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From Pure Science to Applied Projects: Direct Use of Geothermal Energy in Patagonia

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ABSTRACT

Although the first geothermal plant started in April 2017 in Chile, for most of the population, the use of geothermal energy still looks like science fiction, and geothermal resource remains underdeveloped. It can only be left to the human imagination the potential of geothermal energy as a feasible opportunity to undertake energy poverty and mitigate the high levels of pollution in a region where people still rely on traditional wood-burning heating methods. Those questions have been examined by the Andean Geothermal Centre of Excellence, CEGA, for the last years. This paper, from a social science perspective, illustrates the case of Aysén community, characterised by high social resistance to energy projects but has seen geothermal energy find a place. For CEGA, the first approach in the territory was to develop two-year geothermal exploration campaign, the scientific study made through public bidding. Three years later, there are three geothermal direct-use projects developed in the region, with CEGA starting an exploration assessment for electricity generation in the north of the region in 2019. This paper highlights local public engagement strategies, technical challenges and the pivotal role of two-ways exchanges among local communities, decision-makers and scientists in order to promote direct-use geothermal projects.

1. INTRODUCTION

1.1 Chile's Geothermal Activity

Chile has more than 90 active volcanoes, mainly localised in the Andes Mountains, with the last eruptions to the date in 2015 occuring in the Calbuco and Villarrica volcanoes (Servicio Nacional de Geología y Minería, 2018). In the county, geothermal resources have been principally used for recreational and touristic purposes, with an installed capacity of over 11 MW_t. Others direct uses of geothermal energy have been restricted to heat pumps (which have high efficiency due to the subsoil thermal stability), in commercial, industrial and institutional buildings, with a total capacity around 8 MW_t (Lahsen, Rojas, Morata, & Aravena, 2015). Nevertheless, Chile has an estimated geothermal power potential between 1,000 and 2,700 MW_e (Aravena et al., 2016).

By the end of the '90s, and due to a national energy crisis, diversification of the energy matrix was an urgency. In this context, in 2000, the Geothermal Concession Law (Law 19,657/2000) was enacted to promote geothermal development, and ten years later, a national geothermal research centre started to operate. The Andean Geothermal Centre of Excellence (CEGA), financed with public funds, has been focused on generating and improving geothermal knowledge in Chile.

In September 2017 Cerro Pabellón, South America's first geothermal power plant, began its operations. It is located in northern Chile in the Atacama Desert at 4,500 m.a.s.l. The plant has a total capacity of 48 MW, avoiding the emission into the atmosphere of more than 166,000 tons of CO_2 (Hernández, 2018).

1.2 Situating the Projects, Aysén Region

Around 2,400 km to the South of Cerro Pabellón geothermal plant, the Aysén region, part of the Chilean Patagonia, is located. Aysén is the country's second southernmost region. With ~103,158 inhabitants represent only 0.6% of the country population (INE Chile, 2017). In the region predominate humid temperate and cold climates, with abundant rainfall and a mean annual temperature around 6 to 10 °C (Hepp, Reyes, & Muñoz, 2018). Due to its geographical conditions, Aysn is considered as an Extreme Zone, giving it special incentives (Diario Oficial de la República de Chile, 2013). Local authorities, following the national trend to diversify the energy matrix, have been promoted to include renewable energies, especially because this region has one of the highest energy prices and the least-dense population centres in Chile. In terms of energy consumption, one of the most relevant demands for heating is wood, because of this urban areas are highly polluted (Morata et al., 2017).

In 2014, researchers from CEGA, along with the regional office of the Ministry of Mining, won a public bidding to develop a two year geothermal exploration campaign encompassing the Aysén region, the positive results of this project leaded to further biddings won by CEGA, allowing the development of 2 pioneer projects focused on utilizing geothermal heat pumps: i) a geothermal greenhouse, and ii) heating of a public school. This paper assesses the public engagement strategies implemented in those projects. In the following section, the main description of each project is included.

