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Chachimbiro Geothermal Prospect: Social outlook after the first deep drilling in Ecuador

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ABSTRACT

Social interaction between the developer and local villagers, local governments, public and private agencies, is of high importance in order to reach a better understanding, planning and addressing of the complex interactions that exist between the parties involved in the development of a geothermal project. Geothermal exploration in Ecuador began in 1979 and the most remarkable milestones happened between 2008 and 2019. Nonetheless, within this timeframe, technical and financial aspects were highly prioritized by the government over the social outcome in the geothermal projects selected for further development. Consequently, the perception and the level of acceptance of the communities surrounding the geothermal areas of interest have not yet been fully understood. The objective of the study was to properly identify and analyze the relationship that exists between the stakeholders and the National geothermal developer of the Chachimbiro geothermal project in the Province of Imbabura. It is the country´s pioneer geothermal initiative since 2015 with a potential of 50 MW that was estimated after the completion of drilling operations in the first and only deep well. The document summarizes ten main metrics, obtained through the use of mapping methodologies under two different perspectives: objective and subjective. Social polls with the representatives of public and private agencies were used to scout the level of perception toward key subjects such as energy related benefits, social acceptance, environmental concerns, among others. Results showed there are 26 stakeholders interested in the development of the project: 46% of them have a decision at the national level, 35% at the cantonal level, 12% at the foreign level and 8% at the provincial level. It also reveals that 58% of stakeholders would have economic interests, 15% technical, 15% social and 12% environmental. In addition, the local community is in favor of the development of renewable energy initiatives and mitigation of climate change; local farmers who knew about geothermal energy associated the resource to the heat from the earth, viewed the drilling of the deep well as positive and believe that it will have an important effect for them in the next 20 years. The primary source of information was identified to come from the project developer. This confirms that this stakeholder had a close relationship with the communities during the project development and provided relevant information regarding the reconnaissance phase. This had a positive effect in the level of knowledge in geothermal energy within the surrounding area. The study concludes no social barrier was perceived and that the methodology allowed the researchers to obtain several points of view that were not previously analyzed by project developers, which can contribute to improve planning and execution of future activities. Final remarks highlight the importance of actively engaging with the community to greatly reduce the risks of having potential conflicts that may delay or compromise the development of geothermal resources in a particular location.

1. INTRODUCTION

Sustainable development calls for the use of sustainable energy systems (Shortall, Davidsdottir, & Axelsson, 2015) that include an assessment of the economic, environmental and social dimensions also known as a triple bottom line (TBL) analysis. Inherently, sustainable use of geothermal resources means that, under a whole systems perspective, this methodology guarantees a strategic and sustainable approach where a 100% renewable energy scenario is considered (Pellizzone A. , Allansdottir, De Franco, Muttoni, & Manzella, 2017; Kunze & Hertel, 2017). Nevertheless, social interaction and interrelationship between the geothermal developer and all stakeholders resulting from the development of geothermal projects, including local communities and authorities have not been well understood and in certain cases, poorly addressed (Pellizzone A. , Allansdottir, De Franco, Muttoni, & Manzella, 2017; Ratio & Fujimitsu, 2015). This has had an impact in the way geothermal resources are utilized by nearby villagers and farmers as a consequence of not knowing the true potential of using geothermal energy to increase the productivity of their lands and small businesses (González Troncoso, 2016). Therefore, a certain level of distrust may possibly emerge towards the developer of a geothermal project that could compromise the viability of the whole programme.

Ecuador is one of the countries with the highest geothermal potential where geothermal energy has not been utilized yet (CEPAL, 2019). Geothermal energy could satisfy all its electricity demand if this renewable resource is developed (Earth Policy Institute, 2011). An energy output of 952 MW from prefeasibility studies on 5 geothermal prospects was estimated in 2010 (MEER, 2010). Moreover, a theoretical potential of over 2000 MW was accounted when considering the total number of active volcanoes in the country (Asimbaya, 2018). In 2017, through a non-reimbursable fund from the Japanese International Cooperation Agency - JICA, the drilling of the first deep exploration well in the history of Ecuador happened in November 2017 in the Chachimbiro project. Therefore, is the most developed geothermal prospect to date. In this context, the objectives of this study are: 1) to measure the perception of the impact generated after complete the prefeasibility stage with a successful deep exploration well; 2) identify all stakeholders related to the Chachimbiro geothermal project; and 3), weigh the influence over the development of the project, based in the level of interrelationship that exist between them.

The results obtained from this case study are aimed to explain visually how connections between the different stakeholders are created and analyze how they impact in a positive or negative way the development of geothermal projects. It is expected that this methodology, which has been adapted from social studies related to water supply and disposal and water infrastructure planning processes, can be used to accurately address the most relevant social aspects that emerge from geothermal energy projects worldwide.

2. BACKGROUND

Imbabura Province is located in the northern part of Ecuador, in the Andes high mountain chain. It comprises a total area of 4559 km^2. A total population of 398244 citizens live in the province (INEC, 2010), which is divided into six cantons. Its capital is the city of Ibarra and the main urban centers are Cotacachi, Otavalo, Atuntaqui and Urcuquí. Since 2019, the province of Imbabura was declared as World Geopark by the United Nations Educational, Scientific and Cultural Organization (UNESCO) for its great multitude of lakes and magnificent geological formations. The economy of the province is based mainly in agriculture, cattle raising and commerce (El Comercio, 2019). Nevertheless, certain locations such as the San Miguel de Urcuquí canton (Figure 1), are well known for its hot springs and contribute to the province's income through tourism. Around 55% of tourists come from the city of Quito (capital of Ecuador), 30% from Colombia, and the remaining 15% from the nearby provinces in Ecuador (El Comercio, 2014).

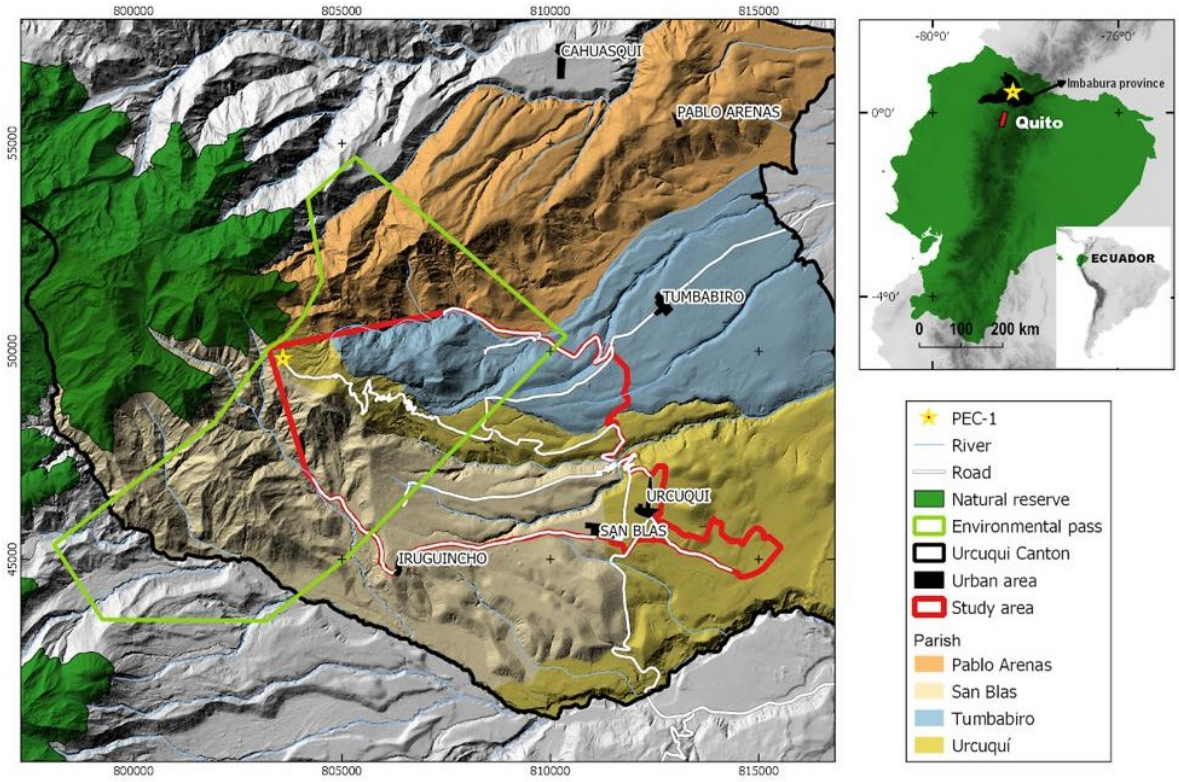

Figure 1. Location of Chachimbiro project and political division of Urcuquí canton.

