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Best practices and geothermal NIMBY interventions

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Executive Summary

Geothermal energy stands as a vital strategic resource, yet encounters various obstacles, notably social resistance. The profound impact of social acceptance should not be overlooked; its absence can significantly impede development and potentially harm the entire geothermal sector at national level. The perception of geothermal energy by local communities is influenced by several factors and local specificities. However, the lack of awareness on risks and benefits linked to projects and the poor knowledge of the technology are among the main factors that negatively influence the perception of local communities.

This report aims to provide a review of previous experiences and strategies implemented or suggested to raise the acceptance of geothermal projects and prevent the NIMBY syndrome in Europe and globally. The ultimate objective is to establish the basis to elaborate and implement a method with the same purposes, within the COMPASS project. Case studies from eight European countries and seven countries in other continents were considered. Information was extracted from the literature (scientific publications and reports from European-funded projects) considering a description of the background of each case investigated, actions implemented or proposed, results achieved, and lessons learned.

The main outcomes from this study allow to highlight the importance of a transparent and bottom-up communication since the projects' early development, involving different kinds of local stakeholders. Local communities should be well informed about risks and benefits linked to a geothermal project. It is advised to use all the information means, including newspapers, and digital platforms like social media and websites. Then, it is necessary to involve local communities in decision-making processes of a project development and propose benefits such as the creation of jobs and direct uses of geothermal heat. Communication, engagement, and benefits are three elements that can contribute to achieve trust and a good public acceptance. If one of these three aspects is not considered and treated appropriately, there is a risk to lose the trust and the project can be contested. Acceptance is closely linked to local social and socioeconomical specificities and there are no standard procedures to address these challenges. Therefore, it is important to study local peculiarities before starting the communication and engagement process and update the approach periodically, since the perception on the same project may change over time.

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1 Introduction

Geothermal energy is one of the sustainable alternatives and amongst the most promising sources to meet the global growing demand of energy and effectively contribute to the transition towards a low-carbon economy. However, the geothermal development is constrained by several challenges, including social resistance (Bertani 2016). The acceptance of geothermal energy represents a multifaceted challenge, impacted by a range of socio-economic, environmental, policy, governance, economic, cultural, and geographic factors (Brohmann et al. 2006). However, one of the main reasons for a poor acceptance is probably the less familiarity with geothermal energy compared to other renewables and the resulting uncertainty over the related technologies (Allansdottir et al. 2019). To be widely accepted as a sustainable alternative to meet the climate change challenges, the integration of geothermal projects with social sciences and humanities is of paramount importance. In this framework, the COMPASS project, whose objectives also include maximizing the implementation and impact of the proposed technological solutions, needs to understand the industrial and societal needs for geothermal energy, considering the different aspects that influence acceptance. This will help to open a dialogue with stakeholders in territories that host geothermal facilities and provide inputs to develop sustainable concepts for geothermal energy deployment.

The lack of knowledge and negative perceptions that affect the acceptance should be addressed in a proper way and considering the local community as an obstacle may worsen relationships with local stakeholders and not provide an adequate basis for building trust (Balzan-Alzate et al. 2021). Social conflicts at the local level should not be underestimated as they may influence geothermal projects either directly, with action groups, or indirectly, affecting the political climate on geothermal energy production. In many cases public oppositions have delayed or even stopped geothermal projects (Wallquist and Holenstein 2015). In addition, echoes of contestations can damage the entire sector: contestations in Monte Amiata (Italy) reached the national Government and the European Parliament (Pellizzone et al. 2015), while opponents to a project in the Canton of Jura (Switzerland) collected signatures to call for a vote to ban deep geothermal (Ejderyan et al. 2019).

Since the social acceptance aspects are becoming an even more important topic for the project development, many operators are putting in place efforts to prevent contestations and the NIMBY (Not In My Backyard) syndrome. Many studies and examples in Europe and across the world explain practices to address social acceptance. Although all authors agree that appropriate and transparent communication is necessary from the early stages of a project, involving citizens and listening to their voices, and that acceptability is improved describing the direct benefits of a geothermal project, approaches used strongly depend on socio-economic, cultural, linguistic and geographic backgrounds.

This report is the result of a review on strategies to raise the risk-benefit awareness on deep geothermal energy projects and acceptance, with the aim of putting the basis to elaborate and implement a method with the same purposes, within the COMPASS project.

2 Methodology

The findings of this study are based on a systematic literature review of existing case studies and researches to raise the social risk-benefit awareness and acceptance to prevent the NIMBY (Not In My

BackYard) syndrome on deep geothermal energy projects, through the engagement of the civil society, local communities and public authorities. The methodology described below was discussed and agreed by the COMPASS consortium during specific meetings.

The work started answering to research questions on what, when, who, where and why actions involving different kind of stakeholders were implemented or suggested to:

a) face the NIMBY syndrome, raise the social risk-benefit awareness and acceptance on deep geothermal projects;
b) engage with the civil society to identify lessons learned, which examples can be considered best practices or not.

Boundaries of the literature review were set considering the following eligibility criteria, for the collection of information on existing experiences:

a) *Source of information*: EU funded projects results, report and publications on previous experiences, scientific publications, geothermal magazines, local/national/international newspapers;
b) *Geothermal technology*: deep geothermal, notably drilling activities power production and direct uses of geothermal heat, including district heating;
c) *Geographic coverage*: International, mainly focused at European level, whereas case studies in other worldwide countries were considered if relevant.

Concerning the source of information (see the Figure 1 for more details), suitable databases for the collection of case studies were identified and agreed within the COMPASS project consortium.

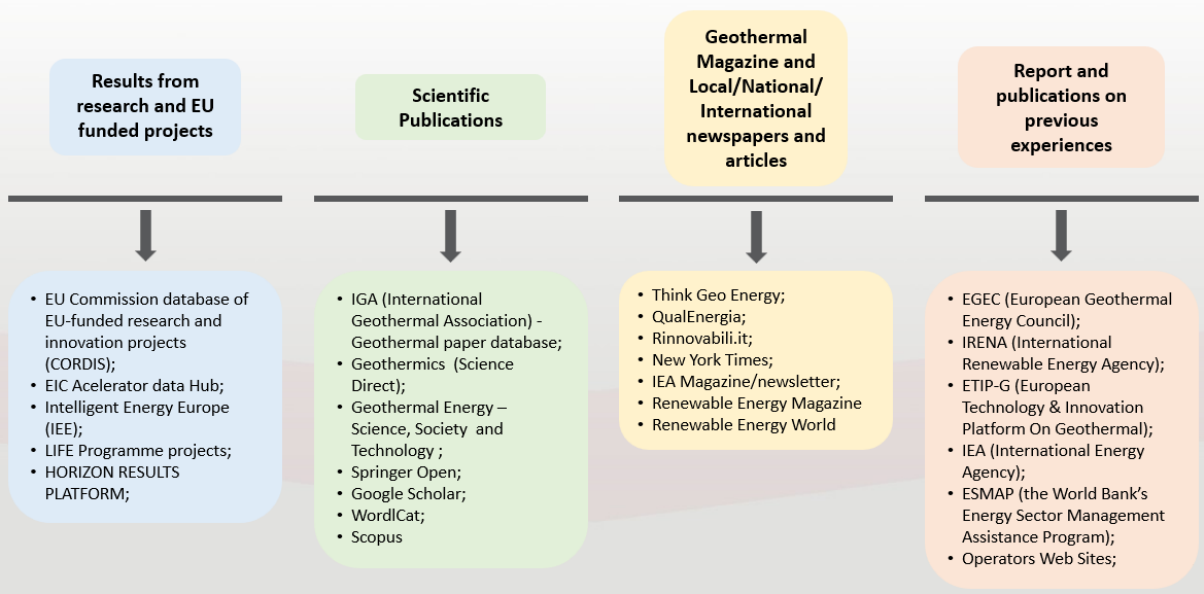


Figure 1: Source of information for the literature review.

The literature research identified more than 40 references on case studies in 15 countries (8 were European countries), from which the partners could extract the following set of information on the acceptance raising examples on deep geothermal projects:

1) *General information on the source of data*, which considered:

- *The reference type*, e.g., scientific publications, technical reports, research and EU funded projects, articles on magazines or newspapers, press release and information collected on operators or association websites;
- *References* of the information;
- A *web link* to the source of information;

2) *Data on the case study*:
   - The *case study title*;
   - The *country* of the case study;
   - The *deep geothermal technologies* concerned, e.g., electricity production, direct uses for productive processes or district heating, low or high temperature resources, drilling activities, other technologies or energy sources;
   - *General description of the case studied*;
   - *Description of the background and challenges addressed*;
   - *Description of the actions*;
   - *Targeted groups concerned by the actions*, e.g., politicians and policy makers, staff of public authorities, local communities, market actors, etc.;
   - If the *actions were implemented or not*;
   - *Description of the results achieved*;
   - *Description of the lessons learned*.

Results of this review, that extracted and collected data considering the elements reported above, are reported in Chapter 3 on studies and examples for raising awareness and acceptance.

Data collected were then analysed to identify strengths and drawbacks of the actions implemented or suggested, to propose tips for the planning of next COMPASS activities on social engagement and communication to the civil society.

3 Studies and examples for raising awareness and acceptance by country

3.1 France

France is the European market leader in geothermal district heating networks, with more than 70 plants, mainly concentrated in the Paris area. As far as electricity production, the most suitable areas are the area around the Central Massif, Alsace and the overseas islands. Two geothermal powerplants are currently in operation in Guadelupe and Alsace, whereas a further plant provides heat to a big starch plant in Alsace (Schmidle-Bloch et al. 2022).

