireplace. This first cycle was set up to eliminate gases directly and so avoid cost of investments associated to the implementation of a system of capture of gases. The second cycle is a steam turbine condensed with a condenser with direct cooling. The vapor is separated at a pressure lower than in the high-pressure initial stage. Finally, the third cycle is an ORC turbine which uses the liquid phase resulting from the second stage of separation.

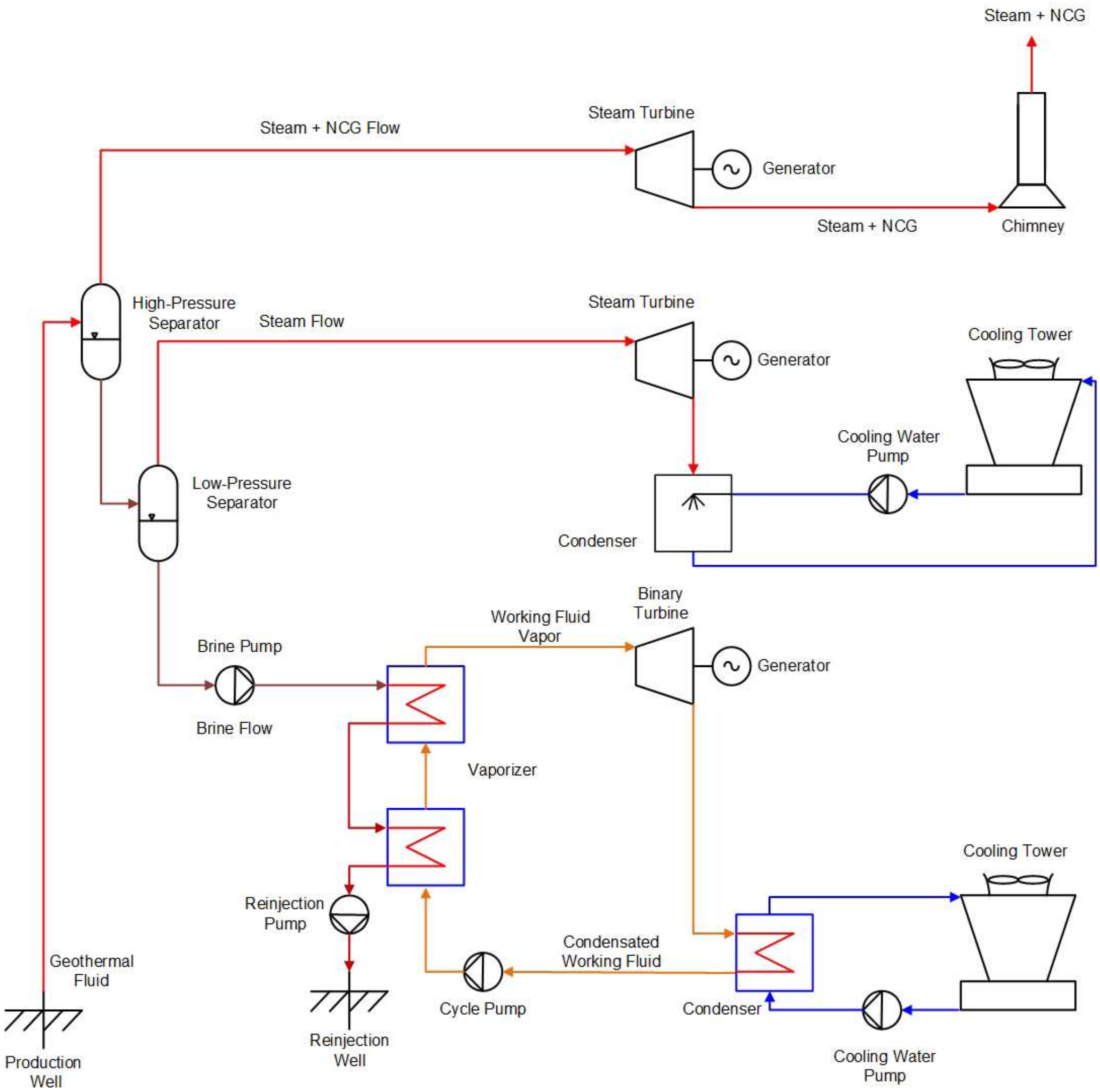


Figure 23 : Main scheme of a combined cycle (© Verkis).

Figure 24 : Photography of the power plant from Berlin to Salvador equipped with a combined cycle powered by 109 MWe (© Verkis).

Notion of thermal efficiency of turbines used in geothermal science

The thermal efficiency of a turbine *η* is defined as the net electric production of the turbine W_{net} divided by the energy supplied to the system by the geothermal fluid Q*in*:

$$\eta_{cycle} = \frac{W_{net}}{Q_{in}} \cdot 100$$

The energy in the form of heat is defined as :

$$Q_{in} = \dot{m} \cdot (h_{in} - h_{out})$$

Where h is the enthalpy of the geothermal fluid at the entrance and at the exit from cycle respectively.

The thermal efficiency of steam turbines condensed is about 12 to 18 % while it is generally from 7 to 12 % for ORC turbines.

Besides, the thermal efficiency of the turbine increases with the temperature of the resource and with the size of the turbine.

The different cooling systems of geothermic power stations

File No.7

Summary

The optimal functioning of the turbines used in geothermics requires a cold source to condense the steam coming out of the turbine and thus improve the thermodynamic yield. This constraint can have repercussions on the environmental impacts generated by a power station. This sheet quickly presents the different cooling systems currently used and shows the benefits and drawbacks of each system.

Introduction.

The cooling and the water vapour condensation at the evacuation of a turbine is a primordial factor when it is a question of maximizing yield. The aim is to obtain a low pressure in the condenser known as barometric (inferior to the atmosphere's pressure) so that the steam from the turbine is "sucked up" and *in fine* generates more power. There are 3 main cooling systems:

- the cooling water systems
- the cooling air systems
- the hybrid systems

Generally, the systems cooled with water are considered like the most efficient in regions, where the climate is temperate to warm. Indeed, during hot summer days, the efficiency of an air cooling are limited, because of the ambient high temperature. Moreover, the cooling water systems are generally cheaper and require less maintenance than those cooled with air. Nevertheless, they require an access to a regular quantity of cold water, which is not always possible.

The cooling water systems.

As their name suggests, these systems require an access to a cold water source. There are two options for the configuration of a cooling water system:

- the direct cooling
- the cooling tower

Both of these cooling systems require a condenser that can be:

- a direct contact condenser
- an exchanger condenser.

The direct contact condenser is a tank in which there is a mix between the steam and the cooling water. The exchanger condenser is closed and there is no direct contact between the steam and the cooling fluid. The direct contact condenser is a lot cheaper. For an ORC type turbine, the exchanger condenser is the only option because there cannot be any direct contact between the working fluid and its environment.

The direct cooling.

In a direct cooling system, the water from a river/ lake/ sea is sent to the condenser to condense the steam before being sent back to the river/ lake/ sea. It is a very efficient cooling system and it is less expensive, because the only things to buy are the pumps and the pipes. However, with this system, the power station has to be next to the cooling source considering that the pumping power for such big water quantities can be high. As a result, the net electric production capacity of the power station is reduced. With this direct cooling system, the condenser effluents, usually at 104°F (40°C) to 122°F (50°C), must be released in a natural environment on the surface or in a river or a sea, which is not always possible on an environmental point of view.

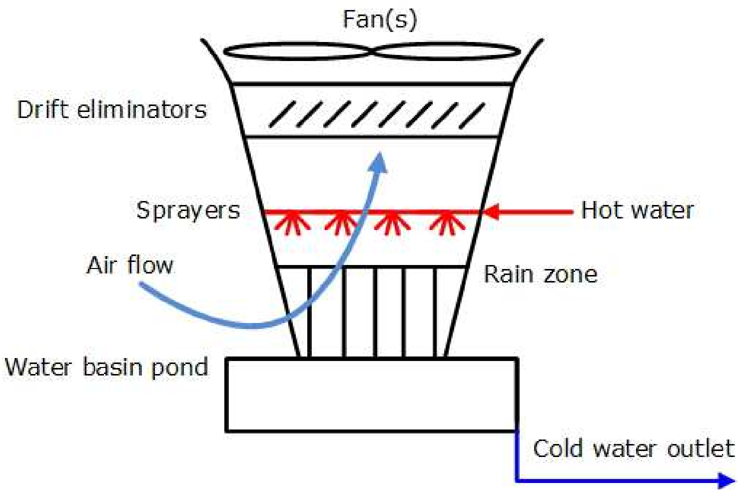


Figure 1: Plan showing how a cooling tower with mechanical induced draft works.

The cooling tower.

The use of cooling towers is the most common method for classic geothermic power stations. Three types of towers exist, depending on the air flow going through the system:

- water cooled towers with mechanical induced draft
- inverse flow towers
- cooling towers with natural or forced draft

In the cooling tower, the hot water from the condenser is sprayed on a surface conceived to increase the exchange surface for the water droplets as they fall. In the case of a tower with mechanical induced draft, the water is sucked up through the tower via a fan system at the top of the tower (Figure 1).

In a tower with natural draft, the movement of the air is naturally created, because its density decreases when it warms up. The cooling towers with natural draft are rarely considered for geothermic power stations, because they are adapted to power stations with a big capacity. A cooling tower with forced natural draft has a fan at the entrance of the tower. It is less efficient than a tower with mechanical induced draft. Thus, it is generally considered when there are maximal height constraints. The cooling water towers with mechanical induced draft are the most common in geothermic power stations.

Cooling towers require an access to a water source, because of the net losses in the circuit, due to the evaporation at the top of the tower. Make-up water can be steam condensates from the factory or surface water.

The size of the tower is proportional to the cooling needs. However, the wet-bulb[*] temperature influences considerably the efficiency of the tower to cool the warm effluents from the condenser. As a consequence, for a same need of cooling, a cooling tower with a low wet-bulb temperature will be a lot smaller than a tower with a high wet-bulb temperature.

[*]The temperature of the wet-bulb is a parameter that depends on the relative humidity of the air and of the ambient temperature. It measures the quantity of water vapor (humidity) that the air can absorb with a given temperature. A low wet-bulb temperature means that the ambient air is dry and can absorb more water steam (humidity) than at a high wet-bulb temperature.

The use of cooling towers can also require appropriate measures such as the filtration of the make-up water and a chemical treatment of the cooling water to fight against the growth of seaweeds and clogging. Finally, other preoccupations can include environmental issues such as visible plumes.

Figure 2: Inverse flow cooling tower at the geothermic power stations in Krafla in Island. (60 MWe) (©Verkis).

The condenser.

The steam debit coming from the evacuation of the turbine penetrates in the condenser where it condenses into liquid water. As the temperature in the condenser diminishes, the pressure also decreases, which increases the power generated in the turbine. The cooling in the condenser is therefore very important during the conception of a geothermic power station. There are two types of condensers in power stations using a cooling water system:

- direct contact condenser
- exchanger condenser

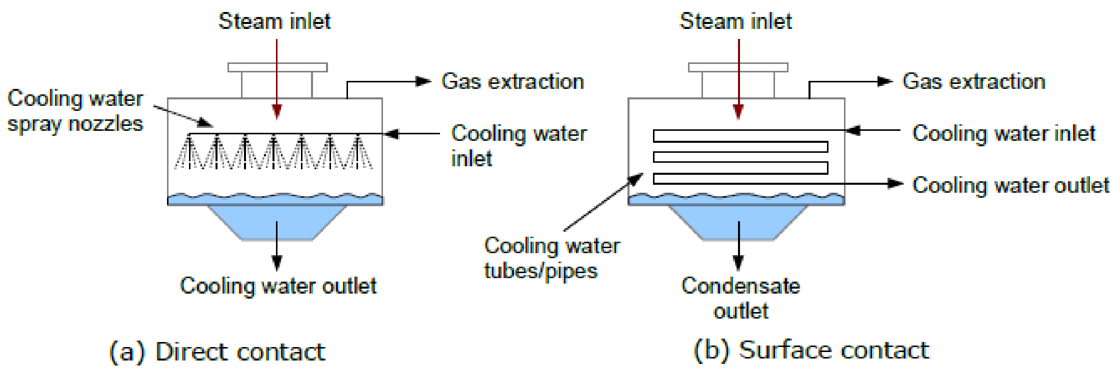


Figure 3: Plan showing how direct contact condensers and exchange condensers work.

The direct contact condenser is only usable for a steam turbine. In that type of condenser, the steam is mixed directly with cooling water, as it is shown in the plan on figure 3. The mixture is then directed to the cooling tower or directly to a natural environment. The size of the condenser depends on the cooling need.

Technology	***Benefits***	***Drawbacks***
Direct cooling	Efficient means of cooling.	The rejection of hot effluents can affect natural environment.

		The power of pumping can be high.
Cooling tower	Can be used where there is an abundance of water. Technology proven with many references. Efficient means of cooling.	Visible steam plumes. Development of seaweeds requiring treatments. Reduced efficiency during hot summer days (even though more efficient than air systems). Proliferation of bacteria such as legionella. Noise of the fans.
Air cooled condenser.	Efficient if cold climate. Can be used everywhere. No visible steam plumes.	Not very efficient in tropical climate. Reduced efficiency during hot summer days. Big exchange surfaces required. Noise of the fans.

Table 1: comparison of the different cooling systems used in geothermic power stations.

The air cooling systems.

The air cooling systems are often used for power stations where there is little or no water available. All the steam condensates are collected and can be reinjected.

The air cooling systems are more efficient than water cooling systems, when the temperature is close to zero. Conversely, for high temperatures, the water cooling is a more efficient option. Moreover, the air cooling requires a lot bigger surface than the water cooling and consumes a lot more electricity for the fan system. This translates into high investment costs. The complexity of the fan system also needs more frequent maintenance.

The following plan shows how an ORC type geothermic turbine with an air condenser works. The air cooling systems are widely used for this type of geothermic power stations.

The hybrid cooling systems.

The hybrid cooling system is not much different to a classic cooling water system, because it also includes a condenser and a cooling tower. The difference is that there is a dry part in the cooling tower, called hybrid.

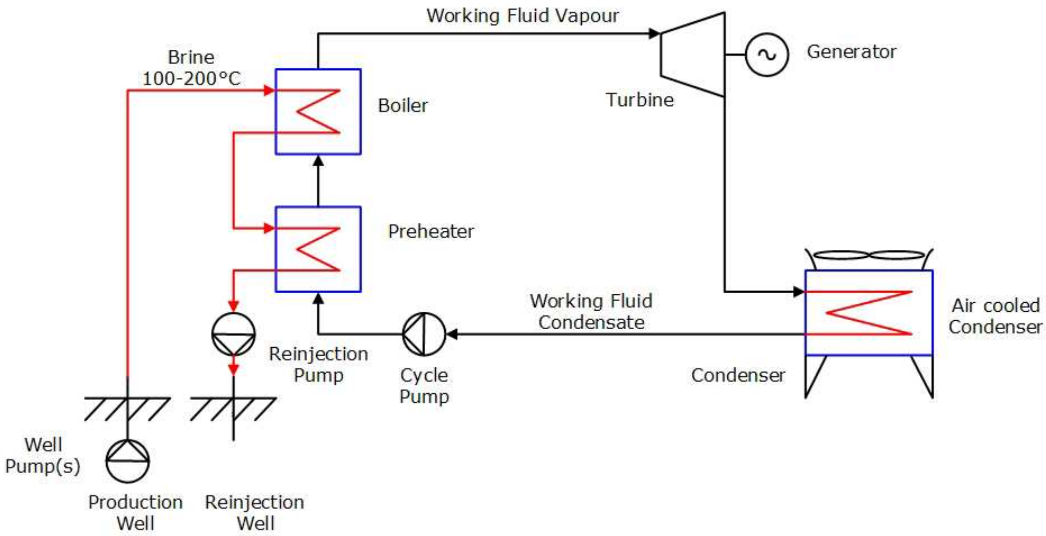


Figure 5: Plan showing how an ORC type turbine using a cooling air system works.

The effluents to cool circulate first through a cooling air system, which lowers their temperature before they go through the cooling tower. As a part of the heat has been evacuated in the dry part of the tower, less water is evaporated in the tower. Nevertheless this requires an extra fan to feed the dry part with air.

The decrease of the steam plume is currently the main justification for hybrid cooling systems. Indeed, the steam plume of the cooling towers is considered like a visual pollution. Several regulation organisms in the world demand that the power stations close or in towns do not produce steam plumes.

The use of a hybrid cooling tower can also be considered to limit the needs in cooling water.

Figure 4: Cooling air system in the power station of Pamukören in Turkey. (ORC type turbine 2x25 MWe of Design Atlas Copco Energas ; ©Verkis).

The management of geothermal resources (production, reinjection) and its renewable characteristic

File No.8

Summary

Geothermic is rightly considered like a renewable source of energy. However, this statement requests that certain sustainable management rules have to be put into practise when it is used, so that it real has this renewable side, which can be seen like an excellent environmental criteria. This sheet illustrates the general approach that can be put into practise.

Introduction.

The production capacity of hydrothermal systems, whether the heat is directly used or used for electricity production, is mainly controlled by the drop of the pressure in the reservoir caused by the extraction of fluids. This pressure drop is determined by the size of the geothermic reservoir, its permeability, its storage capacity, its water charge and its geological structure. More generally, the capacity of geothermic systems is also controlled by their energetic value, driven by the temperature conditions and their size.

The hydrothermal systems can, in most cases, be classified as "closed", with a limited natural charge or no charge at all, or as "open", when the natural charge balances out with the fluid extraction on the long term. The sedimentary geothermic systems give good examples of the first type whereas the volcanic systems tectonically active are good examples of the second type.

The production capacity of energy of hydrothermal systems is extremely variable and it is difficult to value it precisely before production facts are gathered. Moreover, the geothermic reservoirs often have performances that are complicated to predict in the long run. Indeed the nature and the cleanness of the reservoir are generally not well determined and can only be directly observed.

Figure 1: Used equipment during the measure of the pressure and the temperature in a geothermic well in the field Bouillant in Guadeloupe.