a. **Geothermal greenhouse for social reintegration in Aysén (2017):** This one- year project is located in Valle Verde Centre, in Puerto Aysén, an institution that receives inmates to offer them an effective preparation for work, simulating conditions in the free environment, in order to reintegrate them into society. In CET, there are eleven greenhouses, where inmates work to have vegetables for their consumption and also to sell. In this context, a heat pump system was installed in a 108 m^2 greenhouse to ensuring their vegetable grow throughout the year (which is difficult due to low temperatures). The system involves a 22 kW_t geothermal heat pump with a horizontal closed loop collector, that heats the greenhouse through two fan

coils (Muñoz et al., 2017). One of the limitations of this project was the timing because it had to be developed in one year. The funding obtained from the Ministry of Energy focuses on promoting local energy initiative. This kind of bidding asks for a one-year project. In this sense, one important challenge was to carry out the monitory and follow up process, which is a fundamental part of the innovative project. This project had the support of the regional offices of the Ministry of Mining, Energy and Environment and agriculture.

b. **The heating system in a Public School (2018-2020):** This two and a half year project was financed by a Regional Government's fund and it is located in Coyhaique, the regional capital city. The intervention includes to replace the firewood heating system in 11 classrooms, a corridor and two bathrooms (around 600 m^2), beneficiating over 300 students of the Liceo Bicentenario Altos del Mackay, public school. The installation uses an open loop collector, extracting 5 L/s of groundwater, to fed two geothermal heat pumps with a total power of 50 kW_t, that distribute the energy through a fan coil array. This project was developed by CEGA and supported by regional offices of the Ministry of Education, Energy and Environment, and Directorate of Municipal Education.

Both projects won the best Geothermal Project with Social and Environmental Impact in 2018 and 2019 respectively given by the Geothermal Congress for Latin America and the Caribbean Industry (GEOLAC), which are recognised for making an outstanding social and environmental impact on the region and community.

2. METHODOLOGY

The methodology for understanding social and cultural aspects related to the introduction of geothermal heat pump technology in Aysén was based on the principles of Participatory Research Action. This method is based on social justice principles, taking into account that participants are not subjects of research, but rather, they are active contributors to research. In this sense, local members participate in all stages of the research process (Chandler & Torbet, 2003; Kelly, 2005). This method requires periodic evaluations, it allows to assess with participants the process, and also make action plans, and adjustments. At the same, time, ethnographic conversations took place, during both projects. This kind of interactions allows access to everyday spaces and common sense of a context. According to Devillard, Franzé and Pazos (2012), this method includes in the production of discourses, where it is possible to describe social and cultural practices.

3. PUBLIC ENGAGEMENT STRATEGIES

Taking into account that technological innovation has to deal with the social, economic and environmental aspects, a pivotal component of the social approach of CEGA´s projects has been included local needs and community concerns in the design of those projects. In this sense, the first step was to have deep interviews with key members of each community. By two ways exchanges meetings, it was possible to design particular strategies for each project.

In this section, the following local strategies are described:

3.1 Local Workshops for the General Public

To counteract technological knowledge gaps and information and knowledge asymmetries about the technology among the local community, ten workshops in CET Valle Verde community and Altos del Mackay communities have been taking place in the last three years. The main goals were to empower communities and promote spaces for dialogue and trust between researchers from CEGA and local communities. Those activities have been addressed the following themes: geology of the Aysén region, operation of the geothermal heat pump, greenhouse air heating system, and greenhouse vegetable grow. In Altos del Mackay School, workshops were developed in different scales. Six activities were carried out with students and teachers.

Figure 1: Workshop and Social Activities Developed in CET, Valle Verde.

3.2 Citizen Science Experience

A citizen Science, understood as more equitable engagement between experts and the lay public where non-technical public participate in different level in the production of knowledge (Cavalier and Kennedy 2016), was part of the strategies developed in Aysén. This experience was designed between CEGA and science teachers from the school in 2018. Twelve students from Altos del Mackay School every day for two months recorded information about the temperature three times a day. That information was used for different purposes: i) To have a baseline of information ii) To compare the impact of the heat pump system and iii) To design workshop with students about temperature comfort.

Figure 2: Students from Altos del Mackay were part of several research activities.

3.3 Science-Art Wall Paintings

Taking into account a successful experience developed in Santiago by CEGA (2018), where a group of artist and geologists designed a painting wall, a similar experience was promoted in Altos del Mackay School. In this initiative, one local artist, teachers from science and art classes, as well as a group of students designed and painted scientific-art wall paintings. In each wall of the heat pumps room, a description of local geology and cultural aspects were included. This experience was well-received by the local community, having a high level of commitment from teachers and students. Weekly workshops were carried out. In total, this initiative was developed in three months.

Figure 3: Students and teachers from Altos del Mackay School participated in a science wall art activity.

