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Article

Differences in Public Perceptions of Geothermal Energy Technology in Australia

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Abstract: In Australia, geothermal energy technology is still considered an emerging technology for energy generation. Like other emerging energy technologies, how the public perceive the technology and under what conditions they are likely to accept or oppose the technology, remains relatively unknown. In response, this exploratory research utilised online focus groups to identify: (1) the extent of agreement with geothermal technology before and after information, including media reports focusing on a range of the technology's attributes; and (2) how the characteristics of individuals with different levels of agreement vary. After information, within the sample of 101 participants, fewer reported being unsure, the minority disagreed and the majority agreed. Overall, the preference was for projects to be located away from communities. Participants that disagreed or were unsure, were more likely to report lower subjective knowledge of the technology, lower perceived benefits and higher risks, and were less likely to believe people in their community would have the opportunity to participate in consultation. These characteristics suggest there are advances to be made by analyzing what contributes to different levels of acceptance. The findings also suggest that the location of projects will be an important consideration and that the conditions of acceptance are likely to vary amongst community members.

Keywords: geothermal; societal acceptance; energy technology

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1. Geothermal as an Emerging Energy Technology in Australia

Over the last two decades, there has been increasing interest in the mitigation of climate change through the use of low emission energy technologies. However, like many new and emerging technologies, there has also been considerable public opposition to many of the low emission energy technologies being developed [1]. Apart from well known opposition to nuclear power plants [2], substantial opposition has been expressed in relation to wind farms [3], carbon capture and storage technology [4] and geothermal energy projects [5]. Furthermore, there has been increasing recognition by policy-makers and technology developers that not only a lack of opposition but societal acceptance [6] and support at the local level [1] are essential for successful deployment. Geothermal energy technology is an emerging energy technology in Australia and therefore it is relatively unknown how the Australian public is likely to respond to the proposed development of this technology in Australia.

Additionally, Australia has substantial geothermal resources however, there has been limited demonstration of how these resources can be used for power generation [7]. To date, Australia's only geothermal power plant is one that has serviced the remote town of Birdsville, Queensland since 1992, providing approximately 25% of the town's electricity (80 kW) [8]. However, Australia also has some relatively unknown direct-use applications. For example, Perth, Western Australia, has several school and community pools heated by the Perth Basin resource. Tourist spas have also been established, including a facility accessing the Peninsula Hot Springs in Victoria, and another in Queensland that draws from the Great Artesian Basin. More recently, Australian companies have been developing Enhanced Geothermal Systems for larger-scale power generation. These systems consist of hot rocks and the addition of water and/or permeability to extract the heat. With this development, the federal government's Bureau of Resources and Energy Economics forecasts that the use of geothermal resources for energy generation may increase to 8% of total electricity generation in Australia by 2050 [9].

Due to its limited use in Australia there has been very little research to understand the extent to which Australians agree with the use of geothermal energy technology and under what conditions the technology would be accepted. In 2011, the Commonwealth Scientific and Industrial Research Organisation conducted a survey of 1907 Australians which found that just over one-quarter of respondents (27%) reported no knowledge of geothermal, with only 38% of respondents reporting their knowledge as moderate to high [10]. Although self-reported knowledge was low, over half of respondents (57%) agreed with the use of geothermal energy technology in Australia, though 31% reported to be unsure. To contrast, in 2011 a survey of Canadians (n = 1548) found 65% had heard of geothermal [11], whereas in a 2007 Eurobarometer survey found that only 44% of Europeans were aware of geothermal as an alternative energy source [12].

A recent report published on the public acceptance of geothermal electricity production in Europe [13] offered practical insights. The insights were drawn from the German media and six case studies of perceptions of projects (one from France, one from Italy and four from Germany). The analysis of media suggested four critical sources of social resistance: environmental issues, missing-involvement (engagement) issues, financial issues and the NIMBYism-syndrome. The reactions of stakeholders reported on by each case study were mostly favourable. However, the majority of the cases demonstrated that the citizens of nearby communities often had limited knowledge of geothermal technology or the specific project. Depending on the project this was due to different factors, for example, limited

communication efforts or that communications failed to reach the majority of the citizens. In such cases the lack of involvement contributed to uncertainty about the project, negative perceptions and even opposition. Additional factors of influence included local economic and political factors and experiencing seismicity.

Also emerging from CSIRO's research program were responses collected from workshops with members of the public in Australian capital cities during 2008 to 2009 [14]. Again, participants rated themselves as having low levels of knowledge of geothermal energy technology. Despite the low levels of knowledge and concerns about water usage and seismic activity, participants were overall supportive of using geothermal energy technology in Australia, partly due to identifying geothermal as a renewable energy source. Similarly, both acceptance and concern have been evident in how projects have been received to date. For example, direct-use applications, such as heated pools and day spas, have received little attention, however, intense community concern was reported in relation to a proposed geothermal power plant near Geelong in Victoria [15].

To understand how the technology will be perceived as its profile increases in Australia and what factors will potentially characterise acceptance or concern, this research aimed to identify: (1) the extent of agreement with geothermal technology before and after information, including media reports focusing on a range of the technology's attributes; and (2) how the characteristics of individuals with different levels of agreement vary. The provided information, included sources that are readily available on the internet, such as media reports on the technology. Based on existing research of societal acceptance of low emission energy technologies, it was anticipated that acceptance was likely to differ depending on an individual's knowledge of the technology [16], how individuals perceive the benefits and risks of such technology [17], the location of energy projects, local community views of such projects [18], and individuals' demographics [19].

1.1. Knowledge of the Technology

The role of knowledge is widely investigated in technology acceptance studies with previous research indicating that subjective and objective knowledge about an energy technology can have different effects on technology acceptance [16]. While some studies, considered in a review by Huijts *et al.* [16] reported positive interactions between objective knowledge and acceptance in the context of carbon capture and storage (e.g., [20]), hydrogen technology (e.g., [21,22]), Ellis *et al* [23] found little evidence of a relationship between objective knowledge of wind power and its acceptance.

Other research has found technology acceptance to be influenced by subjective and not objective knowledge, for both genetically modified foods [24] and rooftop solar photovoltaic systems [25]. Such findings highlight that acceptance is informed by more than objective facts about the technology. In addition, individuals will not necessarily develop an in-depth understanding of every technology and other factors, such as benefit and risks perceptions, are likely to play a key role in technology acceptance of energy projects.

1.2. Perceived Benefits and Risks of the Technology

Perceptions of benefits and risks of a technology are critical to the public's support of a technology's implementation [17]. Previous research has shown that individuals are more likely to

support a technology when they perceive that the benefits of such technology outweigh the risks [16,17] and this has been demonstrated in the context of controversial technology such as nanotechnology, biotechnology and stem cell research [26]. Furthermore, emerging technologies are often inherently uncertain and therefore their associated risks can be largely unknown [27].

