The Future of Energy in Hawai‘i:

Conversations on Culture, Community, and the Role of Geothermal

Faith Martinez Smith, Clayton Pokorny, Katie McMahon, Estefanny Davalos Elizondo, and Kelly MacGregor

National Renewable Energy Laboratory

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
Operated under Contract No. DE-AC36-08GO28308

This report is available at no cost from NREL at www.nrel.gov/publications.

Technical Report
NREL/TP-6A20-92819
September 2025

The Future of Energy in Hawai‘i:

Conversations on Culture, Community, and the Role of Geothermal

Faith Martinez Smith, Clayton Pokorny, Katie McMahon, Estefanny Davalos Elizondo, and Kelly MacGregor

National Renewable Energy Laboratory

Suggested Citation
Smith, Faith Martinez, Clayton Pokorny, Katie McMahon, Estefanny Davalos Elizondo, and Kelly MacGregor. 2025. *The Future of Energy in Hawai‘i: Conversations on Culture, Community, and the Role of Geothermal.* Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-92819. https://www.nrel.gov/docs/fy25osti/92819.pdf.

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
Operated under Contract No. DE-AC36-08GO28308

This report is available at no cost from NREL at www.nrel.gov/publications.

Technical Report
NREL/TP-6A20-92819
September 2025

15013 Denver West Parkway
Golden, CO 80401
303-275-3000 • www.nrel.gov

NOTICE

This work was authored by NREL for the U.S. Department of Energy (DOE), operated under Contract No. DE-AC36-08GO28308. Funding provided by the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Geothermal Technologies Office. The views expressed herein do not necessarily represent the views of the DOE or the U.S. Government.

Acknowledgments

The authors of this report are grateful for funding from the U.S. Department of Energy Geothermal Technologies Office. We specifically thank the following for their time and expertise: Elisabet Metcalfe, Coryne Tasca, and Lauren Boyd. The authors thank the following National Renewable Energy Laboratory (NREL) staff for their review and edits: Amanda Kolker, Jeff Cook, Dan Bilello, Whitney Trainor-Guitton, Sophie-Min Thomson, and Deanna Cook from the NREL Communications team. We are also incredibly grateful for the support and guidance from the effort's Community Council members: Patrick Branco, Michael Colón, Dr. Brian DeSanti II, Mike Kaleikini, Russell Kaupu, Ron Kodani, Dr. Nicole Lautze, Phil Nigro, Peter Sternlicht, Mililani Trask, and Jennifer Zelko-Schlueter. This report would not be possible without the 100+ individuals who attended the eight Listening Sessions across the Hawaiian Islands in 2024—thank you to all attendees for sharing your perspectives and for taking the time to attend. In addition, the authors extend warm thankfulness and aloha to Michael Colón, Russell Kaupu, Peter Sternlicht, and Dr. Brian DeSanti II for their review.

List of Acronyms and Abbreviations

BESS	battery energy storage systems
CC	Community Council
DC	direct current
DHHL	Department of Hawaiian Home Lands
DOE	U.S. Department of Energy
EGS	enhanced geothermal systems
FY	fiscal year
GSHE	ground-source heat exchangers
GTO	Geothermal Technologies Office
GWh	gigawatt hours
HCEI	Hawai‘i Clean Energy Initiative
HELCO	Hawaiian Electric and Light Company
HECO	Hawaiian Electric Company
HGP-A	Hawai‘i Geothermal Project Abbott
KIUC	Kaua‘i Island Utility Cooperative
MECO	Maui Electric Company
MOU	Memorandum of Understanding
MW	megawatt
MWh	megawatt hours
NGO	non-governmental organization
NREL	National Renewable Energy Laboratory
PDF	Pele Defense Fund
PFA	play fairway analysis
PGV	Puna Geothermal Venture
USGS	United States Geological Survey

Executive Summary

Beginning in 2023, the National Renewable Energy Laboratory (NREL), with funding from the U.S. Department of Energy (DOE) Geothermal Technologies Office (GTO), began an effort to hear perspectives of communities in Hawai‘i regarding geothermal energy. In the context of this effort, communities refers to those living in various locations in the State of Hawai‘i, not necessarily inclusive of living in the same location nor with specific characteristics in mind. These engagement efforts are summarized in this report and were inspired by the *GeoVision* analysis and the *GeoVision* Roadmap (Roadmap).

The 2018 DOE *GeoVision* analysis examined geothermal energy in multiple sectors. Following this analysis, the *GeoVision* Roadmap was created, which built on items identified within the analysis as areas to improve stakeholder engagement with the goal of understanding why geothermal energy development was not occurring more broadly, to provide educational resources to areas where development could occur, and to help foster interest and development of all geothermal technologies.

Given the desire to better understand community and cultural perspectives regarding geothermal, GTO began by developing an outreach methodology one state at a time. Alaska and Hawai‘i were identified as states of interest for engagement efforts, as both states have historically been excluded from the United States Geologic Survey (USGS) geothermal resource assessments and mapping. This is partly due to the paucity of geothermal data and resource information in those states, which both appear to have high geothermal potential, and partly due to unique energy landscapes in Alaska and Hawai‘i. With these considerations in mind, GTO funded NREL to lead state-level engagement and educational outreach efforts starting with Alaska and then moving to Hawai‘i.

Engagement efforts began in Alaska in Fiscal Year 2022 (FY22). In Alaska, the NREL team coordinated closely with existing regional NREL and/or DOE partners in addition to well-connected, energy-focused community organizations to provide virtual engagement and educational opportunities. These efforts were primarily virtual due to the COVID-19 pandemic.

The NREL project team spent 10 months conducting background research on geothermal and cultural perspectives in Hawai‘i. This included historical context, meeting with Native Hawaiian cultural practitioners, meeting with state-level energy and environmental experts, and engaging with well-respected community members with years of experience in geothermal historical and cultural sensitivities in Hawai‘i. The NREL project team worked closely with the NREL State, Local, and Tribal Governments Team to develop a replicable engagement plan for the Hawai‘i-based engagement efforts. As part of this plan, the NREL project team reviewed the methodology used in the Alaska-based efforts to grow and improve efforts in Hawai‘i. Upon consultation with the State, Local, and Tribal Governments Team, the NREL project team moved forward with the following approach:

1. Identification of potential energy stakeholders in Hawai‘i, with input from the Director of the Hawai‘i Groundwater and Geothermal Resources Center

2. Creation of a Community Council representing a broad array of Hawai‘i-based organizations and perspectives

3. Coordination and partnership with Community Council members and their respected organizations and/or agencies

4. Engagement planning with Community Council members (in-person and virtual)

5. Engagement planning with identified stakeholders and interested parties

Community Council members were identified and invited after a series of discussions held by GTO, NREL, and engagement with relevant stakeholders based on their expertise and experience within the energy/environment space, or for those working with Native Hawaiians. The Community Council was meant to bring together a diverse set of actors to represent the broader Hawai‘i community to aid in the development of the effort's stakeholder engagement efforts through in-person Listening Sessions. The breakdown of the proposed membership structure of Community Council members was as follows:

Table ES-1. Membership Structure of Community Council

Member Type	Number of Members
State agencies (e.g., Department of Land and Natural Resources, State Energy Office, etc.)	Up to three
Representatives of Native Hawaiians (e.g., Department of Hawaiian Home Lands, Office of Hawaiian Affairs, Aha Moku Advisory Committee, Kua'aina Ulu 'Auamo, etc.)	Up to three
Non-governmental organizations	Up to three
Existing geothermal development interests	Up to two
Electric utility and public utilities commission	Up to three
Relevant geothermal experts and/or consultants	Up to two

The NREL project team planned and coordinated all in-person engagement efforts, conceived as Listening Sessions with the Community Council members. The in-person engagement included eight Listening Sessions on three Hawaiian Islands – O‘ahu, Maui, and Hawai‘i. Locations were selected in counsel with the Community Council members based on population, potential interest from communities, potential geothermal resource availability, and energy demand. Table ES-2 provides a high-level summary of what was heard at the in-person Listening Sessions; all Listening Sessions included discussions on the full suite of geothermal energy technologies and applications. Immediately following Table ES-2, NREL's summaries of Barriers and Opportunities for geothermal energy development have been included based on Listening Session conversations. Each of the Listening Sessions is illustrated in greater detail in Sections 6.1–6.4 with individual conversations documented in Section 6.5.

Table ES-2. Summary of Listening Sessions

Six Key Areas of Consideration	Oʻahu	Maui	West Hawaiʻi (Kona Side)	East Hawaiʻi (Hilo Side)
Health and Monitoring	- Concerns about poor air quality and toxic sulfur dioxide. - Community distrust due to lack of engagement, prior "rubber stamping."	- Minimal geothermal health impacts discussed due to a focus on wildfire recovery, resilience, and Hawaiian Electric customer safety.	- Concerns over chemical leaks into groundwater systems. - Air quality threats from existing fossil fuel generation were noted.	- Fears of hydrogen sulfide gas release during extreme events. - Belief that the area already has too many hazards for geothermal.
Cultural and Religious Sensitivities	- Importance of early engagement with the community. - Participants emphasized that there are mixed opinions within communities in the State of Hawaiʻi on *any* development.	- Drilling into the land or Earth, referred to as ʻĀina, anywhere may face resistance. - Suggestion to use existing wells to minimize new cultural issues.	- Stress and trauma linked to previous geothermal development in Puna. - Calls for respecting Pele and traditional Hawaiian beliefs.	- Emphasis on responsibility, referred to as kuleana to the land or Earth, referred to as ʻĀina. - Support for acknowledging cultural traditions before moving forward with projects.
Climate Considerations and Energy Resources	- Interest in reducing oil imports and addressing solar/wind intermittency. - Concerns about job losses in Hawaiian fossil fuel sectors.	- Concerns about solar and wind intermittency. - Interest in education on geothermal potential to reduce emissions.	- Questions about environmental impacts of so-called "clean" energy sources. - Interest in using hydrogen for energy storage and transportation.	- Need for local energy independence and resilience given Hawaiʻi's isolation emphasized. - Concerns about the disposal of renewable energy technologies and associated waste.
Economic and Financial Policy Implications	- High electricity costs for residents across the islands. - Hope for local jobs and energy burden reduction through new geothermal.	- High Hawaiian Electric utility rates drive curiosity about geothermal's potential for cost reduction. - Calls for clarity on financial investment needed for geothermal projects.	- Interest in lowering energy costs locally but not subsidizing other islands' energy. - Frustration over grid improvements not benefiting residents directly.	- High reliance on imported fuel increases costs for Hawaiian Electric consumers. - Department of Hawaiian Home Lands (DHHL) geothermal projects could offer economic co-benefits to Native Hawaiians.
Native Hawaiian Considerations	- Historical exclusion of Native Hawaiians in development processes. - Need for proactive community engagement to build trust.	- Education and outreach needed directly in Native Hawaiian communities to share geothermal's potential benefits.	- Skepticism and optimism over DHHL's role in geothermal development. - Concerns about other stressors for Native Hawaiians like cost of living, healthcare, and agriculture challenges.	- Support for DHHL geothermal projects that benefit Native Hawaiians directly. - Desire for high-quality jobs to retain and attract younger generations of Hawaiians.
Environmental Impact and Eruption Concerns	- Concerns about Puna Geothermal Venture (PGV) compliance with environmental policies. - Risks of triggering volcanic explosions.	- Concerns about pumping triggering earthquakes. - Negative comparisons to fracking.	- Need for more education about geothermal environmental impacts. - Frustration with reinjection practices in	- Serious reservations about further deforestation and sulfur gas emissions. - Some cynicism about the environmental "cleanliness" of

Six Key Areas of Consideration	O‘ahu	Maui	West Hawai‘i (Kona Side)	East Hawai‘i (Hilo Side)
	through geothermal reinjection activities.		volcanically active regions.	renewable energy sources.
Other Considerations	- Importance of clear, community-rooted development efforts that avoid overburdening community representatives.	- Challenges in balancing wildfire recovery with renewable energy planning. - Interest in long-term energy storage to combat renewables’ intermittency.	- Call for energy projects that prioritize local benefits. - There may be opportunities to learn from past mistakes with geothermal on East Hawai‘i.	- Need for stronger legal protection for communities and better accountability by developers. - Overwhelming need for education about geothermal and energy technologies in general.

Barriers to Geothermal – All Islands, as Explained in Listening Sessions

- Despite previous University of Hawai‘i research, attendees suggested there was still uncertainty about the geothermal potential on different islands and calls, emphasizing a need for subsurface drilling to inform the cost and profitability of future installations. Limited knowledge about the different uses of geothermal (utility-scale generation, single home heating, district heating, etc.) and few Hawai‘i-based pilot projects make the technology seem inaccessible and risky.

- Participants emphasized that communities in the State of Hawai‘i may be wary of any and all drilling into the land or Earth, referred to as ‘Āina, deemed unnecessary. Attendees expressed concerns that future geothermal power will disrespect Pele, snub traditional cultural beliefs, and not provide local benefits (i.e., reductions to monthly bills, good-paying jobs).

- Community members, particularly those living on the Island of Hawai‘i, harbored concerns about the oversight and regulation on the existing plant at PGV and safety in the event of a toxic gas release. The threat of airborne hydrogen sulfide plumes and contamination of the water supply by reinjected/processed fluid still worries residents, despite technological advancements in recent decades.

Opportunities for Geothermal – All Islands, as Explained in Listening Sessions

- Geothermal energy has a big advantage in that it supplies continuous power with minimal supply and equipment needs after the initial development phase. Those attributes can help address the supply chain and cost fluctuation issues of oil use in Hawai‘i, and intermittency and land use issues related to solar and wind energy development in Hawai‘i. Listening Session attendees repeatedly pointed out how geothermal energy, seemingly free under their feet, could reduce reliance on fuel imports, create new jobs for Hawai‘i residents and Native Hawaiians alike, while doing so with a relatively small footprint on the surface.

- Community voices highlighted a sense of optimism around geothermal development facilitated by the DHHL. Participants believed a geothermal venture that directly benefits Native Hawaiians, includes extensive community input, and chooses a culturally appropriate location would be better received than previous efforts.[1]

- Geothermal generation technologies have improved since the original deployment in Hawai‘i decades ago, allowing them to run more efficiently, minimize/mitigate/eliminate environmental impacts, and effectively monitor air and water quality. If safety and economic feasibility concerns are properly addressed, attendees expressed an eagerness to pursue technology that could help Hawai‘i meet the large electricity loads of modern technology and energy industries (data centers, hydrogen, cryptocurrency mining, etc.).

[1] Opposition primarily led by the Pele Defense Fund (PDF), formed in 1985, opposed geothermal drilling, and held a notable 1,500-person demonstration in 1990. The ongoing development of PGV during this timeframe received further local pushback, and concerns regarding a lack of traditional Hawaiian practices have been noted as recently as 2023.

Table of Contents

List of Figures

List of Tables

1 Introduction

The 2018 U.S. Department of Energy (DOE) *GeoVision* analysis examined geothermal energy in multiple sectors. Following this analysis, a GeoVision Roadmap (Roadmap) was created, which built on items identified within the analysis as areas to improve stakeholder engagement, with the goal of understanding why geothermal energy development was not occurring more broadly, to provide educational resources to areas where development could occur, and to help foster interest and development of all geothermal technologies. The Roadmap includes four "Action Areas" with sub-actions for stakeholders to participate, which are as follows:

1. Research related to resource assessments, improved site characterization, and key technology advancements
2. Regulatory process optimization
3. Maximizing the full value of geothermal energy
4. Improved stakeholder collaboration.

The efforts summarized in this report focused on building on *Action Area 4 – Improved Stakeholder Collaboration*. In parallel, the Geothermal Technologies Office's (GTO) Multi-Year Program's Core Objectives expand on the Roadmap. Within the GTO Multi-Year Program's Core Objectives, the Roadmap identified three Key Action Areas to be built upon:

1. Maintain the Roadmap as a vibrant, active process
2. Improve public education and outreach about geothermal energy
3. Increase awareness of employment and training opportunities across all geothermal energy technologies.

The Hawai'i engagement efforts summarized in this report were inspired by the *GeoVision* and Roadmap and are meant to provide decision makers and the public with information related to geothermal energy perspectives from stakeholders in Hawai'i. The Roadmap is meant to be mutually beneficial for both GTO and geothermal stakeholders who use the Roadmap in their own decision-making and planning processes.

