PROCEEDINGS, 48th Workshop on Geothermal Reservoir Engineering
Stanford University, Stanford, California, February 6-8, 2023
SGP-TR-224

Why Geothermal Energy? A Questionnaire-analysis of Community Acceptance to Promote Energy Justice and Sustainable Development Strategies in Rural Argentina

Jackson Marshall Grimes

Iceland School of Energy at Reykjavik University, Menntavegur 1, 102 Reykjavik, Iceland

Jackson.m.grimes@gmail.com

Keywords: Community Engagement, Social Acceptance, Sustainable Development Goals, Geothermal

ABSTRACT

As greenhouse gases continue to rise, demand is increasing for meaningful and workable solutions to combat climate change. Countries are broadening their energy matrix and exploring opportunities to develop renewable energy power projects, often in regions where industrialization has not occurred. Argentina is one of the South American nations looking to diversify its electricity matrix through the development of geothermal energy. Varvarco is the closest settlement to Argentina's highest potential geothermal field, Domuyo. The Domuyo field has entered the pre-feasibility phase for a 30 MWe geothermal binary plant, with plans for extension up to 100 MWe.

This research is an investigation into the knowledge, perception, and acceptance of geothermal energy amongst the community of Varvarco, the primary stakeholders of the Domuyo project. Through one-on-one interviews, internet surveys, and discussions occurring from January to March 2022, data was gathered on the public opinion of geothermal technologies amongst 37 members of this marginalized population.

The initial hypothesis was that the survey regarding geothermal would reveal a population opposed to geothermal development in their region. However, the investigation found there is high acceptance towards geothermal utilization in some form, likely due to fundamental barriers to sustainable development and the historical energy injustices which have shaped the current socio-economic conditions of Varvarco. This paper addresses opportunities to realize the social license to operate. Based on qualitative data, it is debated why geothermal operations at Domuyo should not be limited to the construction of a geothermal power plant, but also consider direct-use projects which will have more meaningful, equitable, and sustainable impacts within the community of Varvarco.

1. INTRODUCTION

Amongst the renewable energy sources available, geothermal presents a unique advantage. Unlike wind and solar, which face challenges of intermittency and variability, geothermal energy can be produced continuously to provide baseload energy (Fridleifsson, 2001). Beyond geothermal's ability to produce electricity, residual geothermal heat can be used in numerous industrial, residential, commercial, and agricultural sectors (Turnšek et al., 2021). The advancement of our economic systems into circular designs will be critical for our goal of reaching carbon neutrality, and geothermal holds an important position in the realization of a zero-emission planet (Finger et al., 2021).

Domuyo Volcano lies in the province of Neuquén and has the potential to be the site of Argentina's next Geothermal Power Plant (GPP) (Figure 1). The electrical production project is still in the pre-feasibility phase, and with a potential of between 90 and 100 MWe it is the most promising geothermal resource in the country (ADI-NQN, 2020; Chiodi et al., 2020). The Domuyo geothermal field can only be accessed via Provincial Route Number 43 (PRº43), which runs through the center of Varvarco.

Varvarco is a marginalized and remote community with limited opportunities for individuals to improve their economic situation. The proposed site of the Domuyo GPP is 35 km north of Varvarco, a town of 585 residents (Proyectos de Ingeniería S.A. & Grupo ENAL, 2016; hereafter PISA & ENAL, 2016). The community has been classified as stakeholders by the local project financier, Agency for the Promotion and Development of Investments of Neuquén (ADI-NQN), which also owns the mining rights to the geothermal field.

The people of Varvarco's knowledge of geothermal as it relates to the Domuyo geothermal field is the focus of this study. The research activities align with ADI-NQN's short-term activity of conducting a social management study. The primary data gathered in this report is the first investigation on community perception regarding geothermal utilization at Domuyo Volcano. The initial hypothesis is that the survey regarding geothermal would reveal a population opposed to geothermal development in their region.

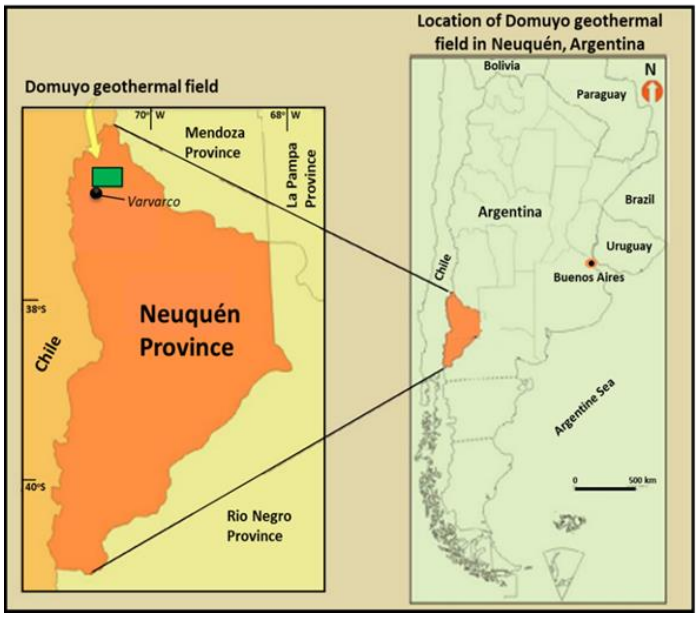


Figure 1: Location of the Domuyo geothermal field and Varvarco, Neuquén within Argentina (Adapted from: Pesce, 2013)

2. BACKGROUND

2.1 Social Acceptance

The first research into social dynamics, or the 'non-technical' factors of renewable energy appeared in the early 1980's (Wüstenhagen et al., 2007). With respect to the social acceptance of wind power, relevant factors went beyond 'public opinion' and began to recognize the roles political and regulatory acceptance hold in the overall process. These early studies influenced future researchers to investigate these concepts further and lead to a refining of the analysis of the social dimension beyond 'public opinion'. By 2007, a new reference framework for analyzing social acceptance had begun to emerge. Wüstenhagen et al., (2007) found social acceptance to be lacking a sound definition and created a framework to begin to give clarity to its meaning, known as the Triangle Model. They summarized the factors into three interdependent categories: Socio-political Acceptance, Market Acceptance, and Community Acceptance.

2.1.1 Socio-political Acceptance

The socio-political category is the broadest level of social acceptance, and it refers to the general opinion of policies or technologies by various groups such as the public, key stakeholders, or the policy makers themselves. While public attitudes towards renewable energy (RE) may be positive among broad majorities, once focus is shifted from global to local viewpoints, general support for RE technologies and policies may begin to encounter resistance (Karytsas & Polyzou, 2021). Often, barriers to the implementation of a project are born from, and can be expressed as, a lack of socio-political acceptance.

2.1.2 Market Acceptance

Market acceptance is the process a RE technology must pass through before an innovation becomes widely endorsed by both consumers and investors. The theory of this level of acceptance is rooted in supply and demand (Wüstenhagen et al., 2007).

Energy is tied not only to its physical siting but to the actual transmission of electricity into the grid. Therefore, it begins to encompass stakeholders such as electrical companies, regional distribution networks, and utility providers. This involvement of larger players of the national or international energy system is a special form of market acceptance known as intra-firm acceptance (Reith et al., 2013). It tends to crossover with socio-political acceptance, as these firms are influential in how the design of policies and decisions unfold (Wüstenhagen et al., 2007).

2.1.3 Community Acceptance

Community acceptance refers to the attitudes and opinions of local stakeholders, primarily residents and local authorities, on siting and planning decisions of RE infrastructure. Decisions by project developers are heavy with risks: environmental, economic, and social. For local communities these risks may manifest as increased taxes, environmental pollution, safety concerns, noise disruptions, ecosystem degradation, and the exacerbation of existing inequalities (Karytsas & Polyzou, 2021). To help identify project specific risks developers should prioritize community engagement.

Due to a GPP's proximity to population centers and the cultural or spiritual connection some communities have with geothermal energy sources (e.g., volcanoes) opposition can arise, such as with the Baturraden GPP at Mt. Slamet in Indonesia (Santoso & Kusumasari, 2019). Instances of controversy surrounding GPP projects have been recorded around the world, including the Lower Kilauea East Rift Zone in Hawaii, the Mt. Apo and Tiwi projects in the Philippines, the Smokvica geothermal system of Macedonia, and the Milos and Nisyros Islands of Greece (Karytsas & Polyzou, 2021; Popovski, 2003). Conflicts such as these demonstrate the need for an improvement in the way consultation and educational outreach occur (Temper et al., 2020). And although each project faced its own challenges, Karytsas and

Polyzou (2021) identified common spatial, contextual, personal, and socio-psychological factors that affected community opinion and perception of the projects.

If properly timed and effective awareness campaigns do not take place, the results can be disastrous for the public consensus of RE projects. Companies should strive to garner support from the public, but this must be balanced with control over any unrealistic expectations (Dewhurst, 2014). Miscommunication and mishandling of expectations can lead to instances of distributional injustice (i.e., how are the costs/benefits shared?) or procedural injustice (i.e., are all stakeholders' participants in the decision-making process?), both of which are integral parts of the emerging field of energy justice.

2.2 Community Engagement

Since research surrounding social acceptance began, it has evolved into a crucial factor for the planning of RE infrastructure. Academic research has revealed the influence acceptance and perception holds over the final feasibility of RE projects. Without local approval, developers run the risk of creating controversy, which can lead to delays and economic losses (Barich et al., 2021).

"It is not possible to complete a successful project if initially not identifying the elements of the local environments, which can influence its social acceptance; and not designing proper organizational, technical, economic, and other solutions in order to remove the negative opinions" [Popovski 2003, pg. 38].

Geothermal projects are not an exception to this rule and more developers are beginning to acknowledge the relevance of non-technical dimensions to the overall success of a project (Soltani et al., 2021). Given the spatial nature of geothermal resources, any attempt to exploit the resource often means affecting communities. Therefore, before any physical progress occurs, robust engagement activities should take place involving core stakeholders to begin the project's development with a sense of transparency and inclusion.

Karytsas and Polyzou (2021), identified three pillars of successful engagement activities for GPPs. They are: avoidance and reduction of unfavorable impacts; generation of added benefits for surrounding communities; and community engagement practices (Figure 2).

When engagement strategies and best practices, listed above, occur in the early stages of a project, developers have an opportunity to establish community acceptance and trust. The relationship can advance from communicative to collaborative, and ultimately to participative. This ongoing dialogue allows for controversies, conflicts, and delays to be reduced, the transparency of activities and plans can increase, issues can be discussed, undesirable effects can be minimized, and the overall relationship between developers and locals can be improved (Barich et al., 2021; Karytsas & Polyzou, 2021).

Pillars of Community Engagement

Avoidance and Reduction of Unfavorable Impacts	*Generation of Added Benefits for Surrounding Communities*	*Community Engagement Practices*
• Environmental protection focusing on prevention and minimization of impacts • Environmental monitoring and mitigation procedures which last throughout a project's lifetime • Integrated measures to conform with relevant health, safety, and environmental legal requirements • Environmental Security Fund, used in recovery or damage reimbursement • Planning of environmental activities to restore and improve any impacted areas.	• Improvement of educational facilities and services • Strengthening of hygiene through improved access to healthcare services • Localized environmental protection strategies which focus on conservation of natural resources, education of citizens on environmental issues • Enriching the local economy • The expansion of infrastructure • Encouraging cultural or social programs	• Commissioning of a socio-economic study • Identifying a group of local actors who can represent all core stakeholders • Extensive consultation with surrounding communities to provide transparent and unrestricted information • Awareness campaigns should be ongoing

Figure 2: Geothermal industry best practices for community engagement as identified by Karytsas & Polyzou, 2021.

2.3 Energy Justice

The realization that energy generation and supply systems have been unevenly distributed across the globe is no surprise when one understands energy as a driver of economic growth, and energy access as a basic human need (Shortall et al., 2015). While the developed world is accustomed to this higher standard of living, as of 2019 nearly 761 million people still are without access to a reliable energy source, and within our current balance of powers many of these individuals' voices are overlooked (GCDL, 2019). The International Energy Agency has predicted that developing countries will be the source for over two thirds of the world's energy demand in the future as they progress towards increased levels of industrialization (IEA, 2018).

Energy Justice (EJ) analyzes where injustices might occur within the current configuration and future designs of energy systems and offers ways on how greater equity might be achieved by addressing institutional and contextual biases (Lacey-Barnacle et al., 2020). The core

of EJ research considers the unequal distribution of the benefits of energy systems, from not only an access standpoint but negative effects such as pollution and displacement.

A meta-study of "Energy Justice" found 61 papers across various fields such as RE, oil and gas, energy policy, energy access, electric vehicles, and water desalination. Amongst the 61 papers, two dominant theoretical frameworks existed: the three-core tenants' framework and the eight-principal decision-making framework (Lacey-Barnacle et al., 2020). From an evaluation of cross-scale linkages between these two frameworks across the 61 papers, three core themes were identified as the most common and constructive in analyzing justice within energy systems. The core themes are:

2.3.1 Decentralization, Access, and Sustainability

Decentralized energy systems are technological configurations where a power generation source is near the population it serves and is disconnected from national power infrastructure (Tornel, 2020). Decentralization is an important piece in combating energy injustices in developing countries as it can equip rural communities with reliable energy access. This deepening of resilience amongst communities ensures energy security and allows for diverse avenues for individuals to create sustainable futures.

2.3.2 Institutional Instability and Corruption

On the global scale energy policy tends to prioritize access and availability for higher population and economic centers above those found in rural communities. The desire to provide power to larger hubs additionally tends to overlook the environmental or sustainability aspects of large-scale energy projects, which correlates to a lack of appropriate governance infrastructure at the state or national level (Lacey-Barnacle et al., 2020). Thus, the challenges found in the decision-making process are exacerbated in countries where economic and political instabilities historically exist. This can be attributed to the fact that nations are more concerned with reductions of energy prices, the bottom-line cost of electricity generation, delivering and maintaining energy services by the cheapest model possible, and large projects to reduce GHGs (Tornel, 2020).

Energy focused activism tends to be more prevalent in developing nations where the goals of multinational corporations and national governments conflict with those of local populations (Raman, 2013). An environmental justice movement against GPPs in Indonesia stemmed from a lack of access to information, a lack of consultation or community involvement in the deployment and operation of projects, a lack of compensation, and a disregard for environmental impacts (Santoso & Kusumasari, 2019). Resistance to energy projects comes in many forms, and mass media should not be overlooked as a means to bring attention to areas where institutional injustices and human rights abuses occur (Temper et al., 2020).

2.3.3 Marginalized Communities and Gender Inequalities

The Institute for Global Initiatives defines marginalized communities as those *"confined to the lower or peripheral edge of the society. Such a group is denied involvement in mainstream economic, political, cultural, and social activities due to their living conditions, lifestyles, or exclusion"* [IGI Global, n.d.].

Within the framework of EJ, we can define them as any group (particularly indigenous, rural, and nomadic) vulnerable to economic or energy developments. These are communities with little recognition at the political level and have almost no voice amongst decision-makers when the siting of energy projects is discussed (Tornel, 2020). This lack of consideration for local inputs has only allowed for the continuation of inequalities.

Beyond solely marginalized communities, there is a connection between gender and energy injustices. Historically in lesser developed regions, women predominately undertake the activity of gathering firewood for heating and cooking, and most areas where biomass is still used as a fuel source are far away from power production facilities (Pachauri et al., 2004). By replacing the time-consuming burden of obtaining firewood, RE technologies open a myriad of new opportunities for women, such as new economic endeavors or the opportunity to continue their education (ESMAP, 2019).

2.4 Sustainable Development Goals

In September of 2015, world leaders moved to adopt a list of 17 Sustainable Development Goals (SDGs). The establishment of the SDGs provides a framework for the discussion on sustainability as it applies to poverty, hunger, health concerns, lack of education, gender inequality, environmental degradation, unequal energy access, and more.

The effectiveness and efficiency of the SDGs since their adoption by policymakers has been heavily debated. Stafford-Smith et al., (2016) suggest that to adequately achieve these SDGs there needs to be greater cohesion between industrial sectors (e.g., finance, agriculture, energy, and transport) and societal actors (local authorities, government agencies, private sector, and civil society) and between developed and developing nations.

Geothermal is a clean and reliable source of heat and electric power supply with many synergies and opportunities for addressing the SDGs. The United Nations Framework Classification for Geothermal Energy report, co-authored by the International Renewable Energy Agency (IRENA), the International Geothermal Association (IGA), and the Energy Sector Management Assistance Program (ESMAP), identifies seven SDGs (2, 3, 6, 7, 9, 12, and 13) which geothermal energy production can address (IRENA & IGA, 2021). The report recognizes the foundation that energy holds for enhancing the sustainability of sectors such as industrial development, agricultural production, environmental preservation, and health services.