Evaluation method of the capacity of a geothermic reservoir.

The production capacity of geothermic systems can be valued by different evaluation methods, including the volumetric method that comes from mineral, oil and gas industries. In the case of geothermic resources, this method simply involves evaluating the energy contained in a reservoir volume and evaluating which quantity can be extracted and used in a given period of time. It is a static method.

The establishment of a dynamic model of the geothermic systems is more precise than the establishment of a static model, because it takes in count the dynamic response of the reservoir (for example the pressure drop), as well as its structure and its nature. The establishment of a detailed digital model is in theory the most precise method of establishment of a dynamic model, but it requires to have reliable knowledge of all the system's parameters. To be reliable, all the geothermic system models, whether they are static or dynamic, should be based on a precise conceptual model of the corresponding system.

The establishment of a dynamic model plays a key role in the comprehension of the nature of geothermic systems. It also constitutes the strongest tool to predict their response to future production scenarios. Reliable models are also an essential element for a good management of geothermic resources when they are functioning.

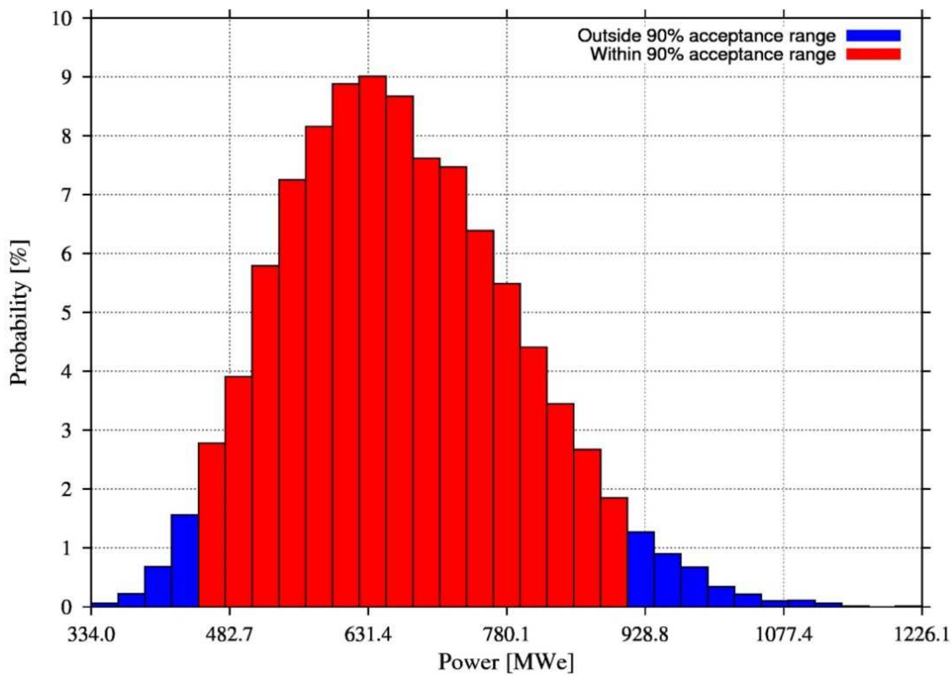


Figure 2: An example of a volumetric evaluation result of a geothermic system; the Monte Carlo method is used to obtain a probability distribution of the results, based on the uncertainty of the input parameters.

The management of the geothermal resource.

The use of geothermic energy consists in extracting the energy from the complex underground reservoirs. A complete and efficient management of this resource is an essential element for the success of geothermic projects. It implies for example controlling properly the energy extraction so that it does not cause the overexploitation of the resource and other unwanted effects. The management consists in choosing between different strategies, either maintaining an existing production strategy or choosing between several future production scenarios, considering reservoir conditions. Operators of a geothermic resource must be able to take these decisions and have an idea of the possible results of each different strategy. Thus, a good management of geothermic resources relies firstly on a good comprehension of the system.

The information concerning the nature and the attributes of a geothermic reservoir are obtained thanks to a considerate follow-up of its response on the long run (during years even decades) during its exploitation. The direct measures include mainly the fluid debits, as well as the changes of pressure and temperature in the reservoir. The changes in the chemical composition of the geothermal fluid must also be watched. The indirect measures include the surveillance of changes in the reservoir via different observation methods on the surface: measures of ground movement, of microgravity, micro-seismic surveillance… These measures also supply key facts for the establishment of digital models of reservoirs, which are an essential management tool.

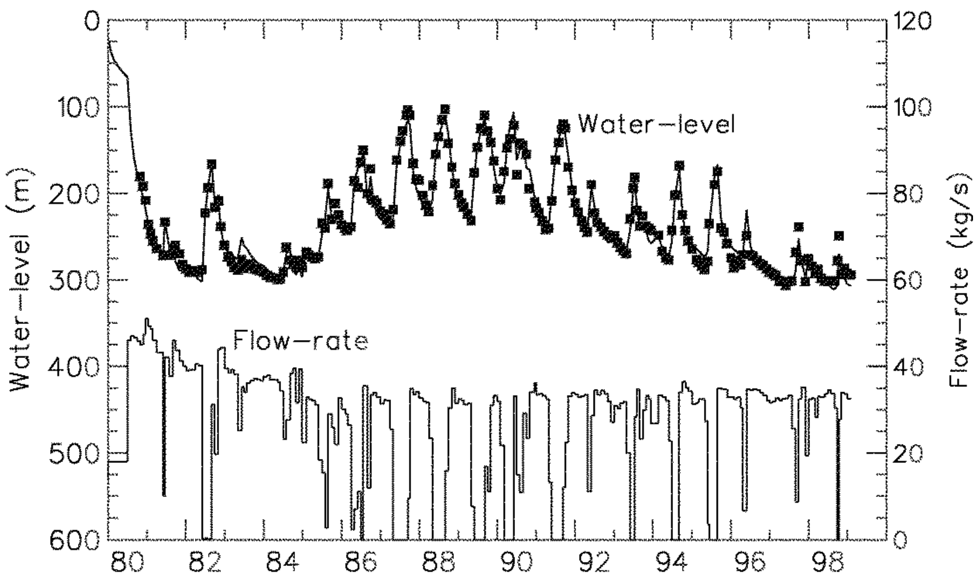


Figure 3: The pressure variation of the reservoir (measured in terms of wter level) in a geothermic system in Island, precisely simulated with a parametric model; black squares = facts, full lines = results of the model.

Even if geothermic is considered like a clean and renewable source of energy, its development has environmental and social impacts that must be taken in count in the resource management. Indeed, there are visible surface changes, that is to say that they affect the landscapes and the natural characteristics, such as the changes in the thermal activity. Different solutions to minimize the impacts exist. Of all these solutions, the reinjection is probably one of the most beneficial solutions. Apart from obvious environmental benefits, the reinjection also allows to maintain the pressure of the reservoir by completing the natural charge. When it is well managed, the reinjection increases the production potential of the geothermal resource, especially for closed systems.

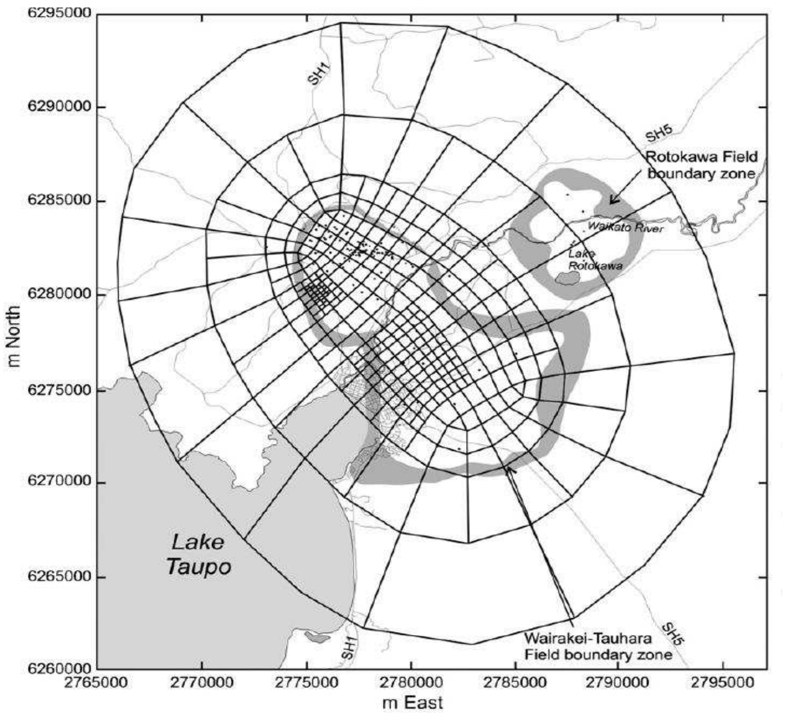


Figure 4: the horizontal grid of a digital model of a high enthalpy geothermic system.

Sustainable development.

Sustainable development consists in meeting the needs of the present without compromising the ability of future generations to meet their own needs. The geothermic resources of the earth have the potential to contribute significantly to a sustainable use of energy, in order to help reduce climate changes. The experience of the use of geothermic systems worldwide during several decades shows that the exploitation can strike a balance between charge and the energy production that can be maintained during a long period of time. Consequently, a time scale of sustainable development for geothermic use, of 100 to 300 years, is possible.

Moreover, studies show that the exploitation impacts are often reversible on a scale of time similar to the use period. Geothermic resources can be used sustainably via (1) a constant exploitation above a sustainable threshold, (2) an increase of the production by stages and (3) a cyclic use including production periods exceeding the sustainable limit alternating with recuperation periods, during which other geothermic resources must be put to contribution to fill empty spaces.

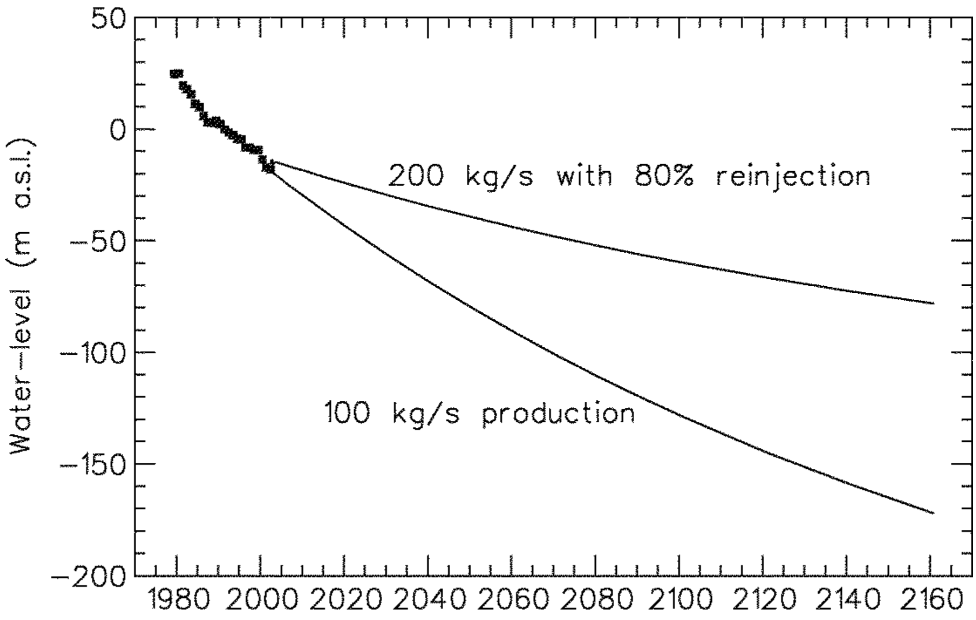


Figure 5: Results of an evaluation on the sustainability of the exploitation of geothermic resources in Beijing, China, with a prediction of pressure conditions in the reservoir for a 200 year period.

The formulation of an environmental politic consists in fixing general aims of sustainable development and consequently defining precise indicators to measure the degree of sustainability of a geothermic exploitation.

The societal acceptability, particularly by the local communities, is also an important condition for the good application and management of projects using geothermic. Direct applications of geothermic meet little social contradictions because of their evident social benefits. To recap, the three main conditions to obtain the societal acceptability are the minimization of environmental impacts, the prevention of harmful effects for the population's health and the creation of tangible benefits for the local population.

Geothermal energy and the health / safety of personnel

File No.9

Summary

Like any industrial facility, a geothermal plant poses risks to the health and safety of personnel who are responsible for its operation and maintenance. Mastering these risks should therefore be seen as part of a process of environmental excellence.

The purpose of this document is to succinctly present the nature of these risks, the regulatory aspects and finally a list of good practices to be implemented in order to reduce risks.

Nature of risks to health / personal safety

Most of the risks to personal health / safety posed by a geothermal system are the classic risks which are similar to those presented by any site or industrial facility including:

- risks related to the operation of rotating machines;
- risks related to pressure vessels;
- the risks associated with electrical equipment;
- the risks associated with the movement of machines;
- risks associated with the handling of chemicals;
- the risks of working in confined spaces;
- the risks of heat and high temperatures;
- risks related to air pollution;
- risks related to noise;
- etc. ...

It should be considered that some of these risks are more specifically present at the realization of geothermal projects (drilling site, plant operation) and can potentially affect health and personal safety:

- risks related to gas emissions and especially H2S, hydrogen sulphide;
- the risks of working in confined spaces;
- risks related to heat;
- risks related to noise.

It is important to fully understand the risks related to the exposure of H2S gas as it is one of the main characteristics of geothermal energy and the risks to personal health and safety are potentially high. Exposure to H2S gas emissions are caused by the accidental release of fluid during drilling, by the discharge of geothermal fluid, during production testing, during transient operating phases, during the failure of pipes during maintenance, during activities in confined spaces such as basement wells, condensers and separator balloons... They may also be present when the geothermal fluid is released into the natural environment. Table 1 summarizes the toxicological effects of H2S on the human body.

A geothermal plant has many confined spaces (balloons, condensers, well cellars and turbine cooling towers) that constitute hazardous areas for personnel during maintenance work.

Heat and high temperature conditions constitute to an omnipresent risk, especially in the case of accidental fluid leaks. Noise sources are numerous during drilling and they are also present at the operation close to the turbine.

H2S content in the atmosphere	***Expected toxicological effects***
0,13 ppm	Olfactory threshold
4,6 ppm	Perceptible odour
10 ppm	Eye irritation threshold
27 ppm	Strong unpleasant smell
100 ppm	Irritation of the ocular and respiratory mucous membranes
200-300 ppm	Inflammation of the eyes (conjunctivitis) and inflammation of the respiratory mucosa, loss of smell
500-700 ppm	Unconsciousness, risk of death after 30 minutes - 1 hour
700-1000 ppm	Rapid loss of consciousness, difficulty breathing resulting in death shortly
1000-2000 ppm	Rapid loss of consciousness with respiratory arrest, resulting in death in minutes

ppm: parts per million

Table 1: Summary table of the expected toxicological effects of hydrogen sulphide H2S on humans (Labour Department of New Zealand).

Regulations concerning personnel health and safety

Most countries have legislations and / or the Labour Code (Occupational Safety and Health Act) which regulate the aspects of health and safety in industrial plants and are extended in geothermal installations.

In France, geothermal energy is regarded as a mineral resource and it is the Mining Code and the **General Regulations of Mining** (*Règlement Général des Industries extractives* (RGIE)) which regulate the conditions of working in a geothermal plant. They harmonise with the Labour Code and the laws of environment. The basic document is the **Health and Safety File** (*Dossier de Santé et de Sécurité* (DSS)) which is the equivalent of the single document imposed by the Labour Code. The development of the DSS approach is described on Figure 1. Its objectives are:

- The **determination and the assessment of risks** to which personnel are likely to be exposed;
- The **identification of necessary measures** in the design, use and maintenance of workplaces and equipment, to ensure personnel health and safety.

The Health and Safety File can correlate to the **Safety Management System** (SMS) implemented abroad and that usually has two parts: a Safety manual and the Emergency response manual.

Whatever type of document or country concerned, the development of these documents has a similar approach and generally follows these four steps:

1. Identification of risks;

2. Elaboration of prevention measures;

3. Setting up a risk management plan;

4. Setting up a control and monitoring plan.

1. Implication of all staff

⇓

2. Collect relevant information on the site

⇓

3. Identification of work functions

⇓

4. Identification of hazards and risks

⇓

5. Evaluation and risk prioritisation

⇓

6. Identification of prevention measures

⇓

7. Constitution of the Health and Safety File

⇓

8. Constitution and monitoring of the Security and Action Plan

Figure 25 : Elaboration of the Health and Safety file

Several countries with a geothermal industry and international organizations financing geothermal projects have published guides on these personnel health and safety aspects in the field of geothermal plants used to generate electricity that can serve as references:

- Environmental, health and safety guidelines for the production of geothermal electricity. International Finance Corporation, World Bank, 2007;
- Revised geothermal safety and health rules and regulation & Code of Practices. Philippines Department of Energy. Department circular 2000-02-001, 2003;
- Developing a safety management system SMS for a petroleum and geothermal energy operation - guide. Government of Western Australia Department of Mines and Petroleum Resources safety, 2012.

Focus on the prevention of risks related to hydrogen sulphide

In France, there are no specific regulations concerning the prevention of risks related to the exposure to hydrogen sulphide for staff working in geothermal installations. Regarding risk prevention related to H2S for the appropriate industry, the requirements of the Labour Code apply. They set average values and exposure limits:

⇒ The **Exposure Limit Value** (*Valeur Limite d'Exposition* (VLE)) is a maximum value measured for a maximum of 15 minutes in an atmosphere containing hydrogen sulphide, to prevent the immediate toxic effects or short-term effects. It is set at 10 ppm (equal to 14 mg / m3);

⇒ The **Average Exposure Value** (*Valeur Moyenne d'Exposition* (VME)) is measured or estimated on the duration of an 8 hour work shift. It is intended to protect workers from long-term effects. The VME can be exceeded for short periods, provided they do not exceed the VLE. The VME is 5 ppm (equal to 7 mg / m3).