1.1 Selection of States: Alaska and Hawai'i

Given the desire to better understand community perspectives regarding geothermal, GTO wanted to begin by developing an outreach methodology one state at a time. Alaska and Hawai'i were identified as states of interest for engagement efforts as both states have historically been excluded from the United States Geologic Survey (USGS) geothermal resource assessments and mapping. This is partly due to the paucity of geothermal data and resource information in those states, which both appear to have high geothermal potential, and partly due to unique energy landscapes in Alaska and Hawai'i. With these considerations in mind, GTO funded the National Renewable Energy Laboratory (NREL) to lead state-level engagement and educational outreach efforts starting with Alaska and then moving to Hawai'i.

The NREL team began engagement efforts in Alaska in Fiscal Year 2022 (FY22). In Alaska, the NREL team coordinated closely with existing regional NREL and/or DOE partners in addition to well-connected energy-focused organizations to provide virtual engagement and educational opportunities. These efforts were primarily virtual due to the COVID-19 pandemic.

Efforts associated with engagement in Alaska wrapped up in the first half of FY23 and a transition to begin working in the State of Hawai‘i began shortly after, with efforts continuing throughout FY24 and into FY25. This paper is meant to summarize the NREL team's efforts in Hawai‘i and the findings from the community Listening Sessions that were held across several Hawaiian Islands.

2 Background

2.1 Hawai‘i Clean Energy Initiative and Local Utilities

Motivations Behind the Hawai‘i Clean Energy Initiative

As a remote, mountainous, volcanic, and tropical island chain, the State of Hawai‘i is unique in its geography and its energy context. While the state has natural access to solar, wind, hydro, biomass, and geothermal renewable resources, it relies heavily (and still primarily) on imported oil for use in transportation and in electricity generation (U.S. EIA 2024). “Despite having the third-lowest total energy consumption among the states, Hawai‘i uses almost nine times more energy than it produces” (U.S. EIA 2024) and often pays a premium price for that energy. Furthermore, Hawai‘i’s average electricity price is nearly triple the U.S. average, underscoring the financial impact of shipping fuels to the islands. In 2024, the State of Hawai‘i imported 17,923 barrels of oil to be used for electricity refined into jet fuel, gasoline for internal combustion engine vehicles, or other petrochemical products (Hawai‘i State Energy Office 2024a). Figure 1 shows trends in overall Hawai‘i oil imports and the countries from which it imported oil in 2024.

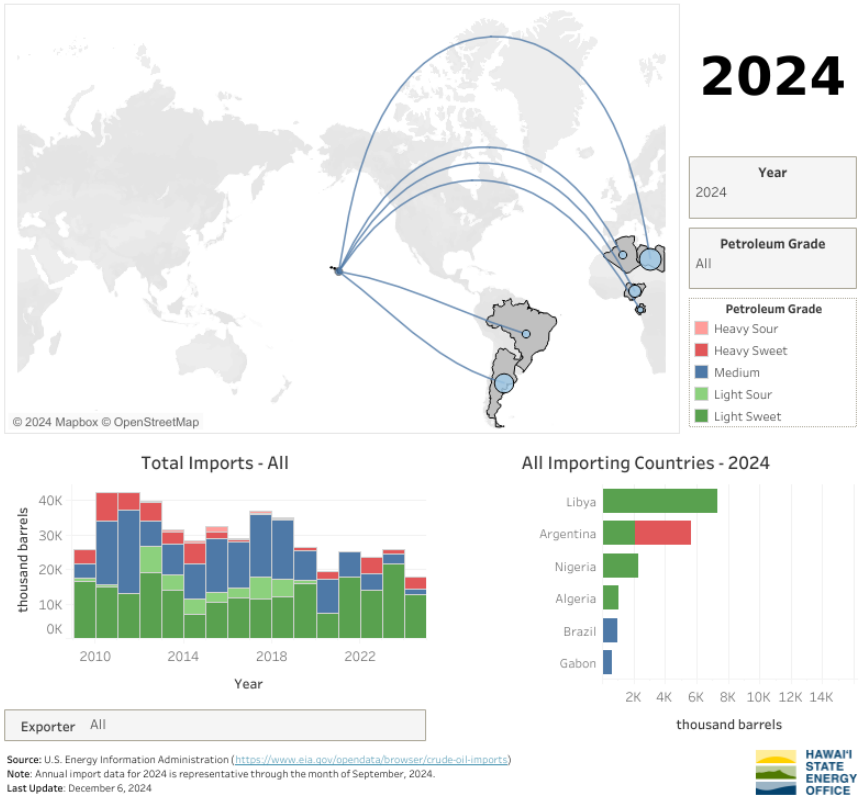


Figure 1. Hawai‘i foreign crude oil imports

This graphic from the Hawai‘i State Energy Office webpage describes the total Hawai‘i crude oil import volume and importing countries. Figure from the Hawai‘i State Energy Office (2024a).

To address both high energy costs and reduce the dependence on fuel imports, the State of Hawai‘i signed a Memorandum of Understanding (MOU) with DOE in 2008. The 2008 MOU identified energy goals focused on growth, innovation, accessibility, and workforce development.

The 2008 DOE and Hawai‘i partnership estimated that 60%–70% of future energy needs could be met with a combination of local renewable energy generation and demand-reducing energy efficiency upgrades. These findings spurred an ambitious suite of legislative goals addressing energy efficiency, generation, transmission, and electric vehicle transportation and formally created the Hawai‘i Clean Energy Initiative (HCEI) through multiple statutes and regulation. These legislative acts include:

- Act 155, Session Laws of Hawai‘i 2009 – codified energy efficiency goals by establishing an Energy Efficiency Portfolio Standard
- House Bill 623, 2015 Session – set a 100% renewable portfolio standard for utilities by 2045[2]
- Act 238, Session Laws of Hawai‘i 2022 – required the Hawai‘i State Energy Office to generate a report analyzing the pathways to achieve state and economy-wide emissions reductions.

Ever since, HCEI has worked to transform the financial, regulatory, and institutional systems governing Hawaiian energy planning and power delivery (Hawai‘i State Energy Office 2025). The ongoing MOU focuses on aligning state goals with private and public partners and building out short-, medium-, and long-term energy deployment plans. Further, in 2025, Hawai‘i Governor Josh Green signed a new executive order which calls for installation of 50,000 distributed energy systems by 2030 and directs state agencies to streamline permitting in ways that lower costs and speed up project development (Green 2025).

Hawaiian Island Chain Utilities

Hawai‘i residents purchase electricity from one of two primary utilities: Hawaiian Electric or the Kaua‘i Island Utility Cooperative (KIUC). The bigger of the two, Hawaiian Electric, serves 1.4 million residents (95% of the state population) on the islands of O‘ahu, Maui, Hawai‘i, Lāna‘i, and Moloka‘i, and includes two subsidiary utilities: Maui Electric Company (MECO) and Hawai‘i Electric Light Company (HELCO) (Hawaiian Electric 2024a). KIUC serves only the western island, Kaua‘i.

Hawaiian Electric has publicly supported the HCEI by making significant efforts to diversify their energy portfolio while maintaining levels of service. In 2022, Hawaiian Electric shut down their last coal-fired power plant (Hawaiian Electric 2024a). At least six other fossil-powered generating units will be retired and replaced with renewable alternatives over the next two decades to reduce their dependence on out-of-state energy sources (Hawaiian Electric 2024a). The utility’s HCEI also proposes plans to expand its electric vehicle charging network (Hawaiian

[2] https://legiscan.com/HI/text/HB623/

Electric 2023b) with the addition of 150 single-port DC fast chargers and 150 dual-port Level 2 chargers at 75 sites by 2030. While increasing the share of renewables across Hawaiian Electric's portfolio could potentially allow for reduced rates, both residential and commercial customers still see nation-high prices on their bills[3] (U.S. EIA 2024).

Table 1. Hawaiian Electric 2023 Average Price of Electricity by Island

This table is based on data for the electricity rates of different consumer types in cents/kWh. Data from Hawaiian Electric (2023a).

Rate Schedule	O'ahu	Hawai'i Island	Maui	Moloka'i	Lāna'i
"R" Residential	43.22	46.52	43.31	51.74	52.49
"G" Small Power Use Business	43.35	51.46	48.13	60.37	57.46
"J" Medium Power Use Business	37.39	42.43	41.59	50.83	54.22
"P" Large Power Use Business	35.33	38.52	39.11	42.03	50.81
"DS" Large Power Use Business, Directly Served	33.28	N/A	N/A	N/A	N/A
"F" Street and Park Lighting	40.32	44.12	39.52	48.62	51.50

KIUC has a more ambitious goal to generate 100% of its electricity from renewable sources by 2033 (Kaua'i Island Utility Cooperative 2024). Around 57% of the island's 235.9-megawatt (MW) generation capacity is renewable at present, on track for the cooperative's 70% renewable by 2030 interim goal (Kaua'i Island Utility Cooperative 2024). This 57% is further bolstered by over 42 MW of customer-sited solar. KIUC's electricity goal does not include geothermal energy as a resource option, so the NREL project team, in consultation with Hawai'i State Energy Office, decided to conserve resources and focus exclusively on Hawaiian Electric's grid footprint for this effort.

2.2 Current Energy Resource Mix

The following section describes Hawaiian Electric's current generation mix and planned projects across its entire portfolio. As noted in Table 2, the electricity mixes on different islands depend entirely on their existing infrastructure as there is no inter-island transmission. Specifics about the location and capacity of each island's generation resources are illustrated in Hawaiian Electric's 2023-2024 Sustainability Maps publication, which can be found in Appendix A.1.

[3] The average electricity price in the U.S. is 15.95 cents/kWh for residential households and 12.89 cents/kWh for businesses (U.S. EIA 2024).

Table 1. Hawaiian Electric 2023 Total System Generation Mix

This table documents the Hawaiian Electric generation mix by county in 2023. Data from Hawaiian Electric (2025)

% of Generation	Oʻahu	Hawaiʻi Island	Maui County
Biomass (including municipal solid waste)	4.5% (339,257 MWh)	0.0%	0.0%
Geothermal	0.0%	19.1% (258,940 MWh)	0.0%
Utility-scale photovoltaic and solar thermal	6.8% (516,367 MWh)	4.8% (64,511 MWh)	4.8% (64,827 MWh)
Hydro	0.0%	2.6% (34,714 MWh)	0.0%
Wind	3.8% (292,637 MWh)	11.2% (150,894 MWh)	16.5% (222,639 MWh)
Biofuels	0.2% (17,083 MWh)	3.0% (41,069 MWh)	<0.1% (646 MWh)
Customer-sited, grid-connected renewables	15.5% (1,179,330 MWh)	18.0% (243,501 MWh)	19.8% (268,365 MWh)
Oil	69.2% (5,260,439 MWh)	41.3% (559,278 MWh)	58.9% (796,836 MWh)
Coal	0.0%	0.0%	0.0%
TOTAL:	**100% (7,605,113 MWh)**	**100% (1,352,908 MWh)**	**100% (1,353,312 MWh)**

In 2023, renewable energy sources contributed 3,695 gigawatt hours (GWh) or 35.8% of Hawaiian Electric's generation portfolio, an increase of 303 GWh of production from 2023 (Hawaiian Electric 2025).

Additionally, Hawaiian Electric continues to make significant investments in utility-scale renewable energy and battery energy storage projects. The following tables document all future projects that have been approved by regulators (and are ready for construction) as well as those that are still in negotiations.

Table 3. Hawaiian Electric Regulator-Approved Renewable Projects

This table is based on the Hawaiian Electric renewable energy and battery energy storage system (BESS) projects approved by regulators as of 11/20/24. Note: Puna Geothermal Venture is an expansion to 46 MW rather than a new project. Data from Hawaiian Electric (2024c).

Name	Island	Developer	Tech	Size	Estimated Completion
Hoohana Solar 1, LLC	Oʻahu (Kunia)	Hanwha Energy USA Holdings Corp (174 Power Global)	Solar + BESS	52 MW, 208 MWh (BESS)	2025
Mountain View Solar	Oʻahu (Waianae)	AES Corporation	Solar + BESS	7 MW, 35 MWh (BESS)	2025
Puna Geothermal Venture	Hawaiʻi Island (Puna)	Ormat Technologies Inc.	Geothermal	46 MW	2026

Name	Island	Developer	Tech	Size	Estimated Completion
Waena BESS	Maui (Kahului)	Hawaiian Electric Company	BESS	40 MW, 160 MWh	2026
Waiawa Phase 2 Solar	O‘ahu (Waiawa)	AES Corporation	Solar + BESS	30 MW, 240 MWh (BESS)	2025

Table 4. Hawaiian Electric Renewable Projects in Negotiation

This table is based on the Hawaiian Electric renewable energy and BESS projects in negotiation as of 11/20/24. Data from Hawaiian Electric (2024c).

Name	Island	Developer	Tech	Size	Estimated Completion
Puuloa Energy	O‘ahu	Ameresco, Inc.	Internal Combustion (biofuel)	99 MW	2027
Puuloa Solar	O‘ahu	Ameresco, Inc.	Solar + BESS	6 MW + BESS	2026
Kalaeloa Partners	O‘ahu	Kalaeloa Partners, L.P.	Combustion Turbine (biofuel)	208 MW	2033
Waiau Repower	O‘ahu	Hawaiian Electric Company, Inc.	Combustion Turbine (biofuel)	253 MW	2033
Mahi Solar and Storage	O‘ahu	Longroad Development Company, LLC	Solar + BESS	120 MW + BESS	2027
Kuihelani Phase 2 Solar	Maui	AES Corporation	Solar + BESS	40 MW + BESS	2027
Kaheawa Wind 1	Maui	Terraform US	Wind	30 MW	2026
Pulehu Solar & Storage	Maui	Longroad Energy Holdings LLC	Solar + BESS	20 MW + BESS	2027
Ukiu Energy	Maui	Ameresco, Inc.	Internal Combustion (biofuel)	40 MW	2027
Keamuku Solar	Hawai‘i Island	AES Corporation	Solar + BESS	86 MW + BESS	2030
Hamakua Firm Renewable Energy	Hawai‘i Island	Pacific Current LLC	Combined Cycle + BESS	60 MW + BESS	2030

A wide variety of energy technologies is needed to help meet the HCEI goals and state renewable portfolio standards (Hawai‘i State Energy Office 2025). Due to land constraints on the

islands, renewable technologies beyond solar, wind, hydropower, and battery energy storage systems are being considered. Geothermal energy is under consideration as it has the smallest renewable energy resource footprint (roughly 404 m^2 per GWh compared to the footprints of wind (1,335 m^2) or solar photovoltaic (3,327 m^2) for the same generation) and can generate electricity 24 hours a day, seven days a week, regardless of weather conditions (GeoVision 2018). This firm geothermal power generation (Hawai‘i State Energy Office 2024b), supplemented with storage, may be needed to replace decommissioned fossil-fired thermal generators, such as the AES Hawai‘i coal plant retired in 2022 (Hawai‘i State Energy Office 2025).

3 Cultural Perspectives on Geothermal Energy in Hawai‘i

3.1 Native Hawaiian Storytelling and Histories

The Hawaiian Island chain has been inhabited for over a thousand years by the Kānaka Maoli, the Indigenous people of Hawai‘i. Many Native Hawaiians today are still reverent toward the islands and the Earth, often referred to as ‘Āina, a Hawaiian word for “land,” which sustains them. ‘Āina represents having a reciprocal, familial relationship with the world, and connecting to the land, or ‘Āina, is of extreme importance to the physical, emotional, and spiritual lives of Native Hawaiians (Trust for Public Land 2024). For many Hawaiians, the natural world is an inherently spiritual place, the home of their Hawaiian gods and goddesses, called Akua. One significant spiritual figure is the Goddess Pele, or Grandmother (referred to as “Tūtū”) Pele, the goddess of volcanoes, who brings both the power to destroy and the power to create new land. Some Native Hawaiians still regard Tūtū Pele “not with fear but with filial respect; and with a touching resignation should a lava flow consume their homes” (Kawainui Kane 1996).

The Kānaka Maoli are from the ancient homeland, Polynesia. According to Native Hawaiians, the great gods were born in Polynesia, beginning with Kane the Creator who ruled over the others. He was followed by Kanaloa of the Ocean; Ku, who was the “patron to the works of men”; and Lono, the “patron of agriculture and healing” (Kawainui Kane 1996). The supreme female spirit is described by Native Hawaiians as the goddess “Hina in some roles, and as Haumea in others, the patroness of fertility and of women’s works; mother of lesser gods and, as La`ila`i, mother of humankind” (Kawainui Kane 1996). Native Hawaiians believe Pele was “born of Haumea in the ancient homeland,” and did not go to Hawai‘i for a long time. Native Hawaiian stories of her departure include a flood driving her away, perhaps her longing to travel, or that she was “expelled by her elder sister, Nā-maka-o-Kaha`i, who was outraged because Pele had seduced her husband” (Kawainui Kane 1996). Nā-maka-o-Kaha`i is considered the goddess of the sea and water and pursued Pele to Hawai‘i.