2.5 Varvarco Socio-economic Context

2.5.1 Investigation Site

Varvarco is the closest town to the Domuyo volcanic complex, and it is the focus of this study. It is 23 km in a direct line over topography and 35 km via PRo43, southwest of the potential GPP site. It is the only urban center located within the area of influence as defined by ADI-NQN for the Domuyo GPP (Figure 3).

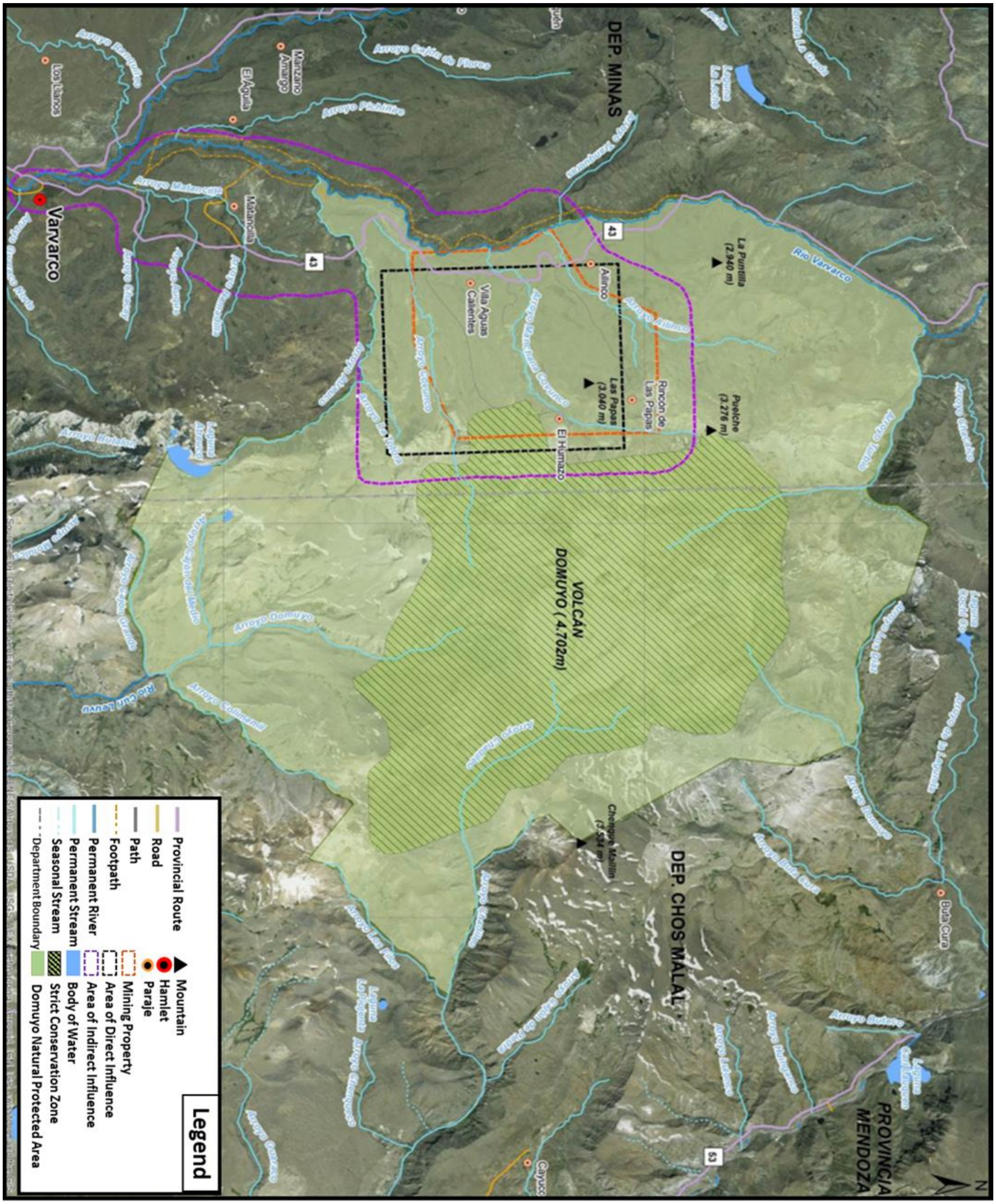


Figure 3: Map of Varvarco and Domuyo, area of influence defined by PISA & ENAL (Adapted from: PISA & ENAL, 2016).

The community of Varvarco is positioned on a small plateau above the southern bank of where the Varvarco and Neuquén Rivers conjoin to its west. Immediately to the east is a plantation of Ponderosa pines planted by the Neuquén Forest Corporation (CORFONE), which is harvested for lumber production (PISA & ENAL, 2016). The name Varvarco means "murmuring waters", believed to reference either the geothermal surface manifestations surrounding Domuyo, or the constant low roar of where the Neuquén and Varvarco Rivers meet just below the town (PISA & ENAL, 2016).

The town's urban design is centered around PRo43 which runs the length of the community, locally it is known as Avenida Domuyo (Domuyo Avenue). Those living outside of the urban zone are primarily nomadic-pastoralists who migrate between pastures from season to season. They live in *parajes*, which are small shacks not connected to any utility services, and often only inhabited during summer months (Figure 4).

Figure 4: Typical *Paraje* within the Investigation Site.

2.5.2 Water

The Neuquén River basin encompasses an area of 49,958 km2 and covers nearly the entire northern area of Neuquén Province (PISA & ENAL, 2016). The Neuquén River is born from the Andes mountains of the Chilean Argentine border region. From the months of May to July (rainfall) and October to December (snowmelt) violent floods can occur. The Varvarco River is its main tributary.

The Varvarco River sub-basin holds an area of 1,424 km2 and is born from the Varvarco Campo and Varvarco Tapia lagoons high in the Andes (PISA & ENAL, 2016). It has several tributaries from the Domuyo Volcanic complex that give it cloudy properties as these waters are loaded with mud and clay. It is a fast river with an average flow of 58 m3/sec; when it conjoins with the Neuquén River it reaches an average flow of 103 m3/sec (PISA & ENAL, 2016).

The community of Varvarco sources water for the municipal utility system from the Varvarco River, just 100 m above where it meets the Neuquén River. The water quality of the river dramatically affects potability.

2.5.3 Economics

Animal husbandry is an economic mainstay of the region, with a long culture of ranching amongst the people. Livestock is primarily goats; however, sheep, cattle, and horses are present as well. The rancheros are nomadic pastoralists. Minas, the region of Neuquén in which Varvarco is located, lists more than 90% of the surface area as pasture (PISA & ENAL, 2016).

Farming in Varvarco is developed solely for subsistence and is carried out by individual families on small plots with low productivity.

Lumber production in Varvarco has taken place over the last 30 years, with activity in the region causing conflicts with the nomadic herders as pine plantations have cut off livestock passages used between the winter and summer seasons.

Tourism has the greatest economic effect on Varvarco; however, it only occurs during the summer months. There are 18 surface manifestations ranging from hot springs, to geysers, fumaroles, and intermittent streams of hot water along the Cordillera del Viento. Four of the most important of them in terms of tourism are El Humazo, Los Tachos, and Las Olletas and Aguas Calientes. The tourist cabins at Aguas Calientes are not connected to the electricity grid, lighting is only available by a diesel generator, and they use thermal waters for space heating, which is unique in this region.

2.5.4 Electricity

Electrical services in Varvarco are controlled by the Provincial Energy Entity of Neuquén or EPEN by its Spanish abbreviation. EPEN controls all the distribution of power throughout Neuquén Province. EPEN Electricity services end shortly outside the urban zone of Varvarco at La Matancilla, where a small cluster of households are found. Many of the parajes must rely on a solar panel for electricity during the day, which was provided to them through a rural electrification program. The electricity supply in Varvarco is at the mercy of the elements. High wind speeds and flooding from snow melt or rain often cause electrical disruptions across the utility system.

2.6 Domuyo Geological Setting

Domuyo Volcano is the highest point in the Patagonia region at 4,709 m (Pesce, 2013). In 1984, a study by JICA (Japan International Cooperation Agency) on the geologic, geochemical, and gravimetry conditions of Domuyo gave the first conceptual models of its' geothermal reservoir.

2.6.1 Japan International Cooperation Agency (JICA) (1984)

The JICA study involved three stages.

Stage 1: Captured 15,000 km^2 of aerial photographs and satellite images were taken of the region surrounding Domuyo Volcano (ADI-NQN, 2020). Hydrological, structural, topographic, and large-scale geological features were defined. Based on observations made in this stage of the JICA study an area of 220 km^2 was selected to be investigated further (PISA & ENAL, 2016).

Stage 2: It began with a topographic study of the selected 220 km^2, and the field tasks comprised of geological, geochemical, and gravimetric surveys. The culmination of these field surveys resulted in refining the study to an area of 40 km^2 (ADI-NQN, 2020).

Stage 3: It consisted of electrical prospecting, seismic, gradient-well drilling, isotopic analysis of thermal fluids, and measurements of the physical properties of drill cores. JICA identified three areas of interest. Now referred to as the West, Transitional, and East Zones (Figure 5).

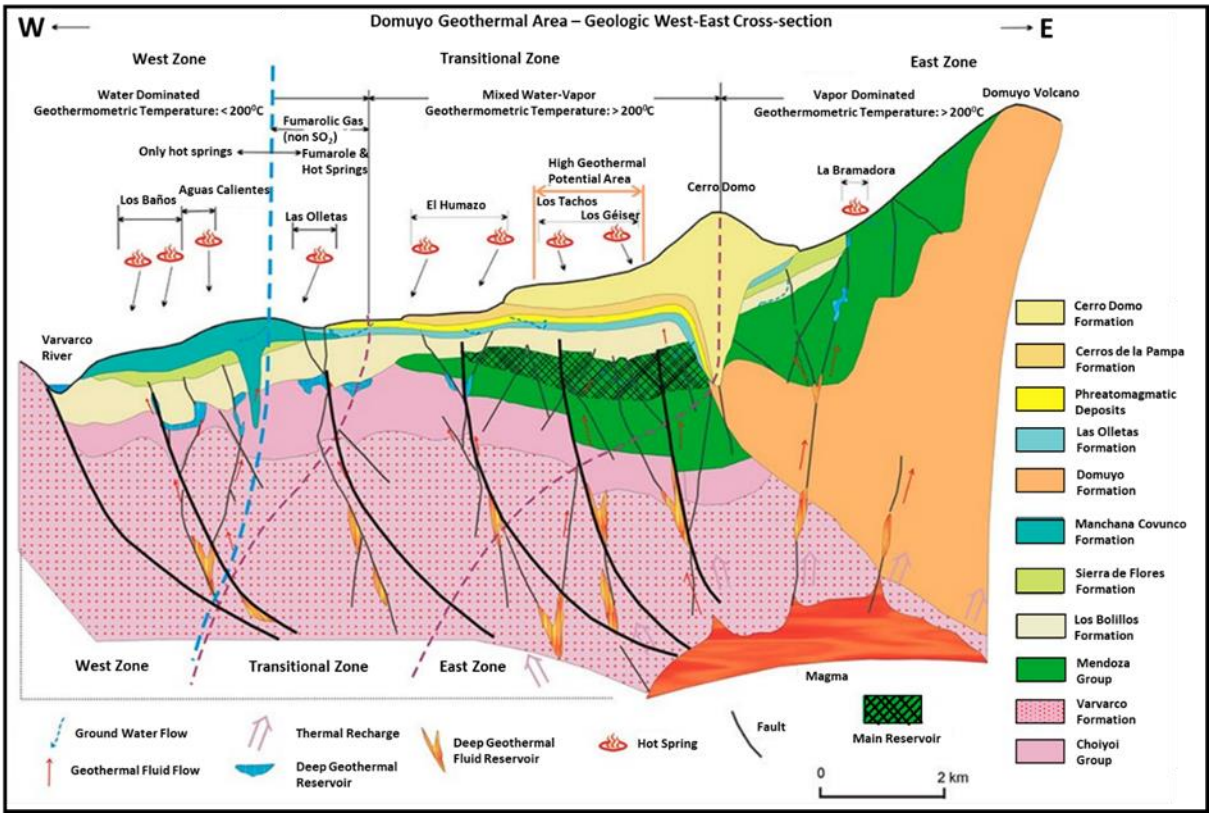


Figure 5: Geologic cross-section of the Domuyo geothermal field (Adapted from: Pesce, 2013).

West Zone: Includes the surface manifestations locally known as Las Olletas, Aguas Calientes, and Los Baños (Figure 5). These manifestations are water type dominant, with geothermometry temperatures under 200^{0}C and rarely accompanied by fumarolic gases. The basement lies at depths between 200 m to 700 m while the depth of the faults or fractures are in the range of less than 200 m (ADI-NQN, 2020). The intermediate layer, which is correlative with slag and pumiceous tuffs from the Tertiary to Quaternary, is believed to have been affected by hydrothermal alteration and presents high temperature in association with water. This zone has been determined to be distant from the heat source.

Transitional Zone: This zone covers an area which includes active thermal manifestations with liquid and gas discharges, referred to as El Humazo, Los Tachos, and Los Géiser (Figure 5). These manifestations are water-steam type dominant, with geothermometry temperatures reading above 200^{0}C. The depth of the basement exceeds 800 m indicating the existence of a collapsed structure with the development of associated fractures. The section between 200 m to 800 m depth is correlated with the Tertiary and Pre-Tertiary formations, accompanied by faults and fractures (ADI-NQN, 2020). This section is assumed to have been hydrothermally altered and presents high temperature as indicated by geophysical studies.

East Zone: The greatest heat potential is found in this zone. The surface manifestation named La Bramadora is vapor dominant with geothermometer temperatures exceeding 200°C (Figure 5), the temperature at 100 m constantly exceeds 50°C (ADI-NQN, 2020). The area is made up of a thick succession of Tertiary formations and Mesozoic. The basement is latent in depth. Hydrothermal alteration zones were identified in the surface layer and evidenced by the distribution of surface alteration zones, the distribution of geochemical anomalies, and soil temperature.

After an in-depth JICA selected two potential areas at the borders of the Transitional Zone. Now referred to as Area's A and B, both are adjacent to geothermal manifestations dominated by water-steam explosions (Figure 6).

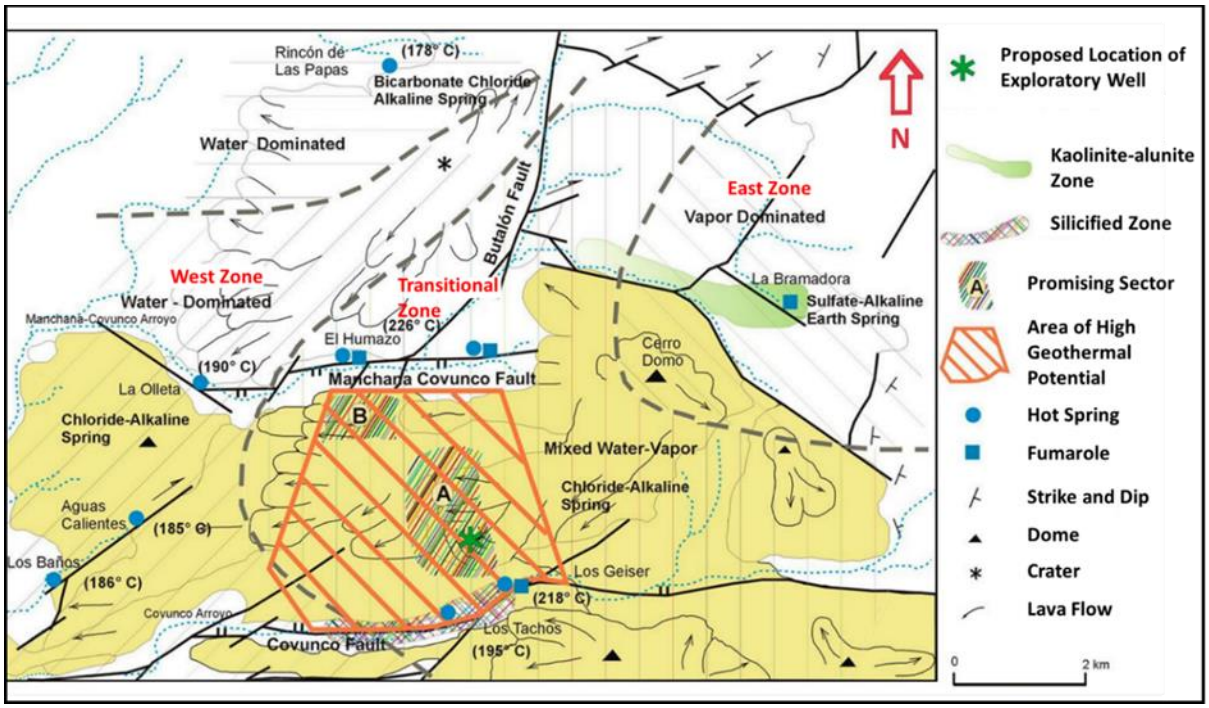


Figure 6: Map showing different sectors of the Domuyo geothermal field (Adapted from: Pesce, 2013).

