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Unleash the Heat: Exploring Geothermal Energy Perspectives and Energy Literacy in São Miguel, Azores

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Abstract

The green energy transition is moving ahead in EU countries at very different paces, and there are some key challenges that all regions currently face in trying to phase fossil fuels out of their energy mixes. One of these challenges is that most regions simply cannot harness enough renewable energy sources and simultaneously have the storage technology for creating a baseload power source as reliable as oil, coal and natural gas. That is, unless you sit in the middle of the Atlantic Ocean on the boundary of three tectonic plates, with a continuous and reliable renewable energy source beneath your feet. São Miguel, the biggest of Portugal's Azores Islands, has an abundance of geothermal activity and is currently harnessing this natural heat to provide around 40% of the island's electricity. Although geothermal energy has been extensively studied and utilized in volcanic regions, there is still a lack of research on the attitudes and perceptions of the communities surrounding these areas towards this energy source. It is important to address potential stigmas surrounding geothermal energy and to bridge the gap between the scientific community and the public to ensure the effective implementation of this renewable energy source. This paper uses survey-based research to assess energy literacy and geothermal energy perspectives in São Miguel, and explore potential relationships between them. The study aims to identify community priorities and concerns regarding energy production in São Miguel, providing insights that can guide community outreach and education efforts focused on improving energy literacy and promoting sustainable energy practices.

1. Introduction

1.1 The Azores

The Azores Islands are an autonomous region of Portugal composed of nine volcanic islands located in the middle of the Atlantic Ocean, about 1,500 kilometers west of mainland Portugal. The Islands are located on the Mid-Atlantic Ridge, a tectonic plate boundary where the North American, African and Eurasian plates meet. This geological setting brings a high level of volcanic and seismic activity to the Azores Archipelago, which is accompanied by a high potential for harnessing geothermal energy. "Geothermal energy is heat that flows continuously from the Earth's core to the surface—and has been doing so for about 4.5 billion years. This heat is continually replenished by the decay of naturally occurring radioactive elements in the Earth's interior and will remain available for billions of years, ensuring an essentially inexhaustible supply of energy" (Geothermal FAQs, 2023). São Miguel is the largest and most populous island in the Archipelago, containing about 56% of the population, and geothermal energy production currently provides up to 44% of its electricity needs (Franco, 2021).

Geothermal activity does not solely provide energy, but is of high cultural importance in São Miguel for its many other uses. As with all places, geothermal plant development is viewed

from distinct geothermal imaginaries, differing across scales as the technologies interact with relevant contextual characteristics and priorities (Lambert, 2022). In São Miguel, the island's geothermal activity provides natural hot springs which the local communities around them have used for centuries for their healing properties and relaxation. Additionally, one of the island's most traditional dishes, "Cozido das Furnas" is a stew made using a unique cooking method of being heated in the ground, and is an important symbol of São Miguel's cultural heritage. In addition to these traditional uses of geothermal activity, in more recent years geotourism and geothermal energy production have provided São Miguel with sustainable energy and local economic development.

1.2 Energy Literacy

Energy literacy is a common precursor to levels of renewable energy acceptance within communities, and while the definition of energy literacy is debated and there is yet to be a cohesive scale for determining one's literacy, it is well agreed-upon in the literature that there are three dimensions to be considered when defining the term. The first dimension is knowledge about energy resources and technologies, the second is the attitude towards the adoption of modern energy resources, and the third is behavior towards energy efficiency and savings actions (Mehmood, 2022). In this study, only aspects of knowledge and attitude-based energy literacy will be covered. To accurately assess the behavioral energy perspectives of participants, many questions would need to be added to the survey to evaluate the awareness of residents about the impact of their daily energy consumption and sense of individual’s responsibility at the local and global levels (Mehmood, 2022). Instead, this research focuses on residents' knowledge of basic renewable and geothermal energy processes and the environmental impact of different energy usage scenarios, as well as attitudes towards different energy applications at the local level in São Miguel.

A 2021 study on renewable energy literacy and a geothermal project in Indonesia concluded that lessons about geothermal energy are still lacking, and the introduction should be early for school children. Survey results from this study also showed that most people get knowledge about energy during college (Umam et al., 2021). It is imperative that basic energy education be completed before college so that the general public has a better understanding of energy production and consumption, enabling them to make informed decisions regarding energy use at both personal and broader levels. Apart from incorporating a more traditional education into lesson plans, it is also important for energy companies and the government to provide the public with information and an open line of communication. There is currently a lack of studies relating geothermal energy and public perception/public engagement, when compared to other renewable energies (Manzella et al., 2019).

1.3 Research Questions:

This research aims to answer the following questions, in the context of São Miguel:

Question 1: Does public opinion of geothermal energy skew positive or negative, and are there differences depending on age and/or municipality?
Question 2: Is energy literacy correlated with opinions on geothermal energy?
Question 3: What are resident's main priorities regarding energy production?

A crucial step to achieving an equitable and efficient energy transition is gaining acceptance at not just the national but also the local level. There is currently a wide research gap in identifying the barriers to achieving local acceptance of geothermal energy technologies. The "Not in my Backyard" (NIMBY) concept, which acknowledges the importance of people's relationship with place, as this can involve identities, experiences and history along with the physical landscape, has been long identified as a cause of local opposition to energy development projects (Lambert, 2022). However, local knowledge and behaviors differ greatly depending on the place, scale of the project, and type of energy technology being developed. For this reason, it is crucial to gather perspectives in every community that experiences changes in energy developments and technologies, especially as we accelerate the green energy transition worldwide.

2. Background

2.1 Energy Production in São Miguel

The Azores and Madeira autonomous regions of Portugal set their own energy and climate policies and strategies, independent from mainland Portugal. Currently, all nine Azores islands use fossil fuels as their main energy source. There is no electrical interconnection between the islands and the mainland, just the fossil fuels that are imported from mainland Portugal and burned at power stations on each island. Other islands in the Archipelago mainly rely on wind and mini hydro for their share of renewables, except for Terceira where a 4 MW geothermal plant provides the island with 11% of its electricity needs (Franco, 2019). Islands provide favorable conditions for the use of most renewable energies, but it is complicated to have a 100% renewable system in a micro-network like the Azores islands because the huge oscillation in the weather during the year makes it difficult to predict the energy production of each renewable source (Melo, 2019). However, geothermal energy is not subject to these limitations, as it has continuous availability, completely independent of weather conditions. While there is high geothermal potential on most of the nine islands, geothermal on the smaller islands is not economically feasible due to the low power demand and high up-front costs of a plant.

