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Improving collaboration between native Hawaiians and energy professionals to explore geothermal energy potential in Hawai'i

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Climate change is threatening vulnerable geographies including island nations, posing major economic and social risks. The development of renewables, specifically geothermal energy in the Hawaiian archipelago offers promising possibilities to achieve energy independence and security. However, geothermal development faces opposition from the Native Hawaiian community, stemming from Hawaiian cultural identity and beliefs that natural resources are akua (gods). Throughout Hawai'i's history Native Hawaiians have been marginalized in decision making processes, overlooking cultural implications of development. In this article we explore how to improve collaboration with Native Hawaiians to guide future geothermal energy development in Hawai'i. We conducted seven semi-structured interviews with individuals from three groups: (1) Native Hawaiians community members, (2) Native Hawaiian geothermal professionals, and (3) non-native geothermal professionals. Using a grounded theory approach, we discovered the interviews emphasized the status of geothermal development, feelings towards geothermal, perceived obstacles, knowledge gaps and recommendations to improve development. Interviews were manually transcribed and analyzed to identify similarities and differences in responses. Due to the limited number of interviews, our results are not statistically robust, but do offer insights for equitable culturally grounded geothermal energy development. Findings include six key themes. (1) Renewable energy is critical for Hawai'i's future sustainability. (2) The primary obstacles facing geothermal energy expansion are not cultural. The largest obstacles are regulatory and financial. (3) Reasons and opportunities to support Geothermal exploration and expansion exist. Geothermal provides Hawai'i a firm energy resource with a minimal ecological footprint. (4) Cultural implications surrounding geothermal are significant. (5) There is a need to rebuild collaboration and trust. Past developments failed to collaborate with local communities, destroying trust. (6) Opportunities to improve social / environmental justice and benefits for native/local communities forced to host green energy projects. Interview were then coded based on these overarching themes, extracting related text using Microsoft Excel. The information from this research allowed us to produce a narrative synthesis detailing areas of conflict and knowledge gaps and allowed us to create recommendations to improve collaboration between energy professionals and Native Hawaiians. This research has implications to guide potential green energy development in indigenous communities across the world.

KEYWORDS

geothermal energy, renewable energy, geothermal, energy, indigenous, native Hawaiian, Hawaii, collaboration

Introduction

Climate change is a growing threat with rising temperatures due to greenhouse gas emissions causing sea level rise, extreme weather events, and the spread of invasive species. The primary driver of climate change is the burning of fossil fuels. Global reliance on fossil fuels originated during the industrial revolution in the 18th century with exploitation of non-renewable energy sources such as coal, natural oil, and gas, increasing steadily over the last 300 years (Li, 2011). Escalating global energy consumption is related to improvements in quality of life, as a result of the industrialization of developing nations and the population increase in the world (Li, 2011). Reduction of greenhouse gasses to combat climate change is more than solely an environmental or engineering issue, with implications for equity, culture and social justice as well (Byers et al., 2018).

Fossil fuels currently supply 80% of global energy, though production of CO2 from the burning of fossil fuels is a major contributor to climate change (Welsby et al., 2021). In 2015, at the United Nations Global Climate Change Conference, the world's leaders agreed to the historic Paris Climate Accords. The Paris Accords set global goals, with 193 parties (192 countries and the European Union) signing the accords and agreeing to substantially reduce global greenhouse gas emissions to limit the global temperature increase in this century to 2 degrees Celsius while pursuing efforts to limit the increase even further to 1.5 degrees (The Paris Agreement, 2015). This agreement launched a global initiative to use green, renewable energy alternatives to meet the goals set by the Paris Agreement and mitigate the worst effects of climate change (Welsby et al., 2021).

Island nations and indigenous populations face elevated risk from the effects of climate change including rising sea levels, coastal erosion, and extreme weather events (Mcmillen et al., 2014). Hawai'i, the most isolated land mass on earth, relies heavily on fossil fuel imports to support its energy usage. Hawai'i has the highest oil dependency in the U.S., deriving nearly 90% of its primary energy resource from oil (Arent et al., 2009). In November of 2022, Hawai'i imported three million barrels of foreign crude oil (Department of Business, Economic Development and Tourism, 2023). The islands' lack of energy security and heavy reliance on imported fossil fuels, not only makes Hawai'i vulnerable to natural disasters which cut off imported food and energy supplies, but contributes to the very climate change impacts which threaten the archipelago. Hawai'i needs to shift away from fossil fuels towards renewable energy in order to protect the islands' future. In support of the 2008 Paris Accords, the Hawai'i Clean Energy initiative, supported by a diverse set of stakeholders and government agencies, led by the Hawai'i State Energy Office, set a deadline to become 100% powered by renewables by the year 2045.