Hot springs that emerge in the Urcuquí canton, which are mainly Chloride- Bicarbonate waters with temperatures ranging between 35.0 °C and 73.5 °C, have been utilized for bathing resorts, balneology and swimming pools since their discovery in 1868 (Servicio Nacional de Gestión de Riesgos y Emergencias, 2019). Special attention was initially brought to the idea of using this resource for electricity generation. Known as the Chachimbiro geothermal field, this location has been studied for more than 4 decades; however, only during the last few years, studies reached the exploratory drilling stage and in 2017, the first and only deep geothermal well was drilled. This milestone was possible as a result from a non-reimbursable fund and technical cooperation of JICA to Ecuadorian Electric Public Corporation- CELEC EP. The well, located at an elevation of 3460 m.a.s.l. (Picture 1) reached a depth of 1980m with a BHT of 235 °C (Asimbaya, 2018). A potential of 50 MW was estimated based on these results.

Picture 1. First geothermal drilling in Ecuador.

During the development of the prefeasibility studies, the geothermal developer (CELEC EP) also invested in infrastructure upgrades and social services for the local communities surrounding the project's area of influence. Among the most relevant contributions, the following are described (CELEC EP TERMOPICHINCHA, 2019):

- Upgrade of the road that leads to the drilling platform (9 km).
- Job creation through ancillary service's hiring.
- Prioritization of local manpower hiring for the project.
- Medical and dental services for local communities.
- Construction of a water supply line for local communities.

Despite these infrastructure upgrades, no follow-up studies have been undertaken to better comprehend and assess the impact generated by the project and to measure the level of satisfaction and future expectations from the local communities and villagers. To close this gap, the present study aims: 1) to measure the perception of the impact generated after complete the prefeasibility stage with a successful deep exploration well; 2) identify all stakeholders related to the Chachimbiro geothermal project; and 3), weigh the influence over the development of the project.

3. METHODOLOGY

Two polls were constructed using different sampling techniques in order to capture not only objective (observable and measurable) data but also information of subjective nature. It includes points of view, feelings, perceptions, and concerns given by the stakeholders and local villagers who live within the project's area of influence. Results were processed using native statistical tools in Excel and maps were generated using open source software (QGIS). A visual network analysis of all the stakeholders was done using GEPHI. A detailed description of the process is shown in the following sections.

3.1. Level of knowledge and perception

The first poll was conducted around the area where most economic, environmental and social impacts were accounted for after all prefeasibility studies, including personnel and equipment mobilization for the first well drilling between 2015 and 2018 (Figure 2). The area of influence is located within the Urcuquí canton and include the following communities: Azaya, Cochapata, Ajumbuela, Iruguincho, Pisangacho and El Tablón; Santagua, Hacienda Chachimbiro, Arco Iris and Timbuyacu recreational hot spring centers and YACHAY TECH University.

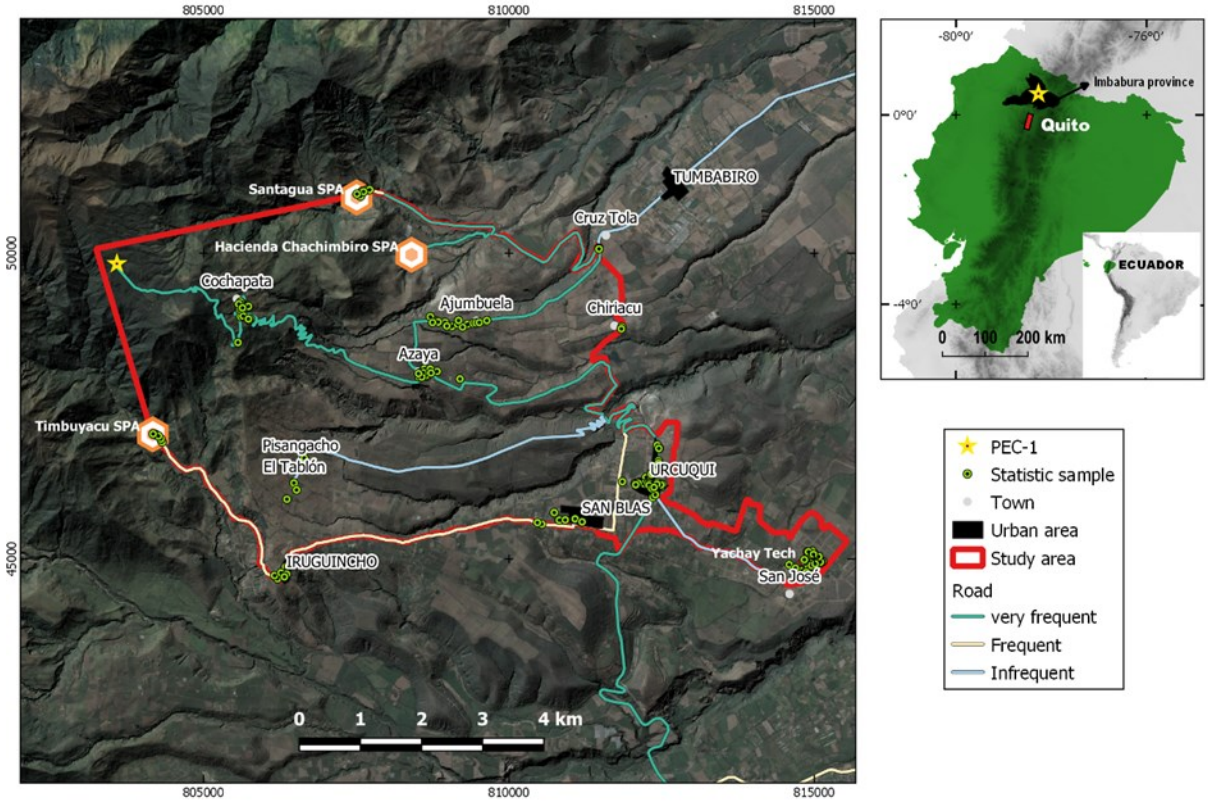

Figure 2. Study area inside the Urcuquí Canton.

The poll draft was elaborated based on the results obtained from Pellizzone et al. (2015), Ratio & Fujimitsu (2015), Pellizzone et al. (2017) and Vargas (2018). The final questionnaire was adapted to the particularities of the Chachimbiro prospect and was developed after a thorough revision from the technical experts in charge of the social and environmental division of CELEC EP.

The sample was of non-probabilistic nature (convenience sampling) and was comprised of residents from the Urcuquí community and tourists found along the road that leads to the drilling platform, parks, urban centers, recreation centers, and local schools. In total, four field trips were performed between August 2018 and June 2019 to collect the data; additional information was gathered through the use of electronic services (e-mails, chats, video and audio calls).

3.2. Stakeholder analysis and social network analysis

A second poll was conducted to the stakeholders at a cantonal, national and international level who have a certain degree of influence over the project. Representatives from the government, civil society, academia, donors and cooperation agencies that were involved somehow in the project were also interviewed. To collect the data, a questionnaire adapted from Lienerte et al. (2013) and Dos Muchangos et al. (2017), was used (Appendix 2).

A preliminary list based in bibliographical information was used to select the stakeholders. A snowball sampling technique was implemented to include the stakeholders that were considered important by the surveyed villagers. The level of influence and degree of affectation was measured with the aid of a Likert type visual scale (Likert, 1932) using five equal intervals from 0 to 10 as shown in Table 1. The results were processed using native statistical tools in Excel.

Scale	Level of influence	Degree of affectation
0	No influence	No affectation
2.5	Has little influence	Has minor affectation
5	Has influence	Has affectation
7.5	Strong influence	Has great affectation
10	Decides over the development of the project	Strongly affected by the development of the project

Table 1. Quantification scale of influence and impact.

Villagers were asked to rate the type of relationship they think they have with the stakeholders. A criterion of centrality was applied (equal to the number of connections that an interested party has with other interested parties) to analyze and explain the cooperative relationship. GHEPI software was used to process the data.