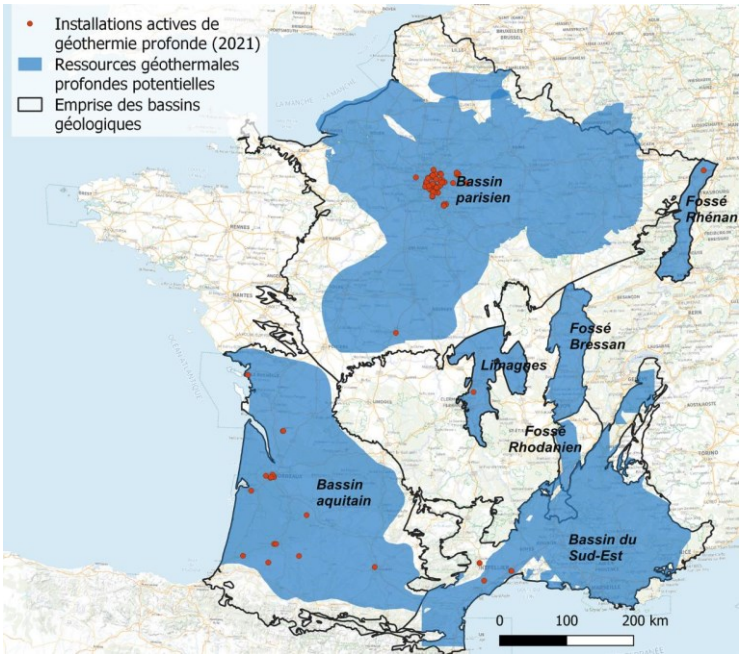


Figure 2: Mapping of deep geothermal resources in France (Source: BRGM).

Case studies considered for France are referred to the social acceptance towards deep geothermal projects in Alsace, notably near the French border to Germany (Schmidle et al 2019), in the northern part of the region and in the in the Metropolitan City of Strasbourg (Chavot et al. 2018), and in the Paris Basin (Schmidle et al 2019).

The case studies described by Chavot et al. (2018) were conducted within the Horizon 2020 DESTRESS project, an initiative aimed at demonstrating methods for enhanced geothermal systems, with solutions for a more economical, sustainable and environmentally responsible exploitation of underground heat. Part of this project examined the main social, cultural and political factors influencing the population's perception of geothermal projects and was based on views and reports related with the 2015/2016 inquiry, media reports and local newspapers, interviews of stakeholders and other observations. While in Northern Alsace geothermal energy is well accepted, projects in Strasbourg experienced contestations.

Two deep geothermal plants were in operation in Nothern Alsace in 2015 (Soultz-sous-Forêts, power and heat; Rittershoffen, heat production), six applications for exploratory drilling had been submitted to the prefecture, to build heat production only, or heat and power plants. Five of these projects, namely the sites of Robertsau, Eckbolsheim, Mittelhausbergen, Illkirch-Graffenstaden and Vendenheim, concerned the region around the city of Strasbourg and, according to results from a public enquiry conducted in 2015, the first was strongly contested by residents' associations, while the second and the third were opposed by municipalities. Reasons for these oppositions were related to concerns on the seismic and explosion risks, the reliability of the operator due to its lack of previous experience, the lack of compensations for the territories and the projects' failure to consider environmental and urban planning constraints. In addition, the lack of coherence of the projects and the choice of the plants location, with respect to local development plans, the aquifer and the distance from existing district heating networks, were contested.

In the case of the projects in Wissembourg, in the northern Alsace, and Illkirch-Grafenstaden, upstream discussions and partnerships between the operator and the municipal government have

reinforced the coherence of the project with local policy, facilitating the acceptance. Geothermal energy fits with long-lasting environmental policies and actions and sustainable economic development, consistent with local social identities in Illkirch-Grafenstaden and Northern Alsace.

The other research considered for this study (Schmidle-Bloch et al. 2019) concerns the social acceptance screening, through data analysis two geothermal exploitation projects in two unspecified small and medium municipalities in the Strasbourg area (municipality X and municipality Y)and a geothermal district heating in the Paris area. For Strasburg, the study considered media surveys, reports of public inquiry, congress communications and interviews organised with operational managers, local authority representatives and Geological State agency representatives. Documentation of public enquiry, communication tools developed by operators and interviews were considered for the Parisian case. Collected information allowed the authors to propose three actions that operators may undertake to increase the social acceptance towards geothermal projects:

1) Work on the relational part of acceptability: increase technological awareness and knowledge, demonstration of the expertise and sustainability of the operator to increase trust, proof of successful projects and communication of benefits linked to a deep geothermal project.
2) Work on the strategy and policy part of acceptability: understand local specificities, analyse the energy policy and calendar of the territory, find cooperation at early stages with public bodies, use trusted third-party to disseminate communication (NGO and associations), consider the political calendar for local elections, interact with citizens before carrying out a public inquiry, identify and promote the clear and visible local benefits.
3) Work on timing and networks: anticipate the communication, communication and strategy timing management, identification of the communication channel and of the trusted third-party.

3.2 Germany

At the end of 2021, 30 geothermal district heating plants were in operation in Germany, mostly in the Upper Rhine Graben and in Bavaria. Other facilities directly use deep resources for different purposes. Geothermal power plants are 11 and use the Kalina or ORC binary technology. They are in Bavaria and in the Upper Rhine Graben, while a good geothermal potential is available also in the northern sector of Germany, as reported in Figure 3, as well as in these two regions (Weber et al. 2022).

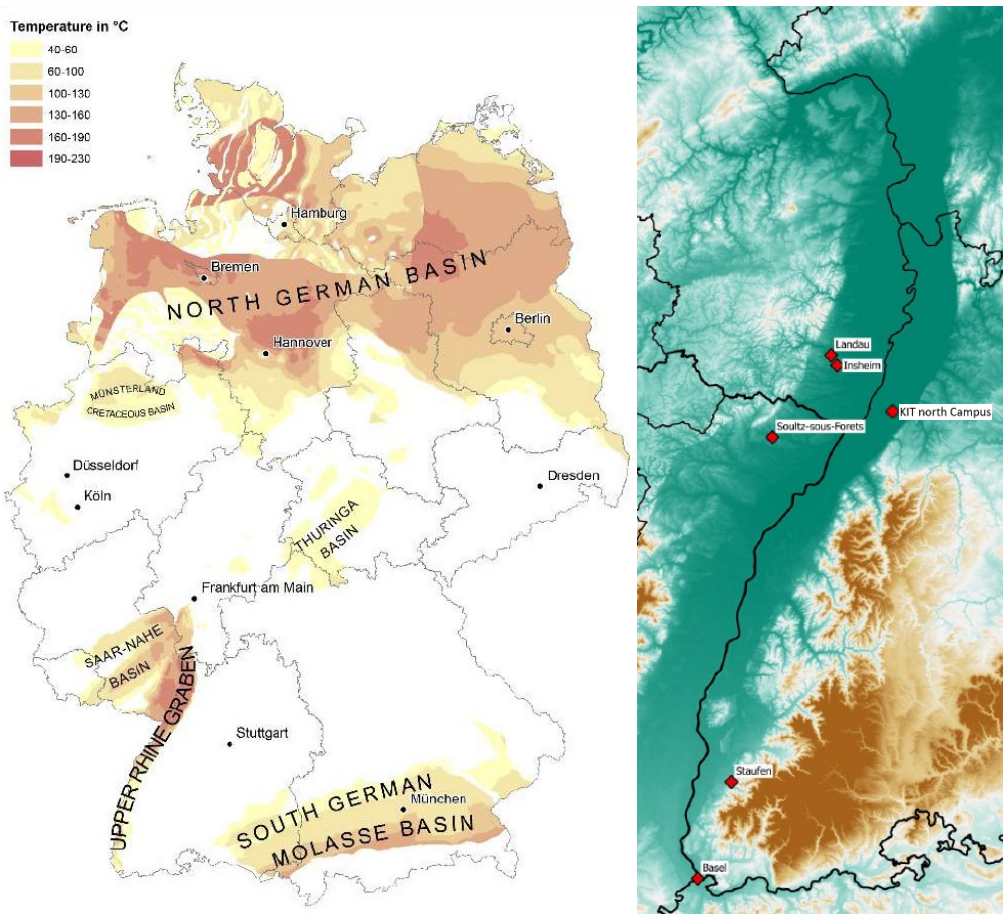


Figure 3: (a) Regions with hydrothermal resources in Germany (inferred and indicated) and associated temperature ranges (map from Weber et al. 2022), **(b)** The location of geothermal projects considered for this report (adapted from Douwe et al. 2016).

The German case studies concern initiatives to engage with citizens and co-design deep geothermal plants, such as the Trebur project, strategies implemented by the operator Deutsche ErdWärme in the Upper Rhine Graben area, at the border with France (Douwe et al. 2016; Deutsche ErdWärme website), and actions planned to liaise with potentially affected citizens by a heat-supply plant in the Campus North area of the Karlsruhe Institute of Technology (KIT) (Roesch et al. 2020).

Concerning the Upper Rhine Graben area, Douwe at al. (2016) reported that seismic events during the stimulations for the international geothermal EGS research project in Soultz-sous-Forëts, in Alsace (1988), triggered local discussions, but further operations were accepted after information on these events were provided. Therefore, geothermal development before the Basel seismic events in 2006-2007 was welcomed and widely accepted in the Upper Rhine Graben area. Furthermore, heaving and earthquakes during the drilling of 140 m wells for a heat pump heating system in Staufen (near Freiburg), and operation of the power plant in Landau (Rheinland-Pfaltz), in 2007 and 2009, were a setback for public perception in the whole area, without distinction between deep and shallow geothermal. Two types of groups active in the development of geothermal plants were identified, according to their intention and strategy:

- The local initiatives: open to discussion and settle agreements with developers, to achieve improvements in the geothermal energy production with acceptable effects for neighbours and the environment. They are organized in local networks and share experience and views.

- The action groups: their aim is to prevent geothermal projects, without interest in discussing with the operators and developers. They are formed and stimulated by one or more individuals and cooperate with other action groups at national and international level.

The **Trebur Project**, managed by Überlandwerke Groß-Gerau (ÜWG) in the south of the Main River and not far from Frankfurt, started the drilling phase with approval of the local communities, after a successful public engagement process, which consisted in:

1) A study on local stakeholders and their views on geothermal energy;
2) Public meetings to share information on the project and discuss;
3) Implementation of a stakeholder group to discuss on geothermal energy in all its aspects and consequences with more than 20 local stakeholders, amongst environmental protection groups, farmers, public institutions and individuals;
4) Report to summarise discussions and describe conditions required to accept the project.