Background

One significant renewable energy source found in the Hawaiian Islands is geothermal. Hawai'i's geographical location directly above a volcanic hotspot beneath the Pacific tectonic plate, makes it a prime location for geothermal energy. However, Kanaka Maoli, the native population and host culture of the Hawaiian Islands maintain strong cultural and spiritual ties to Hawai'i's volcanic resources. In Hawaiian culture, volcanic activity of the islands is the domain of Tūtū Pele, Hawaiian akua (goddess) of volcanoes and fire. Pele is also the creator of the Hawaiian Islands. Kanaka Maoli greatly respect and admire Tūtū (grandmother) Pele and often refer to lava itself as Tūtū Pele in a physical form. In fact, pele is the Hawaiian word for lava. Tūtū Pele is most often associated with Hawai'i's currently active volcano Kīlauea, which is located on Hawai'i Island. Hawai'i Island is the only island with an active volcano and therefore arguably can be expected to be the location with the majority of Hawai'i's geothermal resources, though the rest of the island chain is for the most part unexplored and there are indicators of the existence of geothermal resources. Due to the immense cultural and spiritual importance of volcanic energy, there is a need to improve Native Hawaiians' inclusion in decision making processes and the cultural considerations surrounding any geothermal research and development.

With the 2045 goal, Hawai'i must look to expand its renewable energy capital. Due to Hawai'i's geographical location, and volcanic formation, geothermal energy is a primary, yet controversial renewable energy candidate, due to the cultural significance of volcanic energy. Geothermal energy comes from volcanic subsurface magma stored beneath the Earth's surface. This underground heat source can be tapped into and used to heat water into steam to generate electricity. The harvesting of geothermal energy began in Hawai'i in 1976 when the first geothermal well was drilled in the Puna district of Hawai'i Island. This site hosts the only geothermal energy plant currently operating in Hawai'i, Puna Geothermal Venture (PGV). PGV is a 38-Megawatt binary-cycle power plant located on the Kīlauea East Rift Zone, which became commercially operational in 1993. In 2021, geothermal energy from PGV provided Hawai'i Island with 17.6% of its electricity needs. Prior to the Kīlauea eruption in 2018, geothermal energy from PGV provided an estimated 31% of the island's energy (Kun, 2022). Prior studies looking into Hawai'i's geothermal resources have found that other islands such as Maui, and to a lesser extent O'ahu, may have the necessary resources to support geothermal energy plants (Ito et al., 2017). The expansion of current geothermal energy capacity on Hawai'i Island as well as other islands can provide Hawai'i with a clean carbon free energy source. Geothermal energy expansions would also greatly help Hawai'i reach its 2045 renewable energy goal.

To date, much of the industrialization that has occurred in the Hawaiian Islands has been met with opposition from the Native Hawaiian community. More recently, the expansion and development of renewable energy systems across the islands continue to receive backlash and protests from Native Hawaiians and local residents alike. Since the 1970s, when geothermal energy in Hawai'i was proposed and research was being done, it was met with opposition from the Native Hawaiian community. Protests have been ongoing with different arguments and questions being raised throughout the years. In the 1990's, Native Hawaiians along with other Hawai'i Island residents protested against the expansion of PGV and its plans to drill new wells within Wao Kele O Puna Forest Reserve. Wao Kele O Puna is the largest remaining lowland rainforest in Hawai'i and home to some of Hawai'i's rare and endangered native flora and fauna. The protests in 1990 were primarily focused on the protection of the Hawaiian rainforest. However, other protest points arose, such as Native Hawaiians considering geothermal energy as the desecration of Pele and the health risks from hydrogen sulfide gas leaks that drilling for geothermal poses to the communities of Puna. Despite these

protests, the drilling of additional wells in Wao Kele O Puna continued and protests were overlooked. Since the 1990's, the most recent protests against PGV were in 2014, which were in response to hydrogen sulfide gas leaks from PGV in 2013 and 2014. These leaks affected the neighboring communities and resulted in community members being hospitalized, lawsuits, and EPA citing PGV for 14 safety violations (McNarie, 2018).

Throughout the history of Hawai'i, specifically after the overthrow of the Hawaiian Monarchy, Native Hawaiians have continuously been disregarded, silenced, and their needs pushed aside. When it comes to development, there has been little to no collaboration between Native Hawaiians and decision makers. There has also been little to no inclusion of Native Hawaiians in conversations of proposed policies and development projects (Keaulana et al., 2019). Hawaiian voices have been overlooked and silenced many times when they do not align with the views of the government and those in positions of power (Manuel-Sagon, 2020). These issues took the global stage with Native Hawaiian protests against the building of the Thirty Meter Telescope (TMT) atop Mauna Kea. Mauna Kea is one of the most sacred places in the Hawaiian Islands, and stands as a place of worship, an ancestor to Native Hawaiians, and a piko (umbilicus, or site of convergence) for the lāhui Hawai'i (Kahanamoku et al., 2020). Native Hawaiians have long opposed Mauna Kea's usage as a scientific astronomy center and the resulting desecration of the land such as building of roads, introduction of invasive species, abandonment of degraded and outdated buildings, and physical pollution (Rüland, 2024). However, despite a continued show of force with over 15,000 Native Hawaiias demonstrating their shared opposition through blockades to Mauna Kea and peaceful protests (Kahanamoku et al., 2020), government officials continue to look for ways to move along with the project (Saraf, 2020). These same issues are evident when it comes to renewable energy development in Hawai'i. Renewable energy technologies that utilize natural resources such as wind, solar, geothermal, and the oceans present issues due to these resources' cultural ties to indigenous ancestral forces and Akua (Hawaiian gods). Examples of this are the wind farm developments in Maui and Kahuku. These projects are evidence of the continued discrepancy of collaboration between Native Hawaiians and decision makers as these projects have continued to be streamlined despite continued opposition from local communities and Native Hawaiians. Similarly, since its introduction to Hawai'i, geothermal has been managed by the government and electrical corporations, such as Hawaiian Electric Industries, without quality collaboration with Native Hawaiians.