São Miguel's Ribeira Grande geothermal field is composed of the Ribeira Grande and Pico Vermelho plants, which have been utilized for 40 years and currently provide 23 MW of power to the island. Geothermal energy exploration on the island started in the 1970s, but there were no significant developments until the 2000s, when an initial drilling employed by EDA RENOVÁVEIS indicated an estimated available output of 3.5 MW (Franco, 2021). São Miguel has by far the highest power consumption of the islands, as its population counts for over half of the Archipelago's total population of 243,000 (Azores Population, 2019). With extensive research ensuring that there is room for an expansion of the Pico Vermelho plant without the risk of over-exploiting the resource, the plant is currently expanding to produce an additional 10 MW of power (Franco, 2019). Geothermal production in São Miguel has followed this same stepwise strategy since its initial exploration in the 1970's. Figure 1 illustrates how geothermal energy production in São Miguel has steadily grown in phases since the mid-1990s.

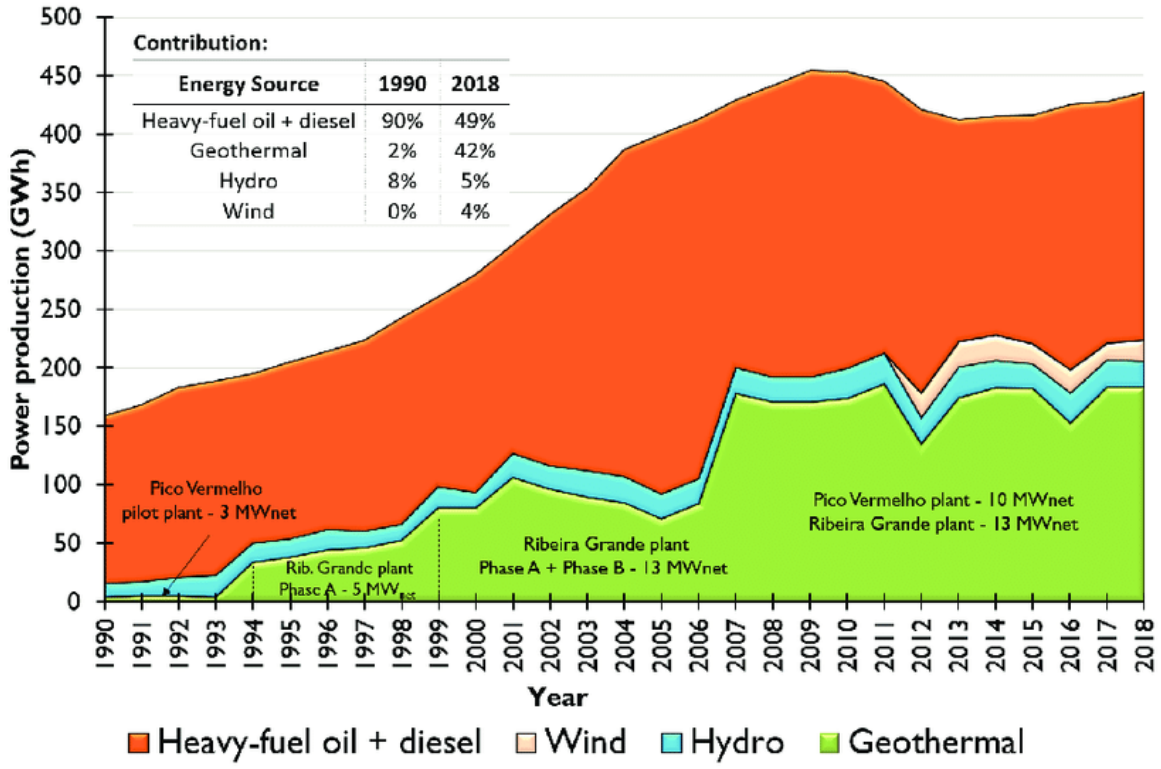


***Figure 1**: History of power generation on São Miguel Island (EDA, S. A., 2007 to 2018; EDA RENOVÁVEIS, S. A., 2007 to 2018).*

Geothermal is the only renewable energy source that currently has the potential to replace fossil fuels as a baseload power source in São Miguel. The Pico Vermelho plant has a steady capacity factor above 95% and availability that is consistently over 99%, making geothermal at this site a reliable baseload power source (Franco, 2019). "In the Azores, the geothermal tariff is relatively stable (~0.10 €/kWh), whilst the production cost from the thermal plants fluctuates highly over time, as it is greatly dependent on the crude oil price on the international market.

Moreover, geothermal production allows the investment to stay in the local economy, whilst the money spent on purchasing fuel is lost by the region" (Franco, 2019). Figure 2 illustrates how geothermal production in São Miguel has had a hugely positive economic impact by avoiding thousands of tons of fuel imports each year. Given today's turbulent energy market with the invasion of Ukraine by Russia, avoiding reliance on imported fossil fuels is a priority for Portugal and each of the Azores islands. Most fossil fuels burned in the Archipelago are extracted in Nigeria and Algeria, transported to mainland Portugal, and finally shipped to each island. While Portugal only imports 5% of its energy from Russia, oil prices everywhere have raised significantly, and in order to maintain resilience in times of crisis in the energy market, it is in Portugal's best interest to shift to more renewable energy production (Silva, 2022).