Risk perception is a social construct and thus previous research has shown that individuals are likely to react to hazards differently, with each individual's characteristics or specific technical knowledge resulting in quite different judgments about benefits and risks [27,28]. Likewise, the perceptions of the benefits of energy technologies depend on factors such as individuals' level of trust in institutions [16], their subjective knowledge, values and beliefs [25], and therefore individuals might perceive the same benefits differently. For example, a previous study about societal acceptance of carbon capture and storage found that while some people evaluated the benefits as being greater than the risks, others evaluated those same risks as being greater than the benefits [29]. Similarly, Cacciatore *et al.* [30] found that individuals that could make a link between the concept of nanotechnology and examples of how the technology could be applied were more likely to take risks into account.

Energy technologies also present a complex combination of benefits and risks at both the local and global level, for example, there is disparity between local risks and global benefits for nuclear energy [31] and carbon capture and storage [29]. Previous research into public perceptions of geothermal energy in Australia has shown similar results, as concerns about geothermal energy technology are mostly local: water usage and seismic activity instigated by geothermal drilling [14]. Whereas benefits of geothermal energy technology commonly identified by the community, such as low emission energy have an effect at a larger scale, either nationally or globally.

1.3. Project Location and Procedural Justice

Historically, geothermal energy projects have demonstrated that closeness to the end-use application is critical to achieving efficient heat transfer when projects are intended for direct-use or combined direct-use and electricity generation. Research into societal acceptance of energy projects has suggested that the location of energy technology demonstrations can impact acceptance, with concerns that such projects might threaten the locality or its safety [18]. In the context of renewable energy projects, this concept is usually referred as the "Not In My Backyard" (NIMBYism) phenomenon. The assumption underlying NIMBYism is that individuals hold more negative attitudes when the project is proposed for their local residential area than they would normally [18]. However, further research has suggested that opposition towards a particular technology is broader than proximity alone and involves a "range of social and personal factors affecting human interactions with social and political institutions" [32]. As argued by Devine-Wright [18], a multidimensional framework concept is required to understand how contextual, social, economical and personal factors shape public perceptions of energy technologies.

Research has also shown that it is important to engage with the public in the early stages of technology development [29,33]. Early engagement with the community, through a variety of mechanisms has emerged as the best approach to facilitate meaningful participation, to empower the community and to build trust of the institutions deploying the technology. An effective engagement

process happens when the decision process is judged to be fair, also known as procedural justice [34]. For example, in the context of carbon capture and storage, Bradbury *et al.* [35] found that the public was concerned about whether the project implementation would be fair and transparent, including having mechanisms for voicing concerns.

1.4. Demographics

Several studies have reported demographics interacting with the acceptance of energy technologies. For example Carr-Cornish *et al.* [36] segmented a sample of responses from an Australian population and found that the segment that preferred renewable energy were more likely to consist of individuals that were female and have low to moderate household incomes. Whereas individuals in the segment that supported a range of technologies, were more likely to be male, tertiary educated, middle aged, with moderate to high household incomes. A study that reported explicitly on geothermal, found that gender impacted support for a geothermal facility on the Greek island of Nisyros, where women were less likely to support the technology than men [19]. In addition, previous studies have indicated that women tend to show more concern with the risks associated with technologies than men [37].

2. Method

The exploratory research questions of this study were addressed using online focus groups and a mixed methods approach. The mixed method approach afforded both in-depth explorations of participants' perceptions through typed dialogue, as well as questionnaires which allowed comparison of participants' responses [38]. Online focus groups were utilised because, as with offline focus groups, discussion is immediate, free-flowing and allows for affect—it also allowed participants to attend who may not have been able to travel to a physical focus group setting [39]. The sample could also be accessed in a timely manner and a complete record of the discussion data was immediately available for analysis.

2.1. Sample

A total of 136 individuals participated in the online focus groups, combined these participants had similar age, gender and location characteristics to that of the Australian population. However, the sample reported on in this paper consisted of the 101 participants that completed at least 95% of both pre- and post-questionnaires. The remaining sample had characteristics which were consistent with the Australian population, providing a relatively representative sample, although some demographics were over- or under-represented [40] and the data collection method was biased toward internet users. For example, participants ranged from 20 to 68 years, with a mean age of 43 years (SD = 12.91) higher than the national median of 37 years. The Australian population consists of 49% males and 51% females, and the same proportion of male and females were sampled. While participants reported a range of education levels, 35% of the survey sample had a bachelor/honours degree, compared to14% of the Australian population [40]. Similar to the Australian population, participants were from a range of employment situations with 39% of participants employed full-time (40%; [40]). Participants' incomes ranged from less than $20,000 to $150,000 or more, and the median was $60,000 to $79,999,

which is slightly higher than the national average of $58,375. At least one participant was from each of Australia's states and territories except Western Australia. The distribution was similar to the population; 36% of participants were from New South Wales, 29% from Victoria, 25% from Queensland, 4% from South Australia, 3% from Tasmania, and 1% respectively from the Australian Capital Territory and the Northern Territory.

2.2. Material

The online focus groups were conducted using an online qualitative research (OQR) platform, called Revelation │Next [41]. At the start and end of the online focus groups participants were asked to complete a questionnaire which included measures such as agreement with the use of geothermal energy technology in Australia; self-rated knowledge of geothermal; perceptions of the benefits and risks of geothermal energy; preferences for project location and procedural justice; and demographic information—specifically age, gender, education, employment and income. Amongst other institutions, trust in the research organisation (CSIRO) conducting the study was also measured to provide insight into participants' perceptions of the research process.

Agreement with the technology was measured by asking "Please select the option that best matches how strongly you agree or disagree with using the following energy sources and technologies in Australia". A range of technologies were listed and responses to geothermal were reported in this study. Participants could respond from 1—strongly disagree, 3—neither disagree nor agree, to 5—strongly agree and "I have no idea". This measure was adapted from a survey by Hobman *et al.* [10] of the Australian public's preference for energy sources and related technologies. To compare participants with different attitudes toward the use of geothermal energy technology, the attitude measure was re-coded into three attitude groups: "Disagree", "Unsure" and "Agree". The "Disagree" group included participants with ratings of 1—strongly disagree and 2—disagree. The "Unsure" group included participants with ratings of 3—neither disagree nor agree or "I have no idea". The "Agree" group included participants with ratings of 4—agree and 5—stongly agree.

Self-rated knowledge was measured by asking participants to "Please rate your knowledge from 1—no knowledge to 5—high knowledge of the following energy sources and technologies in Australia". Again a range of technologies were listed and responses to geothermal were reported in this study. The self-rated measure of knowledge was also adapted from Hobman *et al.* [10].