4. RESULTS

4.1. Level of knowledge and perception

4.1.1 Sample description

216 villagers were asked to participate in the poll. 158 accepted and answered the questions in Annex 1. The sample consisted of villagers with an age range between 15 and 82 years, the majority were mestizos (89%), female (58%) with basic studies (39%) that are dedicated to the provision of services (23%) and agricultural / livestock work (21%) (Annex 2). Of these, 94 are from the Urcuquí Canton (59%) and the remaining 64 (41%) come mainly from the provinces of Imbabura, Pichincha and Carchi:

- Originally from the Urcuquí Canton: the majority belong to the parish of the same name (56%) and have their own home (74%) with electric service (99%), fixed telephone service (50%), water supply for human consumption (99%), garbage disposal (97%), sewerage (74%), internet (48%) and public transport (81%).
- Not native from the Urcuquí Canton:
    - 23 people are based in the study area, the majority are Ecuadorians (87%) who migrated between 1963 and 2017 mainly for work (52%). The majority have their own home (48%) with electric service (100%), fixed telephone service (52%), water supply for human consumption (96%), garbage disposal (100%), sewerage (87%), internet (65%) and public transport (91%).
    - 41 people are not based in the study area; the majority are there for work (63%).

4.1.2. Level of knowledge and perception over environmental and energy issues

An alternate prioritization between environmental issues and energy access was observed. 86% considered that reducing pollution was very important or quite important, 83% responded the same for energy access, 79% for climate change, 77% for energy price stability, 74% for reduction of energy consumption, 71% for energy issues in national policies and 69% for renewable energy development. They also answered whether they knew about renewable energy or not; affirmative answers were registered as follows: 63% solar energy, 49% geothermal energy, 47% wind energy and 20% biomass. Those who answered if they knew about renewable energy were asked what effect each of them will have in the next 20 years; 76% replied that solar energy will have an important or quite important effect, 67% answered the same for wind energy, 66% for geothermal energy and 63% for biomass. On the other hand, the “I don't know” response rate stood out when consulting about renewable energy development (20%), especially with biomass (80%).

4.1.3. Level of knowledge on geothermal energy

158 villagers were asked if they know what geothermal energy is. 77 individuals (49%) responded they knew about this renewable energy and associated it mainly with the heat of the earth (44%), steam (29%) and volcanos (12%); They also indicated that it could be used for electricity generation (39%) and in hot springs / pools (32%). When asked what is the first thing they imagine when listening to the word “geothermal power plant”, several responses were obtained such as electricity generation (9%), energy (6%), renewable energy source (4%), electricity generation power plant that use geothermal energy (4%), energy source (2%), energy produced by water, steam, turbines and generators (2%), electricity (2%), economic development (2%), environment (2%), water (2%), among others, but the majority answered “I don't know” (27%). This group mentioned they obtained information from CELEC EP (22%), from the school / college / university (22%) and from friends / family (21%). On the other hand, the 158 respondents said they were more familiar with activities related to hot springs / pools (45%) and with electricity generation (32%).

4.1.4. Perception of impacts generated by the execution of geo-scientific studies and drilling operations

158 individuals were asked if they have observed or heard about the work carried out in Chachimbiro between 2015 and 2018. 77 (49%) answered positively. This group was made up of people who knew and didn’t know what geothermal energy was. The group that confirmed they know about geothermal energy was later asked if they had observed any benefits from the project developer (CELEC EP) in the community; more than a half (53%) observed the creation of commercial activities and / or services (19%), infrastructure (13%), delivery of goods (11%), health (4%), education (4%) and others (2%). Of this group, 38% perceived as positive the impact generated by the work carried out between 2015 and 2018, 12% perceived it as negative and 50% opted for the

answer “I don't know”. 50% of them said they would recommend other communities to allow the development of geothermal energy, 16% said no and 34% maybe. 76% said they would like to receive a lot of information or enough information about the environmental impacts generated by the development of geothermal energy, 72% responded the same for consumption and / or depletion of geothermal sources, 68% for the economic impact on communities local and 66% for project management and geothermal plants.

4.1.5. Perception regarding sources of information

Out of the 158 participants in the poll, 44% said emergency service agencies such as firefighters and police are very reliable or quite reliable as a source of information; 31% answered the same for CELEC EP, 30% said universities and researchers, 26% mentioned community representatives, 24% said tourism companies, 20% mentioned local administration, 17% said journalists and media, 15% mentioned JICA and 14% the national government. Of the 77 respondents who know about geothermal energy, 19% indicated that they always or frequently interact, meet and / or consult their concerns regarding the development of geothermal energy with community representatives, 17% responded equally with CELEC EP, 8% with universities and researchers, 5% with tourism companies, 4% with JICA, 3% with local administration, 2% with the national government, 1% emergency service agencies such as firefighters and police and 0% with journalists and media communication.

4.2. Stakeholder analysis and social network analysis

4.2.1. Stakeholder analysis

14 stakeholders were identified based on bibliographical review. Although, by applying the snowball sampling approach, the number of stakeholders increased to 26 (Table 2). After the results were quantified, 2 graphs were elaborated to compare the influence perceived by the stakeholders against the probability that they were affected by the decisions over the project. Figure 3 shows all stakeholders grouped by levels of decision (canton, province, national, foreign) and Figure 4 shows the same information but with all stakeholders grouped by perceived interest (economic, social, environmental and technical); perceived interest was assigned by calculating the statistical mode from the poll results. Figures 3 and 4 show that 46% of stakeholders have a level of decision at a national level, 35% at cantonal level, 12% at a foreign level and 8% at the provincial level and, that 58% of the stakeholders would have economic interests, 15% technical, 15% social and 12% environmental; in both figures, the diameter of the bubble is directly proportional to the number of times the stakeholder was mentioned.

Canton	Province	National	Foreign
1. Recreation center and hotels	10. Construction companies	12. CELEC EP	24. Foreign Consultants
2. Fire department	11. Prefecture of Imbabura / ADG* of Imbabura	13. CELEC EP Termopichincha Business Unit	25. JICA°
3. Ajumbuela community		14. National consultants	26. IADB°°
4. Azaya community		15. Drilling companies	
5. Cochapata community		16. EPN**	
6. San Francisco community		17. IIGE***	
7. ADG* San Miguel de Urcuquí		18. Ministry of Economy and Finance	
8. Añaburo Farm		19. Ministry of Energy and non Renewable Natural Resources	
9. Urcuquí (town)		20. Ministry of Environment	
		21. Novopan S. A.	
		22. SENAGUA°°°	
		23. YACHAY TECH University	

* Decentralized Autonomous Government

** National Polytechnic School

*** National Institute for Geological and Energy Research

° Japan International Cooperation Agency

°° Inter-American Development Bank

°°° Secretary of Water Resources

Table 2. Chachimbiro’s stakeholders identified.

The figures allow to appreciate 5 groups:

- Group One: 4 stakeholders at the top of the figures show that they are the most influential in the planning of the project and are affected by its execution; of these, 1 has a foreign decision level (JICA) and 3 national (CELEC EP, Ministry of Energy and Non-Renewable Resources and, Ministry of Economy and Finance); 2 of them show economic, 1 technical and 1 social interests.
- Group Two: 5 stakeholders on the right side of the figures show intermediate influence and are very affected; of them, 1 has a national decision level (CELEC EP Termopichincha) and 4 cantonal (Communities of Cochapata, Azaya, Ajumbuela and San Francisco); 4 of them show economic and 1 social interests.
- Group Three: 6 stakeholders in the lower left of the figures show very small influence and are little affected; of them, 3 have national decision level (EPN, IIGE and YACHAY TECH University), 2 provincial (Construction companies and ADG province of Imbabura) and 1 cantonal (town of Urcuquí), 2 of them with interests economic, 3 technical and 1 social.

- Group Four: 4 stakeholders on the left side of the figures show intermediate influence and are little affected; of them, 2 have a national decision level (Ministry of Environment and SENAGUA), 1 Cantonal (Fire department) and 1 Foreign (IBD); 3 of them show environmental and 1 social interest.
- Group Five: 7 stakeholders in the center of the figures show influence and have a mid-level affectation; of these, 1 has a foreign decision level (Foreign consultants), 3 National (National consultants, Drilling companies and Novopan S. A.) and 3 cantonal (Recreation center and hotels, ADG San Miguel de Urcuquí and Añaburo Farm); the 7 show economic interest.