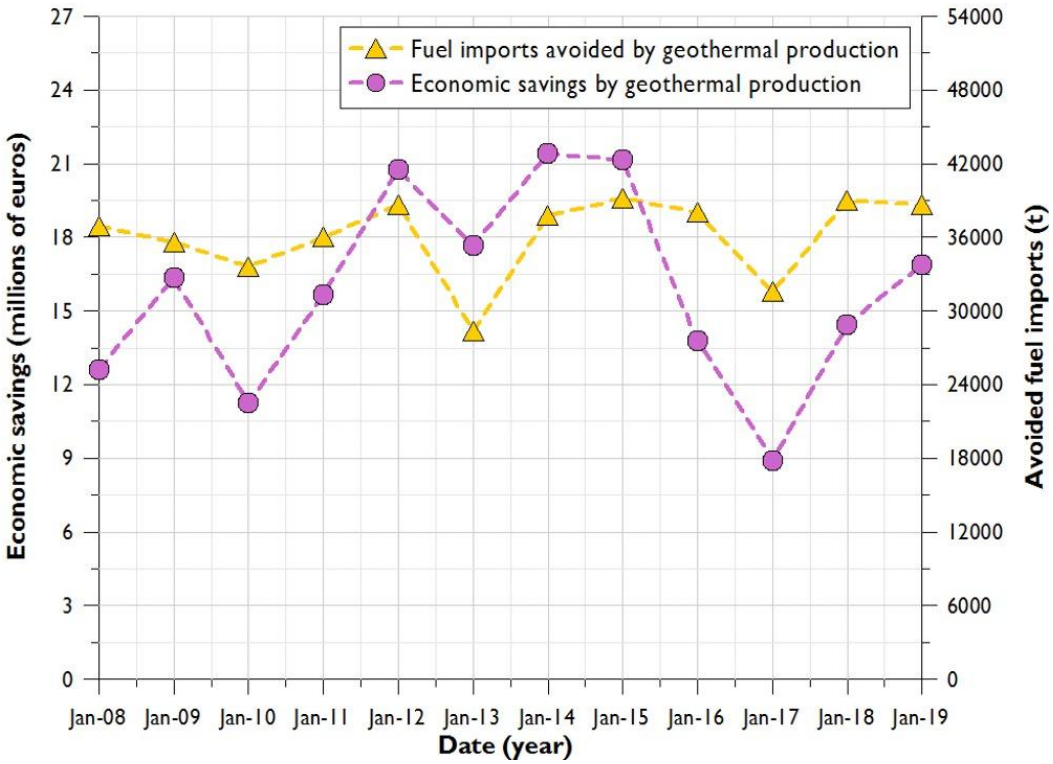


***Figure 2**: History of savings on fuel imports by geothermal production on São Miguel Island (EDA, S. A., 2007 to 2018; EDA RENOVÁVEIS, S. A., 2007 to 2018).*

It is important to note that along with the high costs of importing fossil fuels, there are huge environmental costs associated with continuing to import fuels to São Miguel. Not only is the burning of fossil fuels harmful to the environment and surrounding communities, but also the carbon footprint of just transporting these fuels to remote islands like the Azores makes local renewable energy a much more sustainable source for island communities. As islands are particularly prone to the consequences of climate change, it is in their own interest to rely on an energy network independent of fossil fuels.

While islands tend to be favorable sites for wind and photovoltaic development, these intermittent power sources must be accompanied by advanced storage systems. There are projects underway in São Miguel and Terceira Islands installing Battery Energy Storage Systems (BESS) to store excess power produced during off-peak hours and discharge it to the grid during peak-load or medium-load hours (Franco, 2019). While storage technologies are continuously improving, intermittent power sources accompanied by BESS is not economically feasible in São Miguel when compared to the integration of additional geothermal energy. While the development of other renewables and storage systems are beneficial, these are not yet solutions for São Miguel to phase out fossil fuels. The amount of battery technology that would be necessary to power the island would be very costly, and more wind farms would need to be developed, which oftentimes is difficult to license land for due to noise and visual impacts to the local community, as well as the wildlife impact of turbines (Advantages and Challenges of Wind Energy, 2023).

2.2 Geothermal Energy Considerations

Unlike fossil fuel power plants which emit greenhouse gasses, geothermal energy plants have a minuscule impact on the environment (Soltani, 2021). However, as with any type of renewable energy, geothermal has environmental impacts that must be acknowledged. "It is damaging for project developers, political authorities, and scientists to downplay the risk perceived by the population about geothermal energy. Instead, the population's concerns should be better understood and attended to. With energy literacy comes knowledge about the benefits of and need for renewable energy development, but also necessary is accurate communication about potential risks associated with each renewable energy type.

Generally, the largest environmental impact associated with wind energy is the risk of killing birds and wildlife, with solar it is often the mass plots of land needed and its associated habitat loss, for hydroelectric it is the blockage to river systems, and for batteries, it is lithium extraction. Geothermal plants naturally emit CO2 during production, but emissions are lower by a factor of 20 against oil and coal powered generation, and are also usually lower when compared to solar and biomass (Soltani, 2021).

Water use and contamination of soil and groundwater are other impacts that can be associated with geothermal energy production. The Ribeira Grande plant uses sodium-chloride water including a residual concentration of heavy metals, but environmental degradation is avoided due to the reinjection technologies developed at the plant. Since 2012, 94% of the geothermal fluids used in the geothermal field are reinjected back into the deep reservoir, and these reinjection rates are among the highest in the geothermal industry (Franco, 2021).

Additional impacts that geothermal energy exploration can have are fissures in the ground, earthquakes, and the appearance of fumaroles. Knowing these risks is part of being educated on the processes of geothermal energy production, but it is also important to know that these risks are considered very low. All the work done within the Ribeira Grande geothermal

field is closely followed by experts in geothermal energy from the University of the Azores and abroad, and no decisions are made without a careful assessment of possible impacts that it could have. Despite reassurances backed by the scientific community, there are often uncertainties within communities surrounding geothermal energy production sites, and these ambiguities are what this study aims to identify.

2.3 Other case studies: Geothermal and Renewable Energy Production

While literature on the social acceptance of geothermal energy is currently still limited, most studies have found that geological hazards are a common concern of communities surrounding geothermal plants. "The most negative perceptions of deep geothermal systems are generally linked to the seismicity risk inherent with this technology" (Spampatti, 2022). Extraction and injection of fluid into geothermal wells causes stress underground, which can induce seismicity.

However, the advanced technologies that exist in geothermal plant operations today can provide "balance in production and injection rates, monitor the local deformation and reservoir pressure, and construct hard barriers for facilities and warning systems" (Soltani, 2021). When geothermal energy extraction causes earthquakes with magnitudes strong enough to be felt by the surrounding community, this is due to monitoring issues that can be easily prevented. When fluid injections trigger seismic activity, monitoring technologies are able to detect these risks before small earthquakes progress into larger ones (Garthwaite, 2019). If earthquakes were linked to geothermal energy extraction, scientists would be able to identify this linkage immediately and the plant would not be able to progress with new drillings.