The geothermal research which has been done in Hawai'i is old with most studies being done between the 1990's and early 2000's. The most recent study, the Playfairway project (Lautze et al., 2017a,b; Ito et al., 2017; Lautze et al., 2020; in review) ended in 2020. There is a need for more research to evaluate obstacles and opportunities for geothermal energy in Hawai'i particularly given advances in technology for extraction and exploration. There is also a critical need to more fully understand cultural and community considerations related to geothermal energy in Hawai'i. How might Native Hawaiian communities guide geothermal development to ensure social justice and environmental sustainability?

The overarching question of this study is (1) How to improve collaboration between Native Hawaiians, policy makers, and industry professionals to guide the future of geothermal energy exploration in the Hawaiian Islands?

Our objectives are to: (1) identify the primary hurdles policy makers and energy professionals see facing geothermal energy exploration in Hawai'i and potential solutions, (2) identify key cultural and community concerns, along with recommendations Native Hawaiians have for geothermal and its possible expansion, and (3) provide stakeholders with recommendations on how to improve collaborative work with communities and Native Hawaiians for Hawai'i's energy future. This research stands to inform avenues for community collaboration, equity, and social justice in future renewable energy development in Hawai'i and across the world.

Methods

We, both authors of this article are Native Hawaiian scholars born and raised in the Hawaiian islands, with genealogical ties across the island chain and to both O'ahu and Hawai'i island where our study is centered. Neither of us has worked with or researched geothermal energy in the past. However, though raised two decades apart, we have both observed and grown up with the controversies surrounding geothermal energy in our islands throughout our lifetimes, watching demonstrations on the news, and hearing political debates and statements regarding green energy, both in support and opposition. The lead author on this paper aims to focus on green energy issues in Hawai'i as part of his career, and developed the focus of this research as part of his graduate studies.

Recruitment

For our project, we conducted semi-structured interviews with three groups of stakeholders (1) non-native energy professionals in the geothermal energy field, (2) Native Hawaiian energy professionals in the geothermal field, and (3) Native Hawaiian community members with connections to the geothermal conflict. It was important to our research team to engage Native Hawaiians who are known to oppose geothermal energy as well as those working within the industry. We started by reaching out to geothermal professionals affiliated with or working within the University of Hawai'i, as well as Native Hawaiians and other community members known for their involvement with geothermal issues, many of whom were identified in newspaper articles and reports. We asked these initial contacts and interviewees to refer others, using snowball sampling to continue to gather participants, on both the island of O'ahu and Hawai'i island where most geothermal energy, opposition, research and policy making are centered. For our interviews with energy professionals, we recruited participants who had experience and knowledge of the geothermal energy sector as well as the clean energy initiatives within Hawai'i. Recruitment of candidates was conducted by contacting agencies, identifying individuals of interest from agency websites, and snowball sampling. Interview participants were selected from Puna Geothermal Venture (PGV), Hawai'i Groundwater & Geothermal Resource Center (HGGRC) at UH Mānoa, Hawai'i State Energy Office as well as Sustainable Energy Hawai'i. We also identified Native Hawaiians currently working or having worked within the geothermal energy sector who could give the unique viewpoint of Native Hawaiians on both sides of the conflict.

For interviews with Native Hawaiians, we recruited individuals with personal and cultural ties to Hawai'i Island, those who have had first-hand experience in legal or community battles against PGV in the past, and Native Hawaiian community leaders who hold positions of power within their communities or the government. We also looked specifically into residents of Puna, which has a large Native Hawaiian population and have had to deal with the effects of PGV directly. These participants were selected and identified through research into public protests, activist movements, and through reaching out to known community leaders and to local organizations for their suggestions and to help make introductions where needed.

Hawai'i is a small community with a limited pool of individuals working with and engaged with geothermal energy. We were able to interview about half of the people identified through snowball sampling. Four individuals we approached directly declined to be interviewed, while a few others reached by other interviewees also declined, most likely due to the controversial nature of the topic. Our sample size was also constrained by the time duration of this study within the lead authors graduate studies.