For information, there are also regulations regarding chronic exposure to hydrogen sulphide which apply outside the geothermal plants and concern the population likely to permanently live in an environment exposed to diffused emissions of H2S gas. These regulations are based on **Toxicological Reference Values** (*Valeurs Toxicologiques de Référence* (VTR)). In France, due to a lack of regulatory values, are generally used VTRs which are defined by foreign organisations, including American organisations (Table 2).

Table 2: Toxicological reference values (VTR) regarding chronic exposure to hydrogen sulphide defined by two American organisations

Prescriber organisation	***Toxicological Reference Values***		
	µg/m³	***ppb***	***ppm***
US-EPA (2003)	2	1,4	0,0014
OEHHA (2008)	10	7	0,007

Implementation of preventive measures and risk reduction

The application of preventive measures and risk reduction for the health and safety of personnel is done through the implementation of the Action Plan of the Health and Safety Document (France) or the risk management plan.

For information, a number of good practices are summarized below.

Personnel protection measures

- Mandatory wearing of personal safety equipment (helmet, goggles, gloves, H2S sensor if working in a risk area, ...);
- Delimitation and signalling areas at risk and by the nature of the risks;
- Appropriate signage to the nature of the risks;
- Organization of patrols of two people in potentially dangerous areas or at night, or the use of a lone worker alert system;
- Installation of H2S sensors fixed in the exposed areas;
- Regular verification of equipment (lifting, pressure balloons ...) by inspection

bodies.

Preparation measures for emergency situations

- Regular organization of evacuation drills;
- Staff first-aid training;
- Providing medicine cabinets in workshops and other buildings concerned;
- Installation of fire plans in conjunction wih the fire department.

Personnel training measures

- Internal staff training course on possible risks;
- Implementation of authorisation plans and work permits for the personnel, depending on the areas of intervention.

Organisational measures

- Updating emergency procedures;
- Updating response procedures in areas at risk;
- Cataloguing of common safety guidelines and procedures;
- Cataloguing of Safety Data Sheets of the products used;
- Display of "good practices";

Example of instructions regarding the exposure to hydrogen sulphide

- To be provided with a portable H2S detector in working order and calibrated;
- To stay out of the danger zone when the emission alarm is reporting a higher H2S content TLV (10 ppm)
- Not to stay 8 hours continuously in a zone where the H2S content is higher than 5 ppm.
- Not to lean over the basins where the H2S content at the surface of the water may reach or exceed 50 ppm.

Regulations applicable to geothermal projects

File No.10

Summary

Like any industrial project, the construction of a geothermal power plant project for the production of electricity is governed by different regulations. First and since it is a mining resource, it is subject to the Mining Code. It can also be framed by the other regulations such as the Environmental Code, the Town Planning Code and the Energy Code. Finally, it must be in compliance with the existing territory planning documents, including those related to protected natural areas. This form summarizes the main regulations that apply in France and which generally have their counterparts abroad.

The Mining Code

In France, as in many countries, geothermal falls within the Mining Code. It therefore requires the authorisations granted by the State. Decree No.78-498, March 28th, 1978, specifies the procedures for the exploration and exploitation of geothermal deposits. It distinguishes geothermal deposits according to their temperature:

- High temperature deposits (over 150°C)
- Low temperature deposits (less than 150°C)
- Low temperature deposits and minor constituents (less than 100 meters deep and within 200 therms per hour)

Only high temperature deposits (>150°C) interest us in the context of this guide. The Mining Code distinguishes between three types of activities, research (or exploration), operation and execution of exploration and exploitation work (see Table 1.). Regarding ***research***, the Research Exclusive License (PER) is entitled to explore geothermal resource and provides a privileged right to the holder to exploit the resource that it identifies. Regarding ***operation***, Concession entitles the holder to exploit the geothermal resource. In the overseas departments, geothermal deposits can also be operated under an operating license. The procedures to obtain these **mining claims** are governed by Decree No.2006-648, June 2nd, 2006.

Table 1: A summary of regulations that apply to high temperature geothermal deposits (>150°C) used for the production of electricity in France under the Mining Code.

Relevant activities	*Mining claims / Authorisation*	*Validity period*	*Regulations*	*Issuance*
Research / Exploration	PER Research Exclusive Licence	5 years + 5 years	Decree No 2006-648, 2nd of June, 2006	Ministerial decree
Operation	Concession	50 years		Ministerial decree
	Operation Permit (overseas departments)	5 years + 5 years + 5 years		Ministerial decree
Execution of exploration and exploitation work	DAOTM Authorisation to open the exploration and exploitation work Application	Duration of work	Decree No 2006-649, 2nd of June, 2006	Prefectoral decree

Parallel to the granting of these mining titles, The Mining Code provides a procedure for the ***execution of exploration and development work***, which is aimed at protecting the environment, people (workers and third parties) and property. This is the procedure for an Authorisation to open the exploration and exploitation work application (Demande d'autorisation d'ouverture de travaux miniers - DAOTM) whose content is specified by Decree No.2006-649, June 2nd, 2006. This procedure concerns drilling work, construction work and the operational work of the plant. The Mining Code also states that any geophysical survey or geochemical prospecting campaign must be subject to prior notification to the competent administrative authority.

Impact Study, Hazard Study, Public Inquiry

Applications for mining claims (exclusive research license, concession and an operation permit) must be accompanied by an environmental impact study, whose content is specified by the Decree No.2011-2019, June 29th, 2011. In addition, Concession and Operation permit applications are subject to a public inquiry, as defined by decree No.2011-2019, December 29th, 2011.

Applications for Authorisation for the opening of mining operations, must also be accompanied by an impact assessment and completed by a safety report, as defined in Article L. 512-1 of the environmental code. They are educated by the prefect by public inquiry and consultation of the various departments of the concerned State. Where these requests are combined with an application for a mining title, there shall be a single impact study and public inquiry.

Table 2: Summary of obligations for environmental study and public information prescribed by the various regulations that apply to a geothermal power plant project in France.

Procedures	*Obligations*
Research Exclusive Licence (PER) Application	- Impact Assessment
Concession Application **Operation Permit Application**	- Impact Assessment, Public Inquiry
Authorisation to open the exploration and exploitation work (DAOTM) Application	- Impact Assessment, Hazard Study, Public Inquiry
Authorisation of a classified facility for environmental protection (ICPE) Application	- Impact Assessment, Hazard Study, Health & Safety Instructions, Public Inquiry
Authorisation to operate an electricity generating facility Application	- Environmental clauses list

The Environmental Code

A geothermal power plant project must also take into account the Environmental Code. However, the legislator has provided a link with the Mining Code; for example, authorisation to open the mining work is authorised under the Water Act (Environmental Code).

Under the Environmental Code, certain facilities may be classified as installations which are subject to environmental protection (ICPE). This is the case of geothermal power plants with a binary cycle turbine (or Rankine cycle) due to the presence of an organic fluid such as isopentane or ammonia, which may present a significant risk to the environment. The application for the authorisation of an ICPE must be accompanied by an impact assessment and a specific hazard study, which is then subject to a public inquiry.

The Energy Code

In some countries, the production of electricity can be governed by a code of energy. In France, the energy code introduced a licensing procedure for the operation of a power plant and geothermal plants. This procedure is defined in Decree No.2000-877 for the authorisation to exploit the power generation facilities. The request for authorization to exploit shall be appraised by the Ministry of Energy. Among the information supplied, it shall include a note stating the usefulness of the site for power generation and an annotated list of environmental provisions that might be applicable at the site.

The Town Planning Code

Under the Town Planning Code, a number of procedures can be applied to a geothermal power project in the area of the Caribbean islands. These include:

- The Littoral Act and the Mountain Act, which impose planning rules. For instance, the Littoral Act defines the coast's remarkable and specific areas as well as the area of the 50 geometrical paces where urbanization is prohibited.
- Planning documents, such as the Local Development Plan (Plan Local d'Urbanisme – PLU) and the Territorial Coherence Scheme (Schéma de Cohérence Territoriale - SCot).
- Building permit.
- The requirements for preventive archaeology.

Table 3: Summary of the main regulations that govern geothermal power projects in France.

Regulations	*Object*
Decree No.78-498	Geothermal deposits' definition
Decree No.2006-948, Mining Code	Mining permits : Research Exclusive Licence, Operation Permit, Concession
Decree No.2006-949, Mining Code	Authorisation to open the exploration and exploitation work Application, Works Completion Declaration
Decree No.2011-2019	Works and Planning Impact assessment
Decree No.2011-2018	Public Inquiry relating to actions that may affect the environment
Environmental Code	Classified Facility for Environmental protection
Energy Code	Authorisation to operate an electricity generating facility

Territorial planning documents

As with any project, the owner of a geothermal plant must verify that the project is compatible with the guidelines and objectives defined by the land planning documents and schemes. These include:

- The Master Plan for Water Development and Management (Schéma Directeur d'Aménagement et de Gestion des Eaux - SDAGE).
- Regional Planning Scheme / Sea Enhancement Diagram (Schéma d'Aménagement Régional/Schéma de Mise en Valeur de la Mer – SAR/SMVM).

- Air, Climate & Energy Regional Scheme (Le Schéma Régional Air Climat Energie – SRCAE)
- Natural Risk Prevention Plan (Plan de Prévention des Risques Naturels - PPRN).

Protected areas under the environment

The implementation of a geothermal power plant project within a protected area under the environment depends on the regulations of the latter. Some prohibit any implantation of an industrial installation such as a geothermal plant. This is for example the case for a National Park or a Biological Reserve (see Figure 1.). Others allow the implementation of a plant provided the project meets the environmental requirements, which may be more or less restrictive. For instance, this is the case for registered natural sites or for a Regional Nature Park.

It is usually when developing the impact statement accompanying the application Permit Exclusive Research (PER) that the project owner must check if the sway of his project is likely to affect protected areas and that he must ensure the project is compatible with the objectives and orientation of the latter in terms of environmental protection.

Figure 1: The Mount Pelee in Martinique site has an integral biological reserve, within which the implementation of a geothermal plant cannot be considered.

Experience feedback

One of the key points of ***project acceptance by the population*** of a geothermal power plant project highlighted by different returns experience is the compliance of the project leader regarding existing regulations and particularly those concerning the environment. It is important that the latter takes into account the various regulations that may apply to the project based on the natural and human environment in which it is inserted. This is especially true for the Caribbean islands environment, which is particularly rich and fragile. In addition, as part of an ***environmental excellence process***, it is important that this consideration intervenes at the preliminary phases of the project. In this case, from the preliminary reconnaissance phase or detailed exploration programs.

Impact Study of a geothermal project Content

Sheet No.11

Summary

The impact study, a project's environmental and societal assessment, is both a regulatory procedure and a recognised environmental integration process. This file outlines the different sections of an impact study by providing an explanation of the expectations and of the basic guidance. This form also includes a section on key points of success that presents some methodological issues in depth.

Contents of the impact study report

Proposal

→ The proposed content is based on the French regulatory framework that meets international standards, with some differences that will be specified.

In France, the content of the impact study is defined in Articles L122-3 and R.122-5 of the Environment Code, supplemented by Article R.512-8 particularly in the case of classified installations that are classed under environmental protection (Installations Classées pour la Protection de l'Environnement - ICPE).

→ The content covers the different sections of an impact assessment, providing an explanation of the expectations and basic guidance. The following 'Key Points of Success' section shows the methodological points in more detail.

Table 1: Typical content of an impact study

Section	Objective	Commentary	Guidance
Regulatory Framework	➢ Clarify the law applicable to the project, depending on the context of implementation and donors concerned, it can be at a national or international level.	A geothermal project can be partly funded by the World Bank and international donors who have requirements in terms of environmental procedures and it must to be taken into account as part of the impact study.	In France, this component is not explicitly expected, it is interesting to include a paragraph relating to the regulatory environment that presents the texts of laws governing the impact study, the criteria for submissions and procedural steps.
Project Description	➢ Present the general and technical characteristics, as well as ancillary facilities and equipment of the project.	This should allow the reader to have a synthetic vision of the project and its issues.	Given the complexity of a geothermal project, in order to understand the impact study report, it should include clear and concise illustrations. The readable and directly accessible nature of these representations, is complemented by a more literal and quantified description.
Initial state analysis	▪ For each environmental theme, gather the sufficient and necessary information for the environmental assessment of the project. ▪ Characterize the state of each component of the environment. ▪ Establish linkages and interactions between each of these components, provide a systematic restoration of the initial state. ▪ Prioritise issues.	The concept of the environment must be interpreted broadly, including both dimensions on the physical, biological and human environments and the interrelationships between these elements from different backgrounds. The purpose of this analysis phase is to provide knowledge of the sensitivities and possibilities of the affected territories and areas, as well as the situation with respect to regulatory standards or quality objectives. It is also a reference state (current and future) in which it will be necessary to build on in later stages.	The Impact Assessment report sets out the criteria to define the perimeters of study. The restitution of this analysis, results in the production of synthetic maps, illustrating the level of challenge of the spaces constituting the study area as well as their sensitivity. The synthesis of this analysis includes the classification of the different environmental issues. ↳ Key points of success ① and ②
Evaluation of the effects of the project	➢ Identify and evaluate the effects of the project, according to their importance: characterise, quantify and spatialise, according to the elements of the analysis of the initial state.	The evaluation covers all the points of the initial state. The effects are treated according to the same degree of accuracy, whether they are considered positive or negative.	It is interesting to offer in the impact study report, cartographic representations, which superimpose the project and the analysis of the initial state. ↳ Key points of success ③ and ④
Assessment of the impacts to	➢ Identify and evaluate the effects of the consecutive improvements and / or	When the project contributes to the implementation of a work program that is staggered over	The definition of the program may not be effective at the time of writing the impact study report. The purpose is then to summarily

Section	Objective	Commentary	Guidance
the works works	carried out in parallel and having a link with the project, if possible: to characterise, quantify and spatialise, according to the elements of the analysis of the initial state.	time, the impact assessment includes an assessment of the impacts of the overall program. This notion is of particular importance in the context of a High Energy geothermal project: depending on the concerned phase, the impact study should approach the later phases of the project.	determine the possible effects. ↳ Key points of success ③ and ④
Analysis of the cumulative effects	➢ Study the cumulative effects of the project with other known projects.	The French legislation sets out a clear framework, the analysis of cumulative effects focuses on projects that have been subject to: ▪ An impact study and a public inquiry under the Water Act. ✓ A notice of the environmental authority.	The report presents a list of projects considered, each one of them specifies the environmental aspects over which the cumulative effects of these projects are effective. Of the components where the combined approach is deemed appropriate, the report should explicitly present the foreseeable changes of the existing known projects, related to the object and effects of the previously proposed cumulative impact study.
Outline of the main alternative solutions and reasons why the project has been selected	➢ Analyse variants. ➢ Justify the solution: choice of location, choice of equipment, choice of implementation...	The evaluation phase and the comparison of alternatives phase is essential. It is seen as a step forward to facilitate the decision-making to the project that will have the least possible negative impacts. Project development is therefore iterative, based on the findings of the analysis of the initial state of the environment and the effects assessed with the progress of studies. This phase is also essential to allow the justification of why the solution has been selected.	The impact assessment report should include a chapter that transcribes the iterative approach, and how the issues identified in the analysis of the initial state were considered. It describes the prospective studies that could lead to the choice of the projects location, and also variants that are considered in the project development. It also shows how the choices that have been made, have taken into account the environmental and human health dimensions and it outlines the reasons for choosing the project, with regard to the effects on the environment and human health.
Project compatibility with the territory planning documents	➢ Check the compatibility of the project with planning documents. ➢ Indicate the elements to ensure that the project meets the objectives and orientations of the various planning documents of the territory.	This component will strengthen the project's justification, by showing how it fits into the territorial planning.	The impact assessment report identifies various territorial planning documents (which are numerous in France) and transcribes the information needed to underline the equivalence between these documents and the project.
Definition of measures	⇒ Prioritise measures to ensure impacts are avoided. ⇒ Propose measures of reduction, by showing that the impact is not technically or economically possible. ⇒ Propose compensation measures to offset the effects that cannot be deleted or reduced. ⇒ Analyse the residual effects: identify, quantify, qualify and spatialize	The client accepts responsibility for the effective implementation of the proposed measures (nature, implementation, financing ...). It therefore has an obligation of means and results. This part is to establish the means used to verify: ▪ The project integration level in its environment, If the proposed measures are appropriate.	The impact study must be precise regarding the proposed measures, in particular for each measure proposed, it must present: the technical, financial and property feasibility of every measure to ensure its effective implementation on the ground; the location plan, the surface area, the technical description, the cost of the measures, the expected impact of these measures and the procedures for monitoring these effects (which in practice corresponds to the definition of the environmental management plan, in an international regulatory framework, see following line).

Section	Objective	Commentary	Guidance
	⇒ Define environmental and social monitoring programs.		The impact assessment report devotes a section to the monitoring procedures, detailing the who, where, when and how. This section is named environmental management plan or environmental and societal management plan, in the international standard. ↳ Key point of success ⑤
Analysis of the methods used	▪ Quote the consulted bibliography and the organizations contacted. ▪ Describe the techniques used in specific assessments and the choices made to determine the impact study. ▪ Present difficulties met.	This presentation must clearly show how the analysis was carried out and also, through the expression of the difficulties met, it must give an idea of the limits of the scope of results.	Field expertise achievement dates and the conditions in which they have been conducted are presented. The technical difficulties encountered in the field are clearly expressed.
Authors of the impact study	▪ Briefly present the different participants of the impact study.	This is to enhance the credibility of the study to the public eye and to ensure the transparency of the decision.	The authors' career path can be presented, possibly in the form of a curriculum vitae.
Non Technical Summary	▪ Resume in a synthetic form the essential elements and conclusions of each part of the impact study.	It must be easily accessible and be an autonomous part for the understanding of key issues and impacts of the project.	The non-technical summary follows the structure of the impact study. It popularizes the main conclusions and should also include graphical representations that are useful for the understanding of the subject. ↳ Key points of success ⑥

Key points of success

Objective of this section

The purpose of this chapter is to show some key points of the impact study, while requiring special attention.