According to Native Hawaiians stories, Pele’s elder brother, Kā-moho-ali`i, took the form of a shark and guided a canoe with Pele and some of her brothers and sisters to the northern islands of the Hawaiian archipelago. Pele, however, needed a “pit for her home wherein the sacred fires could be protected” (Kawainui Kane 1996). Pele moved down the island chain “through Ni`ihau and Kaua‘i,” still being pursued from Tahiti by her angry older sister. Wherever Pele tried to create a crater to protect the sacred fires, Nā-maka-o-Kaha`i filled them with waters (Kawainui Kane, 1996). These Native Hawaiian stories align with the geologic age of the island chain—as Pele moves toward the Island of Hawai‘i, the islands are younger. It is believed a final battle took place on Maui between Nā-maka-o-Kaha`i and Pele, where Pele was torn apart, leaving her mortal bones on a hill named Ka-iwi-o-Pele (“the bones of Pele”), freeing her spirit and elevating her to a godly status (Kawainui Kane 1996). As her mortal body died in the Hawaiian Islands, she is a goddess native to the islands—her spirit left Maui for her final resting place on Hawai‘i Island in the Halema`uma`u Crater at the summit of Kīlauea. Pele is said to reveal herself through smoke plumes or lava, and all volcanic activity in the islands is considered the domain of Pele.

Native Hawaiians have recorded Pele chants, or "oli," that speak to the sacredness, referred to as "kapu," of the goddess and of her laws, or "kānāwai" (Kamana and Vaughan 2024). The "kānāwai Pele (laws of Pele) were enacted so that the population at large knew how to approach that which was kapu (sacred) and behave accordingly" (Kamana and Vaughan 2024). Native culture and law "prohibits activities in a volcanically active area," and with this understanding it has been said that "geothermal drilling trespasses on the kānāwai" laws (Kamana and Vaughan 2024).

3.2 Additional Historical Context and Cultural Perspectives

Many Native Hawaiians, particularly those living on Hawai‘i, maintain an active, spiritual connection to the goddess, often describing her as a "semi-protector," an "ancestor," or even "part of the family" (Armstrong 2018). She is in some ways inseparable from the culture of the Puna district and the city of Pahoa where visitors can see murals of her cradling fire, buy Pele postcards, "dine at Pele's Kitchen, or stay at a bed-and-breakfast near Volcanoes National Park called Pele's Breath" (Romero and Kalifa 2018). More broadly, the entire Kīlauea volcano and the surrounding rainforest of the East Rift Zone are considered sacred areas for many cultural practitioners, making geothermal exploration in the region potentially a direct threat to their goddess, traditions, and way of life (Dobbyn 2023).

Interest in geothermal in Hawai‘i emerged in the 1960s and 1970s as public landowners like Richard Lyman, the University of Hawai‘i, and the Hawai‘i legislature began to look for ways to diversify away from oil. In 1970, the "Project Pele" program was created to develop geothermal energy, seeded with $200,000 and hopes of soliciting matching federal dollars. From the beginning, a Native Hawaiian advocacy group expressed objections about (1) drilling that could violate Native Hawaiian religious and spiritual beliefs without consultation of the Native people, and (2) that steam generated should benefit Native Hawaiians per the Hawaiian constitution (Markrich 2023). With these issues emerging, development was tabled until the oil embargo of 1973 and 1974 created new urgency for alternative energy sources. Backed by new federal funds, the first geothermal well, Hawai‘i Geothermal Project Abbott (HGP-A) was drilled to 6,140 feet. Soon after, HELCO released an RFP for a 25-MW plant, eventually won by Hawai‘i's only existing geothermal power plant, Puna Geothermal Venture (PGV). Early drilling in the 1980s and 1990s did not include environmental impact statements, impacted large parcels of forestland, and featured the accidental release of steam and hydrogen sulfide. Drilling accidents at PGV wells KS-7 and KS-8 in February and June 1991, respectively, resulted in 32 hours of steam release and significant public backlash (Markrich 2023).

The Pele Defense Fund (PDF) was an advocacy organization formed in 1985 to protect the traditional Hawaiian rights and customs, preserve virgin rainforest, and oppose further geothermal drilling in the face of the HGP-A and PGV development. PDF led several acts of protest, including a 1,500-person demonstration against geothermal energy at the Wao Kele O Puna rainforest in 1990 (Faulstich 2010). 140 people were arrested at the 1990 demonstration, and ultimately public opinion turned against the project (Trust for Public Land 2006). In 2001, the private owner of Wao Kele O Puna put the forest up for sale, creating an opportunity for PDF to pursue permanent protection for the forest. After securing rights in perpetuity to enter, hunt, and gather plants via a state court ruling, PDF collaborated with the Trust for Public Land and the USDA Forest Legacy Program to purchase the forest and confer its ownership to the Office

of Hawaiian Affairs (Trust for Public Land 2006). PDF and other groups like the Puna Pono Alliance have consistently expressed concerns for pollution to the land, water, and forest caused by toxic gas emissions, brine ponds rich with heavy metals, and the improper reinjection of chemical-laden fluids through the water table (Markrich 2023).

Although large protests like PDFs march at Wao Kele O Puna are less common now, both Native Hawaiians and residents of Hawai‘i alike continue to voice concerns to PGV, regarding disrespecting cultural traditions and discounting geothermal energy's cultural and environmental impacts (Dobbyn 2023). PGV hosts regular public meetings where opponents to geothermal regularly express concerns about emergency response, health impacts, and risks they feel are being ignored. The 2014 Tropical Storm Iselle severed transmission lines to the grid, forcing a shutdown and the release of steam containing hydrogen sulfide. More than 210 residents reported health complaints consistent with hydrogen sulfide gas exposure, something described by a local nurse as a "clear pattern of illness" (Dobbyn 2023). This event underscored a 2013 public health report by Peter Adler which identified some risks at PGV and claimed the "actual extent and impacts of these risks (will) remain unresolved" without further study (Dobbyn 2023). Others worry about induced seismicity caused by water reinjection, which could worsen eruption events. Finally, cultural practitioners like Palikapu Dedman, who helped found PDF, have critiqued the geothermal facility by pointing out that they have policies to look at air quality and water quality but nothing about traditional Hawaiian practices. The latest PGV environmental study contains a section on cultural impacts, but concludes there are no ongoing cultural practices located within the PGV project area, which has angered Dedman and others who recognize the region as sacred (Dobbyn 2023).

Conversely, some Native Hawaiians have developed their own belief systems, might not hold traditional beliefs regarding Pele in the same manner, or are beginning to soften their stance on geothermal with respect to the goddess (Armstrong 2018). Emblematic of this shift in public opinion, the Department of Hawaiian Home Lands (DHHL) has recently considered geothermal development as an avenue for financial self-determination, an opportunity that might allow Native Hawaiians to use geothermal resources as "gifts" of Tūtū Pele for power and to house Native Hawaiians (Trask 2023). Newer advocates often insist that new installations provide measurable benefits to nearby Native Hawaiian communities such as electricity credits to reduce energy costs, opportunities for well-paying jobs at the plant, and extensive monitoring systems with publicly available data. Further, if located elsewhere on DHHL lands outside the East Rift Zone and Kīlauea volcano, a new geothermal power plant might avoid the critiques of some cultural practitioners who believe PGV disrespects the goddess and directly taps her energy (Dobbyn 2023).

3.3 Public Health Concerns

Since the 1980s, public health impacts have been of central importance to advocacy groups and community members in Pahoa who feel at risk due to PGV's activities, including related emissions. Despite being described as a safe energy source, geothermal plant steam emissions have the potential to contain "CO_2, hydrogen sulfide (H_2S), hydrogen, ammonia and methane, radon (Rn), volatile metals, silicates, carbonates, metal sulfides and sulfates and traces of mercury (Hg), arsenic (As), antimony, selenium and chromium" (Bustaffa et al. 2020). Similarly, geothermal waters and brines may contain chlorides, sulfides, or heavy metals. Often, the

pollutant with the greatest potential for public health concerns is hydrogen sulfide. In low concentrations, hydrogen sulfide exposure is positively associated with respiratory symptoms, mortality from respiratory disease, and lung cancer, and at high levels, it is associated with increased rates of hospitalization for respiratory disease, central nervous system disorders, and cardiovascular disease. The authors of a review of 19 studies on pollution exposure from geothermal and health effects recognized that while hydrogen sulfide is often a key pollutant, examining co-exposure to other toxins and pre-existing health conditions is also important; deeper biomonitoring surveys using blood tests, urine tests, respiratory health exams, and in-depth personal health questionnaires are best to provide insight on risk factors to health in geothermal areas (Bustaffa et al. 2020).

In Hawai‘i, there have been public health studies on Puna and Pahoa, but experts have called for more extensive studies and monitoring of air and water emissions to draw clearer conclusions. Near Pahoa, the smells of sulfur dioxide have accompanied eruptions for millennia and geothermal drilling from the beginning of the 1970s exploration (Markrich 2023). In 2012, Hawai‘i Island Mayor William Kenoi asked Peter Adler to author a report on the health impacts of geothermal energy production. Dr. Adler, with the help of a study group of Puna residents, found that Puna's public health profile is unclear; there is no good health baseline that documents mortality, diseases, and other health metrics (Adler 2013). Further, despite evidence of health effects from exposure to geothermal before 1993 (namely from the 1991 blowout), the study group could not conclude there were clear health impacts in the 20 years since. Finally, the group acknowledges that there are risks posed by industrial chemicals and naturally occurring compounds and metals in Lower Puna. Critically, they call for better monitoring of air and water quality to make definitive conclusions (Adler 2013).

Several years after the Adler study, a USGS report on the shallow wells in the Puna region explored impacts of geothermal power production on groundwater quality. When testing for tracers of geothermal operations, chemicals that might be left behind from geothermal reinjection, the study group found no evidence that geothermal constituents in the groundwater came from a commercially developed reservoir such as PGV's (Evans et al. 2015). Recently, residents have continued to advocate for further studies to confirm these conclusions or provide new insight into health conditions linked to geothermal. A local councilwoman proposed and acquired county funds for a $500,000 groundwater study to learn more about the underground risks at PGV (Brestovansky 2024).

4 Geothermal Resources in Hawai‘i

4.1 Summary of Geothermal Resources in Hawai‘i

Although Hawai‘i’s active volcanism and tectonic setting above a mantle hotspot suggest the existence of subsurface heat (Lautze et al. 2017), detailed studies of the potential for geothermal resources in the state have been severely limited. Most of Hawai‘i’s geothermal activities are “blind”—their hot springs, and steam vents are not exposed on the surface as the geothermal waters instead flow underneath the volcanic cover (Lautze et al. 2021). The limited subsurface data from exploratory drilling, along with the concealed nature of geothermal resources, creates uncertainty about the potential for large-scale energy generation, geothermal heating and cooling, and/or direct-use applications. Beyond the Puna region, Hawai‘i has few deep wells, leaving most of the islands unexplored for geothermal resources (Lautze et al. 2017).

The current resource baseline relies heavily on three previous scientific efforts to catalogue subsurface hydrothermal activity. The first and most complete statewide evaluation of geothermal resources was done in 1985 by the Hawai‘i Institute of Geophysics (Thomas 1985). This study identified 15 potential geothermal resource areas on four of the five major islands in the Hawaiian Island chain (O‘ahu, Maui, Moloka‘i, and Hawai‘i Island), excluding Kaua‘i, Lāna‘i, and Kaho‘olawe (Thomas 1985). After that, in 2013 a U.S. Army-funded drilling project to look for groundwater in the Humu‘ula Saddle region between the Mauna Kea and Mauna Loa volcanoes led to the discovery of geothermal waters at 140°C and at a depth of 1.7 km, with a temperature gradient of 165°C/km from 1 km depth, in a location that had not previously been identified as a geothermal area of interest (Thomas 2014).

The third, and most recent, geothermal resource assessment in Hawai‘i was conducted by the University of Hawai‘i in 2014. The project, funded by DOE as part of a broader effort to analyze geothermal exploration best practices across the United States, used a play fairway analysis (PFA) methodology to search for hidden geothermal resources across the state. The Hawai‘i PFA project included three phases that comprised an updated resource assessment, a roadmap for further exploration efforts, and identification of geothermal regions that needed more investigation (Lautze et al. 2017). The results of this PFA study are summarized as follows:

> (1) Phase 1: compiled and integrated geoscience datasets and identified 10 locations across the state for further exploration efforts;
>
> (2) Phase 2: collected new groundwater data and new geophysical data in the 10 previously located areas to produce favorability maps of geothermal resources; and
>
> (3) Phase 3: conducted drilling of a groundwater well in the Lāna‘i Palawai Basin (the deepest well off of Hawai‘i Island), performed more geophysical surveys, and integrated all Phase 2 and 3 results to generate favorability maps.[4]

The principal findings of this project included five journal publications, featuring an assessment of the geothermal resource beneath Lāna‘i, and a better understanding of future research needs.

[4] See the Geothermal Data Repository website to review all publications, data, and models.

The Hawai‘i PFA identified a geothermal gradient of 42°C/km on Lāna‘i, twice what had previously been found in the state. A 2024 study by Lautze et al., published in Geothermics, presents results from a specific slim-hole drilling site on Lāna‘i, which was deepened from 427 m to 1,057 m. Measurements suggest accessible temperatures of 130–200°C at depths of 2–3 km, comparable to gradients observed in exploration wells near Kīlauea’s East Rift Zone. Despite this promising result, the authors still felt the location of this well was not ideal. To address their concerns and anticipate future study of the statewide resource, the project team identified other locations for deep-gradient well drilling across the different islands (see Lautze et al. (2024) for more details about this study).

A more recent study conducted by NREL expands on the Hawai‘i PFA findings by integrating the probability heat map developed by Lautze and Haskins (2024) to enhance assumptions about geothermal gradients. The resulting temperature maps at various depths employ a gradient probability framework, where gradients range from 16°C/km at 0%–50% probability to a linear interpolation between 16°C/km and 100°C/km for 50%–100% probability. These modeled gradients are consistent with those observed in geothermal exploration wells across Hawai‘i, providing valuable insights for future resource exploration at different depths (Figure 2 and 3).

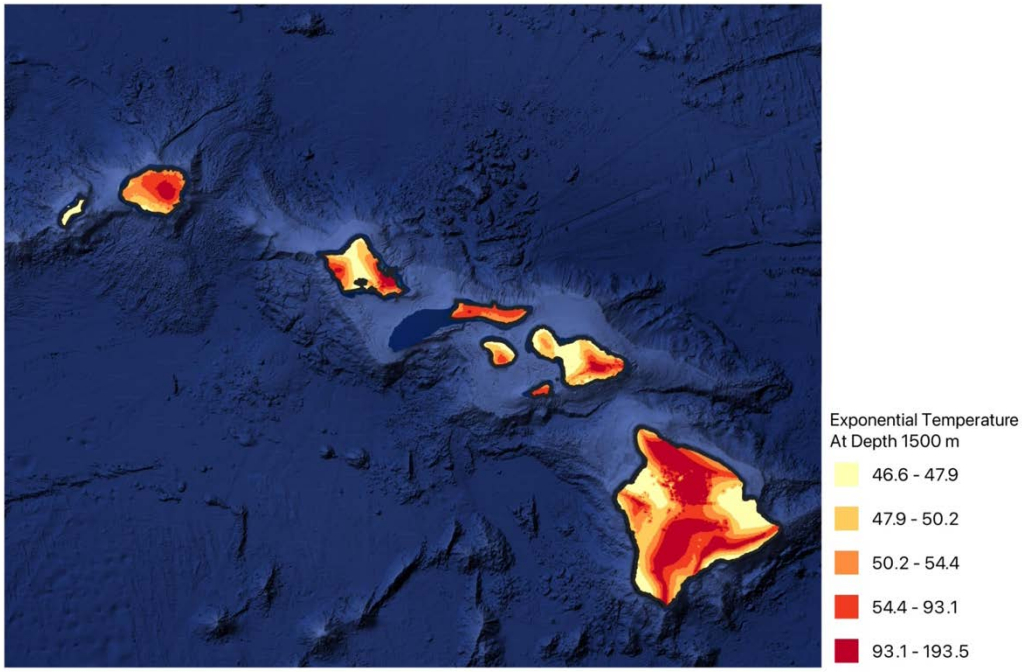


Figure 2. Gradient temperature maps across the State of Hawai‘i. Temperatures range from 46.6 to 193.5°C at 1,500 m.