To measure benefits and risks, participants were asked to rate their agreement with five benefit statements and four risk statements. Specifically participants were asked: "Please select the option that best matches how strongly you agree or disagree that the development of geothermal resources in Australia will": e.g., "Reduce greenhouse gas emissions" and "Induce earthquakes". Responses could range from 1—strongly disagree, 3—neither disagree nor agree, to 5—strongly agree. This question was informed by research of the actual benefits and risks of geothermal energy technology [7] and followed methodology previously used in risk assessment research [17].

Two questions were asked to measure participants' preferences regarding project location. At both the start and finish a question was asked of the distance projects should be from built-up areas. Participants were asked: "Please indicate the distance a geothermal project should be from built-up areas in your community (e.g., houses, businesses)". The response options were: less than 1km, at least

1 km, at least 5 km, at least 10 km, at least 50 km, at least 100 km and greater than 100 km. Only in the end questionnaire participants were asked about how concerned they would be if a project was proposed for their community. Participants were specifically asked: "On a scale of 1 (not at all concerned) to 5 (very much concerned) please select the number that best matches how you would feel if a geothermal project was proposed within 1km of built areas in your local community". These measures were adapted from the Special Eurobarometer 364 [42] on public awareness and acceptance of carbon capture and storage.

In the final questionnaire participants were also asked about procedural justice, the extent they believed they could participate in decisions about a project. They were asked: "Please rate from 1 (not at all) to 5 (very much) the extent to which you believe people in your community would have the opportunity to participate in decisions about geothermal energy projects". Also, to measure trust in a range of institutions, including CSIRO, participants were asked: "Please rate from 1 (not at all) to 5 (very much) the extent to which you trust [institution specified] to provide honest information about geothermal resources and projects in Australia".

Between completing the pre- and post-questionnaires participants were asked to view and discuss their reaction to four pieces of information about geothermal energy technology that are currently available on the internet. A geothermal energy researcher with industry experience, assisted with the identification of relevant materials. Participants were first presented with an overview of the technology and Australia's industry. This was done by providing participants with a CSIRO authored factsheet [43] about the technology and a YouTube video recording of a 7 min TV news segment that aired on the Australian Broadcasting Commission (ABC) in 2011 [44]. Following this, participants were presented with two articles, one that was positively framed and focused on the potential for enhanced geothermal systems and a second that was more negatively framed and focused on the hydraulic fracturing aspect of enhanced geothermal systems. The predominately positive news article was "Enhanced geothermal systems: Have a little faith" and published on the renewable energy news website, Renewable EnergyWorld.com [45]. The more negatively framed article was "France fractured by fracking-like geothermal projects" and published online in The Age [46].

2.3. Procedure

A market research firm was used to recruit participants for the nine online focus groups. Each focus group was moderated by one of two CSIRO researchers and the initial group was moderated by both to ensure consistency of approach. All groups followed the same procedure though the order in which the positive and negative news articles were presented varied to negate the news articles having a primacy or recency effect on responses. From the 101 participants that completed the questionnaires, 60 viewed the positive article first and 41 viewed the negative article first. The groups commenced when participants responded to their email invitation to log into the Revelation | Next platform. To maintain their privacy they used only their first name or an alias. The groups ran for approximately 2 h in which participants completed seven activities. First participants completed the questionnaires as presented in Table 1 followed by Activity 2 which was a written discussion of their awareness of geothermal energy. Activity 3 to 5 all involved the provision of information and discussion. Activity 6 was the final discussion, which was followed by a questionnaire.

Table 1. Online focus group activities, including information provided and discussion prompts.

Activity schedule	Purpose	Questions
1. Pre-questionnaire	Collect quantitative data on existing attitudes and demographics	See Section 2.2. Materials
2. Initial group discussion	Collect qualitative data on existing attitudes towards geothermal energy	Please write down what comes to your mind when you think about geothermal energy
3. What is geothermal energy?	Provide information about technology. Participants were asked to read the CSIRO factsheet and view the ABC news segment	Facilitated discussion. - Was this information new to you? - Was this information clear? - What particular points are most relevant to you?
4/5. Geothermal projects 2012 article 5/4. Geothermal projects 2013 article	Provide information on the risks and benefits of geothermal technology presented in media articles. One article was positively framed and one article was negatively framed	Facilitated discussion. - What did you think about the information presented in the article? - What do you think the project and technology discussion in that article?
6. What do you think?	Explore participants' overall opinions and attitudes towards geothermal technology	Facilitated discussion. Given the information you have been provided on geothermal technology, the industry in Australia and examples from around world, overall: (a) What do you think about Australia's effort to date to develop geothermal resources? (b) What would be important to you if geothermal projects are implemented across Australia?
7. Post-questionnaire	Collect quantitative data on participants attitudes after provision of information	See Section 2.2. Materials

All of the questionnaire responses and discussion interactions were collected securely online. The questionnaire responses were analysed using the Statistical Package for the Social Sciences (SPSS) version 20. Descriptive statistics were used to identify the distribution of responses. To compare responses collected at the start with those at the end, two-tailed paired sample *t*-tests were used. Analysis of variance (ANOVA) was used to compare the responses of each attitude group ("Disagree", "Unsure", "Agree") on continuous variables and cross-tabulations with Pearson's chi-squared tests were used to make comparisons on categorical variables. Differences were considered significant at $p < 0.05$. Qualitative data from the facilitated discussion were thematically coded using NVivo 10, a form of Computer Assisted Qualitative Data Analysis Software.

3. Results

Overall the questionnaire responses confirmed that there was considerable agreement with the use of geothermal energy technology in Australia. On the recoded scale of 1—disagree to 3—agree, the

mean measure of agreement was high at both the start, 2.58 (SD = 0.50) and end, 2.67 (SD = 0.60), to the extent there was no significant difference, $t(99) = -1.38$, $p = 0.171$.

Also, the perceptions of those that viewed the positive article first were similar to those that viewed the negative article first. For example, at the start the mean agreement of these groups was only marginally significant, $t(83) = 2.034$, $p = 0.045$ and at the end the difference was definitely not significant, $t(64) = 1.855$, $p = 0.068$. Additionally there was no statistically significant difference in the mean change of participants that viewed the positive article first, $t(59) = -1.230$, $p = 0.224$ or of those that viewed the negative article first, $t(39) = -0.684$, $p = 0.498$. Trust in CSIRO increased significantly during the process from 3.94 (SD = 0.952) at the start to 4.18 (SD = 0.833), $t(99) = -3.129$, $p < 0.05$. This increase suggests that providing both negative and positive information from media sources did not have an adverse effect on the trust participants had in the organisation conducting the research.

Although there was no significant change in mean ratings of participants' agreement with the technology, the proportion of participants that either disagreed, were unsure or agreed with the technology did significantly change [$\chi^2(2, N = 100) = 10.71$, $p = 0.005$]. Shown in Table 2 is the percentage of participants that reported disagree, unsure and agree at both the start (last column) and end (last row). At the start, participants were either unsure of the technology or agreed with the technology, however, by the end there was more variation in responses; a small percentage of participants disagreed, fewer participants were unsure, and more agreed.