Area A: With a dimension of 2.5 km in the N-S direction and a length of 1 km in the E-W direction covering 2.5 km^2 (ADI-NQN, 2020). The reservoir rock is expected to be dacitic to andesitic tuffs from the late Mesozoic to Tertiary, with medium to low density and moderate to high porosity. The geophysical survey indicated a structure that would have originated from a great collapse of the basement and a subsequent super-imposition of layers. The concentration and development of faults and crush zones is expected to provide the potential reservoir that extends not only laterally, but also in depth.

Area B: Located south of El Humazo (Figure 6), has a length of 1.2 km in the N-S direction and 0.5 km in the E-W direction and covers an area of 0.6 km^2 (ADI-NQN, 2020). It is believed to have rocks with high density and low effective porosity. Surveys indicate that the structure of the reservoir in the area would be formed by an intense local collapse, zones of faulting and crushing in the basement, or superimposition of formations of the Middle Mesozoic. This structure is expected to extend in depth.

JICA established that the highest priority target area should be Area A (ADI-NQN, 2020). It would be another 33 years before a second in-depth exploration study of the Domuyo geothermal system occurred.

2.6.2 Energy Sector Study Program (PESE) (2017)

The PESE study included geological, geochemical, and geophysical analysis with photo interpretations of high-resolution satellite images. The geoscience components were used to define key aspects of the Domuyo geothermal conceptual model, evaluate the geothermal field's potential, and define drilling targets. The geophysical studies consisted of gravimetric measurements at 130 sites, magneto-telluric surveys at 90 sites, and time-domain electromagnetic measurements at 40 sites (ADI-NQN, 2020).

"Conceptual Model of the Geothermal Field of the Domuyo Project" determined that the reservoir is liquid-type dominant and lodged in igneous or sedimentary rocks with secondary permeability. The seal rock was found to be of volcanic type, the Domuyo pyroclastic flows. The geothermal fluid zone of ascent is centered around El Humazo with the fluids moving laterally, discharging primarily towards the south-to-southwest and to a lesser extent north. Geothermometer readings infer a temperature of 240-270^{0}C in the ascent zone, and 190-220^{0}C in the lateral flow zone. The research indicates it is unlikely that a significant vapor layer exists on top of the reservoir. Due to the sampled fumaroles being of secondary nature, no suggestions can be made about the chemical composition or content of the gases in the reservoir. The potential of the reservoir falls in the range of 100 MWe with a deviation of 15 MWe using the Volumetric Method with Montecarlo simulation (ADI-NQN, 2020).

2.6.3 Schedule of Future Activities for the Development of the Domuyo Project

ADI-NQN has continued to promote the Domuyo project by scheduling future feasibility studies programs.

Short-term Activities:

1. Social Management Study – ADI-NQN believes obtaining social acceptance from the population of the localities which fall within the area of influence will be a major challenge for the Domuyo GPP project. These communities are Varvarco, Ailinco, and La Matancilla (direct influence) and Las Ovejas (indirect influence).

2. Environmental Impact Report for the Drilling Stage – Upon obtaining social acceptance , ADI-NQN will solicit the completion of an Environmental Impact Report for the proposed drilling sites. The Domuyo geothermal field falls within the Domuyo Natural Protected Area and will require the approval of strict guidelines issued by the Provincial Directorate of Protected Natural Areas.

Medium-term Activities: Set to be carried out successively in the order of a) Drilling Plan, and then b) Feasibility Study (ADI-NQN, 2020). The contents of the proposed activities are as follows:

A) Drilling Plan: Three deep exploratory wells on the foothills of Domuyo were defined for drilling with an average height of 2,450 m above sea level (PISA & ENAL, 2016). In the next stage of exploration, wells will reach a minimum depth of 1500 m (ADI-NQN, 2020). All drilling locations lie within the María Victoria mining property.

B) Feasibility Study: This activity will only be carried out if the exploratory wells are deemed a success. The statistic to be considered a successful well will depend on the project objective, however, the worldwide commercially acceptable rate is a well that has power ≥ 3 MWe or a flow ≥ 21.6 tn/h (ADI-NQN, 2020). Upon completion of the technical and financial feasibility phases of the study, the developer will work to obtain a Power Purchasing Agreement from the Argentine Wholesale Electricity Market Clearing Company (CAMMESA) and other private electricity consumers.

Long-term Activities: For the Domuyo project, long-term activities are the drilling of production wells, construction of the geothermal plant, and construction of transmission lines.

Construction of the pilot GPP will begin with the drilling of the production wells. At time of writing, ADI-NQN assumes the pilot plant will have a maximum capacity of 5 MWe. The pilot plant will require construction of a 33-kW electrical transmission line (ADI-NQN, 2020).

3. METHODOLOGY

3.1 Questionnaire Design

The original research question for this investigation was what effects the consultation and education of geothermal risks and benefits would have on the overall acceptance of geothermal development amongst a community. Unfortunately, due to local institutional barriers which are discussed in the Results of this report, I was unable to distribute the questionnaire, host the educational seminar, and redistribute the survey. Therefore, this research evolved into the initial public outreach activity amongst the Domuyo GPP's primary stakeholders.

In designing the questionnaire, the aim was to establish continuity and comparability with previously published research. It has been further adapted to fit the particulars of the community of Varvarco.

Balzan-Alzate et al., (2020) selected five countries to investigate acceptance of deep geothermal energy production, not geothermal energy as a whole. The nations were chosen in order to be representative of the three stages of geothermal development: Advanced (France), Moderate (Belgium, Canada, and Chile), and Early (Colombia). Argentina can be considered in the early development phase.

In the Indonesian case study, Malau et al., (2019) selected respondents who had been affected by the development of the 250 MW GPP in the District of Pauh Duo, Solok Selatan Regency. The questions adapted from this report were the most appropriate for the level of knowledge the people of Varvarco would have regarding geothermal. Still, further explanation was needed for the respondents from Varvarco to understand the purpose of certain questions.

The Italian study tested citizens of various socio-demographic backgrounds. At the time of the study the Palermo region had experienced a deterioration of socio-economic stability brought on by rapid de-industrialization, unemployment, economic crisis, and regional elections (Pellizzone et al., 2015). These socio-economic conditions made it an ideal site to investigate citizen attitudes towards new technology.

The new Varvarco questionnaire consisted of 36 questions and was divided into three sections: Acceptance and Comprehension; Social Dynamics; and Comments and Questions. A blank version of the questionnaire can be found in **Appendix I**.

3.1.1 Acceptance and Comprehension

The questions presented revolved around local perception of geothermal development, regional energy challenges, COVID-19 social complications, and levels of confidence in information sources. This section explores the opinion of the respondents through self-assessment of the relevant topics.

Grimes

This portion of the survey contained 12 multiple-choice quantitative questions. This is the section containing questions adapted from Balzan-Alzate et al., (2020), Malau et al., (2019), and Pellizzone et al., (2015). Descriptive text was added to describe vocabulary in one question which asked for the interviewee's opinion on the two most relevant energy challenges within the Varvarco region.

3.1.2 Social Dynamics

In this section, 18 questions were formed to build an image of daily life in Varvarco, learn how the community felt about the use of certain geothermal resources, and obtain socio-demographic information. The result was a mix of qualitative and quantitative data which is fundamental to the research.

3.1.3 Comments and Questions

The six questions were designed to prompt a dialogue between the surveyors and respondents. They are open-ended and solely of a qualitative nature.

3.2 Data Collection

ADI-NQN's tender called for a professional to perform a social-management study and begin the process of community consultation. Although this project did not investigate all the components of a socio-economic study, it did serve to identify stakeholders and their opinions on geothermal.

Data gathered in Varvarco was obtained through a series of 34 semi-structured interviews which took place through door-to-door consultations. The survey was presented in Spanish.

Many of the survey respondents wished to be asked the questions of the survey rather than completing them by themselves. This was necessary as a portion of them expressed an inability to read or write, as well as a general lack of knowledge surrounding the topic of geothermal energy. Every interview required some level of explanation for the questions, based on the respondent's level of education and experience. Due to this, each survey lasted approximately one hour.

34 interviews were conducted in-person, 32 of which were completed, two individuals lost interest and did not wish to complete the survey. In addition, three responses from new survey respondents were collected online via the geotermiayvarvarco.com webpage. For a total of 35 completed interviews for the Varvarco questionnaire.

4. RESULTS

The results of the questions with the most relevance to the report are discussed here. For the complete results of each survey question see **Appendix II**.

4.1 Community Engagement

By conducting this study, I began the process of public consultation regarding geothermal energy in Varvarco. The strategies used are a part of Karytsas and Polyzou's (2021) third pillar of successfully fostering social acceptance of GPPs; Community Engagement. Results of those activities are presented here, followed by an analysis of the socio-economic conditions within Varvarco and how they may have influenced public perception of geothermal energy.

4.1.1 Commissioning of a Socio-economic Study

This survey represents the first attempt to discuss geothermal in depth with many of the citizens of Varvarco. Question 1 (Q.1) asked "What do you know about Geothermal Energy" 43% of the 37 interviewees had never heard of geothermal (Q.1), and 59% of them did not know it was RE source (Q.2).

Regardless of 43% of the respondents admitting to not knowing any benefits of geothermal energy (Q.5) and 62% were in support of developing the Domuyo geothermal field (Q.6).

Q.7 asked what the three most important pre-requisite conditions were for the construction of the Domuyo GPP. The two highest selected conditions were "Does not affect thermal water" and "Guarantees of respect for the landscape and protection of the environment", respectively accounting for 27% and 29% of the total responses. Not a single individual chose "No matter the conditions, I will not support this type of project".

Q.9 inquired about energy-related issues in the region. "Cost of Energy" was the most prevalent issue receiving 23% of the votes, followed by "Development of Renewable Energies" at 21%, and "Environmental Impacts" ranked third at 19%. These answers illustrate a community experiencing economic hardships related to energy affordability and who are eager to expand into RE technologies. They are also deeply tied to the land, it gives them the firewood that keeps them warm, the hot springs which bring tourists and good health[1], and provides wide pastures for their livestock to graze.

[1] One woman in the community suffered from psoriasis during her childhood, after years of visiting Aguas Calientes her condition was cured

Q.11 asked what information regarding GPPs individuals would like more information on. "Effect on hot springs" had the highest percentage of "very interested" at 75%, followed by "Environmental Impacts" at 69%. This high interest in how geothermal technology might affect the natural system reinforces the fact that respecting the environment and constant monitoring of potential risks will be vital in developing community acceptance (Q.7). While the development of Domuyo is welcomed, it will be paramount that a balance between utilization and ecological health is kept.

4.1.2 Identifying Local Actors to Represent Core Stakeholders

Initially, conducting the survey was unsuccessful as they were wary of an outsider, however, once the community learned I was a student at the Iceland School of Energy at Reykjavik University they were intrigued and happy to talk.

An actor who would be a prime candidate for representing Varvarco is the local radio host. The radio announcer hosted me after the survey period had been completed for a short, broadcast talk about geothermal energy. A simple description of how the heat of the earth heats water deep in the surface, which is then pumped up from the ground to create electricity, where it can subsequently be utilized in direct-use applications, and eventually reinjected into the Earth, thus making it a renewable energy was given. After this meeting several people in Varvarco told me that had heard our talk on the radio and were interested in learning more.

When asked what sources of information interviewees trusted, local news was the second most trusted source (33%), behind universities (84%) (Q.12). Additionally, when asked how they preferred to access information 23% of the responses mentioned radio (Q.33). There is an online newspaper that covers events in the region surrounding Varvarco, but many of the people do not have access to the internet. Therefore, radio is the most effective forum for disseminating information about the Domuyo project amongst the community and keeping them up to date with planned activities.

4.1.3 Consultation with Communities to Provide Unrestricted Information on Geothermal

An initial goal of this research was to host a town-hall meeting on the risks of geothermal and to re-issue the survey to see if opinion had turned negative or stayed positive. When asked if they would like to have a discussion or presentation on the topic, 90% of respondents were interested (Q.10). Unfortunately, due to local institutional barriers I was unable to conduct a town-hall style meeting. However, it was possible to give presentations on geothermal to the students of the primary and secondary schools.

4.1.4 Developing an Awareness Campaign

To provide not only transparent, but continuous information on geothermal to the community of Varvarco I designed the webpage geotermiayvarvarco.com. The website gave a short description of my research goal, a link to an online version of the survey, and numerous links to educational videos, infographics, and papers.

4.2 The Situation in Varvarco

As a rural community, in a remote location, at a high altitude in the Andes, Varvarco faces tremendous challenges year-round. Families in the rural zone suffer even greater hardships than those in the urban center of Varvarco. They are not connected to any gas, water, or energy infrastructure.

4.2.1 Water

No data is available on the chemical content of the water the community uses, but I was told not to drink the water without first boiling it. The current distribution system pumps water from the Varvarco River where it undergoes minimal filtration before entering the municipal utility system. When washing dishes in the kitchen there is a strong smell of sulfur if using cold water. Bottled water is the main source of hydration. During the survey period, there were several gaps in the days in which bottled water was available in the village, reemphasizing the supply-chain challenges which hamper Varvarco. 24% of the interviewees from the urban zone listed access to drinking water as a major concern (Q.35). The families in the rural zone near Domuyo are able obtain water from mountain streams and alpine lakes and did not mention drinking water as a concern.

4.2.2 Food

The chemical content of this water makes it difficult for families to cultivate crops. Many of the greenhouses in Varvarco have been abandoned as the cost of fresh water is too high and its availability is too low. When asked how they would feel about using the heat from the hot springs to grow crops, only 17% of the respondents said "No" (Q.28). I assume this agreement to the question stems from the ongoing condition of fresh produce not being consistently available. From an SDG perspective this is a community where water and food can become scarce, and therefore basic human needs are frequently unmet. The challenge for a geothermally-enhanced greenhouse remains where would fresh water be sourced from, however if water infrastructure investments are made, the snowmelt which is at its pinnacle in the Spring could be better stored for prolonged use throughout the year.

4.2.3 Employment

Employment opportunities in Varvarco are in short supply, and the people are very interested in the economic opportunity a geothermal project may bring. Anytime "Jobs" were mentioned throughout the survey it scored high, in Q.7 it was the third most selected condition at 18%. While in Q.11, 85% of respondents were interested in learning more about job creation related to geothermal. For Q.27, regarding using geothermal water to grow crops, one respondent recognized this as an opportunity to create jobs for the community. 36% of the people questioned in the urban zone of Varvarco work for the municipality, which pays its employees through government funded programs (Q.16). The types of work are labor, and service related. When respondents were asked if they would be happy if work was

available at the Domuyo GPP, 97% of them said yes (Q.25). In fact, one individual said, "*It should be mandatory to have jobs for the people of Varvarco."*

4.2.4 Gas and Heating

Much of the economic activity in the region occurs seasonally, whether that is tourism or husbandry-based, work slows down during the winter. However not all work, as many families must gather firewood to prepare for cold winters where gas heating is not always accessible. The CORFONE tree plantation provides no biomass for the community as the smoke from burning the Ponderosa Pine wood is noxious to inhale. One family shared that sometimes there is a shortage of firewood, and it becomes expensive to buy. When work is unavailable the cost of heating your home becomes a challenge. In Q.18, 53% of families in Varvarco said it was expensive to heat their homes, some of those in the rural area explained "*It is not expensive, but it is time consuming and labor intensive*." Q.9 asked the interviewees what they believed the most important energy-related issues in their area were, "Cost of Energy" scored the highest with 23% of the responses.

Within the interviews conducted in the urban zone, five households use solely firewood for heating and cooking, six families from the urban zone said they were not connected to the gas grid as it was too expensive for them. The rest use gas, or a combination of gas, electricity, and firewood. However, within the interviews I conducted, when asked how they would feel about using the heat from the hot springs to heat their home, 100% of respondents of the survey were in favor (Q.28).

Beyond the fact that gas was too expensive for some families, even the arrival of gas for those connected to the home distribution network is not always guaranteed. The only transportation corridor PRº43 is paved up to Las Ovejas, 20 km south of Varvarco. PRº43 often becomes inaccessible during the winter months, and it is not uncommon for gas, food, and water to become scarce. In the question related to hardships brought on by COVID-19, the respondents stated, "*Gas and food are always more difficult for us to have during the winter"* (Q.8).

The primary school and health center are not connected to the gas distribution network and thus rely on a different delivery truck to bring the much-needed gas during winter months.