A similar approach was adopted earlier by ÜWG for a project in Groß-Gerau (close to Trebur), and included: a social site characterization with media analysis and interviews; establishment of an advisory board representing different stakeholder groups and that was divided in working groups addressing four topics to liaise with the operator; civil dialogue, with public meetings and workshops (Wallquist and Holenstein, 2015). Both in the case of Groß-Gerau and Trebur, the strategy implemented allowed the geothermal project development in a friendly and supportive public environment and highlighted that communication and public engagement may lead to more robust decisions on if, where and how geothermal power should be deployed.

Another successful example of public acceptance achieved on geothermal was implemented by **Deutsche ErdWärme**, a development company with four projects under development in Baden Württemberg. According to information reported on the Deutsche ErdWärme website and information reported by Douwe at al. (2016), actions implemented by the company to engage with local communities included:

1) Discussion on future plans and projects with local communities and their council and administrative heads, after the submission of the exploration permit request;
2) Information campaign and publication of all relevant information on the planned projects on the company website;
3) Respect for needs and expectations of local communities (e.g., restoring abandoned geothermal well sites), providing evidence of financial standing and reliability;
4) Dialogue process to improve the planning of the projects using local knowledge and skills;
5) Guided site visits for policy makers and selection of citizens to the construction site or the completed geothermal plant.

The dialogue is triggered through an opening specific event, which is followed by an information event for all citizens, press and greater public. In 2016, Douwe et al. reported that the company was planning to implement a local counsellor board, to deeply discuss critical and vital matters of the project and closely link the communication to the dialogue process and to the outcome of the meetings of the local counsellor board. The process should have been managed by a German nature protection organization.

In addition to the engagement actions implemented, the ErdWärme website can be considered a good practice example for operators and project developers, since it reports clear information on:

- The company shareholders, to demonstrate the financial reliability;
- Clear description of actions and tools adopted for the environmental protection and impacts mitigation in each development phase of a geothermal project;

- The company's commitment to promote the local development;
- Clear description of geothermal energy, project's development phases, a section with FAQs and contacts to ask more information;
- Specific sections with projects' description and results of monitoring;
- Videorecording of public engagement events.

In addition, the company has an information centre, promotes educational initiatives with schools and gives the opportunity to visit its drilling sites.

Another case study concerns the concept to co-design with local communities a deep geothermal heat facility in the **KIT north campus** and, if desired and feasible, to supply heat also to neighbouring municipalities (Roesh et al. 2020). The rejection expectations about deep geothermal projects are strictly related to lifting cracks that are occurred in other areas during similar projects. Therefore, it is necessary to find a suitable way to explain the real range of risks and reassure local communities about some concerns. In this context, steps proposed by the authors can be resumed as follows:

1) Investigate, analyse and reflect the state of research on the involvement of social actors in the project planning, or approval.
2) To design the methodological approach of the criteria workshops, relevant topics, the strategy for the participants selection and the processing concept, grounding on previous experiences.
3) The criteria elaborated need to be sharpened and further developed by being underpinned by scientific findings.
4) Qualitative interviews with different actors and citizens should help to gain insights into different mind settings, expectations and concerns. Experts like scientists should be interviewed to prepare a scenario workshop.
5) A scenario workshop has to be organized with the citizens involved in the first workshop. Socio-technical scenarios prepared will be discussed, modified, further developed and evaluated in small groups. The workshop should allow to develop at least two scenarios, which are societal feasible and address the prerequisites for acceptability.

3.3 Hungary

Geothermal energy in Hungary plays a pivotal role in the country's energy transition efforts. As a nation rich in geothermal resources, Hungary has increasingly harnessed this sustainable energy source. Geothermal power plants and district heating systems have emerged, reducing greenhouse gas emissions and enhancing energy security.

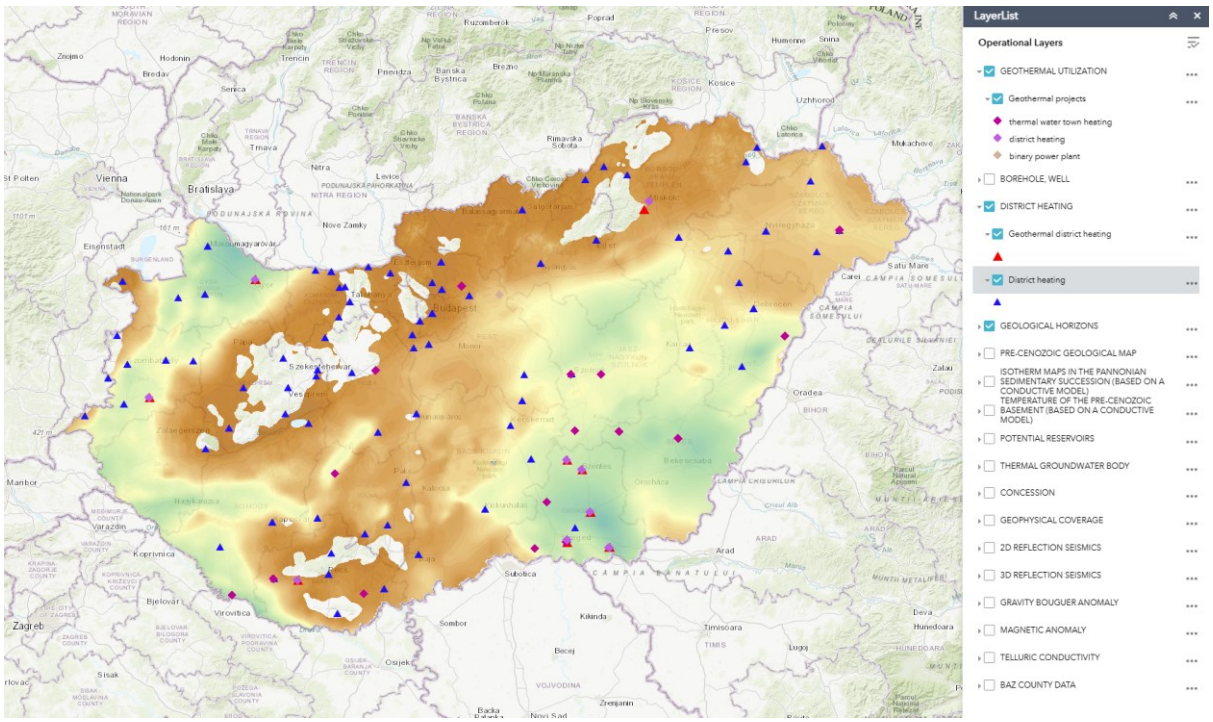


Figure 4: Interactive map of the Hungarian Geothermal System (OGRe) showing the distribution of geothermal energy resources and projects in the country https://map.mbfsz.gov.hu/ogre_en/

In understanding the social landscape, the Crowdthermal project specifically scrutinized the social acceptance facets within Hungarian geothermal projects, alongside Spanish and Icelandic ones. In Hungary, the primary focus was on the Szeged geothermal initiative and Mórahalom in the southern region, this comprehensive exploration aimed to uncover community perspectives.

The **Szeged geothermal project** involves utilizing geothermal resources to provide district heating for the city of Szeged. It is ought to be one of the largest districts heating in Europe. A comprehensive exploration of resource perception within the local community was conducted in 2022. It revealed that the local community in Szeged generally has a high level of acceptance for renewable energies, including geothermal energy. Participants associated geothermal energy with a sense of meaning and future orientation. While they recognized the financial and communal benefits of geothermal energy, risk perception remained uncertain. The study also highlighted some challenges, particularly annoyance factors related to geothermal energy, with noise being the most significant concern. Communication and procedural justice played a critical role, with mixed perceptions about fairness and public participation. Many participants felt inadequately informed and perceived limited influence over the project. Interpersonal justice ratings were moderately positive, indicating trust in project leaders and a perceived value match between leaders and the community. The study also explored the impact of the project on social capital, local identity, and knowledge, with results indicating a neutral effect in these areas. Comparing the 2022 results to a 2020 survey showed that there was increased support for local geothermal projects. However, the willingness to financially participate decreased, possibly due to variations in question phrasing (De Gregorio et al., 2022).

In the City of Mórahalom, an innovative model project was implemented by replacing the natural gas-based energy supply with locally available, renewable (geothermal and photovoltaic) sources. The project serves a number of small villages in the area with a population of 5-10,000. The **Mórahalom pilot project** provided valuable insights into the perceptions of the local community regarding

renewable energy, particularly geothermal energy. The study revealed that participants generally held positive attitudes towards renewable energy, the energy transition, and geothermal energy, with none expressing negative views. Geothermal energy was associated with meaningfulness, future orientation, and environmental friendliness. However, the study also uncovered concerns related to procedural fairness, risk perception, and the cost of geothermal energy. Participants showed uncertainty and diversity in their opinions about the risks associated with geothermal energy. Political risks were seen as the most problematic, followed by environmental risks, indicating a need for addressing these concerns. In terms of benefits, participants agreed with the positive effects of geothermal projects, particularly on the well-being of the community and the financial favourability of geothermal energy. Trust and credibility in project leaders were generally high, and there was a perceived value match between the community and project leaders. The study also explored the impact of geothermal projects on social capital, local identity, and knowledge. Participants generally agreed that geothermal projects had positive effects on community cohesion, neighbourhood connections, trust, and a sense of belonging. Integration of the projects into the local identity was also observed, with a sense of pride in the community's achievements through cooperation with project managers. While there was a slight interest in participation in the planning process, financial participation did not elicit strong reactions (De Gregorio et al., 2022).

The case studies conducted in Szeged and Mórahalom highlighted a strong social acceptance of geothermal energy, emphasizing the importance of positive attitudes, trust, and perceived local benefits. Hildebrand et al. (2022) investigated geothermal energy projects and their social acceptance in Hungary, utilizing the Social License to Operate (SLO) model by Barich et al. (2021). Focusing on the Szeged case study, the research emphasized the critical link between local acceptance, positive attitudes toward renewable energy, and perceived local benefits. The study underscored the correlation between acceptance levels and factors like trust, procedural justice, and social impact. The application of the SLO model offers a comprehensive understanding of community interaction with energy projects, recommending its use across various project phases. Overall, the research highlights the significance of public involvement in ensuring the success of geothermal energy projects, emphasizing the need for standardized questionnaires to comprehensively explore different contexts (De Gregorio et al., 2022; Hildebrand et al., 2022).