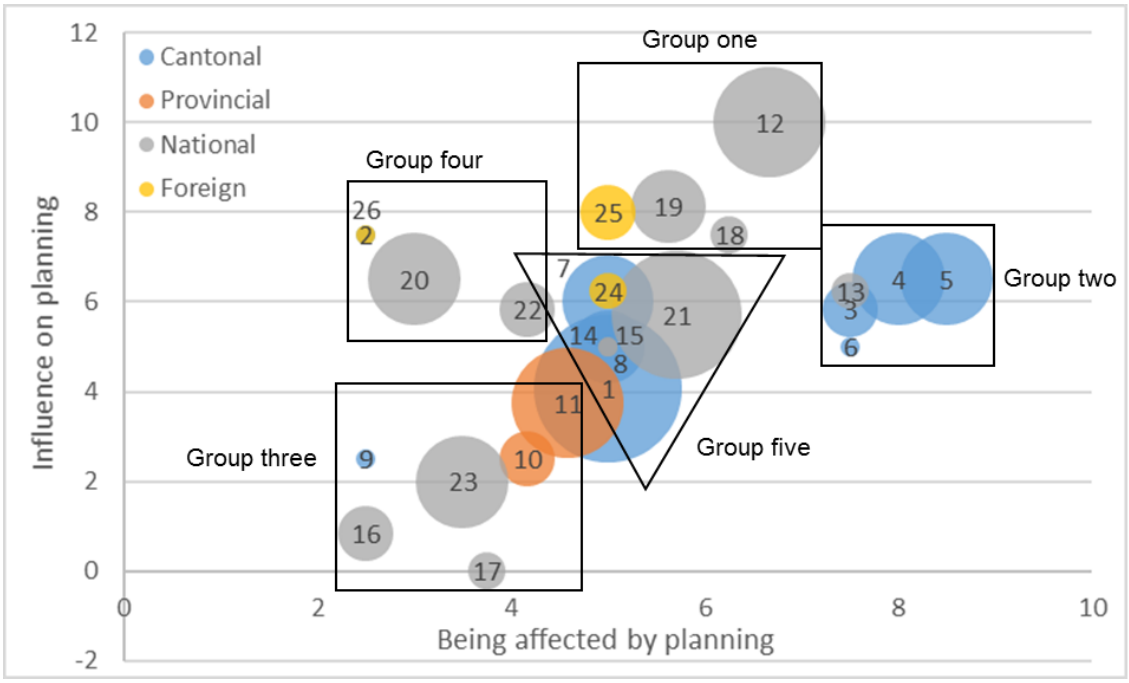

Figure 3. Decisional level – Perceived mean influence on and being affected by develop of Chachimbiro geothermal project; use the numbering from Table 2.

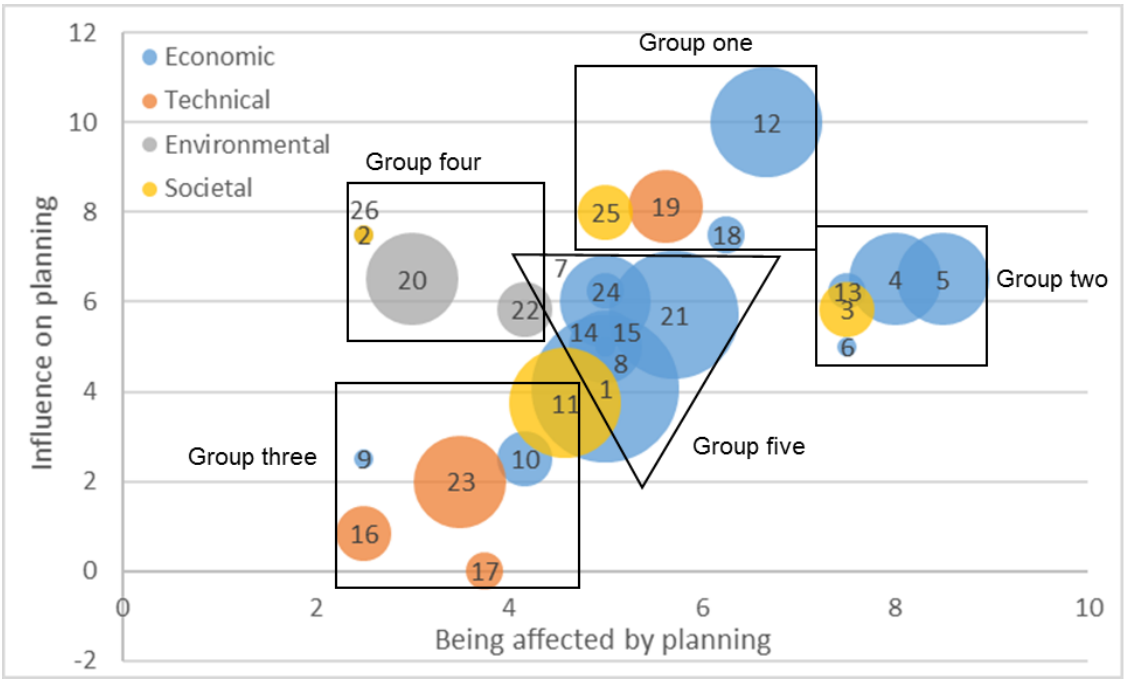

Figure 4. Interest – Perceived mean influence on and being affected by development of Chachimbiro geothermal project use; the numbering from Table 2.

4.2.2. Network analysis

In order to analyze the social network, stakeholders were asked to rate the type of relationship they considered to have with other stakeholders during the execution of geoscientific activities and well drilling operations; 24 connections were described: 21 of cooperation type, 2 financial and 1 of conflict type; some of these coexist in a combined manner as financial-cooperation and financial-conflict. The cooperation relationships were then chosen and, with the help of GHEPI software, Figures 5 and 6 were

developed applying the centrality criterion; as in the previous section, both figures show the same information grouping the stakeholders by decision levels and by the perceived interest; the size of the node is directly proportional to the relationship of the stakeholder, and the thickness of the outer circle reflects the strength of the relationship between the stakeholders. The number of stakeholders was reduced from 26 to 14 due that stakeholders only mentioned the other parties with whom they had some kind of relationship during the development of the prefeasibility stage. Figures 5 and 6 show that 57% of stakeholders have decision at a national level, 29% at a cantonal level and 14% at a foreign level. In addition, 64% of the stakeholders would have economic interests, 21% technical, 7% social and 7% environmental interests. The figures allow to appreciate 3 groups:

- Network center: 1 stakeholder with national decision level and economic interest, presents 10 connections (CELEC EP).
- Social network: 5 stakeholders; 2 with foreign decision level, 2 cantonal and 1 national; 4 with economic interest and 1 social.
    - With 4 connections: JICA, Azaya community and National consultants.
    - With 3 connections: Cochapata community and Foreign consultants.
- Periphery of the network: 8 stakeholders; 6 with national decision level and 2 cantonal; 4 with economic interest, 3 technical and 1 environmental.
    - With 2 connections: IIGE and ADG San Miguel de Urcuquí.
    - With 1 connection: Recreational center and hotels, Drilling companies, Ministry of Energy and non-Renewable Natural Resouces, Novopan S. A., SENAGUA y YACHAY TECH University.

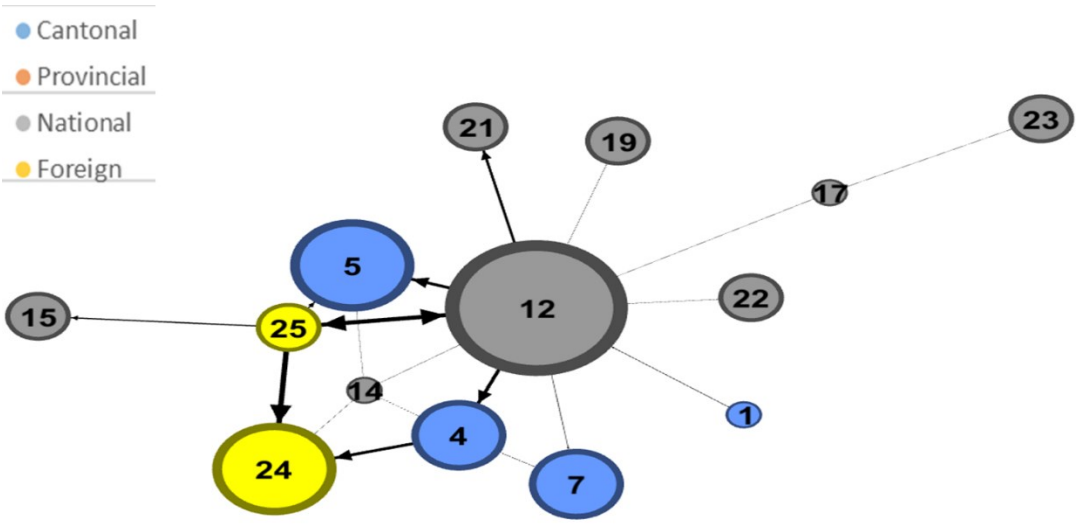

Figure 5. Cooperation network by decisional level; use the numbering from Table 2.