When asked about problems in the community one parent stated, "*Heating in winter would improve the quality of life, for example, classes would not be suspended when there is a lack of gas. The health center has the same problem and even the professionals who worked there left due to lack of heating*" (Q.34). This unreliability of gas can be deadly to those living in the Andes mountains who have no backup system in place. The decentralization of communities in these remote places is therefore not a matter of decarbonizing energy systems, but a matter of safety, of equal opportunity to pursue an education and have access to basic health services. Within Argentina, 16 of the 23 provinces are working to create policies which encourage the integration of more RE technologies, and given the vast geography of the nation, decentralized energy systems may have far reaching impacts if the proper regulatory factors can be put into place (Schaube et al., 2017).

4.2.5 Electricity

The electricity supply situation in Varvarco is also difficult. When asked what a challenge is for their community, 70% of individuals from within the urban zone of Varvarco cited the unreliability of electricity or frequent power outages as a primary issue (Q.35). During discussions with interviewees, several of them informed me that the power outages last much longer during the winter.

4.2.6 Government

Another condition in Varvarco that deserves attention is that of the role of local government. In research surrounding acceptance of GPPs, a focus is placed on the position that local government holds in successfully opening a dialogue between developers and citizen stakeholders (Karytsas & Polyzou, 2021), Local authorities can act as a natural group of representatives to speak for affected communities. Unfortunately, when interviewees were asked what source of information they trusted the most, amongst nine options, local government was the third least trusted source at 9% approval, only ahead of social media and provincial government (Q.12).

At the outset of the project I attempted to contact the head of the local governing body of Varvarco, the mayor. With four failed attempts to communicate directly with him, I believe that finding a governmental representative to be a liaison between the core stakeholders of Varvarco and future developers of the Domuyo GPP may be a difficult task. There are two comments from the survey which give a glimpse into the dichotomy between the townspeople of Varvarco and its' local government. Both statements were made in response to Q.35, "What is a challenge in your community?"

"The heating system because you can't rely on wood. And people cannot give their opinion to the mayor or the governor, I have even received threats from the previous mayor."

"Access to firewood and gas, and a lack of work. The mayor gave the possibility for municipal workers to change for a job that pays more, but when this informal job was finished, we could not return to work in the municipality."

5. DISCUSSION

The initial hypothesis of both the researcher and ADI-NQN to find the population of Varvarco to be resistant to geothermal development was found to be false. The data gathered from the questionnaire paints a picture much different than what had expected from a social management study. Due to the poor socio-economic situation of the community, regardless of prior knowledge of geothermal energy, the stakeholders of Varvarco are open to development of the geothermal resources which make up the Domuyo volcanic complex.

As a researcher investigating acceptance and opinion on new geothermal amongst a community that faces constant hardship, it comes as no shock that they approve and are hopeful for development in their region. The disconnection from energy services, the unreliable access to goods, and a local government which appears unstable are reasons to discuss why geothermal should be deployed in Varvarco. This situation appears to be a prime example of how justice principles manifest in peoples' lives. Beyond the challenges of heating their homes and finding work to feed their families, the people of Varvarco have a hard time even trusting their government. When conversing with a member of the community about his outlook on the development of Domuyo he stated,

"As long as everyone in the town receives aid, I am okay with it, we are tired of struggling to get anything."

The next step for the Domuyo project will be the beginning of the contracted Social Management Study and Environmental Impact Report for the Drilling Stage. I suggest the project developers consider direct-use geothermal demonstration and profitability projects, in conjunction with the Domuyo GPP, to further secure community acceptance and the social license to operate. Potential avenues are discussed through the lens of the SDGs. This section concludes with a discussion on how energy justice principles have transpired within Varvarco.

5.1 Promoting SDGs through Geothermal in Varvarco

The people of Varvarco conquer the challenges many marginalized communities face year after year. By including direct-use projects within the design of the Domuyo GPP, Varvarco could have a chance to break the cycles of poverty, hunger, and inequality that are present in the region. In this section I briefly describe the ways in which geothermal can help meet some of the SDGs.

5.1.1 SDG 1 – No Poverty

Poverty levels can be linked to energy consumption patterns at the household level. Marginalized communities with a lack of access to clean energy sources often depend on biomass for heat which is not only inefficient but polluting (Pachauri et al., 2004). Direct-heat use in regions where it is available, and Ground Source Heat Pumps (GSHPs) almost anywhere in the world, can be used to replace the need for biomass (Shortall et al., 2015).

GPP's often have direct and indirect income effects on the populations in the area around them. Direct effects like salaries for new employees may be limited, but indirect effects can potentially last for the lifetime of the project. Contributions from GPP developers can help to end poverty in affected communities via royalties, taxes, or initiatives like rural electrification and infrastructure development which bring new opportunities to impoverished regions (Shortall et al., 2015). The people of Varvarco need the influx of jobs and revenue that can be realized from geothermal projects.

5.1.2 SDG 2 – Zero Hunger

The increased availability of reliable electricity brought on by GPPs can be used for food preservation and water pumping for irrigation during dry seasons; thus, helping to improve food security (Shortall et al., 2015). However, geothermal energy can provide much more than power production. Through cascading use of residual hot water from the electrical production process crops, fish, and other food products can be cultivated. 32 countries now use direct heat from geothermal to help greenhouses blossom in regions where food security has been a long-standing issue (Lund & Toth, 2021). Aquaculture is becoming more common with 21 countries reporting this type of use in 2021. Kenya, a semi-arid country with few rivers, is beginning to experiment using their abundant geothermal energy for fish farming. At Kenya's Menengai geothermal field, where it once took 12 to 14 months to grow Nile Tilapia to 1 kg adult fish, geothermal heating has reduced the growing period to six months which allows for two production seasons per year—a much-needed boost to meet annual food demand (John & Jalilinasrabady, 2021).

Data from the survey indicated that subsistence issues such as food are the most significant issues for the people of Varvarco. Geothermal can help address this not only from an influx of revenue from the exploration and construction of the site, but also the geothermal resource itself can be used to accelerate the growth of vegetables and fish. Self-sufficiency is the key to truly addressing the scarcity of food and geothermal production can help address this for the people of Varvarco.

5.1.3 SDG 3 – Good Health and Well-being

Increasing energy provisions through GPPs allows for remote districts to improve hygiene via hot water, purify their water supply, and refrigerate medicines; thus, reducing the need to travel long distances for health services (Shortall et al., 2015). The therapeutic qualities of naturally occurring geothermal waters have been used by various cultures for centuries (Cataldi et al., 1999). Research today has proven geothermal waters can be used to cure several rheumatic diseases such as psoriasis and arthritis (Farcas et al., 2007). At a hot spring in Sohna, Haryana, India pilgrims and patients visit the site to treat skin problems and stay for a week at a time (Dolma, 2020).

GSHPs can decarbonize the space heating sector and work towards SDG 3 by replacing biomass; thus, reducing indoor pollution and associated health risks. These benefits, however, are not restricted to the developing world. 54 countries show use of GSHPs accounting for 71.6% of geothermal capacity worldwide (Lund & Toth, 2021).

Many people in Varvarco rely on firewood to heat their homes. Although no studies have been done on this community linking health concerns to burning wood, it is well known that inhaling smoke is damaging to the body. Eliminating the need to burn, gather, and buy firewood will improve health, allow time for other ventures, and save money.

5.1.4 SDG 4 – Quality Education

GPPs tend to be developed where economic activity has not historically been centered. GPP facilities require highly educated personnel who are often flown in to oversee construction of the project. Once the project enters the Operation and Maintenance (O&M) phase there

is a unique opportunity presented to incorporate local labor resources. If community engagement occurs early in the planning phase individuals who are interested in the workings of a GPP can be identified and training initiatives can help build a centralized workforce.

Improving education is a recognizable method for elevating people from poverty. In Varvarco there is an emphasis on education, but the reality is that men and women start work from an early age to help meet the needs of family, community, and culture. Developers of GPPs must realize that the opportunity to assist impacted communities lies in the establishment of social programs. As previously mentioned, the primary school often closes during winter months as they run out of gas. By replacing the current gas system with geothermal heat pumps, it will allow for the children to attend classes no matter external factors.

5.1.5 SDG 6 – Clean Water and Sanitation

Geothermal projects can enhance access to water in several different ways. Greater access to electricity can be used to pump water during dry seasons. GPP developers sometimes drill freshwater wells to meet production requirements. If policymakers and nations incentivize the drilling of additional wells, these could be used by nearby communities to meet local water demands (Shortall et al., 2015).

Geothermal energy for desalination has been practiced as early as the 1970's in the United States, however, new advances in seawater desalination are occurring in the Baja Peninsula off the west coast of Mexico. The research group iiDEA, has been experimenting with using geothermal to replace solar and wind in the desalination process and has widespread implications for producing distilled water in regions where low-enthalpy geothermal is present and demand for clean water is high (Aviña-Jiménez et al., 2016).

The area surrounding Domuyo is extremely dry and clean water resources are in short supply. As the drilling and construction phases of the GPP require water this will most likely put a strain on resource availability. To mitigate any risks or conflicts this would be an opportunity for the developer to drill a water well for the people of Varvarco and earn the social-license-to-operate. As access to water is another of the greatest challenges the people in Varvarco face they would be thrilled to have aid in overcoming this problem.

5.1.6 SDG 7 – Affordable and Clean Energy

Direct development of geothermal power clearly promotes SDG 7 as it is a renewable resource with average global GHG emissions that are 90% less than coal plants and 75% less than natural gas production facilities (ESMAP, 2019). And still this number is increasing every year with the creation of new technologies such as carbon sequestration, resulting in GPPs approaching carbon neutrality (Snæbjörnsdóttir et al., 2020). Additionally, geothermal energy is unique in its ability to produce stable, reliable, and consistent baseload power at relatively low cost when compared to other technologies. When a GPP enters the operational stage, it will generate a steady output of energy, for decades when managed properly, at a competitive cost compared to other baseload energy sources such as hydrocarbons.

In terms of affordability, GPPs have a high initial capital investment cost, however, most of this expenditure is covered by international financers, not local residents (ESMAP, 2019). Once the GPP is operating energy costs stay constant, unlike fossil fuels pricing which is subject to international market conditions, an issue exacerbated by COVID-19. The spatial nature of geothermal generation brings energy closer to end-users and helps minimize costs and transmission losses.

Even though up-front costs may be significant when developing geothermal, its renewable nature provides an opportunity for reduced costs over time. The community of Varvarco needs a new energy source to meet local demands.

5.1.7 SDG 8 – Affordable and Clean Energy & SDG 10 – Reduced Inequalities

Job opportunities for locals arise during the exploration, drilling, and construction periods of projects, which can last for at least four years in the case of greenfield projects (Soltani et al., 2021). The O&M phase often requires full-time and permanent work which local labor is an ideal source to draw from. Jobs that manifest as a part of GPP construction or operation are classified as direct jobs. Indirect jobs resulting from the geothermal industry are those that provide goods or services to companies associated with the construction or O&M of GPPs. These can range from research and development (R&D) professionals, security guards, service and business management personnel, architects, government regulators, lawyers, those involved in the tourist industry, or the employees who will work in the direct-utilization industries that surround GPPs (Shortall et al., 2015).

Surrounding the Domo San Pedro GPP in Mexico are several small communities where economic advancement was previously non-existent. A dehydration plant now in operation which utilizes residual hot water from the Domo San Pedro GPP, can produce up to 200 kg of dried fruit per day (Lund & Toth, 2021). The jobs created by this facility have improved the quality of life amongst the communities involved in the project (Alberto & Tello, 2020). If GPPs are considered for cascaded and direct use opportunities from the outset of the project, a wide variety of jobs can manifest from these applications, not only in the agricultural sector but R&D and training opportunities for higher caliber positions (ESMAP, 2019).

Developing a GPP provides the opportunity for creating jobs in Varvarco that will serve as a tool for reducing inequalities and stimulating economic growth. It is a matter of financing and political will for any true change to occur.

5.2 Thinking on Energy Justice

GPPs can embody several models of benefit sharing and can contribute to sustainable policies beyond SDG 7, such as social development and infrastructure initiatives (SDG 1), training opportunities (SDG 4), and bridging the gaps of gender inequalities (SDG 5) (Shortall et al., 2015). These indirect and direct benefits can be seen as means to increase levels of social and economic equity, but it is important to realize that delivering energy access does not equate to the end of energy poverty (Tornel, 2020).

Although the Domuyo GPP is certain to bring improved energy security to Varvarco, it is unclear whether the development will directly benefit the micro-economic situation of the community. If the introduced technologies are linked to social issues that exist within local

systems, they can help to create a vision amongst populations where they see new energy developments as a direct benefit to their future endeavors.

However, the historical conditions that have shaped Varvarco means they do not see national government investment within their region as a positive. Outside interaction is often viewed with skepticism and it will take a robust discourse between stakeholders and shareholders to build a relationship of trust. Research on EJ principles shows that in general that within the developed world distributive justice is the primary challenge, while in the Global South inequalities manifest in the form of procedural justice and collective rights (Temper et al., 2020; Tornel, 2020). From an objective and independent perspective, I believe the challenges in rural Argentina stem just as much from distributional injustices as procedural.

5.2.1 Decentralization, Access, and Sustainability

If the Domuyo GPP is a success, it would be easy to assume that energy access will improve. However, I do not believe it would be so simple.

The current design will connect the Domuyo GPP via a 33-kW transmission to an existing transformer station 55 km away in Las Ovejas. The condition of the power lines from Las Ovejas to Varvarco is poor. As has been previously discussed power outages occur regularly in Varvarco and it is not a condition from a lack of capacity in the grid, but an issue of services. The power lines are disrupted by wind, snow, and rain. For the people of Varvarco a more immediate course of action would be to improve the current electrical infrastructure. Additionally, the cost of electricity is already too high for many of the people in Varvarco. Unless the developer of the project creates a fund for the community or a subsidy for electricity bills there is no guarantee there will be an improvement in access.

In some ways Varvarco is already a community experiencing energy decentralization. The system they rely on is still hydrocarbon based and with uncertainty surrounding the timetable for gas delivery services the community must often take care of themselves. As seen from the survey results, a large number of households in Varvarco rely on gathering firewood to stay warm for the winter. A simple solution would be to install GSHPs in some of the public buildings like the school or health center. So that at least in a time of crisis the people would have a safe place to shelter. The problem of course with this is who is going to pay for it.

If we continue to push communities off their land for massive RE projects, we are only perpetuating the energy injustices of the past. If a small portion of funding for geothermal projects were set aside to invest in the community, rapid socio-economic improvements would occur. The people in Varvarco need jobs, food, and water. Geothermal can be a means for them to have all those things, if developed responsibly.

5.2.2 Institutional Instability and Corruption

The nation of Argentina has long experienced institutional instability. Whether that comes in the form of currency devaluations, regime overhauls, or widespread social movements, these barriers can make it difficult for individuals to elevate their position. Even in the microcosm of Varvarco we see local government being inconsistent. I have talked about building trust between project developers and core stakeholders, but it is equally important that the public can rely on their elected officials.

This is a region that has long experienced government neglect and though the thought of geothermal home heating sounds amazing, many of them believe it will never happen. I do not want to say they are without hope, but several of them told me this was a "*fantasy*". A policy implication I can see here is that government institutions should invest more in educating communities on RE options. Hardly anyone in Varvarco had heard of geothermal even though studies have been taking place over the last 30 plus years.

This a giant project for Argentina to be undergoing. This will be the first geothermal project in decades, and they will be attempting to construct it in a well-known, highly sensitive ecosystem. Environmental oversight and risk management will be of the utmost importance for the successful and sustainable development of this project.

5.2.3 Marginalized Communities and Gender Inequalities

Though Varvarco is a marginalized community, the parajes around Domuyo deserve special attention. These families will be the most impacted by the construction of a GPP and its access roads as it will be built in the pasturelands they have used for generations (Figure 7).

Figure 7: Ranchero living in the direct area of influence of the Domuyo Geothermal Power Plant.

They are nomadic-pastoralists, and while many of them leave during the winter months those who stay behind must survive without any access to electricity, as there is no electrical grid to connect to. All six families I interviewed in the rural zone of Varvarco only use firewood to heat their homes as they must save their gas for cooking (Q.17). I am concerned that these individuals will suffer from a case of distributive justice as they will see the construction of a GPP on their ancestral land and most likely receive few, if any benefits.

A social impact fund for a geothermal laundry or geothermal heat pumps for their homes would be a simple and early way of introducing the rancheros to not only geothermal, and some of the people and machines who may be involved in future activities, but to drastically improve their living conditions during the winter months and help gain the social license to operate.

6. CONCLUSIONS

Due to local institutional barriers, this research evolved into the critical, initial public outreach activity amongst stakeholders in Varvarco, the most highly-impacted population center within the direct area of influence of the Domuyo geothermal power plant.

A survey on knowledge and acceptance of geothermal, socio-demographics, and overall conditions of the community was distributed to 37 core stakeholders from Varvarco. This analysis found the community faces fundamental barriers to sustainable development. The cost of energy, access to electricity, gas, food, water, and biomass, and a lack of equal economic and educational opportunities are the greatest challenges to the people of Varvarco. Regardless of previous knowledge surrounding geothermal, the majority of respondents had a positive opinion on the utilization of geothermal resources in several forms.

