Realizing Geothermal Aspirations of Ngāti Whātua o Kaipara at the Parakai Geothermal Site Using the Kaitiaki Geothermal Development Model

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1. Abstract

Ngāti Whātua o Kaipara have had land returned to them as part of their Waitangi Claim that contains the Parakai geothermal field. Ngāti Whātua are keen to understand the nature of the geothermal resource and how they might, in their role as kaitaiki, develop the resource. They are exploring many options including aquaculture, horticulture, and a continuation or development of existing pool infrastructure. A different option assessed herein is the feasibility of using the geothermal resource for cooking using traditional techniques. Additionally, Ngāti Whātua wish to understand how their decision-making can be consistent with kaitiakitanga. To ensure Ngāti Whātua realise their developments aspirations while fulfilling their kaitiaki obligations, By using the Mauri Model as a decision-making framework, can assess both the feasibility and sustainability of this option while fulfilling their kaitiaki aspirations and obligations of.

2.0 Introduction

Since 1975, Māori, the indigenous peoples of New Zealand, have been able to seek redress as compensation for land confiscated by the Crown through various subterfuges and receive other settlements due to a history of breaches of the Treaty of Waitangi.[1] The return of land to Ngāti Whātua o Kaipara (hereafter referred to as Ngāti Whātua) has created the opportunity for the discussion of land management and development options. The Parakai geothermal field was included as part of the settlement package. In particular, Ngāti Whātua have shown interest in utilizing the geothermal source within that area.

Ngāti Whātua wish to explore possible development options of the geothermal resource using an approach that incorporates indigenous "ethos, ethics, set of principles, and practices" rooted in sustainability and the concept of *kaitiakitanga,* or 'guardianship'.[2] The Kaitiaki Geothermal Development Model (KGDM) incorporates these indigenous ideas into the potential development and management of a geothermal resource opportunity.[3] The KGDM is built around the Mauri Model, which embodies this approach by evaluating options based on four fundamental criteria—economic, environmental, social, and cultural well being—while meeting governmental policies and requirements.[4] The New Zealand legislative framework that pertains to geothermal systems and development are primarily observed within the Resource Management Act (1991 and 1997) and the Local Government Act (2002).

By using the Mauri model, with the Māori community's worldview in mind, methods for utilizing the Parakai geothermal resource can be analyzed based on mauri impact; ranging from diminishing to neutral to enhancing. Two critical steps in this process that must occur are: first,

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[1] "Treaty Settlements: Waitangi Tribunal." *Ministry of Justice*. New Zealand Ministry of Justice.

[2] D.C.H. Hikuroa, et. al., "Integrating Indigenous Values into Geothermal Development," *Geothermal Resource Council* 34, (2010): 51.

[3] Ibid.

[4] Ibid.

quantifying the potential energy source and, second, understanding the aspirations of Ngāti Whātua. With this information, various options can be explored and plans subsequently formulated. The KGDM approach facilitates Ngāti Whātua determining indicators and then evaluating the development options against those indicators using the Mauri Model, which takes into account various criteria that collectively determine the impact to the mauri of the site. Its application is discussed in detail in Section 5: Evaluation. Through this process, options can be chosen and implemented with assurance that it is both the most feasible and sustainable while addressing the aspirations of Ngāti Whātua.

3.0 Background

3.1 Geothermal Energy

Geothermal energy sources are produced by the interaction of plate tectonics and resultant heat with the hydrological cycle. The movement of tectonic plates is fueled by convection from the interior of the Earth, which gives rise to boundaries and faults where magma rises close to or onto the surface.[5] It is generally at these plate boundaries and/or where volcanism occurs, water that has percolated deep underground within porous rock or water trapped in sediments is dragged down on the subducting plate can be heated to high temperatures.[6]

3.2 Types of Geothermal Sources and their Uses

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[5] United States Geological Survey, “Some Unanswered Questions,” *This Dynamic Earth*, (1999).

[6] "Using Low Temperature Geothermal Resources." *GNS*: 3.