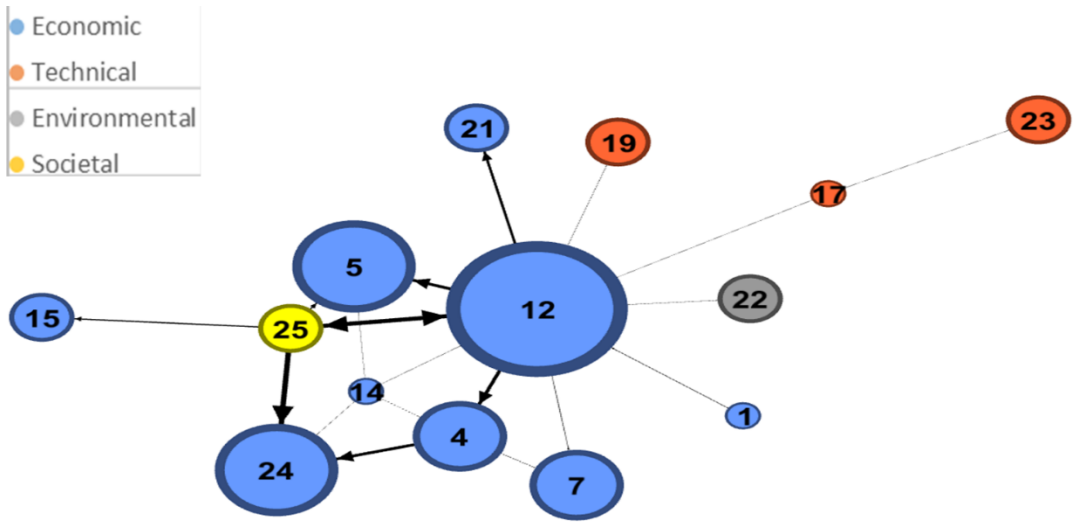

Figure 6. Cooperation network by interest; use the numbering from Table 2.

5. DISCUSSION

5.1. Considerations to the methodology

The use of qualitative sampling methods could greatly affect the reliability of the study due to the impossibility of extrapolating results to a whole community (Sampieri, 2014). On the other hand, using a methodology that combines objective as well as subjective data allowed the research team to obtain a broader and more complete picture of the environment being studied. Potential weaknesses emerging from objective and subjective data were minimized through the combination of quantitative and qualitative analysis on the basis that, one approach visualize what the other does not and that the weaknesses of each one are minimized by their counterpart.

As it was mentioned previously, two sampling methods were used to collect the data for analysis. It is important to consider the limitations of using these methods to avoid falling out of the scope of the study. A summary of the main advantages and disadvantages of the convenience and the snowball sampling methods is presented in table 3.

Sampling method	Advantages	Disavantages
By convenience	• Low cost. • Sample variables can be controlled. • It facilitates obtaining a large amount of information in a short period of time. • It allows to discover unusual characteristics.	• It does not guarantee representativeness. • It does not generalize and is of subjective nature. • It present bias due to the influence of the researcher or the subjects being interviewed
Snowball	• Low cost. • It allows to sample populations of difficult access. • It allows to estimate unusual characteristics. • It requires little planning and few human resources.	• It does not guarantee representativeness. • Especially sensitive to bias. • Little control over the constitution of the sample (uncontrolled size).

Table 3. Advantages and disadvantages of the convenience and the snowball sampling methods.

The following restrictions were applied to the present study upon request of CELEC EP so that future stages of the geothermal project were not compromised:

- The poll did not contain questions that would somehow reflect a negative aspect towards the project such as the presence of loud noises or a particular smell coming from the drilling platform. This was thought to have affected somehow the neutrality of the poll, however none of these aspects were mentioned by the villagers.
- Two important stakeholders (Novopan S.A. and Añaburo Farm) were not included in the poll due that it may somehow affect the negotiations with the developer to continue further stages of the project. However, both stakeholders are located inside the area of intervention; they have a mid-level influence over the development of the project since they own the land where the only access road goes through as well as the land where the drilling targets are located (Figures 3 and 4).

5.3. Level of knowledge

In general, the level of knowledge about geothermal energy worldwide is low and possibly one of the causes that has prevented its fast deployment. Vargas (2018) indicates that the lack of access to key information, such as successful examples of direct use and graphic material on how a geothermal power plant works, affects social attitudes. The author justifies this statement with the following comment from a hot spring administrator: "*This type of energy is not intuitive, like solar or wind energy. We have not seen how this energy works, so it is difficult to imagine how heat can be extracted from the earth without damaging the environment and the underground water resource*". Therefore, an attempt to measure the level of knowledge about geothermal energy was made in the Urcuquí canton and was quantified in order to identify the percentage of people who would apparently be able to give their opinions (provide reliable answers) about the development of this renewable energy in their communities.

In the communities of Cochapata and Azaya, it was found that most people have a basic education level (Figure 7), but they know more about geothermal energy than other neighboring communities with similar level of education (Figure 8). In the communities of Urcuquí, San Blas, Timbuyacu, Santagua and YACHAY TECH University there were a greater number of people who claimed to have third and fourth level education (this was group formed by people who were not from the Urcuquí Canton but regularly travel to the site for work and / or tourism). Although in the latter places social outreach did not happen with the same intensity as in the communities near the drilling site, people were found to know more about geothermal energy; At YACHAY TECH University, for example, all respondents knew what geothermal energy was and all claimed to have higher education. This suggests that the level of knowledge in geothermal energy is related to the level of education and also that the social outreach carried out by the project developer did contribute to raise the level of knowledge about geothermal energy in the communities near the drilling site; The latter was confirmed with the network analysis, where it is observed that the communities of Cochapata and Azaya have a close relationship with CELEC EP and with other network stakeholders (Figures 5 and 6).

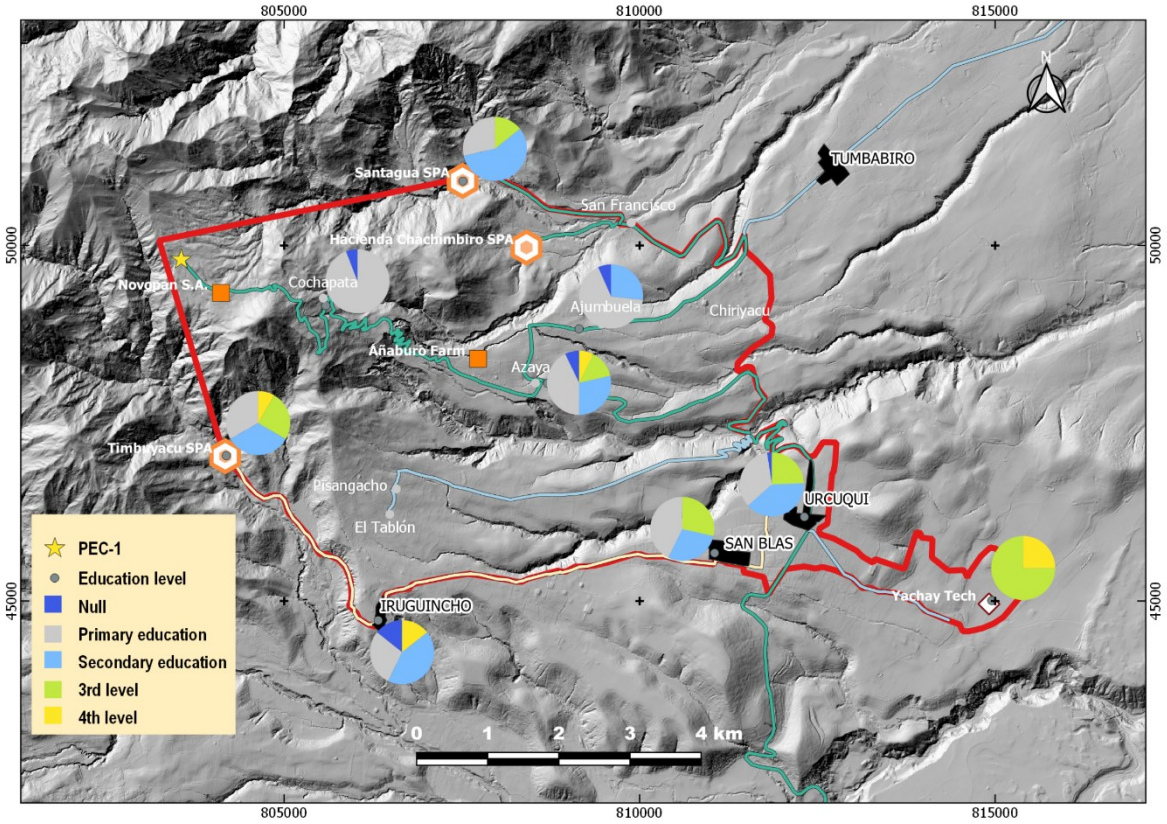

Figure 7. Level of education of the participants in the Urcuquí canton.