Perceptions on the effects of geothermal extraction can often be augmented or inaccurate due to uncertainties about the technologies. In a survey conducted in central Italy, where geothermal energy is harnessed, participants were asked a variety of questions involving different renewable energies. Results show a shared uncertainty about geothermal energy when compared to solar and wind technologies. When asked about the effect of solar and wind on our way of life in the next 20 years, 86% marked solar as having a positive effect, 84% marked wind as having a positive effect, and only 46% marked geothermal as having a positive effect. However, a vast 44% of respondents marked "don't know" about the effects of geothermal (Pellizzone et al., 2016).

Surrounding communities may view geothermal energy production as polluting and non-renewable, since it is produced from drilling underground, an exploration process closer to coal/oil than wind and solar. A 2022 study based in South Korea found that "the similarity of enhanced geothermal systems to fracking techniques and the potential for earthquakes were discussed as sources of concern at the local level, and the perceived, rather than actual, threat of disruption to the future of a place can also drive oppositional attitudes" (Lambert, 2022). While the production of most other renewable energy sources is fully visible to the public eye, the processes of geothermal energy production can only be told, and not seen. This creates the issue

of uncertainty involving geothermal energy production, because it is common for individuals to lack trust in public institutions and energy companies.

In the central Italy case, when asked ‘How much do you trust the following as information sources?'', 76% of respondents answered that they trust ‘very much’ or ‘much’ universities and research councils, and 39% answered the same for non-governmental organizations (NGOs). “Public institutions at the local, national, and European level were less trusted, and respondents showed low levels of trust in energy companies and the media” (Pellizzone et al., 2016). This shows how important local University involvement can be in bridging the gap between energy companies, local communities, and other stakeholders.

Despite geothermal being the best, most accessible option for São Miguel to rid its reliance on fossil fuel imports, the expansion of any energy exploration project, renewable or not, can face a variety of perspectives from its surrounding communities.

3. Methodology

This research took place in three phases: literature review, conducting surveys and interviews, and data analysis. To begin, a comprehensive literature review was conducted on various case studies related to geothermal energy production and perspectives, as well as studies and frameworks related to energy literacy. In addition, research was conducted on energy production in São Miguel. Next, a survey was conducted via email (google forms) and in-person interviews, and a sample of 171 individuals was gathered. Lastly, survey results were analyzed to identify important trends and patterns that may have implications for social outreach and energy literacy education efforts and improving communication between energy developers and the community. Essentially, energy literacy is assessed to provide geothermal energy stakeholders with information to guide education and community outreach efforts, and geothermal energy perspectives are assessed to identify the similarities and the gaps between community energy priorities and geothermal energy development in São Miguel.

3.1 Survey Design

The survey was designed to gather a wide data set with as few questions as possible, and contains eighteen questions in total. The survey was made available in both English and Portuguese to ensure that all participants could comprehend. Questions can be organized into the following categories: five demographic questions, six knowledge-based energy literacy questions, one self-assessment question asking participants to rate their energy knowledge, two subjective questions about the environmental impacts of geothermal energy production, and four questions which evoke participants to gather their opinions and priorities related to geothermal energy production on the island. All questions are close-ended except the last question which asks if participants have any closing remarks regarding geothermal energy production in São Miguel. This final open-ended question is important, because when interviews cannot be

conducted in-person and survey questions are all close-ended, it can be challenging to assess one's true priorities or opinions on the matter.

Because of its length, this survey does not cover all dimensions of energy literacy, but places an emphasis on the knowledge dimension. Questions are focused on gathering participant's knowledge of both renewable vs. non-renewable energy sources and also opinions of geothermal energy exploration and production in the local context. There is no common scale that establishes a limit up to which the energy literacy level is considered low, and authors generally establish their own scales and cutoff values (Martins). As there are only six energy literacy questions in this survey, participants will not be generalized into any sort of "level" of energy literacy. A score will still be created for each participant, with a score of six meaning all energy literacy questions were answered correctly. The goal is to assess whether there are any notable differences in energy literacy scores based on municipality, age or other demographics, and how these levels of energy literacy may determine perspectives on geothermal and different energy scenarios in São Miguel.

As for the opinion questions, these are to be compared with energy literacy scores and also assessed independently to see what participants' primary concerns related to energy and geothermal energy production in São Miguel. Some questions are more explicit, asking participants to choose 1-2 priorities surrounding geothermal energy production and 1-2 most urgent energy-related problems to address in São Miguel, whereas other questions are subjective, and gauge participants' perspectives on the environmental impacts of geothermal energy production. Since geothermal production can generate pollution and impact the environment, but levels greatly depend on the efficiency and monitoring of the plant, these questions are subjective and asked on a scale of "strongly agree" to "strongly disagree". Every question has the option for participants to opt-out and answer "I don't know", as this is important to ensure validity and prevent false responses. The full survey can be found in Appendix A.

3.2 Data Analysis

Survey and interview responses were gathered and organized in an Excel spreadsheet before being analyzed. First, energy literacy scores were calculated for each subset of the population being studied. Calculations were made in Excel, using the data analysis feature, and were also done manually. Each individual’s total number of questions answered correctly divided by the total number of energy literacy questions (6) is an energy literacy score. Energy literacy results were then compared to various additional responses and demographics and searched for any trends. All bar charts and graphs were made in Excel and Adobe Illustrator.

3.3 Limitations

The primary limitation of this study was time. The online survey was open for two weeks, and in-person interviews were conducted periodically throughout this time frame. The

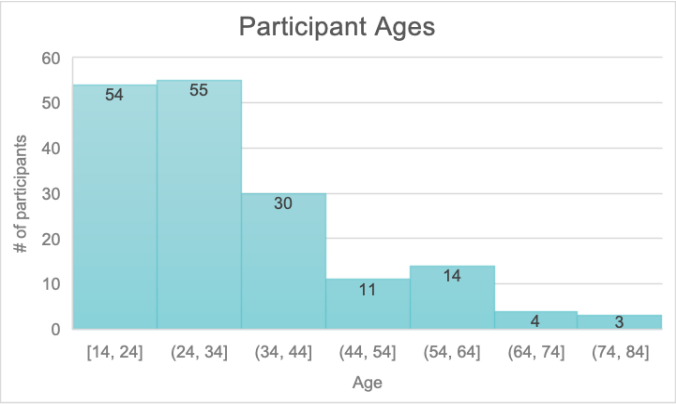
survey had to be short, and therefore was unable to gather all dimensions of energy literacy, since more individuals were expected to complete the survey if it takes 5 minutes and no more. Additionally, while in-person interviews were conducted, it is expected that there are certain subsets of the population that were not able to be reached, such as those without emails to send the survey to, or those working during the hours that in-person interviews were conducted.

