

An online survey to explore the awareness and acceptance of geothermal energy among an educated segment of the population in five European and American countries

Daniel Balzan-Alzate (✉ dbalzan@ing.uchile.cl)

Universidad de Chile <https://orcid.org/0000-0003-3016-3452>

Jacqueline López-Sánchez

Universidad de Medellín

Daniela Blessent

Universidad de Medellín

Jasmin Raymond

Institut national de la recherche scientifique

Chrystel Dezayes

Bureau de Recherches Géologiques et Minières

Juan Pablo Portela

Universidad de Medellín

Estefania Ramírez Restrepo

Universidad de Medellín

David Moreno Rendón

Universidad de Medellín

Michel Malo

Institut national de la recherche scientifique

Pascal Godemiaux

Université de Mons

Linda Daniele

Universidad de Chile

Tanguy Le Borgne

Université de Rennes1

Research

Keywords: Geothermal resources, awareness, questionnaire, renewable energies, communities.

Posted Date: October 24th, 2020

DOI: <https://doi.org/10.21203/rs.3.rs-40991/v2>

License:  This work is licensed under a Creative Commons Attribution 4.0 International License. [Read Full License](#)

Version of Record: A version of this preprint was published on March 2nd, 2021. See the published version at <https://doi.org/10.1186/s40517-021-00188-x>.

Abstract

Advances in new technologies and the desire to achieve a sustainable and safe energy supply, enable communities to transition from conventional to renewable resources, such as geothermal energy. Perception and acceptance amongst different audiences have a high impact on the feasibility of energy projects, which is an important aspect to analyze. For this reason, this study focuses on describing the level of awareness and acceptance of deep geothermal energy within an educated segment of the population in five European and American countries (Canada, Colombia, Chile, Belgium, and France) at different stages of geothermal development. This study was conducted through an online survey, which was targeted to post-secondary students and professionals. Some of the most significant conclusions are: 1) there is a high degree of awareness of geothermal energy among the respondents in Chile and Canada, a medium level in Belgium and France, and a low one in Colombia; 2) there is a favorable acceptance of a geothermal project in each country, even when hydraulic stimulation is considered; 3) environmental aspects and community safety are the most important issues that must be addressed to support a pilot geothermal project.

1. Introduction

Population increase and industrial growth have generated a worldwide surge in energy demand, which has historically been met by burning fossil fuels, generating greenhouse gas (GHG) emissions, and making their reduction a global challenge (Karmaker et al. 2020). The use of fossil fuels increases the potential for global warming, and the alteration of natural ecosystem processes (Mondani et al. 2017; Amin and Rahman 2019). In the last decade, an increase in the concentration of GHG has been recorded. According to the World Meteorological Organization (WMO), the concentration reached historical values in 2016, with an atmospheric carbon dioxide (CO₂) concentration growing at a record speed, showing the highest values in recent years (WMO 2019). The large emissions of GHG, especially CO₂, produced by anthropogenic activities and their influence on climate conditions have become a major ecological and political challenge (Mondani et al. 2017). One of the goals detailed in the United Nations Organization 2030 agenda is to guarantee access to affordable, safe, sustainable and modern energy for all, in addition to the adoption of measures to fight climate change and its effects (UN 2015). Renewable energies are an efficient and effective solution (Dincer 2000). They are considered a promising and clean alternative worldwide, as they are produced from natural, non-depleting sources, such as sun, wind, waves, water and Earth's heat (Wüstenhagen et al. 2007; Lins et al. 2014; Owusu and Asumadu-Sarkodie 2016).

Among the renewable energies, one of the most sustainable options is geothermal energy (Dincer and Acar 2015). According to IPCC (2011), the global technical potential for electricity generation by means of geothermal energy is estimated to 200 GW. The geothermal capacity installed worldwide, in 2018, was 13.33 GW, of which 1.65 GW in Latin America (Mexico, Guatemala, El Salvador, Nicaragua, Costa Rica, Honduras, and Chile), 2.55 GW in United States, 2.96 GW in Europe, 4.44 GW in Asia, and 0.67 GW in Africa, and 1.05 in Oceania (IRENA 2019). It has been estimated that future geothermal deployment can meet between 2.5% and 4.1% of the global electricity demand, and about 5% of heating and cooling needs by 2050 (Goldstein et al. 2012). Use of deep geothermal energy sources is limited to specific areas with favorable conditions, having a heat source, a recharge mechanism, and an accessible depth, among others (DiPippo 2012). In many cases these conditions are not met, however technological advances have enabled their viability through enhanced geothermal systems (EGS). The use of hydraulic stimulation, one of EGS's existing techniques in addition to chemical and thermal stimulations (Watanabe et al. 2016), to improve the permeability of geothermal reservoirs began with the Hot Dry Rock concept put forward at Los Alamos (New Mexico) in the 70's (Olasolo et al. 2016). Dickson et al. (2004) additionally indicated that the direct use of heat is possible with the implementation of techniques to ensure permeability and circulation of fluids. EGS are projected as an important technology to the global growth of geothermal energy. The International Energy Agency (IEA) forecasted a global geothermal production of 140-160 GW in 2050, with a 60% share provided by EGS (IEA 2011). Such systems have been studied with field experiments throughout the world in different geological environments (Palacio-Villa et al. 2020), for example, the Fenton Hill project in the United States

(Reiter et al. 1976), Soultz-sous-Forêts in France (Cuenot et al. 2008), Basel in Switzerland (Wyss and Rybach 2010), Groß Schönebeck in Germany (Huenges et al. 2006), Paralana in Australia (King et al. 2009), Ogachi in Japan (Kaieda 2012).

Although geothermal energy is seen as a promising source of renewable energy, its development is constrained by several challenges, most notably social resistance (Bertani, 2016). Acceptance problems in different social sectors, lack of knowledge and negative perceptions, can affect the development of energy technologies (Dowd et al. 2011). It is important to understand that technology, society, and governance are interrelated, since a change in one, is likely to affect the others. Therefore, their interdependencies impact the acceptance of change and technology by society, an aspect that plays an important role in the evolution of new energy developments. As expressed by Jasanoff (2004), the relationship between science and technology has a common value, i.e., science generates an impact on society and society impacts science. Entrepreneurs, scientists, and policy makers working in the field of new energy technologies are constantly finding new reasons to involve the public in innovation (Jugend et al. 2020). Energy research should focus on problem oriented, interdisciplinary, and socially inclusive studies (Sovacool et al. 2015; Lennon et al. 2018).

Citizen participation can help to prevent, or at least anticipate, possible future controversies, to provide ideas for new and better products and services, and to increase the openness and transparency of scientific and technological developments, which is a prerequisite for a trust relationship between different actors (Meller et al. 2018). Involvement of citizens has also demonstrated that they can be proactive and come up with interesting suggestions, such as including energy and environmental issues in educational programs, from elementary school to universities (Pellizzone et al. 2015). One tool that enables the connection between different actors involved in the development of a project, is the communication of the environmental issues and energy technologies that shape public opinion, change policies, and affects our world (Dowd et al. 2011).

The implementation of appropriate communication strategies on energy transition projects such as geothermal energy can have a positive impact on the way projects are understood and accepted. An example is the study presented by Carr-Cornish and Romanach (2014) about the change in perception of a geothermal project when participants acquired knowledge on the subject, noting that the change in attitude is evident even when concerns related to groundwater contamination or induced seismicity persist. Furthermore, the location of a geothermal plant is a key aspect for its acceptance by local communities, as a preferred distance of at least 100 km from built-up areas is indicated by three-quarters of participants in the study conducted by Carr-Cornish and Romanach (2014). The study of Pellizzone et al. (2017) conducted in Viterbo, Italy, revealed that the perception of renewable energies including geothermal energy is positive and optimistic, but, like Carr-Cornish and Romanach (2014), they indicated that when the construction of a geothermal project is considered in immediate surroundings, the favorable perception of the concerned population diminishes, giving rise to the phenomenon known as "Not in my backyard". Acceptance is complex and varies according to the proximity of the geothermal power plant to the communities, which is identified as a relevant factor that should be considered from the first stages of any project. In fact, in seven European countries (Hungary, Italy, Macedonia, Poland, Romania, Serbia, and Slovakia), geothermal resources have been exploited below their real potential because of low or complete lack of public acceptance, among other reasons (Kępińska and Kasztelewicz 2015).

The discussion of geothermal projects in different social sectors is generally based on environmental, economic, and political aspects (Meller et al. 2018). Moreover, the media have also a crucial role on this discussion, depending on how they present deep geothermal energy to the public, as analyzed by Stauffacher et al. (2015), who highlighted the requirement of transparency and diligent monitoring of communication and public engagement. There are multiple factors that affect opinion on geothermal energy, such as contamination of groundwater, sustainability of water resources, uncertainty on reversibility, seismic activity, cost-benefit ratio, level of knowledge about the technologies, dissemination channels, the integration of various actors in project planning and public consultation exercises, among others (Dowd et al. 2011; Carr-Cornish and Romanach 2014; Chavot et al. 2018). In the context of the research project IGCP636Y "Unifying international research forces to unlock the geothermal energy" of the UNESCO's International

Geoscience Program (IGCP).an online survey was conducted among an audience constituted mainly by people with a scientific background and high education level in Canada, Colombia, Chile, France, and Belgium. The International Geoscience Programme (IGCP) started in 1972 and fosters international scientific cooperation in geosciences. Among other aspects, its mission includes promoting sustainable use of natural resources, such as hot deep fluids and heat stored in the subsoil which provide geothermal energy. IGCP projects focus on global issues of geosciences within these five themes: Earth Resources, Global Change, Geohazards, Hydrogeology, and Geodynamic. The project IGCP636 belongs to the first topic, and it is currently on its second phase 2020-2025. The objective of this survey was to explore and describe the general attitude toward geothermal energy of the participants. This survey represents the first stage of a future analysis that can involve different sectors of society, and thus describe and explore the social acceptance of geothermal energy in different countries. The relevant results obtained from this survey are discussed in this paper.