Red shades illustrate higher gradient temperatures, and yellow shades illustrate lower temperatures. Figure from Trainor-Guitton et al. (2025).

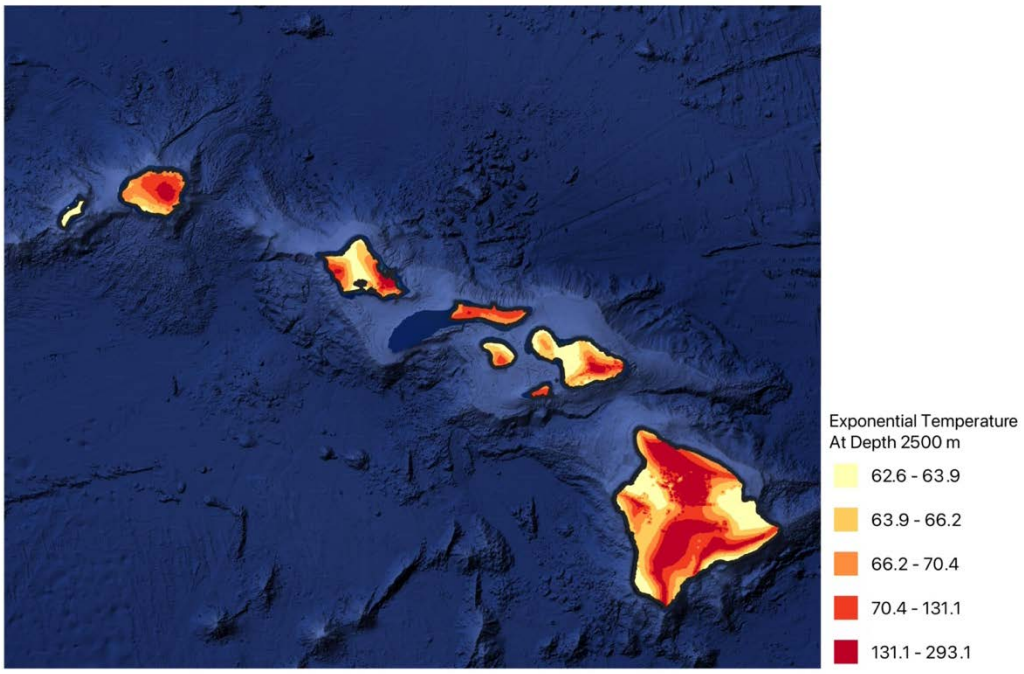


Figure 3. Gradient temperature maps across the State of Hawai‘i. Temperatures range from 62.6 to 293.1°C at 2,500 m.

Red shades illustrate higher gradient temperatures, and yellow shades illustrate lower temperatures. Figure from Trainor-Guitton et al. (2025).

4.2 Geothermal Electricity Potential in Hawai‘i

Currently, the only geothermal system in the State of Hawai‘i producing geothermal electric power is the Kīlauea East Rift Zone on Hawai‘i Island. The aforementioned Puna Geothermal Venture (PGV), owned and operated by Ormat Technologies, Inc. (since 2004), secured its first contract to deliver electricity to HELCO in 1986. By 1993, under previous ownership, the plant became operational and provided 25 MW of electricity to the utility and was expanded to a 38-MWe power purchase agreement in 2011. In 2018, Kīlauea erupted and triggered lava flows across the eastern portion of Hawai‘i. By early May, lava flows had reached the boundaries of the PGV site, forcing workers to evacuate the sites, cap its 11 wells, and remove flammable chemicals (Reuters in Pahoa 2018). The plant reopened in November 2020 after roads were cleared and the wells could be reopened. Prior to the Kīlauea eruption in 2018, PGV provided 31% of Hawai‘i Island’s energy, and in 2024 it supplied 19.1% as it is being restored to maximum power capacity (Hawaiian Electric 2025). In 2019, PGV and Hawaiian Electric began negotiating another revision to their power purchase agreement, which would allow for increased production at the plant. On March 16, 2022, the Hawai‘i Public Utilities Commission approved the agreement, which would allow PGV to generate up to 46 MW, largely contingent upon a successful environmental review (Brestovansky 2022). In early 2024, a final environmental impact statement was accepted by the County of Hawai‘i, clearing the way for capacity upgrades and an increase to the aforementioned 46-MWe production (State of Hawai‘i 2024).

Lautze et al. (2017) suggested that while geothermal resources are predictably found on the younger, volcanic Hawai‘i Island, exploring nearby or more densely populated islands such as

Lānaʻi, Maui, and Oʻahu is highly advantageous. Geothermal power generation on these islands could offer greater economic feasibility and help mitigate the region's high energy costs (Lautze et al. 2017). While the population of Hawaiʻi Island is smaller than both Maui and Oʻahu, its land size is roughly twice the size of the other Hawaiian Islands combined and currently receives over half of its energy from renewable sources (State of Hawaiʻi 2024). The additional land mass provides room for energy resources with larger footprints, such as wind and solar. The Hawaiʻi PFA project pinpointed 10 areas as potentially viable for geothermal electricity generation but emphasized the need for more detailed exploration. To rank these sites, Lautze et al. (2017) used criteria like grid integration, market access, and natural hazards to assign an overall development viability score. Table 5 presents a summary of these results.

Other NREL analysis focuses on using the Renewable Energy Potential (reV) Model to determine geothermal resource potential. Originally developed for wind and solar energy (Maclaurin et al. 2021), the reV model has been adapted to integrate geothermal variables, offering insights into deployment constraints associated with land use, environmental and cultural considerations, and grid integration. The NREL reV team has utilized the latest probability of geothermal resource maps (Lautze et al. 2024) to estimate a low and high megawatt potential for all Hawaiian Islands at three different depths and for two different geothermal technologies hydrothermal and enhanced geothermal systems (EGS) (see Figures 4 and 5).

Specifically, the reV team used the PFA probability of heat map as a look-up table for which temperature gradient to use (Lautze et al. 2024). For probabilities <50%, a gradient of 16°C/km is used. For 50%–100%, a linear interpolation between 16°C/km and 100°C/km is used to extrapolate the temperatures to 1.5 km and 2.5 km depths.[5] Note that no estimate of permeability is available, which will make the hydrothermal estimates more uncertain than EGS. Additionally, reV uses GIS data layers to exclude land based on ecological, cultural, and terrain limitations, with feedback from both the Hawaiʻi State Energy Office and DHHL. reV's dataset provides detailed geospatial and techno-economic information for evaluating geothermal energy potential, including spatial coordinates, estimated capacity factors, developable area, resource potential, and annual energy production metrics. Economic parameters such as levelized cost of electricity, site development costs, transmission costs, and fixed-charge rates are also incorporated. For more detailed data and analysis, visit the Geothermal Data Repository (GDR).[5]

Multiple other community-level engagement and technical assistance efforts are proceeding in Hawaiʻi as a part of NREL's State, Local, and Tribal Program outside of DOE GTO-funded efforts such as this. For example, the Energy to Communities (E2C) and Energy Technology Innovation Partnership Project (ETIPP) technical assistance programs have supported work on Molokaʻi, in Hawaiʻi County; in Lahaina, Kahikinui, and Upcountry on Maui; in Honolulu, Hau'ula, and Waianae on Oʻahu; and on Kauaʻi. Other national laboratories have also engaged with Hawaiian Electric and KIUC on Kauaʻi to analyze the impact of additional energy resources (e.g., solar, wind, geothermal, biomass) on the state power grid. Oak Ridge National Laboratory has engaged with both utilities to help the operators maintain a supply and demand balance within an increasingly variable, distributed system. Sandia National Laboratory furthers this

[5] https://gdr.openei.org/submissions/1702

effort by researching how inverter-based resources can mitigate bulk system frequency contingency events. Finally, Argonne National Laboratory has developed storm damage assessment tools such as HEADOUT to model weather impacts on the Hawaiian grid.

Beyond the national lab system, several other projects are investigating the subsurface of the islands. The Hawai‘i Groundwater and Geothermal Resources Center (HGGRC), which led the Hawai‘i PFA project, is now researching the potential for CO_2 injection and mineralization in the flanks of Hawaiian volcanoes, ultimately for sequestering anthropogenic carbon. The USGS also studies Hawaiian geothermal and groundwater activities, running a large research station at Kīlauea and several smaller studies of groundwater chemistry across the East Rift Zone.[6]

Table 5. Development Viability of Sites

This table describes the potential viability for geothermal electricity generation of 10 areas across the State of Hawai‘i. Production from Hawai‘i's only operational geothermal facility, PGV, was used to scale the probabilities in column 2. Adapted from Lautze et al. (2017).

Site	% of PGV	Confidence % Max	Viability
(A) N MKea (Hawai‘i)	48–95% (high)	65–90% (high)	medium-high
(B) W Saddle (Hawai‘i)	12–60% (low to medium)	65–95% (high)	medium
(C) SW MLoa (Hawai‘i)	50–170% (high)	60–85% (medium)	medium-low
(D) E. Haleakalā (Maui)	10–24% (low)	25–65% (low to medium)	medium
(E) SW Haleakalā (Maui)	7–17% (low)	25–75% (low to medium)	high
(F) N Haleakalā (Maui)	7–19% (low)	55%–85% (medium to high)	low
(G) Lāna‘i	5–24% (low)	55–80% (medium)	very high
(H) S Ko‘olau (O‘ahu)	1–10% (low)	65–85% (medium to high)	medium-high
(I) Wai‘anae (O‘ahu)	2–7% (low)	65–85% (medium to high)	very high
(J) Kaua‘i	1–2% (low)	50–85% (medium to high)	medium

[6] https://www.usgs.gov/data/groundwater-chemistry-lower-east-rift-zone-and-summit-kilauea-volcano-hawaii

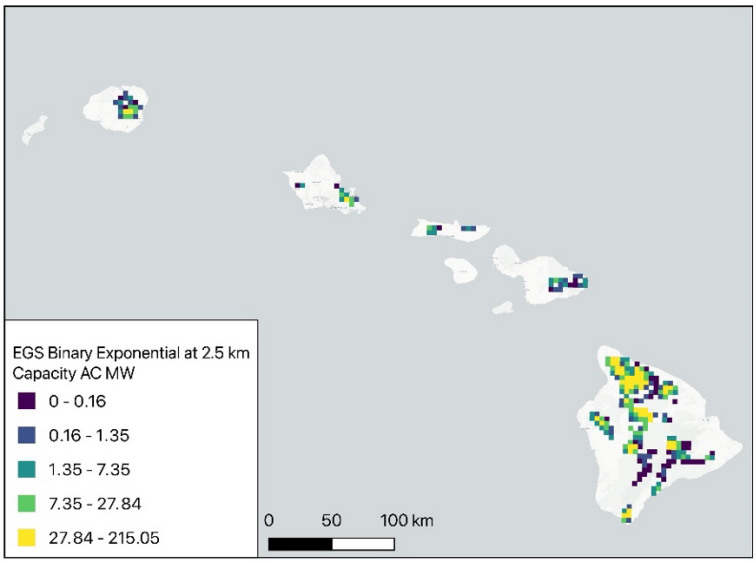


Figure 4. Geothermal electricity generation capacity across the State of Hawai‘i. This shows EGS with an exponential model at 2.5 km with a total of 8.84 GW.

In these reV exponential model figures, yellow indicates a higher MW capacity potential while dark purple illustrates a lower MW capacity potential. Adapted from NREL (2025).[7]

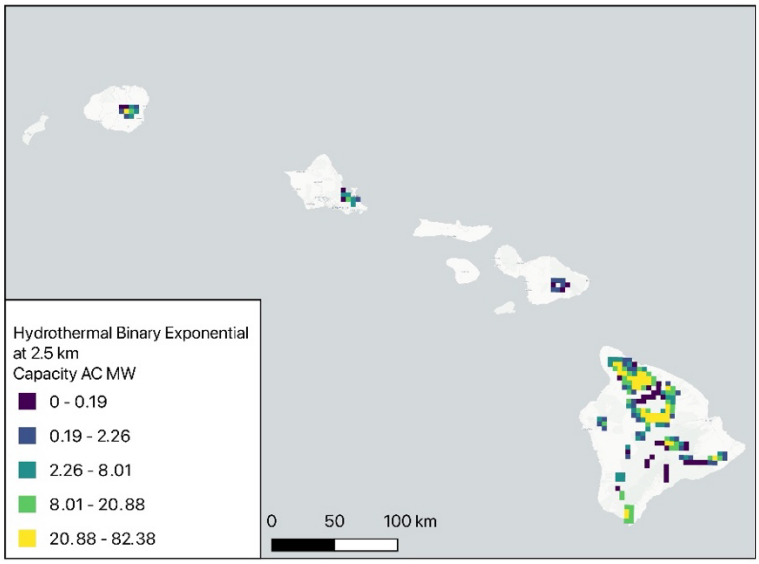


Figure 5. Geothermal electricity generation capacity across the State of Hawai‘i. This shows hydrothermal potential with an exponential model at 1.5 km with a total of 2.39 GW.

In these reV exponential model figures, yellow indicates a higher MW capacity potential while dark purple illustrates a lower MW capacity potential. Adapted from NREL (2025).[8]

---

[7] Please note these preliminary supply curves and levelized cost of electricity in Figures 4 and 5 should be considered with care due to the high uncertainty in geothermal resource potential data and due to the methods for estimating capacity from temperature. It should be noted that the cost assumptions for both scenarios are based on a continental United States (CONUS) study and therefore are not ideal for Hawai‘i.

[8] Please note these preliminary supply curves and levelized cost of electricity in Figures 4 and 5 should be considered with care due to the high uncertainty in geothermal resource potential data. It should be noted that the cost assumptions for both scenarios are based on the CONUS study and therefore are not ideal for Hawai‘i.

4.3 Direct-Use Geothermal Heating and Cooling Potential in Hawai‘i

There may also be potential across the State of Hawai‘i for "direct use" of geothermal—utilizing it for heating or cooling without converting it to electricity. Several experimental direct-use projects were constructed in Hawai‘i's Puna region between the 1980s and 2000, utilizing warm wastewater or steam from nearby wells. These early efforts included cultivating decorative palms, stabilizing the colors on hand-dyed silk, drying timber, pasteurizing growth medium (for biological use in biology labs), manufacturing silica bronze, and drying green papaya powder (Boyd et al. 2002). Artists with the Hawai‘i Glass Project used leftover silica from geothermal fluids to create pieces of art. In addition, 32 ponds (0.80 hectare) owned by Tropical Ponds Hawai‘i, which cultivates ornamental fish, were heated using geothermal energy. Before entering the ponds, the well water was cooled from 43°C to 21°–27°C (Lund 2021). Despite continued volcanic activity, none of these projects still operate, and there are no direct-use operations in Hawai‘i today. The major Kīlauea eruption of 2018 covered most of the area near Puna that had supported the original direct-use efforts.

DOE-GTO has explored some direct-use geothermal applications. They have funded the Geothermal Heating and Cooling Geospatial Datasets and Analysis project led by NREL, which is part of a broader effort to integrate geothermal power and heating/cooling technologies into national energy strategies and local energy plans. Alaska and Hawai‘i are included in this initiative. Additionally, GTO has funded the Regional Partnerships for Geothermal Data to aid in subsurface data acquisition, resource characterization, and data dissemination for power or direct-use applications. Further, the District-Scale Geothermal Energy Pilots initiative supports five communities that install district-scale thermal energy networks, showcasing the potential for geothermal to meet HVAC demand while reducing cost.

Another Hawaiian direct-use project is the "Preliminary Assessment of Ground-Source Heat Exchangers for Cooling in Hawai‘i," which looked at whether ground-source heat exchangers (GSHE)[9] could work for cooling in Hawai‘i's tropical climate. Led by Daniel Dores and Nicole Lautze from the University of Hawai‘i in 2020, this study explored different scenarios where GSHE could be effective, especially in areas with limestone and basalt geology. The research found that these lithologies, combined with the right temperature conditions, could make GSHE an effective option for cooling buildings during the five summer months in Hawai‘i (Dores and Lautze 2020). The study also considered factors like energy efficiency, rock conductivity, and how these affect GSHE performance, while providing maps and calculations related to local geological features.