Interviews

During this study, we conducted seven interviews, in person (4) and virtually (3) using the platform Zoom. As part of our research, we visited Hawai'i Island, where we were able to conduct the majority of our in-person interviews. We visited and toured PGV on Hawai'i Island and conducted our interviews with PGV employees in person and on site. We utilized zoom in order to reach multiple Hawai'i island interviewees who were not available on this trip and requested use of zoom for convenience in scheduling. All O'ahu island interviews were conducted in person. Zoom interviews did not differ from those conducted in person on either island, in length of interview, depth of responses or engagement by interviewees.

Our interview questions (Supplementary Table S1) included both overarching questions that could be answered by all candidates, as well as specific questions directed to Native Hawaiian or energy professional participants. After asking for participants' consent, I, the lead author, was able to audio record all but one interview. We then took the audio recordings and notes from our interviews and transcribed them using a transcription service Otter.ai. All transcriptions were reviewed twice by the lead author to ensure accuracy, especially for Native Hawaiian words not captured by Otter.ai (see Tables 1, 2).

Content analysis

Once we had conducted and transcribed our interviews, we analyzed all seven using a grounded theory approach (Khan, 2014). We reviewed each interview transcript, identified key themes emerging throughout, and created an overarching list of themes across all interviews. We then coded each interview based on this overarching theme list, extracting text related to each theme, using Microsoft Excel. This content analysis also allowed us to identify how the Native Hawaiian interviewees' views agreed or disagreed with the non-Hawaiians groups. The information and knowledge collected from these interviews and content analyses has allowed us to produce a narrative synthesis detailing areas of conflict and current knowledge gaps, along with opportunities to improve collaboration between energy professionals and the Native Hawaiian community.

Results

After conducting our interviews and content analysis, we were able to identify six major themes that were evident across multiple interviews. The first three themes identified, focus around geothermal energy and its current status in Hawai'i.

1. Renewable energy is critical to help Hawai'i's future sustainability.
2. The primary obstacles facing geothermal energy expansion are not cultural.
3. Reasons and opportunities to support Geothermal exploration and expansion exist.

The final three themes that were identified focus on the importance of collaboration and the cultural and community implications surrounding geothermal energy.

4. Cultural implications surrounding geothermal are significant.
5. There is a need to rebuild collaboration and trust.
6. Opportunities to improve social / environmental justice and benefits for native/local communities forced to host green energy projects.

Each theme is described below with representative quotes and examples.

The following table provide a visual representation of themes across interviews.

TABLE 1 Breakdown of interview participants.

Participants (7)	Male/female (4/3)	Hawaiian (4)	Industry professional (5)	Where do they live?
Interviewee 1	Female	No	Yes	Oahu
Interviewee 2	Male	Yes	Yes	Hilo
Interviewee 3	Male	No	Yes	Hilo
Interviewee 4	Female	Yes	No	Hilo
Interviewee 5	Female	Yes	No	Kona
Interviewee 6	Male	Yes	Yes	Hilo
Interviewee 7	Male	No	Yes	Oahu

TABLE 2 Identifying how many members of a participant group talked about each theme and how many times each theme was mentioned.

Themes	Non-natives in geothermal (3) (participants/mentions)	Native Hawaiians in geothermal (2) (participants/mentions)	Native Hawaiian community members (2) (participants/mentions)
Renewable energy is critical to help Hawai'i's future sustainability.	3/9	2/4	2/2
Primary obstacles facing geothermal energy expansion	2/5	2/2	0/0
Reasons and opportunities to support Geothermal exploration and expansion	3/5	2/4	0/0
Cultural implications surrounding geothermal are significant	2/4	2/5	2/9
Need to rebuild collaboration and trust	1/3	2/3	2/7
Opportunities to improve social/environmental justice and benefits for native/local communities forced to host green energy projects	0/0	1/1	2/4

Renewable energy is critical to help Hawai'i's future sustainability

Every participant interviewed agreed upon the need for Hawai'i to shift away from fossil fuels and towards renewable, green energy sources, however interviewees expressed varied opinions on how to achieve this shift. A wide range of renewable energy sources identified by interviewees include geothermal, solar, wind, nuclear, and hydrogen power. All renewable energy options come with specific pros and cons, especially ones specific to an island environment like Hawai'i. Some of the most popular and well-known renewables here in Hawai'i are solar and wind, but the feasibility of those two energy sources providing Hawai'i with its energy needs is unclear. While the common consensus among those within the energy sector is that geothermal is an abundant and unique resource to Hawai'i that can support the state's energy needs.