3.4 Iceland

Iceland stands as a pioneer in the effective utilization of geothermal energy for space heating and electricity generation. Throughout the 20th century, Iceland underwent a remarkable transformation from being among Europe's economically deprived nations, relying on peat and imported coal for energy, to achieving a notably high standard of living primarily supported by renewable resources. By 2014, approximately 85% of Iceland's primary energy consumption derived from native renewable sources, with geothermal energy accounting for 66% of this renewable energy mix.

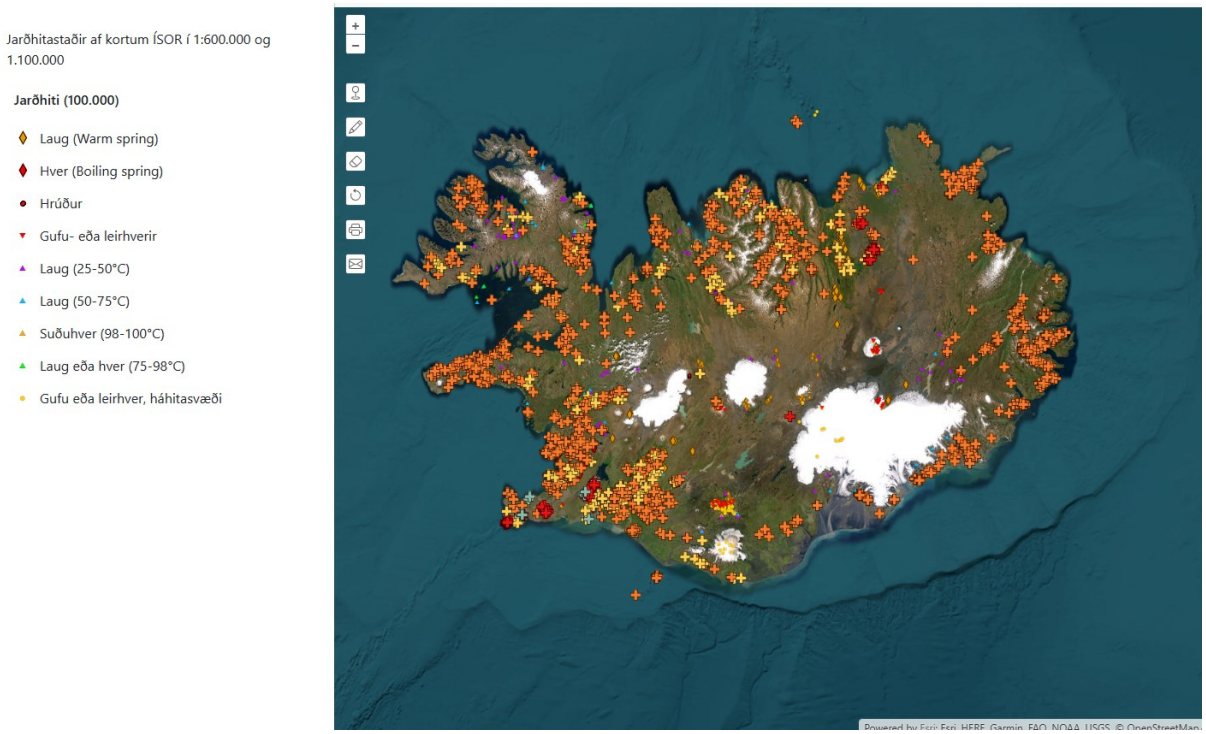


Figure 5: Interactive map of Iceland's geothermal areas and boreholes. Source: https://arcgisserver.isor.is/

Understanding the historical context and the widespread integration of renewable resources leads to an inquiry into how this shift has been perceived and embraced by Icelandic communities, forming the basis for the subsequent discussion on social acceptance.

Typical environmental and social impacts associated with geothermal development in Iceland are: geological changes including the impact on the geothermal reservoir; use of cold water resources for cooling and as basic resource for delivery of hot water to customer (after heating by geothermal water in heat exchangers); landscape and aesthetic effects; tourism and recreation; biological resources; noise, air and water pollution; and impacts on cultural heritage (Hellisheiði Geothermal Project, 2018).

In order to tackle these issues, a working group of Icelandic power companies and government agencies in Iceland developed the Geothermal Sustainability Assessment Protocol, framework to assess the performance of geothermal power projects according to a defined set of sustainability topics, encompassing environmental, social, technical, and financial issues. In its evaluation of the Hellisheiði power plant relayed the efforts of corporate social responsibility that OR/ON were deploying. These efforts included organizing monthly meetings with key stakeholders in order to capture emerging risks, land rehabilitation in the area around the power plant to restore the flora, especially the Icelandic moss, and promotion of value through the permanent Geothermal Exhibition at the power plant.

The literature on geothermal social acceptance in Iceland is constrained around a few case studies. A study on stakeholder engagement during the development of the Theistareykir geothermal power plant in Northeast Iceland (Bjarnadóttir and Knútsson, 2021) showed that the benefits that the power plant brought to the community and its timely development created a high level of satisfaction among the local communities. It not only provided electrical stability and increased power availability in Northeast Iceland but also opened up new industrial opportunities in the region. The project's success was accredited to continuous collaboration and open communication with local communities and

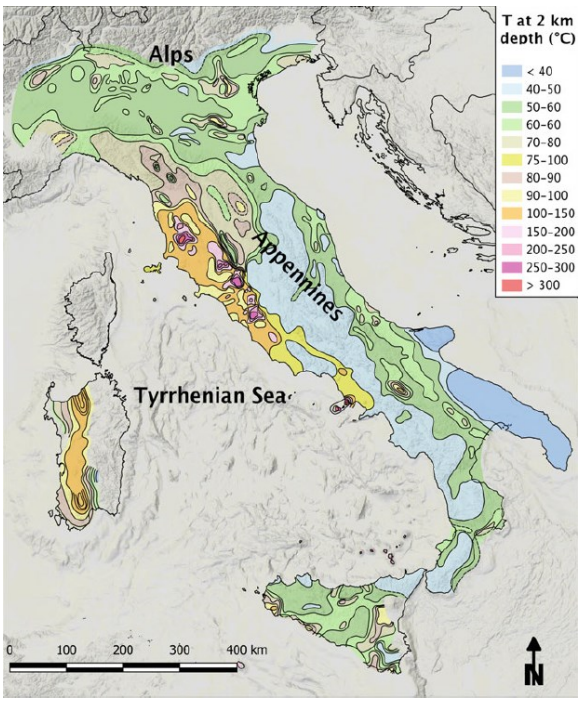
stakeholders. Despite some opposition, the project's success was largely attributed to its robust stakeholder engagement, which garnered positive local support during the construction phase. The project's recognition as a finalist in the 2019 IPMA Global Project Excellence Award for large projects further emphasizes the best practices in geothermal power execution, especially regarding stakeholder engagement and community consensus.

Reimer (2023) explored public acceptance and opposition to geothermal projects in Iceland. It revealed relatively high knowledge and acceptance among Icelandic citizens, identifying influential themes such as Usage, Economics and Public Policy, Environmental Impact, and Longevity in shaping acceptance or opposition to geothermal projects. The study underscored the importance of addressing community concerns and early planning to foster public acceptance.

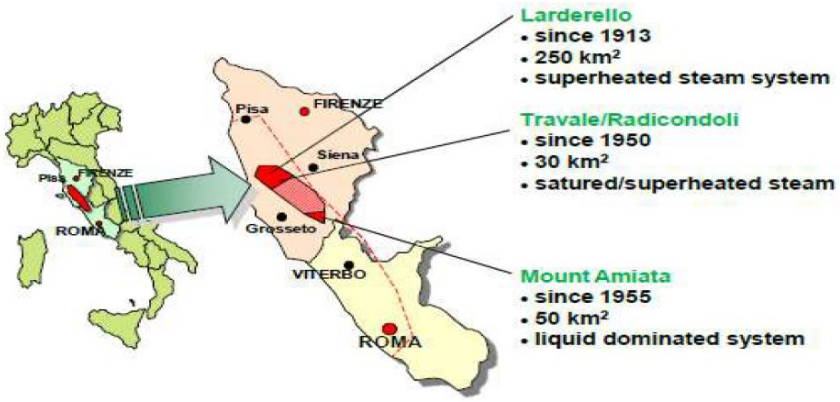
The Crowdthermal project also addressed social acceptance of geothermal energy development the context of crowdfunding. Using the Social License to Operate framework developed within the project and applying it to the case study of a possible geothermal-powered greenhouse in Húsavik, Northern Iceland, the project concluded that geothermal is perceived as the “default” energy resource by the local communities and the main challenge was rather the financial framework integration that would allow the greenhouse project to take place.

3.5 Italy

Italy is one of the world’s leading geothermal countries, with 34 geothermal power plants installed in Tuscany, and 19 geothermal district heating networks, between central and northern regions. The potential for power generation is mostly concentrated in Tyrrhenian regions, while deep resources for direct uses are available also in northern regions. Despite Italy has a big potential and was the world’s first country to install a geothermal power plant, no additional units were installed after 2014 (Della Vedova et al. 2022) and the geothermal development is generally rather slow.



(a)



(b)

Figure 6: (a) the temperature distribution at 2 km depth in Italy (Cataldi et al. 1995), **(b)** location of the geothermal fields in Italy (Della Vedova et al. 2022).

Agreements to promote the local development, in line with the vocations and the economic traditions of territories have been signed by the operator of powerplants the Tuscan regional government and geothermal territories from 2007. This resulted in advantages for geothermal territories, thanks to mechanisms to redistribute revenues from geothermal leases and exploitation to territories. Hundreds of local development projects in infrastructures, ICT, renovation of old towns, territorial marketing, investment attraction, support to local business, promotion of renewables and energy efficiency, and on communication, have been implemented from 2007. Despite this, depopulation and unemployment still characterize these territories and small groups of citizens are opposing geothermal projects (Torsello et al. 2019).