2. Overview Of Geothermal Resources In The Surveyed Countries

A short overview of geothermal resource characterization and potential is provided in the following sections for each country included in the survey. To better understand the results of the public survey, a state of geothermal development was assigned to each country studied. Early (exploration activities), moderate (few power or heat geothermal plants operating or demonstration projects) and advanced (several commercial heat or power plants) development statuses are the proposed categories to classify the development in each country.

Considering the current context of the geothermal industry and/or exploration studies conducted in each country, as detailed in the following sections, an advanced level of development is assigned to France, moderate to Belgium, Canada, and Chile, while an early development is appointed to Colombia. These countries are therefore case studies that are representative of all development stages, giving a complete overview of geothermal development in different situations across Latin America, North America, and Europe.

2.1 Canada

Geothermal energy in Canada is used primarily for heating and cooling purposes, with over 103,523 geothermal heat pump systems having shallow ground heat exchangers installed across the country, totaling an estimated 1,449 MW of heating capacity and 11,111 TJ of annual energy use (Raymond et al. 2015). However, there is currently no commercial exploitation of deep geothermal resources for electricity production. Exploration of deep geothermal resources has been conducted since 1973, with the identification of several strategic points, including the Meager Creek geothermal area, 160 km north of Vancouver, where deep wells were drilled during the 1980s for the purpose of carrying out tests (Jessop et al. 1991). New geothermal exploration projects are now ongoing in sedimentary basins, for example targeting deep resources in Saskatchewan. The state of deep geothermal development in Canada can be classified as moderate, where activities are mainly focused on deep resource evaluation and drilling for exploration purposes. The estimated maximum exergy potential for the most promising geothermal resources in the deepest parts of the Canadian basins is 150 kJ/kg (Majorowicz and Grasby 2019). Although the deep geothermal industry is not mature, it shows a promising outlook.

2.2 Colombia

The studies of geothermal resources in Colombia began in the 1970s (Arango et al. 1970). However, geothermal exploitation has not yet been developed since Colombia has limited technical and scientific capacity for the development of geothermal resources and the areas of interest are located in isolated volcanic zones (Mejia et al. 2014). The only geothermal exploration well in Colombia (Nereidas 1) was drilled in 1997 on the western flank of the Nevado del Ruiz Volcano (VRN), and could not reach the predicted depth of 2000 m because it suffered a strong deviation (Monsalve et al. 1998). Colombia has a great potential for the exploitation of geothermal energy, thanks to its strategic location within the fire belt, which allows different thermal manifestations to be seen throughout the country (Moreno-Rendón et al. 2020).

Projections indicate that the geothermal potential on the Nevado del Ruiz volcanic complex is 50 MW. In addition, the binational geothermal project Tufiño - Chiles - Cerro Negro that is being developed on the borders of Colombia and Ecuador presents an estimated potential of 138 MW (Mejia et al. 2014), which is evidence of the geothermal potential of the country. Colombia can therefore be characterized as an early development stage country, since only exploration studies have been conducted (Alfaro 2015) and knowledge and expertise are still limited. Nevertheless, the national development plan 2018-2022 mentions the introduction of a geothermal regulation framework and all the actors involved in its creation (Colombian National Planning Department, 2019), opening doors to the development of this type of resource.

2.3 Chile

Chile's geothermal exploration started between 1921 and 1922 with exploration campaigns led by Larderello's Italian technical team, which drilled two 70 and 80 m deep wells in the Antofagasta region (Lahsen et al. 2015). Exploration of geothermal resources was subsequently suspended until 1968. Between 1968 and 1976 geological, geochemical, and geophysical information was collected in the Surire, Puchuldiza, and El Taito geothermal fields (Procesi 2014). In addition, exploratory wells were drilled to evaluate the feasibility of the areas for electric energy production (Morata 2014). The geothermal potential that can be exploited in the country is approximately 2100 MW for the 2017-2050 period, with 600 MW in 2017-2030 and 1500 MW in the following period of 2031-2050 (Chilean Ministry of Energy 2018). Enel Green Power together with the National Petroleum Company built the first geothermal plant called Cerro Pabellón with a capacity of 48 MW distributed in two units (Jorquera 2017). In 2016, a National Survey about energy was conducted in Chile (Chilean Department of Energy 2017) and the results indicate that around 30 % of Chilean population knows about geothermal energy as a source of electricity; moreover, among those who are aware of this type of energy, 70 % agree with the construction of geothermal power plants. Chile is then considered at a moderate geothermal development stage.

2.4 Belgium

The first well for geothermal exploration in Belgium was drilled in 1975 (Hoes et al. 2013). The current geothermal exploitation in the Mons area is entirely dedicated to heat production and district heating. With a temperature of approximately 70°C, three pumping wells provide heating energy to hospitals, public buildings and businesses. In 2017, the installed capacity was 8.1 MW. The use of geothermal energy in the Mons region is expected to increase in the coming years (Scharff 2019). Several wells were exploited in the chalk reservoir of Flanders, for heating swimming pools and fish farming, but these operations have been stopped. Another project is currently being completed in the north, near the city of Antwerp (Richter 2018). The Balmatt project is the first experience of deep geothermal energy production in Belgium combined with heat generation. The research organization VITO is building the Balmatt heating plant; three deep wells have been drilled between 2016 and 2018 and to improve the understanding of the reservoir, a more detailed analysis was started, using data gathered from those three wells (Lagrou et al. 2019). A faulted area in the Campine Dinantian limestone deposit is the target at a depth of 2.8 to 3.8 km (Loveless et al. 2014). Belgium can be considered at a moderate geothermal development stage.

2.5 France

Geothermal development in the country is expected to grow using ground source heat pumps as well as geothermal district heating, with an estimated installed thermal capacity of 345 MWt (Vernier et al. 2015). France is one of the leading European countries in geothermal district heating. French power plants are located in Guadeloupe and in Alsace, at Soultz-sous-forêts. The power plant Bouillante, in Guadeloupe, consists of two units, a double flash unit operating since 1986 and a single flash unit inaugurated in 2004. They produce 15 MW, which represents about 5% of the island's electricity supply (Bouchot et al. 2010). The power plant has the potential to be expanded by 30 MW for a total capacity of 45 MW by 2021 (Richter 2016). The Soultz EGS pilot plant in the mainland North-East part of France has been connected to the grid

at the beginning of 2011. This plant, which is part of an innovative European research program based on EGS technology, was initiated in 1987 by the Bureau de Recherches Géologiques et Minières (Genter 1990). Moreover, the geothermal heat plant in Rittershoffen inaugurated in 2017 is the first geothermal heat plant worldwide for industrial uses. It is a model for the energy transition, and together with the EGS power project in Soultz-Sous-Forêts, it demonstrates that deep geothermal energy can be developed almost anywhere, powering and heating a cleaner, more sustainable Europe (Mouchot et al. 2018). France can be considered at a high geothermal development stage.

3. Research Methods

In the framework of the IGCP636Y UNESCO project led by the University of Medellin (Colombia), in collaboration with the Institut national de la recherche scientifique (INRS) (Canada), Universidad de Chile (Chile), Université de Mons (Belgium), Université de Rennes (France), and Bureau de Recherches Géologiques et Minières BRGM (France), an survey of fifteen questions was conducted, with six of them discussed below. The questions non-described related to general topics associated with renewable energies, and not specifically to geothermal energy, which is why they are not presented here. The countries where chosen are a function of the project collaborators. The survey aimed to explore the opinion of the respondents on deep geothermal energy and its possible development, including, eventually, the use of hydraulic stimulation as a feasibility mechanism.

3.1 Questionnaire design

The survey was available in English, Spanish, Dutch, and French, with a qualitative approach, and formulation to accommodate the respondent's desire to answer or not, including the option to select "I do not know - I prefer not to answer". Two descriptive texts were provided as background information to answer two of the six questions discussed in the article (Annex A). The first text was used to support the question: "What is your opinion of the use of geothermal energy for electricity production in your country?". Deep (high enthalpy) and shallow geothermal energy (low enthalpy) were differentiated in this first text. The second text was used to explain that hydraulic stimulation is sometime required in geothermal projects to improve the permeability of the rock and thus increase the feasibility of a project for electricity generation. The following question was asked: "If hydraulic stimulation is required, what is your acceptance of the development of a pilot geothermal energy project in your country?". The texts were designed in a clear and simple way so that technical details or words used did not influence the answers of the respondents (Annex A).

3.2 Data collection

The survey was built on the QuestionPro platform and shared through emails, social medias, dissemination at geothermal conferences, bulletins from the Center of Excellence in Geothermal Energy of the Andes (CEGA), and from the BGRM in France. The respondents were therefore people primarily having a high level of education, with a completed or ongoing university education. Sharing the survey online was the best option to achieve the goal of this study with the available project resources, although some segments of the population could not be represented among the respondents. This survey has therefore been considered an exercise to establish the basis for a future survey that can evaluate the social perception in each of the countries, with responses representative of the whole society.

This survey was based on a previous study conducted by Malo et al. (2015) in the province of Quebec (Canada) and the main differences were: (1) the translation to different languages, since the survey conducted in Quebec was done in English and French, (2) the dissemination method, since the survey conducted by Malo et al (2015) was coordinated by a professional company, Legér, a Canadian Institute specialized in surveys, (3) the coverage, since the work conducted by Malo et al. (2015) presented a local approach (Quebec province). The survey conducted in Québec was designed by the market research and analytics Canadian company Leger that pre-tested the questionnaire with a selected number of

respondents to ensure its internal logic and smooth operation. The analysis described here is therefore based on a well-founded structure and well-designed survey. The average time required to complete the survey was 9 minutes.

3.3 Sample

The survey was distributed at the end of 2016 for approximately 4 months. The responses received were filtered to consider only those that were given by people enrolled in a university program or that already completed it, in order to select the same segment of population in each country. 1063 responses have been therefore considered for the analysis described here and they are distributed as follows: Belgium 150, Canada 258, Colombia 249, Chile 193, and France 213. All the results analyzed here are related to multiple-choice questions. Demographic information was queried at the beginning of the survey to verify the respondents fit into the segment of population considered in this study, based on the highest education program in progress or completed by the respondent. To check if the responses to survey were statically representative of the population in each country in terms of gender, one question about gender was included in the survey. In general, the distribution of the population in each country is similar to the distribution of the responses to the survey by each country, the percentage of difference is 8.5% (Table 1).

Table 1. Percentage distribution of respondents by gender

	Percentage distribution by gender									
	Canada		Colombia		Chile		Belgium		France	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
Whole country	50.3	49.7	50.9	49.1	50.8	49.2	50.7	49.3	51.7	48.3
Respondents to this survey	46.6	53.4	50.7	49.3	56	44	45.3	54.7	43.2	56.8

Additionally, the age ranges of respondents are shown in Table 2.

Table 2. Percentage distribution of respondents by age

	Age	Percentage
Colombia	17-30	49.5
	31-50	37.3
	51-80	13.2
Chile	17-30	55.8
	31-50	33.9
	51-80	10.3
Canada	17-30	25.4
	31-50	55.1
	51-80	19.5
Belgium	17-30	33.7
	31-50	44.9
	51-80	21.5
France	17-30	21.2
	31-50	53.4
	51-80	25.5

4. Results

The answers to the questions of the survey analyzed here are presented in this section. The results on the acceptance of deep geothermal energy to generate electricity, with and without hydraulic stimulation, are presented together to compare how the acceptance percentage changes if EGS technology is considered (Table 3)."

4.1 Description of main issues related with energy production

As a result of the question "What are the main issues related to energy production in your region?", environmental impacts and the development of renewable energies appear to be the main concern in each of the countries surveyed, except for Chile, where respondents attribute the type of resource used as the second most important aspect (Figure 1). The type of resource used to produce energy and the cost of energy production are the third and fourth topics selected for Canada, Colombia, Belgium, and France, while achieving energy diversification, energy supply and energy independence appear to be of lesser importance among the respondents.

Figure 1. Description of main issues related with energy production.

4.2 Self-assessed level of knowledge

Based on a self-assessment, respondents expressed their level of knowledge about geothermal energy. Figure 2 shows the results obtained from the population surveyed starting from a qualitative scale that gradually increases from "Never heard" to "Very well", with the option of answering the question or not. The results show that for the respondents in Chile and Canada there is high knowledge with 79% and 64%, respectively, for the answers "Well" and "Very well". France with 49% and Belgium with 44% present greater knowledge than Colombia with 35%, but less than Chile and Canada. It is important to note that, except for Colombia with 9%, only less than 3% of respondents indicated they have never heard about geothermal energy. These results show that the respondents in Chile and Canada know very well geothermal energy, while in France and Belgium they have an average knowledge and a low one in Colombia.

Figure 2. Knowledge about geothermal energy.

4.3 Acceptance of geothermal energy production

In relation to the acceptance of geothermal energy production, respondents were asked on a qualitative scale from "Strongly disagree" to "Strongly agree", with the option of answering "I don't know/ I prefer not to answer", about their level of acceptance of geothermal energy production in their country. It is shown that the respondents in each country indicated a high level of acceptance for "Strongly agree" and "Agree", where Chile shows a higher level of acceptance compared to the other countries with a percentage between "Strongly agree" and "Agree" of 92%, followed by Canada with 78% and France, Belgium and Colombia with 71%, 72%, and 66%, respectively (Figure 3).

Figure 3. Acceptance to produce geothermal energy.

4.4 Acceptance of deep geothermal energy to generate electricity, with and without hydraulic stimulation

Questions with respect to this subject were accompanied with an explanatory text (Annex A). The focus of the questions was to explore the acceptance of a geothermal project for electricity generation, with and without the use of hydraulic stimulation. After the first explanatory text about the difference of geothermal energy for electricity generation and heating production, the respondents show high acceptance, with a minimum value of 79.49 % for Belgium and a maximum of 96.46 % for Chile. After the description of hydraulic stimulation applied to geothermal reservoirs, a decrease in the acceptance was observed, with a maximum reduction for France of 17.97% and minimum for Canada of 7.41%. It is also important to mention that the respondents showed insecurity with respect to the implementation of geothermal energy requiring hydraulic stimulation, but they are not inclined to accept or deny its acceptance, that is, impartiality increases (Table 1).

- Table 3. Acceptance of geothermal energy for electricity generation, with and without hydraulic stimulation.

		Strongly agree and Somewhat agree	Strongly disagree and Somewhat disagree	I do not know / I prefer not to answer	
1	Acceptance of deep geothermal energy to generate electricity (without mentioning hydraulic stimulation)	Belgium	79.49	12.82	7.69
		Canada	84.81	11.48	3.70
		Colombia	84.72	11.35	3.93
		Chile	96.46	2.53	1.01
		France	78.34	15.21	6.45
2	Acceptance of deep geothermal energy considering, eventually, the use of hydraulic stimulation	Belgium	62.82	22.44	14.74
		Canada	77.41	15.56	7.04
		Colombia	69.43	25.76	4.80
		Chile	86.87	10.61	2.53
		France	60.37	28.11	11.52
% difference	Belgium	-16.67	9.62	7.05	
2 - 1	Canada	-7.41	4.07	3.33	
	Colombia	-15.28	14.41	0.87	
	Chile	-9.60	8.08	1.52	
	France	-17.97	12.90	5.07	

4.5 Conditions that should be satisfied to support a geothermal pilot project

Figure 4 shows the conditions that must be met to ensure acceptance of geothermal energy projects. Among the most important issues identified are guarantees for the conservation of the landscape and protection of the environment, guarantees in terms of the safety of personnel and of the communities close to the plant, and information and consultation with the community on the activities carried out in the territory. It is important to bear in mind that the least importance was given to financial compensation to the community and to guarantees for the preservation of employment or for new employment opportunities.

Figure 4. Conditions that should be satisfied to support a pilot geothermal project.

5. Discussion

The respondents were asked to self-assess their degree of awareness about geothermal energy and to express their opinion and perception about energetic issues, acceptance of geothermal energy for electricity production, and implementation of a pilot project with and without the use of hydraulic stimulation. The selected segment of

population has, in general, a medium/high awareness about geothermal energy. Therefore, this exercise indicates that outreach activities should be focused to the remaining segments of the population. In the following subsections, each topic is separately discussed, following the same order used to describe the results in the previous section: 1) issues related with energy production, 2) self-assessed level of knowledge, 3) acceptance of geothermal energy production, 4) impact of hydraulic stimulation, and 5) conditions that should be satisfied to support a pilot geothermal project.

The highlights of these study can be summarized as follows: 1) this exercise provides the first attempt to investigate the geothermal perception of a segment of population in countries belonging to different development categories, 2) in general, high-level educated people have medium/high knowledge of geothermal energy and they may contribute to develop knowledge-sharing mechanisms throughout the whole society, and 3) outreach activities that should be implemented to foster geothermal development have to be addressed to specific segments of population.

In the analyzed countries high-level educated people show higher awareness about geothermal energy than what is indicated by studies that are representative of the whole population. Likewise, in the five countries there is a growing interest in promoting the use of geothermal resources, such that joint studies are useful to share experience and policies.

The main differences are associated with the local economic, social, politic, and energy background: in the literature it is hard to find studies that compare the geothermal energy perception in countries belonging to different development condition as it is done here, with countries from Europe, North, and South America. However, it would be hard to quantitatively compare the answers to this survey if the respondents live in completely different scenarios. Furthermore, the development of a geothermal project is site-specific and can have opposite outcome within the same country, as shown by Yasukawa et al. (2018) in Japan. Therefore, this study focuses on a qualitative analysis of similarities and differences that provides an interesting insight into geothermal perception for a specific segment of the population.

5.1 Description of main issues related with energy production

Energy is seen as a critical factor in providing prosperity for a modern society, but, on the other hand, is a potential source of environmental damage (Wadström et al. 2019). Therefore, there is a close relationship between the production of electricity and environmental impacts, which is determined by sources used for its production. Sources of electrical energy such as fossil fuels, water resources and nuclear fuel are associated to an environmental cost, such as GHG emissions, rigorous procedures for long-term storage of nuclear waste or degradation of aquatic ecosystems. These factors, together with the high dependence of Chile on fossil fuels (O’Ryan et al. 2020), of Colombia and Canada on hydroelectric energy (Gómez and Navarro 2018; CER 2020), of France and Belgium on nuclear energy, make up a critical panorama in environmental aspects and explain the strong concern of respondents about the environmental impacts associated with electricity production. Along the same line, the future development of renewable energies, which are presented as a tool to fight the main environmental aspects associated with electricity production (Owusu and Asumadu-Sarkodie 2016), is the second most important issue identified in the results (Figure 1).

The results obtained can also be interpreted considering the specific context of some of the countries. In Chile, there was a serious electricity crisis that required rationing in 1998 and 1999, and subsequently, there was a significant increase in the cost of power generation in 2007 and 2008, which showed that Chilean installed capacity was not sufficient and that the entire energy system was weak, since it depended mainly on imports. On the other hand, France has the highest percentage (7.5%), among all the countries analyzed, in terms of energy diversification, perhaps because nuclear energy in 2015 represented 78% of electricity generation, the highest share worldwide (IEA 2017). The exploitation of nuclear energy implies the definition of rigorous storage procedures to ensure the long-term management of nuclear waste.

Energy efficiency, supply, and independence can be analyzed together in Belgium. The obtained responses can be affected by the risk of electricity shortage experienced during the winters preceding this survey and explained by technical

problems and the temporary closure of some nuclear power plants. This feeling can be exacerbated by the government decision to close all nuclear power plants by 2025 (IEA 2016), affecting the energy matrix of the country, where 49.9% of the energy, in 2017, came from nuclear power (FEBEG 2020). If nuclear power plants are closed by 2025, there will be an impact on the economy: energy imports will be required, and cost will be affected. Therefore, this can explain why respondents are interested in the issue of energy independence.

In addition, it is important to highlight that the cost of energy is one of the main issues raised in these countries and can be related to the need to develop renewable energies, since they should have a lower cost for the users than conventional energy based on fossil fuels.

5.2 Self-assessed level of knowledge

The level of knowledge of geothermal energy is addressed here from a general viewpoint, considering both low and high enthalpy systems. Therefore, the results to this question are described from a general perspective. Although there is a limited overall understanding associated with geothermal energy for general public (Cataldi 1999), Figure 2 shows a medium-high level of knowledge, except for Colombia, where a lower level of knowledge is shown.

In Chile, a study conducted by Vargas (2018) about a community near the Villarrica volcano in the Araucanía region suggests that there is a low level of understanding of the technology involved in geothermal energy production. Moreover, the Chilean National Survey conducted in 2016, indicate that around the 30 % of Chilean population is aware of geothermal energy as a source of electricity (Chilean Department of Energy 2017).

In Canada, Malo et al. (2015) indicated that the population in the Quebec province has a low level of knowledge about surface and deep geothermal energy.

The panorama in Europe is not different to what is happening in Canada, Chile, and Colombia with respect to the level of knowledge: according to the European Geothermal Energy Council, the levels of information and awareness about the different technologies, in particular geothermal energy, can be qualified as low.

Colombia presents the lowest knowledge, which may be related to the level of early geothermal development. It is important to note that the Colombian Association of Geothermal Energy (AGEOCOL) has created different events to disseminate information on geothermal energy, which began in December 2016 with the first national geothermal energy meeting (RENAG) held in Bogotá, just after the implementation of this survey. This could explain the low degree of awareness about geothermal energy recorded.

The results of this survey contrast with the general level of knowledge indicated by the studies mentioned here, except from Colombia. The results strictly apply to a specific group of the population, mainly constituted by persons with post-secondary education.

5.3 Acceptance of geothermal energy production

The level of knowledge of a given technology is not necessarily proportional to its acceptance. Therefore, a question was established to better explore the acceptance of geothermal energy production. This is based on the concept that the social acceptance of geothermal development is not simple (Allansdottir et al. 2019). The results of the question indicate (as presented in section 5.1) that the acceptance of geothermal energy by people who completed the survey is high for all countries, even though the acceptance of a technology is not easy to address from a social perspective. The moderate-high acceptance shown by the respondents may also be associated to the general awareness of global warming and climate change, as well as the importance of a diversified energy matrix, which are topics more and more mentioned in the news and scientific community. It seems that an intuitive or technical knowledge of general or specific aspects of geothermal energy allows people to associate geothermal systems as a technology that opens the door to the energy

transition. However, this result is specific for this study and it should not be generalized. In fact, there is limited evidence that more informed individuals show higher acceptance of low carbon technologies, and although some studies indicated a correlation between knowledge and acceptance, others reveal that the levels of support were independent of levels of awareness (Devine-Wright, 2007). Moreover, acceptance varies for each specific project and area of implementation, but a good public information campaign can help communities to correctly understand the different challenges of the project (Colla et al. 2020). In general, the acceptance of new energy technologies has been investigated by different scientific disciplines, but a coherent overview is still missing (von Wirth et al. 2018). It is therefore worth conducting specific case-studies, such as the survey described here focused on geothermal energy, to increase the range of available experiences that can be analyzed and compared to foster the development of renewable energies.

5.4 Acceptance of deep geothermal energy to generate electricity, with and without hydraulic stimulation

The question about the acceptance of geothermal energy for electricity generation, indicating a maximum value for Chile with 96.46% and a minimum for Belgium with 79.49%, showed the consistency of the respondents with the answers presented in the previous sections. In contrast, in Chile, the National Survey conducted in 2016 and covering all population segments indicated a lower acceptance (Chilean Department of Energy 2017), confirming that the acceptance varies with the population segment investigated. When evaluating geothermal electricity production with hydraulic stimulation, the results showed a decrease in all countries, with a maximum decrease of 17.97% for France and a minimum of 7.41% for Canada. It is notorious that hydraulic stimulation techniques generate an impact or have a great relevance in the acceptance of the people surveyed, since it can be confused with hydraulic stimulation processes for shale gas extraction. Hydraulic stimulation for geothermal energy has been compared by the public with techniques implemented in hydrocarbon exploitation and associated with fracking (Biello 2013; Sun et al. 2017). Therefore, in several regions of France, there are people who are opposed to hydraulic stimulation for geothermal energy since they point out the risk caused by technology used to facilitate water circulation in the rocks (Meng and Ashby 2014; Chavot et al. 2018). Even though there is a decrease in the acceptance of high enthalpy energy with the implementation of hydraulic stimulation, the acceptance is above 50%, with a minimum of 62.82% in Canada and a maximum of 87.81% for Chile, indicating that for the public surveyed geothermal energy has fair acceptance.

5.5 Conditions that should be satisfied to support a pilot geothermal project

The implementation of a new energy technology, such as geothermal, is limited by community acceptance of its development. To narrow the gap between energy development and acceptance, several conditions must be met to enable communities to support pilot projects. In this case, the public surveyed has selected some aspects that they believe should be satisfied. The aspect that is highlighted as most important is the guarantee of environmental protection, which has been a common factor in the acceptance of geothermal studies (Carr-Cornish and Romanach 2014; Chavot et al. 2018), since the relationship between electrical energy and environmental impacts has resulted, in recent years, in the acceleration of climate change. Therefore, in the implementation of new technologies, a balance must be achieved between electrical production and the environment, and aspects such as the contamination of water resources must be minimized, while appropriate long-term monitoring must be ensured. The second aspect selected by the respondents reflects the need to guarantee the safety of the communities living close to the plant; this aspect can be related to the phenomenon known as "Not in my backyard", where communication plays a relevant role. Involving communities in geothermal projects can improve their position in the acceptance of geothermal energy. Although this survey has been carried out for a specific sector of the society, the answers are consistent with the results of other work focused on social acceptance (Carr-Cornish and Romanach 2014; Malo et al. 2015; Pellizzone et al. 2017). Therefore, environmental aspects, citizen participation, and the integration of social objectives should be a central focus in the implementation of geothermal energy.

6. Conclusion

The analysis of the results of the online survey conducted in Canada, Colombia, Chile, Belgium, and France to explore and describe geothermal energy awareness and acceptance in a social segment primarily constituted by people with post-secondary education, can be summarized as follows:

1. Chile and Canada are the countries where the population surveyed shows high degree of awareness of geothermal energy, while France and Belgium are characterized by a medium level and Colombia by a low one. These results are strongly dependent to the public segment selected for this survey, since, if the whole population is considered, a different scenario can be obtained, as shown by the Chilean National Energy Survey conducted in 2016 (Chilean Department of Energy 2017).
2. In general, there is a strong acceptance of electricity generation from deep geothermal resources, although this acceptance decreases in case hydraulic stimulation is required. Nevertheless, a positive assessment is still observed in all countries.
3. The geothermal potential of the considered countries, together with a positive acceptance of this type of energy, can help to unlock geothermal resources or to increase their current utilization. However, the results presented here do not fully characterize complete social acceptance, since the respondents are not representative of the whole society.
4. In general, France and Belgium have similar behavior and trends in percentages for all questions, while several differences can be observed when comparing North and South American countries.
5. Based on this first experience, a general survey that involves different society sectors to evaluate the social acceptance of geothermal energy in each of the countries can be envisioned. This future exercise will allow a comparison between North America, South America, and Europe and can be used to establish guidelines to work with the communities providing discussion opportunities for the growth of this energy source.
6. Awareness campaigns can be organized for different actors and sectors of the society, to generate basic guidelines to foster geothermal development since geothermal energy is generally not well known.
7. Data were collected through an online survey, without any restriction to people who may answer. As consequence, after closing the questionnaire, respondents with high-level education were selected and considered for the analysis.
8. The available participants for this research project were somewhat limited as the QuestionPro platform could left open only for three months; reminders to invite the public to fill out the survey were regularly sent, but there were no tools to directly contact the respondents. Being an online survey, only the connected part of the population could be reached.
9. The acceptance and awareness of a technology can be based on the understanding of technical aspects or it can be just intuitive. In this survey both facets are considered and are not differentiated, since they both represent the knowledge of the respondents. The acceptance and awareness of geothermal energy have to be analyzed considering the current specific energy context of each country, as context changes may affect the future perception.

Declarations

Availability of data and material

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

Funding

UNESCO (United Nations Educational, Scientific and Cultural Organization) and IUGS (International Union of Geological Sciences) within the International Geoscience Programme (IGCP) funded the QuestionPro license. The original questionnaire developed in Canada and which was adapted for all surveyed countries was established through a research project supported by the *Fonds de recherche du Québec – nature et technologies*.

Authors' contributions

Conceptualization Daniel Balzan, Daniela Blessent, Jacqueline López; methodology, Jacqueline López; validation, Jasmin Raymond; formal analysis, Jacqueline López, Juan Portela, David Moreno, Michael Malo; investigation, Daniel Balzan; resources Daniela Blessent, Jasmin Raymond; data curation, Estefania Ramirez, Linda Daniele, Chrystel Dezayes, Pascal Goderniaux, Tanguy Le Borgne; writing—original draft preparation, Daniel Balzan, Jacqueline López; writing—review and editing Daniel Balzan, Daniela Blessent, Jasmin Raymond, Chrystel Dezayes. All authors have read and agreed to the published version of the manuscript

Acknowledgements

This work is part of the project “IGCP 636-Unifying international research forces to unlock and strengthen geothermal exploitation of Americas and Europe” developed between 2016-2020. The authors acknowledge the UNESCO (United Nations Educational, Scientific and Cultural Organization), IUGS (International Union of Geothermal Sciences) within the International Geoscience Programme (IGCP). We also acknowledge all the anonymous respondents who completed the survey in the five participating countries. The first author acknowledges the Agencia Nacional de Investigación y Desarrollo de Chile (ANID) through the public funding program: FONDAP no. 15090013 (Andean Geothermal Center of Excellence, CEGA), which provides his MSc scholarship.

References

- Alfaro C. Improvement of Perception of the Geothermal Energy as a Potential Source of Electrical Energy in Colombia, Country Update. In: Proceedings World Geothermal Congress, Melbourne. 2015; p. 15.**
- Allansdottir A., Pellizzone A., Sciuolo A. Geothermal Energy and Public Engagement. In: Manzella A., Allansdottir A., Pellizzone A. (eds) Geothermal Energy and Society. Lecture Notes in Energy. Springer, Cham. 2019; 67: 55-65.**
- Amin SB, Rahman S. Renewable energy practices in Bangladesh. In: Renewable Energy Practices in Bangladesh. Springer, Cham 2019; 93-96.**
- Arango EE, Buitrago AJ, Cataldi R, Ferrara GC, Panichi C, Villegas VJ. Preliminary study on the Ruiz geothermal project (Colombia). Geothermics. 1970; 2(1):43-56.**
[https://doi.org/10.1016/0375-6505\(70\)90005-2](https://doi.org/10.1016/0375-6505(70)90005-2).

- Bertani R. Geothermal power generation in the world 2010–2014 update report. *Geothermics*. 2016; 60:31-43. <https://doi.org/10.1016/j.geothermics.2015.11.003>.
- Biello D. 2013. Fracking Can Be Done Safely, but Will It Be? *Scientific America*. Sustainability. 2013. <https://www.scientificamerican.com/article/can-fracking-be-done-without-impacting-water/>
- Bouchot V, Sanjuan B, Traineau H, Guillou-Frottier L, Thimon I, Baltassat JM, Fabriol H, Bourgeois B, Lasne E. Assessment of the Bouillante Geothermal Field (Guadeloupe, French West Indies): Toward a Conceptual Model of the High Temperature Geothermal System. In: *Proceedings World Geothermal Congress, Bali, Indonesia; 2010*. p 8.
- Carr-Cornish S, Romanach L. Differences in Public Perceptions of Geothermal Energy Technology in Australia. *Energies*. 2014; 7:1555-1575. <https://doi.org/10.3390/en7031555>.
- Cataldi R. Social acceptance: a sine qua non for geothermal development in the 21st century. *Bulletin d'Hydrogéologie*. 1999; 17:467-476.
- CER Canada Energy Regulator. Canada's Adoption of Renewable Power Sources – Energy Market Analysis. 2020. <https://www.cer-rec.gc.ca/nrg/sttstc/lctrct/rprt/2017cnddptnrnwblpwr/hdr-eng.html>
- Chavot P, Heimlich C, Masseran A, Serrano Y, Zoungrana J, Bodin C. Social shaping of deep geothermal projects in Alsace: politics, stakeholder attitudes and local democracy. *Geothermal Energy*. 2018; 6(26). <https://doi.org/10.1186/s40517-018-0111-6>.
- Chilean Department of Energy. Resultados Principales de Encuesta Nacional de Energía 2016. 2017. <https://www.energia.gob.cl/noticias/nacional/encuesta-nacional-de-energia-2016>
- Chilean Ministry of Energy. Mesa de geotermía: rol de la geotermía en el desarrollo de la matriz eléctrica chilena. Ministerio de Energía. 2018.
- Colla M, Ioannou A, Falcone G. Critical review of competitiveness indicators for energy projects. *Renewable and Sustainable Energy Reviews* 2020, 125, 109794. <https://doi.org/10.1016/j.rser.2020.109794>
- Colombian National Planning Department. Plan Nacional de Desarrollo 2018-2022: Pacto por Colombia, pacto por la equidad. 2019; p. 1660.
- Cuenot N, Faucher JP, Fritsch D, Genter A, Szablinski D. The European EGS project at Soultz-sous-Forêts: From extensive exploration to power production. In: *Proceedings IEEE Power and Energy Society General Meeting Conversion and Delivery of Electrical Energy in the 21st Century, Pittsburgh, Pennsylvania, 2008*. p. 8. [10.1109/PES12175.2008](https://doi.org/10.1109/PES12175.2008)
- Devine-Wright P. Reconsidering Public Attitudes and Public Acceptance of Renewable Energy Technologies: A Critical Review. Manchester Architecture Research Centre, University of Manchester. 2007. Working Paper 1.4.
- Dincer I. Renewable energy and sustainable development: a crucial review. *Renewable and Sustainable Energy Reviews*. 2000; 4(2):157-175. [https://doi.org/10.1016/S1364-0321\(99\)00011-8](https://doi.org/10.1016/S1364-0321(99)00011-8).
- Dincer I, Acar C. A review on clean energy solutions for better sustainability. *International journal of energy research*. 2015; 39(5): 585–606. <https://doi.org/10.1002/er.3329>.

DiPippo R. Enhanced Geothermal Systems-Projects and Plants. Geothermal Power Plants: Principles, Applications, Case Studies and Environmental Impacts. Third Edition. Butterworth-Heinemann. Elsevier. 2012. ISBN 978-0-08-098206-9.

Dickson MH, Fanelli M. What is Geothermal Energy? 2004.
<http://users.metu.edu.tr/mahmut/pete450/Dickson.pdf>

Dowd AM, Boughen N, Ashworth P, Carr-Cornish S. Geothermal technology in Australia: investigating social acceptance. Energy Policy. 2011; 39(10):6301–6307.
<https://doi.org/10.1016/j.enpol.2011.07.029>.

FEBEG Fédération Belge des Entreprises Électriques et Gazières. Annual Report FEBEG. 2020.https://www.febeg.be/sites/default/files/febeg_annual_report_slide_deck_2019_fr_final.pdf

Genter A. Géothermie roches chaudes sèches. Le granite de Soultz-sous-Forêts (Bas-Rhin, France). Fracturation naturelle, altérations hydrothermales et interaction eau-roche. Bureau de recherches géologiques et minières (BRGM), Document No. 185, Ed. BRGM, Orléans, France. 1990; p. 201.

Goldstein B, Hiriart G, Tester J, Gutierrez-Negri L, Bertani R, Bromley C, Huenges E, Ragnarsson A, Mongillo M, Lund JW, Rybach L, Zui V, Muraoka H. Geothermal Energy, Nature, Use, and Expectations. In: Meyers R.A. (eds) Encyclopedia of Sustainability Science and Technology. Springer, New York, NY. 2012; 4190- 4201.

Gómez T, Navarro D. Assessing the obstacles to the participation of renewable energy sources in the electricity market of Colombia. Renewable and Sustainable Energy Reviews. 2018; 90:131-141. <https://doi.org/10.1016/j.rser.2018.03.015>.

Hoes, H. Petitclerc, E. Declercq, P.Y. Laenen, B. 2013. Geothermal Energy Use, Country Update for Belgium. European Geothermal Congress, Pisa, Italy, 3-7 June. p 7.

Huenges E, Saada A, Brandt W, Moeck I, Holl HG, Zimmermann G, Blöcher G, Köhler S, Legarth B, Tischner T. Current status of the EGS gross schönebeck project: On the way to demonstrate sustainable brine production from deep sediments of the North German Basin. In: Proceedings GRC 2006 Annual Meeting: Geothermal Resources-Securing Our Energy Future, Transactions - Geothermal Resources Council. 2006. 30: 341-345.

IEA, International Energy Agency. Energy Policies of IEA Countries, France, Review. IEA Publications. 2017; p. 211.

IEA, International Energy Agency. Energy Policies of IEA Countries, Belgium: 2016 Review. IEA Publications. 2016; p. 178.

IEA, International Energy Agency. Technology Roadmap – Geothermal Heat and Power. IEA publications, Paris, France. 2011.

IPCC, Intergovernmental Panel on Climate Change. Renewable Energy Sources and Climate Change Mitigation. Special Report of the Intergovernmental Panel on Climate Change. Cambridge University Press. 2012; p. 1088.

IRENA. Renewable capacity statistics. International Renewable Energy Agency, Abu Dhabi. 2019. ISBN 978-92-9260-123-2; p. 60.

Jasanoff S. States of Knowledge: The Co-Production of Science and the Social Order. Routledge 2004; p. 317.

Jessop AM, Ghomshei MM, Drury MJ. Geothermal energy in Canada. Geothermics. 1991; 20(5-6):369-385. [https://doi.org/10.1016/0375-6505\(91\)90027-S](https://doi.org/10.1016/0375-6505(91)90027-S).

Jorquera C. Primera planta geotérmica de América del sur – Cerro Pabellón de 48 MW inicia operación. Piensa en geotermia. 2017. <http://www.piensageotermia.com/primeraplantageotermica-de-america-del-sur-cerro-pabellon-de-48-mw-inicia-operacion>. Accessed 3 April 2019.

Jugend D, De Camargo Fiorini P, Armellini F, Ferrari A.G. 2020. Public support for innovation: A systematic review of the literature and implications for open innovation. Technological Forecasting & Social Change 156: 119985

Kaieda H. Ogachi EGS Reservoir Analysis. Central Research Institute of Electric Power Industry, Abiko, Chiba, Japón. GRC Transactions. 2012; 36:487-492.

Karmaker AM, Rahman M, Hossain A, Ahmed R. Exploration and Corrective Measures of Greenhouse Gas Emission from Fossil Fuel Power Stations for Bangladesh. Journal of Cleaner Production. 2020. 244(118645). <https://doi.org/10.1016/j.jclepro.2019.118645>.

Kępińska B, Kasztelewicz A. Public perception of geothermal energy in selected European countries. In: Proceedings World Geothermal Congress, Melbourne, Australia. 2015; p. 12.

King JP, Reid PW, Bendall B. Progress at the Paralana EGS Project in South Australia. In: Proceedings Australian Geothermal Energy. 2009; 74-76.

Lagrou D, Petitclerc E, Hoes H, Dupont N, Laenen B, Geothermal Energy Use, Country Update for Belgium. 2019. In: Proceedings European Geothermal Congress, Den Haag, The Netherland. 2019; p. 6.

Lahsen A, F Sepúlveda, Rojas J, Palacios C. Present Status of Geothermal Exploration in Chile. In: Proceedings World Geothermal Congress, Melbourne, Australia; 2015. p. 8.

Lennon B, Dunphy NP, Sanvicente E. Community acceptability and the energy transition: a citizens' perspective. Energy, Sustainability and Society. 2019; 9:35. <https://doi.org/10.1186/s13705-019-0218-z>

Lins C, Williamson LE, Leitner S, Teske S. The first decade: 2004-2014: 10 years of renewable energy progress. Renewable Energy Policy Network for the 21st Century. 2014- ISBN: 978-3-9815934-4-0. <http://hdl.handle.net/10453/117208>.

Loveless S, Pluymaekers M, Lagrou D, De Boever E, Doornenbal H, Laenen B. Mapping the geothermal potential of fault zones in the Belgium-Netherlands border region. European Geosciences Union General Assembly. Energy Procedia. 2014; 59:351-358. <https://doi.org/10.1016/j.egypro.2014.10.388>.

Majorowicz J, Grasby S. Deep geothermal energy in Canadian sedimentary basins Vs. Fossils based energy we try to replace – Exergy [KJ/KG] compared. Renewable Energy. 2019; 141:259-277. <https://doi.org/10.1016/j.renene.2019.03.098>

Malo M, Moutemet JP, Bédard K, Raymond J. Public Awareness and Opinion on Deep Geothermal Energy in the Context of Shale Gas Exploration in the Province of Québec, Canada.

In: Proceedings World Geothermal Congress, Melbourne, Australia. 2015. p. 8.

Mejia E, Rayo L, Méndez J, Echeverri J. Geothermal Development in Colombia. In: Proceeding Short Course VI on Utilization of Low- and Medium-Enthalpy Geothermal Resources and Financial Aspects of Utilization, La Geo, El Salvador. 2014. p. 7.

Meller C, Schill E, Bremer J, Kolditz O, Bleicher A, Benighaus C, Chavot P, Gros M, Pellizzone, A. Renn, O. Schilling, F. Kohl, T. Acceptability of geothermal installations.: a geoethical concept for GeoLaB. *Geothermics*. 2018. 75:133-145. <https://doi.org/10.1016/j.geothermics.2017.07.008>.

Meng Q, Ashby S. Distance: A critical aspect for environmental impact assessment of hydraulic fracking, *The Extractive Industries and Society*. 2014; 1(2): 124-126.

Mondani F, Aleagha S, Khoramivafa M, Ghobadi R. Evaluation of greenhouse gases emission based on energy consumption in wheat Agroecosystems. *Energy Reports*. 2017; 3:37-45. <https://doi.org/10.1016/j.egy.2017.01.002>.

Monsalve ML, Rodriguez GI, Mendez RA, Bernal NF. Geology of the Well Nereidas 1, Nevado Del Ruiz Volcano, Colombia. *Geothermal Resources Council Transactions*. 1998; 22:263-268.

Morata D. ¿Chile: un país geotérmico en un futuro inmediato? *Anales*. 2004; 5: 71-86.

Moreno-Rendón DA, López-Sánchez J, Blessent D. Geothermal energy in Colombia as of 2018. *Ingeniería y universidad: engineering for development*. 2020; 24(1) <https://doi.org/10.11144/Javeriana.iyu24.geic>

Mouchot J, Genter A, Cuenot N, Scheiber J, Seibel O, Bosia C, Ravier G. First Year of Operation from EGS geothermal plants in Alsace, France: Scaling Issues. In: Proceedings 43rd Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, California. 2018; p 12.

Olasolo P, Juaréz M.C, Morales M.P, D'Amico S, Liarte I.A. Enhanced geothermal systems (EGS): A review. *Renewable and Sustainable Energy Reviews*. 2016; 56: 133-144. <https://doi.org/10.1016/j.rser.2015.11.031>

O'Ryan R, Nasirov S, Álvarez-Espinosa A. Renewable energy expansion in the Chilean power market: A dynamic general equilibrium approach to determine CO2 emission baselines. *Journal of Cleaner Production*. 2020; 247(119645). <https://doi.org/10.1016/j.jclepro.2019.119645>.

Owusu PA, Asumadu-Sarkodie S. A review of renewable energy sources, sustainability issues and climate change mitigation. *Cogent Engineering*. 2016; 3:1167990. p. 14. <https://doi.org/10.1080/23311916.2016.1167990>.

Palacio-Villa MA, Blessent D, López-Sánchez J, Moreno D. Sistemas geotérmicos mejorados: revisión y análisis de casos de estudio. *Boletín de Geología*. 2020; 42(1):101-118. doi: 10.18273/revbol.v42n1-2020006.

Pellizzone A, Allansdottir A, De Franco R, Muttoni G, Manzella A. Exploring public engagement with geothermal energy in southern Italy: a case study. *Energy Policy*. 2015; (85):1-11.

Pellizzone A, Allansdottir, A. De Franco, R. Muttoni, G. Manzella, A. Geothermal energy and the public: a case study on deliberative citizens' engagement in central Italy. *Energy Policy*. 2017; 101:561–570. <https://doi.org/10.1016/j.enpol.2016.11.013>.

Procesi M. Geothermal Potential Evaluation for Northern Chile and Suggestions for New Energy Plans. *Energies* 2014; 7: 5444-5459

Raymond J, Malo M, Tanguay D, Grasby SE, Bakhteyar F. Direct utilization of geothermal energy from coast to coast: a review of current applications and research in Canada. In: Proceedings of the World Geothermal Congress, Melbourne, Australia. 2015; p 10.

Reiter M, Weidman C, Edwards CL, Hartman H. Subsurface Temperature Data in Jemez Mountains, New Mexico. Socorro, NM: New Mexico Bureau of Mines and Mineral Resources. Report No. Circular 151. 1976.

Richter A. Having been sold to Ormat, the Bouillante geothermal power plant in Guadeloupe in the Caribbean could be expanded by 30 MW for a total capacity of 45 MW by 2021. ThinkGeoEnergy. 2016. <http://www.thinkgeoenergy.com/plans-for-30-mw-expansion-for-guadeloupe-geothermal-plant/>. Accessed 3 April 2019.

Richter A. Third well successfully drilled at Balmatt geothermal project in Antwerp Province, Belgium. ThinkGeoEnergy. 2018. <https://www.thinkgeoenergy.com/third-well-successfully-drilled-at-balmatt-geothermal-project-in-antwerp-province-belgium/>. Accessed 7 April 2019.

Scharff C. Un nouveau projet géothermique lancé en pleine ville de Mons. L'Echo. 2019. <https://www.lecho.be/dossier/pme-wallonie/un-nouveau-projet-geothermique-lance-en-pleine-ville-de-mons/10098823.html>. Accessed 7 April 2019.

Sovacool BK, Ryan SE, Stern PC, Janda K, Rochlin G, Spreng D, Pasqualetti MJ, Wilhite H, Lutzenhiser L. Integrating social science in energy research. Energy Research & Social Science. 2015; 6:95–99. <http://dx.doi.org/10.1016/j.erss.2014.12.005>.

Stauffacher M, Muggli N, Scolobig A, Moser C. Framing deep geothermal energy in mass media: the case of Switzerland. Technological Forecasting and Social Change. 2015; 98:60-70.

Sun Z, Zang X, Xu Y, Yao J, Wang H, Lv S, Sun Z, Huang Y, Cai M, Huang X. Numerical simulation of the heat extraction in EGS with thermal-hydraulic-mechanical coupling method based on discrete fractures model. Energy. 2017; 120:20-33. <https://doi.org/10.1016/j.energy.2016.10.046>.

UN, United Nations. About the Sustainable Development Goals. 2015. <https://www.un.org/sustainabledevelopment/sustainable-development-goals/>

Vargas S. Understanding social acceptance of geothermal energy: Case of study for Araucanía region, Chile. Geothermics 2018; 72:138-144.

Vernier R, Laplaige P, Desplan A, Boissavy C. France Country Update. In: Proceedings World Geothermal Congress, Melbourne, Australia; 2015. p. 8.

von Wirth T, Gislason L, Seidl R. Distributed energy systems on a neighborhood scale: Reviewing drivers of and barriers to social acceptance. Renewable and Sustainable Energy Reviews 2018. 82: 2618–2628. <http://dx.doi.org/10.1016/j.rser.2017.09.086>

Wadström C, Wittberg E, Salah G, Jayasekera R. Role of renewable energy on industrial output in Canada. Energy Economics 2019; 81:626-638.

Watanabe N, Blöcher, Cacace M, Held S, Kohl T. Geoenergy Modeling III: Enhanced Geothermal Systems. Springer. 2016. p. 119.

WMO, World Meteorological Organization. Greenhouse gas concentrations in atmosphere reach yet another high. 2019. <https://public.wmo.int/en/media/press-release/greenhouse-gas->

concentrations-atmosphere-reach-yet-another-high.

Wüstenhagen R, Wolsink M, Bürer MJ. Social acceptance of renewable energy innovation: An introduction to the concept. *Energy policy* 2007; 35(5):2683-2691.

Wyss R, Rybach L. Developing Deep Geothermal Resources in Switzerland. In: *Proceedings World Geothermal Congress, Bali, Indonesia; 2010. p. 4.*

Yasukawa K., Kubota H., Soma N., Noda T. 2018. Integration of natural and social environment in the implementation of geothermal projects. *Geothermics* 73 (2018) 111–123.

Figures

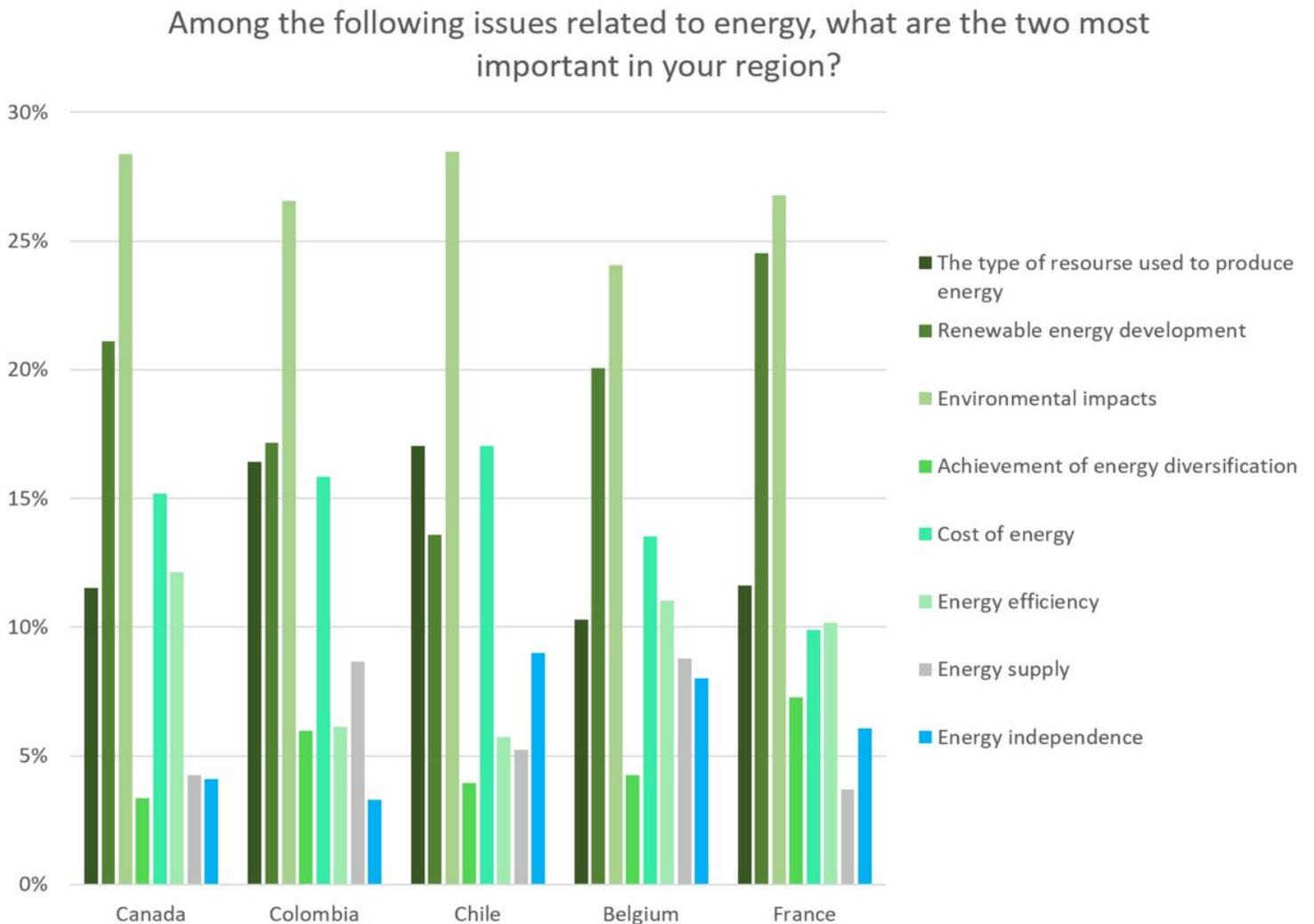


Figure 1

Diagnostic of main issues related with energy production.

Self-assessed level of knowledge

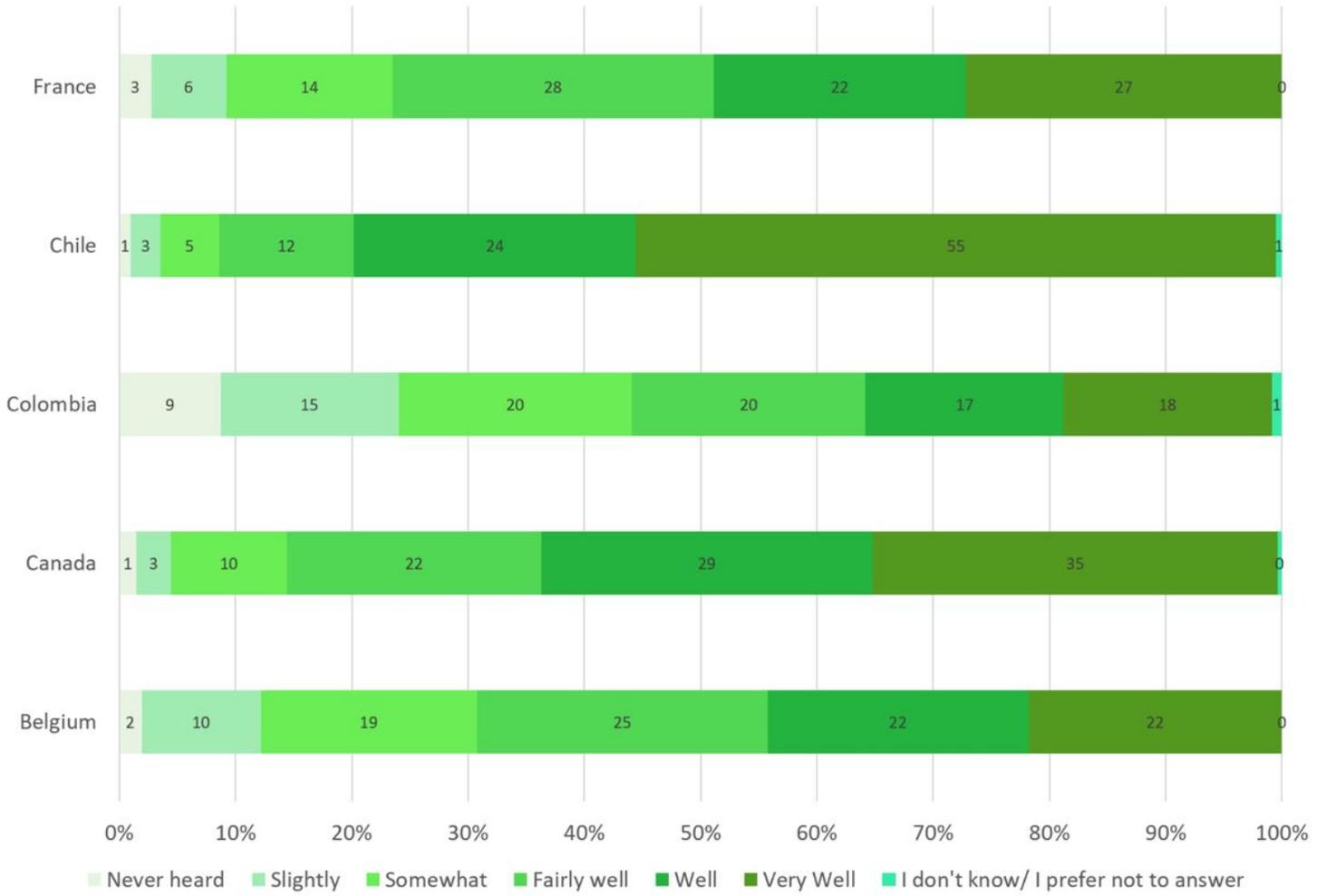


Figure 2

Knowledge about geothermal energy.

Geothermal energy production acceptability

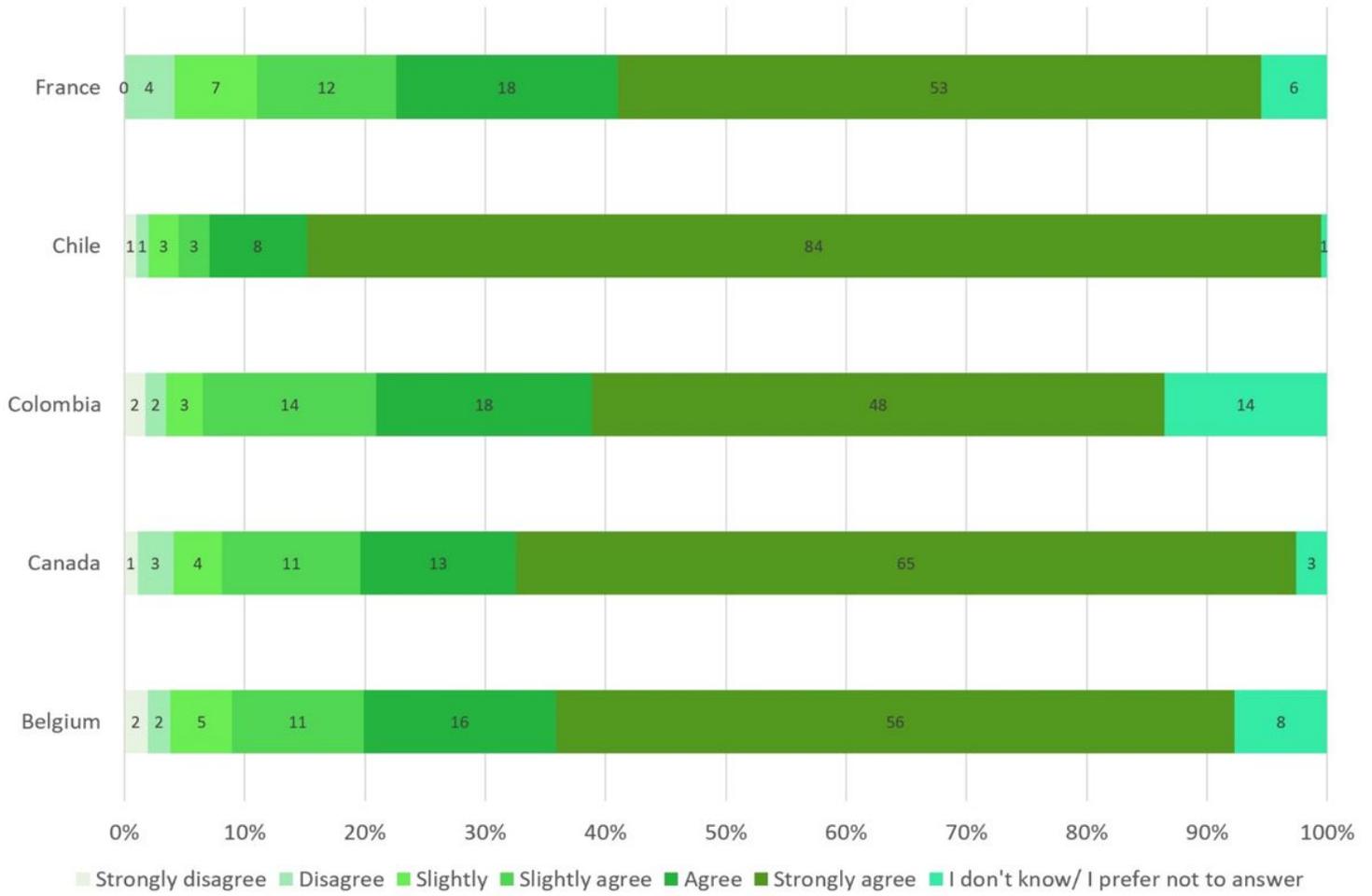


Figure 3

Acceptance to produce geothermal energy.

Among the following conditions, what must be necessarily satisfied for you to support a pilot project of deep geothermal energy in your region ?

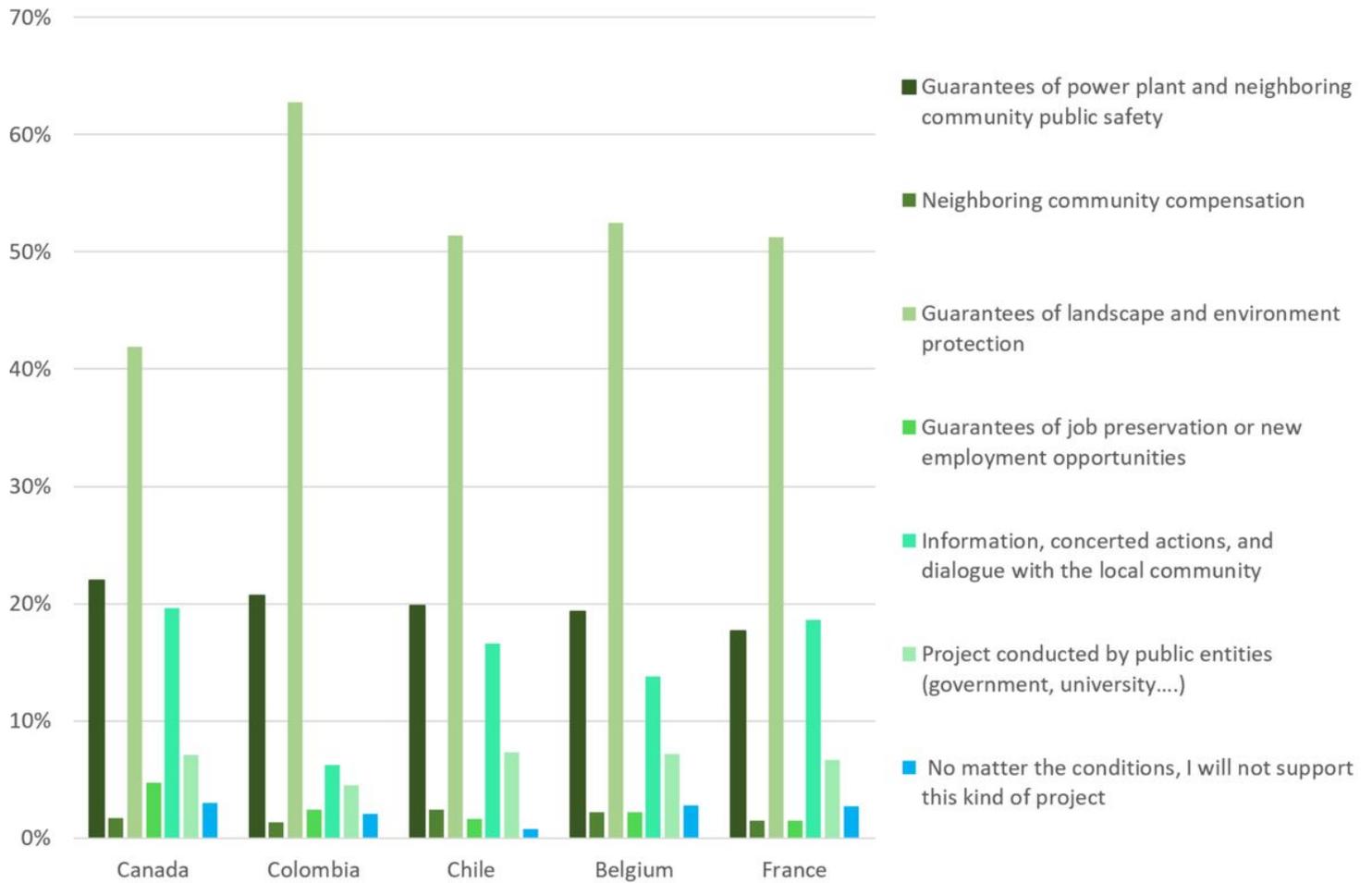
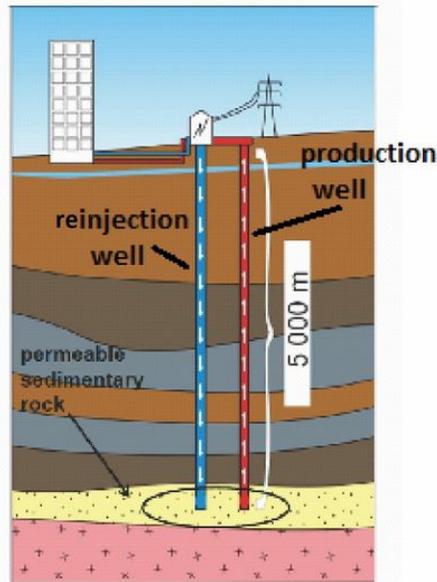
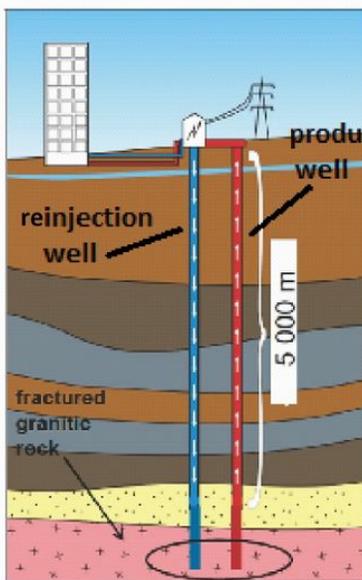
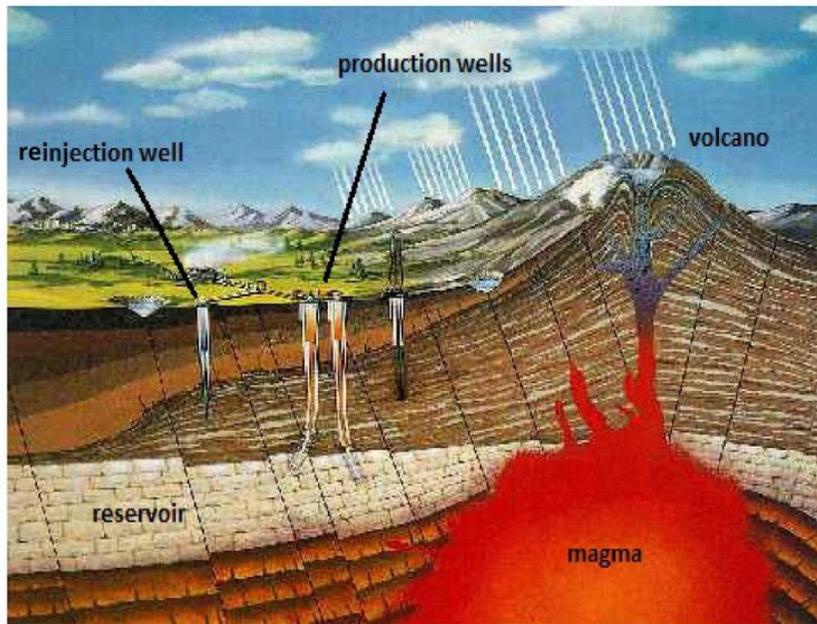


Figure 4

Conditions that should be satisfied to support a pilot geothermal project.



Different types of geothermal resource exploitation

Figure 5

Scheme of deep geothermal energy development

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [Questions of the survey analyzed in this paper.docx](#)