Geothermal sources have considerable ranges of variability of temperature and pressure. To assist decisions regarding use of the resource, two categories of geothermal sources have been defined; low-temperature and high-temperature. High-temperature sources are defined as those above 150°C and are generally reserved for electricity generation, as they yield huge amounts of energy due to their high enthalpy.[7] There are various ways to extract energy from geothermal sources depending on the type of resource, ranging from hydrothermal to hot rock.[8]

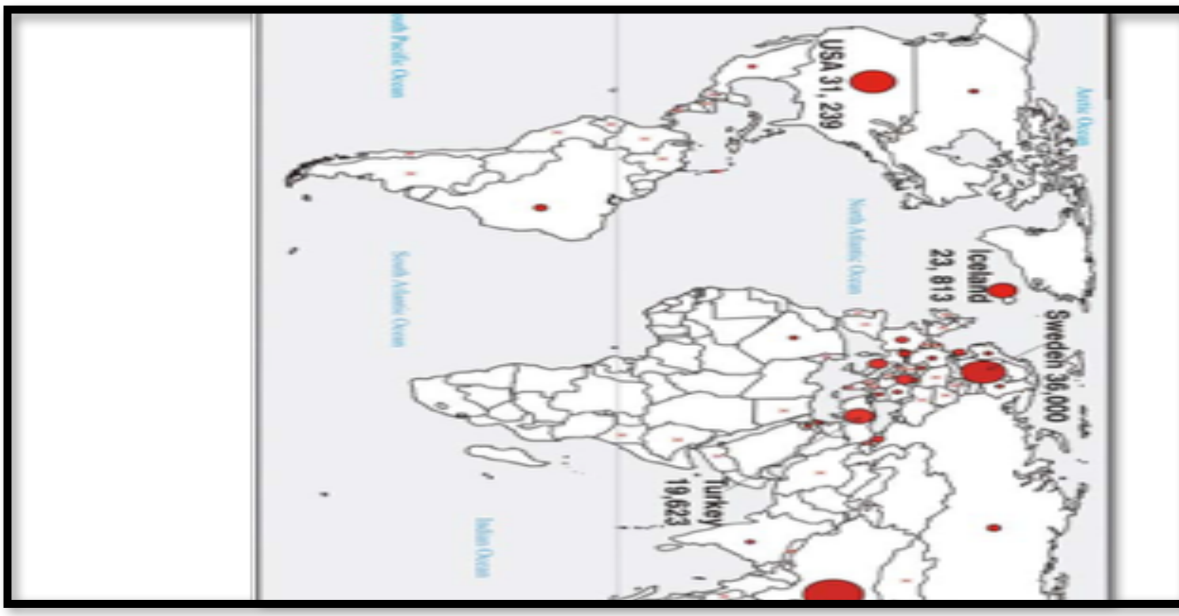

Figure 1. Direct use of low-temperature geothermal resources across the world. (Source: World Geothermal Congress, 2005.)

Low-temperature geothermal resources were the first to be utilized by people for things like bathing, warmth, and cooking. Sources classified as low temperature are those below 150°C.[9] The applications available through this resource vary and include space heating, drying, growing food products and swimming pools. Thus, low temperature geothermal energy offers a diverse number

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[7] Ibid., 2.

[8] John W. Lund, "Characteristics, Development and Utilization of Geothermal Resources," *Oregon Institute of Technology: Geo-Heat Center* (2007): 2.

[9] Ibid.

of opportunities for the surrounding society and economy. In 2005, it was estimated that a total of 261,418 various direct use geothermal installations were in place world wide; the largest increase in usage was seen in the geothermal heat pump category.[10]

3.4 New Zealand's Geothermal Sources

New Zealand rests on the boundary between the Australian plate and the Pacific place, which has created a very active fault and volcanic zone.[11] New Zealand also has a relatively high and consistent rainfall. The combination of these is why New Zealand, especially the North Island, has so many hot springs, which allows the Taupo and Rotorua districts in the central North Island to utilize the geothermal energy to generate electricity. In 2014, New Zealand produced 43000 GWh of electricity, which accounted for 16% of the country's annual electricity production total.[12] While geothermal energy has potential to generate a large quantity of electricity, only 3.7% of New Zealand's geothermic installations are devoted to such a process. Direct use of

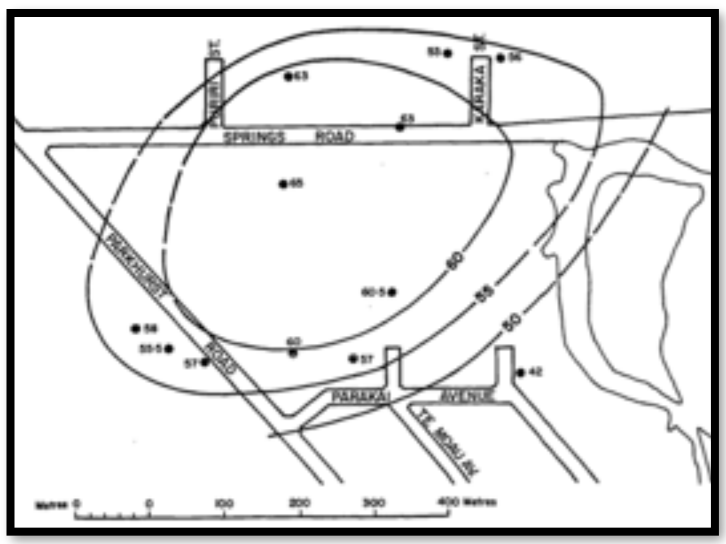

Figure 2. Parakai Site Field Temperatures (Source: Parakai Geothermal Groundwater Resource Statement and Management Plan)

[10] "Assessment of Possible Renewable Energy Target – Direct Use: Geothermal," East Harbour Management Services and GNS Science, 2007: 42.

[11] "Using Low Temperature Geothermal Resources." 4.

[12] Brian Carey, et. al., "2015 New Zealand Country Update," *Proceedings World Geothermal Congress* (Melbourne, AU: 2015), 3.

geothermal energy has various applications, most of which is bathing that constitutes 37.5% of the country's geothermic installations, with heat pumps and tourism also widely used.[13]

3.5 Parakai Geothermal Site

The Parakai geothermal field's temperature ranges from 60-65°C, making it a low-temperature resource.[14] The origin of the field is likely groundwater from rainfall into the local catchment, which percolates down through sedimentary sequences of the Waitemata Group to basement rock and is eventually heated by the existing geothermal gradient, thus rising back through Waitemata sandstone before forming an aquifer with the overlying compact alluvial sediments.[15] The permitted users of this geothermal source range from commercial to private, including motels, a water park, and home heating or spas.[16] The Parakai Springs (Aquatic Parks NZ Ltd.) are allocated the most water, around 300 m3/day, accounting for about 55% of the field's use.[17] Around 75 wells or bores have tapped the Parakai geothermal field in the past, the first of which was in 1905, but only 20 wells are currently doing so and 14 of these are actually in use.[18]

In extracting a safe and sustainable quantity of water annually, the pressure within the geothermal field produced due to the extraction must be equal to the pressure within the current

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[13] "New Zealand Geothermal Use Database: Geothermal Use Statistics," *GNS Science*, accessed April 17, 2016, http://data.gns.cri.nz/geothermal/charts.html.

[14] "Assessment of Possible Renewable Energy Target – Direct Use: Geothermal." 88.

[15] "Parakai Geothermal Groundwater Resource Statement and Management Plan." ARC Environmental Technical Publication, no. 25 (1993): 6.

[16] Ibid.,30.

[17] Ibid., 35.

[18] "Assessment of Possible Renewable Energy Target – Direct Use: Geothermal." 88; "Parakai Geothermal Groundwater Resource Statement and Management Plan." 9.

non-geothermal waters surrounding the field.[19] Equilibrium has been calculated and will be met if the geothermal water level remains 2.5 meters above sea level, allowing for a 700 m3/day yearly average rate of usage, as deemed sufficient in 1993.[20] It is important to acknowledge the direct relationship between the aquifer use and water levels and must be monitored and kept in balance.

Monitoring of tapped bores since 1978 has provided insight into water level fluctuations, which show a mean increase in the average water level ranging 2-3 meters due to the decreased usage of the waters.[21] Additionally, annual water levels fluctuate with the winter months yielding a minimum, likely due to the increased need for more hot water to compensate for the colder temperatures that cause heat loss in multiple ways.[22]

4.0 Potential Options to Fulfill Aspirations

The possible development options of the geothermal resource by Ngāti Whātua cover a wide range, with variable cost, function, sustainability, and social and cultural significance. All of these factors can be evaluated with the Mauri Model. While the options desired are hot pools, horticulture, and aquaculture, the primary and main focus of this paper is examining the feasibility of using the resource for traditional cooking methods.

4.1 Hot Pools, Current and Proposed

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[19] "Parakai Geothermal Groundwater Resource Statement and Management Plan." 36.

[20] Ibid., 43.

[21] Ibid., 22.

[22] Ibid., 35.

Parakai Springs is currently employing the hot water from the geothermal source in the area to provide both 32°C and 40°C pools and recently spa and therapeutic ventures.[23] Traditionally, hot springs were used for a number of different purposes, all taking root in the pools' medicinal benefits. Hot pools as well as mud pools were used to treat various afflictions, including, but not limited to eczema, leprosy, and arthritis.[24] Even ingestion of the waters was used to cure indigestion or stomach pains.[25] Other cultural applications of the hot pools are seen in both burial and childbirth processes or rituals, which are entrenched in the idea of *tapu*, or sacred origin of the waters that are seen in various Māori stories.[26]

The Parakai Springs' lease will expire in 2026, opening an opportunity for Ngāti Whātua to explore options to enter into a collaboraive joint-venture and share in undertaking the maintenance and expansion of the pools. This would allow both parties to share in costs of any new projects, while allowing Ngāti Whātua to explore cultural tourism as a development opportunity to provide additional economic benefits for both entities.

4.2 Aquaculture

Geothermal aquaculture allows for the sustainable farming of aquatic species at a certain location that would otherwise be considered thermally unsuitable by utilizing a geothermal source. Some species typically grown in these conditions are salmon, shrimp, crabs, and mussels

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[23] "Parakai Springs Facilities," *Parakai Springs*, accessed May 2, 2016, http://www.parakaisprings.co.nz/Facilities/.

[24] C.M. Severne, "Traditional Use of Geothermal Resources by New Zealand Māori." in *Stories From a Heated Earth: Our Geothermal Heritage,* ed. R. Cataldi, S.F. Hodgson, J.W. Lund (Davis, CA: Geothermal Resources Council, 1999), 442.

[25] Ibid., 443.

[26] Ibid.

as well as even algae, duckweed, and kelp (guide).[27] Sixteen countries thus far have installed aquaculture systems and actively grow aquatic animals and even some plants, including the United States, Slovakia, and New Zealand.[28] A prime example of this approach in New Zealand is seen at Wairakei, Taupo where Malaysian freshwater prawns are farmed. This aquaculture installation's method utilizes both the 55°C wastewater from the Wairakei Geothermal Power Plant and the 10°C water from the Waikato River.[29]

Species	Tolerable Range (in °C)	Optimum Range (in °C)
Oysters	0-36	24-26
Penaeid Shrimp, Pink	11-40	23-29
Salmon, Pacific	4-25	15
Eels	0-36	22-30
Trout	0-31	17

Table 1. Species and their water temperature ranges for growth. (Source: "Chapter 15: Aquaculture", Geothermal Direct Use Engineering Design Guidebook, 1991.)

4.2.1 Methods and Requirements

In determining the temperature necessary for a chosen species a number of components should be considered:

- Heat loss: especially that due to evaporation, convection, radiation, or conduction. Heat loss is dependent on various factors, mainly wind velocity, pool temperature, air temperature, and pond area. There are methods to avoid or minimize heat loss. These include pool covers (for outdoor pools), pool enclosures (commonly greenhouses), and

[27] I. Thain, A.G. Reyes, and T. Hunt, "A Practical Guide to Exploiting Low Temperature Geothermal Resources", *GNS Science Report,* 2006, 16.

[28] Thain, Reyes, and Hunt, "A Practical Guide to Exploiting Low Temperature Geothermal Resources", 17.

[29] Lisa Lind, Libby O'Brien, and Jo Bell, "Geothermal Energy Helps to Grow Prawns," *GNS Science*: 1; Thain, Reyes, and Hunt, "A Practical Guide to Exploiting Low Temperature Geothermal Resources", 28.

utilizing the thermal mass of the water (which is dependent on several pool and environment characteristics, including the sensitivity of species being grown).[30]

- Water flow: flow requirements are dependent on the desired pool temperature, the resource(s) temperature(s) (which likely include a hot geothermal source and a cold cooling source), and calculated heat loss (which are further dependent on other factors—see (a) above).[31]

4.3 Horticulture

Geothermal sourced energy can be used in a number of different ways for horticulture. The heated water can be used in an open-field agricultural capacity or in a greenhouse capacity whether through irrigation or hot air/water circulation.[32] Greenhouse heating requires geothermal water temperatures to be 60-80°C, depending on the type of crops desired.[33] The basic methods of heating greenhouses are bare pipe, finned pipe, fan coil air heater and buried pipe depending on the type of heating desired.[34] It is important to note that these different heating methods are determinant of the different building methods available.

Vegetables	Day (in °C)	Night (in °C)
Peppers	65-85	60-65
Tomato	70-75	62-65

30 Kevin D. Rafferty, "Chapter 15: Aquaculture." in *Geothermal Direct Use Engineering Design Guidebook*, ed. Paul J. Lienau and Ben C. Lunis (Klamath Falls, OR: Oregon Institute of Technology, 1991), 327-332.

31 Rafferty, "Chapter 15: Aquaculture." 327-332.

32 Thain, Reyes, and Hunt, "A Practical Guide to Exploiting Low Temperature Geothermal Resources", 20.

33 Ibid.

34 Kevin D. Rafferty, "Chapter 14: Greenhouses." in *Geothermal Direct Use Engineering Design Guidebook*, ed. Paul J. Lienau and Ben C. Lunis (Klamath Falls, OR: Oregon Institute of Technology, 1991), 308.

Cucumber	75-77	70
Flowers		
Roses	60-62	62
Poinsettias	70-80	64-72
Carnations	75	50

Table 2. Vegetables and flowers and their temperature ranges throughout the day. (Source: "Chapter 14: Greenhouses", Geothermal Direct Use Engineering Design Guidebook, 1991.)

4.3.1 Methods and Requirements

In determining the temperature necessary for a chosen flower or vegetable a number of components should be considered

- Heat loss: as determined by material used (fiberglass, plastic film, glass, etc.), air temperature differences, wind velocity, and the various heating systems available. Each construction method, as mentioned above, has a specific set of factors that influence heat loss and the exact temperature necessary, as well as the estimated cost.[35]

4.4 Food Preparation

One traditional technique of cooking used by Māori is the hāngī, or earth oven. This method allows large quantities of food to be cooked — and thus is optimal for communal utilization. Conventionally the hāngī technique used fire to heat stones which provided the heat for the earth oven, the meat and vegetables were covered with leaves or flax mats and buried in a

[35] Rafferty, "Chapter 14: Greenhouses." 307-326.

Figure 3. Two Women Suspending food filled baskets over a hot spring (Source: "Geothermal Energy—Heat from the Earth," *Te Ara—The Encyclopedia of New*

shallow pit with both hot water and hot rocks to create steam.[36] In Rotorua hāngī style cooking uses geothermal sourced heat in steam form, therefore the energy from the fires usually needed to cook the food is removed from the process, thus making the method sustainable. Another technique used traditionally simplifies the process by directly submersing food inside flax bags into hot pools.[37] Te Puia's Whakarewarewa, The Living Māori Village, uses this traditional style of cooking in its tourism operations.[38] A cooking method most similar to this traditional style using the Parakai water is 'sous vide'. By using conduction as the technique to transfer heat, food vacuumed in plastic bags can be cooked in a low-temperature water bath, around 55°C.[39]

Figure 4. A hāngi cross section (Source: "Māori foods – kai Māori – Foods introduced by Europeans," *Te Ara—The Encyclopedia of New Zealand)*

4.4.1 Methods and Requirements

There are many options when it comes to choosing style of a cooking technique. Direct submersion into water, hot rocks, or even a heat exchanging

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[36] "The New Zealand Māori Hangi Foods, Preparations, and Methods Used," *Genuine Māori Cuisine*, 2005, http://www.genuineMāoricuisine.com/Folders/Hangi.html.

[37] Carol Stewart, "Geothermal Energy—Heat from the Earth," *Te Ara—The Encyclopedia of New Zealand*, 2013.

[38] http://www.whakarewarewa.com/

[39] Douglas Baldwin, "A Practical Guide to Sous Vide Cooking," 2008, http://www.douglasbaldwin.com/sous-vide.html#Version_History.

plate could be used depending on the desired aesthetic and material available as well as monetary restraints. With a geothermal source, a bore already in place could be utilized to give the hot water necessary. With the 65°C water the Parakai site provides, the hāngī style of cooking cannot be used, as it requires steam (100°C water at the minimum). However, by putting a modern sous-vide twist on the Māori traditional style of cooking, the geothermal source could still be utilized for this purpose. Understanding the mechanisms that are associated with this potential project is important:

- Transfer of heat: this is dependent on conduction, which in turn depends on thermal diffusivity, thermal conductivity, density, and specific heat relevant to the specific food preparation that are also independently reliant on location, time, and temperature.[40] This can be meticulously calculated using a three dimensional equation. It is important to acknowledge safe practices when it comes to food preparation, especially concerning meat. Simply put, the lower the temperature, the longer the cooking duration.[41]
- Heat loss: this, again, is largely dependent upon material (for water transport and holding) and cooking bath area. Air temperature differences and wind velocity (if in an open area) might need to be considered as well. The amount of water necessary to continuously heat the cooking bath is also dependent upon the type of material used to hold the water or how large the cooker will be. There are many traditional hāngī recipes, which may be

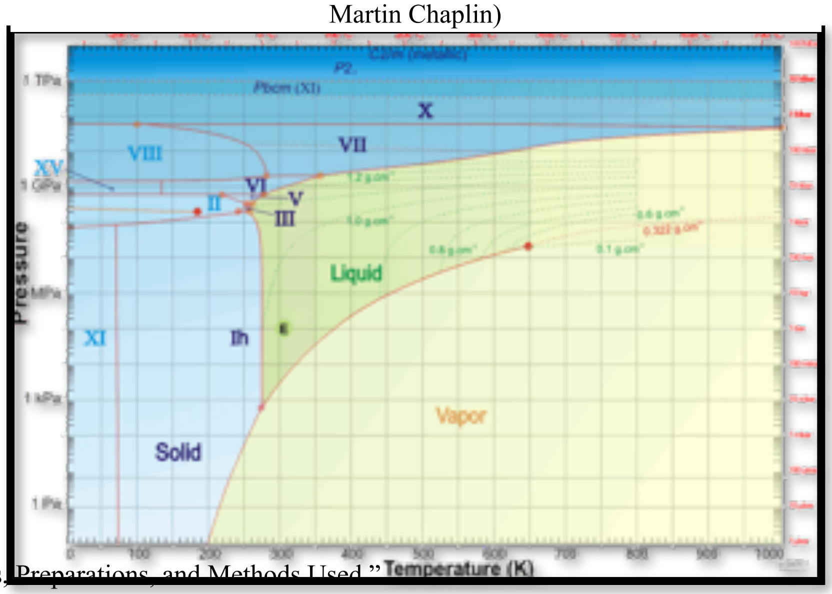
[40] Douglas Baldwin, "A Practical Guide to Sous Vide Cooking."

[41] Ibid.

able to be used, but typically the foods prepared include a variety of meats, potatoes, and vegetables.[42]

While sous vide techniques mixed with the traditional knowledge of hāngī cooking are sufficient, it is interesting to examine the possibility of creating steam for cooking. The Parakai well water is 65°C maximum, and is at sea level, or 0 m elevation, meaning it is around 101 kPa (or 1 atmosphere) in pressure.[43] Water boils at 100°C at this pressure or elevation. Therefore, the temperature of the water must either be raised by 35°C, or the pressure must be reduced by about 76 kPa if boiling water is desired for cooking purposes.[44] To achieve the pressure reduction, a vacuum could be used. About 74% vacuum would decrease the pressure to the necessary 25 kPa in order for the water to boil.[45] However, the sous-vide style of cooking, although it requires longer time duration, does not require any further input to the naturally occurring geothermal water.

Figure 5. Water Phase Diagram (Source: *Water Structure and Science*, Martin Chaplin)



5.0 Evaluation

5.1 The Mauri Model

Mauri is the connection between the physical and spiritual

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[42] “The New Zealand Māori Hangi Foods, Preparations, and Methods Used.”

[43] “Altitude above Sea Level and Air Pressure,” *Engineering ToolBox,* http://www.engineeringtoolbox.com/air-altitude-pressure-d_462.html.

[44] “Water—Pressure and Boiling Points,” *Engineering ToolBox,* http://www.engineeringtoolbox.com/boiling-point-water-d_926.html.

[45] “Vacuum,” *Engineering ToolBox,* http://www.engineeringtoolbox.com/vacuum-d_837.html.

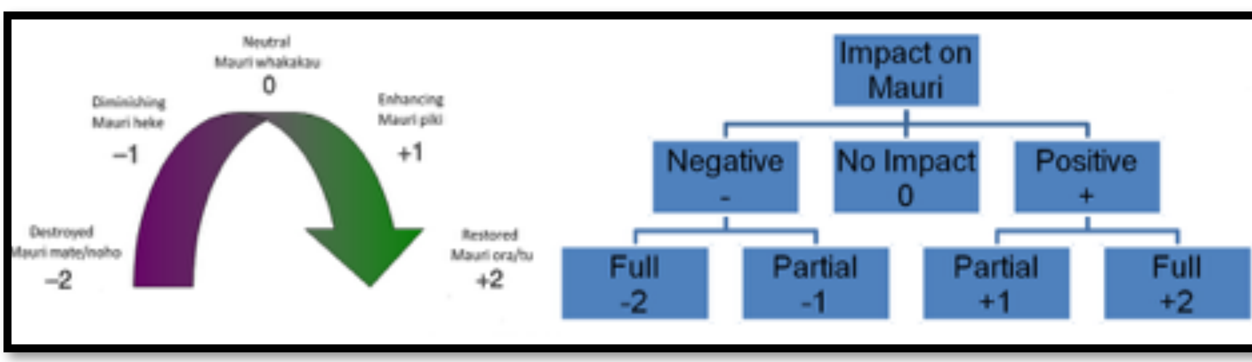
and interconnects all things.[46]

Using an assessment of mauri impact is an appropriate proxy for the health of the economy, society, culture, and environment, as it takes each into account. The Mauri Model measures how an option will impact a site's mauri by evaluating it on an enhancing and diminishing whole value scale ranging -2 to +2, with 0 being neutral having no impact. Impact grades of full and partial also exist, as seen in figure 6 below.

5.2 Mauri Model Assessment

Below is a hypothetical analysis of Ngāti Whātua's aspiration to implement a traditional food cooking technique, such as a hāngi, or version of it, using the Parakai geothermal resource.

Figure 6. Measuring the mauri and calculating impact (Source: *mauriOmeter*)



Criteria	Indicator	Status Quo	Calculate	Project	Calculate
Environmental	Pollution	0		0	

[46] Antony Feek and Te Kipa Kepa Morgan, "Mauri Model Analysis: Proposed Rotorua Eastern Arterial 4 Lane Highway Bypass," (2013): 16.

	Sustainability	0	0	+1	1
	Resource Management	0		+1	
Economic	Implementation	+1	0.5	-1	-0.5
	Maintenance	+1		-1	
	Benefit	-1		+1	
Cultural	Traditional Knowledge	0	0	+1	1.5
	Tikanga Māori	0		+1	
	Kaitiakitanga	0		+1	
Social	Aesthetic	0	0	+1	1.5
	Land Use	0		+1	
	Connection	0		+1	
Results			0.125		0.875

Table 3. A potential calculated assessment of the mauri of the site based upon the Mauri Model.

Each indicator given to the corresponding criteria is a suggested element that could influence the site's mauri. Pollution is always a concern when utilizing a resource. However, Parakai Springs' water analysis has revealed the element levels of the influx of water is nearly equal to the backflush of the facility, which has settled any water or land alteration dispute. As long as these levels remain constant, there should be no issue of pollution. Sustainability is suggested to increase the mauri of the site because without using the geothermal resource for energy, the site cannot serve its potential sustainability purpose. Resource management is a component that refers to the regulations and plans in place for New Zealand's sustainability goals and resource regulations. The project would both meet regulations and enhance New Zealand's sustainable energy objective.

Economically, implementation of the project would provide both benefit and drawbacks for the parties involved. When evaluating this criterion, it is important to realize the long-term advantages. The site will cost initially in implementation and consistently with maintenance. However, it is proposed that the possible tourism will ultimately yield the facility a net profit from the project.

The most heavily weighed criterion is the project's cultural significance. Traditional knowledge will undoubtedly be utilized in this endeavor with reflection upon the historical Māori cooking techniques. Tikanga Māori refers to the 'right way of doing things', which is also intertwined with sustainability in that the project would not use and waste resources, but make use of a renewable energy source as was traditionally done. Much of this evaluation is rooted in *kaitiakitanga* or 'guardianship' and the implementation of such a project would allow Ngāti Whātua to responsibly manage the environment based on the Māori worldview.

The project would not only benefit the Māori community, but the community surrounding the Parakai site. If executed properly, the site will enhance the aesthetic of both the Parakai Springs facilities and of the community, proving as well to be an excellent use of land for the encompassing area. Traditional Māori style of cooking, such as the hāngi, prepares large quantities of food at a time and, thus, while perhaps historically intentional, the project would incidentally provide the opportunity for the community to gather and connect.

6.0 Discussion

By implementing the proposed project, the Mauri of the site would significantly increase, due to its cultural, communal, environmental, and economical significance. It is also noteworthy to examine the long-term affect this project direction could have upon the mauri of the site, which seems to be moderately enhancing. By installing a geothermal sourced earth oven, the site would benefit in multiple ways. First, using geothermal energy to fuel the cooking of food is entirely sustainable and meets the New Zealand government's own renewable energy aspirations (such as the 2011-2021 New Zealand Energy Strategy by the Ministry of Economic Development) as well as other organization's goals (such as the New Zealand Geothermal Association's 2015 Action Plan). This potential project would not only aid in the movement toward sustainable energy, but is a responsible resource management plan, as desired by the Resource Management Act (1991 and 1997) and the Local Government Act (2002).

Figure 7. A group uncovers a hāngi (Source: John Wilson, "Society—Food, drink and dress," *Te Ara- The Encyclopedia of New Zealand)*

Additionally, the cost and maintenance of this project would not be large, especially if executed simultaneously with other Parakai Springs developments and in partnership with the facility. On the other hand, the project would be an economic benefit, as it prospectively will draw tourism and local attention. The reason for this interest will be aesthetic as well as historic, which pulls at both cultural and social strings.

Furthermore, and of paramount interest, this project has significant cultural importance, especially to Ngāti Whātua. This installation will provide a direct path back to traditional knowledge, allowing for ancient and historical practices to be revived. However, not only does the enterprise allow for Māori culture to thrive, but local as well. Hāngi style food preparation allows huge quantities of food and is thus meant for communities to gather together and connect over a simple meal.

7.0 Conclusion

Geothermal sources of energy will have increasing importance in the face of anthropogenic climate change. Turning to renewable energy sources is imperative to, not only slow global warming, but to bring resolve to the energy crisis. The idea of mauri acknowledges the balance between humans and the environment and the Mauri Model allows us to understand and manage humanity's potential impact on the world. By being a leading group in the shift towards renewable power is an exemplary action. Not only is geothermal energy sustainable and can be environmentally friendly, but it is low cost and allows a community or area to be energy independent. The installation of the traditional cooking implement brings these ideas to life.

8.0 Acknowledgments

Dr. Dan Hikuroa provided limitless aid, critique, and expertise to this paper. Dion Tilson of Parakai Springs supplied pertinent information about the geothermal site as well as the pool's facilities. Malcolm Paterson clearly presented both the history and aspirations of Ngāti Whātua o Kaipara. Katelyn Doherty delivered critique of the paper.

Appendix

Figures

Figure 1. Direct use of low-temperature geothermal resources across the world. Carey, Brian, Mike Dunstall, Spence McClintock, Brian White, Greg Bignall, Katherine Luketina, Bridget Robson, Sadiq, Zarrouk, and Anya Seward. “2015 New Zealand Country Update.” *Proceedings World Geothermal Congress*, Melbourne, AU: 2015.

Figure 2. Parakai Site Field Temperatures. “Parakai Geothermal Groundwater Resource Statement and Management Plan.” ARC Environmental Technical Publication, no. 25 (1993).

Figure 3. Two Women Suspending food filled baskets over a hot spring. Stewart, Carol. “Geothermal Energy—Heat from the Earth.” *Te Ara—The Encyclopedia of New Zealand*, (2013).

Figure 4. A hāngi cross section. Royal, Charles and Jenny Kaka-Scott, “Māori foods – kai Māori – Foods introduced by Europeans.” *Te Ara—The Encyclopedia of New Zealand*, (2013).

Figure 5. Water Phase Diagram. Chaplin, Martin. “Water Structure and Science.” *Creative Commons Attribution*, (2016).

Figure 6. Diagrams that portray how mauri is measured and how impact is calculated. *MauriOmeter*. Accessed April 14, 2016. http://www.mauriometer.com/

Tables

Table 1. Species and their water temperature ranges for growth. Rafferty, Kevin D. “Chapter 15: Aquaculture.” In *Geothermal Direct Use Engineering Design Guidebook*, edited by Paul J. Lienau and Ben C. Lunis, 327-332. Klamath Falls, OR: Oregon Institute of Technology, 1991.

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