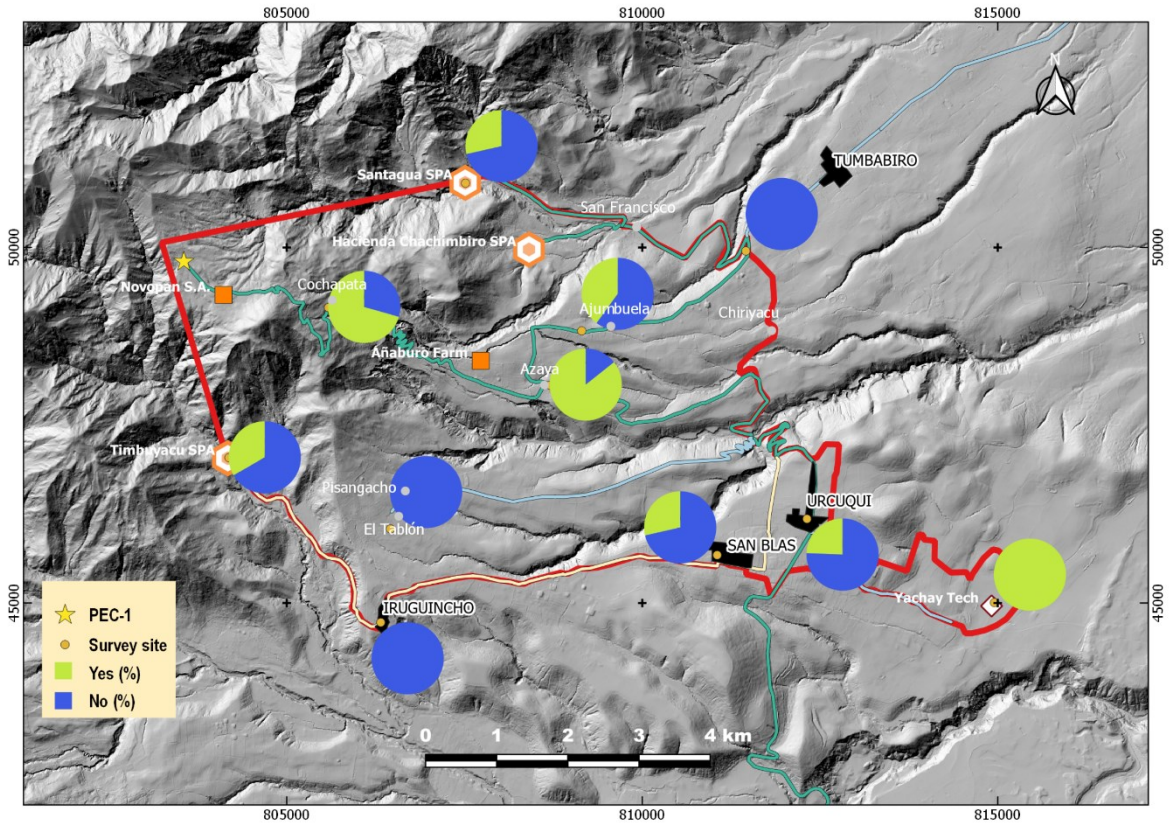

Figure 8. Level of knowledge regarding geothermal energy.

The primary source of information was identified to come from CELEC EP (Figures 9). This confirms that the stakeholder had a close relationship with the communities during the project development and provided relevant information regarding the reconnaissance phase. This had a positive effect in the level of knowledge in geothermal energy within the surrounding area, which was observed in the poll results. Local residents claimed to know more about geothermal energy than wind energy or biomass energy. Moreover, they mentioned that, in the next 20 years, this energy will have an effect as important as that produced by wind energy; this is an encouraging finding considering that geothermal energy is generally one of the least known renewable resources worldwide (IDAE, 2008; Roca, 2016). In addition, results from the analysis of qualitative data suggest that after being reached out by the developer, information was transferred from mouth to mouth between friends and family to the rest of the communities.

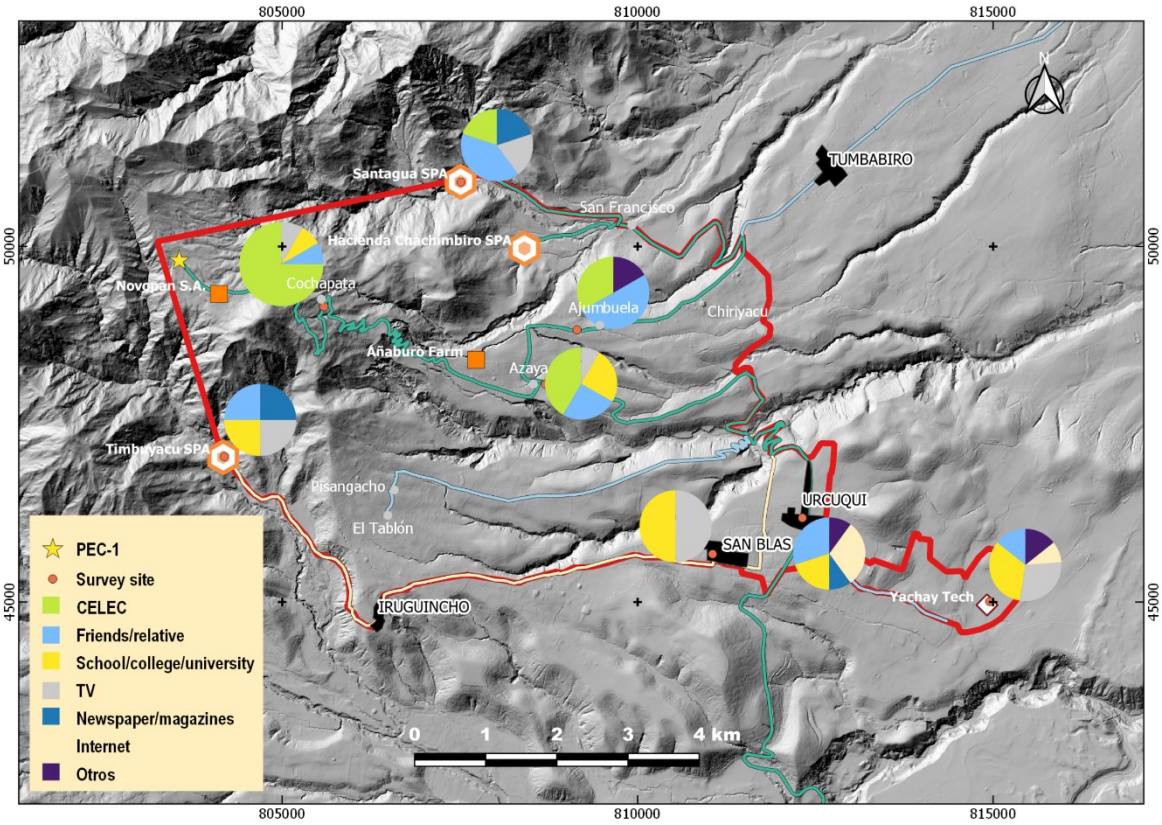

Figure 9. Sources of information concerning geothermal energy.

5.2. Social Barriers

In the community of Ajumbuela, the majority of residents answered "I don't Know" when asked whether the impact resulting from drilling operations were positive or negative. This reflects that any side effect was not perceived by the community and therefore, a certain degree of neutrality was kept, attributed to a clear sign of unawareness. Nevertheless, they wish to receive some of the benefits that other communities that were closer to the intervention area had (Figure 10). Despite some of the negative impacts felt by a minority group such as loud noises and dust caused by the mobilization and operation of machinery nearby the drilling site, no rejection towards the project was perceived since these impacts were minimum and temporary.

In the community of Iruguincho, residents did not perceive any impacts related to drilling operations. On the other hand, in the towns of San Blas and Urcuquí, inhabitants mentioned they perceived positive impacts. Possibly, the level of education has an effect on the responses as it was noticed at YACHAY TECH University, where most of the inhabitants exceed the primary education level. In any case, no rejection towards the project was noticed in any of these 4 communities.

In recreational bathing facilities, most owners and local visitors mentioned not knowing whether the impact resulting from drilling operations were positive or negative. Nonetheless, an important number of them assume they could be generated negative impacts attributed to thermal water quality: decrease in flow and temperature, changes in chemical composition and healing properties. Since no fluids were extracted from the test well, it cannot be linked to any particular activity related to the project. As it happens with other locations worldwide, users and administrators of thermal hot springs feel uncertainty regarding what might happen with geothermal resources they use for profit. They also expressed concern on how drilling operations or the installment of a nearby power plant would affect their economic activities. To counteract this, the developer approached owners of recreational bathing facilities. After several meetings, CELEC EP gained acceptance to continue with the development of the project, as stated by one administrator of a thermal hot spring in the following comment: "*At the beginning we were afraid that something was going to happen with the hot springs, but they made us understand that nothing would happen with them, being that way we would have no problem in supporting this initiative*".

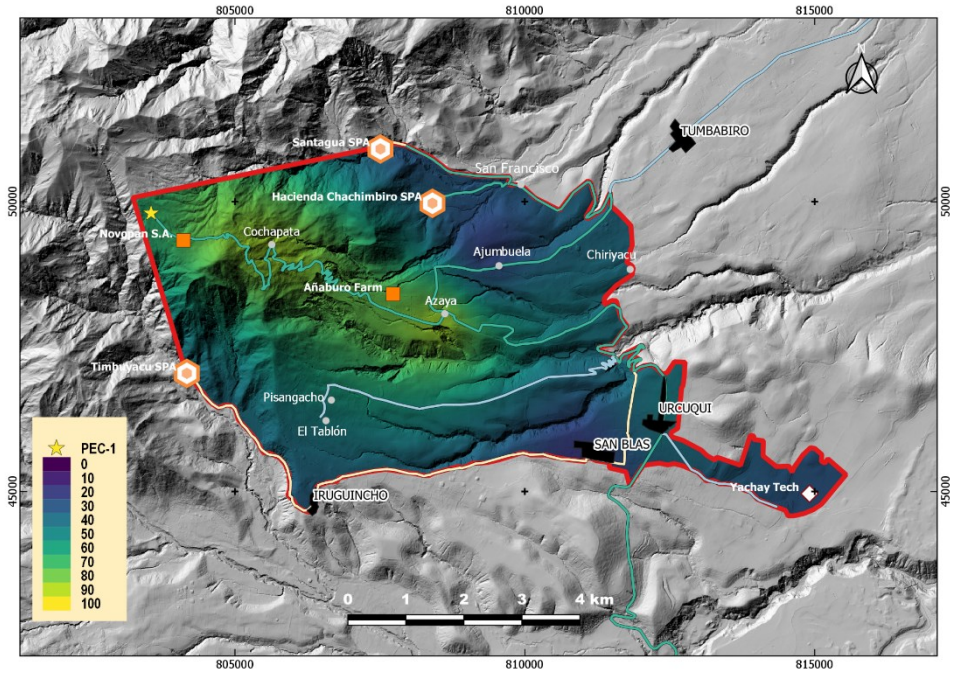

Figure 10. Sites where the benefits generated by the development of the Chachimbiro project were observed.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions

Based on the perceptions of the population near the drilling site and, on the perceptions of the stakeholders that participated in the planning and execution of the Chachimbiro project (except Novopan S. A. and Añaburo Farm), the study summarizes the following concluding remarks:

- An affectation map was developed (Figure 11) around the communities near the drilling site, which could be used to plan the drilling program that would aim to determine the extent of the hydrothermal reservoir and confirm the potential of the resource. Three communities were affected by the execution of the project (Cochapata, Azaya and Ajumbuela). However, only two, Cochapata and Azaya (closest to the drilling site), have seen the benefits from the project developer.

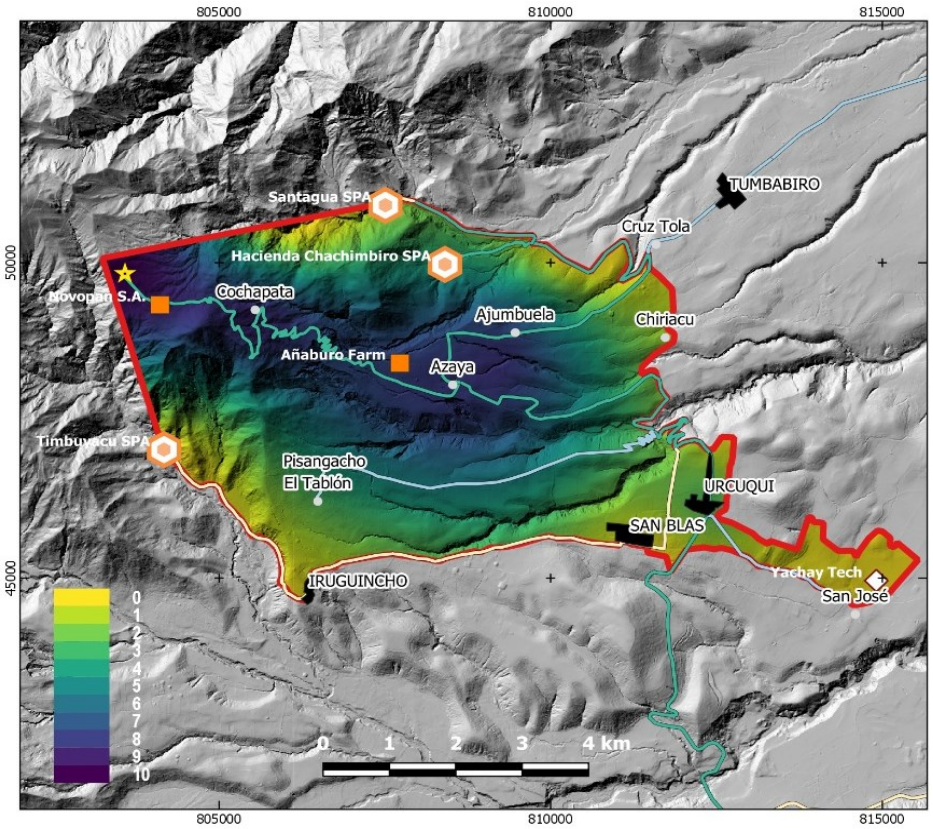

Figure 11. Affectation map of nearby communities.

- There are 26 stakeholders interested in the development of the project: 46% of them have a level of decision at a national level, 35% at cantonal level, 12% at a foreign level and 8% at the provincial level and, that 58% of the stakeholders would have economic interests, 15% technical, 15% social and 12% environmental.
- Visualization of the social network (Figures 5 and 6) shows that the geothermal developer (CELEC EP) is located at the center of the network. This indicates, it has the most cooperation links with the rest of the stakeholders, especially with the local communities who are also located close to the center of the network. Conversely, the group located at the outer edge of the graph represent the ones with less interaction.
- The combination of stakeholder and social media analysis allowed the researchers to obtain several points of view that were not previously analyzed by project developers, which can contribute to improve planning and execution of future activities.
- Around 50% of the responses denote not knowing whether or not any impact has been generated as consequence of the implementation of prefeasibility studies (included drilling operations), despite the fact that important upgrades to the infrastructure were undertaken by the developer.
- Around 76% of the interviewers would like to receive more information about environmental impacts that a geothermal energy project may generate in their communities.
- As with any other medium to big scale renewable energy project, social acceptance is a key factor that will play a decisive role in all stages of the project, from its conception to the operation and even its final decommission (Stephenson y Ioannou, 2010). Higher or lower levels of support or opposition that arise from the interaction between values, beliefs, knowledge, opinions and motivations of individuals and groups can become enablers or barriers in the development of a state or private initiative renewable energy project (Devine-Wright, 2005). To analyze this at a deeper level in a specific case study, an approach to measure social acceptance towards the Chachimbiro geothermal project was attempted.
- Results also reflect that, the population of the Urcuquí Canton does not have the same level of knowledge or awareness about geothermal energy; that the impacts created by the implementation of a geothermal project are not clear; that the work carried out between 2015 and 2018 was hardly perceived by the population; and that there was no social barrier at the time the study was performed.
- On the other hand, in the communities of Cochapata and Azaya, more than half perceived the impacts derived from the execution of drilling operations; most of them were positive and include commercial activities and services, infrastructure upgrades (roads and water supply systems), medical services and education programs (Figure 10). They also mentioned that the developer met the offers made to the communities in the areas of influence and that they are “very grateful to the social department for all the works and efforts made” (community representative).
- Conversely, negative impacts perceived in these two communities were the “accumulation of stone material, incidents with light cables and water pipes (during the mobilization of the drilling equipment), which were repaired immediately” (community representative). These responses suggest a social acceptance towards the development of the project in these two communities that received the most attention by the project developer (CELEC EP). They also reflect that the activities carried out managed to raise the level of awareness in the population (at least in basic notions about geothermal energy), mitigate the negative impacts and gain supporters as a result from the offers made by the developer during social outreach campaigns.
- It was found that the majority of the villagers that were interviewed claim to know more about geothermal energy than any other renewable energy. This is not commonly to be the case since, overall, geothermal energy is the least know sustainable resource worldwide. It is then assumed that in this particular case, the developer has had a certain level of success in spreading the concept of geothermal resources to the nearby communities. On the other hand, it has also been observed that the use of geothermal energy is more associated by the villagers with electricity generation than any other direct use of the resource. This aspect has also been seen in the network analysis, where the institutes associated to this area are in the center of the social network scheme.
- Two sources of primary information were particularly mentioned in the poll: CELEC EP and schools and universities. Nevertheless, sharing of information also happened through spreading the word between villagers with a relatively high rate of success.
- A total of ten main metrics were obtained through the use of mapping methodologies under objective and subjective perspective:
    - Decisional level – Perceived mean influence on and being affected by develop of Chachimbiro geothermal project.
    - Interest – Perceived mean influence on and being affected by development of Chachimbiro geothermal project.
    - Cooperation network by decisional level.
    - Cooperation network by interest.
    - Level of education.
    - Level of knowledge regarding geothermal energy.
    - Sources of information concerning geothermal energy.
    - Sites where the benefits generated by the development of the Chachimbiro project were observed.
    - Affectation map of nearby communities.