GSHEs can reduce demand on the grid as well as lower energy bills and lead to increased reliability. According to the study, GSHE technologies can also lead to improved energy security, energy efficiency, and grid stability through management of emerging lead and peak demand growth. Peak load can be reduced by GSHEs in all climate zones excluding winter peak loads in cold climate zones (Gertler 2025). Additional research and data could be leveraged to determine if these technologies could have wide-scale applicability for the islands. Additionally, the State of Hawai‘i has a priority permitting incentive for eligible building projects that meet "energy and environmental design building standards"; these standards include the use of

[9] GSHE can also be referred to as ground-source heat pumps and geothermal heat pumps (Dores and Lautze 2019).

geothermal heat pumps, among other technologies. This incentive applies to commercial, construction, industrial, residential, and installers/contractors.[10] It is important to mention that while geothermal heat pump technologies can be effectively developed almost anywhere, few studies have focused on the use of heat exchangers in Hawai‘i (e.g., Morita et al. 1992; Bu et al. 2019). More data and research are required to examine how those technologies could be designed to suit the Hawaiian Islands.

There are several global examples of successful direct-use applications. A sampling of these from Aotearoa New Zealand, the African continent, and in Iceland are included in Table 6.

Table 6. Examples of Other Geothermal Direct-Use Applications

Location	Application Type
New Zealand	Aquaculture at Huka Prawn Park. Huka Prawn Park harnesses geothermal energy to heat the prawn ponds.[11]
New Zealand	Horticulture at PlentyFlora[12] and Gourmet Mokai.[13] These locations use geothermal energy to heat their glasshouses for flower production (PlentyFlora) and for tomatoes and capsicums (Gourmet Mokai).
New Zealand	Milk drying at Miraka[14], a Māori-owned dairy using geothermal energy to dry milk.
Kenya	Horticulture at Oserian Development Company,[15] where geothermal is used to heat water for flower greenhouses, enrichment of carbon dioxide levels in the greenhouses, and to sterilize soils to kill plant pathogens.
Kenya	Aquaculture at Menengai[16] where fish ponds are heated using geothermal energy.
Algeria	The Hammam Essalihine is a tourist site near the city of Al Hama. It is a Roman era geothermal hot spring with multiple swimming pools.[17]
Iceland	The Blue Lagoon is a geothermal bathing facility or hot spring at Bjarnarflag.[18]
Iceland	An industrial application includes seaweed drying at the Thorverk plant in Reykhólar.[19]
Iceland	Fish drying in the Reykjanes Peninsula. Haustak Hf[20] has utilized geothermal energy to dry fish on wooden racks via hot air.

[10] For more information visit: https://programs.dsireusa.org/system/program/detail/2287/priority-permit-processing-for-green-buildings.
[11] For more information visit: https://hukaprawnpark.co.nz/
[12] For more information visit: https://www.gerbera.co.nz/files/Horticulture_-_PlentyFlora.pdf
[13] For more information visit: https://nzgourmet.co.nz/our-operations/gourmet-mokai/
[14] For more information visit: https://www.miraka.co.nz/
[15] For more information visit: https://www.grocentre.is/static/files/GTP/ShortCourses/Kenya/SC-30/0905directusesgeothermalenergykenyamm3001.pdf; https://www.linkedin.com/company/oserian-development-company-limited/about/
[16] For more information visit: https://www.gdc.co.ke/direct-use/
[17] For more information visit: https://khenchela.mta.gov.dz/en/hammam-essalihine-2/.
[18] For more information visit: https://www.bluelagoon.com/
[19] For more information visit: https://www.thorverk.is/
[20] For more information visit: https://haustak.is/about-us/

4.4 Continued State-Level Support for Geothermal Exploration

As described in Section 4.2, there are several areas with a high probability of subsurface heat suitable for a utility-scale geothermal electric power plant. Many interested parties in Hawai‘i are pursuing funds for exploratory drilling, a capital-intensive process that has previously been subsidized with state dollars. The DHHL has stated an interest in exploring geothermal resources on its lands and was awarded $500,000 in 2022 under Act 205, allowing leadership to zero in on three areas “of high interest” (Dayton 2023). DHHL geothermal efforts are anchored in a 2014 decision by the Hawai‘i attorney general, providing the Department full control of geothermal royalties from the subsurface of their land. First, the attorney general concluded that DHHL is entitled to 100% of royalties derived from geothermal resource development on its lands, writing that “allocating royalties from geothermal development on DHHL to the Board of Land and Natural Resources or the counties flatly violates section 4 of the Admission Act and Article XII, sections 1 and 3, of the Hawai‘i Constitution” (DHHL 2014). Further, he writes that only DHHL is authorized to manage and dispose of geothermal resources on its lands under the terms of the Hawaiian Homes Commission Act (DHHL 2014).

Proponents of geothermal exploration by DHHL, including the Hawaiian Homes Commission Chairman Kali Watson, have pitched geothermal as a potential yearly revenue stream allowing them to fund housing and other initiatives. When interviewed in 2023, Chairman Watson stated that the key was this new “revenue stream” for DHHL. He suggested that the Department would not ignore potential revenue if they could listen to and address community concerns, developing a resource in the appropriate manner. If geothermal power can generate significant income, the DHHL will likely continue to back further exploration (Dayton 2023). In July 2024, Governor Josh Green signed Act 230, balancing state finances and including $3 million in general funds for geothermal energy exploration (Green 2024), roughly half of the $6 million the DHHL originally advocated for (Dayton 2023).

Separate from the DHHL efforts, the Hawai‘i State Energy Office appropriated $5 million of COVID-era federal stimulus in March 2024 to conduct slim-hole drilling at several undisclosed sites across the state (Rodriguez 2024). When interviewed, Hawai‘i State Energy Office’s Chief Energy Officer Mark Glick emphasized that understanding the statewide potential of geothermal is a priority for the office and indicated that they are looking seriously at Maui Island and locations along the Hawai‘i East Rift Zone (Rodriguez 2024).

5 Engagement Methodology

This section summarizes how the NREL project team identified energy stakeholders in Hawai‘i, the initial and continued outreach with those stakeholders, the creation of a Community Council, virtual engagement throughout the effort, and in-person engagement efforts.

Background Research

The NREL project team spent 10 months conducting background research on geothermal and cultural perspectives in Hawai‘i. This included historical context, meeting with Native Hawaiian cultural practitioners, meeting with state-level energy and environmental experts, and engaging with well-respected community members with years of experience in geothermal specific interests in Hawai‘i. The NREL project team worked closely with the NREL State, Local, and Tribal Governments Team to develop a replicable engagement plan for the Hawai‘i-based engagement efforts. As part of this plan, the NREL project team reviewed the methodology used in the Alaska-based efforts to grow and improve efforts in Hawai‘i. Upon consultation with the State, Local, and Tribal Governments Team, the NREL project team moved forward with the following approach:

1. Identification of potential energy stakeholders in Hawai‘i
2. Creation of a Community Council
3. Coordination and Partnership with Community Council members and their respected organizations and/or agencies
4. Engagement planning with Community Council members (in-person and virtual)
5. Engagement planning with identified stakeholders and interested parties

As part of this, the NREL team engaged directly with Dr. Nicole Lautze at the University of Hawai‘i at Manoa. Dr. Lautze is the Director of the Hawai‘i Groundwater and Geothermal Resources Center. The Center leads the collection of historical and new data as well as the dissemination of data and information for groundwater and geothermal resources in Hawai‘i. The NREL Geothermal Program previously worked with Dr. Lautze on the Hawai‘i PFA (Lautze et al. 2017) and sought her expertise in identifying Hawai‘i stakeholders, reviewing identified stakeholders, and making introductions to stakeholders.

Stakeholder Identification

This effort began with initial identification of potential energy stakeholders in Hawai‘i. This included state and federal agencies, state-based non-profit organizations, state-based non-governmental organizations, environmental non-governmental organizations, organizations working with Native Hawaiians, and those in academia. The identified stakeholders were organized in an internal NREL spreadsheet including name, organization, title at organization, email address, and phone number. Within the spreadsheet, specific keywords were included to summarize each organization’s area of focus.

The spreadsheet was considered a living document and was updated throughout the project to include new and expanded stakeholders identified through individual conversations with previously identified stakeholders, the Community Council members and their networks, or through those who reached out via the NREL project team webpage and/or the effort's separate email address (i.e., Geo.Engagement@nrel.gov).

Communication Plan

The NREL project team created a webpage entitled "Hawai'i Community Engagement" for the effort to be summarized for external interests and partners to use. This webpage was updated regularly to include dates and locations for in-person Listening Sessions. Additionally, the NREL project team used this webpage for interested parties to subscribe to information related to the effort by inputting their email addresses. Finally, the webpage included the effort's contact information—an NREL specific email address accessible by the effort's Project Investigator and the team's Communications Office contact (i.e., Geo.Engagement@nrel.gov).

Community Council

While working with the NREL State, Local, and Tribal Governments Team, which has decades of experience and expertise in community and stakeholder engagement, the NREL project team discussed the idea of identifying local organizations or stakeholders to advise and assist the NREL project team to ensure all relevant Hawai'i stakeholders would be included. Initial identified stakeholders included any and all identified interested in energy technologies, state agencies, local non-profits, educational institutions, and representation of Native Hawaiian interests or organizations representing those interests. This group of organizations or stakeholders was meant to advise and assist the NREL project team with any relevant stakeholder introductions, and to help structure the in-person stakeholder Listening Sessions, the Community Council (CC) was coined.

CC members were identified and invited after a series of discussions held by GTO, NREL, and engagement with relevant stakeholders based on their expertise and experience within the energy/environment space, or for those working with Native Hawaiians. The CC was meant to bring together a diverse set of actors to represent the broader Hawai'i community to aid in the development of the effort's stakeholder engagement efforts through in-person Listening Sessions. The CC was open for new membership throughout the duration of the effort to organizations and individuals who communicated interest with the NREL project team. The breakdown of the proposed membership structure of CC members was as follows:

Table 7. Membership Structure of Community Council

Member Type	Number of Members
State agencies (e.g., Department of Land and Natural Resources, Hawai‘i State Energy Office, etc.)	Up to three
Representatives of Native Hawaiians (e.g., DHHL, Office of Hawaiian Affairs, Aha Moku Advisory Committee, Kua'aina Ulu 'Auamo, etc.)	Up to three
Non-governmental organizations	Up to three
Existing geothermal development interests	Up to two
Electric utility and public utilities commission	Up to three
Relevant geothermal experts and/or consultants	Up to two

Due to the geographic diversity of the NREL project team, GTO team, and CC members, combined with the COVID-19 pandemic and its variability, the CC meetings were virtual in nature. Virtual meetings were held via Microsoft Teams and/or Zoom. CC members were asked to:

- Review the list of identified stakeholders (i.e., NREL-created spreadsheet)
- Provide feedback throughout the development of the virtual and in-person Listening Sessions to create thoughtful and thorough in-person Listening Sessions on multiple Hawaiian Islands
    - This included helping the NREL team identify islands and specific locations to host Listening Sessions, particularly high priority areas to visit
- Attend monthly CC meetings to discuss effort updates and primarily plan in-person engagement efforts
- Attend any in-person events, as feasible.

To ensure the CC had clear expectations for their participation, the NREL project team created a CC Charter, outlining all roles and responsibilities of the CC members in addition to providing project management details such as record keeping, agenda and materials sharing, as well as confirmation that participation in the CC would be a voluntary effort. The CC membership was finalized with a virtual kick-off meeting on Tuesday, December 19, 2023.

Shortly after the CC membership was finalized, CC members began working with the NREL team to identify and plan in-person engagement sessions. Originally, the team had planned to visit the seven of the eight main Hawai‘i islands. Following multiple discussions, Maui, O‘ahu

and Hawai‘i islands were identified as areas to prioritize. While the NREL team was initially interested in visiting Kaua‘i, the decision was made to focus on Maui, O‘ahu, and Hawai‘i islands because Kaua‘i has an existing energy plan that does not include geothermal energy. The CC encouraged the NREL team to focus its time and limited budget in visiting the other islands. (KIUC 2023). Interested stakeholders within Maui County (i.e., Moloka‘i, Lāna‘i, and Maui islands) were encouraged to attend the Maui Island session. For those interested, the NREL project team was able to provide resources for interested participants to travel to and from Moloka‘i and Lāna‘i islands. Two individuals expressed interest in utilizing this option, but were ultimately unable to attend due to their own scheduling conflicts.

Virtual Engagement

All individuals and/or organizations identified as potential energy stakeholders in the spreadsheet described above were contacted to request an interview initially in July 2023. For those who responded, the NREL project team coordinated with the individuals via email to schedule individual conversations or informational interviews. For those who did not respond to the initial outreach efforts, the NREL project team followed up again in August 2023 and again in November and December 2023. The NREL project team spoke separately with more than 40 individuals and organizations with varying perspectives related to geothermal energy and who were located on multiple Hawaiian Islands.

Each of these individual video calls ranged from 30–60 minutes in duration and included the following agenda:

- NREL project team member introductions and guest introductions
- Effort overview and purpose
- Discussion on interviewees perspectives related to geothermal energy.

To guide each conversation, the NREL project team had a core group of questions for all interviews. These are as follows:

1. What do you think the State (of Hawai‘i) needs to reach the HCEI goals?
2. What role, if any, do you see geothermal energy playing in reaching those goals?
3. Why do you think there hasn’t been greater geothermal deployment across the islands?

For the context of each conversation, the NREL project team defined geothermal resources to include all utilization types including electricity generation, direct-use applications, as well as heating and cooling applications.

Following these engagement efforts, the NREL project team sent thank you emails to all participants. In the initial stages, the NREL project team utilized a feedback form. However, it was found to be underutilized, and email responses were captured instead. Throughout the course of the effort, the NREL project team monitored the dedicated webpage contact information email inbox as well, which included sending over 100 individual emails.

In-Person Engagement

The NREL project team planned and coordinated all in-person engagement efforts, conceived as Listening Sessions with the CC members. The in-person engagement included eight Listening Sessions on three Hawaiian Islands—O‘ahu, Maui, and Hawai‘i. Locations were selected in counsel with the CC members based on population, potential interest from communities, potential geothermal resource availability, and energy demand. The CC members suggested having an open forum with guided questions facilitated by the NREL project team followed by an optional “Introduction to Geothermal Technologies” presentation. The NREL project team agreed to the open forum and presentation. In all sessions, the team answered other questions related to renewable energy technologies, potential technical assistance opportunities available through NREL and/or DOE, and collected questions the specific team members were unable to answer to follow up with the best point of contact at NREL upon their return to the mainland. Eight public Listening Sessions were held across the three islands.

In addition to hosting the Listening Sessions summarized in Table 7, the NREL project team met with CC members on O‘ahu, Maui, and Hawai‘i islands. CC members, individual interviewees, and supporters of the effort scheduled meetings for the NREL project team members to meet with individuals while in the state as well. These meetings are not included in the total number of individual meetings mentioned above.

The NREL project team utilized existing connections from the CC members to identify locally owned and, in most cases, Native Hawaiian owned and operated businesses to host the in-person engagement efforts. For five of the eight Listening Sessions, CC members also assisted the in-person efforts by hosting the NREL project team and Listening Sessions. The following table summarizes the location of the Listening Sessions.

Table 8. Summary of Listening Session Dates and Locations

Date	Listening Session	Location	Attendees by Category
March 20, 2024	O‘ahu 1	Waiwai Collective	30% Non-profits, 30% Research/Academic Interests, 10% State Employees
March 21, 2024	O‘ahu 2	Waiwai Collective	17% State Employees, 33% Non-profits, 33% Research/Academic Interests
March 22, 2024	Maui	Maui Arts and Cultural Center	17% State Employees, 33% Non-profits, 33% Research/Academic Interests
May 16, 2024	Kailua-Kona	County of Hawai‘i Facility	44% Private Citizens, 11% Non-profits, 22% Home Association Members
May 16, 2024	Waimea 1	DHHL Facility	43% Private Citizens, 29% Non-profits, 21% State Employees
July 28, 2024	Pahoa	County of Hawai‘i Facility	14% Private Citizens, 14% State Employees, 28% Non-profits
July 30, 2024	Hilo	County of Hawai‘i Facility (Keaukaha Elementary School)	26% Non-profits, 42% Private Citizens, 26% State Employees
July 31, 2024	Waimea 2	DHHL Facility	44% Private Citizens, 22% State Employees, 11% Geothermal Production Interests

For all Listening Sessions, multiple venues were identified and contacted to ensure availability and adequate space would exist. For each venue, amenities such as parking, catering, and room setup was considered and factored into the site selection. Additional consideration included NREL required legal review of any contracts for venue rental. As illustrated in Table 7, the NREL project team was hosted by CC members in most situations, which included adequate space, parking, snacks, and necessary tech for the NREL team’s presentations and proper audio systems due to size of the venue (e.g., microphone if needed). For all Listening Sessions, the NREL project team recorded the audio of the discussions. All attendees were notified and verbally acknowledged acceptance of this at each Listening Session. The NREL project team confirmed that no individuals in any conversation would be attributed in this paper directly and that the audio would not be released publicly. This is clear in Section 6, where the Listening Sessions and individual conversations have been synthesized.