Table 2. Attitudes toward geothermal energy technology being used in Australia.

Start	**End**			
	Disagree	**Unsure**	**Agree**	**Total**
Disagree	–	–	–	–
Unsure	5% (5)	13% (13)	24% (24)	42% (42)
Agree	2% (2)	6% (6)	50% (50)	58% (58)
Total	7% (7)	19% (19)	74% (74)	100% (100)

Consistent with participants' attitudes that were measured through the questionnaire, qualitative responses collected in the last facilitated discussion (Activity 6), confirmed that although mean agreement was high, participants expressed a range of agreement levels with use of the technology in Australia. For example, the following quote reflects strong agreement:

I'm pleased that Australia is making some effort to explore and develop its geothermal resources, but I'd like to see more action given our enormous potential for energy derived through geothermal technology. I sense we are somewhat lagging other parts of the world in this respect, which is disappointing.

The following quotes demonstrate expressions of agreement, but with conditions, such as safety, no hydraulic fracturing and measured funding:

I think that Australia can play a significant role in the development of geothermal energy and should continue to do so if it can be proven to be 'safe'. To me, I am very happy to see geothermal projects in Australia, but importantly for me, we must not implement fracking or anything similar.

Geological disturbance must be avoided; we simply don't know the potential long term consequences on geological disturbance.

It should be slowly funded as it is until we know we are not throwing money down a hole.

Some participants indicated they did not have enough information to form a judgment and that they perceived the need for more research:

I struggle with this right now, simply because we have incomplete information. If this were to be implemented here in Australia, I would want to know that there was going to be no disastrous or potentially disastrous results. In theory it's a great idea, and one that appears to be a long term supply, but none of that will matter if we end up with earthquakes and poisoned water!

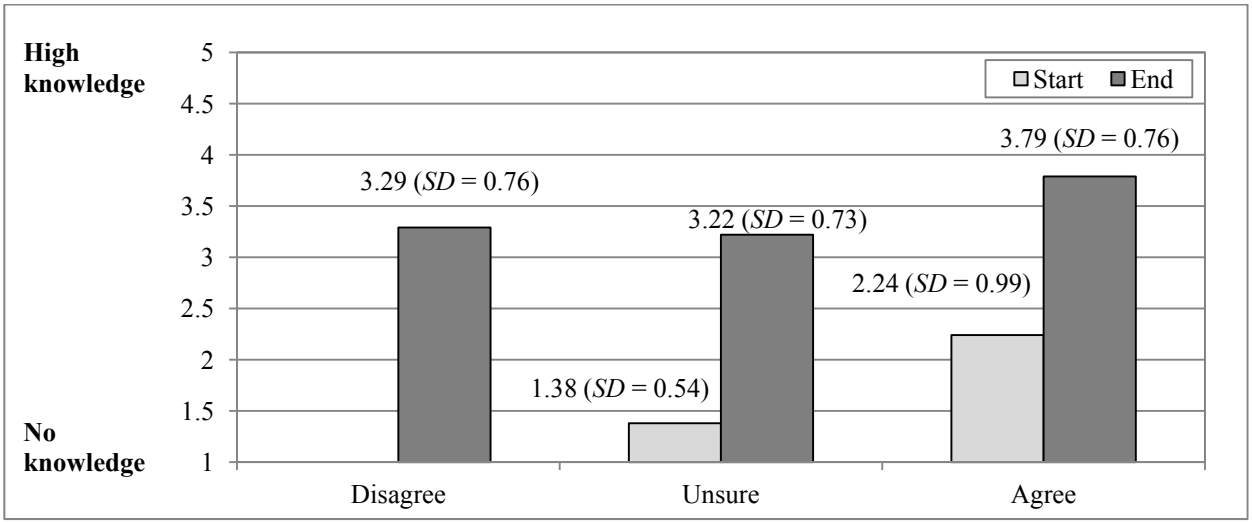
Expressions of disagreement emphasised the need for more research and also alternative technologies:

I think a lot more testing, scientific discussion and research is required before Australia can step into this kind of technology. I feel there are several easier, sustainable and less dangerous alternatives to geothermal energy systems available to us at the moment. Let's utilise these options first.

3.1. Self-Rated Knowledge

Figure 1 shows the mean self-ratings of knowledge for each attitude group, both at the start and end of the processes. Overall the mean rating significantly changed from the start to the end, $t(97) = -16.440$, $p < 0.001$. The mean at the start was low, 1.89 ($SD = 0.93$) and at the end the mean was moderate, 3.65 ($SD = 0.79$). The mean self-ratings were significantly higher for participants that agreed with using the technology in Australia compared to those that were either unsure or disagreed, at both the start, $F(1, 99) = 25.971$, $p < 0.001$, and end, $F(2, 95) = 5.012$, $p < 0.05$.

Figure 1. Mean self-ratings of knowledge of geothermal by attitude group.



Similar to the questionnaire responses, the qualitative responses collected in the first facilitated discussion (Activity 2) confirmed that the majority of participants stated limited to moderate awareness of the technology, especially in Australia. The quotes below reflect a participant expressing low awareness and another expressing moderate awareness:

Until the opportunity has opened for this discussion, I wasn't aware that Australia was involved in any projects to develop any business opportunities or were conducting public company business.

This is a subject that I have only heard about in the past two or three years, so I'm still learning the intricacies about it.

Participants also showed interest in being better informed:

I'm really interested to learn more about it, because it's important to advocate for the development and implementation of safe sustainable energy sources.

No, I don't feel well informed at all. It is a shame that it is not more widely discussed/debated as is coal seam gas and coal extraction for electricity.

Participants reported to recognise the technology from a range of information sources, most often from a media source:

I have heard it discussed in the media, but I am not sure if it's operational or how widespread it is.

I have seen a bit about if overseas on some of the grand design shows on the ABC they have used it as heating for their homes instead of other sources it is interesting.

3.2. Agreement with Benefits and Risks

The questionnaire results showed that different perceptions of the benefits and risks of the technology were linked with different levels of agreement with the use of the technology. At the start of the online focus groups, the mean ratings of four benefit and two risk statements were significantly different between participants that were unsure with the use of geothermal technology in Australia and those that agreed. The significant differences were identified using analysis of variance (ANOVA) and the results for benefit statements were: $F(1, 98) = 16.360$, $p < 0.001$ for "have benefits that outweigh the risks"; $F(1, 99) = 27.558$, $p < 0.001$ for "benefit future generations"; $F(1, 99) = 23.110$, $p < 0.001$ for "reduce greenhouse gas emissions"; and $F(1, 99) = 25.347$, $p < 0.001$ for "improve energy security". The results for the risks statements were: $F(1, 99) = 4.856$, $p < 0.05$ for "induce earthquakes"; and $F(1, 98) = 4.763$, $p < 0.05$ for "negatively impact on groundwater".