① Adequate definition of the areas of study

→ The areas of study are an important consideration in the impact assessment, as they define the area of investigation where the background research, field surveys, measurements, samples and population surveys will be carried out.

→ The areas of study are determined according to different criteria, depending on the components of the environment, but also on the nature of the projects and their potential direct and indirect effects. It is thus necessary to consider:

-the implantation sites: spaces where elements of the project will often have a direct and permanent effect (the developments' physical and functional impact).

↳ During the impact study related to exploration drilling: it applies to areas of exploration drilling but also related to the planning of potential future pathways giving access to these platforms (which should have small dimensions due to the small number of machines used), but also areas dedicated to the possible installation of a drilling mud storage and recycling system (depending on the drilling technique used).

↳ During the impact study related to the entire project (development drilling, power plants and related facilities): at this stage of the project, it is not only about the operating drilling platforms (which are located at or near the exploration drilling that was previously completed, which has a higher grip surface) but also rights of way related to the enlargement (s) of the access ways to these platforms (dimensions and weights of vehicles mobilized must be taken into account, leading to additional constraints in terms of space and the quality of the roads). It also takes into account the surfaces for the construction of a geothermal fluid network, the embodiment of the electric network, the implementation of the geothermal power plant and the potential access associated with these various developments.

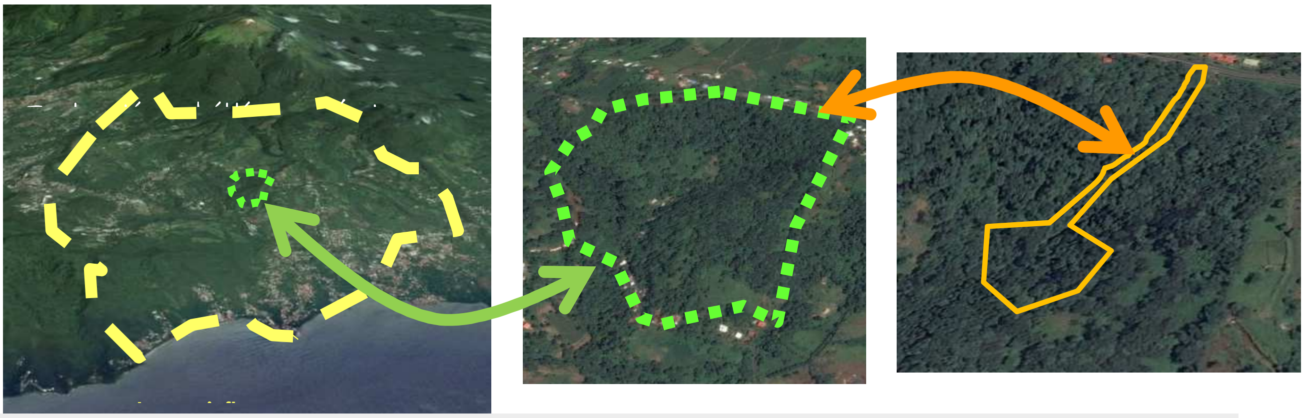
Under the terms of implementation during the exploration phase, the entire storage system and drilling mud recycling system was built at the operating platforms. If this was not the case, this planning must also appear at the study areas.

-areas of influence: where the project has spatial effects due to the nature of the affected parameters (landscape, socio-economic) and indirect effects due to the functional relationships between the various compartments of the environment.

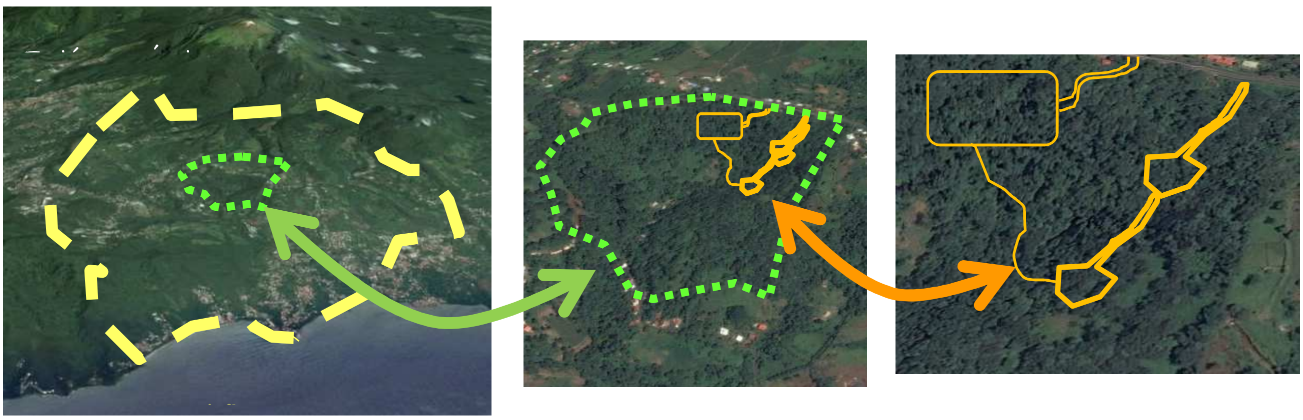
↳ During the impact study related to exploration drilling: it concerns areas affected by the implementation of new geothermal developments that depend on the circumstances and the challenges given by the environmental. For example, when it is visible from afar, the drilling platform must be well integrated into the surrounding landscape.

↳ During the impact study related to the entire project (development drilling, power plants and related facilities): it concerns areas affected by the implementation of new geothermal developments that depend upon the circumstances and the challenges given by the environment, for example the impact of the establishment of an electrical network, which could possibly cause fragmentation of the environmental framework.

→ These areas of study therefore vary according to the reality of the terrain, the characteristics of the project and the subject being studied. The choice of the areas being studied may well have been modified or refined during the impact study, to reflect the results of the various impact assessments



(iterative process).



Principle of delimitation of the studied areas based on the reflection scales © Biotope, May 2015

② Establishment of an environmental initial state (refer to page 11)

→ One of the key points of the impact study is the establishment of an environmental initial state. This initial state is particularly important because it will serve as reference (or zero) to measure the project's long-term impacts on the environment. This initial state theoretically focuses on the territory likely to be concerned by the whole project.

→ The concept of environment encompasses a set of interrelated concerns. For the purpose of a relatively wide approach, the environment is often split into several components. **Each component requires special expertise depending on the environmental issues at stake.**

→ The analysis of the site and of its environmental initial state should be based on documented research and bibliographic data. Above all, it must be based on field investigations, which will gradually intensify as the technical definition of the project is specified. It is especially necessary to **have a more in-depth study regarding some environmental themes, if high stakes are detected or if the information on these issues are partial or non-existent.**

③ Characterized analysis of the effects

→ An essential stage of the assessment is the impact analysis stage that allows the project owner to comparatively test both the landscape schemes and the considered alternatives, but also to carefully analyse the consequences of the selected project in its environment, in order to ensure it is overall acceptable.

→ As mentioned above, the description of the impacts must be proportionate to the issues and must help to prioritise them by identifying the significant negative impacts. The impacts of a project must be analysed and measured in relation to a situational analysis and by taking into account the objectives set by public policies (compliance with environmental regulations).

Firstly, the factual knowledge of the project's initial state and technical features, allows the assessment of the typology of the considered effect (qualitative aspect). The classification of these effects is shown in the following table.

Secondly, the analysis of the quantitative aspect (the determination of impact's intensity) is based on various criteria, such as: the sensitivity of the area or the environmental component affected by the project, the scope of the impact (spatial dimension: length, area, depth ...), the duration of the impact (temporary or irreversible nature), the frequency of the impact (occasional, permanent, delayed) and/or the probability of the impact...

↳ During the early phases of a geothermal project, the impacts are usually non-existent or very low. The first noticeable effects on the environment occur during the exploration phase and are linked to the drilling sites and the associated infrastructure.

→ An assessment of societal impacts is necessary to anticipate the positive or negative consequences for the territory in which it will be implemented. This societal impact assessment is often presented as a component of the environmental impact study. If the challenges are seen as important, the study may be the subject of a particular approach and could lead to the drafting of a separate societal impact study.

Table 2: Classification of environmental impacts

		Definition	Example
Type	Direct	The project's immediate consequences on the environment, in space and in time.	→ Modification of the local hydrological cycle.
	Indirect	Result of the cause and effect pattern originating from a direct impact.	→ Disappearance of an animal species due to the destruction of its habitats.
	Induced	Not related to the project itself but other developments or changes induced by the project.	→ Land consolidation after the creation of a road.
	Cumulative	Result of the accumulation and interaction of many direct and indirect effects generated by one project or several projects in time and space, which could lead to sudden or progressive changes in the environment.	→ Accumulation of various kinds of discharges in the same environment, which is linked to the project and to a separate project.
Direction	Positive	Favourable result or an improvement, a progressive step.	→ Boosting the local socio-economic context.
	Negative	Harmful effect.	→ Soil water pollution, production of waste.
Duration	Temporary	Impact felt during a given period, limited in time, or that either disappears immediately after cessation of the cause, or when its intensity diminishes gradually until complete disappearance.	→ Noise emitted by construction equipment during the construction phase.
	Permanent	Persisting over time and that can remain unchangeable.	→ Destruction of the natural environment due to the project's activity.
Appearance	Short term	The distinction between "short", "medium" or "long" term refers to the occurrence of an impact as a result of an event that may occur from the very beginning of the work operations, to the plant becoming decommissioned.	→ Disturbance of a wildlife species' reproduction, as a result of vibrations and noises during work operations.
	Medium term	The short-term impact originates from all the immediate impacts linked with the occurrence of an event. These effects appear very soon after the event.	→ Degradation of natural habitats as a result of the introduction of invasive species.
	Long term	It is considered that the medium and long term impacts occur after a shorter or longer period following the event. These impacts do not systematically appear. They are more likely to occur when the events are significant or repeated over an extended period.	→ Participation in the fight against climate change by the absence of greenhouse gas emissions during the operating phase.

④ The health component, conduction of a particular analysis

→ Deep geothermal energy, as any industrial operation, is likely to lead to emissions detrimental to human health. For example, geothermal fluids (steam or hot water) usually contain gases such as CO2, H2S, ammonia (NH3), methane (CH4) and trace amounts of other gases. They may also contain small amounts of dissolving toxic chemicals in concentrations that generally increase with temperature and can be harmful if released into the environment. However, it should be noted that a number of proven technologies, often developed for other types of energy production and other industries, are marketed to control, filter or chemically modify the emission flow from geothermal plants in operation.

→ This component should allow the translation of potential effects of the project's risks to human health. A specific chapter should be devoted to and focused on the effects that are inherent in the normal activity of the installation and that may pose a risk to human health.

In France, the *Institut de Veille Sanitaire* (InVS) and the *Institut National de l'Environnement Industriel et des Risques* (INERIS) offers several guides and tools to use in the context of the completion of the analysis.

Identification of potentially hazardous substances and nuisances

Census of the agents (chemical or physical) on the considered site and issued or rejected by the facilities and site activities.

Identification of the hazardous potential of these agents: types of health implications (diseases, target organs ...).

Reference limit values of emissions

Summary, for each listed agent, of the limit values of emissions regarding labour regulations and the regulations for the protection of the environment and the work of experts.

Definition of the relationship between dose and response: the dose - response relationship, a specific exposure route, establishes the link between the dose of the substance in contact with the body and the occurrence of toxic effects considered critical and expressed by toxicological evidence or Value toxicological Reference (VTR).

Assessment of human exposure and risk characterization

Estimated network contamination of different environments.

Defining populations potentially exposed to pollution.

Quantitative estimation of human exposure.

Risks are characterized from the results obtained in the previous steps.

Proposed organisation of the health component

⑤ Monitoring and determination of measures

→ ARO (Avoid, Reduce, Offset) sequence application

To prove that the chosen project is the best compromise for the environment, it is necessary to justify that an adapted approach has guided the design of the deep geothermal project. This design should first seek to avoid impacts on the environment. When the logic of maximum impact avoidance has prevailed but that some impacts remain technically or economically unavoidable, impact reduction measures are sought through appropriate technical solutions and reasonable cost. If there still are residual impacts whose effects on the environment are generally acceptable, after revaluation of pre-identified post-impact measures of avoidance / reduction, it is necessary to define compensatory measures in response to these residual impacts whose intensity cannot be neglected.

In addition to the implementation of technical measures, the project owner may be directed towards supporting measures, which are proposals that can prove the environmental quality of the project (e.g., public awareness and information operations).

Website references::

http://www.invs.sante.fr/publications/guides/etude_impact/

AVOID

- **Design a project of lesser envronmental impact** by retaining an alternative technique (or outline) to eliminate the project's negative impact, which is identified as a priority
  Ex: definition of the application perimeter outside a protected area.

REDUCE

- **Reduce the residual impacts to the lowest possible level** by defining specific provisions, mostly technical adjustments
  Ex: recycling of drilling muds, collection of runoff waters

COMPENSATE

- **Adopt a counterpart that is equivalent, relevant, reliable and efficent**
  Ex: creation of a pond, financial compensation, noise-prevention developments, etc.

→ **Monitoring of measures**

All measurements should be monitored during and following their implementation in order to **check / assess their effectiveness** and, if necessary, define adapted **corrective measures in case of deviation from the target**.

The means to be implemented within the framework of monitoring measures must be described, quantified and explained in the impact study. To this end the indicators are to be defined by the contracting authority or approved by the administrative authorities to measure the state of implementation of the measures and their effectiveness.

The technical, administrative and financial feasibility of these measures should always be checked for the measure to be acceptable, especially for the implementation of measures reducing and offsetting impacts. To this end, the quantification of the cost of mitigation measures is essential. It must be possible to verify the validity and appropriateness of the amount presented in relation to the nature of the planned measure. Note that encryption of any measures of avoidance, reduction or compensation shall always include the monitoring of the measure's effectiveness.

⑤ The non-technical summary, a communication item

→ The impact study must meet the technical and scientific issues raised by a geothermal project but must also inform the public. The non-technical summary is a real communication tool created to facilitate the access to information on the impact assessment:

-It should allow the reader to get a general idea of the impacts generated by the project studied, without having to read the entire impact study, as it repeats and summarises all of the essential elements and the conclusions to each part of the study. The reader then becomes aware of the facts. If he wishes to have evidence or have knowledge of the justifications and other demonstrations and calculations, the reader may then refer to the study itself.

-It is accessible by all, as it is written in terms that are understandable by anyone accessing the file. It employs no specific technical terms, chemical or mathematical formulas.

→ This part of the impact assessment is therefore crucial and should be easily identifiable. It is advisable

Website reference :

to position it at the beginning of the impact study or in a separate document that precedes the study report. For the reader, it is the first gateway to the impact study.

Since 2005, Dominica has initiated a program for the construction of a geothermal project in the Roseau Valley, in cooperation with France under the Caribbean interregional cooperation objectives. As part of this cooperation a **Requirements specification for the study of the impact of a proposed geothermal power project in an island and / or tropical context** has been achieved. This specification is available at the following internet address. It provides additional lighting, it enables to: direct the future of the project leader of Dominica geothermal plant for carrying out the impact assessment; define the regulations applicable to the plant project; ensure that this impact study will be conducted and must take into account all the impacts of this type of project.

Impact study: description of the initial state of the environment

Sheet n°12

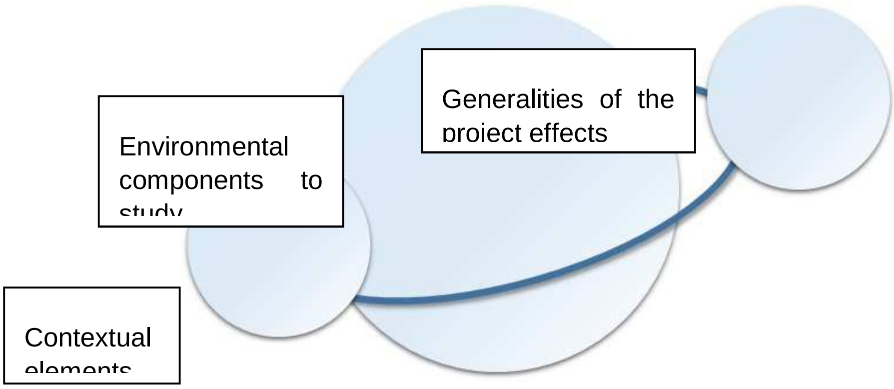
Summary

The impact of the setting up of a geothermic unit on a given environment can be assessed by taking in count its effects compared to the situation as it was before it was exploited. For a planned installation, it is therefore compulsory to know the state of the environment as it was initially. This sheet offers to point out description components of the initial state of the environment in the framework of the realisation of a geothermic electricity production project in the Caribbean islands.

Thought basis.

Definition.

- ➔ The description of the initial state needs to give enough information to be able to identify, assess and class the possible effects of a geothermic project of electricity production in an existing environment.
- ➔ Therefore, it is a question of identifying the environmental interests and tendencies shown by the context of the setting up place, but also to know the probable generic repercussions, that are possible with a geothermic installation in order to target the environmental components to study in detail that are likely to endure from striking impacts.
- ➔ Indeed, the initial state is the situation of the environment when it is not yet influenced by a project, with its own natural characteristics and its pre-existing harmful substances. The themes for which the project is likely to induce striking variations must benefit from a precise treatment, so that the impacts can be the best possible compared to the pre-existing situation.



Dimensions to think about the definition of components to study in the framework of the initial state of the environment of an impact study.

Contextual elements.

The first part of this guide draws up an environmental and social report of the Lesser Antilles.To sum up the following elements are to remember:

- ➔ The Lesser Antilles have a rich and specific (strong endemic wildlife) tropical biodiversity that make them one of the regions that has the strongest ecological interest but also particularly threatened by human activity. The freshwater resource is vulnerable. The population of these isles has an attachment to their natural environment.
- ➔ Each isle has its own topographical, cultural and historical characteristics and its unequal levels of economic development but the economy of the Caribbean nearly always stands on tourism, services and agriculture sectors. Considering energy, these isles are very dependent on petrol products.
- ➔ These isles are subject to multiple risks and are very vulnerable to natural catastrophes (cyclone, water elevation, earthquakes, ground movements, volcanic eruptions).