The results of community engagement practices identified the local radio host as a strong candidate to represent other stakeholders in Varvarco and serve as an intermediate to deliver local priorities and concerns to the project developer. Additionally, to initiate an ongoing awareness campaign and begin to provide transparent and unrestricted information to the community the website *geotermiayvarvarco.com* was established.

ADI-NQN expected to find a group resistant to the development of Domuyo but given the current socio-economic conditions of Varvarco they seem willing to participate in the planning process. The most important conditions to the people of Varvarco when constructing the Domuyo power plant will be respect of the landscape and natural environment, an effective re-injection scheme to guarantee the hot springs are not affected, and the inclusion of a direct-use or tourism program to create jobs and elevate their quality of life.

GPPs are long-term infrastructure projects requiring millions of dollars to develop but in the end are net-positive gains for financers. However, we cannot continue to focus on the money. The inclusion of a social impact program investing in the utilization of waste heat from the Domuyo GPP, or ground source heat pump systems, for the community health center and primary school would solidify acceptance of geothermal technologies, as well as immediately promote SDGs 3 & 4. Additionally, if direct-use projects are integrated into Domuyo GPP design they will not only increase efficiency of the system but create numerous opportunities for direct and indirect economic advancement within Varvarco. Furthermore, if the projects focus on agricultural production there is a chance for the project to address food security. Thus, direct-use strategies could aid in achieving SDGs 1, 2, 8 & 10.

Re-distributing this survey amongst the remaining population of Varvarco would improve the character of the data. As well as better articulation of what defines geothermal development, while being cautious not to influence responses.

6.1 Acknowledgements

The primary data gathered in this report was funded by the Agency for the Promotion and Development of Investments of Neuquén (ADI-NQN) for the purpose of advancing the Domuyo Geothermal Project.

Two non-published documents (ADI-NQN, 2020; PISA & ENAL, 2016) were shared with the author by ADI-NQN. All use of the data from these two reports was approved by ADI-NQN and is not available for public use. If one wishes to obtain the documents cited, they must contact ADI-NQN via email at neuquen@adinqn.gov.ar

For downloadable access to the IGCP-636 videos and infographics please visit the project website at https://igcp636.com/

I would like to thank Mr. Carlos Esteban of ADI-NQN and Mr. Gastón Cancellarich of Küme Newen for their assistance in gathering survey responses.

For deeper insights into this report please see the full thesis at: http://hdl.handle.net/1946/42083

REFERENCES

ADI-NQN. 2020: Proyecto Geotérmico Domuyo - Año 2020. Gobierno de la Provincia del Neuquén - Ministerio de Economía e Infraestructura.

Alberto, D., & Tello, S. 2020: Dehydrating Food with Geothermal Energy for Zero Waste. Internet: https://aim2flourish.com/innovations/dehydrating-food-with-geothermal-energy-for-zero-waste (3.5.2022)

Aviña-Jiménez, H., de la Rosa-Urbalejo, D., & García-Gutiérrez, A. 2016: Desalination Using Geothermal Energy. GRC Transactions, 40: 141–146. https://publications.mygeoenergynow.org/grc/1032318.pdf

Balzan-Alzate, D., López-Sánchez, J., Blessent, D., Raymond, J., Dezayes, C., Portela, J. P., Restrepo, E. R., Rendón, D. M., Malo, M., Goderniaux, P., Daniele, L., & le Borgne, T. 2021: 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. Geothermal Energy, 9: 9. https://doi.org/10.1186/s40517-021-00188-x

Barich, A., Stokłosa, A. W., Hildebrand, J., Elíasson, O., Medgyes, T., Quinonez, G., Casillas, A. C., & Fernandez, I. 2021: Social License to Operate in Geothermal Energy. Energies, 15(1): 139. https://doi.org/10.3390/en15010139

Cataldi, R., Hodgson, S. F., Lund, J. W., Council, G. R., & International Geothermal Association. 1999: Stories from a Heated Earth: Our Geothermal Heritage (1st ed.). Geothermal Resources Council: 588 p.

Chiodi, A. L., Filipovich, R. E., Esteban, C. L., Pesce, A. H., & Stefanini, V. A. (2020, April). Geothermal Country Update of Argentina: 2015–2020. World Geothermal Congress 2020, Reykjavik, Iceland. https://www.researchgate.net/publication/341192978_Geothermal_Country_Update_of_Argentina_2015-2020

Dewhurst, K. 2014: Social and Political Consequences of Geothermal: A Case Study From the Nereidas Valley, Nevado del Ruiz, Colombia. GRC Transactions, Vol. 38: 847–850. https://publications.mygeoenergynow.org/grc/1033631.pdf

Dolma, K. 2020: Energy and Food Security using Geothermal Energy: A Case Study of Chumathang, Union Territory of Ladakh, India (Thesis). University of Reykjavik. https://skemman.is/handle/1946/37112

ESMAP. 2019: Gender Equality in The Geothermal Energy Sector: Road to Sustainability. Energy Sector Management Assistance Program Knowledge Series, no. 028/19. World Bank, Washington, DC. © World Bank. https://openknowledge.worldbank.org/handle/10986/31607

Farcas, D., Burta, L., Antics, A., Gabor, G., & Tiurbe, A. 2007: Thermal Treatment in Patients with Rheumatic Diseases on Felix Spa Romania. European Geothermal Congress, Unterhaching, Germany. https://pangea.stanford.edu/ERE/pdf/IGAstandard/EGC/2007/204.pdf

Finger, D. C., Saevarsdottir, G., Svavarsson, H. G., Björnsdóttir, B., Arason, S., & Böhme, L. 2021: Improved Value Generation from Residual Resources in Iceland: The First Step Towards a Circular Economy. Circular Economy and Sustainability, 1(2): 525–543. https://doi.org/10.1007/s43615-021-00010-7

Fridleifsson, I. B. 2001: Geothermal energy for the benefit of the people. Renewable and Sustainable Energy Reviews, 5(3): 299–312. https://doi.org/10.1016/s1364-0321(01)00002-8

GCDL. 2019: *Number of people without access to electricity* [Dataset]. Global Change Data Lab. Internet: https://ourworldindata.org/grapher/people-without-electricity-country?tab=table&country=%7EARG (3.5.2022)

IEA. 2018: *World Energy Outlook 2017* (2017 ed.). OECD. https://www.iea.org/reports/world-energy-outlook-2017

IGI Global. n.d.: *What is Marginalized Communities*. Internet: https://www.igi-global.com/dictionary/technologies-for-digital-inclusion/50719#:%7E:text=In%20general%20terms%2C%20marginalized%20communities%20are%20communities%20confined,due%20to%20their%20living%20conditions%2C%20lifestyles%20or%20exclusion (13.5.2022)

IRENA & IGA. 2021: United Nations Framework Classification for Geothermal Energy Pilot applications in the Caribbean, Ethiopia, and Indonesia. International Renewable Energy Agency. https://irena.org/-/media/Files/IRENA/Agency/Publication/2021/Jun/IRENA_UN-Geothermal_Classification_2021.pdf

John, N., & Jalilinasrabady, S. 2021: Potential of cascaded use of geothermal energy to uplift fish production in Kenyan aquaculture. GRC Transactions, Vol. 45: 486-498.

Karytsas, S., & Polyzou, O. 2021: Social acceptance of geothermal power plants. *Thermodynamic Analysis and Optimization of Geothermal Power Plants*, 65–79. https://doi.org/10.1016/B978-0-12-821037-6.00004-4

La Puebla. 2018: Varvarco festejó su 45° aniversario con la inauguración de la red de distribución de gas. Diario La Puebla. Internet: https://lapuebla.net/2018/10/25/varvarco-festejo-su-45-aniversario-con-la-inauguracion-de-la-red-de-distribucion-de-gas/ (3.5.2022)

Lacey-Barnacle, M., Robison, R., & Foulds, C. 2020: Energy justice in the developing world: a review of theoretical frameworks, key research themes and policy implications. Energy for Sustainable Development, 55: 122–138. https://doi.org/10.1016/j.esd.2020.01.010

Lund, J. W., & Toth, A. N. 2021: Direct utilization of geothermal energy 2020 worldwide review. Geothermics, 90: 101915. https://doi.org/10.1016/j.geothermics.2020.101915

Malau, H., Fajri, H., Yuanjaya, P., Saputra, B., & Maani, K. D. 2020: Knowledge of Local Communities Affected by the Development of Geothermal Energy. IOP Conference Series: Earth and Environmental Science, 448(1): 012112. https://doi.org/10.1088/1755-1315/448/1/012112

Pachauri, S., Mueller, A., Kemmler, A., & Spreng, D. 2004: On Measuring Energy Poverty in Indian Households. World Development, 32(12): 2083–2104. https://doi.org/10.1016/j.worlddev.2004.08.005

Pellizzone, A., Allansdottir, A., de Franco, R., Muttoni, G., & Manzella, A. 2015: Social Acceptance of Geothermal Energy in Southern Italy. World Geothermal Congress 2015, Melbourne, Australia. https://www.researchgate.net/publication/284019407

Pesce, A. H. 2013: The Domuyo Geothermal Area, Neuquén, Argentina. GRC Transactions, 37: 309–314. https://publications.mygeoenergynow.org/grc/1030586.pdf

Popovski, K. 2003: Political and public acceptance of geothermal energy. The United Nations University - Geothermal Training Programme. https://rafhladan.is/bitstream/handle/10802/4807/UNU-GTP-2003-01-03.pdf?sequence=1

Proyectos de Ingeniería S.A. & Grupo ENAL. 2016: Modelo Conceptual del Campo Geotérmico del Proyecto Domuyo: Estudios Básicos de aspectos Socio-ambientales y Económicos - Informe Final (Documento No 039.MT.02.02.03-Revisión 01). Ministerio de Energía y Mineria Argentina - Secretario de Energía Eléctrica.

Raman, S. 2013: Fossilizing Renewable Energies. Science as Culture, 22(2): 172–180. https://doi.org/10.1080/09505431.2013.786998

Reith, S., Kölbel, T., Schlagermann, P., Pellizzone, A., & Allansdottir, A. 2013: Public acceptance of geothermal electricity production. Intelligent Energy Europe Programme of the European Union. http://www.geoelec.eu/wp-content/uploads/2014/03/D-4.4-GEOELEC-report-on-public-acceptance.pdf

Santoso, P. F., & Kusumasari, B. 2019: Key Elements of Environmental Justice in the Geothermal Power Plant Resistance Movement. Jurnal Politik, 5(1): 65. https://doi.org/10.7454/jp.v5i1.207

Schaube, P., Ortiz, W., & Recalde, M. 2018: Status and future dynamics of decentralised renewable energy niche building processes in Argentina. Energy Research & Social Science, 35: 57–67. https://doi.org/10.1016/j.erss.2017.10.037

Shortall, R., Davidsdottir, B., & Axelsson, G. 2015: Geothermal energy for sustainable development: A review of sustainability impacts and assessment frameworks. Renewable and Sustainable Energy Reviews, 44: 391–406. https://doi.org/10.1016/j.rser.2014.12.020

Snæbjörnsdóttir, S.Ó., Sigfússon, B., Marieni, C., Goldberg, D., Gislason, S.R., Oelkers, E.H., 2020: Carbon dioxide storage through mineral carbonation. Nature Reviews Earth & Environment 1: 90–102. https://www.nature.com/articles/s43017-019-0011-8

Soltani, M., Moradi Kashkooli, F., Souri, M., Rafiei, B., Jabarifar, M., Gharali, K., & Nathwani, J. S. 2021: Environmental, economic, and social impacts of geothermal energy systems. Renewable and Sustainable Energy Reviews, 140: 110750. https://doi.org/10.1016/j.rser.2021.110750

Stafford-Smith, M., Griggs, D., Gaffney, O., Ullah, F., Reyers, B., Kanie, N., Stigson, B., Shrivastava, P., Leach, M., & O'Connell, D. 2016: Integration: the key to implementing the Sustainable Development Goals. Sustainability Science, 12(6): 911–919. https://doi.org/10.1007/s11625-016-0383-3

Temper, L., Avila, S., Bene, D. D., Gobby, J., Kosoy, N., Billon, P. L., Martinez-Alier, J., Perkins, P., Roy, B., Scheidel, A., & Walter, M. 2020: Movements shaping climate futures: A systematic mapping of protests against fossil fuel and low-carbon energy projects. Environmental Research Letters, 15(12): 123004. https://doi.org/10.1088/1748-9326/abc197

Tornel, C. 2020: Integrating social and justice dimensions to energy transitions: the case of Mexico. The Regulation and Policy of Latin American Energy Transitions, 16: 283–301. https://doi.org/10.1016/b978-0-12-819521-5.00016-4

Turnšek, M., Thorarinsdottir, R., Boedijn, A., Romero, E., Espinal, C., de Ven, R., & Pavlakovič, B. 2021: Adding Value to Geothermal Food Production through Experience Design. World Geothermal Congress 2020+1, Reykjavik, Iceland. https://pangea.stanford.edu/ERE/db/WGC/papers/WGC/2020/34008.pdf

Vargas-Payera, S., Martínez-Reyes, A., & Ejderyan, O. 2020: Factors and dynamics of the social perception of geothermal energy: Case study of the Tolhuaca exploration project in Chile. Geothermics, 88: 101907. https://doi.org/10.1016/j.geothermics.2020.101907

Wüstenhagen, R., Wolsink, M., & Bürer, M. J. (2007). Social acceptance of renewable energy innovation: An introduction to the concept. Energy Policy, 35(5): 2683–2691. https://doi.org/10.1016/j.enpol.2006.12.001

I. APPENDIX I – COMMUNITY OF VARVARCO – BLANK QUESTIONNAIRE

"Geothermal energy consists of extracting the heat stored in the Earth's interior. There are two types of geothermal energy : heat production and electricity production. The process of installing geothermal energy to produce heat or electricity involves dr illing wells to obtain the heat stored in the ground. Some parts of the world use geothermal energy to heat homes, commercia l buildings and schools; as well as for farming, food processing or tourism. It is also possible to generate electricity where there are large heat re servoirs in the ground."

I.1 Acceptance and Comprehension

1) Q.1: What do you know about geothermal energy?
   - Never heard
   - Slightly
   - Somewhat
   - Well
   - Very well

2) Q.2: What do you know about geothermal energy as a renewable energy?
   - Do not know
   - Know a little
   - Know enough
   - Well informed

3) Q.3: What do you know about the existence of geothermal energy in the area where you live?
   - Do not know
   - Know a little
   - Know enough
   - Well informed

4) Q.4: To the best of your knowledge, geothermal energy is_____?
   - Energy used by developed nations
   - Modern energy
   - Energy that does not come from fossil fuels (oil and gas)
   - Renewable energy
   - Non-destructive energy
   - Do not know

5) Q.5: What do you know about the benefits of geothermal energy?
   - It is used to avoid dependence on fossil fuels (oil and gas)
   - It allows the environment to be cleaner of pollution
   - No need to damage nature
   - To be enjoyed by all citizens
   - For the electricity supply to be met, so there are no power cuts
   - Don't know/Other

6) Q.6: What is your opinion on the development of geothermal energy in the Domuyo Volcano district?
   - Strongly oppose
   - Opposed
   - No opinion
   - Support
   - Strongly support

7) Q.7: What three conditions must be met for you to support a geothermal project in your region?
   - No matter the conditions, I will not support this type of project
   - Does not affect thermal waters
   - Project carried out by public entities (Examples: Government, university)
   - Guarantees of job creation/ Information and community consultation
   - Guarantees of respect for the landscape and protection of the environment
   - Economic compensation for your community
   - Guarantees for the safety of the personnel and communities near the power plant

8) Q.8: Has it been more difficult to obtain gas or food during the COVID-19 pandemic?
    - Easier
    - The same
    - More difficult

9) Q.9: Among the following energy-related issues, in your opinion, which are the two most important in your region?

Energy Efficiency: means using less energy to do the same job and, in the process, lowering energy bills and reducing pollution.

Energy Diversification: consists of having a broader mix of conventional energy (oil, gas), renewable energy (wind, solar, geothermal) and battery storage to provide electricity.

Energy Independence: means that a country can create all the energy it needs to power homes, cars, businesses, etc., and does not depend on buying energy from foreign countries.

Fossil fuel dependence: reliance on conventional fuels (oil, gas) for heating or electricity.

- Don't know/ Prefer not to answer
- Energy Supply
- Energy independence
- Energy efficiency
- Cost of energy
- Energy diversification
- Environmental impacts
- Development of renewable energies
- The type of resource used to produce energy

10) Q.10: How interested would you be in a live presentation and discussion on geothermal energy with the researcher?
    - Not at all
    - A little
    - Somewhat
    - Interested
    - Very interested

11) Q.11: Speaking of geothermal power plants, would you like more information about_____?

Scale: None – A little – Somewhat – Interested – Very interested

- Effect on Hot Springs
- Tourist Opportunities
- Home Heating
- Environmental Impacts
- Micro-seismic Risk
- Use of Geothermal Resource
- Job Creation
- Power Plant Management
- Access to electricity

12) Q.12: How much do you trust the following sources of information?

Scale: None – A little – Somewhat – A lot – Totally

- International news
- National news
- Local news
- Social media
- Universities
- Energy companies

- National government
- Provincial government
- Local government

I.2 Social Dynamics

13) Q.13: How old are you?

14) Q.14: What is your gender?

15) Q.15: What is the highest level of education you have completed?

16) Q.16: What is your occupation?

17) Q.17: How do you heat your home or business?

18) Q.18: Is it expensive to heat your home or business?

19) Q.19: How many people live in your house?

20) Q.20: How do you use heat on a daily basis?

21) Q.21: What do you know about hot springs?

22) Q.22: How many times a year do you go to the hot springs that surround Domuyo?

23) Q.23: What is your cultural or personal connection with the hot springs that surround Domuyo?

24) Q.24: Do you think the hot springs surrounding Domuyo should be developed?

25) Q.25: Would you be happy if there was a job for you or your family at a geothermal power plant?

26) Q.26: If there was a heated pool in your community, would you go to it? How much would you pay?

27) Q.27: How do you feel about using heat from the hot springs to grow crops?

28) Q.28: How do you feel about using heat from the hot springs to heat your home?

29) Q.29: How do you feel about tourists using the hot springs?

30) Q.30: Would you like to have more tourists?

I.3 Comments and Questions

31) Q.31: What questions do you have about geothermal energy?

32) Q.32: What questions do you have about renewable energy?

33) Q.33: How do you prefer to access information?

34) Q.34: What is a problem in your community do you think could be solved by better access to heat or electricity?

35) Q.35: What is a challenge in your community?

36) Q.36: Comments or questions for the researcher?

II. APPENDIX II – COMMUNITY OF VARVARCO – QUESTIONNAIRE REUSLTS

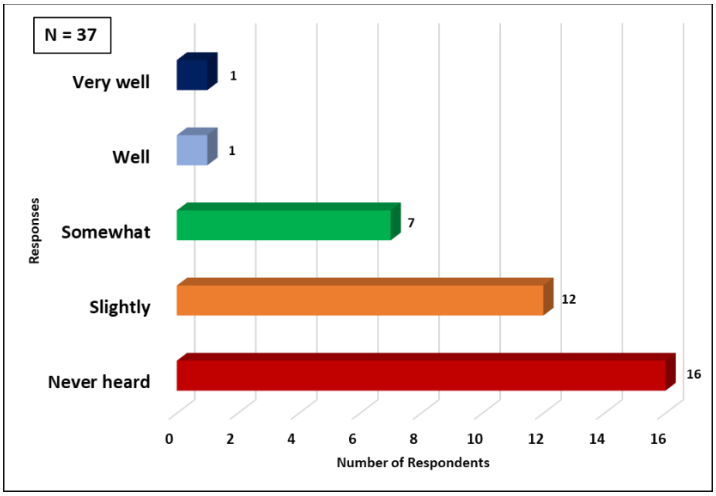
Within this Appendix, the results of each survey question are presented. The explanation behind the inclusion, or exclusion, of each question of the survey is discussed. The Appendix is divided into three sections: Acceptance and Comprehension; Social Dynamics; and Comments and Questions.

II.1 Acceptance and Comprehension

For this section, each of the 12 questions is presented as a sub-section with a brief description of how the answer choices differed from the original questions from Balzan-Alzate et al., (2020), Malau et al., (2019), or Pellizzone et al. (2015), and a figure to represent the responses. In each figure, N equals the number of total responses for the question.

II.1.1 What do you know about geothermal energy

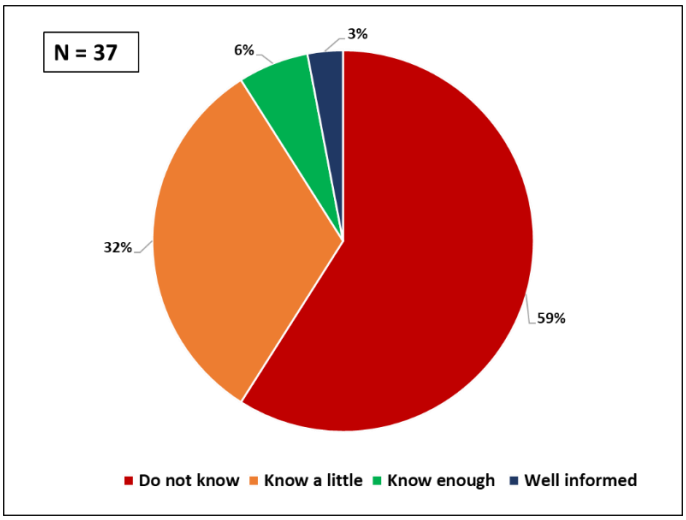
This question was adapted from the five-country survey by Balzan-Alzate et al., (2021) and it is the same question with the same answers. Except the answer choice of "Fairly Well" was removed, because it is too nuanced for the participants of this survey.



Question 1: What do you know about geothermal energy?

II.1.2 What do you know about geothermal energy as a renewable energy?

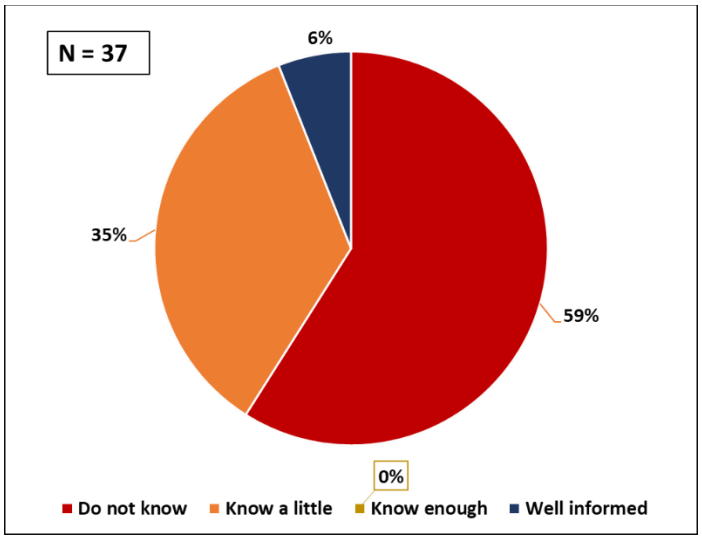
This question is adapted from Malau et al., (2019) survey in Indonesia. The question itself is the same but the answer choices are different due to translation of languages.



Question 2: What do you know about geothermal energy as a renewable energy?

II.1.3 What do you know about the existence of geothermal energy in the area where you live?

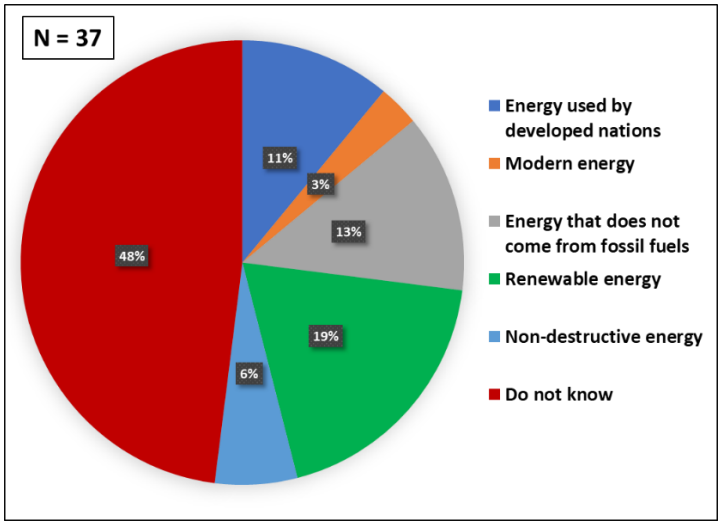
This question is the same as asked in Malau et al. (2019). Only the final translation of answer choices is different.



Question 3: What do you know about the existence of geothermal energy in the area where you live?

II.1.4 To the best of your knowledge, geothermal energy is _____ ?

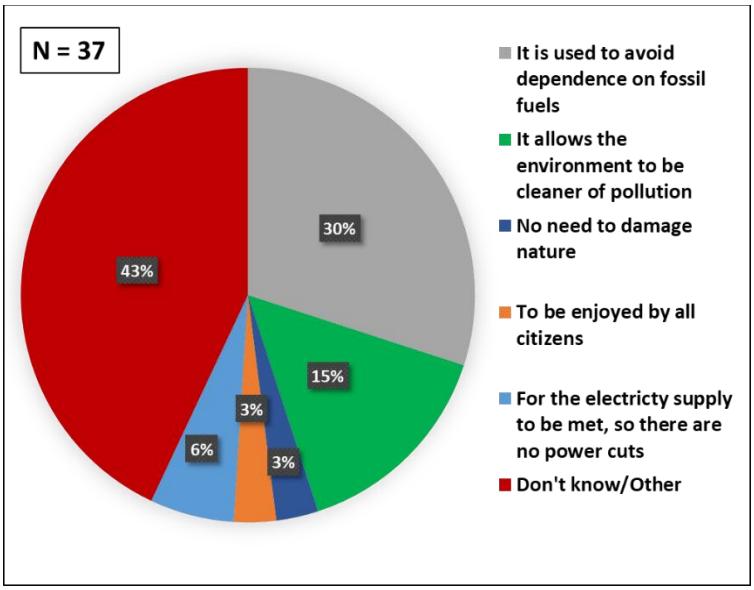
This question is originally found in Malau et al. (2019). Two answer choices were eliminated for this survey, "Green Energy" and "Other". "Green Energy" was removed as it would require a definition. Additionally, in preliminary conversations with academics in Argentina, I was told "Green Energy" has a negative political connotation. As people associate it with "Green Money", which is the idea that RE projects are linked with political corruption. "Other" was removed as it is too vague an answer for the level of insight I wished to obtain.



Question 4: To the best of your knowledge, geothermal energy is _____?

II.1.5 What do you know about the benefits of geothermal energy?

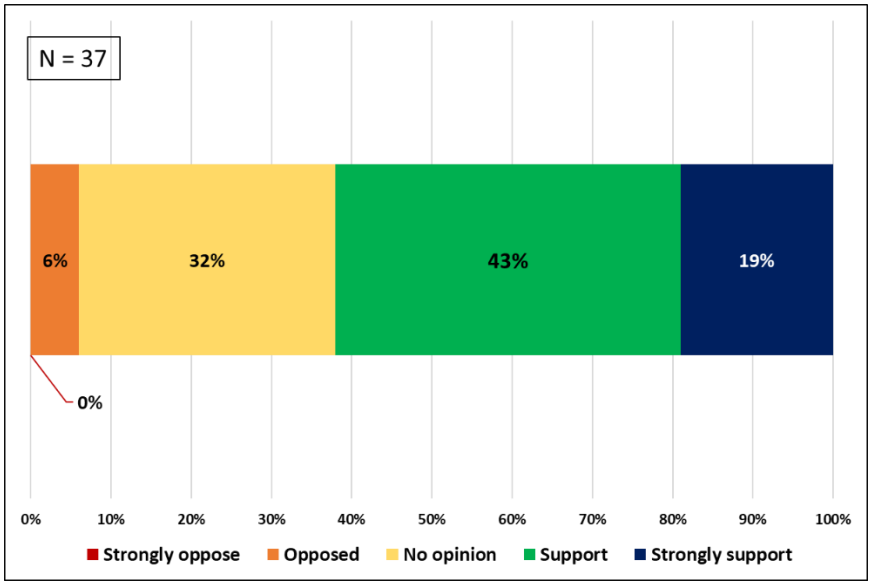
Here the question is the same as it is found in Malau et al. (2019) study. However, two answers were removed. "Other" and the "So that Indonesia can advance and not miss" as I do not believe the local knowledge of geothermal was high enough to understand the relevance of this answer choice. In addition, in choice E, I included "so there are no power cuts" so that "Electricity supply" would be self-explanatory.



Question 5: What do you know about the benefits of geothermal energy?

II.1.6 What is your opinion on the development of geothermal energy in the Domuyo Volcano district?

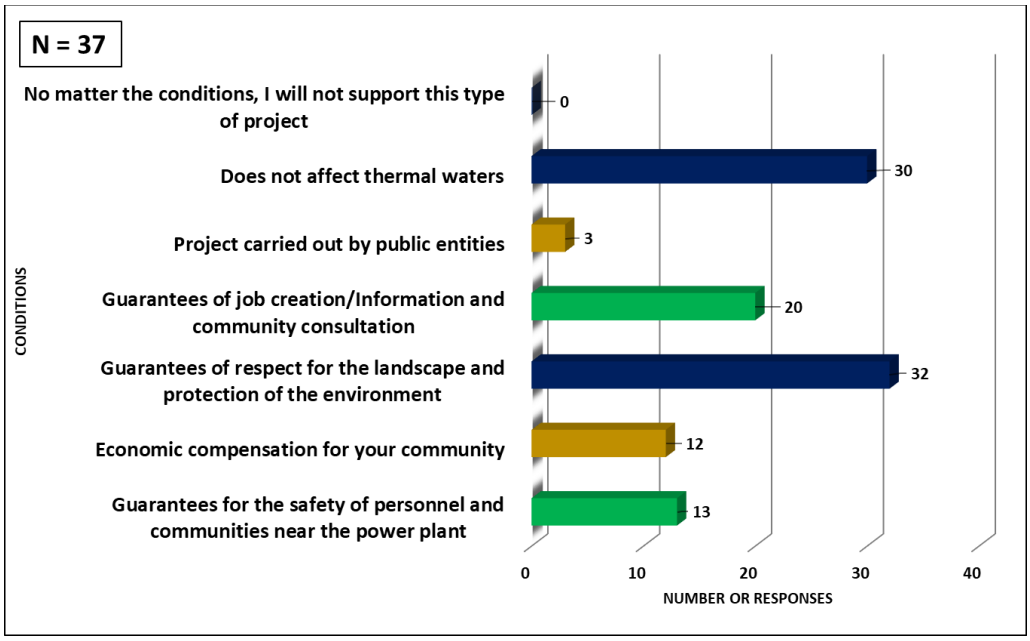
This question derived from a question in the Balzan-Alzate et al. (2021) study. The choice to remove "deep" and "generate electricity" from the question was due to the lack of previous knowledge about geothermal energy amongst the community of Varvarco. Additionally, the research focuses on geothermal in general, not solely for electricity production. The second purpose was to give the respondents in Varvarco an idea of where the GPP project is being sited. The choice was made to merge "Slightly" and "Slightly Agree" into "No Opinion", as well as remove the choice of "I don't know/ Prefer not to answer" to achieve more concise answers.



Question 6: What is your opinion on the development of geothermal energy in the Domuyo Volcano district?

II.1.7 What three conditions must be met for you to support a geothermal project in your region?

This question was taken from the Balzan-Alzate et al., (2021) survey, however, in their report they did not specify the number of conditions which a respondent may choose. Given the smaller sample size of my report I decided to prompt three choices to see a range of conditions which might be important to the community of Varvarco. I added the conditions of "Project carried out by public entities" and "Does not affect thermal waters" to see if these options were relevant to the people of Varvarco. The "project carried out by public entities" was suggested by a professor of Argentine economics, in relation to the previously mentioned issue of "Green money". This was to gauge if public oversight of the GPP development would be important in Varvarco. Unfortunately, during the formatting and printing of the surveys at the ADI-NQN offices in Neuquén City, the option choices for "Guarantees of job creation" and "Information and community consultation" were merged.



Question 7: What three conditions must be met for you to support a geothermal project in your region?

II.1.8 Has it been more difficult to obtain gas or food during the COVID-19 pandemic?

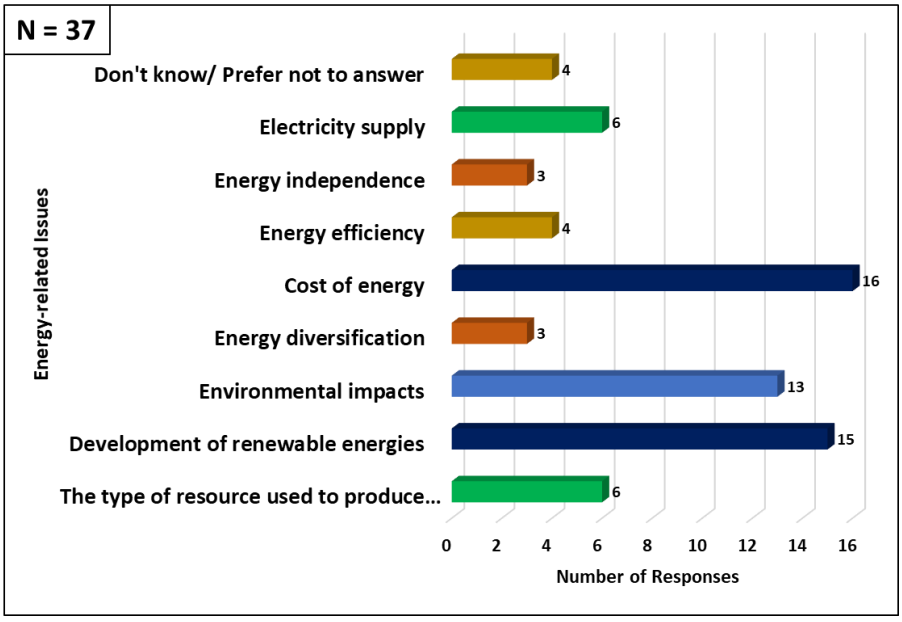
This question is original to the author and was designed to learn about how the community reacted during the pandemic and to learn of supply chain issues that might have affected them. Not everyone answered this question, as it was removed after the first 13 respondents all selected "B. The Same". COVID-19 did not affect their supply-chain, it is always a problem. The respondents replied with answers such as:

"Food and gas were not complications in the pandemic, but the freezing of roads was."

"Gas and food are always more difficult for us to have during the winter".

II.1.9 Among the following energy-related issues, in your opinion, which two are the most important in your region?

This question is modeled exactly as the question is found in Balzan-Alzate et al., (2021) study. The only difference is the inclusion of the answer choice "I don't know/ I prefer not to answer". In addition, a short descriptive text was added to the beginning of the question to help the respondent understand certain answer options. See **Appendix I**.

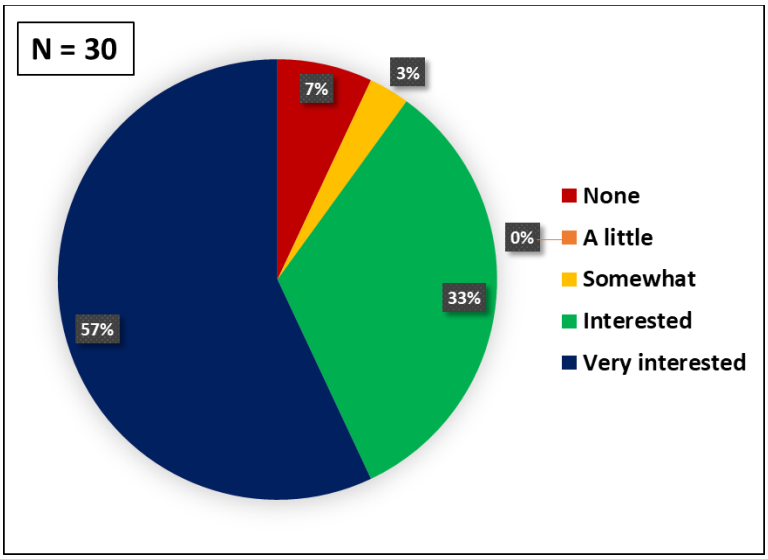


Question 9: Among the following energy-related issues, in your opinion, which two are the most important in your region?

II.1.10 How interested would you be in a live presentation and discussion on geothermal energy with the researcher?

This question was written by the author to gauge whether the respondents would be interested in learning more about geothermal. At this time one of the respondents from the urban area of Varvarco could no longer complete the interview. She was a business owner with customers, and I did not wish to intrude. Therefore, 36 data points are used in the following sections.

This question was only asked to the individuals who lived within the urban zone of Varvarco as the distance is too great for the rancheros to travel, resulting in only 30 data points for this question.

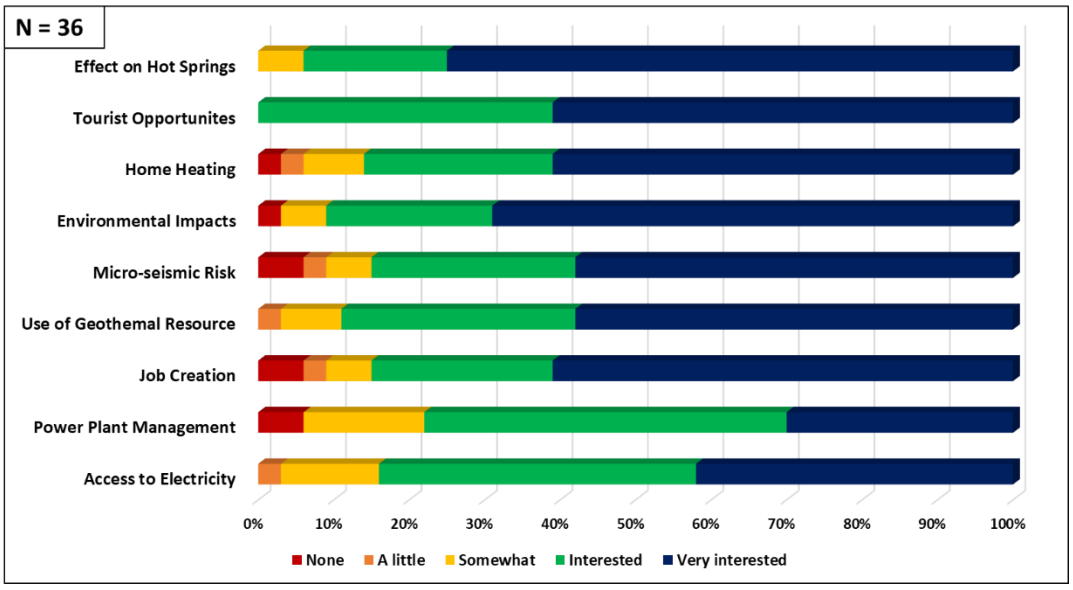


Question 10: How interested would you be in a live presentation and discussion on geothermal energy with the researcher?

II.1.11 Speaking of geothermal power plants, would you like more information about _____?

The purpose of this question is to understand what type of information the respondents would like to receive in greater detail. This question was derived from Pellizzone et al., (2015). Some of the answer choices, however, have been changed to better suite the situation in Varvarco. "Electric grid" has been changed to "Access to electricity", "Economic impact on local communities" has been broken into "Job creation" and "Tourism opportunities", and "Geothermal source depletion" is now simply "Use of geothermal resource". "Home heating" and "Effect on hot springs" were added to the answer selections to allow for more data to be gathered. For this question the respondent was given a list of nine options with the request to score each option on a scale of 0 to 4, the scale related to:

0 (None) – 1 (A little) – 2 (Somewhat) – 3 (Interested) – 4 (Very interested)

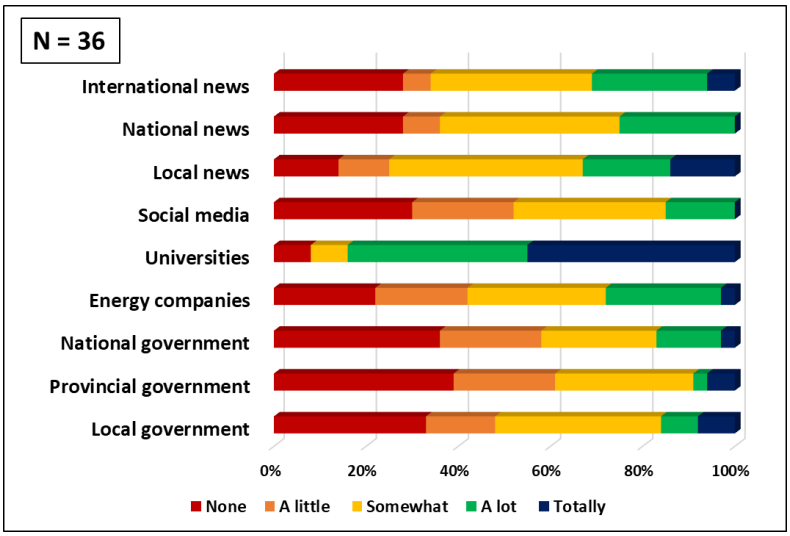


Question 11: Speaking of geothermal power plants, would you like more information about _____?

II.1.12 How much do you trust the following sources of information?

This question was adapted from the Pellizzone et al., (2015) report, the question itself is worded the same, however, the answer choices are different. The options "Local Administrations", "European Union", "Journalists", and "Government" were modified or expanded. For this question respondents were asked to score each of the answer choices on the following 0 to 4 scale:

0 (None) – 1 (A little) – 2 (Somewhat) – 3 (A lot) – 4 (Totally)



Question 12: How much do you trust the following sources of information?

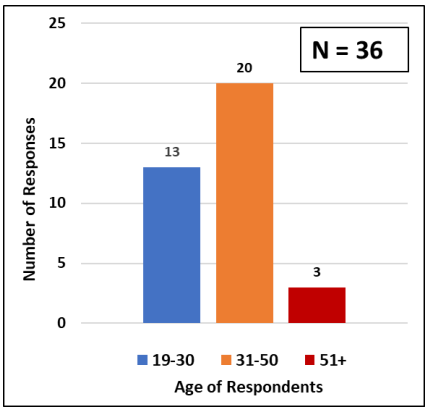
II.2 Social Dynamics

Within this section, the 19 questions created by the author were used to better understand daily life in Varvarco, learn how the community felt about the use of geothermal heat and technologies, and obtain socio-demographic information. Of the total 37 interviews conducted in Varvarco, 35 participants finished this portion of the survey. The answers of the respondents are displayed in either graphic representation or a description of the responses obtained.

For some of the questions the decision was made to separate results, or to not ask the question at all, to the individuals who lived in the parajes in the rural zone of Varvarco.

II.2.1 How old are you?

The youngest individuals who participated were 19, and the oldest was 70. The average age of the respondents is 35. The ages have been grouped into three sections.



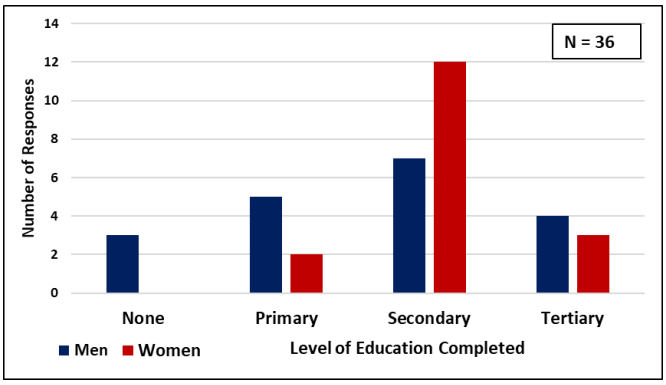
Question 13: How old are you?

II.2.2 What is your gender?

Of the 36 interviewees, 47% or 17 were women, while 53% or 19 were male. Considering the relatively small sample size, this closely approximated Neuquén Provinces female/male population distribution of 50.4% female and 49.6% male (INDEC – Neuquén, 2017).

II.2.3 What is the highest level of education you have completed?

This dataset has been sex dis-aggregated to show how women and men differ in their education levels. More women have time to continue their education as they are not working in manual or field labor and are able to stay in the urban center of Varvarco throughout the year. Primary education is essentially through middle school, secondary is high school, and tertiary is trade school.



Question 15: What is the highest level of education you have completed?

II.2.4 What is your occupation?

Of the 30 interviews conducted within the urban zone of Varvarco, 10 different job types were recorded. They are as follows:

- Two individuals worked at the Hosteria[2] Varvarco, one of whom is also a student hoping to become a flight attendant
- Four respondents worked as employees (clerks) at local markets. One of the female store clerks additionally works as a teacher of agro-ecological techniques in a nearby town
- Six individuals surveyed own local businesses; a hardware store, the meat market, two business owners of local markets, the tire shop (he also works for CORFONE), and the ice cream shop (the woman owning the ice cream shop is also a student in tertiary school)
- One individual surveyed is a full-time student, studying agronomic engineering
- Two respondents work at the local secondary school (CPEM N°94)[3], one of whom is the Director, and the other is the Vice-Principal
- One individual is the local missionary/priest
- One individual is retired. He is one of the original founders of the Aguas Calientes tourist cabins at the Aguas Calientes hot springs near Domuyo. He worked there for 30 years.
- 13 of the interviewees are employed by the municipality. Within this occupation there are several different job types. Three work as cleaning ladies and attendants at the municipal tourist Cabañas[4]. Five work at the Tourist Information office. Two are hiking/mountain guides to tourists. Two are service assistants (gardening/maintenance) at CPEM N°94. One is the local radio announcer/host.

Of the six respondents interviewed in the rural zone of Varvarco:

- Five work as rancheros, herding goats, horses, sheep, and cows
- One identified as an unemployed housewife (her husband is a rancher; he was not interviewed)

II.2.5 How do you heat your home or business?

Of the 36 interviewees conducted:

Table II.2.5: How do you heat your home or business?

Methods of Home Heating	Homeowners (Urban Zone)	Homeowners (Rural Zone)
Only Gas	15	0
Only Firewood	5	6
Combination of Gas, Firewood, and Electricity	10	0

Of the six business owners, within their business: One uses electricity, one has no heating, three use gas, and one uses firewood.

[2] A Hosteria is very similar to a hotel, only smaller. Hosteria Varvarco is owned by a family from the capital of the Province of Neuquén, Neuquén City.
[3] CPEM is the Spanish abbreviation for Provincial Center for Secondary Education
[4] A Cabaña is a wooden cabin. This is where I stayed during the research period in Varvarco.

II.2.6 Is it expensive to heat your home or business?

The responses to this question have been separated by Urban and Rural, as the sections of the population live in different infrastructure and socio-economic conditions. Of the 30 interviewees conducted within the urban zone of Varvarco:

Table II.2.6: Is it expensive to heat your home or business?

Responses		
No	***Yes***	***I Don't Know***
37%	53%	10%

Some respondents included descriptive answers such as:

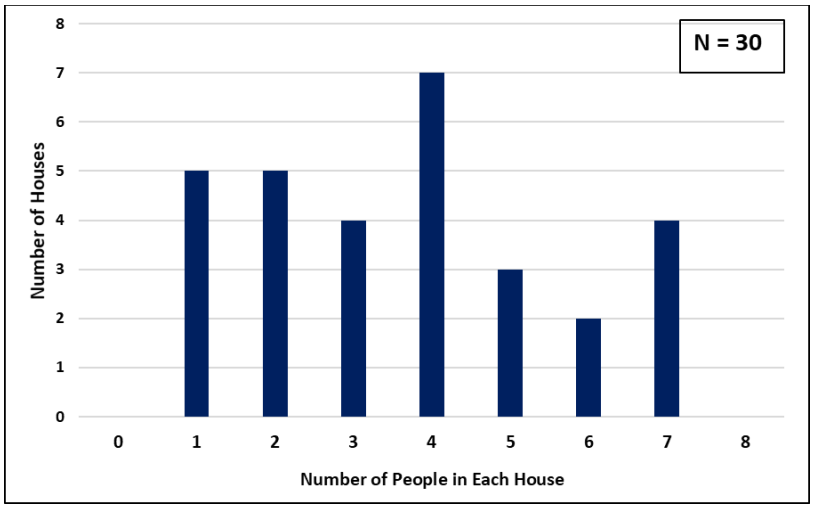
- "*Gas is not expensive because we are connected to the central system, but the cost of electricity has doubled in the last four months. When we ask EPEN why, they say they don't know."*
- *"Gas was not expensive, but it keeps going up. Firewood has been getting more expensive as well because of the shortages"*
- *"Firewood is not expensive because we gather it, but it takes time and is not always enough."*

For the six respondents in the rural zone of Varvarco:

- Two said *"Yes, it is expensive"*
- The other four explained *"No we gather firewood from the fields. But it costs us time and is labor intensive."*

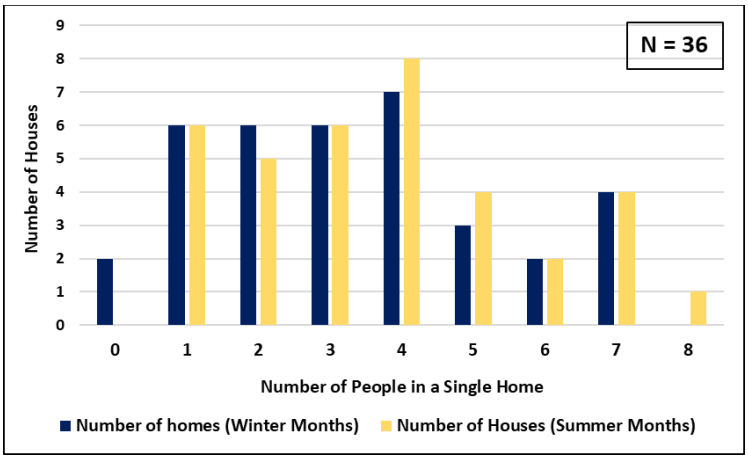
II.2.7 How many people live in your house?

Of the respondents in the urban center of Varvarco:



Question 19: How many people live in your house, excluding parajes.

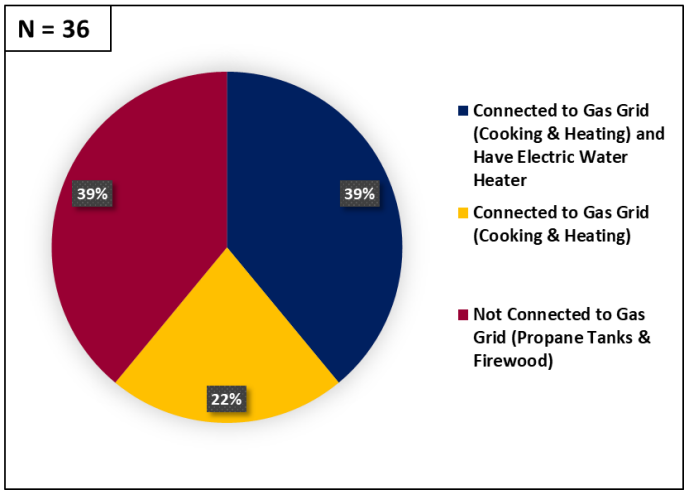
For the respondents in the rural areas of Varvarco the answer was not as straight forward. Many of the individuals only live in the area during the summer months as they are nomadic pastoralists. The figure below shows the change in the total number of people living in households from summer to winter.



Question 19: How many people live in your house, including parajes.

II.2.8 How do you use heat on a daily basis?

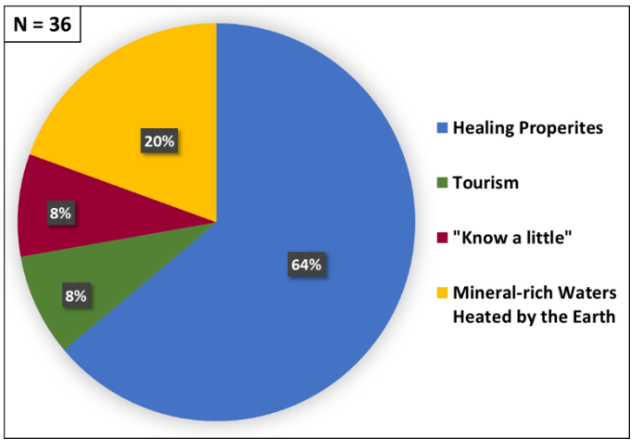
Within the urban area of Varvarco, this question found many different combinations of the way people use heat, but the responses were consistent in three categories based on what medium they accomplished cooking, heating their homes, and bathing.



Question 20: How do you use heat on a daily basis?

II.2.9 What do you know about hot springs?

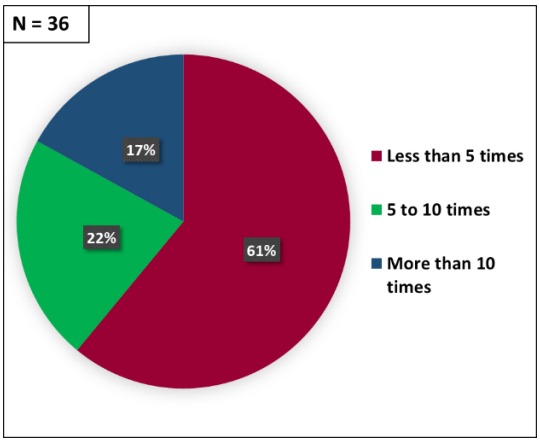
The open-ended responses to this question can be designated into four categories: Healing Properties; Tourism; "Know a little"; and Mineral-rich Waters Heated by the Earth.



Question 21: What do you know about hot springs?

II.2.10 How many times a year do you go to the hot springs that surround Domuyo?

When asked this question, only two individuals mentioned that they went to hot springs other than Aguas Calientes (i.e., Los Tachos, El Humazo, Las Olletas). It should be noted that these two individuals are the mountain/hiking guides. They are a part of the 17% of respondents who go more than 10 times a year.

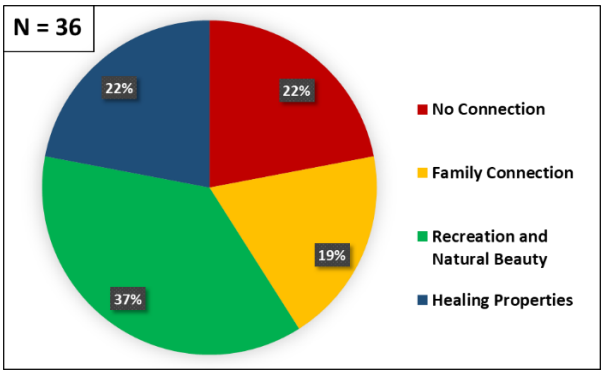


Question 22: How many times a year do you go to the hot springs that surround Domuyo?

II.2.11 What is your cultural or personal connection to the hot springs that surround Domuyo?

Responses to this question have been grouped into four categories: No Connection; Family Connection; Recreation and Natural Beauty; and Healing Properties. One of the more detailed responses to this question were:

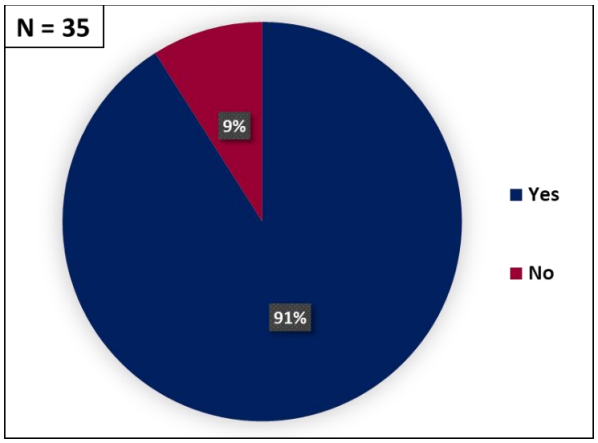
- *"We have lived for generations at the foot of Domuyo and the hot springs have always been praised for their healing properties."*



Question 23: What is your cultural or personal connection to the hot springs that surround Domuyo?

II.2.12 Do you think the hot springs surrounding Domuyo should be developed?

By the time this question was reached one of the participants had lost interest. Therefore, there is 35 responses for each question in the remainder of this questionnaire.



Question 24: Do you think the hot springs surrounding Domuyo should be developed?

Many of the individuals in favor of development stated they would want certain assurances. They made statements such as:

- *"I think they have a lot of potential and that they should be used, but always respecting the environment and the culture"*
- *"Yes, with better maintenance. Aguas Calientes seems to be less taken care of every time I go. Road will need to be bigger"*
- *"Tourism is in the process of development, but I don't want large-scale development. As for food production I have never considered it as an alternative. Geothermal energy production as well as anything that is NOT from fossil sources, I think are mandatory developments that we have to carry out as humanity."*

One of the individuals who said No to development stated this:

- *"I prefer it to remain untouched. If there is an investment to improve it, I would think that building bathrooms would be the first investment."*

II.2.13 Would you be happy if there was a job for you or your family at a geothermal power plant?

Of the 35 people who were asked this question only one said No. Some of the responses were as follows:

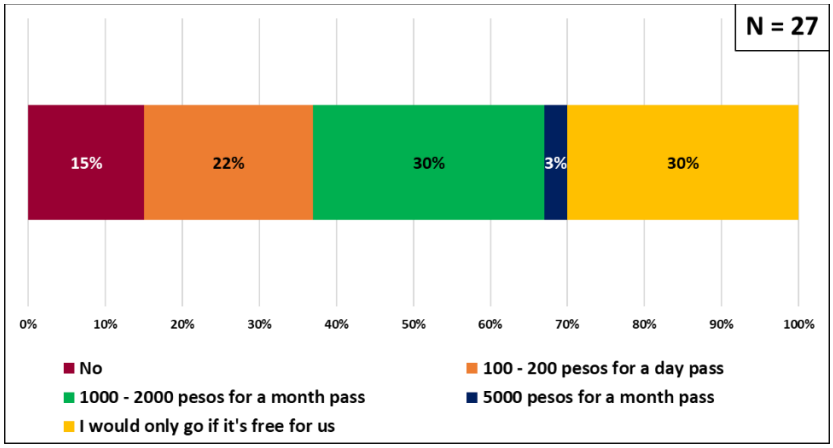
- *"If the plant were in the countryside, yes, and the closer to the mountain range the better."*
- *"Yes, but who would work here? What types of jobs would they have?"*

The individual who said No stated:

- *"I don't think so, it occurs to me that it is dangerous."*

II.2.14 If there was a heated pool in your community, would you go to it? How much would you pay?

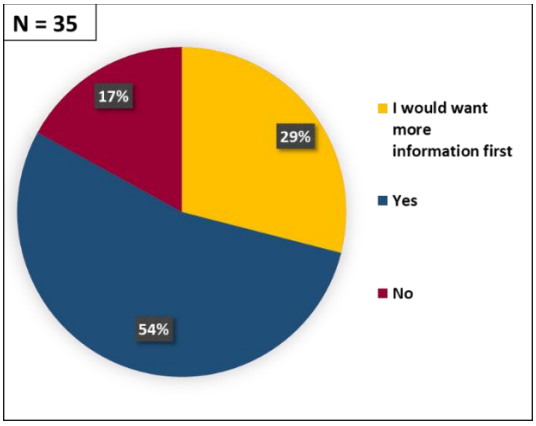
After the first two respondents answered this question: "*Of course*" and "*Well who wouldn't*?" I decided to add the question "How much would you pay?". The families in the rural area were not asked this question because they live 30 km or more from Varvarco, primarily use horses for transportation, and do not live in the area during winter months.



Question 26: If there was a heated pool in your community, would you go to it? How much would you pay?

II.2.15 How do you feel about using the heat from the hot springs to grow crops?

This question solicited some interesting responses as the concept was foreign to them. This re-emphasizes the fact that the people in Varvarco have predominantly never heard of geothermal energy or the different technical applications.



Question 27: How do you feel about using the heat from the hot springs to grow crops?

The individuals who wanted more information told us yes but were not sure of the process, such as "*I'm not sure, I think the taste would be different*". Some people also stated they did not understand the question, which I included in the "I would want more information first" category. It should also be noted that I did not specify that the geothermal waters would be used for heating greenhouses as opposed to simply watering plants, which may have caused a misunderstanding.

One of the respondents who said Yes realized that this would also be a good opportunity to create jobs.

The people who said No had responses like:

- *"No, out of respect for the identity of nature, I think some things should not be mixed"*
- *"It would not be good; I think that the metals in water could affect the crops"*

II.2.16 How do you feel about using the heat from the hot spring to heat your home?

Of the 35 responses, 100% of them said Yes. People made statements like:

- *"Well, I would like to. I would sleep easier knowing that there are no gas leaks"*
- *"I think it is good, because it can save firewood and care for the environment due to the smoke generated by firewood"*
- *"I would like to; it would be good. As long as the nature of the water itself is not altered"*
- *"Well, I know it is good because the cabins at Aguas Calientes have it"*

II.2.17 How do you feel about tourists using the hot springs?

Among the 35 responses, 100% of them approve of the tourists using the hot springs. However, they made comments such as:

- *"I support tourism development. There should be more infrastructure and camping in the area of the cabins in Aguas Calientes."*
- *"There should be more control to avoid damage to the flora and fauna, but I am in favor of allowing tourists to use the waters."*
- *"Fortunately, tourism is moving towards responsible tourism. There is a growing respect for the natural resources and many like to come again so they are careful, the people of the area tend to be more careless."*

II.2.18 Would you like to have more tourists?

Of the 35 responses, 30 of them are in favor of more tourists. Comments included:

- *"I would like more tourists to come but currently the town needs to grow a lot in these areas, there is a need for more commitment to undertake this."*
- *"Yes, tourism is very important in our area since it is one of the few incomes that the community has."*

Those who stated No, had comments such as:

- *"No, the government does not invest in infrastructure for tourism here, there is bad information and Varvarco cannot take advantage of it."*

II.3 Comments and Questions

The six questions in this section were designed to prompt a dialogue between the surveyors and respondents. The results are presented in a discussion format.

II.3.1 What questions do you have about geothermal energy?

Of the 35 interviewees who were asked this question only three had responses. They are the following:

- *"How many years would it take for this project to be working? Who's going to pay for this? What government will be involved in this? How long have they been talking about the Domuyo project?"*
- *"What does a geothermal plant do? How does it work?"*
- *"I would like to know if this type of energy is going to bring work to anyone or does it require some kind of specialization?"*

The lack of responses to this question leads me to believe people were either uncomfortable with letting on how little they knew about the technology or did not know what kind of questions to ask. When we were discussing the possible benefits of geothermal with them after the survey, they did not believe it would happen in Varvarco.

II.3.2 What questions do you have about renewable energy?

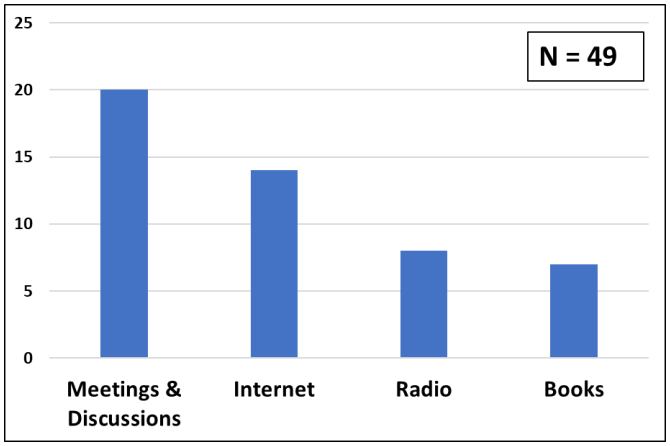
Of the 35 interviewees asked this question only two responded. Their responses were:

- *"I don't believe in what the government says about it, they are building a new hydroelectric plant in Nahueve and the energy is being sold to Chile."*
- *"I know they are the best option, but I want to know what risks and disadvantages they have?"*

Once again, the minimal number of responses could be attributed to a general lack of knowledge about RE's or loss of interest in the survey.

II.3.3 How do you prefer to access information?

For this question people gave multiple ways of which they preferred to be given/access information. Some of the respondents noted that they could not read so would need to be told information. Since the interviewees gave multiple options for how they would like to receive information the responses are presented in ranked order and how many people mentioned that form of information.



Question 33: How do you prefer to access information?

II.3.4 What problem in your community do you think could be solved with better access to heat or electricity?

This question prompted quality responses, however, after we acquired so many responses stating the same statement, the decision was made to only ask Question 37 as it is broader and does not specify "…solved with better access to heat or electricity?". I wanted to understand any difficulties the community might have, to consider ways geothermal may aid the people of Varvarco, other than via heating and electricity. Some of the highlight or more in-depth responses to this question are the following:

- *"The cost of electricity and gas is very high because I am not connected to the grid. I use firewood for heating."*
- *"Lots of power outages, and stable heating. Gas can't always be brought during the winter."*
- *"The power outages, whether because there is wind, because a pole is down or because it is winter."*
- *"If we had better access to gas, it would not be necessary to look for firewood, it is difficult to find."*
- *"Continuity with the gas, because if it happens that the truck does not arrive to town then we are left without gas for at least one week. The power cuts could be improved."*
- *"Power outages and the cost of electricity. It increases a lot, and it is not rational. I always use the same and when I ask EPEN, they answer that they don't know the reason for the price increase."*

II.3.5 What is a challenge in your community?

From Question 36, the lack of gas during the winter, frequent power cuts, and the difficulty of obtaining firewood were common responses to Question 37 as well. Therefore, I have only listed here new challenges that were mentioned:

- *"Heating, lack of employment, power cuts, lack of food in winter due to freezing of roads, and lack of drinking water."*
- *"Communication by telephone and internet is unreliable, our land communication such roads and routes, and drinking water is scare during the summer."*
- *"The lack of drinking water, the connection of the roads which are detrimental to the merchants, and the power cuts."*
- *"One challenge is the problems that the farmers have with locust infestations and with the pumas that kill our goats and sheep. Another problem is access to electricity and heating."*

II.3.6 Comments or questions for the researcher?

I was hoping this question would allow the opportunity for interviewees to ask me any type of question, maybe further explanation on some of the geothermal technologies, or how I thought geothermal may work in Varvarco. However, only two interviewees asked questions. The two responses were:

- *"What type of installations would be made in the Domuyo area? Would it be necessary to have access to these facilities throughout the year? If so, would the company in charge of these facilities be responsible for maintaining the route in good condition?"*
- *"Why do the people who are funding the Domuyo project need this survey? Here the industry of oil and gas is pretty big, they are not going to let you do this."*