Figure 2 illustrates how the mean ratings of benefits by participants in agreement with the technology were consistently higher and risks were significantly lower, when compared to the responses of the participants that were unsure about the technology. Two risk statements that did not show any statistically significant differences were: $F(1, 98) = 0.199$, $p = 0.657$ for "have risks that are unknown" with a mean of 3.41 ($SD = 0.805$); and $F(1, 99) = 0.181$, $p = 0.671$ for "increase the price of electricity" with a mean of 2.86 ($SD = 0.861$). One statement about benefits also did not show any statistically significant differences: $F(1, 98) = 1.289$, $p = 0.259$ "have benefits that are unknown" with a mean of 3.51 ($SD = 0.611$).

Figure 2. Mean ratings of benefits and risk by attitude group at the start.

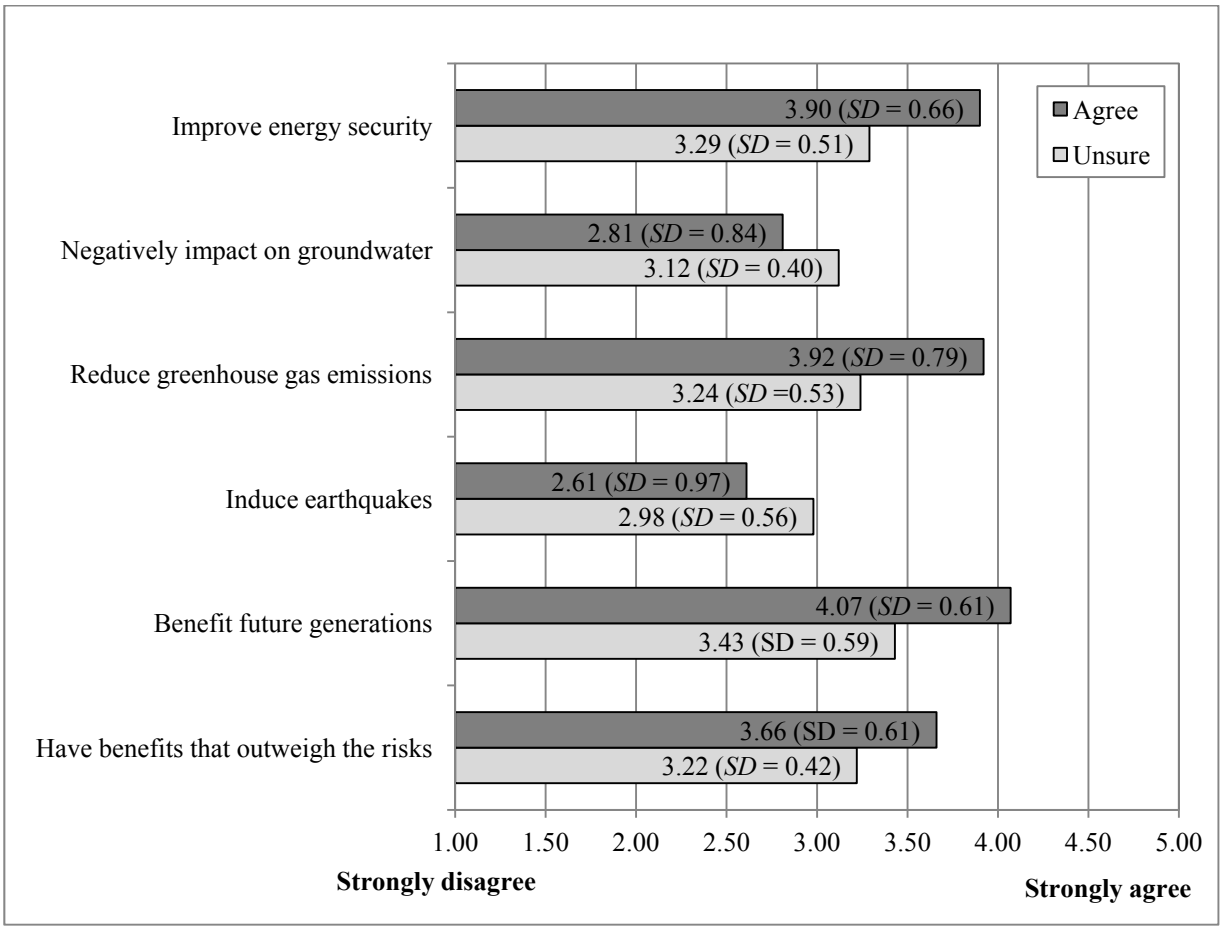
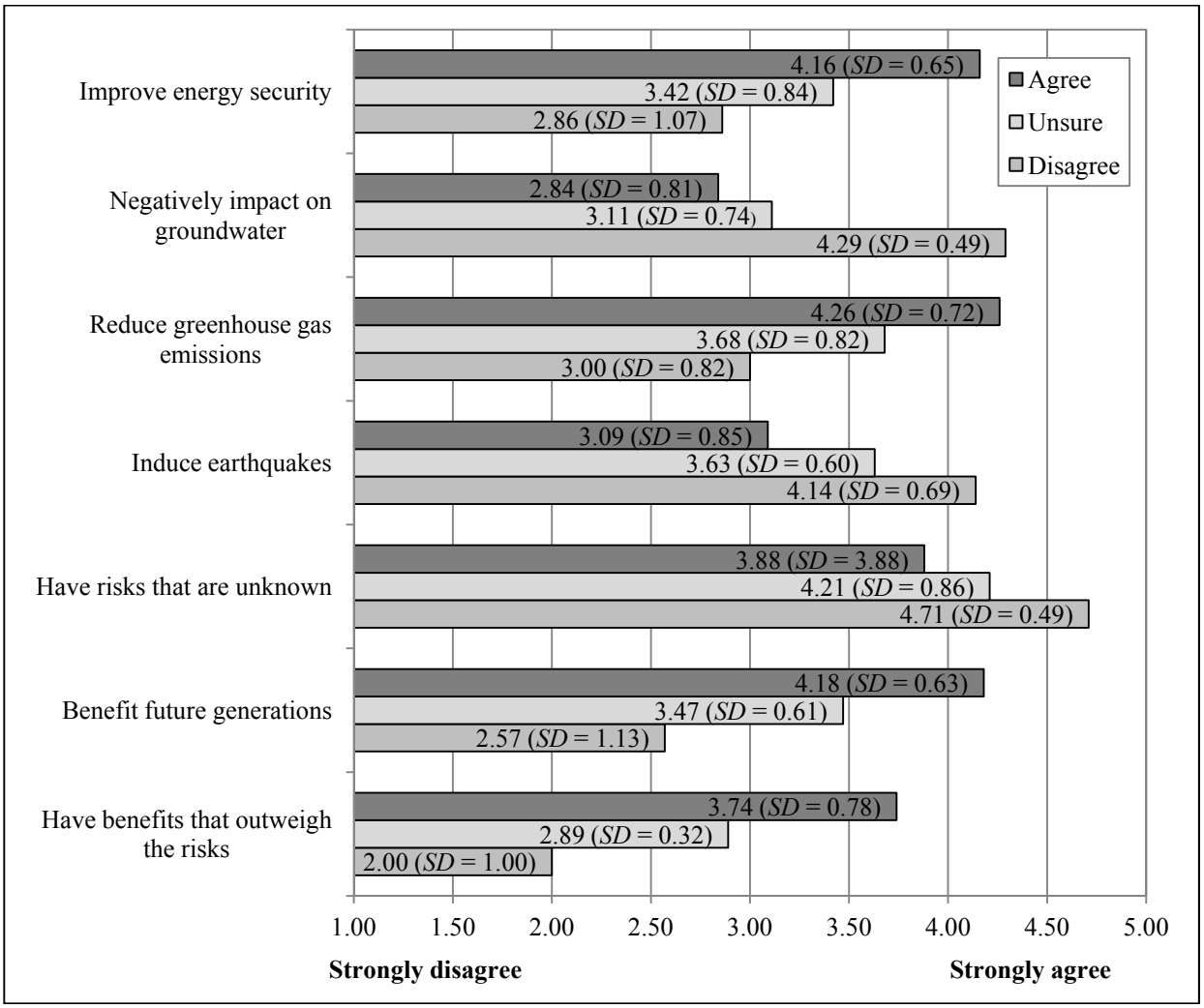