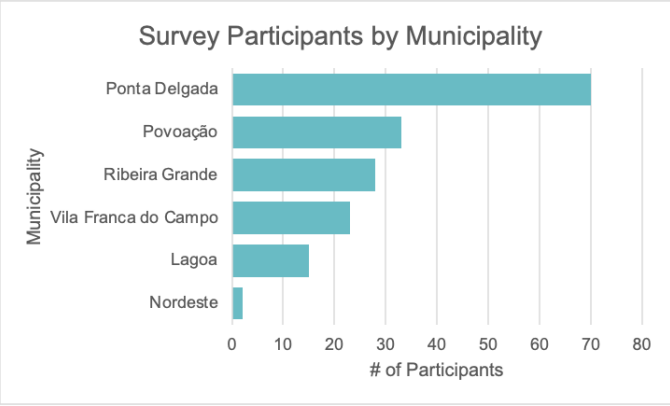
3.4 Ethics

Verbal consent was received from all interviewees, and individuals were informed that their responses would be collected and analyzed, but identities would not be revealed. Basic demographics were asked from online survey respondents and in-person interviews, but all identities were kept anonymous, and emails of survey participants were not shown.

4. Results and Discussion

Participants are somewhat evenly distributed by gender, with 56% of responses from men, 43% women, and 1% other. Ages range from 14 to 84, with an average participant age of 34, and a higher frequency of responses from younger age ranges. Data was gathered from all six municipalities, but only two participants reside in Nordeste, and we cannot make any conclusions about overall energy literacy or opinions of geothermal energy in this municipality due to the small sample size. Ponta Delgada has the largest population of São Miguel's six municipalities, comprising around 32% of the island's inhabitants. 41% of survey respondents reside in Ponta Delgada, which is somewhat consistent with population distribution and energy use. It is important to note that Ribeira Grande is the municipality situated closest to the Ribeira Grande and Pico Vermelho power plants, followed by Lagoa and Vila Franca do Campo. Additionally, participants vary across education levels, with a Bachelors degree as 27% of respondent's highest level of education, and secondary education as another 27% of respondent's highest level of education.





4.1 Research Question 1

The first question this research attempts to answer is resident's average acceptance of geothermal energy production. Based on survey results, it is clear that there is general support for geothermal energy production in São Miguel. In figure 3 we can see the overall distribution of geothermal acceptance, based on the question "What is your level of acceptance of geothermal energy production in São Miguel?". 63% of respondents reported that they strongly agree or agree with geothermal energy production on the island, and no respondents selected that they 'strongly disagree' with geothermal production on the island. Only 13% of participants who responded said they 'disagree' or 'slightly disagree' with geothermal exploration, showing that based on this survey, public opinion of geothermal energy is positively skewed.

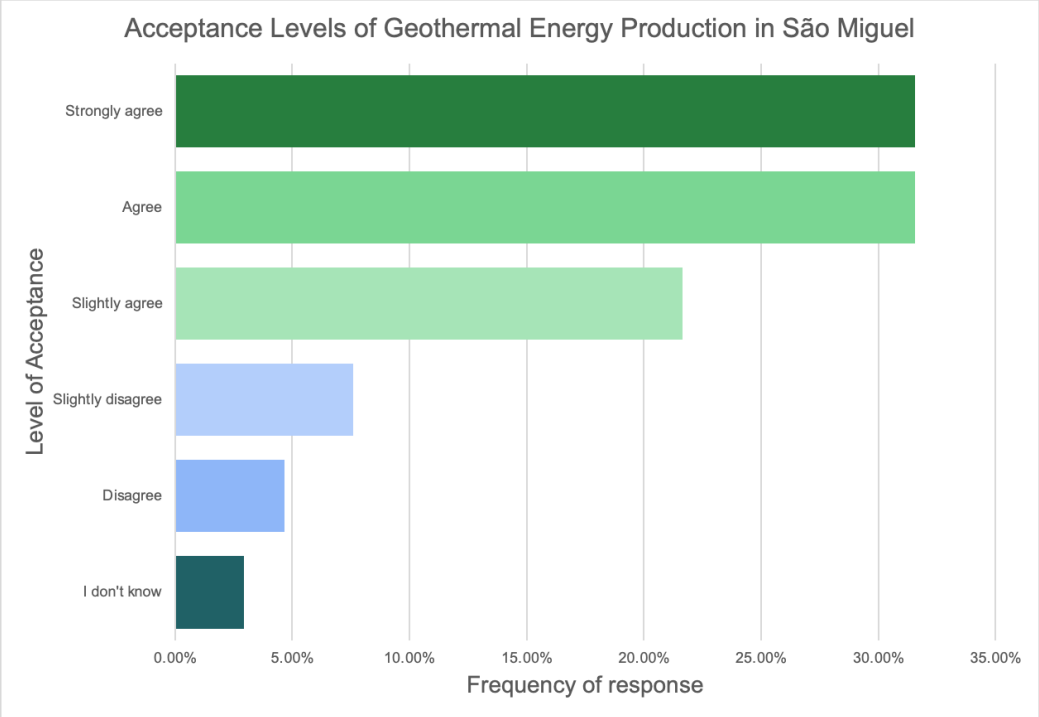


Figure 3

An important finding from survey results is that geothermal energy acceptance does vary by age. Figure 4 shows the average age for each level of geothermal energy production acceptance. The average age of respondents who selected "agree" is 30, and the average age of respondents who selected "disagree" is 40. In general, the higher the acceptance level, the lower the average age of the participant.