- *"In my opinion. The only options are geothermal or nuclear" (Interviewee 1).*
- *"The green energy transition is something being imposed on us, not just because of climate change but because the fossil fuels that we have been using aren't abundant enough or affordable enough to continue the way we are living." (Interviewee 3).*
- *"Renewable energy and sustainability, are very much indigenous practice, but it has to be done in a way that is in harmony with environmental processes and Aina" (Interviewee 4).*
- *"I do see the value in geothermal. You just have to find the right balance with traditional beliefs and modern concepts" (Interviewee 6).*

Primary obstacles facing geothermal energy expansion are not cultural

It was clear across interviews with energy professionals that currently, the biggest obstacles facing geothermal are project funding and government support. To date there has been little to no funding for different geothermal exploratory entities in Hawai'i from both the state and federal levels.

- *"There's no funding right now to do anything and I've now talked to some developers… developers are less interested in Hawai'i" (Interviewee 1).*

Puna Geothermal Venture (PGV) experienced decreased funding following the 2018 Kilauea eruption, which caused damage to the PGV plant. However, PGV recently received funding to expand and ramp up to 46 megawatts of power for Hawai'i Island. However, geothermal does have high upfront costs as opposed to other renewables.

- *"It's expensive. To do anything in the field and trying to understand the subsurface, what's pretty deep beneath our feet is costly." (Interviewee 1).*

Lack of government support is a major obstacle due to the volume of current regulations in place and difficult permitting processes, which are prohibitive for both foreign and local developers pursuing geothermal exploration.

- *"Developers are less interested in Hawai'i because of our regulations. If you call it geothermal exploration it triggers a whole bunch of processes that you have to go through" (Interviewee 1).*
- *"I would say the biggest obstacle is regulatory. It's the government" (Interviewee 3).*
- *"It's the permitting process and the EIS process. Its the regulatory environment, which also governs how the business would operate" (Interviewee 3).*

Additionally, a key obstacle that was identified by interviewees included educational outreach to improve on the current knowledge gaps and misinformation surrounding geothermal.

- *"Educational outreach is something I think everyone's well aware needs to be addressed…. That to me, that's the biggest obstacle" (Interviewee 2).*

Specific knowledge gaps named by interviewees include perceived risks associated with geothermal such as gas leaks if plants are damaged due to earthquakes or eruptions. Pro geothermal interviewees stated that perceptions of these risks are due to misunderstanding of the processes involved in geothermal energy production. Native Hawaiian interviewees not working in the geothermal sector made it clear that they were not experts on the topic but cited safety risks they had heard of, while also being interested to

learn more about production processes and the actual associated safety hazards.

Reasons and opportunities to support geothermal exploration and expansion exist

The biggest reason for support of geothermal energy in Hawai'i throughout our interviews was that Hawai'i's geothermal resources could provide the islands with a firm energy resource that can be tapped into and utilized for years. A firm energy resource is one that is available twenty four hours a day, seven days a week, independent of intermittent/ changing weather conditions like wind and solar energy. Geothermal energy also has the smallest ecological footprint among renewable energy options, meaning less area is required to produce a given amount of energy, which is important with Hawai'i's limited availability of land. Also each of the main Hawaiian islands could potentially produce its own geothermal energy. Some interviewees emphasized the uniqueness and cultural significance of geothermal resources they felt should be viewed as a gift from the Akua (Gods) that can be utilized for the betterment of Hawai'i's people.

- "*Geothermal is a firm dispatchable energy resource and indigenous that's available 24/7. Compared to solar with batteries that's only available when the sun is shining, hydro whenever the rivers running, and wind whenever the winds blowing." (Interviewee 2).*
- *"Those are all great resources, and we support that 100%, but when you just look at the technical aspects. We like wind, solar, hydro, but we love geothermal" (Interviewee 2).*
- "*Geothermal, it's firm baseload so it's not intermittent. It has the smallest footprint. In an island nation where we do not have a lot of space… on 10% of the land, you get five times as much electricity… I compare PGV to a Waianae solar farm, and it was 20% of the land, you get five times as much electricity." (Interviewee 1).*

Cultural implications surrounding geothermal are significant

Five interviewees described how Hawai'i's geothermal resources are deeply tied to the akua Pele, representing her in physical and elemental forms. There are numerous oli Pele (chants) which speak to the kapu (sacredness) and kanawai (laws) of Pele. Kanawai Pele were enacted so that the population at large knew how to approach that which was kapu and behave accordingly. Certain oli pele and kanawai state that any land exhibiting volcanic activity via steam, sulfur, earthquakes, vents, etc. is part of Pele's domain and therefore kapu (Kanahele). Native Hawaiian culture and law prohibit engaging in activities in a volcanically active area. In this understanding, geothermal drilling trespasses on the kanawai (Kanahele). Interviewees also emphasized the need for fuller understanding of how resources are connected, especially when drilling into unseen realms of 'āina. Considering our ecosystems holistically, what potentailly unknown harms could occur to our island ecosystems due to geothermal energy processes.