Figure 3 shows the mean ratings of benefits and risks for each attitude group in the post-questionnaire. Similar to the pre-questionnaire, there were significant differences: $F(2, 96) = 24.721$, $p < 0.001$ for "have benefits that outweigh the risks"; $F(2, 96) = 23.779$, $p < 0.001$ for "benefit future generations"; $F(2, 97) = 7.945$, $p < 0.05$ for "induce earthquakes"; $F(2, 97) = 11.997$, $p = 0.001$ for "reduce greenhouse gas emissions"; $F(2, 97) = 112.976$, $p < 0.001$ for "negatively impact on groundwater"; and $F(2, 96) = 12.976$, $p < 0.001$ for "improve energy security". Additionally there was a significant difference in agreement with 'have risks that are unknown', $F(2, 98) = 4.275$, $p < 0.05$. There were no significant differences between the responses of each attitude group to: $F(1, 98) = 0.49$, $p = 0.952$ for "have benefits that are unknown" with an overall mean of 3.53 ($SD = 0.881$); and $F(1, 97) = 2.627$, $p = 0.077$ for "increase the price of electricity" with an overall mean of 2.84 ($SD = 0.987$). Overall, similar to the pre-questionnaire, participants' that agreed with the use of the technology compared to participants that were unsure or disagreed rated the benefits of using the technology higher and the risks lower.

Figure 3. Mean ratings of benefit and risk statements by attitude group at the end.



During the final facilitated discussion (Activity 6), when participants were asked to share their perspectives on the technology being used in Australia, a range of benefits and risks were discussed. The potential for seismic activity best illustrated in the quotes below:

Possible seismic activity, as reported from international projects and negative effect on the Artesian Basin.

NO FRACKING. The method to get through the rock has to be safe and sustainable. The projects have to be far enough away from cities and the populous so that it does not cause injury or environmental concerns.

There were mixed responses to the implications for ground water, some participants did not foresee negative effects, others did:

The water gets pumped in, it comes out hot, then gets pumped back in cold. It is great that the water can be reused—there is always a worry for water shortages.

I would treat it in a similar manner to coal seam gas production. I would not want it near residential areas or homes. It would need to be shown to be safe: i.e., no chance of it producing seismic activity or polluting groundwater or the environment.

Participants also perceived benefits such as low emissions, an abundant supply and potential cost savings:

I think Australia needs to do more to develop its geothermal resources. We can't keep going the way we are. Putting aside the greenhouse emissions and environmental factors, we Aussies are struggling with our power bills that keep rising.

A common conclusion amongst participants was that the benefits outweighed the risks:

Clean renewable resource that we could all benefit from. More jobs and a better economy. With the way electricity prices are going up we have to do something. I really think the benefits outweigh the negatives.

Another frequent conclusion was that the technology had potentially hazardous unknown risks:

I think Australia is right to be cautious for now. At least until we know more about the risks and benefits.

3.3. Project Location and Procedural Justice

As shown in Figure 4, participants reported similar preferences at the start and end of the process regarding the distance geothermal projects should be from built-up areas in their community. To meet the minimum distance preference of approximately half of the sample (55% in the start questionnaire; 57% in the end questionnaire) projects needed to be 'at least 50 km' and to meet the minimum distance preference of three-quarters of the sample (78% in the pre-questionnaire; 71% in the post-questionnaire) projects needed to be 'at least 100 km'. Regarding the differences between groups, at the start, the participants from the 'Unsure' and 'Agree' attitude groups rated their distance preferences similarly, $\chi^2(2, N = 101) = 6.30$, $p = 0.327$. At the end the preferences were more distinct for each attitude group, though the differences were not significant, $\chi^2(2, N = 100) = 20.20$, $p = 0.063$.

At the end of the focus group process participants were asked to rate their concerns if a geothermal project was proposed within 1km of built-up areas in their local community. Mean ratings of concern varied significantly between participants that disagreed, were unsure and agreed with the technology's use in Australia, $F(2, 97) = 9.478$, $p < 0.001$. The mean rating of participants in the "Disagree" and "Unsure" attitude groups were higher, 4.71 ($SD = 0.286$) and 4.63 ($SD = 0.684$), compared to the participants of the "Agree" group, 3.66 ($SD = 1.114$).

The facilitated discussion (Activity 6) captured some of the participants concerns about the technology and the possibility of it being used close to communities:

I don't think this technology should be utilised at all let alone in any populated area.