One of the reasons for this is the low social acceptance of some local communities who have concerns on potential environmental impacts. In addition, citizens do not feel that they are sufficiently informed to have a voice in the innovation process and there is mistrust towards policy makers and public authorities. Confidence is higher towards researchers and scientists (Manzella et al. 2018).

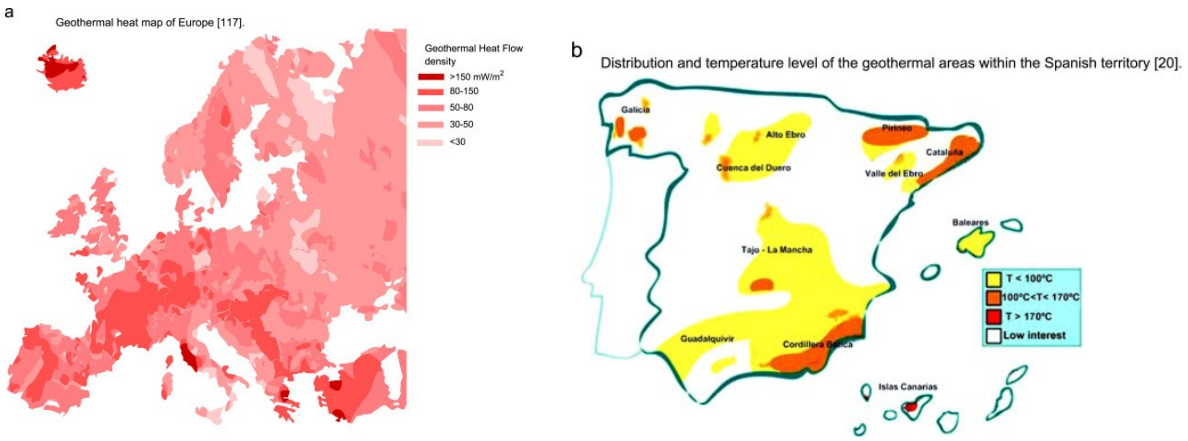
Despite this, Italy has no social engagement cases implemented for specific projects, but it is worth to report outcomes from surveys and focus groups carried out in areas far from geothermal installations in Tuscany and closer to these plants: Palermo and Viterbo respectively, both with geothermal potential). The survey involved a sample of 400 people in each territory, to explore views and social attitudes towards technologies harnessing geothermal resources. Researchers used both qualitative and quantitative approaches: 1) Focus Groups for four different groups: students, stakeholders, citizens of Termini Imerese, unemployed Fiat workers; 2) A phone survey with samples calibrated by gender, age, education, job condition and residence (Reith et al. 2013; Pellizzone et al. 2019). Results reported a poor awareness on geothermal technologies in both areas and highlighted concerns about impacts on groundwater in Viterbo. Discussions moved spontaneously from techno-scientific issues to trust-related issues, such as distrust in the political system, in commercial companies and in how decisions would be taken (Manzella et al. 2018). More information and communication on geothermal were requested by all participants (Reith et al. 2013; Pellizzone et al. 2019). Researchers concluded that dialogue between citizens and stakeholders is essential when planning investments related to the development of new or poorly known technologies.

A second example is the communication and engagement process implemented by the operator Sorgenia Geothermal that owns the Val di Paglia project, one of the most advanced geothermal projects to build a binary plant. Despite this plant will fall into the Monte Amiata area, which has a historically a strong scepticism towards geothermal, the candidates that won municipal elections put this project in their electoral program. The company website has a specific section on geothermal and on the power plant, with very detailed information on the technology and impacts. In addition, in early 2020 a hybrid public assembly was organized by the municipality involving local communities and the public, in order to show all the aspects related to the project: economic benefits for the territory, impact on landscape, environmental studies, induced seismicity. Despite the acceptance was raised, but the project was hampered by the Superintendence for Cultural Heritage and the Minister for Cultural Heritage. Subsequently, it was unblocked by the cabinet.

3.6 Spain

Spain holds a substantial potential for geothermal energy, specifically emphasizing direct heating systems and binary cycle electricity production. The estimated geothermal resource potential reaches 610 GWt.

To meet energy-saving targets outlined in the Energy Plan 2011–2020, Spain aims to generate 50 MWe of electricity and 66 MWt for direct heating using geothermal energy. Binary cycle plants are viewed as an effective means to attain these objectives.



(a) **(b)**

Figure 7: (a) Geothermal heat map of Europe (Hurter & Haenel, 2002). **(b)** Distribution and temperature level of the geothermal areas within the Spanish territory (IDEA, 2011)

Spain's Renewable Energy Plan for 2011–2020 delineates specific goals for geothermal energy generation, particularly focusing on electricity and direct heating usage.

Within the Crowdthermal project, a case study in Spain involved two housing cooperatives in Madrid — EAI 310 and Arroyo Bodonal—leveraging shallow geothermal energy for heating, cooling, and domestic hot water. The study revealed that when the community leads the project, a social license to operate is established in advance. Engaged stakeholders, equipped with project-related knowledge, gradually draw in new participants, leading to the formation of cooperatives to drive the project's development. This grassroots engagement approach ensures a consistent flow of information and commitment within the community.

3.7 Switzerland

Switzerland has a high deep geothermal potential, notably to produce electricity with the EGS (or petrothermal) technology. However, only one district heating network uses deep geothermal in the canton of Basel-Stadt and no power plants are operation. This is mostly due to the poor knowledge of the local deep underground conditions and many researches have been launched since 2018 (Link and Minning 2022).

Case studies considered here are related to different deep geothermal projects and planning that adopted different communication and engagement approaches with local communities.

The construction of the Switzerland's first petrothermal plant in **Basel** was proposed in 2004. In December 2006, operations for the stimulation of the reservoir caused a 3.6 magnitude seismic tremor, which caused no damages but had a strong reaction in the local population. The project was definitively abandoned in 2009. In the same year, a study began to install a hydrothermal plant in the city of **St. Gallen**. The project was approved in a public vote by a large majority and it included a large-scale seismic monitoring. A 3.5 magnitude earthquake occurred after the drilling operations began in 2013 but the project was abandoned in 2014, due to insufficient water production (Ejderyan et al. 2020).

The only petrothermal project at an advanced planning stage is in the rural town of **Haute-Sorne**. Geo Energie Swisse is the company in charge of developing the project, which aims to build a 5 MW power plant using the heat from a crystalline bedrock at a depth of 5.000 m. The construction permit was issued in 2015, after the project was presented to the authorities and the public. The project implementation was delayed due to the dissent of a local population group, which collected signatures to vote the ban of geothermal projects in the canton of Jura. The company submitted a report on seismic risk management to the Swiss government and was authorised to proceed with the project by implementing additional safety measures (Geo Energie Swisse website; Ejderyan et al. 2020).

The GEothermie2020 programme was launched in 2014 by cantonal authorities and public utilities in **Geneva** to assess the geothermal resources in the area. The programme is being developed through different projects (Ejderyan et al. 2020). Geo-Energie Suisse, is planning a pilot project for underground thermal energy storage. In **Berne**, while three other exploitation projects for power generation (in Etzwilen, Triengen/Pfaffnau and in the Alpine region) were suspended and waited to be re-evaluated in the light of the positive federal court ruling on the project in Haute-Sorne (Geo Energie Swisse).

In the case of **Basel**, the developers organized press releases, conferences and guided tours in which they highlighted the potential benefits. The project was covered by media, but no active outreach was done to engage the public. After the earthquake, local people denounced a lack of information on the consequences and management of the project, which was later abandoned (Ejderyan et al. 2020, Ejderyan et al. 2019). In the city of **St. Gallen**, the municipal administration launched a preliminary inquiry on public perceptions, expectations, fears and knowledge regarding the geothermal project, in parallel with the feasibility study. The study was based on 31 in-depth semi-structured interviews with key stakeholders and members of the public. Public opposition was minimal and the overall perception was largely positive, although some doubts about the risks of exploration remained. The tremors occurred represented a setback for the project, which continued having a positive impact on the population until its closure (Ejderyan et al. 2019; 2020).

Despite the results obtained in St. Gallen, in **Haute Sorne**, Geo-Energie Suisse implemented following measures to raise social acceptance towards its project:

1) The public was informed immediately after the site was chosen;
2) A committee consisting of local politicians and representatives of local companies and NGOs, was selected to act as an intermediary between the local communities and the developers. The committee was in charge of informing the company about public concerns and provided updates on the progress of the project to the population, with a newsletter and public events.
3) Informative events and guided tours to neighbouring plants in France and Germany.

Despite these initiatives and the support of authorities, the project was delayed due to the dissent of a local population group, which claimed that the project would generate noise and negatively impact the landscape and water resources (Ejderyan et al. 2019; 2020).

Developers of the GEothermie programme in **Geneva** considered necessary the involvement of interested stakeholders, the transnational consultation with neighbouring communities in France and the collaboration with universities. Inclusion of the local communities in the development of the programme is a key aspect and regular updates are posted on the programme's website, while public information events and site visits are organised as each programme milestone is reached (Ejderyan et al. 2019; 2020; Ruef et al. 2020). Regarding the feasibility of the storage in **Bern** and the other projects

for power generation, a comic strip was issued to involve the local population and explain the exploitation model proposed by Geo Energie Suisse (Geo-Energie Swisse).

3.8 Türkiye

Türkiye is a rapidly developing country and aims to self-produce energy to meet its needs, with geothermal as one of the most promising energy sources to support the country's renewable development. Due to its complex geology and active tectonic properties, Türkiye has high geothermal potential distributed throughout the whole country. The installed geothermal capacity increased from 15 MWe in 2008, to 1.155 MWe in 2018 (Sahiller et al. 2020), with 65 running plants in 2021. All these plants are located in the Western Anatolia region (south or east of Izmir), as reported in Figure X. Geothermal district heating systems were 18 in 2021 (Mertoglu et al. 2022).

Figure 8: Geothermal energy map in Türkiye (Jeotermal Santraller Haritası).

The development of Geothermal Power Plants can provide widespread improvement of community, public, private sector and environment if it is supported with professionally surveyed and conducted incentive methods, such as feed-in tariff mechanisms and regulations. In this case, the growth of geothermal energy is accompanied by an all-round development of the country: Industry, tourism, agriculture, education and infrastructure are among the top sectors that geothermal energy developed directly or indirectly (Mertoglu et al. 2022). Turkish authorities are pursuing a strategy to foster public awareness and increase local community involvement in the development of geothermal projects, since local communities often do not have the means to evaluate the pros and cons of a project. Investors are obliged to organize and join a "Public Involvement Meeting" to obtain feedbacks for the Environmental Impact Assessment (EIA) on their project. The main goal is to inform the local community and to collect their thoughts, problems and suggestions about the project. The assembly is generally organized jointly by the Ministry, investors and EIA companies for each project separately. Local and national newspapers announce the date, time and location of the assembly at least 10 days

before. Agendas mostly contain the topics addressed by the EIA report that will be created for the project. The EIA company reads the draft of the EIA report's contents to the public and then the local community is expected to offer their consideration and suggestion.

The development of geothermal potential in Türkiye, which occurred thanks to government support, was carried out by combining electricity production and direct uses of heat (district heating of homes and greenhouses, spa tourism) from a circular economy perspective. In addition, the Zorlu Energy group carries out risk assessments which are analysing environmental and social effects of investments in accordance with international standards. Then, investments are made considering these findings (Sahiller et al. 2020).

3.9 United Kingdom

Geothermal energy in the UK holds significant promise as a sustainable, low-carbon energy source for heating, cooling, and power generation. The country boasts substantial accessible geothermal resources, with the potential to meet its heating needs for a century and contribute significantly to England's (9%) and Scotland's (85%) electricity demands (Gluyas et al., 2018; Abesser et al., 2020). Heat networks are instrumental in achieving net-zero emissions goals, unlocking large-scale renewable heat sources, including geothermal energy. Demonstrated success stories in Paris and Munich emphasize their potential to serve vast populations while reducing carbon emissions.

Geothermal initiatives not only offer economic benefits and job creation but also have the potential to provide over 10,000 direct jobs and 25,000 indirect jobs by 2050 with 360 projects. In regions facing socio-economic challenges, the alignment of district heating opportunities with deep geothermal potential can be transformative.

The United Downs Deep Geothermal Power project, contributing £1.5 million to Cornwall's economy, exemplifies the economic boost such projects can bring. Furthermore, the transition to deep geothermal energy provides an avenue for the oil and gas sector to pivot toward low-carbon technology, aligning with sustainability and reduced carbon emissions.

The Jubilee Pool in Penzance, Cornwall, achieved a milestone by incorporating geothermal heating, extending its benefits to economically disadvantaged communities with a 20% Locals' Discount and tailored therapies for up to 180 individuals per week.

However, there is a substantial gap in understanding public perceptions of geothermal technologies in the UK. While stakeholders consulted in a recent study generally view public acceptance positively, concerns linger, potentially stemming from negative perceptions associated with other subsurface energy technologies, as noted in "perception spillover". Recent planning applications have underscored these concerns, focusing on issues like noise disturbances and perceived "industrialization of the countryside."

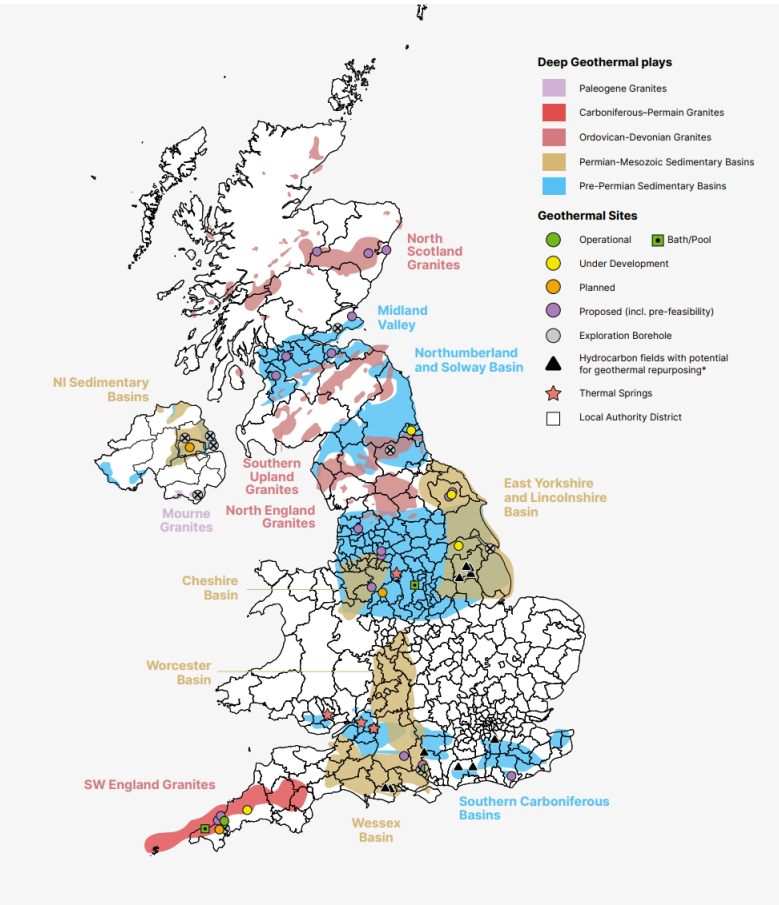


Figure 9: Map showing the location of the potential deep geothermal targets across the UK alongside selected onshore hydrocarbon fields (triangles), occurrences of known thermal springs (stars) and geothermal projects at different stages of development from pre-feasibility to operational.

A recent study (Abesser et al., 2023) recommends addressing these challenges through a short-term approach of broader consultation with stakeholders, including the public, to inform public consultation procedures and foster a positive public experience with geothermal energy.

Furthermore, facilitating communication between stakeholder groups necessitates collaboration between the UK Government and existing groups in the short term. In the medium term, involving experts from industry, academia, and regulatory bodies in specialist groups, akin to Northern Ireland's Geothermal Advisory Committee, can provide guidance on building the geothermal energy sector. These measures aim to harmonize the geothermal sector's growth and success, with a particular focus on public acceptance and collaboration.

3.10Rest of the world

3.10.1 Chile

Despite Chile has a huge potential, the geothermal development is slow. The country has only one power plant and geothermal represented 0,2% of the energy mix in 2019 (Vargas-Payera et al. 2020). The highest geothermal potential is in volcanic areas, such as the Andes in the far north and in the

south-central regions (Sanchez-Alfaro et al. 2015). The level of understanding and social support for deep geothermal projects is generally low in the country. A guideline of suggestions for participation in energy projects was published in 2016 by the Ministry of Energy, highlighting six principles that must be fulfilled by any project: inclusiveness of local communities; opportunity and relevance, that is early and constant participation; transparency in the engagement process; decision-making power of actors; participative planning throughout the project's lifetime; the promotion of the local social and economic development (Martinez-Reyes et al. 2020).

The case studies considered in this review concern a research on local perception in Tolhuaca volcano area and the feasibility study for the installation of a cogeneration plant in the Puyuhuapi. The exploration campaign in Tolhuaca lasted from 2009 to 2016, but the project was abandoned for financial difficulties (Martinez-Reyes et al. 2020). The study for the plant in Puyuhuapi lasted from 2020 to 2022 and the use of waste heat for direct uses was proposed (CEGA, 2022).

The engagement process for in Tolhuaca involved different kind of stakeholders, started before the geothermal exploration phase and was developed by the operators Geo Global Energy Chile and Mighty River Power (GGE-MRP), through steps as detailed in Figure 9 (Martinez-Reyes et al. 2020). The project was abandoned in 2016, without public events.

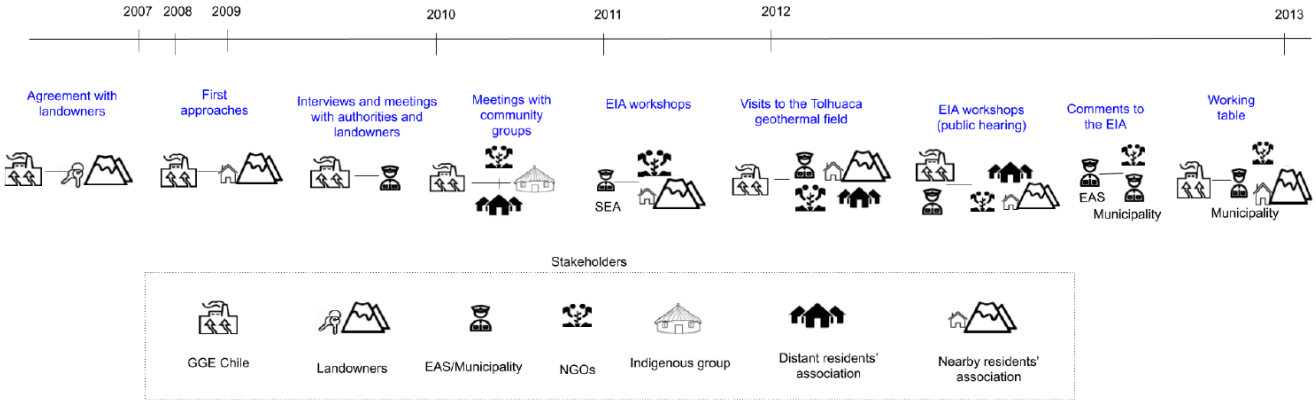


Figure 10: Stakeholder engagement approach of GGE-MRP (Martinez-Reyes et al. 2020)

Qualitative analysis with focus groups and interviews were carried out within the research of Vargas et al. (2020) to understand changes in local perception throughout the project duration. Five focus groups and four semi-structured interviews were conducted with 9 groups of key local stakeholders. Results indicate that the overall stakeholders' perception improved during the project lifetime, since it was influenced not only by the operators' engagement activities, but also by the exploration project activities and contextual elements. Other studies (Martinez-Reyes et al. 2020) also reported that part of the public engagement strategy was the offer of direct benefits to the communities near Tolhuaca, including jobs, access roads and economic 1% of the revenues.

The social perception of the project in Puyuhuapi was identified through online and face-to-face interviews and workshops. A survey involving 122 local families in the locality identified the level of energy vulnerability. A high level of energy poverty and the lack of equitable access to high-quality energy services resulted for Puyuhuapi. The main problems identified from the social engagement side concern the management of the population's expectations, which may be too high, the induced seismicity and the quantification in a comparable way of the project impacts and benefits on the

population. Researchers concluded that first steps of the project implementation should concern participatory events to inform and identify cultural and social factors of the project (CEGA, 2022).

3.10.2 New Zealand

New Zealand has a high potential and geothermal energy provides stable baseload electricity, which is important in New Zealand's context of phasing out coal and gas, as well as to compensate fluctuations of other renewables like hydro and wind. Currently, energy supply meets demand and there are no large electricity plants under construction. One of the biggest obstacles to geothermal development in New Zealand is the rejection and difficult acceptance due to the fact that the most part of geothermal phenomenon are considered sacred by Maori (Luketina et al. 2019).This means that it is necessary to find an acceptable solution sharing decision with local and religious authorities.

The approaches proposed by Doorman et al. (2020) and Luketina and Parson (2019) studied by in two cases considered are to engage with local communities and local socio economical and religious authorities in the entire process, before and during the exploitation phase. This solution can be fulfilled through a constant information policy about the conservation and the state of health of geothermal source, to reduce local communities concerns and the formation of local committee. In addition, the implementation of geothermal direct use facilities can contribute to augment the acceptance, and even to increase economic and social benefits.

3.10.3 Kenya

Thanks to its position into a bifurcation of the East African Rift System, Kenya has a huge estimated potential, with most of geothermal systems hosted by volcanoes (Omenda et al., 2021). Despite this potential is still untapped, geothermal is the main energy source of the country, covering more than 40% of the electricity produced in Kenya (Omenda et al., 2021). This makes Kenya one of the world's leading geothermal countries and the main producer of electricity from geothermal in Africa.

Kenya gives emphasis on public engagement, to comply with the Environmental Management and Coordination Act established in early 2000 (Karystas et al. 2019), when carrying out Environmental and Social Impact Assessment (ESIA), and public involvement is conceived of as both a sustainability objective and a principle of best practice (Barasa 2015).

A case study identified for this review is related to the stakeholder consultations during the ENSIA for Olkaria I units 4 and 5 and Olkaria IV power plants, built by KenGen. The development of these projects also necessitated involuntary resettlements. The local community was adequately informed about the proposed power projects, the choice of location and the implications of the projects on the land and their livelihoods. This was done during ESIA studies and preparation of the resentment action plan, thorough public meetings and workshops (Barasa 2015).

A second example of social engagement is related to the involvement of local communities after an accidental vent of fluid into the atmosphere after the shutdown of a well head generator that damaged surrounding crops fields. The operator KenGen organised public engagement events to tackle fears towards the plant, mistrust and the sensation to be "left alone" of local damaged farmers. In addition, the company contributed to improve the plantations and improved the emergency discharge system of wells (Barasa and Mthenge 2015).

3.10.4 Japan

The literature on social acceptance of geothermal energy in Japan is notably scarce, emphasizing the underlying issue of underdeveloped geothermal resources within the country. Japan boasts a substantial geothermal potential of 23 GWe (Muraoka, 2009), yet its current installed capacity is a mere 520 MWe (Yasukawa, 2015). Apart from direct uses like bathing and ground-source heat pumps, the nation has limited utilization. Legal, economic, and social factors are major barriers, particularly the persistent challenge of social acceptance.

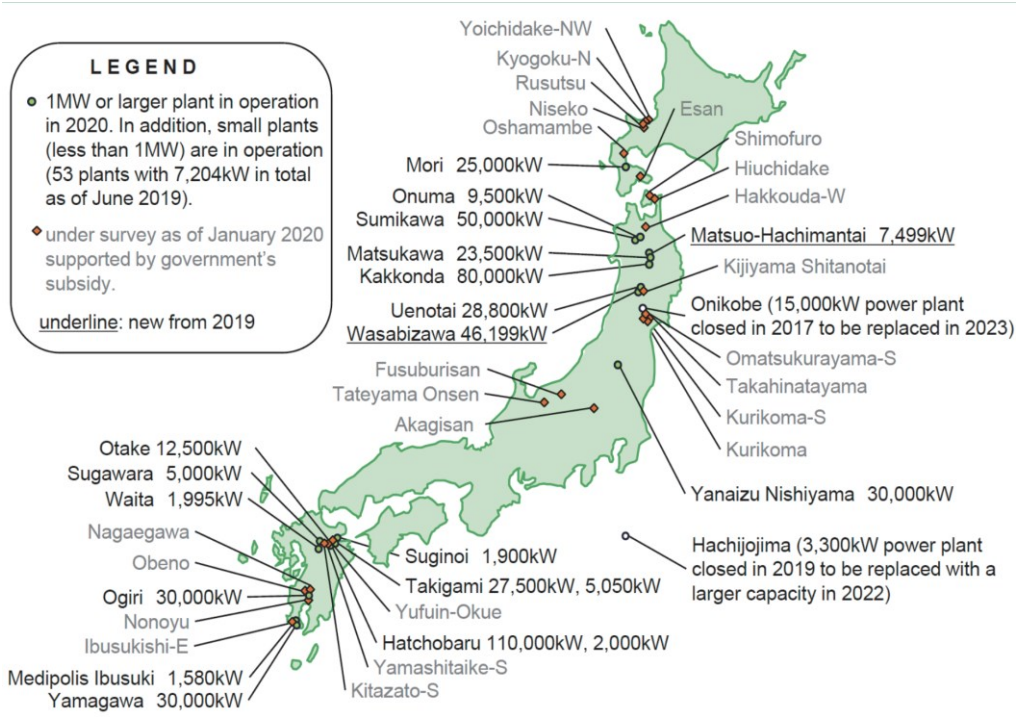


Figure 11: Geothermal power plants and undergoing survey projects in Japan as of January 2020 (GRSJ, 2020).

Following the nuclear accident in 2011, the central government introduced supportive policies and altered regulations to encourage geothermal development. However, despite changes in policies and incentives, the issue of social acceptance remains a significant obstacle. Reports point to delays and terminations of geothermal projects due to opposition by hot spring owners fearing the potential degradation of their springs (Uechi et al., 2013).

The resistance stems from the intricate balance of regional community activities and the potential disruptions that sudden geothermal development might cause. The disturbance in established local activities could lead to mixed reactions from stakeholders, triggering opposition campaigns. Various research reports and studies, such as Barasa (2015), Batac and Dugan (2015), and others, have explored the social acceptance of geothermal development in Japan.

Studies like Uechi et al. (2013) emphasize the importance of open information regarding both benefits and risks, along with equity in the developmental process, for social acceptance. They highlight the contrasting results between successful and unsuccessful geothermal projects in terms of benefit and risk recognition, emphasizing the significance of proactive risk management agreements with local stakeholders.

Yasukawa et al. (2018) suggest an integrated approach involving geoscientific, socio-technical, and sociological methods to facilitate the smooth development of geothermal plants without adverse impacts. It proposes geoscientific analyses to ensure minimal influence post-development, socio-technical strategies for overall system design to maximize both profitability and social acceptance, and sociological considerations to address differing perspectives in various regions with high geothermal potential.

The socio-technical approach suggested by Yasukawa et al. (2018) introduces the Overall System Design (OSD) procedure, focusing on business profitability and social acceptance. It suggests constant updating of the optimal design based on observed data and improvements in social acceptance to enhance stakeholders' understanding of the benefits of geothermal development.

From the sociological perspective, Yasukawa et al. (2018) underscore the necessity for diverse approaches tailored to different regional development prospects, considering stakeholder attitudes and needs. It emphasizes the need for constant engagement with local stakeholders to enhance their understanding while minimizing environmental impacts.

In summary, a collaborative effort encompassing geoscientific, socio-technical, and sociological approaches is pivotal to mitigate potential negative impacts of geothermal development on natural and social environments. This integrated approach could pave the way for effective and socially accepted geothermal projects in Japan.

In their study on cultural factors of energy development, Shortall & Khazzari (2017) focused on examining the cultural dimensions of geothermal energy development in Japan and Iceland through Hofstede's cultural framework. It aims to identify challenges faced by policymakers and to what extent national culture or other factors shape geothermal energy policies in these countries.

The comparison reveals stark differences in the development of geothermal resources between Japan and Iceland due to their unique cultural values, affecting risk-taking, innovation, and approach to challenges. Despite distinct cultural scores, both countries face similar issues related to public participation in environmental impact assessments (EIAs).

The findings emphasize the need for increased public involvement in decision-making processes. For Japan, educating onsen owners and enthusiasts about the impact of geothermal power plants on hot springs or including them in decision-making could be beneficial. The Hofstede's cultural framework serves as a critical tool for comparing approaches in geothermal energy development between countries, demonstrating the significance of understanding cultural dimensions in sustainable energy system transformations.

3.10.5 The Philippines

Geothermal energy in the Philippines plays a significant role in the country's renewable energy portfolio. Known for its abundant geothermal resources, the Philippines ranks among the world's top producers of geothermal power. The utilization of geothermal energy began in the 1970s, with key geothermal fields located primarily in the island of Luzon, notably the Makiling-Banahaw Geothermal Complex. This renewable energy source contributes a substantial portion to the country's electricity generation, providing a reliable and sustainable energy option while reducing dependency on fossil fuels. However, social acceptance, community engagement, and environmental considerations

remain crucial factors in the successful deployment and expansion of geothermal projects in the Philippines.

A case study on the Makiling-Banahaw Geothermal Complex in the Philippines carried out by Ratio et al., 2020 provides a comprehensive understanding of the social dynamics and public engagement regarding geothermal energy. The study uncovers several key elements regarding stakeholder engagement, community support, and factors influencing social acceptance:

Stakeholder Engagement and Supporting Factors: The success of the Makiling-Banahaw Geothermal Complex is attributed to stakeholder engagement, energy policies, and funding mechanisms. Transparent communication and periodic information campaigns initiated by geothermal resource developers and the local government were identified as effective tools for meaningful public engagement.

Trust and Integration with Local Communities: Frequent interaction among stakeholders helped reinforce public support for the geothermal project. The geothermal resource developers' efforts, such as medical missions, scholarships, and tolerating informal settlers, played a crucial role in building trust and garnering support from the community.

Challenges and Dissatisfaction: Challenges arose from economic tradeoffs, delays in wealth share remittance to the local government, and dissatisfaction with the distribution of shares. This dissatisfaction caused distrust with the national government and the geothermal resource developers.

Knowledge and Perception: Residents closer to the geothermal facilities demonstrated better knowledge and perception of geothermal energy. They associated certain environmental concerns like air and noise pollution, earthquakes, agricultural damage, and subsidence with geothermal activities.

Factors Affecting Social Acceptance: Factors influencing social acceptance included gender, proximity to the facilities, land ownership, education level, and trust in the information sources. Male stakeholders in closer proximity to geothermal plants showed more confidence in their literacy about geothermal technology.

Means of Information Dissemination: People's interaction played a significant role in shaping perceptions rather than mass media or government agencies. This underlines the importance of local engagement and dialogue.

Recommendations for Improvement: The study suggests that transparent communication policies, more frequent engagement, and enhanced stakeholder dialogues are critical to reinforce public support. It highlights the need for increased local participation in consultations and transparent reporting by geothermal resource developers.

Site-Specific Nature of Study: The conclusions drawn from the Makiling-Banahaw Geothermal Complex might be biased and specific to this particular location, urging the need to study other geothermal projects, especially those dealing with conflicts in national park regulations or indigenous community involvement.

4 Critical examination of the main evidence from the case studies

The examples and studies analysed for this review clearly highlight that geothermal projects linked to the territory, through communication initiatives from third parties to raise awareness and social engagement in decision-making processes, are not contested and have a greater chance of receiving the green light from local authorities. In some cases, such as in St. Gallen in Switzerland, open and transparent communication of the risks associated with the use of deep geothermal resources allowed the project to be resumed after a seismic event of magnitude 3,5 during drilling operations, thanks to the broad public support. Indeed, when the risks of the project were communicated also before the event, there was always emphasis on the measures in place to deal with them (Eyderyan et al. 2019).

In contrast, partial or incorrect information can be a serious threat to geothermal development, so as the fragmentation of information, uncertainty, and doubts about the sources of data (Manzella et al. 2018). Imposed projects, without prior debate, that deny the right to have a say in environment and urban development and merely invoke energy transition, generate lasting and sometimes violent misunderstandings between operators, local elected officials, and residents. In these cases, communities protest because of environmental concerns and them not trusting the operators, or because they do not see benefits linked to the project. Oppositions due to imposed projects may also be one of the causes for the project abandonment, as in the case of the Strasbourg area, where out of five projects, two were contested and abandoned, while three were approved despite objections (Chavot et al. 2018).

A distinction should be made between two methods of communication: the public communication, which is usually conducted by independent experts, and the communication processes, which are managed by private companies (Allansdottir et al. 2019). Both kinds of communications complete each other and are important to allow the public to have all the information they need to have an opinion on the project and take decisions.

The implementation of an ineffective communication without social engagement may lead to local contestations. The project in Basel was sopped after a 3,2-magnitude earthquake during the injection of high pressurised water for the hydraulic stimulation of the geothermal reservoir, since controversies about the absence of communication, the quality of the project itself and the lack of a risk assessment were contested by local communities and authorities (Eyderyan et al. 2020). A monodirectional communication can create public scepticisms, as it was the case of the public assembly held by the municipality in Monte Amiata for the Sorgenia Geothermal project. Despite the efforts of the company to clearly provide information on geothermal energy, the project and its risks, as well as the results of the Life Cycle Assessment, and the collaboration with the municipality, the public could only ask questions about the project at the end of the assembly, but no sessions were held to engage with citizens in the decision-making process (Sorgenia Geothermal website). Similarly, in Haute-Sorne, some residents would have preferred discussions at municipal council sessions to influence more decisions, instead of the information meetings held by the project promoters with governmental officials, which they reported it did not provide legitimacy (Ejderyan et al. 2019).

In several cases considered for this review, the communication was proposed by, or involving, the local authorities (e.g., in Italy), as public authorities pursue the public interest and are to be considered above parties in these processes. However, outcomes from the survey carried out in Viterbo and

Palermo (Italy) (Pellizzone et al. 2015 and 2017) highlight how in some cases the local communities do not trust neither the operators, nor the local administrators (they are perceived as not impartial), rather than in the technology itself, and would prefer the involvement of local scientists (Pellizzone et al. 2019).

Although all the studies considered for this review report agree that it is necessary to start involving all the local stakeholders, authorities and citizens from the early exploration stages of a geothermal project, there are no standard procedures for participation (Vargas-Payera 2020; Reuf et al. 2020). Participative formats are different depending on the stakeholders and local perspectives and may change during a project lifetime, as it was the case in St. Gallen and Haute-Sorne (Switzerland). Despite positive or negative preconditions may exist in specific locations when siting, the forms in which promoters engage with the local public can influence these conditions (Ejderyan et al. 2019).

The local acceptance is also gained through highlighting the benefits or improvement of the community's living conditions, in addition to communicate the project, involve communities in decision making process and minimize impacts. St. Gallen and Geneva showed that the direct use of geothermal heat can play an important part in making deep geothermal locally acceptable (Ejderyan et al. 2020). However, in a hypothetical construction of a geothermal plant, it is key to clearly indicate whether the social benefits will be universal for the entire population or not (CEGA, 2022). Offering benefits can lead to the creation of expectations, which is a double-edged sword if these are high and cannot be comply with, as it was in the case of Tolhuaca in Chile (Martinez-Reyes 2020).

Table 1: Positive and negative examples of strategies to raise social acceptance on deep geothermal projects in communication and engagement initiatives.

	Positive example	Negative example
Communication	· Communication starts from early stages of the project development. · Communication tailored to different kinds of stakeholders and local conditions. · Communication of risks and mitigation measures. · Involve local authorities and scientists. · Clearly explain benefits. · Explain benefits from direct uses of heat.	· Top-down communication. · Communication only from operators. · Partial or incorrect communication. · Creation of high expectations. · Communicate benefits only.
Social engagement	· Citizen involvement in decision making processes. · Involvement of different kinds of local stakeholders.	· Plan the actions without involving local actors and authorities. · Top-down approach. · "Closed doors" initiatives, without involving local communities.

In addition, benefits and communication without social engagement may in any case lead to oppositions. For example, despite many benefits for geothermal territories in Italy and their citizens, as well as a long-lasting communication on geothermal are resulting from the implementation of agreements on geothermal energy, small groups of citizens are still opposing operating and future geothermal projects.

5 Towards an increase of acceptance – main tips

This section attempts to provide suggestions to develop a process of raising the acceptance towards deep geothermal energy projects, grounding on case studies described and discussed in the previous chapters. Operators and public authorities are the target of these suggestions, while part or all these suggestions will be used by the COMPASS project consortium to plan the next communication and social engagement activities.

The recommendations are reported in a list that starts from the initial stages of the project development.

1. **Before exploration permit – study of the local background:**
    a. Evaluate the assessment of the maturity and the energy strategies of local authorities, their awareness and position on geothermal energy;
    b. Analyse the political, social and cultural background of the territory;
    c. Map the stakeholders and analyse their interests and positions;
    d. Identify potential "allies" and trusted third parties

    Points above can be carried out analysing social media, local newspapers and through structured interviews to different kind of stakeholders.

    e. Plan a strategy, according to evidence of the points above, to start communicating the project to different groups of stakeholders (the strategy should be periodically updated and adapted). To tailor the strategy to different stakeholder groups and define acceptability-related topics to be communicated: risks and benefits for the environment, economy and society.
2. **During the explorations – communication and information:**
    a. Liaise with local authorities and show both the project and the communication and engagement plan, and ask their collaboration;
    b. Communicate the project locally, through workshops, social networks and newspapers. Provide transparent and bottom-up communication, including open information on all the potential benefits and risks;
    c. Organize also bigger events with neighbouring communities;
    d. To organize visits to drilling sites;
    e. Organize a first round of meetings with small groups, composed by a selection of representatives for each stakeholder category, to discuss on benefits (including direct uses of heat) and risks linked to the project and co-design the project implementation;
    f. Explain the project and risks through an up to date website, with recordings of public events;
    g. Provide contacts to give more information on the project;
    h. Identify criteria for the development of socio-technical scenarios for the deep geothermal project.
3. **Before submitting the application for the exploitation permit – co-design process:**

   a. Analyse the results of the first round of meetings with small groups of stakeholder representatives and elaborate a range of possible developments for the deep geothermal project, with a collaboration between scientists and engineers;
   b. Organize a second round of meetings to present possible project developments, discuss, make changes if necessary and select them.

4. **After the application for the exploitation permit – communication activities:**
   a. Communicate the project and its locally agreed development through public events, newspapers, and social media.

The communication and engagement strategy should be adapted over time.

The communication and engagement of local communities and authorities are critical factors for the success of a project and operators and developers should dedicate part of the project budget to these activities.

6 Conclusion

According to the findings of the case study in Tolhuaca (Chile) (Vargas-Payera et al. 2020), there is a wide range of factors that influence the perception of deep geothermal energy projects and that can be grouped in three interrelated categories: the project activities, the engagement process, and the context.

A good public acceptance can be achieved not only through a proper and transparent communication on the project, but also through the engagement of local communities in the decision-making process. Indeed, the deep geothermal project should be well rooted in the territory and citizens should be aware on linked risks and mitigation actions. However, direct socioeconomic benefits for the territory, to compensate the use of a local resource, should be proposed and communicated, including the direct uses of geothermal heat, both for space heating and cooling and for productive process.

Approaches to increase the social acceptance of deep geothermal projects depend on the local conditions and should be adapted over time, but in any case, operators and project developers must communicate the project and its technology, engage with citizens, and propose benefits as direct uses of heat. If one of these three elements is overlooked, there is a risk that the project will be contested.

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