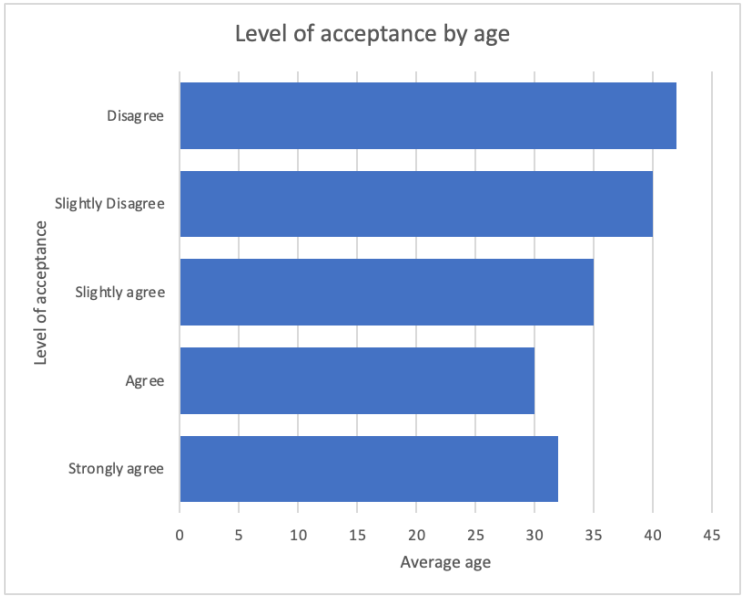


Figure 4

Another important takeaway is resident's perspectives on the environmental impact of geothermal energy production. To drill and extract geothermal energy, there is a small amount of carbon dioxide and potentially other greenhouse gasses released, but emission levels are extremely slim, especially in more efficient plants. The questions of whether geothermal energy production generates pollution and has impacts on the environment are relative, It is important to gauge resident's individual perspectives on the environmental impacts of geothermal production, as it is a renewable source of energy with much lower levels of pollution compared to fossil fuels, but it still has some environmental impacts such as land and water use. Tables 1 and 2 show the results of two subjective questions related to the environmental impacts of geothermal.

Can geothermal energy production generate pollution?	**% of responses**
Slightly agree	27.49%
Disagree	26.32%
Slightly disagree	20.47%
Agree	11.70%
I don't know	6.43%
Strongly disagree	6.43%
Strongly agree	1.17%

Table 1

Do you think that geothermal exploration has impacts on the environment?	% of responses
Slightly agree	30.41%
Slightly disagree	17.54%
Disagree	16.37%
Agree	14.04%
Strongly disagree	9.94%
I don't know	8.19%
Strongly agree	3.51%

Table 2

Results indicate that residents do not consider the environmental impacts of geothermal energy production to be significant, but most respondents indicate that they slightly agree that its production is able to generate pollution and impact the environment. The results show that while residents do not perceive the environmental impacts of geothermal energy production to be significant, a majority of respondents indicate that they slightly agree that its production generates pollution and affects the environment. Regarding the stronger opinions, those who strongly disagree with the statement that geothermal production generates pollution indicated being significantly more confident in their geothermal energy knowledge than those who strongly agree with the statement. These results show the extent to which perspectives on the impacts of geothermal energy production can vary, but the frequency of beliefs being more neutral rather than extreme indicates that residents are likely to be open to discussing and considering different perspectives and information before forming strong opinions on this matter.

4.2 Research Question 2

To address the second research question, data was analyzed to determine whether energy literacy is correlated with opinions on geothermal energy. Results indicate that those who strongly agree and agree with geothermal exploration in São Miguel have a higher average energy literacy than those who slightly disagree and disagree. No participants selected that they ‘strongly disagree’ with geothermal production on the island. Only 21 of 166 participants who selected a response said they ‘disagree’ or ‘slightly disagree’ with geothermal exploration.

Figure 5 illustrates the total average scores for each energy literacy assessment question. The average overall score is .62, meaning that on average, survey participants answered 62% of questions correctly.

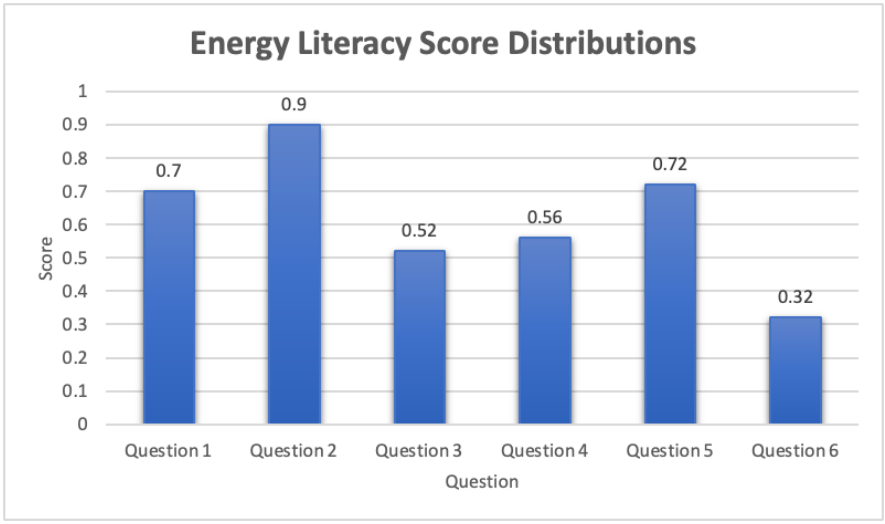


Figure 5 - Appendix C lists all energy literacy questions and the correct response for each

Question 2 had the highest overall frequency of correct responses, indicating a high level of knowledge regarding renewable vs. non-renewable energy sources. In contrast, Question 6 had a very low frequency of correct responses, indicating that general levels of knowledge on the physical process and potential impacts of geothermal energy production is low. Another interesting insight is that Question 4, which asks which energy source power generation in São Miguel relies on most, was only answered accurately, as fossil fuels, by 56% of respondents. Many individuals did not know, or believed that power generation mainly relies on geothermal.

As for the correlation between energy literacy and age, figure 6 illustrates how higher energy literacy scores are correlated with participants of younger age groups. Illustrated in figure 7 are the average energy literacy scores associated with each municipality. Overall, there are no significant differences between municipalities, but the most extensive difference is between Ribeira Grande, with an average score of .56, and Nordeste, with an average score of .75.

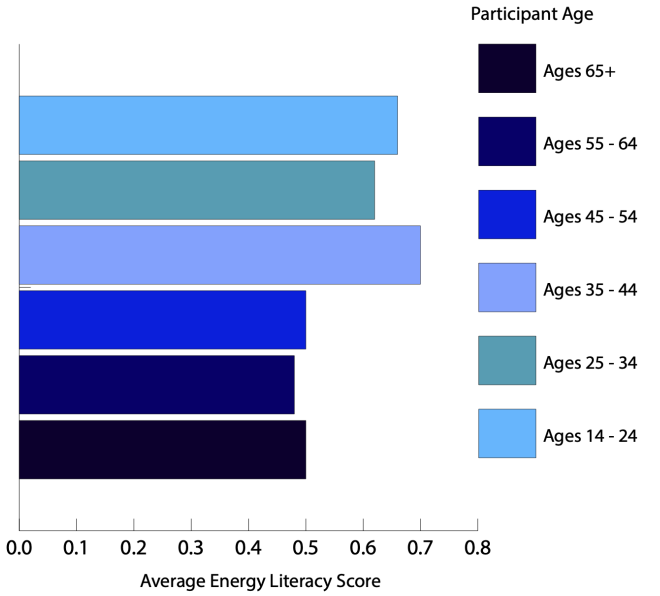


Figure 6

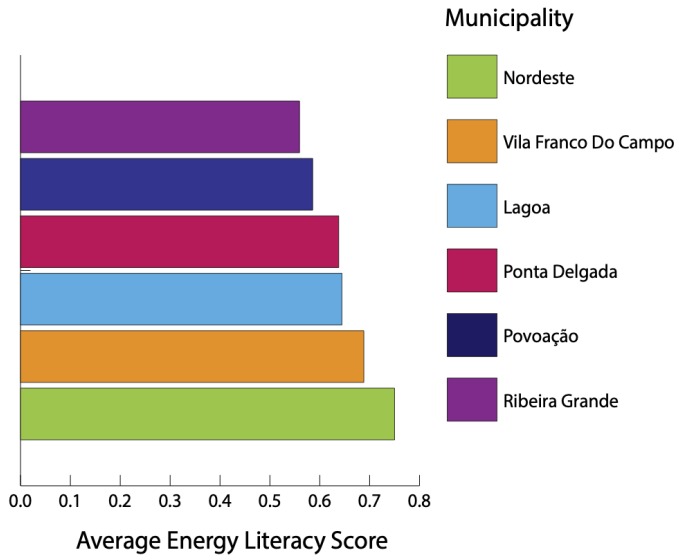


Figure 7

Finally, figure 8 illustrates the average energy literacy score of respondents compared to their self-reported level of acceptance of geothermal energy production. This shows a clear positive relationship between energy literacy scores and geothermal energy acceptance in São Miguel. The lowest average energy literacy scores are associated with individuals who selected 'slightly disagree' or 'disagree' with geothermal energy production in São Miguel.

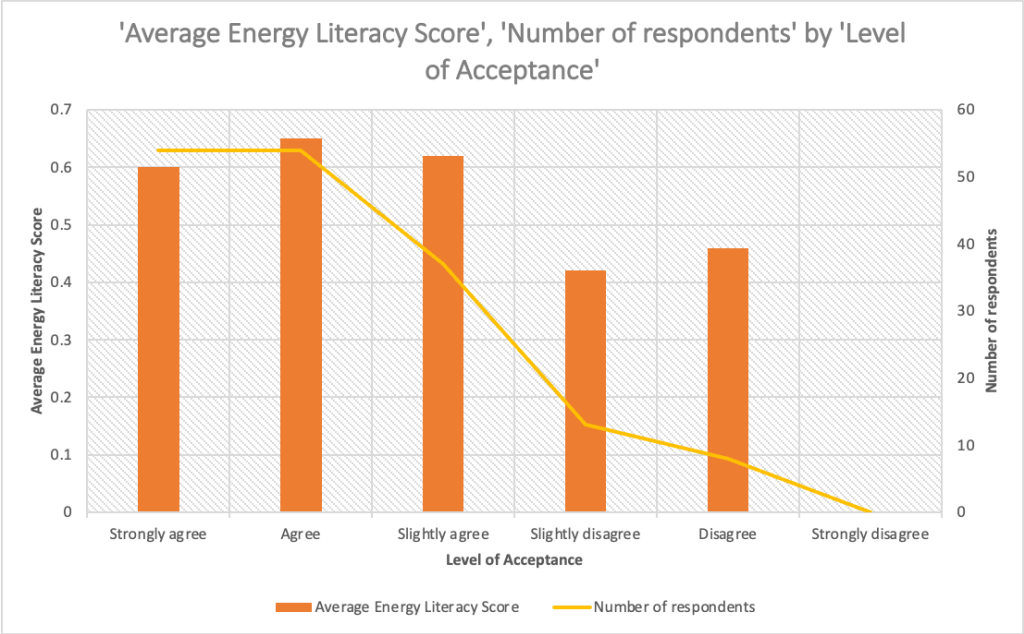


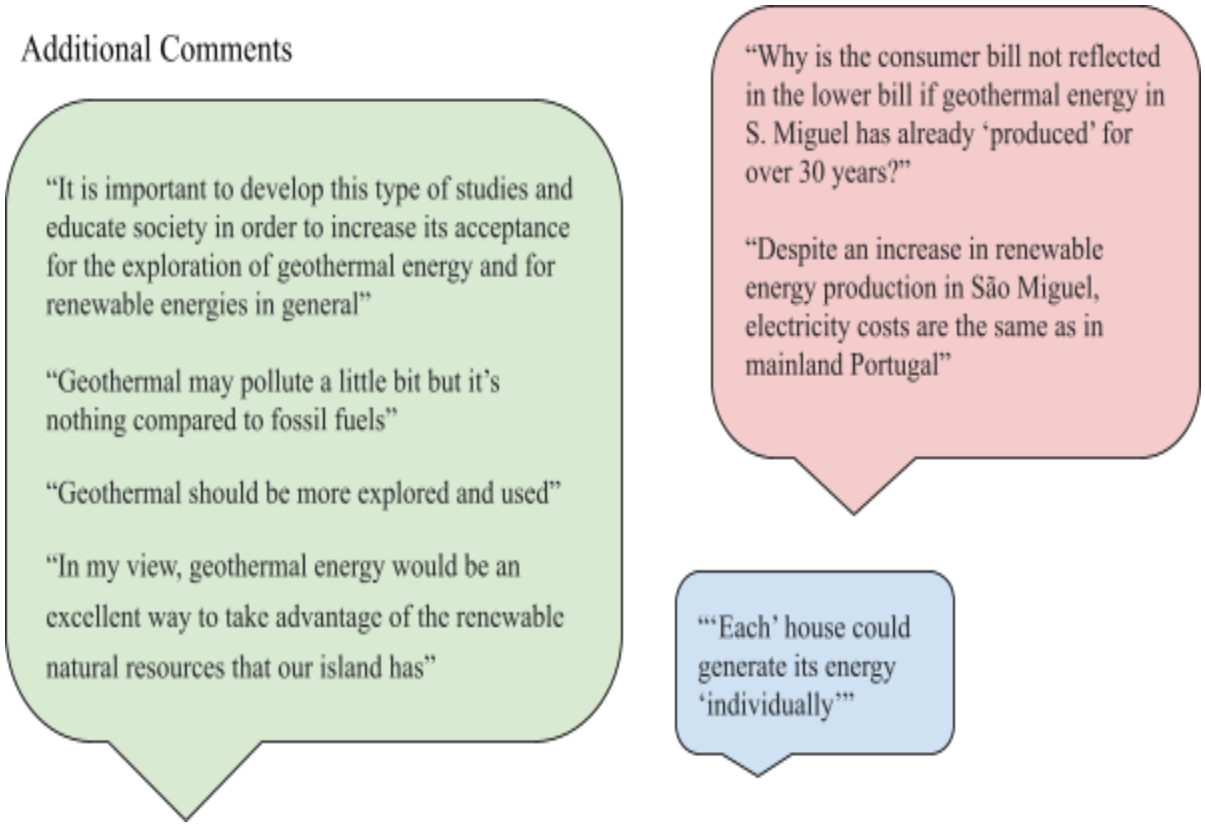
Figure 8

4.3 Research Question 3

Independent of municipality, an overwhelming majority of respondents chose their two main priorities around geothermal energy production as 'public safety guarantees for surrounding communities' and 'guarantees of environmental protection and respect for the landscape', closely followed by 'Increased geothermal energy education'.

As for broader energy-related problems, the most common answer included both 'lowering energy costs' and 'lowering the environmental impacts associated with energy production'. 104 individuals listed 'lowering energy costs' as a problem that they would like to see solved in São Miguel, which is around 60% of respondents. The next most common priority listed is achieving energy independence (less dependence on Russia and China). These priorities complement the overall survey results of the vast majority of respondents supporting geothermal production in São Miguel, as geothermal energy production has significantly lower environmental impacts than imported fossil fuels, and long-term costs reduce as reliance on fossil fuels drops.

Illustrated below are all additional comments left by respondents at the end of the survey. Overall, comments express encouragement of renewable and geothermal energy development in São Miguel, but there are a few concerns raised regarding electricity costs remaining the same despite increased development of geothermal production.



5. Conclusion

Like many national visions of energy, the Azores Islands have visions of becoming energy independent and relying solely on locally produced renewable sources. For all island communities, an increased use of renewable energy sources "has the potential to address many energy difficulties experienced by non-interconnected islands created by dependence on fossil-fuel imports, high energy costs, emissions from diesel generators, and unreliable energy supplies" (Kallis et al., 2021). To lessen or completely rid of reliance on imported fossil fuels, each island in the Azores Archipelago must harness energy from the most abundant and cost-effective sources available. In Sao Miguel, the only renewable energy source with the current potential to be their baseload power source is geothermal.

This study found a high level of support for geothermal energy exploration on the island but also illustrates how not every participant has the same priorities or the same level of acceptance regarding geothermal. "Perceptions that island communities hold shared values towards renewable energy are problematic, when island populations consist of groups and individuals with diverse experiences, knowledge, values, and priorities" (Kallis et al., 2021). Despite the common belief that island communities are tight-knit and hold the same values, it is necessary to consider the many roles that people serve in their communities and how their viewpoints are typically very diverse. The study finds that overall, higher levels of energy literacy were correlated with a higher acceptance of geothermal energy production in São Miguel. This indicates that with a higher level of energy literacy, community acceptance of geothermal energy production may increase. This finding is important to consider as São Miguel attempts to increase geothermal exploration and decrease its reliance on fossil fuels, which are energy goals this survey found to be of high importance to respondents.

5.1 Suggestions for the Future

Similar to the average world data collected on energy literacy levels, São Miguel is in need of a more comprehensive education on the basic principles of energy, its production and its various effects. With an average 62% score on the six basic energy literacy questions created for the survey, it is important for governmental education programs to consider a more advanced education in energy systems and production. To align place-based narratives with environmentally conscious attitudes and decisions, it is necessary to better educate the general public on energy usage and supply scenarios and their consequent environmental impact. "In order to improve public energy literacy, a series of renewable energy projects need to be established in government buildings, public schools, even hospitals and other public institutions, etc., to demonstrate the benefits and convenience of renewables in increasing access to clean energy" (Mehmood, 2022). Energy education is particularly important to implement in locations like São Miguel where further renewable energy development is very likely.

Regarding considerations for Electricidade dos Açores (EDA), the primary energy company operating in the Azores, there are two key ways that they can better include the community and gain acceptance for further geothermal energy development. Generating added benefits for communities surrounding the geothermal plant (education advancements, conservation efforts, infrastructure development) and community engagement practices. "Formation of a group of local actors with the representation of government authorities, members of surrounding communities, environmental conservation associations, representatives from the agriculture and business sectors, etc. provide communities with details about the activities of the company and forthcoming plans and discussion with the intention of achieving shared trust" (Karytsas, 2021). It is important that there is a high level of trust between energy providers/developers and the local community, and residents should be aware of the Ribeira Grande geothermal field, its tentative plans and its strategy of stepwise development. “Developing the engagement practices of an industry and increasing its capacity for managing complex relationships, is an important but challenging part of establishing and maintaining a social license within and across energy industries" (Hall et al., 2015). Some ideas to increase community involvement include project site tours, seminars, user-friendly websites, brochures, media releases, an education center, and coordination of scientific meetings.

While the majority of respondents indicated acceptance of geothermal energy production on the island, it is still important to reach certain demographics that either disagree with geothermal energy exploration, or that are uncertain about its operation and effects. Geothermal activity in São Miguel is a wonderful opportunity for the island to become energy independent and reduce fossil fuel combustion. While most residents are aware of this opportunity and support geothermal energy production, there is still a need to improve energy literacy levels so that the community is able to make informed decisions about energy use and share perspectives on the benefits of geothermal and renewable energy technologies.

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8. Appendix

Appendix A: Survey questions (PDF)

Appendix B: Survey Response Data (Excel)

Appendix C: Energy Literacy Questions and Answer Key