6.2. Recommendations

Based in the experiences and shortcomings that were experienced during the study and, for future case studies where the methodology used in this paper is applied, it is recommended to consider the following key points in order to make the research more efficient and less time-consuming:

- In field sorties, assigning 75% of time to data gathering in rural areas and 25% to urban areas is highly suggested; This responds to different reasons among which a reduced population density, weak cell phone signal and access difficulty or restriction that is often seen in rural areas.
- Making short questionnaires will assure the interview time is not prolonged more than necessary. It will also maintain the interviewed focused.
- Having a sociologist in the team will facilitate outreach and communication with the local communities.
- Minimizing bias when talking about positive and negative impacts in questionnaires will guarantee a clean response.

In this context, it would be opportune to launch permanent social outreach campaigns in all bathing facilities located within the area of influence. This will open a window of opportunity to communicate all possible impacts (positive or negative) derived from a geothermal project with a strong emphasis in direct uses that will result from a cascade development of the resource.

Results from hydrological studies, which are an essential part of a reconnaissance campaign in a geothermal project, are of special interest to identify in advance any possible changes in thermal conditions that would affect local communities. Consequently, any mitigation strategies can be jointly implemented along with the owners. “If there is an affectation it must be solved; it will be a problem that cannot be passed” (Ministry of Energy and non Renewable Natural Resources representative). Only in this way will the level of knowledge be raised and acceptance of this group will be obtained. At the moment there are misunderstandings and rumors that must be clarified to mitigate the uncertainty and fear of people regarding the negative impacts to thermal water and thus avoid the creation of a social barrier.

In 2016, before drilling the well, Bona and Coviello published the results of an evaluation of the social context of geothermal projects in South America with reference to their acceptability by local communities, institutions, organizations and society in general; the alternatives to rate the projects, from worst to best, were: severe, difficult, moderate and favorable. Chachimbiro was rated as “moderate”, which means that it is a project with potential conflicts with the social environment, but manageable. The condition of the project would be maintained after the first drilling if the findings of this study are considered by the developer. In this sense, it would be convenient for CELEC EP to push the project into a “favorable condition” which means a project well accepted and promoted by the social environment. In order to reach this objective, it is suggested to take advantage of the following advantages presented by the project:

- In the Urcuquí Canton, there is no previous experience from any energy power projects being implemented. Therefore, no negative influence exists among local residents that could compromise the development of the resource.
- There are no indigenous groups with strong beliefs in volcanoes that impede the development of the project; For indigenous groups, the land is not only an object of possession and production, but it is an entity that represents the basis of their own existence in physical and spiritual terms (Bona & Coviello, 2016).
- The relationship between resource managers and the developer is good, unlike other sites where it is often tense (Vargas, 2018).

In order to move towards the sustainability of geothermal projects, it is also recommended that:

- In new projects, diagnose the levels of knowledge on renewable energy, climate change and sustainable development to prepare a socialization program that contributes to the achievement of the objectives proposed by the project developer. It would also be appropriate to use environmental management tools such as the Environmental Impact Assessment (EIA) to forecast the impacts that could be generated by the execution of the project.
- In projects with certain level of study, use social management tools such as the one presented in this document to understand the state of the social dimension.
- In the Chachimbiro project, improve communication and relationship with other stakeholders, especially those with technical, environmental and social interests; continue the study of the social dimension during all phases of the project; consider potential direct uses as part of the project.

It is finally worth mentioning that the decisions taken in the planning of the following stages in the Chachimbiro project will affect the development of geothermal energy for electricity generation and direct uses in Ecuador.

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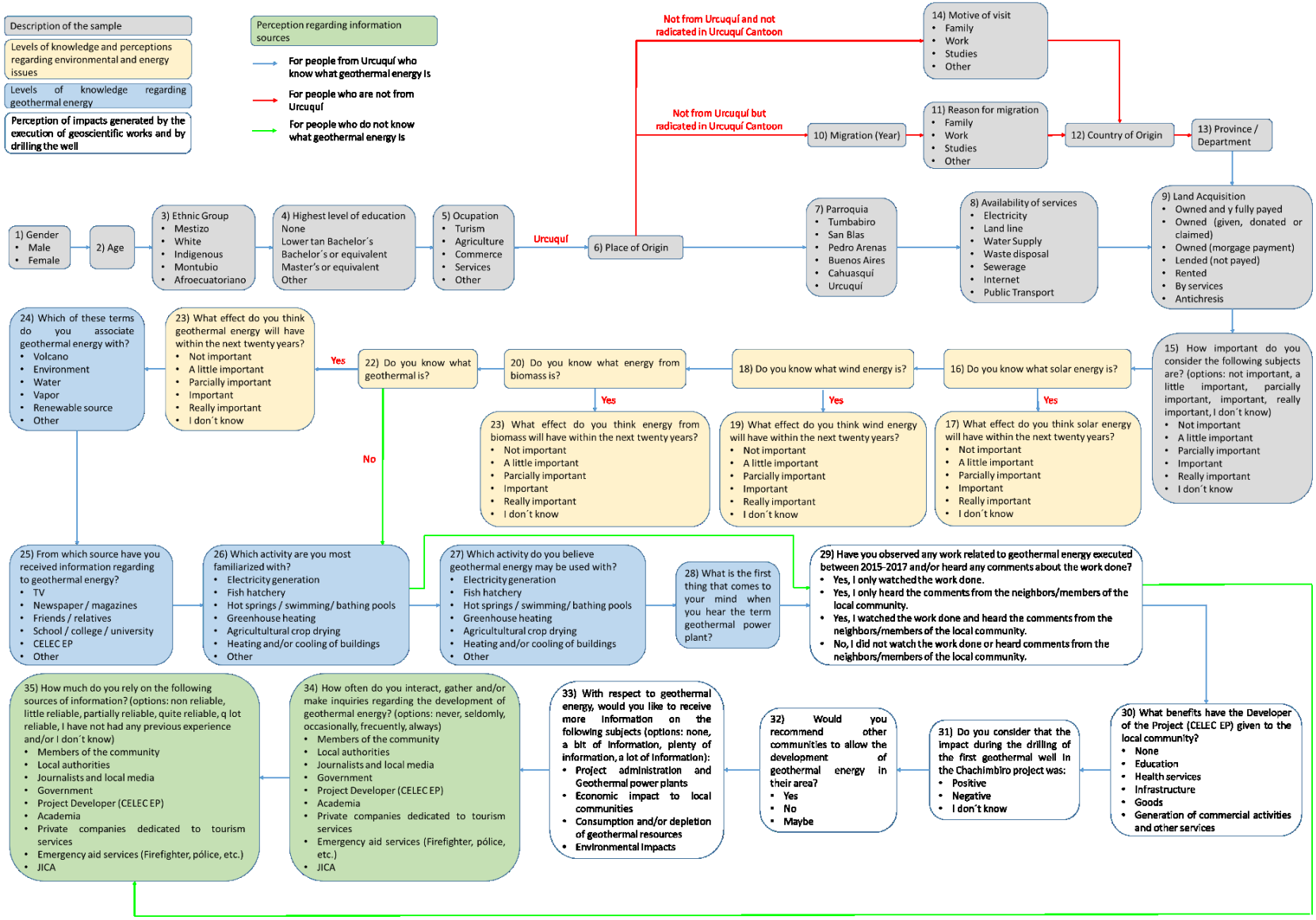
Appendix 1: Flow diagram of the survey of levels of knowledge and perceptions



Appendix 2: Flow diagram for the survey stakeholder analysis and social network analysis.