- *"It's one of those things knowing the sacredness and the importance of the realm It delves into. It makes me nervous that we are messing with things that maybe should not be. All these realms of darkness or underground… those are kapu areas you want to have the highest respect for" (Interviewee 4).*
- *"You do not want to take the essence of that element. I'm anti geothermal energy only because you are messing with the akua. We have several chants that tell us that the akua are kapu, and you should not go digging around for it." (Interviewee 5).*

There is a need to rebuild collaboration and trust

All interviewees articulated the need to rebuilding collaboration and trust lost due to past developments, including early geothermal projects, failing to include indigenous communities, acknowledge their concerns, and respect local and cultural knowledge. Community engagement and collaboration are vital along with strong relationships and trust in order for any geothermal research or development in Hawai'i to be successful. Native Hawaiians respected by their communities, with knowledge of affected areas and resources need to be at the forefront of decision-making processes for proposed projects.

- *"Trauma from (the overthrow and) settler colonialism is never ending …. it does not go away. So when you see others coming in and being like, "This is what you need, this is what's good for you." Telling instead of asking, (not) recognizing that the people of the place have knowledge and understanding." (Interviewee 4).*
- *"You might understand the energy processes, but you do not understand this place and the people and the(ir) needs." (Interviewee 4).*
- *"There's no consultation with Native Hawaiians to let them know, Hey, this is what we are proposing. There could be cultural concerns, environmental concerns, so you have to do that consultation and outreach."(Interviewee 6).*
- *"For any forward movement, recognizing community involvement is critical… I do not think that there's going to be any push to move forward without community and indigenous involvement" (Interviewee 3).*

Opportunities to improve social/ environmental justice and benefits for native/local communities forced to host green energy projects

Most Interviewees expressed that developers and researchers need to understand the physical, emotional, and spiritual costs and harms that are forced upon indigenous communities when large renewable energy or other projects are developed in their home areas. Interviewees suggested that geothermal research and development needs to benefit communities in multiple ways including financial opportunities, job opportunities and training, and increased community engagement. Benefits like these along with sustainable and culturally sensitive practices can massively improve the current

relationships local communities have with outside corporations and developers.

- *"It's one of those things that makes me nervous because Puna has a greater native Hawaiian population than other places. So already, we have environmental justice issues when we think about the population of the area" (Interviewee 4).*
- *"If you correlate it with water. Every time there's a water shortage the locals have to conserve water but the hotels and the golf courses do not. Is that gonna happen if something's wrong with geothermal? Then locals do not have energy but we can still power the hotels?" (Interviewee 5).*
- *"That's part of the problem, Hawaiians are always getting dumped on in our own Land" (Interviewee 5).*

Discussion

Globally, geothermal has become a growing industry in countries including Canada, Iceland, Japan, Aotearoa (New Zealand), Kenya and Indonesia, all countries utilizing their geothermal resources, while seeking balance in addressing cultural concerns. In 2019, geothermal produced 13,900 megawatts of energy globally (Avci et al., 2020). In British Columbia (BC) Canada, most geothermal resources reside within traditional territories of the indigenous First Nations people. Development requires consultation with native groups and social impact assessments to identify and mitigate potential infringements on First Nations rights and impacts on sacred sites (Kunkel et al., 2012). In BC, geothermal is promoted as a indigenous resource with First Nations' interests utilized to ensure geothermal energy development is sustainable and can provide economic and social benefits for indigenous communities (Kunkel et al., 2012). Similarly, in Aotearoa, the majority of the geothermal resources are located on tribal lands, allowing for development and management of their resources to be culturally sensitive and beneficial to the indigenous communities (Bargh, 2012). Both these countries provide examples of how the world can move towards green energy to address climate change and the need for sustainability in a way that is collaborative and just for indigenous peoples.

In this research, we interviewed five professionals working in geothermal in Hawai'i, both Native Hawaiian and non-Hawaiian, along with two Native Hawaiian community practitioners and leaders from impacted areas. We found strong commonality in the desire for Hawai'i to expand on green energy developments and become more sustainable despite a long history of controversy surrounding geothermal energy in the islands. In this study we aimed to elucidate current cultural and community concerns related to geothermal and derive recommendations for how geothermal expansion in Hawai'i might proceed in a way that achieves community collaboration, equity, and social justice. In this section we will tie these recommendations to global examples to illuminate their potential broader relevance. Due to the limited number of interviews in this study, our results and recommendations are not generalizable or statistically robust. However, they do offer insights and pathways that may offer possibilities for equitable and culturally grounded geothermal energy development in Hawai'i, and some considerations that may be of use in other parts of the world and with other forms of geothermal energy as well.