Upon selection and confirmation of the O‘ahu and Maui venues, outreach to the communities were included in the venue’s social media channels, through local stakeholders the NREL project team had engaged with, CC member organization list servs, and local governments willing to

share about the Listening Sessions. To ease sharing efforts, the NREL project team worked with NREL Communications to develop toolkits for these organizations to share about the Listening Sessions via social media, newsletters, and/or via email.

It is important to note that as a DOE national laboratory, NREL is unable to pay for any advertisement or marketing services directly. This includes posting on paid boards for local newspapers or print media. As such, utilization of the CC member organizations, previous individual interviewees, NREL social media, the NREL effort's webpage, and DOE social media, including the GTO Drill Down and Quarterly Webinars, were crucial to this effort. This limitation is discussed more in Section 7.1 as part of lessons learned.

The NREL project team offered financial assistance to those interested in attending the in-person engagement efforts on neighboring islands, including reimbursement of flights, hotel, and per-diem to ensure widespread participation. Only two individuals indicated interest in participating and in using these available resources, but they were unable to schedule time to attend in-person. The NREL project team spoke with these individuals virtually to hear their perspectives associated with geothermal energy instead.

Following the Listening Session, the NREL project team would break to thank participants. If participants were interested, the team gave an "Introduction to Geothermal Technologies" presentation, which described the different technologies and their applicability in varying environments. This was meant to be an educational effort to address any lack of information. At all Listening Sessions, the NREL project team brought educational fact sheets (included in Section A.2) for attendees to take as interested and/or needed.

Geothermal Rising Conference 2024 – Waikoloa Village, Hawai'i

The NREL project team also attended the Geothermal Rising Conference in Waikoloa, Hawai'i, in October 2024. Team members presented on the engagement efforts summarized in this paper in two main ways—a poster highlighting the effort and a plenary panel discussing the importance of engagement efforts for energy development, with an emphasis on geothermal development and Native Hawaiian interests. The plenary panel was organized and moderated by the Principal Investigator for this effort, Faith Martinez Smith, with the following panelists participating: Michael Colón (Ulupono Initiative), Makai Freitas (DHHL Hawai'i Island Commissioner), and Jacqui Hoover (Hawai'i Island Economic Development Board).

6 Summary of Listening Sessions

The following subsections represent in-person engagement via location-based Listening Sessions (Sections 6.1–6.4) as heard by NREL team members as well as individual conversations with over 40 individuals and organizations (Section 6.5). These are broken down by island to include considerations regarding geothermal energy resources, as well as potential barriers and opportunities for geothermal technologies. The six categories of considerations were created to help categorize the information garnered at Listening Sessions. Quotes are not attributed individually to protect anonymity, but are still included to capture the thoughts of attendees. Following all Listening Sessions, the NREL team offered an optional Introduction to Geothermal Technologies presentation followed by a question-and-answer session.

6.1 O‘ahu

Two Listening Sessions were hosted on O‘ahu on the mornings of March 20 and 21, 2024. Across the two meetings, the following attendees or organizations were engaged: NREL, the Hawai‘i State Energy Office, the Hawai‘i Public Utilities Commission, the County of Hawai‘i, the State of Hawai‘i Engineering Division, Waika Consulting, the University of Hawai‘i at Manoa, Sustainable Energy Hawai‘i, Hawai‘i Green Growth, Ulupono Initiative, community leaders from O‘ahu’s northern coast, and private citizens. The first session lasted two and a quarter hours while the second went for an hour and a half. Attendees from both meetings shared the following perspectives about geothermal and other energy resources.

6.1.1 Considerations Regarding Geothermal Energy Resources

Health and Monitoring

Participants explained that there is significant distrust of geothermal in some communities that feel like they have been exposed to poor air quality and toxic sulfur dioxide. Any “rubber stamping” or “streamlining” efforts that don’t involve community engagement and ongoing due diligence will likely be met with resistance. There were also stated concerns about the vulnerability of the Hawai‘i grid generally to a major, multi-day outage that could have community health implications.

Cultural and Religious Sensitivities

The O‘ahu participants shared that many cultural concerns and previous grievances could likely be overcome by early engagement with community members; one person cautioned to not “exclude people from the process happening in their backyard, bring people into cultural concerns or issues early on.” Community ownership, borrowing from the practices of the New Zealand Māori or a Native American tribe, also emerged as a potential solution that gives local people a stake in development.

One attendee of the second session emphasized how there would always be differences of opinion among Hawaiians, saying “I’ve lived here for 65 years, and I can tell you that there's some Hawaiians that are going to protest everything, and there’s other Hawaiians who want to make everything happen.” Participants emphasized that anyone interested in developing geothermal or any energy resource should approach it *knowing,* not *suspecting,* that there will be differences of opinion.

Climate Considerations and Energy Resources

While the O‘ahu residents agreed that there is a clear interest in reducing imports of oil and taking care of the Earth, some people are concerned about “the loss of fossil fuel jobs, which are often well-paid, unionized jobs for fewer renewable energy jobs.” Participants said renewable energy deployment in Hawai‘i should benefit all Hawaiians fairly. They also addressed the need to plan for the intermittency of solar and wind generation to ensure islanders receive *reliable* electricity.

Economic and Financial Policy Implications

Conversations on economics ranged from the high cost of electricity for Hawai‘i residents to the high capital requirements for geothermal exploration and generation. Attendees stressed how high energy bills are despite very low levels of consumption and worried about the volatility of the international oil price (and the associated impact on Hawaiian Electric consumers). Many shared stories of how they or their neighbors avoid energy use “because they can’t afford it.” Regarding geothermal development, one attendee remarked “it’s going to come down to money,” explaining that the state or federal government will need to appropriate funds or offer incentives to make things possible for Hawai‘i developers. Overhead capital will be needed for exploration, generation, *and* transmission infrastructure. Finally, across both sessions, participants brought up the hope that any new development would create local, long-term job opportunities for the Hawai‘i workforce.

Native Hawaiian Considerations

In the second session, one participant explained how Native Hawaiians, many of whom are also economically disadvantaged, have been excluded from previous development efforts. The participant said, “you also need to remember the historical perspective of people coming in the system telling Native Hawaiians, ‘This is good for you,’ not involving them in the process, and then it doesn’t happen.” The also conversation explored how those interested in involving Native Hawaiians with geothermal development need to make multiple efforts to go into the communities; people may not have the time, money, or flexibility to contribute otherwise.

Environmental Impact and Eruption Concerns

Attendees raised some concerns about the existing PGV plant’s proximity to Kīlauea and potential for a pumping-triggered explosion, saying “I don't think it’s a great idea to do geothermal on a volcano. I kind of want to be a little bit away from it. You don’t want to do an atomic bomb, you know, like in a magma chamber or something.” One participant also provided a broad concern that future development might not comply with the National Environmental Policy Act.

Other Considerations

Both conversations also touched on wind energy, PGV outages, undersea cable transmission between islands, jet fuel and diesel imports, and the curriculum in Hawai‘i schools relating to energy education. Several key considerations emerged with relevance to geothermal. First, one attendee (when discussing wind developments on Maui) stated “they [the community] just don’t like anything shoved down their throats…Nobody likes that. Nobody wants that.” This point makes clear once more how development efforts need to be rooted in community with high levels of clarity. At the same time, another participant cautioned against over-soliciting

stakeholders to not add to their existing burdens; targeting key community leaders or energy champions may help balance the two engagement concerns.

6.1.2 O‘ahu Summary of Barriers to Geothermal

- Participants shared that development on O‘ahu may be challenging due to land constraints. Around 70% of Hawai‘i’s population lives on O‘ahu, raising land costs and project visibility.

- Despite previous University of Hawai‘i research, attendees voiced uncertainty and differing opinions about the geothermal potential on O‘ahu and called for a better understanding of the subsurface resource via drilling.

- Attendees suggested it will be challenging to increase the use of geothermal heat pumps as the costs can be prohibitive and there aren’t examples of their use case on the islands.

6.1.3 O‘ahu Summary of Opportunities for Geothermal

- O‘ahu has the largest electricity loads given its large population compared to the rest of the island chain, and attendees suggested those loads may only grow with modern technology industries (data centers, cryptocurrency mining, etc.).

- Some participants shared that newer geothermal developments could run more efficiently, incorporate sophisticated air and water quality monitoring, and create opportunities for hydrogen production near O‘ahu’s industry.

- Community voices highlighted geothermal on the islands as an essentially free energy resource, after the upfront capital costs are paid, and could help the state reduce its reliance on imported fuels.

- Attendees noted that direct-use opportunities for geothermal include potential applications for aquaculture, greenhouses, and for drying products such as wood, milk, paper, fish and seaweed.

6.2 Maui

The Maui Listening Session was held at the Maui Arts and Cultural Center in Kahului, Hawai‘i, on the morning of March 22, 2024. Attendees represented included the NREL team, the Hawai‘i Climate Change Mitigation and Adaptation Commission, the Local2030 Islands Network, Hawai‘i Green Growth, the Hawai‘i Public Utilities Commission, the Teran James Young Foundation, Michigan Technical University (professor emeritus), and private citizens. Targeted educational materials as fact sheets were developed and incorporated into these sessions. The session lasted about an hour and a half, and attendees shared the following perspectives about geothermal and other energy resources.

6.2.1 Considerations on Geothermal Energy Resources

Health and Monitoring

For Maui residents, geothermal generation's potential health impacts were unaddressed, as the recovery from the Lahaina wildfires took up most of the discussion time. One resident reflected that "resilience and safety is really top of mind" when thinking about their energy needs.

Cultural and Religious Sensitivities

Attendees discussed cultural and religious sensitivities sparingly, although one attendee shared that their friends had said they couldn't support geothermal because it involved drilling into the land or Earth, referred to as ʻĀina. This led another participant to ask about the viability of using existing wells for geothermal to avoid some of the cultural sensitivity.

Climate Considerations and Energy Resources

The participants emphasized an interest in renewable energy (although wind was viewed considerably less favorably on Maui) with concerns about solar and wind's intermittency. The group also expressed an interest in more resources and education about how geothermal could further reduce emissions.

Economic and Financial Policy Implications

Attendees emphasized that "safety [needs] and incredibly high rates are probably top of mind for most people" when they think of energy. There was curiosity about whether geothermal could reduce utility rates, which led into a discussion of levelized cost of energy. Further, the conversation touched on how more exploratory drilling and heating/cooling studies could make financial investment decisions clearer for "first movers," including both residents and Hawaiian Electric.

Native Hawaiian Considerations

The Maui attendees explained that Native Hawaiian communities may think that these types of technologies or investment are beyond them, emphasizing a need for education on what is possible and how it can benefit them.

Environmental Impact and Eruption Concerns

Participants drew connections between aspects of geothermal drilling and oil operations, saying "pumping hot water into the ground feels too much like fracking to me." One member wondered whether geothermal reservoir pumping could trigger earthquakes.

Other Considerations

Conversations around Lahaina and the need for energy safety understandably overshadowed the discussion of geothermal at times, with one resident reflecting on how it's difficult to think about renewable energy when you don't have a place to live. This underscores how important addressing basic needs are for communities, particularly in the light of the then-recent wildfire in Lahaina, Maui. The group also discussed long-term storage solutions (molten salts, different battery chemistries, pumped hydro, geothermal storage) to combat solar and wind intermittency.

6.2.2 Maui Summary of Barriers to Geothermal

- Participants stated that limited knowledge around the different uses of geothermal energy (utility-scale generation, single home heating, district heating, etc.) make it inaccessible to some. Further, many don't know there is potential for geothermal on Maui and the state generally outside the East Rift Zone on Hawai'i Island.

- Maui residents indicated Native Hawaiians on all islands will likely be wary of any and all drilling into the land, referred to as 'Āina in the session, that they deemed unnecessary.

6.2.3 Maui Summary of Opportunities for Geothermal

- Several attendees shared an eagerness to investigate any technology that could potentially reduce the utility rates for Hawai'i residents. The Maui session's participants were more concerned with economic and safety considerations than the "greenness" of a technology.

- Community member expressed a sense of optimism and opportunity around exploring geothermal through new wells *if* the "right people" were invited to the table to consider potential sites.

6.3 West Hawai'i Island

Five separate Listening Sessions were held on Hawai'i Island. To better report on different perspectives across the island, the Listening Session summaries are split between West Hawai'i, including Waimea and Kona, and East Hawai'i, including Hilo and Pahoa.

West Hawai'i sessions were held at Kona and Waimea on May 16, 2024, and a followup session in Waimea was held on July 31, 2024. Across the three meetings, the following attendees or organizations were engaged: NREL, the University of Hawai'i at Manoa, the DHHL, Sustainable Energy Hawai'i, West Hawai'i Fishery Council, the Hawai'i State Energy Office, the Pele Defense Fund, Ormat/PGV, Geothermal Rising, a residential home developer, and private citizens. Attendees from both meetings shared a variety of perspectives about geothermal and other energy resources, summarized below.

6.3.1 West Hawai'i Considerations Regarding Geothermal Energy Resources

Health and Monitoring

Throughout the three sessions, attendees shared air and water quality concerns about the existing PGV plant. Local residents asked for more investigation of groundwater systems at Puna and increased investigation of chemical leaks, and there seemed to be a need for more public air and water quality data from PGV. Attendees also highlighted how burning fossil fuels for transportation or electricity impacts air quality and threatens the elderly population.

Cultural and Religious Sensitivities

Participants shared extensively about the cultural and religious sensitivities around geothermal across Hawai'i Island. In Waimea, an attendee noted what they referred to as a "PTSD" level of stress that accompanies geothermal development. Another community member requested research on the impacts of Natives that have traditional beliefs but are "forced to believe in

another way." One participant emphasized that Native Hawaiians want their sacred rights to be recognized and explained that the "Big Island *is* Pele." Another attendee seconded this request that Pele be respected, noting the influence of being raised with traditional beliefs. They said that although some Native Hawaiians who were not raised with traditional beliefs may believe drilling is "okay," they feel strongly against it.

In Kona, one attendee expressed their belief that Mother Pele wouldn't "be against it" but also acknowledged that "the closer you get to Pele, the higher the level of resistance is going to be."

Climate Considerations and Energy Resources

At the Kona session, there was a noted interest in moving away from fossil sources. One participant also stated that "the entire lifecycle of energy sources needed to be taken into account, such as how the elements are produced and how they are disposed of at end of life." From there, the group discussed how they thought utility incentives were the best way to reduce electricity demand.

Economic and Financial Policy Implications

At the Waimea sessions, there were several conversations about what Hawaiian Electric and the Public Utilities Commission should be doing to reduce costs. One individual noted concerns about private landowners creating solar farms instead of Hawaiian Electric when utility investment in solar might lower costs. One community member noted the lawsuits lodged against PGV's expansion in Puna. Another participant highlighted concerns about relying on foreign materials for photovoltaics. Finally, some attendees addressed using energy to make hydrogen as a method of energy storage and a fuel for transportation.

During the first Waimea session, community members showed interest in lowering their electric bills through geothermal and ensuring some community benefits. One attendee encapsulated these thoughts by saying, "I see geothermal as a way to stop energy costs to the business to residents from going up." Soon after, another participant offered contrasting comments and suggested that the community in Puna receives no benefit given their electricity price is the same as in Waimea. In all three West Hawai‘i sessions, attendees stressed that they have seen their energy bills fluctuate significantly with a net increase year-over-year, even while their demand stayed the same.

A big point of emphasis was that any geothermal development should benefit local communities on the island of generation, rather than subsidizing the large energy demands on O‘ahu. Similarly, there was some frustration expressed about how grid improvements were passed down to consumers who don't feel the difference.

Native Hawaiian Considerations

There were active conversations about DHHL geothermal development across all three sessions. A community member at the first Waimea session noted that there have been many "broken promises" to Native Hawaiians in the past. Another attendee opposed to geothermal stressed that the DHHL is "called Hawaiian homes, not Hawaiian industrial development," and pushed back against the idea that geothermal could be a continuous revenue stream.