Some participants were more accepting of the technology though maintained the technology should be away from their community:

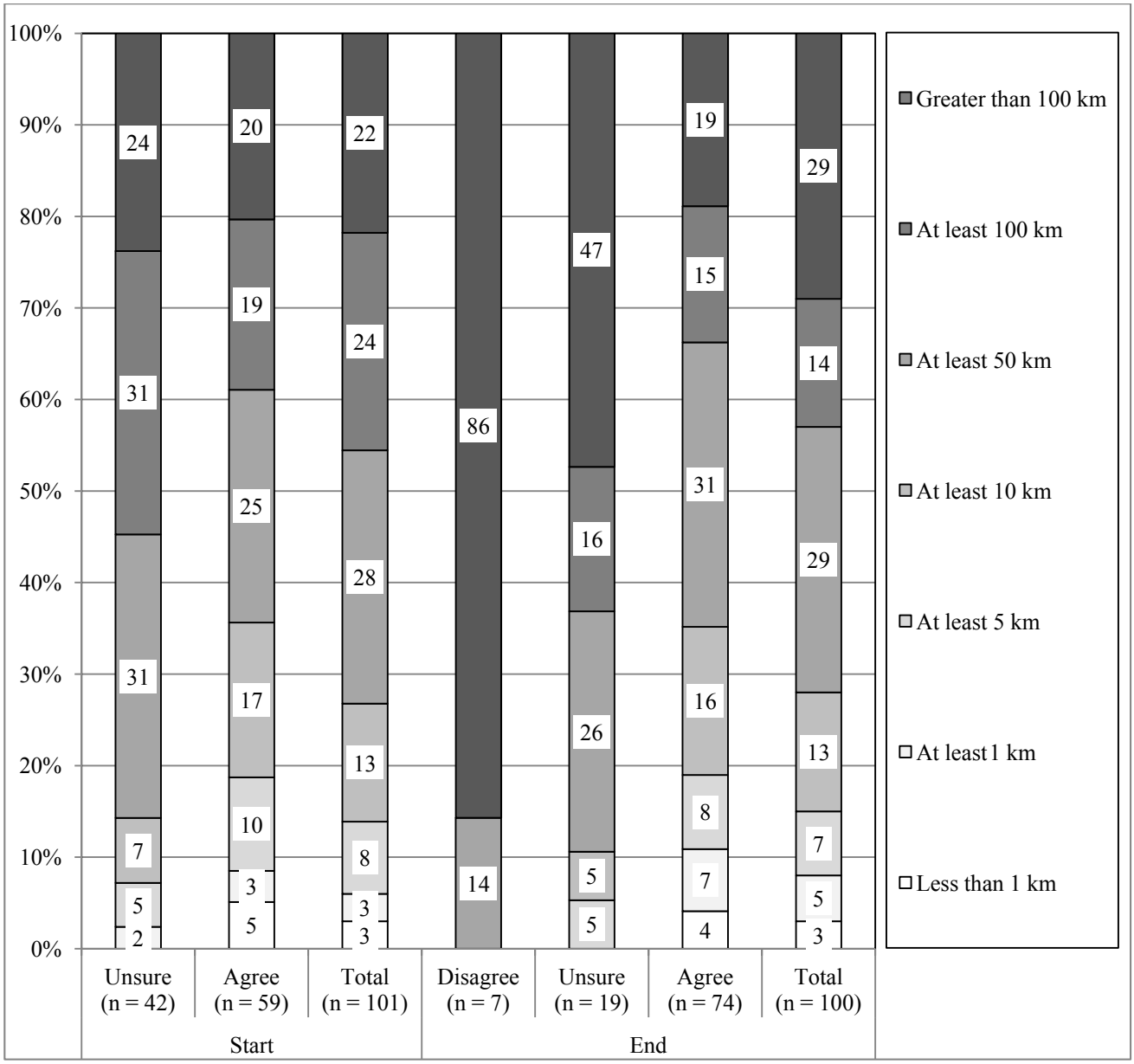
Definitely would not be happy if it was proposed in my area. I'm not sure how far away would make me feel better.

Others reported to be potentially comfortable with projects being in or near their community, though they had conditions such as safety and being consulted:

Provided I was consulted along the way and I was sure it was completely safe—go ahead!

After reading all the information I think I would be ok if they were to start a project in my area, I am not sure how far they should be, far away enough that there is minimal noise, traffic congestion, and an eyesore to the environment?

Figure 4. Percentage of agreement with distance of geothermal projects from built-up areas in the community.



The final questionnaire results also showed that participants have concerns about the procedural justice elements of such projects. Participants were asked to rate from 1 (not at all) to 5 (very much) the extent to which they believed people in their community would have the opportunity to participate in decisions about geothermal energy projects. This question emphasises the participants' belief in having the opportunity to participate, whether participants would actually participate, would be subject to additional factors regarding the particular project and community. The difference in responses

between attitude groups was significant, $F(2, 96) = 6.132$, $p < 0.05$. The mean rating of participants in the "Disagree" and "Unsure" groups were low, 2.00 ($SD = 1.000$) and 2.63 ($SD = 1.116$), whereas the mean response of the "Agree" group was moderate, 3.19 ($SD = 1.276$). Similarly, in the last facilitated discussion (Activity 6) participants indicated the need for more information to be available to the public:

Similar to the first handout, concise information of what Geothermal energy is. Also a table to highlight the benefits versus the negatives. With the negatives, it will be useful to describe how they can be prevented, mediated or dealt with. More media coverage will be useful, as it will reach out to more Australian public. Knowledge eases concerns.

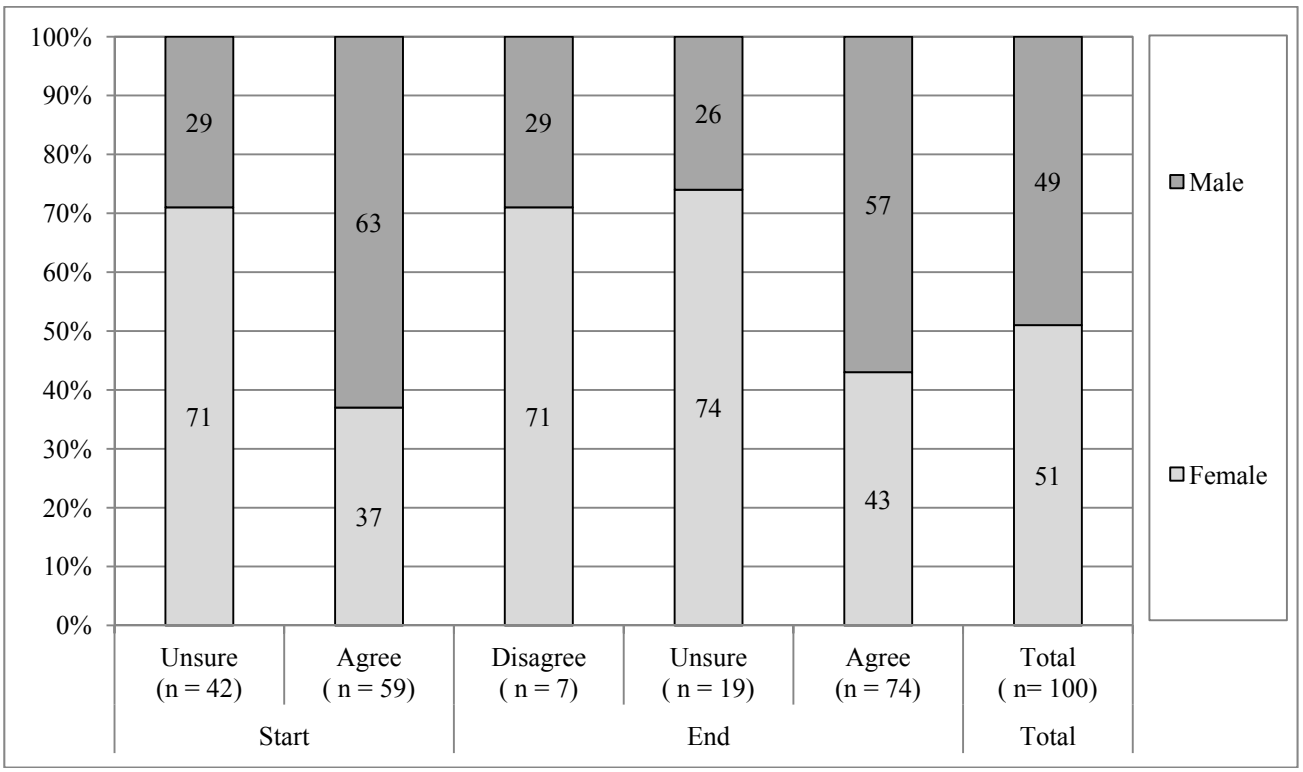
Others emphasised addressing the risks, including hydraulic fracturing and involve the community:

I would be concerned on the fracking issue so wouldn't want it in my backyard unless all concerns were addressed.

If implemented, it would be important to involve (and actually involve and listen to, not just pay lip service!) local communities who are affected by having drilling near them. There would need to be strict regulation of the companies who explore and initiate drilling of sites, to make sure the sites are environmentally sound.

However, I do think that the area that is used to obtain the geothermal energy should be benefited the most from it, I don't like the way that big mining companies take all the profits offshore or away from the area's that they get there resources from.

Figure 5. Gender by attitude group.



3.5. Demographics

Based on their attitude toward the technology, participants were compared across age, gender, education and income. There was only a significant difference for gender. The difference was significant both at the start, $\chi^2(1, N = 100) = 11.45$, $p < 0.001$, and end, $\chi^2(1, N = 100) = 6.86$, $p < 0.05$. Figure 5 shows that there were a similar proportion of males to females, and that consistently, those that were unsure or disagreed were more likely to be female, whereas participants that agreed were more likely to be male.

4. Discussion

The findings from this research appear consistent with previous studies about societal acceptance and awareness of geothermal energy technology in Australia [10,14]. This study, specifically found that at the start, prior to additional information, participants were either unsure of the technology or agreed with the technology. However, after the provision of information, a greater number of participants agreed with the use of the technology in Australia, fewer participants were unsure but a small number of participants disagreed with its use.

Additionally the study considered whether individuals that disagreed, were unsure or agreed with the technology's use in Australia had varying characteristics. Overall, participants that agreed with the technology both at the start and end of the online focus groups were more likely to be male, rate their knowledge as high, report stronger agreement with the technology's benefits and less agreement with the risks. They also indicated the technology could be located closer to their community, with only 34% of those respondents requiring geothermal projects to be located over 100 km as opposed to 63% of unsure respondents, or 100% of those who disagreed with the use of geothermal energy. In addition, respondents who agreed with the technology reported less concern about the technology being proposed for their community and believed they would be able to participate in the decision-making process.

The findings were consistent with previous research that suggests men are more likely to agree with the use of geothermal energy technology [19] than women, and that in general women are more inclined to be concerned with the risks of technology [37]. Also consistent with existing research reviewed by Huijts *et al.* [16], participants who reported higher subjective knowledge were more likely to agree with using the technology in Australia. Furthermore, after information there was an increase in both self-rated knowledge of the technology and agreement with the use of the technology.

Similar to the risk assessment literature, the findings showed that support for geothermal energy technology is dependent on an individual's perception of the technology benefits outweighing the risks [16,17,26]. The questionnaire results showed that after the provision of information, participants in the "Disagree", "Unsure" and "Agree" groups significantly differed in response to the statement 'that risks are unknown', confirming Slovic's [27] work on the implications of risk uncertainty for emerging technology. The risks participants focused on were consistent with the information presented, however, they were also consistent with the risks previously identified by Dowd *et al.* [14] and Reith *et al.* [13] and included seismicity, water usage and pollution. Similar to previous research of the acceptance of carbon capture and storage, benefits identified by participants were mainly global in nature such as geothermal being a low emission energy technology [29,31]. The change in ratings of benefits

and risks, before and after information, demonstrated how individuals can change their perceptions due to available information, including knowledge of advances in the technology.

Consistent with previous research regarding the potential location of energy technologies [18] the majority of focus group participants would prefer that geothermal projects be located at least 100 km away from their community. This finding suggests the important role community engagement could have for direct-use or combined direct-use and electricity generation projects, which need to be proximal to the end-use application. Additionally, the "Disagree" and "Unsure" participants also reported less agreement with the notion that people in their community would have an opportunity to participate in decisions about such projects. This finding is consistent with previous research [13,29,33] and indicates the importance of early and transparent engagement as a means for overcoming community preconceptions and addressing concerns.

Overall this research demonstrates how acceptance of emerging energy technology can be further understood by comparing the characteristics of individuals with different levels of acceptance and at least two other directions for future research are evident. The first is to further explore the effect of information provision and framing on technology acceptance, investigating the influence of information source and trust, as well as the effect of messaging framing about benefits, risks and project location. While the second avenue for future research is limited in Australia due to the lack of commercial hot rocks geothermal plants, future research could extend the findings of this study by surveying both individuals that have had exposure to the technology and those who have not. Similar to Reith *et al.* [13] such analysis would explore the effect of exposure to the technology on risks and benefits perceptions as well as on technology support.

5. Conclusions

This study explored the level of agreement with the use of geothermal energy technology in Australia and how perceptions are impacted by media reports of the technology that are readily available on the internet. In conclusion the findings suggest that while the majority of participants agreed with geothermal technology use in Australia and agreement increased after information, concerns about the potential risks of the technology are present and the dominant preference is for the technology to be deployed away from communities. The reluctance to have the technology near communities could present a challenge for direct-use and combined direct-use and electricity projects which need to be located close to the end-use application. Participants concerns were not addressed at the time they were raised, which may have contributed to participants that were initially unsure or in agreement with the technology, disagreeing with the technology at the end. However, individuals do not have the opportunity to have their concerns addressed while reading news media or other content that is readily available on the internet. Thus the results highlight the importance of responding to uncertainty about the technology's risks and suggest a role for policy-makers and industry in engaging with Australians ahead of large-scale demonstration of the technology.

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Author Contributions

Simone Carr-Cornish and Lygia Romanach developed the study concept and the study design. Lygia Romanach managed and conducted data collection. Simone Carr-Cornish conducted data analysis and lead the writing of the manuscript. Lygia Romanach provided critical revisions of the manuscript. All authors approved the final version of the paper for submission.

Conflicts of Interest

The authors declare no conflict of interest.

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