3.4 Periodic Meetings with Local Professionals from Ministry´ Offices

Taking into account that those projects are carried out in Aysén and researchers from CEGA work in Metropolitan region, a key role is played by local professionals, who has strong local knowledge and they work on the regional offices of Ministry of Education, Energy and Environment. In this sense, transdisciplinary exchanges are a critical component for the success of those experiences. Geothermal heat pumps systems in Aysén context promote synergies among environmental, energy and educational institutions.

4. TECHNICAL CHALLENGES

Since these projects have been focused on prototypes, one of the most important challenges has been their operation. Most of the technical issues faced in the analysed projects in Aysén were based on the location due to adverse climate conditions and the lack of supplies. In the following section, some of the technical challenges faced are described.

4.1 Geothermal Greenhouse for Social Reintegration in Aysén

Since this was a one-year project, starting in January, the activities began in winter to meet the deadlines. The severe weather conditions were faced during the geothermal system implementation. This phase started with the construction of the ditches for the collector and the machine room, which could not advance when the rain was heavier. In addition, due to the two-level design chosen for the collector, the trench filling required coordinating the installer with the backhoe operator, who was not present at a beginning, forcing the filling process to be conducted by hand. The arrival of another backhoe, lent by the municipality of Puerto Aysén, allowed to speed up this process.

One of the most complex technical issues faced was the lack of an appropriate power supply. This problem kept the system inoperative for almost a year, after its opening. The CET´s location has an unstable electrical connection, and due to budgetary restrictions, the electrical improvements required to increase the electrical capacity could not be covered by the fund. A necessary intervention had to be managed directly with Gendarmerie, the institution in charge of the CET, which due to administrative problems, was not implemented until the end of 2018.

Another issue that delayed the installation was the lack of supplies in the region. Because Aysén is an isolated region, most of the supplies were bought from other regions, so availability was limited by transport times. At the same time, the last problem was the lack of a stable internet signal to be able to monitor the system, but that was easily solved with the lease of a Wi-Fi plan. Despite the problems presented above, the system has operated without problems since March 2019.

4.2 Heating System in a Public School

In this case, because it was a two years project, it was most feasible to adjust the phases in order to build the system in better weather conditions and make some progress in areas that would not see delays due to unfeasible weather conditions. Most of the steps were made in summer. Only drilling of the wells, done in spring, had to stop for several days due to the rain. On the other hand, the lack of some equipment was another issue, but since it had a more detailed installation design than the greenhouse, these were smaller.

The use of an open collector revealed a new drawback: the low capacity of reinjection. Besides including a reinjection well smaller than the extraction, most of it is located in impermeable levels, making water reinjection flow complex. A drain to the river, which is located next to the school, had to be done to avoid the overflow of the well chamber.

In this project, a delay was faced due to the weak electric power. In this case, it was required to have a stronger electric system in order to take into consideration the additional consumption of the heat pumps. Because of this situation, the system began its operations two months later of the planning and not at the beginning of the school year as expected. Since then the system has been adjusted to operate optimally and had worked without major inconvenient.

5. CONCLUSIONS

Even though heat pump systems are a technology widely used in countries such as Switzerland or Germany, in the Latin American context, this is an emerging technology. Geothermal heat pumps are not well known in Chile, and even though there are potential to have low enthalpy geothermal projects, heat pumps systems are not commonly used in the country. In this context, the two projects described in this paper are a new application in the Aysén region, being technological innovation initiatives in Latin America. But, the development of innovation projects involves facing several social and technical challenges.

Among social aspects, those cases illustrate the importance of including follow up and monitoring activities. In this sense, the time frame for the execution of projects with public bidding is not necessarily the most suitable to include a monitoring phase. On the other hand, even though heat pump systems do not demand a high level of technical skills to use them, to change a heating system implies to change cultural practices. In this sense, these projects are good examples of the importance of taking into account social and cultural aspects to promote demonstration projects.

At the same time, the analysed initiatives describe that geothermal heat pump systems projects are inherent to uncertainty. When technologies are in emerging stages, there is still no clear market that operates, facing greater challenges and more rugged trajectories than common innovation processes. In this sense, recording processes and learning from the challenges and issues faced are important to promote replicability of those initiatives.

From a technical perspective, working in an isolated region presents different problems, mainly due to the distance that lengthens the response times before an eventuality. On the other hand, getting a correct electrical installation has been a delayed subject in both projects, installation required to be able to operate the equipment. Proper planning and funds are necessary to avoid this inconvenience again.

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