Other individuals focused less on the potential impact of a geothermal plant and more on the existing stressors for Native Hawaiians. One participant noted the cost of living, difficulties with agriculture, and healthcare insecurity are pushing so many families out of the state. They called for energy projects that include community benefits that extend beyond an electric bill.

Environmental Impact and Eruption Concerns

During this Listening Session, there was interest in more education and data on what chemicals are used in geothermal and about emergency "blowout" procedures. One attendee expanded on this notion and declared the process of reinjecting water into volcanically active region irresponsible. They said, "What happens when you pour water over a campfire? You're going to explode. Same thing underneath when you mess with Pele." One throughline in these conversations was that residents feared developments could exacerbate eruptions and wanted better upfront communication on how geothermal exploration would impact their land, above and belowground.

Other Considerations

Many conversations across the three sessions related to other alternative energies (ocean thermal energy conversion, burning trash), the role of the Public Utilities Commission, district geothermal applications, and an overwhelming need for education. One attendee noted that some people still don't know about photovoltaics, making geothermal a complete mystery. In a different session, several participants wondered how the utility could better act in the public good and avoid answering only to stockholders. Finally, another attendee conveyed that there have been a lot of mistakes made with geothermal in the past, and that there are opportunities to learn from these mistakes in the future.

6.3.2 West Hawai'i Summary of Barriers to Geothermal

- Participants expressed concerns about public safety in the event of a well blowout as well as insufficient monitoring of hydrogen sulfide emissions when considering a new project in the East Rift Zone.

- Several attendees worried that any future geothermal developments would not impact local Hawaiian energy bills while simultaneously disrespecting traditional beliefs and the presence of Pele on Hawai'i Island.

6.3.3 West Hawai'i Summary of Opportunities for Geothermal

- Community members noted that DHHL geothermal development could allow for Native Hawaiian concerns to be centered and included in a way that is different from the past. One attendee noted that with a relatively small footprint on the surface, geothermal could be a way to generate continuous energy and revenues for Native Hawaiians, reduce fuel imports, and stimulate the local economy.

- Further exploratory drilling presents an opportunity to better understand groundwater systems and the volcanoes, as well as the potential for geothermal.

6.4 East Hawai‘i Island

As noted, five separate Listening Sessions were held on Hawai‘i Island. To better report on different perspectives across the island, the Listening Session summaries are split between West Hawai‘i, including Waimea and Kona, and East Hawai‘i, including Hilo and Pahoa.

East Hawai‘i sessions were held in Pahoa in 2024 on July 28 and in Hilo on July 30. Across the two meetings, the following attendees or organizations were engaged: NREL, Sierra Club, Hawaiian Homestead Community Association, DHHL, Native Hawaiian Chamber of Commerce, Sustainable Energy Hawai‘i, an association for the Pahoa Community Hospital, and private citizens. The sessions lasted about an hour and a half each, and attendees shared these following perspectives about geothermal and other energy resources.

6.4.1 East Hawai‘i Considerations on Geothermal Energy Resources

Health and Monitoring

There was a strong concern raised in East Hawai‘i sessions about the threat of a hydrogen sulfide gas release from the PGV plant, particularly during an extreme event such as an eruption or tropical storm. A participant in Hilo described anecdotally how during one previous event, more than 100 people had been impacted by the gas in their homes. One attendee noted that geothermal could be fine “in the right place,” but that they already have “too much hazard” around them already.

Cultural and Religious Sensitivities

The cultural history of Native Hawaiians and maintaining a relationship to the Earth, referred to as ‘Āina, was discussed briefly at the sessions. One private citizen reminded the attendees that the island has provided for millions of people for thousands of years, and that everybody that everyone has forgotten their responsibility, referred to as kuleana, to land or ‘Āina. They said, “it’s not that we don’t understand all of these things [geothermal, new technologies] that are helpful for today, it’s just that we [should] look back first at what was and then we move forward.”

Climate Considerations and Energy Resources

The topic of pursuing energy independence with an awareness of renewable technologies and their impacts came up in both sessions. Attendees were quick to highlight the plentiful resources available for commercial solar, wind, and geothermal generation and were curious about the potential for ocean-based energy. One speaker put the state’s situation and distance from the mainland United States bluntly, saying “we cannot stand [rely] on a power line across 2,500 miles of water to send us power.” This distance keeps them relatively independent which means “our resource and energy must come from here [the islands].”

There were also some comments about the safe disposal of renewable energy technologies given the difficulty exporting waste from Hawai‘i.

Economic and Financial Policy Implications

Participants in Hilo and Pahoa discussed how cost is critical for decision-making. With so much reliance on imported fuel, “everything increases in cost if fossil fuels increase in cost, 24/7, 365.”

Attendees noted that the state needs funding to do more exploration and should consider whether that money is better spent on solar or wind, which are already proven but intermittent.

Native Hawaiian Considerations

A significant portion of the conversation discussed the needs of Native Hawaiians and the potential for a DHHL geothermal development. One local resident described that they had heard a development on DHHL lands could avoid some regulatory red tape and provide 100% royalties to the Department. Attendees generally approved of a DHHL geothermal development under the condition that it would directly benefit Native Hawaiians, particularly those on the Hawaiian Homes waitlist. In a similar vein, one participant wondered aloud about whether geothermal plants could provide "high quality, specialized jobs" to the younger generation of Hawai‘i residents and Native Hawaiians and "attract others that have migrated out of here to come back and to hold space in their ancestral land."

Environmental Impact and Eruption Concerns

Participants in both sessions had serious reservations about the past environmental impacts in Puna, calling out the noise from drilling, gas emissions, water table concerns from reinjection, and deforestation in pristine and culturally important forests. Pro-geothermal participants often clarified their stance with the condition that they would only support geothermal if it "can be done in an environmentally friendly way and benefits the community." Others were firmly against further development, calling previous exploration efforts a "devastation" that leveled a forest and took away locals' living, food, and medicine.

Finally, there was some doubt about the "cleanliness" of renewable resources. One attendee probed about how new renewable generation technologies could be disposed of and recycled, expressing angst at how broken (wind) turbines might be shipped abroad to disturb another's land, described by the participant as ‘Āina.

Other Considerations

Throughout both sessions, local attendees described the need for "good negotiators" and thorough legal protection for the community. One person described a previous litigation which ended in a "settlement and a gag order" because they didn't have "enough lawyers to fight a multinational corporation and their lawyers." Put another way, attendees suggested that when the community is small and has limited legal counsel, there needs to be more accountability or oversight of the developer.

6.4.2 East Hawai‘i Summary of Barriers to Geothermal

- The community participants perceive a lack of oversight and proper regulation on the existing geothermal plant at PGV, leading to resident exposure to hydrogen sulfide and potentially harmful reinjections of wastewater/processed water.

- Attendees emphasized further deforestation and clearing near Puna would likely threaten culturally important areas of land or Earth, referred to as ‘Āina.

6.4.3 East Hawai'i Summary of Opportunities for Geothermal

- Community voices highlighted that a DHHL geothermal plant that directly benefits Native Hawaiians and includes extensive community input would likely be better received than previous efforts.

- Attendees shared that geothermal energy generation might be able to reduce fuel imports, address the intermittency of solar power on the grid, and provide new jobs for Native Hawaiians.

6.5 Summary of Individual Conversations and Informational Interviews

As addressed in Section 5, Virtual Engagement, the NREL project team also interviewed more than 40 individuals and organizations outside of the Listening Sessions. These individual conversations and informational interviews were scheduled between July 2023 and September 2024. After describing the effort's purpose, interviewees responded to questions about achieving the state's HCEI goals, the role of geothermal energy generation in meeting those objectives, and barriers that have limited geothermal deployment across the islands. In the following subsection, their responses are documented using the same topic categories as used for Listening Sessions.

6.5.1 Summary Matrix of Individual Conversations and Informational Interviews

Organization Type and/or Private Citizen	Health and Monitoring	Cultural and Religious Sensitivities	Climate Considerations and Energy Resources	Economic and Financial Policy Implications	Native Hawaiian Considerations	Environmental Impact and Eruption Concerns	Other
Private Citizens	X	X	X	X		X	X
Non-Governmental Organizations (NGOs)			X	X			X
Environmental NGOs	X	X	X	X	X	X	X
Trade Association and/or Industry			X	X	X		X
Academic Institution	X	X				X	
Government/State Agency			X			X	

6.5.2 Considerations on Geothermal Energy Resources

The key perspectives on geothermal and considerations of other Hawai‘i energy issues from the individual interviews are noted below:

Health and Monitoring

Several private citizens interviewed had strong concerns about the current regulation, monitoring, and reporting mechanisms at the PGV plant, particularly around toxic gas emissions. They called for more monitors and decried the emergency procedures at PGV. Other interviewees discussed the mixed messages coming out of public health reports on Puna/the Kīlauea region, pointing out how inconclusive information is being used to amplify existing grievances with the plant. In both cases, more information on existing emissions and health impacts were desired.

Cultural and Religious Sensitivities

Across several interviews, the participants mentioned the decades-long history and stigma associated with geothermal, particularly in the sensitive areas around Puna. People “may jump to conclusions” about new geothermal because of their reverence for Pele and the volcanoes as well as anger about a perceived lack of community engagement by past developers. Some interviewees pointed out that serious Pele practitioners consider poking holes and tapping her life force a “desecration.”

Climate Considerations and Energy Resources

Almost everyone who referenced other renewable energy resources believed they had a role to play in combatting negative environmental issues and minimizing fuel imports. Some felt that geothermal is “part of the solution,” but that other pieces such as solar, wind, or nuclear were needed as well. Some harkened back to how other renewables were “safer” than geothermal while others emphasized reliability and how geothermal could bridge the intermittency gap for the islands.

Economic and Financial Policy Implications

Similar to the Listening Sessions, interviewees described the high cost of electricity on the islands and concerns that royalties from geothermal might not assuage community energy burden. They also highlighted the state’s dependence on imported supplies/energy, suggesting that geothermal might provide a pathway to more self-reliance. Finally, some stated the lack of transmission between the islands means that significant financial investment and incentives must be allocated by on-island energy needs.

Native Hawaiian Considerations

Interview participants’ perspectives on Native Hawaiian considerations for geothermal touched on the cultural relationship with Pele/Kīlauea and the need for well-defined community benefits for energy projects. Most individuals were willing to accept geothermal power development on DHHL lands as they believed the Department would implement it in a way that would honor and respect Pele while directly benefiting multiple generations of Native Hawaiians. Most individuals discussed the concerns of Natives leaving the islands due to lack of jobs, soaring housing prices, and the general high cost of living. However, all felt geothermal development

could provide more long-term, union-like job opportunities, reduce home prices for DHHL beneficiaries, and reduce energy costs over time.

Environmental Impact and Eruption Concerns

The interviewed individuals referenced that while criticism against PGV and geothermal has generally decreased (compared to its peak in the late 1900s), concerns still exist among residents. Particularly during an eruption event, the power plant's emergency procedures come under intense scrutiny. Local private citizens balked at the limited seismic data released by the plant and criticized its 2018 emergency plan, even suggesting that it increased the eruption intensity. NREL also heard critiques of PGV's labor practices and the impact of gas emissions on the environment.

Other Considerations

One additional point that emerged from the interviews was a sense of frustration among some private citizens about their ability to take legal action against PGV. The interviewees expressed angst at how little their comments seemed to mean when the County of Hawai‘i approved the recent power purchase agreement's expansion environmental impact statement. Additionally, they described several lawsuits lodged in the state judicial system that seem stymied by forces beyond their control.

6.5.3 Individual Interviews Summary of Barriers to Geothermal

- Private citizens take issue with PGV's existing emergency management plan and monitoring systems for air and groundwater quality. Further geothermal development in the Puna region or any emergency discharge events threatening public health will likely face scrutiny.

- Further drilling, particularly in the East Rift Zone, may be challenging due to the availability of drillers, drilling equipment, and the cultural opposition by those who worship Pele or do not want to see further damage to their local land.

6.5.4 Individual Interviews Summary of Opportunities for Geothermal

- Consistent geothermal power generation could fuel Hawai‘i hydrogen production, creating energy jobs, a new export for the state, and a local fuel alternative to imported petroleum for transportation. Interviewees highlighted the potential to create careers and new opportunities for young people, showing them how to care for their environment.

- Given the state's HCEI goals and eagerness to reduce the reliance on fuel imports, they will need additional on-island generation. Even if it isn't at Puna, some of the interviewees suggested the geothermal resource would likely continue to be explored statewide.

7 Conclusions

This section provides an overview of the lessons learned by the NREL project team throughout the engagement efforts in Hawai‘i.

7.1 Lessons Learned

Larger Geographic Scope

If factors such as budget, time, and team member availability allow, a larger geographical scope may be beneficial. Given the unique geography of Hawai‘i as an archipelago, in-person outreach to each island was not feasible. Islands were prioritized by potential/predicted impacts, with consideration for the given time and budget. However, the ability to host more Listening Sessions across more islands and cities may have led to more engagement with higher attendance.

Expanding Stakeholder Lists

Continually working to expand stakeholder lists and networks should be a key priority for any similar efforts or projects. This effort strove to continually find additional contacts within established stakeholder networks throughout the 18-month time period. Over time, key stakeholder dynamics for a given field will shift and develop. This proved to be true with this project, as initial outreach to stakeholders resulted in some emails bouncing back, or recommendations for new contacts. Constant stakeholder communication was another key factor for expanding the stakeholder list. Recommendations from stakeholders directed the team to relevant new connections that may have been lacking from original outreach. This was especially critical given the fact that the NREL team was based out of state, and the team is grateful for the support of the Community Council and other stakeholders across the Hawaiian Islands who participated.

Listening Session Days, Times, and Length

Each of the three March Listening Sessions were planned for around 3 hours, and this timeframe was generally successful. Some sessions finished earlier than the allotted timeframe, whereas some sessions lasted to the end of the allotted timeframe. Moving forward, the NREL project team adjusted the Listening Sessions in May and July to occur on different times during the day, and on different days for maximum accessibility. Pre-meeting registration helped predict turnout for each session, but only as an estimation, as it was found that actual attendance numbers varied. Recordings of the Listening Sessions were useful, in addition to physical notes, for multiple sources of record keeping.

Local Media Outreach

In terms of outreach, the NREL team also looked to use local media on the islands to advertise. However, most of the local newspapers charged a fee for posting events on their calendars, which was an unallowable expense for government. NREL attempted to work around this hurdle by reaching out to writers and editors directly to see if they would write a short piece, but little success was had with this method.

Virtual Sessions

Despite a key focus for this project being to foster in-person engagement, virtual sessions may have provided a higher level of accessibility and wider reach of interested stakeholders. The emphasis of this effort was on in-person engagement with the goal of developing more meaningful relationships and connections. However, future engagement efforts should consider hosting virtual opportunities along with in-person opportunities for greater accessibility and broader reach of interested participants.

7.2 Future Work

Moving forward, the NREL team will look to replicate the methodology used in the Hawai‘i engagement efforts while implementing lessons learned, as briefly described in Section 7.1. While each state has unique energy resources, goals, and needs, the team will apply insights from the Hawai‘i and Alaska engagements to its current GTO-funded engagement in 2025 within Colorado. If additional funding becomes available, this approach could be extended to other states.

Additionally, the NREL team will continue to support residents in Hawai‘i through a GTO-funded international exchange program between selected Native Hawaiians and the Māori of Aotearoa (i.e., New Zealand). Throughout FY25 and into FY26, participants will be able to interface with Māori leaders who have developed geothermal resources to directly benefit their communities. The exchange program was devised after many Listening Session participants stressed the importance of Native-owned and Native-benefiting energy systems. This effort hopes to build the capacity of organizations that serve Native Hawaiians, empowering those communities to more confidently engage in future energy projects.

At a high level, the exchange program will focus on providing tools and resources for participants to address non-technical barriers associated with geothermal development, including but not limited to regulatory frameworks, permitting, community ownership and decision-making models, and stakeholder participation in energy planning processes.

The Māori are the only current example of Native or Indigenous owned, developed, and operated geothermal power projects in the world. The Māori are also considered a distant relative or cousin to the Hawaiian people with similar beliefs and respect for volcanoes and natural resources. The international exchange effort will include cultural, regulatory, and developmental information sharing through an in-person Hawai‘i-based workshop and a New Zealand-based workshop combined with geothermal site visits and a traditional Māori marae stay. Participants will be selected through a competitive process and must be Native Hawaiian themselves or work directly with and/or in a way that would benefit Native Hawaiians.