Potential effects of a geothermic installation.

The third part of this guide offers a methodological framework of environmental and societal integration that clarifies especially the potential effects that can present a High energy geothermic installation and this during all the period of time that covers such a project (several phases of construction, eventual exploitation and dismantling). The following element are to remember:

- ➔ During the construction phase, the project is at the root of water, ground, air, noise pollutants, waste production, ground occupation changes implying visual effects and effects on users.
- ➔ During the exploitation phase, the main impacts are the noise of the different industrial pieces of equipment, the emission that can include geothermic fluid steam releases (in particular sulphurated hydrogen that smells and is toxic for health).
- ➔ During the dismantling phase, the general incidences linked to a construction site are possible, the most striking effects are linked to the production of a lot of waste, of which some have toxic aspects requiring an adapted treatment.

Suggested basic outline.

In light of the present context and of the potential effects, the following basic outline is offered as a model, analysis tracks back up this reflection.

Site and surrounding.

- ➔ Brief description of the site and of its current use, including the other constructions and installations (existing or planned), directly or indirectly linked to the considered project.
- ➔ Highlight of the investigation parameters (variable according to the considered environmental domains).
- ➔ Map representation with an adapted scale to the project and to the investigation parameters.

Physical environment.

- ➔ Air: meteorology, local/ regional pollution level if possible, inventory of the installations and structures likely to pollute the air in the pre-existing context.
- ➔ Geology and hydrogeology: presentation of the geological structures, characterisation of the geothermic reservoir, acquiferous (functioning, state and use).
- ➔ Superficial water and associated environments: hydrography, hydrology, quality, use, interactions between water streams, lakes and acquiferous.
- ➔ Natural risks: cyclonic risks, volcanic and seismic activities, flooding risk, ground movement risk.

Natural environment.

- ➔ Natural environments of interest: identified and/ or protected biotopes of a national/ regional/ local importance.
- ➔ Ecological diagnosis: floristic readings (habitat description, inventory of the vegetal species), faunistic inventory combined to an ecological analysis (use of the environments by the species, numbers put in perspective with local populations) and according to the context an specific

analysis of the aquatic environment (aquatic fauna and flora, eco-morphological and functional characteristics of water streams)
- ➔ Ecological continuity: typology and quality of the ecological networks, potential

Landscape and heritage.

- ➔ Landscape environment: assessment of the landscape's basis characterization of the landscape units.
- ➔ Heritage environment: inventory of the heritage (built and archaeologic heritage) as well as the noticeable and touristic sites.
- ➔ Perceptions: characterization of the visual link that the project site(s) have with the territory, what they give to see and the way that they are seen, this analysis is supported by commented photographs.

Human environment.

- ➔ Socio-economic context: demography, employment and economic activities, education and housing, put in perspective of local information with the general information about the territory (of the isle), with a particular zoom on the tourism aspect (type, site and equipment).
- ➔ Ground occupation: urbanization, agricultural and forester plots, road network and accessibility, network, use and practises
- ➔ Noise and vibrations: assignment and characteristics of the zones in the perimmetr of influence, with in particular their sensibility degrees to the noise and to the vibrations; topography, other determining elements for the noise spreading; current noise level (calculated or measured in situ).

Synthesis of the issues.

- ➔ Synthesis and spatialization of strong, patrimonial or restrictive elements, hierarchization of the issues and degrees of constraint.

Since 2005, Dominica initiated a program to realize a geothermic project in the Roseau valley, in collaboration with France, in the framework of its aims to collaborate with the Caribbean regions. Through this framework, an initial tate of the environment of the Roseau Valley in Dominica, in anticipation of the development of geothermic electricity production projects was created.

This initial state as well as the synthesis are available at the following website address. Extracts of the synthesis of this document are given as an example.

Reference website: http://www.geothermie-caraibes.org

Extracts of the initial state synthesis on the environment of the Roseau Valley in Dominica, in anticipation of the development of the geothermic electricity production projects. © Caraibes Environnement Développement/ ADME, july 2015


VOLET 3 : BIODIVERSITE / FLORE ET FAUNE TERRESTRE

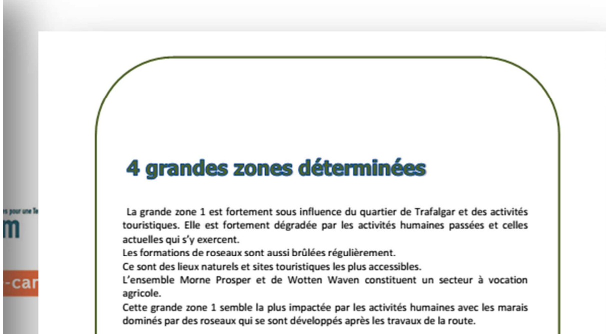
Objectif de l'étude

- Identifier la faune et la flore de la région
- Déterminer à l'échelle de la vallée de Roseau les sites les plus sensibles

Rainforest de Long Ditton Plateau

Méthode mise en œuvre

Une première analyse faune et flore a été effectuée en 2008 par M. Arlington James, officier forestier et expert faune et flore. L'objectif était d'avoir une présentation de la


4 grandes zones déterminées

La grande zone 1 est fortement sous influence du quartier de Trafalgar et des activités touristiques. Elle est fortement dégradée par les activités humaines passées et celles actuelles qui s'y exercent.
Les formations de roseaux sont aussi brûlées régulièrement.
Ce sont des lieux naturels et sites touristiques les plus accessibles.
L'ensemble Morne Prosper et de Wotten Waven constituent un secteur à vocation agricole.
Cette grande zone 1 semble la plus impactée par les activités humaines avec les marais dominés par des roseaux qui se sont développés après les travaux de la route.

Environmental management plans applicable to a geothermal project

Sheet n°13

Summary

The environmental management plan is a key document to a geothermal power plant project, because it specifies the means and procedures implemented by the operator to meet his commitments in view of environmental protection.
This document is produced at the early stages of the project, and is led to live throughout the various phases of development, including throughout the operation period.

Definition

The environmental management plan, usually produced in the form of an Environmental and Social Management Plan (ESMP), presents the set of measures to implement to eliminate the negative effects of the project on the environment (biophysical and human environments), minimize them, offset, or reduce them to acceptable levels. More precisely, the ESMP includes measures to mitigate nuisances, an environmental monitoring and inspection plan, a capacity building program, information and education measures, institutional and implementation arrangements, the implementation schedule and estimated costs for the environmental and social measures.

The environmental management plan specifies the means and procedures implemented by the contracting authority to meet his commitments with regard to environmental protection. The management plan is therefore an integrating tool of environmental aspects related to the project during its implementation, while minimizing the impacts. It is also an important document of communication for the operator towards state services and local actors.

The environmental management plan is based on studies conducted during the different operation phases, including impact studies. It must therefore evolve according to the development of the plant and issues identified.

This plan ensures goals such as :

- To respect the regulatory framework applicable to the project
- To mitigate the negative impacts of the project on biophysical and human environments,
- To ensure the inspection of activities and the monitoring of project impacts,
- To make adjustments or improvements as appropriate,
- To maximize the positive effects of the project.

The content of the various plans

The management plan is divided into various forms according to the project phases:

- The **Environmental and Social Management Plan** (ESMP), which can be implemented from the preliminary phases of the project. It includes:
  - The set of mitigation measures, monitoring measures, and institutional measures to implement and operate in order to eliminate the environmental and social negative effects of the project, minimize them, offset, or reduce them to acceptable levels.
  - Necessary actions to implement those measures : followed by indicators and control measures.
  - The roles and responsibilities of various actors in terms of environmental and social management.

- The **monitoring plan** (or inspection plan). This plan is implemented during the drilling operations and allows to :
  - Verify the impact assessment made during environmental studies, and suggest additional measures if necessary,
  - Verify the effectiveness of measures implemented, with a monitoring program and indicators, and suggest adjustments if necessary.

These plans systematically specify the implementation modalities, the estimated costs and the actors responsible for the application of different measures or monitorings.

These plans, although they are not required under French regulations, are required in other national regulations, and under procedural requirements of the World Bank. In this case, the ESMP constitutes a separate chapter of the impact study.

They can then be broken down into certifications (ISO 14000 in particular).

The content of an ESMP is not statutorily defined, and may vary from one country to another.

The follow table presents a management plan proposal frame.

Setting/Impact to monitor	Monitoring location	Type of monitoring	Indicator and implementation modalities	Monitoring frequency	Implementation responsibility	Estimated costs

The key elements to management plans

The 4 key elements to Environmental and Social Management Plans and Monitoring Plans are :

- The environmental analysis to define the project impacts on the environment (zero point of the environment) ;
- The establishment of action plans to minimize the environmental impacts and enhance the environmental performance of the project (construction and operation) ;
- The training and education of the staff and people involved in the project (drilling companies, plant operator, ...);
- The environmental monitoring program to anticipate and assess the project on the environment and implement corrective and preventive actions during the exploration and operation phases.

The drafting of the ESMP will rely on the environmental policy established by the operator. This policy specifies that the company adheres to the principles of sustainable development by considering the socioeconomic, environmental and economic aspects of the operations.

In order to promote the success of the project, these plans should be presented in public meetings planned and supplemented according to the proposals made by local actors (elected representatives, associations, general public, local residents ...) and with regard to their technical feasibility.

Indeed, public involvement allows reaching several objectives:

- To provide an opportunity for local residents to show their concern and influence decision making early in the project;
- To inform people affected and people interested about the project and its potential impacts;
- To know the local situation and traditional values;
- To reduce conflicts between the different participants (contracting authority, local authorities, etc.);
- To make informed decisions, especially with regard to the most damaging impacts and mitigation measures, in the final decision;
- To improve transparency and accountability of the contracting authorities;
- To establish trust between the contracting authority and Government institutions.

Finally, the monitoring of the implementation of the ESMP requires the establishment of a monitoring committee, usually under the authority of the Chief Operating Officer (COO) and the Environment Officer.

Apart from the monitoring programs set out in the monitoring plan, monitoring of the ESMP will rely on:

- Compliance audits : every year, the direction may conduct an internal compliance audit of the ESMP of the site to ensure that the environmental procedures are properly followed and the targets are reached in accordance with the objectives set in the ESMP. A compliance report will be written to indicate the level of compliance and areas requiring improvement if necessary.
- Management reviews : periodically, the direction may also review the ESMP to ensure continuous improvement. At this stage, environmental and legal aspects as well as processes, goals, targets, roles and responsibilities contained in the ESMP will be reviewed and modified, if necessary, to incorporate improvements required after conducting the compliance audits.

Feedback

Environmental Management and Monitoring Plan proposed in preparation for geothermal power generation projects in Martinique.

In view of the possible future implementation of geothermal power plants in Martinique, ADEME wanted, upstream of these projects, to obtain a global vision of the foreseeable environmental conditions (issues, impacts, measures ...) associated with this type of project on the sites Anses d'Arlet (Petite Anse) and Montagne Pelée (Saint-Pierre et le Prêcheur). In the context of this consideration, an Environmental Management and Monitoring Plan (EMMP) was proposed.

The EMMP takes the form of sheets. For each item studied, the associated EMMP sheet is divided into several parts :

- Reminder of the environmental impact defined in the pre-assessment: only the main impacts are taken into account at this stage,
- Proposal for objectives / targets aimed at reducing significant impacts,
- ***Environmental Management Plan :***
    - Identification of the applicable regulatory requirements,
    - Definition of environmental actions describing: mitigation measures, requirements, specific environmental management plans and procedures to implement in order to avoid or mitigate the negative impacts on the environment, the implementation modalities of these programs and the roles of different actors, the resources required (human, financial, infrastructures, etc), the definition of training and education programs, the establishment of specifications for internal and external communications procedures (traceability)…
    - Cost estimation to be considered (in a first approach)),
    - The responsibilities of the different actors in terms of environmental management.
- ***Monitoring Plan:***
    - Monitoring Indicators,
    - Procedures for monitoring measures : operational control measures related to the application of the EMP: verification/assessment/ management of nonconformities of the EMP, recommendations and corrective action plans (if necessary), establishment of a monitoring / a tracking document of the Monitoring Plan, environmental monitoring measures : environmental controls will be specifically developed for each component of the project in order to monitor emissions and discharges related to the project,

Feedback

Environmental Management and Monitoring Plan proposed in preparation for geothermal power generation projects in Martinique.

Following is an example of sheet proposed in the context of this consideration,

egis	Construction		Fiche n° E

Pollution des eaux

Rappel de l'impact	Pollution par les fluides de chantier (béton, hydrocarbures ...), les fluides de forage (boues, additifs, ciment de forage) et le fluide géothermique

Objectifs visés	Maintenir la qualité des eaux

Réglementation en vigueur
• Directive cadre su l'eau 2000/60/CE • Le plan d'action pour la sauvegarde des ressources en eau de l'Europe du 14/11/2012 • Directive 2008/11/CE du Parlement européen et du Conseil du 16 décembre 2008 établissant des normes de qualité environnementale dans le domaine de l'eau. • Directive 80/68/CEE • Directive 2006/118/CE

Plan de gestion environnemental :

Descriptif actions	
1. Tester et recycler les boues de forages (si pas de présence de composé toxique) **2.** Surveiller l'apparition de fuites au niveau des forages **3.** Création d'une aire de stockage des matériaux extraits : - Bassin étanche revêtus d'une membrane d'étanchéité pour boues pour les essais forage - Bassin de rétention des eaux. - Bassin de dépollution des eaux. - Mise en place d'une instrumentation pour mesurer les niveaux de métaux lourds et d'additifs **4.** Equiper les sanitaires d'un assainissement autonome	
Estimation des coûts	**Responsabilité**
1. Coût intégré au suivi de travaux **2.** Coût intégré au suivi de travaux **3.** Coût intégré au suivi de travaux **4.** Environ 6200 € l'unité	Maitrise d'œuvre

Plan de contrôle :

Modalités de suivi des indicateurs	**Indicateurs de suivi**
Suivi environnemental de chantier	
Estimation des coûts	**Responsabilité**
pm (fait partie du suivi environnemental)	Maitrise d'œuvre

The dismantling of geothermal power plants and the rehabilitation of the site

File n°15

Summary

When an industrial plant reaches its end of life, it is necessary to run its dismantling and to restore the site. The following file scans the different aspects of the dismantling of a geothermal power generation unit.

Definition

What are dismantling and restoration ?

→ It is important to define what is meant by dismantling, if only to properly identify the costs and responsibilities. The dismantling consists in disassembling and removing equipments belonging to the geothermal plant, whether they belong to the drilling area, to the actual plant and to all related facilities (all types of networks).

→ The restoration represents a rehabilitation of the implantation site of the facilities, so that the land can again be compatible with its intended use or original use. The redevelopment may offer a new purpose to the concerned plots under the condition of an agreement with the owner or owners and state services.

When do they take place ?

→ The high temperature geothermal energy is often treated as a renewable energy not dependent on weather or climate conditions. It is called a quasi-continuous energy because only interrupted by the maintenance operations of the plant. Moreover, geothermal reservoirs have the advantage to have a lifetime of several years (30 to 80 years). However, depletion of this resource is possible: the operating speed should not exceed that of the renewal of water supplies. The reinjection overcomes this difficulty. Therefore, like any industrial activity, geothermal high energy generation potentially has an end and, in general, raises the issue of the future of installations, once the production is stopped.

→ Dismantling can therefore take place at the end of life of the installation but also during the life of the plant according to the evolution of the geothermal project. In fact, a part of the site can be redeveloped to optimize equipments and allow an evolution of the production

→ Furthermore, the implementation of a geothermal project has the specificity to include several steps during which the project is likely to be stopped, for example the project may be abandoned if production tests do not show a sustainable resource to exploit.

Procedures

Regulatory aspect in France

Under French law, the rules applicable to the High-temperature geothermal energy are essentially the same as for mines. Indeed, the geothermal sector falls under the Mining Code which in its article L112-1 assimilates geothermal deposits to mines. Decrees No. 2006-648 and No. 2006-649 set out the rules for implementing the Mining Code. Taking into account the dismantling phase and restoration phase comes through the following points.

→ **Provisions laid down during the opening and operation**

↳ Even before the start of operations, the legislature has ensured that the operator anticipates the conditions for abandoning its storage. Indeed, it is stated in the sixth paragraph of Article 6 of Decree No 2006-649 of June 2 2006 that the operator must, in its application for authorization, indicate «on a provisional basis [...] the conditions for stopping work and the estimation of its cost». The operator is also obliged, in the same file, to submit an impact study (fourth paragraph of Article 6 of that decree), whose mission is to ensure that the operator evaluates and masters the long-term impact (including beyond the operation phase) that his geothermal deposits could have on the environment and human health.

↳ During the operations, the State continues to ensure that the operator masters the conditions of abandonment of its underground storage, particularly through the annual operating reports. Indeed, these reports must indicate at least once every 5 years, "the conditions for stopping work and the estimation of its cost" (paragraph 11, Article 36 of Decree No 2006-649 of June 2, 2006).

→ **Provisions laid down when stopping work and during the waiver of a concession**

Stopping the operations of a deposit (or part of it) comes with a legal procedure called « cessation of work » or « permanente cessation of work ». The cessation of work is the first phase of the abandonment process, the second being the renunciation marking the final withdrawal of the concession to the operator and the transfer of responsibility to the state.

↳ The provisions governing the cessation of work are defined in Articles 91, 92 of the Mining Code. Decree No 2006-649 of June 2 2006 (Chapter V of Title III) specifies the implementing rules.

↳ A geothermal deposits concession may be ended in two types of situations :

1- The administration withdraws the title to the operator, for example, because the latter is in default or because it considers that the operator has failed to fulfill its obligations relating to public safety or protection of the environment. This provision of "title withdrawal" is provided in the Article 119-1 of the Mining Code and is applied under the terms set out in Article 54 of Decree 2006-648 of June 2 ;

2- The operator gives up his title. The procedure of "title waiving" of geothermal deposits is defined in Article 55 of Decree 2006-648 of June 2 2006.

→ **General Regulation on Extractive Industries (GREI)**

A certain number of provisions regarding the closure of wells or surveys were introduced in the General Regulation on Extractive Industries by Decree No 2000-278 of the 22nd of March 2000 and its implementing circular. For example, the well abandonment program should also be in accordance with Articles 49-51 concerning the "final closing of the well" in Section 4 of the title on Drilling of the GREI, in case the drilling should be abandoned or any interruption of drilling work in progress would occur.

Technical aspect

→ **Dismantling of well pads**

The closure of a well is a series of operations intended to restore the insulation of different permeable levels to potential flow using cement plugs with the following objectives:
- Insulation of the reservoir levels in the overdraft,
- Insulation of the overdraft,
- Isolation of uncemented annulars.
These cement plugs should prevent the circulation of fluids between the permeable levels, prohibit all possibilities of leakage on the day of effluents, prevent pollution and protect the aquifer levels.

The main points of the abandonment procedure and drilling closure are detailed in Technical Note NDMTW (National Division of Mineral and Thermal Waters) No. 11 of November 1997.

Depending on the case, geothermal wells will not be resealed to be converted into geothermal probes.

→ **Restoration of the site**

Cleaning work and reprofiling of the site will be made to ensure the landowner the best security guarantees and respect of the environment.

This is a classic building site demolition and redevelopment where the good practices are known by the project management.

Environmental impacts

The predominant environmental concerns encountered during the dismantling and restoration phase are presented in accordance with:

→ **Pollution : Elimination of hazardous waste and other chemical products**: the dismantling of all the facilities composing a geothermal unit will be responsible for various wastes, some of which may have a dangerous potential: some substances at the equipment level of the geothermal power plant, chemical inhibitors in storage, plotters, of chemical reagents used during operations ... Transportation and treatment of such wastes must be carried out according to good practice in order not to induce pollution.

→ **The surface disturbance** : Proper care, effective cleaning procedures and appropriate landscaping should reduce the effects of permanent scarring of the affected plots.

Treatment and recycling of wastes from geothermal projects

Sheet 16

Summary

It is common knowledge that every geothermal project, in order to achieve environmental excellence, must take into account its wastes' treatment and recycling. It also contributes to its societal acceptability. Indeed, even minor environmental pollution caused by bad or inexistant waste handling can lead to a project dissolution. The purpose of this sheet is to provide information about wastes and how they should be managed all along a project's lifespan.

When does a geothermal project generate wastes ?

A geothermal project mostly produce wastes at these stages (refer to Table 1):

® during the exploration drillings;

® during the camp development;

® during the building of the power plant;

® during the exploitation of the power plant;

® during the dismantling of the power plant or parts of it

What is the nature of wastes produced by a geothermal project ?

Table 1 sums up the nature of these wastes. In brief, geothermal projects produce:

® only few waste;

® mainly common waste, similar to those produced by most industrial projects;

® mainly waste that can be handled by classic treatment and recycling schemes

NB: In this case, rejects of geothermal fluids into the wild and gas emissions caused by the camp exploitation aren't considered as wastes. Indeed, projects trying to achieve environmental excellence must plan to reinject all the fluids into the tank. Sequential fluids emissions that occur during production trials and transitory phases of the exploitation shall be provisionally stocked into waterproof storage lagoons before being reinjected into the tank or another available aquifer. If environmental standards allow it, emission gas will be released in the atmosphere. Otherwise, they are subject to a treatment, and derivative products such as sulphur are considered wether as valuable by-products, or as wastes.

Wastes environmental management

The management of waste produced by a project must be understood as part of environmental impact assessments and be developed through environmental management plans.

® The environmental assessment must specify the nature and the potential environmental impact of these wastes. It also has to mention the prevention and control measures that should be put into action to eliminate or reduce this impact.

® The environmental management plan explicits how these measures should be implemented

Nature of the wastes	***Drilling***	***Building of the power plant***	***Operations***	***Dismanteling***
Drilling muds and cuttings	X			

Drilling various additives	X			
Machinery oils and fats	X	X	X	X
Casings, scrap, etc.	X	X	X	X
Various packagings	X	X	X	X
Household wastes	X	X	X	
Mineral precipitates	X		X	X
Treatment products for geothermal fluid			X	
Common chemicals	X	X	X	X
Turbine oil			X	X
Equipment, engines, electric cables		X	X	X
Hardware			X	X
Electrical transformer				X
Sheets, plates, heat insulator		X	X	X
Pipes, baloons			X	X
Rubbles		X		X
By-products from the H_2S gas treatment			X	

Table 1: Nature of the most common wastes generated by geothermal power plant projects

Overall, the plant's exploitant and the firms involved can implement the concept of "clean worksite" by following a few rules:

- Wastes' systematic sorting and transfer to the existing treatment and recycling services;
- No wastes landfill and burning on the site;
- Traceability of the wastes, with waste tracking documents;
- Drilling companies and other firm must plan their wastes treatment and recycling and send back the products they didn't use;
- …

Table 2 is an excerpt of a typical environmental management plan applied to drilling mud and cuttings. Wether the mud is only water-based or contains chemical additives, the environmental impact will be weak or important. If the impact is weak, the mud and cuttings can be used as backfill materials. If it is important, they must be transported to landfill sites.

Stage	***Purpose***	***Mitigation measures***	***Applicable standards***	***Cost***	***Responsible operator***	***Start date***	***End date***
Preparatory work	Drilling mud and cuttings management	Suggestion of a waste management plan			Drilling company	Before work	
Drilling work	Drilling mud and cuttings management	Classification of materials based on chemical analysis		XX €	Drilling company	Commencement of work	
Drilling work	Drilling mud and cuttings management	Mud treatment (dehydration), Correct storage, Removal and destination according to the classification			Drilling company	Commencement of work	End of work

Table 2: Excerpt of a typical environmental management plan applied to drilling mud and cuttings

Wastes treatment and recycling systems

If the geothermal project is located in a territory doted with industrial wastes' treatment and recycling systems, these schemes should be used to take over the total waste generated by the project.

If the project takes place in an area which is not equipped with such systems, the project leader must be expected in the short term to ship the waste to an other territory or country.

However, with medium and long term considerations, these schemes may be created by sharing the geothermal project needs and those of other lines of business.

Treatment of geothermal plants' H2S gas emissions

Sheet n°17

H_2S gas emissions, which have important environmental impacts during the exploration phase and especially during the drilling phase, are part of this methodological guide about geothermal plants' projects. This sheet presents the different techniques used to treat gases and to reduce their impacts on the environment and the populations living next to the plants.

Introduction

Geothermal steam contains a mixture of gases that do not condensate at the same pressure and temperature than water vapour. They are called non condensable gases (NCG). These gases' composition differs for each geothermal tank but it is often a combination of gases where CO2, H2S and CH4 are dominating. Most of the time, the concentration of these gases during the vapour phase varies between 0.5% and 3%. This concentration can exceed 20% at vapour phase in some specific sites, like in Turkey for instance.

After having passed through the turbine, non condensable gases are drawn with the steam into the condenser. In this one, the vapour is condensed, but non condensable gases remain at their gaseous form. Therefore, they have to be removed from the condenser. If they are not, they can accumulate and downsize the cooling capacity. If the cooling capacity is downsized, the turbine's efficiency is reduced and so is the production of electricity. Gas rejection systems (ejector venturi scrubbers), using a vapor fraction, are installed to extract these gases from the condenser. The use of a circulation pump can also be considered, but it represents a substantial investment that cannot always be justified.

These non condensable gases occur in small amount, but they contribute (to some extent) to the greenhouse effect. Therefore, geothermal plants must reduce their discharges into the atmosphere as much as possible. This imperative fosters research and development of new methods to catch these gases and to safely reinject them into the underground.

Hydrogen sulphide H_2S

Hydrogen sulphide gas (H2S) is a toxic gas present at low concentrations in the non condensable gases mixture. The most present one is carbon dioxide CO2. In term of toxicity, H2S gas is similar to carbon monoxide (CO) and hydrocyanic acid (HCN). When it comes in contact with hemoglobin, it replaces oxygen (O2), leading to asphyxia.

At very low concentrations (a few ppb), H2S smells like rotten-egg. This odor disappears after 75 ppm. H2S constitues a serious risk to human health when its concentration exceeds 100 ppm. Low altitude lands in very active geothermal areas are exposed to higher risks since gases are more present and slightly heavier than air.

Furthermore, H2S is a corrosive gas, which have a strong affect on copper and silver. This affect cannot be ignored since it can seriously damage electrical and electronic devices. Therefore, specialized methods for air purification are often implemented in geothermal plants to protect vulnerable facilities such as monitoring rooms.

Capture and storage of H_2S gas

H2S gas emissions are natural in volcanic regions and other areas of geothermal activity. The industrial use of geothermal energy poses the problem of their releasing, since H2S gas can be discharged at strong concentration in a unique point. In certain cases, this concentration must be reduced within a given radius of the geothermal plant, to minimize its potential impacts (particularly on electronic devices). It means expensive investments that affect the overall budget of the project.

The most common capture method of H2S gas consists in oxidizing it to obtain a sealable product such as sulphuric acid ((H2SO4) or solid sulphur. However, the market is flooded with these products. New long-term storage methods are being studied. One of these methods consists in dissolving H2S in some water and reinjecting the mixture into the geothermal tank, where it attaches to the basaltic rocks' minerals.

Cleaning processes of non condensable gases

The gases' cleaning is part of the geothermal production cycle; it comes after non condensable gases' capture. This processus can be achieved using water or amine compounds. The scrubber pumps, which speed varies according to the equipment between a few kWh and hundreds of kWh, requires energy.

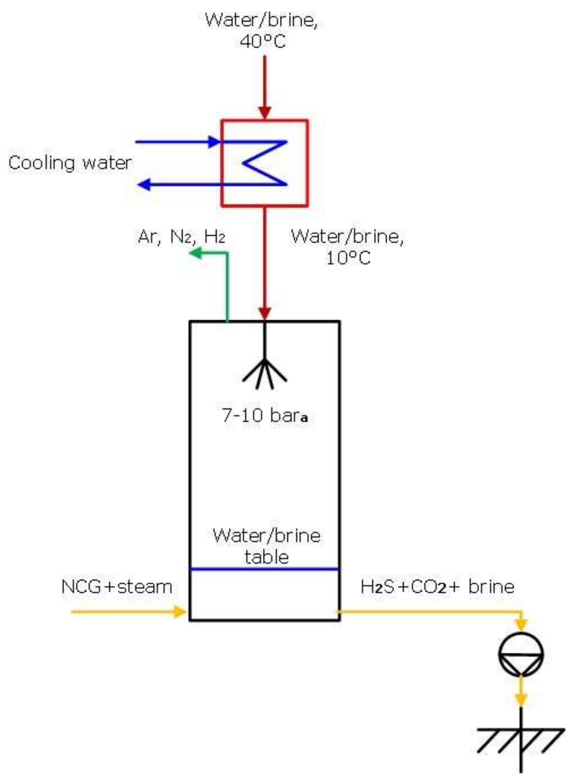


Figure 1: Diagram of the water-based non condensable gases cleaning process

Cleaning gases with water

This cleaning technique consists in injecting non condensable gases at the bottom of a spray tower, where they are sprayed with cold water or high pressure glycoled water (most of the time at 7-10 bars). H2S and CO2 dissolve in the mixture. However, gases such as nitrogen (N2), argon (Ar) and hydrogen (H2) are insoluble and can be eliminated at the top of the tower. The mixture of water and dissolved gas accumulates at the bottom of the tower, where it is pumped to the nearest injection shaft. Figure 1 is a diagram of the water-based cleaning process.

Cleaning gases in canalisations

This cleaning process is similar to the previous one. It requires less cleaning equipment, but it is not suitable for large plants. Non condensable gases are mixed with the liquid phase in a canalisation using an agitator. Agitation eases the solubilization of H2S and CO2. Before the reinjection stage, other non condensable gases are separated from the liquid phase in a separator and then released into the atmosphere. Through this method, it is possible to capture and reinject approximately 70% of the H2S at relatively low cost.

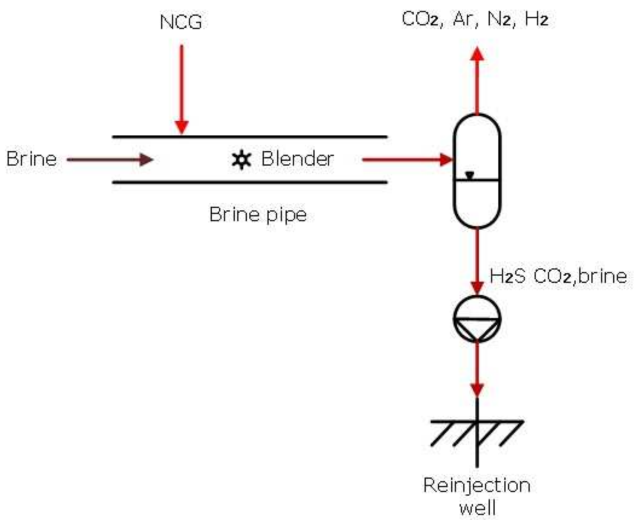


Figure 2 : Diagram of the gas cleaning in canalisations

Cleaning gases using anime compounds

Cleaning gases with amine compounds is a more complex processus, which requires a spray tower and an air separator. Figure 3 is a diagram of this cleaning process. The pressure level of the cleaning is 1.5 bar. The gases are guided towards the spray tower where an anime compounds based solution is sprayed over them. Then, the gases move to the top of the tower by themselves. Amine compounds are alkaline compounds and naturally bind to acid molecules such as H2S (or in certain cases to CO2). The chemical compound thus formed falls to the cooling tower.

Amine compounds used in this method are, for instance: diglycolamine, methyldiethanolamine or diethanolamine. The amine compound with the dissolved gases is then warmed up through a heat exchanger. Afterwards, it is directed towards a separator where it is vaporized, releasing the H2S gas.

The gas moves to the top of the separator, and the amine compound falls to the bottom. The amine compound is warmed up one more time, in order to remove any trace of CO2, then pumped again through the heat exchanger, and finally directed towards the spray tower where it starts a new cycle. The H2S gas is captured and compressed at the reinjection pressure level, and then mixed with a liquid phase for the reinjection.

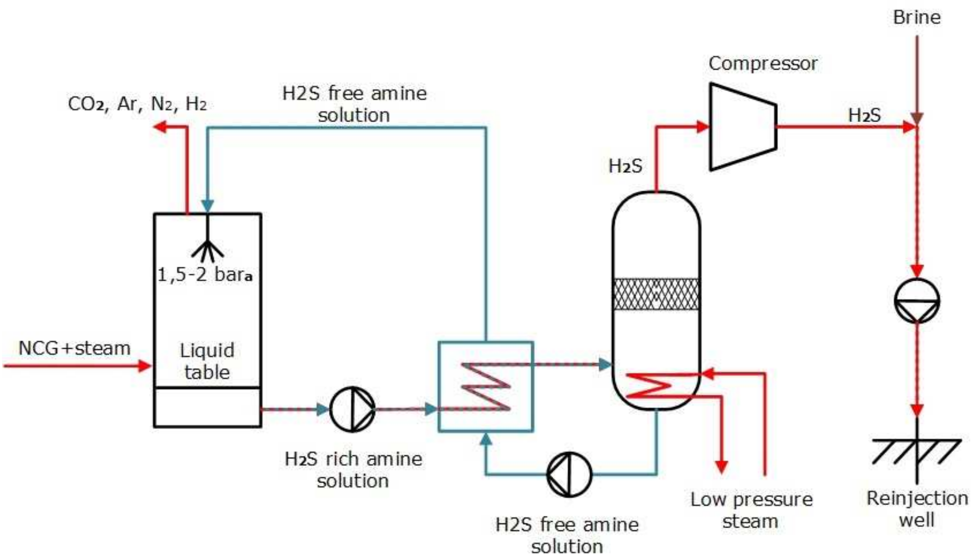


Figure 3 : Diagram of the gas cleaning using amine compounds

Technology	***Pros***	***Cons***
Cleaning with water	Adapted to large-scale use Removes 70-80% of H2S gas	Not as efficient as cleaning with amine compounds
Cleaning in canalisations	Easy to implement on a small scale Removes up to 70% H2S gas	Not as efficient as cleaning with amine compounds or water Cannot be adapted to large-scale use
Cleaning with anime compounds	Very efficient, removes 99% of H2S gas	Complex Specific amine are expensive In case of a leak, amine will have toxic effects on aquatic life

Table 1: Comparison of the various cleaning techniques of non condensable gases

H2S gas elimination and spreading processes

After non condensable gases have been cleaned and when H2S gas is extracted, there are three main gas elimination and spreading techniques:

- Fixation in soil
- Dissolution in the atmosphere
- Production of sulphur and sulphuric acid

Technology	*Pros*	*Cons*
Dissolution in the atmosphere	Adapted to large-scale use Low cost technique	Solves only local problems Depends on weather conditions Aesthetic aspect of the smokestack
Fixation in soil	High success rate (Sulfix project) Long-term storage	High investment: reinjection well, pumps, etc. Requires to find geological horizons adapted to reinjection Clogging of the reinjection wells due to mineral precipitation
Production of sulphur and sulphuric acid	Pure sulphur is used in the production of fertilizers Sulphuric acid is used in industrial processes	Abundance of sellers on the market Low price High shipping cost May pollute water reserves

Table 2: Comparison of the various H2S gas elimination and spreading techniques

Dissolution in the atmosphere

Releasing H2S into the atmosphere may corrode and damage the plant's electrical devices. People living near of the plant may also be affected by the pollution, most particularly people with respiratory problems.

These impacts can be attenuated by releasing gases into the atmosphere far away from the geothermal plant, so that there is sufficient dissolution for the people and devices next to the plant not to be affected. This can be achieved by using a chimney, which should be placed in an aerated place for an ideal dissolution of gases. This method does not require any cleaning of the steam, which is fully evacuated through the chimney.

Fixation in soils

This technique consists in reinjecting H2S dissolved in glycoled water into a basaltic rock formation so that the gas can bind with minerals for a long-term storage. The geothermal plant of Hellisheidi, Island, uses this technique, which is showing promising results.

Production of sulphuric acid

An alternative method consists in producing sulphur and sulphuric acid from H_2S. Sulphur and sulphuric acid are used in many industrial processes. Even if the local competition in this field is scarce, shipping costs may be prohibitive.

The most applied processus for pure sulphur (S) extraction from H_2S is Claus's. This processus is divided into two stages, thermic and catalytic. During the thermic stage, H_2S reacts with oxygen when combusted at 850°C as follows:

$10\ H_2S + 5\ O_2 \rightarrow 2\ H_2S + SO_2 + 7/2\ S_2 + 8\ H_2O$

During the catalytic stage, an external catalyser (most of the time titanium or aluminium oxide) is used to provoke the precipitation of sulphur from sulphur dioxide, which was a byproduct of the thermic stage.

$H_2S + SO_2 \rightarrow 3\ S + 2\ H_2O$

This processus is reliable and efficient, but the investment is very high since it requires very specific equipment.

Consultation with people and associations affected by geothermal projects

Sheet n°18

Summary

Being open to dialogue when elaborating a project is not a requirement, but is wise since it facilitates its local acceptance. The first step of this social dialogue, which must take place at the very beginning of the project (recognition phase), is to provide general information to local people and actors about geothermal, about the project itself, to answer the questions and to ease the concerns. The dialogue must be maintained throughout the life of the project.

The dialogue

Point of the dialogue

→ From the recognition phases, beyond regulatory proceedings required to execute the project, the future operator of the geothermal plant must enter into the dialogue, in order to ensure a maximal commitment of the local population, associations, politicians. This commitment is a guarantee of the project's success, and it limits the risks of opposition.

→ This dialogue is an opportunity to explain what geothermal consists in (this power source is still relatively unknown) and how does a project takes course. People tend to have concerns, doubts and even misconceptions, therefore answering their questions as soon as possible is the best way to avoid local opposition.

→ The dialogue must be carried on all along the life time of the project, until its conclusion, through public information meetings or open house to give account of the operator's respect of its Environmental and Social Management Plan (ESMP).

→ Local actors have a detailed knowledge of the territory and are likely to provide many information to the project initiator. Dialoguing with these actors during the project's preliminary and recognition phases allows to take into account very soon local issues in planning and choosing the plant's location.

Progress of the dialogue

→ To dialogue with people and association about a geothermal project means:

- communicating and informing, through public meetings, newsletters, using all available media (internet, newspapers, radio, …),
- coordinating, by exchanging with local actors and considering the whole territory in the project planning.

→ The coordination must take account of regular public consultations, occurring at every stage of the project and involving:

- the local population and the surrounding communities, during public information meetings, which are an opportunity to explain geothermal's pros and cons and this energy source's environmental impacts

the elected representatives, officials and environmental associations, in order to refine the plant's location choice, depending on the project's impacts on the environment and on local economic development

The dialogue should be initiated by the project owner, who may call on the assistance of specialized consultants.

Two entities can be created to carry out the consultation properly and to gather every opinion:

- *the steering committee*
- *the participatory committee*

The steering committee

In order to ensure the success of the project, the steering committee must associate as a minimum the following actors:

✓ *the project owner,*

✓ *the project architect,*

✓ *the consultants,*

✓ *the investors, the policymakers.*

The participatory committee

•*It must at least include members of the steering committee and the following people:*

public authorities: territorial organs and entities, state and public establishments, local professionals, associations and organisms working for conservation of biodiversity, delegates of the surrounding communities, scientists and qualified individuals

•*This participation committee will be involved in the project's major steps and will take part to the most important decisions, in order to ensure their approval by as many people as possible.*

•*In addition to these intra-committee dialogues and exchanges, the consultation must result to a communication strategy targeted at the general public, which aim is threefold:*

✓ *inform the population,*

✓ *gather enough elements to draw up an assessment of the environmental, cultural and historical situation,*

✓ *find out people's opinion about the project.*

Communication is a central issue, that forms part of project's development. It allows to demonstrate the project's validity and to collect information on how people perceive the project.

•*All along the process, the project initiator must oversee the application of the following principles:*

✓ *transparency, by giving people access to all data about the project, providing explanations when some information cannot be made available (ex: technological secret) and by clearly identifying the position of every involved actor.*

everyone should be able to understand the project; therefore, documents should be popularized before their publishing

✓ *being attentive, by adopting an attitude of openness and recognizing the stakeholders' ability to make suggestions and criticisms liable to lead to the adoption of alternative solutions.*

Plan of the consultation: communication tools

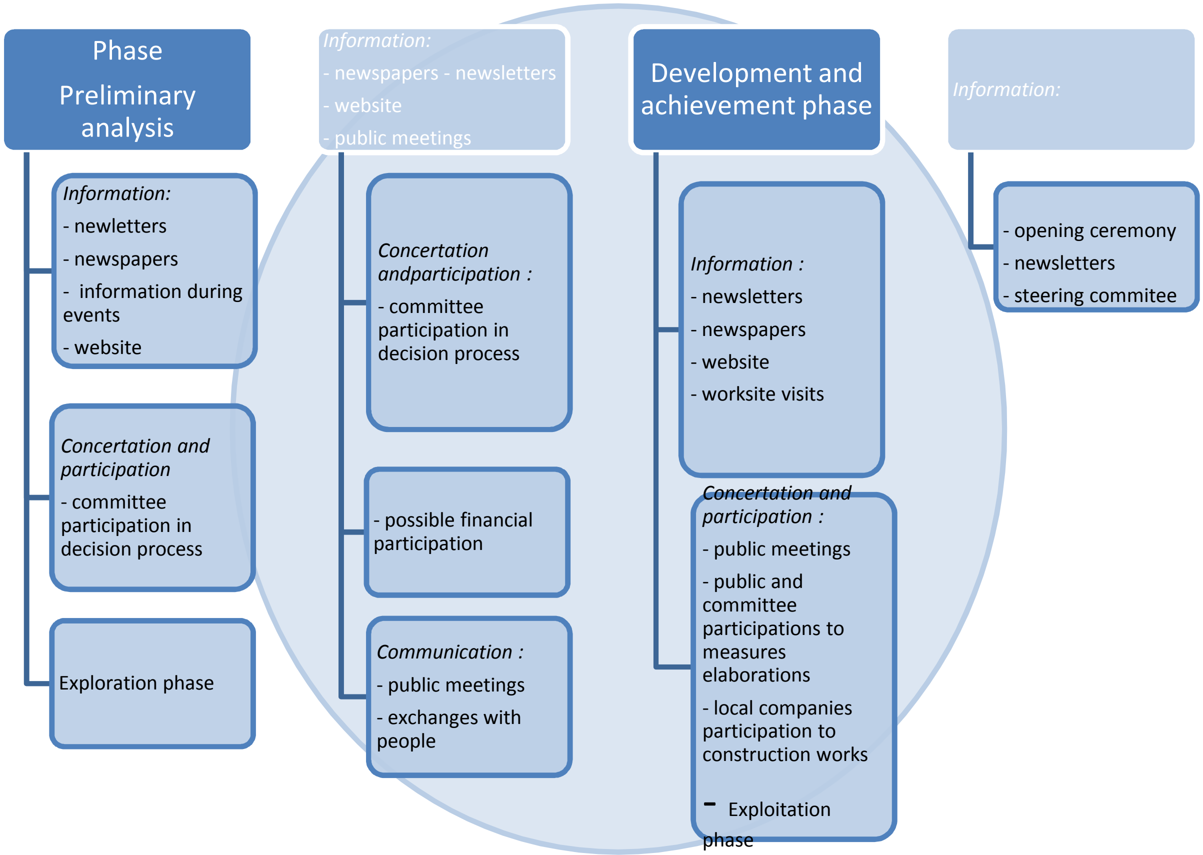
The following table presents the most adapted tools to communicate about a geothermal project. In addition to these classical tools, as outlined above, working with partners to inform people and collect feedbacks can be an excellent way to optimize performances. In order to reach as many people as possible, the project leader must use many different communication and listening tools, and resort to them according to the targeted audience.

Synthesis of the different communication tools

Tool	Target audience	Goal	Communication support	Lifetime	Pros	Cons
Public meeting	Interested audience	- Communicate about the project; - Dialogue with the population; - Answer the questions; - Gather opinions, comments, criticisms	Oral presentation, PowerPoint, movie, animation	All along the project's life	• Presentation of the project (- Questions and answers)	Only reaches a few people
PowerPoint presentation	People attending to public meetings	- Provide clear information for all ; - Provide synthesized information	Electronic document (PowerPoint), easy to project at public meeting : few text but oral presentation	During public meetings	- Clear and concise information; • Pedagogic; Fosters discussions	- Synthetic, and therefore lacks of details - Specific usage
Surveys, questionnaires	Everyone	Having a good idea of how people perceive the project	Simple questions on sheets of paper, and envelopes ; online questionnaires	All along the project's life	- Direct feedback of public opinion; - Large number of opinions; - Ability to retrieve statistics	- May be long to administer; - Retrieved statistics only represent 5 to 10% of the population
Opinion poll, telephone survey	Representative panels	Having a good idea of general public's perception of the project		During and after preparatory phases of the project	- Good overview of public opinion; - Ability to monitor public opinion variations	Need to use a service provider to select which population to question
Press release	Everyone	Inform people about the project's progress	Newspapers, radio, TV, website	All along the project's life: • when a new step has been taken on a regular basis	- Reaches many people; media can dedicate special dossiers to the subject (the press release serving as a pretext)	- No feedback; - Media may decide not to publish articles about this topic
Websites	Web users	- Facilitate access to voluminous and rich information - Update data about the project		All along the project's life	- Ability to update data; - Allows to provide voluminous date (files to download)	- Does not cover the whole population (particularly older and low income people) - Risk of hacking

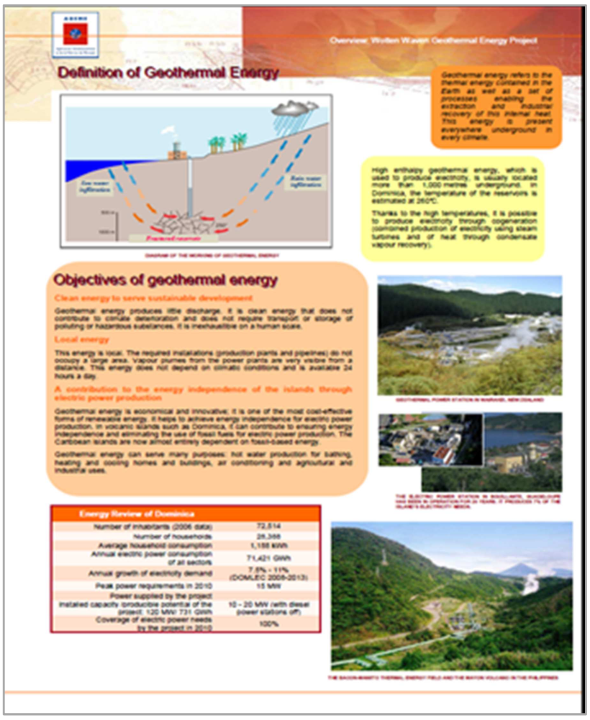
Tool	Targeted audience	Goals	Communication support	Lifetime	Pros	Cons
Forum	Web users	Fosters active participation, encourages people to give their opinion	Websites	During and after the project	- Makes easy for people to give their opinion about the project and to join the debate; - Web users can join the debate from home	- Requires an admin to avoid spill overs; - Requires to be reactive to questions and comments
Debriefing about the worksite progress	- People impacted by the project; - Many interested people	- Inform people; - Gather opinions	- Dialogue with the worksite manager Overview of the worksite; Information panels	Before and during the drilling and construction phases	- Quality information, supplemented by the opinion of a responsible person; - Next to the worksite (allows a better visibility of the project)	- May only attract people already interested by the project
Open doors operations ; visits of the site	Interested people	- Inform people; - Discussion between general public and professionals	- Oral (questions to workers; - Visual (visit of the facilities).	During drilling and constructing operations, during working operations	- Allows to open the worksite to general public, to demystify it - Workers are reliable and available for discussion	- May only attract people already convinced by the project; • Supposes that the workers have sufficient knowledge of the project Only the execution of the project is emphasized
Video	Web users, people watching the video during a visit, a meeting	- Inform people • Pedagogic, even ludic People get a better picture of the project	To be associated to a conference, a meeting or a website	All along the project's life	- Provides clear and concise information - Pedagogic, easy to understand	- Having enough material for a video requires the project to be already at an advanced state - Quite technical tool
Guestbook	People interested by the project	Allow interested people to leave a comment, an opinion	Bound document, available in official receiving sites, where an employee can open it and close it everyday	When the plant is operating	- « Supervised » mean of expression • Possible anonymity, no self-censorship	- People interested by the project, likely to move to the official sites to write in the guestbook • Subject to opening/closing hours Narrow crossing point
Opinion sheet	People attending to a public meeting	- Gathering tangible written opinions; - Encourage quiet people to join the debate	A simple one page document, possibly including a little questionnaire and a « free expression » part	During public meetings, where events take place (visits of the worksite/open doors; information office…)	- A way for quiet people to give their opinion Possible anonymity, no self-censorship	People interested by the project, likely to move to the official sites

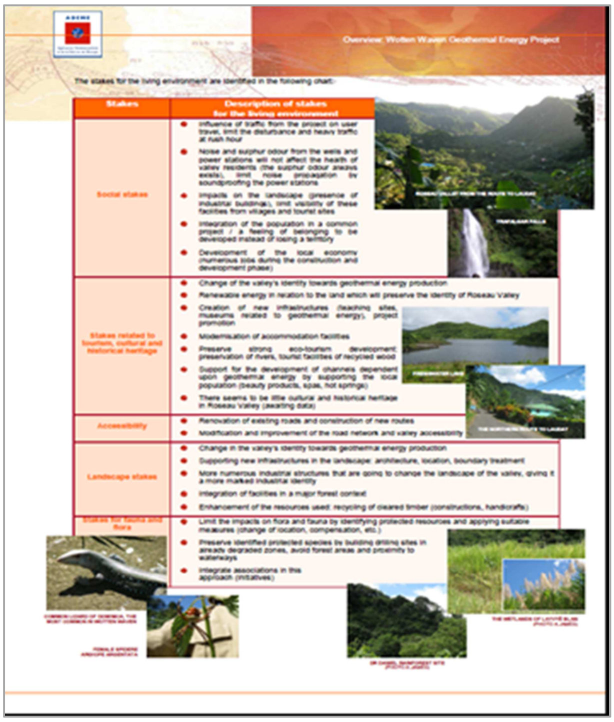
The following diagram presents the different phases of a dialogue, that can be associated to a geothermal project, on the basis of the tools previously presented



Communication supports

Several communication supports can be used to reach a maximum of people: letters, newsletters, local media (newspaper, radio, TV), websites, meetings. Here are some extracts of communication supports (case of Dominica).





Factsheet for everyone about geothermal *Factsheet about local issues linked to the project*

Source ADEME *Source ADEME*

The development of eco-tourist activities around a geothermal project

File n°19

Summary

The consultation and participation of the local players and the public in a territory project represent an important issue for the acceptability of the project. This consultation allows define the best possible project, and also the adapted accompanying measures, with the implement of an Environmental and Social Management Plan.

However, in order to reach the environmental excellence, the process should not concern just a production site, but must try hard to take advantage of this exploitation and the geothermal resources for developing local touristic activities.

Why developing the eco-tourism ?

→ The territory of the Caribbean arc owns a very substantial ecological, and the local populations are well aware of this. If they are rather for the geothermic as an energy allowing to favor the energetic independence of islands, they have still some doubts and fears facing this new technology.

→ In order to favor the acceptability of the power station and involve the local players in a participating project, the concept of a territory project can be developed. This concept must particularly lean on the resources linked to the project, like the geothermal water, whose everything or a part can be reused for other activities, depending on the reinjection or not of the fluid in the groundwater.

→ So, except the possible industrial applications, the geothermal water can be accentuated in some eco-touristic projects, like spa resort.

→ The population and the local governments will can be important to develop this type of activity, by consulting with the manager of the power station. These projects will can be managed by the local governments, with a technical support and an eventual financial support of the manager of the geothermal power station.

→ These touristic projects will can be of benefit to the local population, thanks to the created employment and the additional activities (hotel, food service industry, construction companies).
They also allow to make the big public discover the local geothermal resources often unknown.

Quels projets éco-touristiques développer ?

→The Caribbean arc already owns several touristic advantages, that are enhanced and that attracted several visitors all year long.

→ The eco-touristic projects, which are linked to the geothermic, still inexistent for the moment could materialize under the impetus of the local players.

→ Several types of projects are conceivable:

☞ Thermal centre,

☞ Geothermal discovery centre,

☞ Visits to operating sites,

☞ …

Thermal centre

→ Some examples of thermal centers using the local geothermic resource already exist, like in Switzerland (Bad Schinznach, Lavey-les-Bains) and in Iceland, with the Blue Lagoon site, which is fueled by the water of the geothermal power station of Svartsengi, and containing particularly an artificial lake with water heated to 37-40°C.

→ This type of installation is possible when it is considered to reuse the geothermal fluid while it is forecasted to be release in the nature, and not reinjected.

Although the reinjection principle is recommended to avoid the seismic risks and the subsidence risks, a part of the fluid may however be used, for thermal resorts with smaller scale than Blue Lagoon.

→ Moreover, the local context of the Caribbean islands make difficult the implementation of big scale projects, because of the sensitivity to the natural environments, and the availability of substantial size fields.

→This concept of small-scale health resort can also be considered in relation to hotel complexes wanting to enhance spa resorts (spas, pools).

Thermal centre Blue Lagoon in Iceland

Thermal baths of Bad Schinznach in Switzerland

Geothermic discovery center

→ This type of project can be implemented directly linked to geothermal power station.

→Indeed, the purpose of this type of centre is to present the geothermal energy and its applications to a large public (local population, tourists, schools, …), leaning on skilled specialists of the power station operator and on local organizers.

→ These centres welcome exhibitions (models, reconstruction of the functioning of a power station, videos,…), conferences, pedagogical animations for students, and can lean on visits of the exploitation itself.

→ Some projects of this type are ongoing, particularly geothermal energy's houses at Bouillante in Guadeloupe and at Wotten Waven in Dominica.

→ An information center on geothermal energy exists in Soultz-sous-Forêt, linked with the experimental geothermal power station.

→Some temporary exhibitions can also be organized during local demonstrations.

Caribbean center project of excellence in geothermal energy

In the framework of the Geothermal Caribbean 2 project, a project of a Caribbean center of excellence in geothermal energy is being reviewed.

The creation of this center could allow establishing in the Caribbean a international competences heart regarding the geothermal energy in volcanic context.

It would be destined to undertake the followings missions:

- Supporting Research and Development projects accompanying industrial production projects of geothermal electricity in the Lesser Antilles;

- Delivering training courses (higher and professional education);

-Conducting communication/information actions (exchange between the industrial players and the research players);

- Insuring international exchanges (West Indian arc and Central America) .

Visits to operating sites

→ According to the steps of the project and the security rules for welcoming the public, some visits of electricity production installations from geothermal energy can be realized.

→ These visits will be able to be undertaken regularly in relation to local tourist offices, or punctually during open days. These visits will enable everybody to discover the « behind the scenes » being escorted by a local expert.

→ Countries like Iceland or Costa Rica, especially ahead regarding the use of geothermal resources, particularly put the ecotourism forward.

→ New Zealand develops also tourism activities as Rotorua village, the main tourist destination of the North island of New Zealand after Auckland, and which offers animations and installations around the local geothermal activity.

→ This development of eco-touristic activities can therefore be the conclusion of a geothermic project as a whole, and the federating factor of the territory project for the local and resident players.

The direct and indirect economic consequences of a geothermal project

File n°20

Summary

The main advantage of a geothermal power station project is the production of electricity from a local power source, renewable and environmental friendly particularly regarding the greenhouse gas emissions. It generates also indirect consequences that can be good from an economic, environmental and social standpoint.

The subject of this record is to present briefly the advantages of a geothermal project for the territory on which it is set up.

Introduction

For centuries the geothermal sources have been used for bathing, recovery and cooking. This is only from the beginning of the 20th century that the population began to consider the heat in the earth's interior as a power source with a high potential.

The geothermal energy is considered as a renewable energy to the extend that the heat flow coming from the radioactive decay is durable. Although the production of geothermal power is depending on the capacity of a reservoir, the extracted fluid can be reinjected, making its utilization durable when it is generated in an appropriate manner.

The geothermal electricity production has existed for more than a century and presents a technology commercially tested and mature, contrary to several other renewable energies. It uses classical steam turbines for which the risks of operation and maintenance are well controlled. The Figure 1 shows a comparison between the costs of electricity production from different sources of renewable energies or fossil fuels.

The advantages of the geothermics for the energy production are important and they can be classified in term of economic, environmental and social advantages.

The economic benefits

When the geological conditions are favorable, the geothermics offers economic advantages that are obvious for the electricity production. Compared to the production of electricity from fossil fuel, the geothermal power stations have a relatively high initial investment per unit power. However, their low operationing costs, based on the absence of costs linked to the purchase of fuel as well as their high availability turns into one the most affordable and durable technologies.

On the long lifetime of the plant, the low operationing costs counterbalance the high investment costs. Once the power station is functioning, it can produce electricity for 30 or more years if the utilization of the geothermal resource is managed in a sustainable way. Since it is independent from the price of the fossil fuel, the geothermal energy provides with excellent protection against the bump of the fossil fuel's price and contributes to the energetic security of a country.

Compared to the other renewable energies, it can be used on a 24hour/7day basis and provides with a permanent power, whatever the climatic conditions.

The operation of useful by-products can also improve the economy of the geothermics, like for example the salvage of precious minerals in the geothermic brine such as lithium, zinc, high-quality silica and gold in some cases. Besides, the geothermal fluids that are rich in carbon dioxide are sometimes used for the production of liquid carbon dioxide reserved for the foodstuffs industry (beverage) of the forcing in the greenhouses.

The economic feasibility of the geothermal projects can be considerably enhanced if the cogeneration or the cascading utilization is possible. This is realized for example when the plant is used for generating both electricity and heat or when the fluid outlet of the plant can be used for another direct-use geothermic application like for example the heating or the air conditioning, the balneotherapy, the laundry, etc…

The geothermal power stations present several direct advantages such as the creation of permanent and temporary employments, taw revenues,… Moreover, a geothermal plant can have indirect consequences on the social and economic development of the local community. It includes, for example, a balneotherapy and eco-technologic tourism development that can contribute to enhance the services and infrastructures.

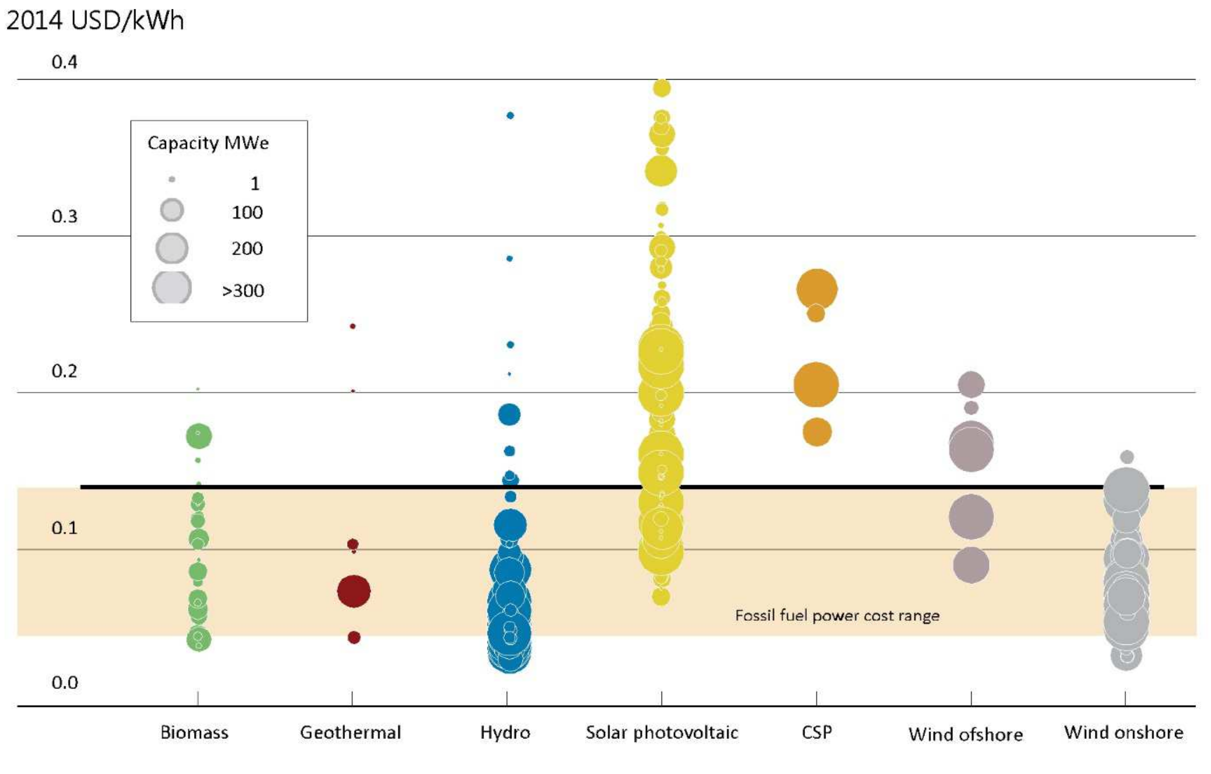


Figure 1 : Electricity production costs (global cost) from renewable energies compared to the generation from fossil fuel. Source : Renewable energy cost of production in 2014, IRENA, 2014

Notice : The size of the circle diameter represents the size of the considered project. The center of each circle is the value for the cost of each project on axis Y. The actual weighted average cost of capital is 7.5% in the OECD countries and China; 10% in the rest of the world.

The advantages for the environment

In terms of the environment, the advantages of the development of the geothermal energy are not contestable. We can summarize them as following:

Greenhouse gas emissions very low compared to the electricity production from fossil fuel;

- Lesser carbon gas emission than power stations being supplied with coal or petroleum;
- Small called up;
- Limited impacts on water and biosphere;
- Reversible effects in the long term;
- Relative environmental impacts that can besides be again distributed by cascading uses;
- …

During the geothermal electricity production there is no combustion process producing carbon dioxide. The direct emissions come from gas naturally present in the underground reservoir. On the contrary the electricity production by combustion of fossil fuel like petroleum, gas, coal, release greenhouse gas that are responsible for the global warming. Thus, one of the main advantages of the geothermal energy is that it contributes to reduce the global warming.

The fossil fuel creates pollution risks during their transport over long distances. The geothermal energy is locally exploited and reduces these pollution risks.

The geothermal power stations need lesser area than hydroelectricity, coal or nuclear. We cn compare also the needs favorably with them of wind or solar.

In general, the negative environmental impacts linked to the use of geothermal energy are minor. They are specific to sites and technologies used and considerably manageable. The production of geothermal fluids can create variable quantities of greenhouse gas but that remain globally low. The figure 2 shows a comparison from greenhouse gas emissions during the electricity production per different power source, measured in equivalent CO_2 per kWh produced.

Because of their limited influence on earth, it is possible to combine harmoniously a geothermal plat with other uses of fields. After the construction of the power station and associated wells, the around areas allow the pasture of cattle or other agricultural uses in several cases. Some geothermal power stations are even neighbor of « National Park ».

The potential negative effects of the extraction of geothermal fluids from the underground reservoir, such as the resulting seismicity and the subsidence phenomenon of the earth can be minimized by some good practices such as the fluid reinjection. Somme good practices can also optimize the use of water and earths, and preserve the natural thermal demonstrations, which are appreciated and often enhanced by the local community (spa).

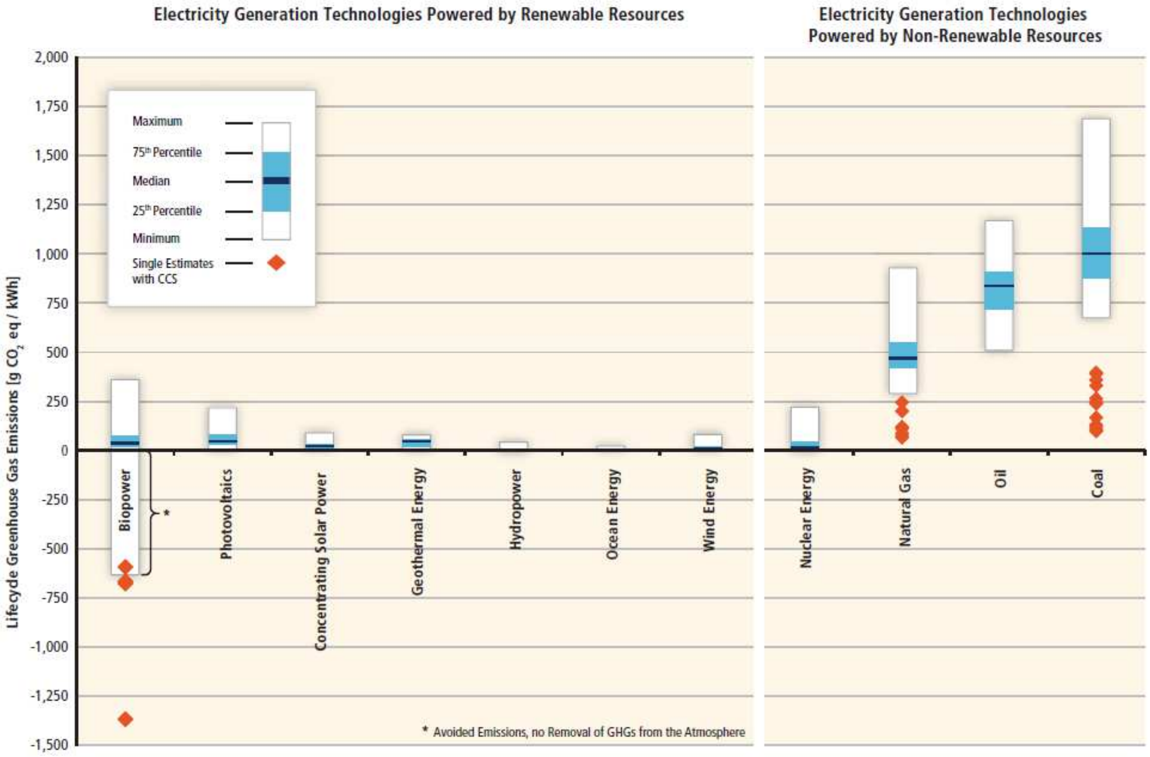


Figure 2. Lifecycle of greenhouse gas for different electricity production sources.
Source: Special report of GIEC on the renewable energies and reduction of climate change, GIEC, Geneva (2011).

The social advantages

The projects of geothermal development can generate indirect consequences that impact the life of the populations, their culture, their services, etc… These impacts can be applied to the local, regional or national level. Among these consequences, we can quote:

- The improvement of life conditions;
- The education and the reinforcement of competences;
- The development of new sources of revenue;
- The improvement of infrastructures and services;

Some geothermal companies and governments have mentioned the social issues by the improvement of the local security, the construction of roads, schools, medical centers and other buildings for the community, which can be funded by some contributions of the profits coming from the power station during its functioning.

These indirect consequences make easier the social integration of the project and complete the main social advantages brought by the creation of employments throughout the life of a project.

REGION GUADELOUPE

PROGRAMME INTERREG CARAÏBES

l'Europe s'engage avec les Antilles-Guyane dans la Grande Caraïbe

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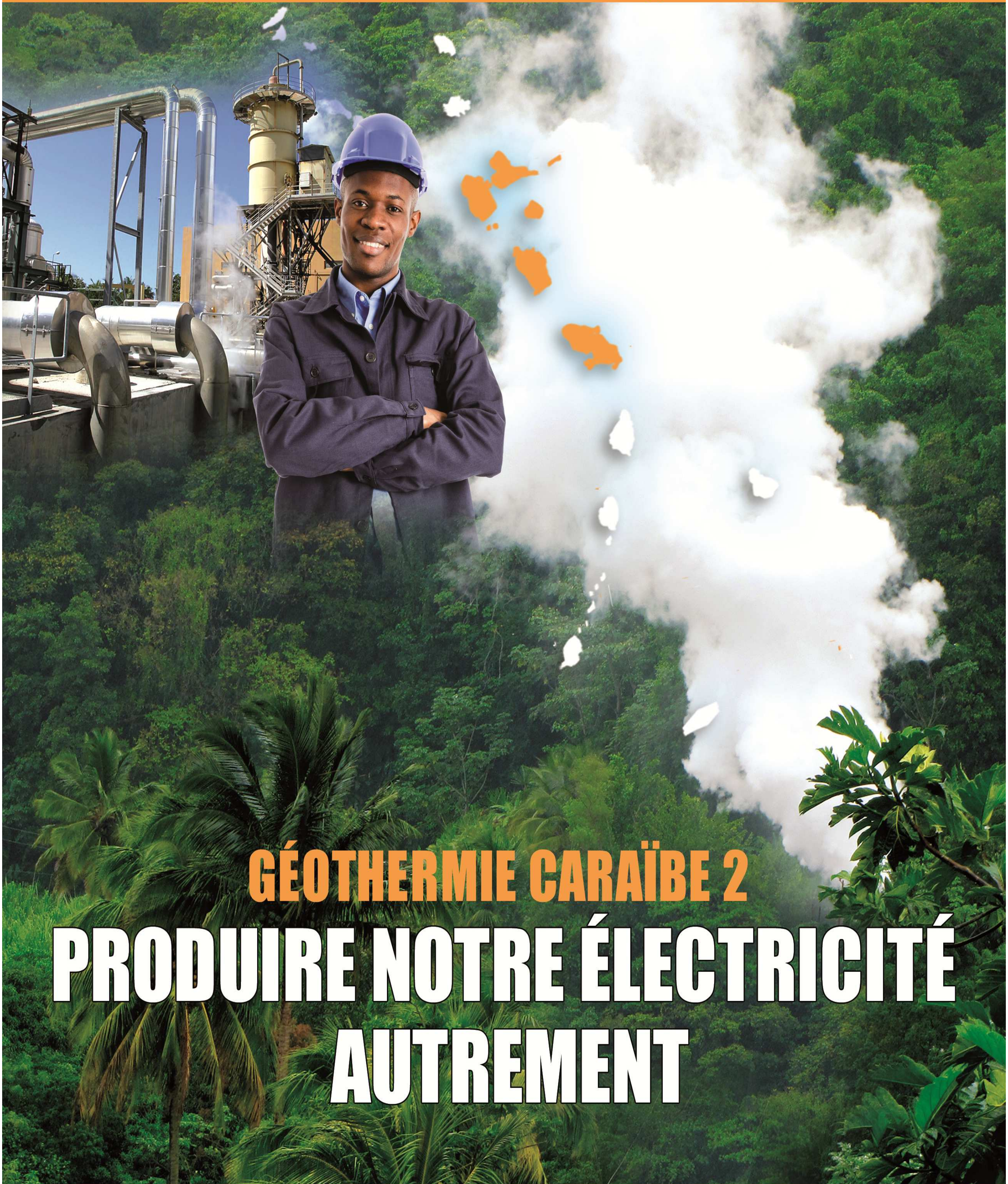

GÉOTHERMIE CARAÏBE 2

PRODUIRE NOTRE ÉLECTRICITÉ AUTREMENT

Région Martinique

ADEME Agence de l'Environnement et de la Maîtrise de l'Energie

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