Recommendations

Address legacy of unjust geothermal development

We found that geothermal development in Hawaii historically has failed to collaborate with indigenous and local communities and to respect their cultural concerns. Similar negative legacies exist elsewhere in the world for example in Kenya where the Olkaria geothermal project has negatively affected the Maasai and Kikuyu people. Despite developers' promises of employment opportunities, the local communities have faced displacement, environmental degradation, and cultural disruption due to the developers of these power plants operating as if they are above the law (Koissaba, 2017). Community members emphasized how developers and the government continuously abused their power and failed to meet terms of past agreements with the communities. Current development processes are oftentimes centered on western ideals rooted in colonialism that have negative effects upon marginalized groups, such as our indigenous communities around the globe (Keaulana et al., 2019). Processes centered around indigenous communities and grounded culturally are necessary to achieve meaningful participation and engagement in development. These processes create more equitable protocols and ensure beneficial outcomes for both the host communities and the developers (Keaulana et al., 2019).

Prioritize development outside of culturally sensitive and vulnerable volcanic areas

Multiple interviewees expressed concerns about drilling in active volcanic areas and the potential impacts of the health of people and the environment. Some concerns expressed included the potential risks of hydrogen sulfide gas leaks in areas vulnerable to weather events and volcanic activity as when Puna Geothermal Venture was damaged during the 2018 Kīlauea eruption. Hawai'i's available geothermal resources are not confined to Puna, and have been previously mapped (Ito et al., 2017; Lautze et al., 2020; in review) on other parts of Hawai'i island and other islands. To achieve energy independence with geothermal requires further research into the viability of development in sites statewide. Current drilling and research outside of PGV is only being done by Hawaii Groundwater and Geothermal Resource Center on the island of Lanai with other research interests coming from the Department of Hawaiian Homelands to investigate geothermal resource availability on their lands. This recommendation did not emerge in other global case studies perhaps because many global geothermal resources are connected to older volcanic geologies that are not actively erupting. However, it is still worthwhile to prioritize geothermal exploration and development outside of the most culturally and ecologically sensitive areas.

Protect communities affected by development

Communities negatively affected by developments need to be protected and receive benefits to offset the potential social, spiritual, environmental, and economic risks or harms. Communities can receive direct energy benefits from geothermal development through means of lower electrical costs and energy produced by plants going directly into the community grid. Development also provides opportunities for jobs, education, and skill training. Geothermal companies should emphasize training skills instead of importing

them. Local residents should be given the first opportunities to work and manage geothermal plants. In Aotearoa (New Zealand), Maori control the majority of geothermal developments through tribal land trusts and indigenous organizations giving Maori control over management, employing their native communities (Bargh, 2012). In Hawai'i, the development on lands controlled by the Department of Hawaiian Homelands provides opportunities for Native Hawaiians and Native Hawaiian organizations to control and manage geothermal energy plants. However, development has to be in balance with ecology and justice with communities having a choice in development. Projects should never be forced upon communities even if there are clear benefits.

Globally geothermal development has offered varied beneficial opportunities for local communities. In Canada geothermal energy has supported sustainable food production in remote northern communities faced with challenges like food security and energy supply (Kinney et al., 2019). Leveraging geothermal resources for heating greenhouses and supporting aquaculture, communities can produce food locally, reducing dependence on expensive imports and fossil fuels. Geothermal heating of greenhouses is also being used in Australia, Iran, Tunisia, Japan and across Europe (Kinney et al., 2019). In Iceland geothermal resources have been tapped into and utilized for electricity, hot springs, snow melting, and heating purposes (Shortall and Kharrazi, 2017). Geothermal resource utilization can provide affected communities with a range of beneficial opportunities outside of financial gains and energy supply.

Recognize indigenous and community knowledge as expert knowledge

Future geothermal development needs to realize that community knowledge is expert knowledge. Native Hawaiian cultural knowledge, especially place based knowledge has been built over generations. Cultural practitioners and long time community members perpetuate traditional knowledge of their resources and the natural environment. This knowledge and understanding should guide development to improve the overall success of geothermal drilling, development, and sustainability. The state government must also accept the cultural knowledge of our communities as fact instead of continuing to allow the cultural bias in western regulatory and legal decision making. Traditional kanawais provide frameworks that can guide geothermal in Hawai'i. The kai'okia kanawai states that any land exhibiting volcanic activity is kapu to pele and should not be interacted with (Kanahele). With this in mind geothermal development in accordance with kanawai would not interfere with the natural lava flows, it would allow for natural regeneration of our landscapes to occur, and development would stay clear of our active volcanic zones (see recommendation 2).

Iceland and Japan are two leading nations in geothermal energy production where cultural values and traditions have guided development of their geothermal resources. In 2017, Iceland produced 665 MW and Japan produced 519 MW of electricity from their respective geothermal plants (Shortall and Kharrazi, 2017). Japan and Iceland both have strong host cultures valuing harmony with nature and environmental preservation. However, the approach to geothermal development and the cultural views on geothermal development in each nation differs. This history has driven geothermal development across Iceland and provided development with support of local communities. Japan has seen a slower, more cautious approach to geothermal development. Much of Japan's geothermal resources are in or around national parks and natural hot springs. Opposition to the development of geothermal resources for electricity is strong from hot spring owners and local governments. Fearing the depletion of geothermal resources may cause the extinction of natural geysers and hot springs, causing irreversible damage to Japan's culturally sensitive natural sites (Shortall and Kharrazi, 2017).

Appoint decision makers from local and indigenous communities

Having the right people in the correct positions to make positive change is key to achieving acknowledgement and acceptance of community knowledge. Native Hawaiians need to be at the forefront of these developments, having positions with ability to make change when necessary. However, being Native Hawaiian does not necessarily make someone an expert on place, needs, or resources. Individuals must be respected members of the community and experts in areas affected by geothermal development. Appointing the right individuals can greatly improve collaboration between developers and Local communities so that communities are not adversely affected by development like in the case of the Olkaria geothermal project in Kenya. Effective stakeholder engagement is necessary in planning and decision-making regarding projects, which could significantly affect local communities. Ineffective stakeholder engagement leads to adverse impacts and infringements of human rights (Koissaba, 2017).

The Hawaiian Islands are the most isolated inhabited land mass on the planet. Therefore, Hawai'i transitioning away from fossil fuels would set an example for how a closed system can gain energy independence. Through energy independence, Hawai'i would not need to worry about the volatility of fossil fuel prices. It would also give Hawai'i energy security to combat natural disasters and events that would isolate it from the continental U.S. which are an increased risk due to climate change. Despite Hawai'i being a small-scale system, by achieving the 2045 Hawai'i Clean Energy Initiative and becoming 100% renewable. Hawai'i can be a leader in climate change resilience on the energy level by looking inwards for energy needs. Hawai'i can become an image of hope for other Island nations around the globe in their fight against fossil fuel reliance.

If Geothermal is going to play a major role in Hawai'i and the planet's green energy future then we need to look inward, guided by native communities' ideas and voices. Through each of the recommendations outlined above, we move closer to rebuilding the trust which has been broken over generations, building a more collaborative and culturally sensitive future. Examples of culturally sensitive green energy and geothermal initiatives are abundant globally with the First Nations people of British Columbia and the Māori of Aotearoa showing possible pathways for other indigenous and local communities as well.

We end with a focus on the case of geothermal energy in Aotearoa because it provides a strong comparison with Hawai'i. Aotearoa is also an island nation, home to a strong native Pacific Islander people, the Māori. There is a lot that connects the Native Hawaiian and the Māori people. Both groups have similar historical origins as people who migrated to our island homelands by wa'a/waka (Canoe), some Māori actually say they come from Hawai'i (Hawaiki). We are both Polynesian peoples, with shared cosmologies and related pantheons of Gods and Goddesses, and more recent experiences of colonization and marginalization by occupying western powers. We both also share deep cultural connections to our island's geothermal resources. Similar to Hawaiian culture where geothermal resources are regarded as kapu and tied to the mythology of Pele, Māori also have stories of the genesis of

Aotearoa's geothermal resources and their connection to the Māori people.

Māori credit their ancestor Ngātoroirangi with bringing geothermal energy to Aotearoa. When Ngātoroirangi arrived in Aotearoa and climbed to the summit of Mt. Tongariro he called to his sisters in Hawaiki for warmth, his sisters sent the embers of Ruamoko and geothermal fluid to warm Aotearoa. Since that time Māori living in the north island have used geothermal energy for economic, political, and social purposes (Bargh, 2012). Rotorua, in the Central North Island, has been the most prominent location for geothermal activity with its visible hot mud pools, geysers, and its strong smell of sulfur. While Māori have utilized geothermal resources for generations, Native Hawaiians have held a much more hands off relationship claiming volcanic energy sources to be kapu and off limits to people.

In Aotearoa, Māori Tribal Land Trusts and Corporations are at the forefront of geothermal energy production, with the majority of Aotearoa's geothermal resources situated on Māori land (Bargh, 2012). Māori are at the forefront of utilization of geothermal energy in Aotearoa as developers, operators, and shareholders (Richter, 2021). Maori's possess greater political sovereignty than native Hawaiians, including tribal self governance and treaties recognizing tribal claims to geothermal resources. Therefore they have more authority to guide geothermal development in culturally appropriate ways that protect people, land and resources (Eru and Lovell, 2021). Māori geothermal developers emphasize increased financial return to shareholders, preservation of land, cultural enhancement, and the education and skill training of their own people (Eru and Lovell, 2021).

Māori historical relationships with their geothermal resources, along with their ability to self-govern within their country provides avenues not currently open to Native Hawaiians. However, the Māori experience highlights the need for Native Hawaiians to lead new industries coming to our islands such as green energy. Native Hawaiians need to be recognized as knowledge holders, decision makers and managers instead of just consulting parties. In order for local and indigenous communities to truly guide sustainable and just green energy development, they need to retain sovereignty and decision making authority within their ancestral homelands.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Office of Research Compliance University of Hawaii at Manoa. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

NK: Writing – original draft, Writing – review & editing. MV: Writing – review & editing.

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The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/frsus.2024.1443407/full#supplementary-material

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