7.3 Gratitude

We would like to expand on the gratitude stated in the Acknowledgments section to more fully thank everyone in Hawai‘i who assisted NREL with this effort. The team was welcomed with warm aloha and supported by individuals and organizations across the islands. Mahalo nui, meaning “thank you very much” in Hawaiian, to everyone who took the time to share and entrust their perspectives with us, whether it was individually during virtual calls or in-person at the Listening Sessions. Mahalo nui loa to the Community Council for dedicating hours of your time

and expertise to ensuring community engagement was handled in a respectful and impactful manner. Community Council members included: Patrick Branco, Michael Colón, Dr. Brian DeSanti II, Mike Kaleikini, Russell Kaupu, Ron Kodani, Dr. Nicole Lautze, Phil Nigro, Peter Sternlicht, Mililani Trask, and Jennifer Zelko-Schlueter. We are humbled by the level of support, education, and trust we received as a part of this effort from the Community Council members in Hawai‘i, residents in Hawai‘i, and Hawaiian communities. Ke aloha mai a hui hou.

Glossary

Term	Definition
ʻĀina	A Native Hawaiian word meaning "land, Earth" (University of Hawaiʻi 2023a).
Intermittency	Refers to the variability of generation from renewable energy sources (generally wind and solar) due to changes in wind speed or solar irradiance.
Hydrogen sulfide	With the chemical formula H_2S, this colorless volcanic gas has the odor of rotten egg.
Kānāwai	A Native Hawaiian word meaning "laws" (Kamana and Vaughan 2024).
Kapu	A Native Hawaiian word meaning "sacredness" (Kamana and Vaughan 2024).
Kuleana	A Native Hawaiian word meaning a "right, privilege, concern, responsibility" (University of Hawaiʻi 2023b).
Oli	A Native Hawaiian word meaning a "traditional chant" or the act of "chanting" (Kamana and Vaughan 2024).
Sulfur dioxide	With chemical formula SO_2, this colorless gas is released by volcanic activity and has the odor of burnt matches.

References

Adler, Peter. “Geothermal Public Health Assessment: Findings & Recommendations.” 2013. The Geothermal Public Health Assessment Study Group. https://punageothermalproject.com/wp-content/uploads/2023/03/Geothermal-Public-Health-Assessment-Report-FINAL.pdf

Armstrong, Jason. “Big Island: Everyone’s Talking About Pele, Hawai‘i’s Fire Goddess.” *Honolulu Civil Beat*, May 8, 2018. https://www.civilbeat.org/2018/05/big-island-everyones-talking-about-pele-the-fire-goddess/.

Boyd, T.L., Thomas, D.M. and Gill, A.T., 2002. Hawai‘i and geothermal: what has been happening? https://evols.library.manoa.hawaii.edu/items/c85be021-65a6-4001-92e1-0b1464c95bef

Brestovansky, Michael. “Commission authorizes amended power agreement for PGV, Hawaiian Electric.” *Hawai‘i Tribune-Herald*, April 7, 2022. https://www.hawaiitribune-herald.com/2022/04/07/Hawai‘i-news/commission-authorizes-amended-power-agreement-for-pgv-hawaiian-electric/

Brestovansky, Michael. “Commission authorizes amended power agreement for PGV, Hawaiian Electric.” *Hawai‘i Tribune-Herald*, March 3, 2024. https://www.hawaiitribune-herald.com/2024/03/03/hawaii-news/puna-groundwater-study-sought-it-would-try-to-determine-whether-pgv-has-an-impact/

Bu, X., Ran, Y. and Zhang, D., 2019. Experimental and simulation studies of geothermal single well for building heating. Renewable Energy, 143, pp.1902-1909.

Bustaffa, Elisa, Cori Liliana, Adele Manzella, et al. “The health of communities living in proximity of geothermal plants generating heat and electricity: A review.” *Science of the Total Environment* 706, no. 2. 2020. https://www.sciencedirect.com/science/article/pii/S0048969719359947

Dayton, Kevin. “Hawaiian Home Lands Seeks $6M To Test For Geothermal Power.” *Honolulu Civil Beat*, November 8, 2023. https://www.civilbeat.org/2023/11/hawaiian-home-lands-seeks-6m-to-test-for-geothermal-power/.

Reuters in Pahoa. “Hawai‘i power plant shut down as lava nears geothermal wells.” *The Guardian*, May 22, 2018. https://www.theguardian.com/us-news/2018/may/22/Hawai‘i-puna-geothermal-venture-power-plant-shut-down-as-lava-nears-geothermal-wells

DHHL. “AG Opinion: Geothermal Proceeds On DHHL Lands,” March 18, 2014. https://dhhl.Hawai‘i.gov/2014/03/18/7897/.

Dobbyn, Paula. “Longtime Geothermal Critics Refuse to Back Down As Puna Plant Eyes Expansion.” *Honolulu Civil Beat*, June 15, 2023. https://www.civilbeat.org/2023/06/longtime-geothermal-critics-refuse-to-back-down-as-puna-plant-eyes-expansion/.

Dores, D. and Lautze, N., 2020. Preliminary assessment of ground-source heat exchangers for cooling in Hawai‘i. Sustainable Energy Technologies and Assessments, 37, p.100579.

Evans, W.C., Bergfield, D., Sutton, A.J., et al. “Groundwater Chemistry in the Vicinity of the Puna Geothermal Venture Power Plant, Hawai‘i, After Two Decades of Production.” USGS. 2015. https://pubs.usgs.gov/publication/sir20155139

Faulstich, Paul. “Hawai‘i’s Rainforest Crunch: Land, People, and Geothermal Development | Cultural Survival.” *Cultural Survival*, March 2, 2010. https://www.culturalsurvival.org/publications/cultural-survival-quarterly/hawaiis-rainforest-crunch-land-people-and-geothermal.

Green, Josh. “Office of the Governor – News Release – Gov. Green Balances Financial Plan and Signs Budget That Invests in Hawai‘i’s Priorities,” July 9, 2024. https://governor.Hawai‘i.gov/newsroom/office-of-the-governor-news-release-gov-green-balances-financial-plan-and-signs-budget-that-invests-in-hawai%ca%bbis-priorities/.

Green, Josh. “Office of the Governor – News Release – Gov. Green Reinforces Commitment to Renewable Energy,” March 2, 2025. https://governor.hawaii.gov/main/governor-green-reinforces-commitment-to-renewable-energy/

Hawai‘i State Energy Office. “Hawai‘i Clean Energy Initiative” Hawai‘i State Energy Office, 2025. https://energy.hawaii.gov/hawaii-clean-energy-initiative/

Hawai‘i State Energy Office. “Non-Renewable Energy Sources.” Hawai‘i State Energy Office, 2024a. https://energy.Hawai‘i.gov/what-we-do/energy-landscape/non-renewable-energy-sources/.

Hawai‘i State Energy Office. “Renewable Energy Sources.” Hawai‘i State Energy Office, 2024b. https://energy.Hawai‘i.gov/what-we-do/energy-landscape/non-renewable-energy-sources/.

Hawaiian Electric. “About Us, Our Vision and Commitments” 2024a. https://www.hawaiianelectric.com/about-us/our-vision-and-commitment.

Hawaiian Electric. “Average Price of Electricity.” 2023a. http://www.hawaiianelectric.com/billing-and-payment/rates-and-regulations/average-price-of-electricity.

Hawaiian Electric. “Hawaiian Electric - 2022-2023 Sustainability Report,” 2023b. https://view.hawaiianelectric.com/2022-2023-sustainability-report/page/1.

Hawaiian Electric. “Hawaiian Electric - 2023-2024 Sustainability Maps,” 2024b. https://view.hawaiianelectric.com/2023-sustainability-maps/page/1.

Hawaiian Electric. “Our Clean Energy Portfolio,” 2025. http://www.hawaiianelectric.com/clean-energy-Hawai‘i/our-clean-energy-portfolio.

Hawaiian Electric. “Renewable Project Status Board,” 2024c. https://www.hawaiianelectric.com/clean-energy-Hawai‘i/our-clean-energy-portfolio/renewable-project-status-board

Kaua‘i Island Utility Cooperative. “Renewable Portfolio.” Kaua‘i Island Utility Cooperative, 2024. https://kiuc.coop/renewable-portfolio.

Kamana, Noa and Vaughn, M. 2024. “Improving collaboration between native Hawaiians and energy professionals to explore geothermal energy potential in Hawai‘i.” *Frontiers in Sustainability*. https://doi.org/10.3389/frsus.2024.1443407.

Kawainui Kane, H. (1996). *Pele Goddess of Hawai‘i’s Volcanoes* (Revised Edition). The Kawainui Press.

Lautze, N., Thomas, D., Hinz, N., Apuzen-Ito, G., Frazer, N. and Waller, D., 2017. Play fairway analysis of geothermal resources across the State of Hawai‘i: 1. Geological, geophysical, and geochemical datasets. Geothermics, 70, pp.376-392.

Lautze, N.C., Thomas, D.M., Apuzen-Ito, G., Frazer, N., Martel, S.J., Hinz, N.H., Whittier, R.B. and Wannamaker, P., 2021. Hawai‘i Play Fairway (No. DOE-Hawai‘i-06729). Univ. of Hawai‘i, Honolulu, HI (United States).

Lautze, N., Thomas, D. and Haskins, E., 2024. Play fairway analysis of geothermal resources across the state of Hawai‘i: 5. Slim hole drilling on Lāna‘i island. Geothermics, 124, p.103147.

Lund, J.W. and Toth, A.N., 2021. Direct utilization of geothermal energy 2020 worldwide review. Geothermics, 90, p.101915.

Markrich, Michael. “History of Geothermal In Hawaii Part II - From Ancient Times to the Present.” Renew Rebuild Hawaii. 2023. https://renewrebuildhawaii.com/blog/2023/history-of-geo-thermal-in-hawaii-part-ii-from-ancient-times-to-the-present

Morita, K., Bollmeier, W.S. and Mizogami, H., 1992. An experiment to prove the concept of the downhole coaxial heat exchanger (DCHE) in Hawai‘i.

Rodriguez, Max. “State to Embark on Search for Geothermal Energy Sources.” *KHON2*, March 3, 2024. https://www.khon2.com/local-news/state-searches-for-geothermal-energy-sources/.

Romero, Simon, and Tamir Kalifa. “Madame Pele, Hawai‘i’s Goddess of Volcanoes, Awes Those Living in Lava’s Path.” *The New York Times*, May 21, 2018, sec. U.S. https://www.nytimes.com/2018/05/21/us/pele-Hawai‘i-volcano.html.

State of Hawai‘i, Department of Business, Economic Development & Tourism. *Hawai‘i Facts & Figures*. January 2024. https://files.Hawai‘i.gov/dbedt/economic/library/facts/Facts_Figures_browsable.pdf

State of Hawai‘i, Office of Planning and Sustainable Development. *The Environmental Notice*. February 8, 2024. https://files.Hawai‘i.gov/dbedt/erp/The_Environmental_Notice/2024-02-08-TEN.pdf

State of Hawai‘i & The U.S. Department of Energy (2008). *DOE-Hawai‘i Clean Energy Partnership*. https://energy.Hawai‘i .gov/wp-content/uploads/2022/06/HCEI_MOU_signed_1-28-08.pdf

State of Hawai‘i & The U.S. Department of Energy (2014). *DOE-Hawai‘i Clean Energy Partnership*. https://energy.Hawai‘i .gov/wp-content/uploads/2022/06/HI-DOE_MOU_9.15.14.pdf

Thomas, D.M., 1985. Geothermal resources assessment in Hawai‘i.

Thomas, D.M., Wallin, E., Lautze, N.C., Lienert, B.R. and Pierce, H.A., 2014, December. A Blind Hydrothermal System in an Ocean Island Environment: Humu'ula Saddle, Hawai‘i Island. In AGU Fall Meeting Abstracts (Vol. 2014, pp. V21A-4731).

Trainor-Guitton, W., Pinchuk, P., Olsson, R., & Maclaurin, G. 2025. *Renewable Energy Potential Model: Hawaii Geothermal Supply Curves*. [Data set]. Geothermal Data Repository. National Renewable Energy Laboratory. https://doi.org/10.15121/2516750

Trask, Mililani. “Honor Pele by Developing Geothermal Respectfully.” Ka Wai Ola, April 1, 2023. https://kawaiola.news/trustees/honor-pele-by-developing-geothermal-respectfully/.

Trust for Public Land. “Aloha ‘‘Āina | Love of the Land - Our Work In.” Accessed December 30, 2024. https://www.tpl.org/our-work/aloha-aina-love-land.

Trust for Public Land. “Protecting Pele’s Forest – Land & People.” November 1, 2006. https://www.tpl.org/resource/protecting-peles-forest-landpeople

University of Hawai‘i. *Hawaiian Word of the Week: ‘‘Āina*. May 2, 2023a.

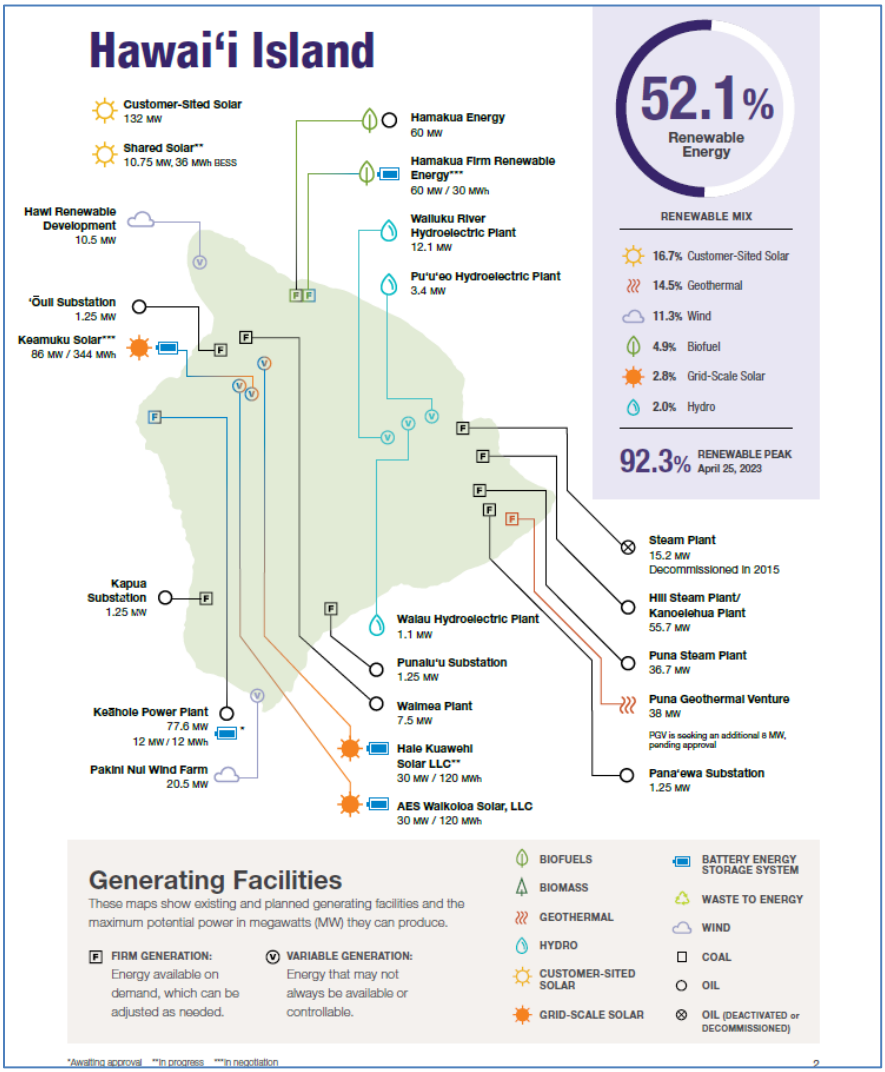
University of Hawai‘i. *Hawaiian Word of the Week: Kuleana*. January 10, 2023b.

U.S. EIA. “Hawai‘i State Profile and Energy Estimates,” 2024. https://www.eia.gov/state/?sid=HI#tabs-2.

Appendix

A.1 Hawaiian Electric 2023–2024 Sustainability Maps

Below is Hawaiian Electric's map of energy resources for Hawai'i Island. The 2023–2024 Sustainability Maps publications include visualizations of the current and future generation facilities across their service territory. Source: (Hawaiian Electric 2024b)



A.2 Fact Sheet Examples

Examples of the fact sheets offered at the in-person engagement sessions.

Fact Sheet: What is Geothermal Energy?

Fact Sheet: What are Geothermal Heat Pumps?

Hawai'i-specific fact sheet: