AN HOLISTIC APPROACH TO IMPACT ASSESSMENT: REVITALISING THE PRESENCE OF MĀORI VALUES FOR CULTURAL SUSTAINABILITY IN GEOTHERMAL DEVELOPMENT

Dylan Taute[1], Kepa Morgan[2], Jason Ingham[1], Rosalind Archer[1], and Tūmanako Fa'aui[1]

[1]The University of Auckland, 24 Symonds Street, City Campus, Auckland, New Zealand

[2] Ngāti Mākino Iwi Authority Level 1, GHA Centre, 1108 Fenton St. Rotorua, New Zealand

dtau326@aucklanduni.ac.nz

Keywords: *Maori values, Indicators of sustainability, Cultural sustainability, Environmental sustainability, Social sustainability, Economic sustainability, Impact assessment, Geothermal development, Geothermal energy production, generation, and utilization, Rūaumoko.*

ABSTRACT

The geothermal resources of Aotearoa New Zealand's[1] Taupō Volcanic Zone (TVZ) provided warmth and ample cooking capabilities for the first Māori who settled in the region. Today, a wealth of Māori values associated with geothermal resources exist within many Māori communities of the TVZ. These Māori geothermal values can be thought to be separated into three components that reflect the different types of concerns and interests to Māori. The first component, being the spiritual component, was derived from the many Māori myths that describe the origins of the TVZ's geothermal resources and the super-natural implications associated with improper use of such resources. The values held within this spiritual component govern Māori behaviour and respect towards geothermal resources. The second component, which concerns the values associated with cultural practices and customs, emerged from the long-standing historical uses and practical benefits of geothermal resources. Finally, in today's context where a multi-worldview spectrum of stakeholders exists, and a competitive field of economic goals typically overrides cultural sustainability goals, the third component, which concerns Māori political values, has emerged to ensure that Māori do not lose out on opportunities in Aotearoa's economic growth through geothermal development. The three resulting components of Māori geothermal values are, customary, spiritual, and political, and are presented herein. In revitalising the representation of Māori values within today's 'western-traditional' impact assessment context, the three components are positioned alongside western values such as environmental, societal, and economical parameters. This parallel consideration of Māori values and western values contributes to a more holistic overview of the geothermal development sector.

1. BACKGROUND

1.1 Māori insight towards geothermal resources

Māori are descended from a long line of ancestors who lived harmoniously with Aotearoa's environment and all its natural resources. Throughout their history, Māori were story-tellers and the stories that Māori promulgated to their taiohi (children) were repeatedly passed down and remain within today's Māori communities (Taute, Fa'aui, & Ingham, 2019). Geothermal resources were among the most sought-after resources for Māori, along-side coastal and freshwater resources, because such resources provided easy access to warmth, cooking and healing capabilities (Kawharu, 2000) (see Figures 1 and 2).

The iwi (tribes) of Te Ārawa and Ngāti Tūwharetoa were the partners to the research that was conducted and is presented herein, as the iwi are the primary Māori residents of the Taupō Volcanic Zone (TVZ) in the central North Island, within which most of Aotearoa's geothermal resources reside. The stories passed down between generations of Te Ārawa and Ngāti Tūwharetoa describe the origins of geothermal resources in the legend of Rūaumoko, the geothermal exploits of ancient Māori ancestor, Ngātoroirangi (Taute, Fa'aui, & Ingham, 2019) and the historical geothermal benefits afforded to Māori (Maxwell, 1990). These stories became firmly embedded in the iwi belief systems and strongly influenced cultural practices, and thus these stories form the foundation from which the iwi-specific Māori values of Te Ārawa and Ngāti Tūwharetoa were developed and still concern many Māori who live amongst the TVZ's geothermal resources today (The Waitangi Tribunal, 1993).

Figure 1: Maori women cooking food in a thermal spring at Rotorua. Ref: PAColl-6585-43. Alexander Turnbull Library. /records/22738510

Figure 2: Maori children at hot pools in Whakarewarewa. Ref: PAColl-8866. Alexander Turnbull Library. /records/22675665

[1] 'Aotearoa New Zealand' is the name of the country (New Zealand) inclusive of its Māori name (Aotearoa). The term 'Aotearoa' shall be used independently throughout the remainder of this paper.

1.2 Māori values for impact assessment

Māori values are the primary embodiment of kaitiakitanga (management), and was once the exclusive method of management of natural resources practiced by early Māori communities. Kaitiakitanga and these embedded Māori values now populate the principles of Māori cultural sustainability, being a single component of natural resource management practiced by authorities today (M. Savage, personal communication, September 19, 2019). Following the introduction of western methods of resource management, technology and convenience became fundamental requirements for Aotearoa's population. Consequently, western values of sustainability became far more prevalent than Māori values (Love, 2001). Māori rights in geothermal resource management were also diminished by legislation that classified geothermal resources as a public resource which councils could compulsorily purchase from Māori land-owners (Boast, 1995; New Zealand Legislation, 1881, 1952).

1.3 Research and industry practice for geothermal development

Much research has been conducted on the historical relationship between Māori and geothermal resources (Stokes, 2000). However, no such research has been conducted from an engineering perspective with the goal of properly incorporating this historical relationship into geothermal engineering. In contrast, much scientific research has been undertaken on geothermal resources, to identify their potential to be used in electricity generation (Bertani, 2016; Hall, 2018; Lund, 2004). Other research has been conducted on geothermal resources to identify their potential direct heat use for spatial heating and recreation. However, such scientific research has rarely included cultural considerations (Lund, 2003; Lund, Freeston, & Boyd, 2011).

Many countries with geothermal resources have developed strategies to manage and develop these geothermal resources. While some strategies in Aotearoa mention that in approaching geothermal development, relevant Māori authorities need to be consulted and Māori values need to be considered, these strategies do not contain explicit instructions to help apply Māori values to the proposed developments (Bay of Plenty Regional Council, 2018; Climo, Bendall, & Carey, 2017). Furthermore, such Māori values identified by industry personnel have tended to be a misrepresentation of the true interests to Māori due to miscommunication between Māori and non-Māori, and oversight of opposing Māori voices in often poorly-conducted Māori engagement practices (L. Kereopa, personal communication, September 19, 2018).

1.4 Issues within Māori engagement practiced in the geothermal industry

This study contributes to a distinctly unexplored research subject area between mōhiotanga Māori (Māori knowledge) and engineering project management. While engineering project management entails a multitude of phases from proposal to execution, the process typically only includes Māori engagement as one phase, rather than ideally as an ongoing requirement throughout all phases. Furthermore, Māori engagement is usually conducted by non-Māori with a 'minimum requirement' mindset, and where pre-conceived notions have already been established. Such an approach to Māori engagement means that while Māori engagement is meant to be a platform from which to inform and co-develop project solutions culturally, Māori engagement rather becomes a platform from which Māori must challenge pre-conceived notions (M. Te Rangi, personal communication, September 19, 2018). A further issue encountered in Māori engagement is inefficient communication between Māori and non-Māori. Within Māori engagement, mātauranga Māori is often presented to non-Māori in a historical context that does not necessarily offer solutions of Māori empowerment in the 'now' context of geothermal developments (S. Tapuke, personal communication, September 19, 2018).

2. RESEARCH GOALS

The intent of this study was to compile a database of relevant indicators of sustainability to populate an impact assessment framework specifically appropriate for geothermal developments in the TVZ. Contrary to the sustainability goals of western impact assessment, which typically only considers western-valued indicators, the indicator database herein highly represents a set of Māori-value cultural indicators. The reintroduction of such cultural indicators expands the sustainability goals from western impact assessment to include the goal of cultural sustainability, thereby imposing a more holistic view of the geothermal development industry and facilitating more holistic decision-making.

The framework mentioned above, and its embedded indicator database, are intended to mitigate some of the inefficiencies between Māori and non-Māori communication within Māori engagement, by providing a starting point for discussions regarding development impacts to Māori culture and communities. In addition, the framework is intended as a mutually understood platform of impact assessment to guide and facilitate the practical application of Māori values in decision-making to the same extent as the application of western values.

3. RESEARCH METHODS

Two forms of 'participatory action research' were conducted. The gathering of mātauranga Māori required a culturally-sensitive engagement method founded on the principals of kaupapa Māori research, while the gathering of technical and socio-economic knowledge required a consultation engagement method. When analysing the gathered information, it was found that mātauranga Māori required primarily qualitative analysis, where in order to interpret the information as cultural indicators of sustainability, the information needed to be refined to a definitive list of indicators that captured the expansive understanding and story-oriented nature of Māori belief, history, and spiritual importance. A more quantitative approach was optimal for the analysis of western-based information regarding environmental, social, and economic impacts of geothermal development.

3.1 Mātauranga Māori from kaupapa Māori research

The participatory action research methods focused on obtaining Māori knowledge from within the Rotorua, Taupō, and Kawerau regions. The research was conducted in the form of wānanga held at marae (Tribal base, which includes a cultural meeting house). Wānanga are the Māori equivalent of interactive workshops and are the preferred method of research engagement by Māori (Pihama et al., 2015). These wānanga were undertaken in 2018, where the combined duration of such wānanga was approximately 24 hours. These wānanga were conducted in accordance with traditional Māori customs with kai (food), and pōwhiri

(traditional Māori greeting protocol), and consisted of tasks to guide discussions and maximise outputs. Rotowhio Marae in the Te Puia tourism grounds of Rotorua was selected as the ideal wānanga venue, because this marae stood as neutral grounds for the gathering of Māori representatives from various hapū who could, therefore, speak freely without restrictions of manuhiritanga (being visitors), while still being in the traditional confines of a marae. Marae are known as cultural bases in which to connect with ancestors, discuss matters around mōhiotanga Māori, and practice cultural traditions such as tangihanga (funerals), Waitangi Day, and koroneihana (coronations).

One of the tasks undertaken in the wānanga focused on the identification and discussion of Māori values. The identified origins of such values were historical beliefs, wairuatanga (spirituality), cultural practice, and Māori politics. These discussions informed most of the compilation of Māori-valued cultural indicators of sustainability, presented herein.

3.2 Western-based knowledge from consultation

Consultation methods were used in gathering western-based understandings of the geothermal development industry. Members from geotechnical science institutions, regional councils, and tourism organisations were independently consulted to provide comments on a draft set of environmental, social, and economic indicators.

An important consideration of this study was to preserve the level of accuracy and attention that the industry currently gives to the technical aspects of geothermal development. The preservation of this technical accuracy was achieved by ensuring that the indicators compiled within the environmental and economic dimensions of sustainability are as comprehensive and as detailed as they would be in an impact assessment practiced by industry professionals. Analogous to the preservation of technical accuracy is the preservation of the scope of consideration for the social aspects of geothermal development impacts. The scope of social considerations was guided by current legislation such as regional policies and the Resource Management Act (New Zealand Legislation, 1991).

4. INDICATORS OF SUSTAINABILITY

There are many types and many definitions of indicators. ‘Predictive,’ or ‘driving-force’ indicators may help to describe the future state of a dynamic system by observing trends over time. ‘Performance,’ or ‘state’ indicators help to describe the current state of a dynamic system. ‘Sustainability,’ ‘impact,’ ‘progress,’ or ‘response’ indicators help to describe how a dynamic system has changed or adapted in response to external forces (Warhurst, 2002). Sustainability indicators are exceptional amongst the other indicator types. The other indicators types tend to be used by organisations to measure the internal success or failure of, often, companies, or socio-economic systems, and tend to be the cause of impact on external systems such as societies, cultures and the environment. Sustainability indicators are essentially positioned in opposition to such ‘success indicators,’ being indicators that are the ‘receivers’ of impacts (Warhurst, 2002).

In most cases the sustainability indicators described above fall into one of four dimensions: environmental, social, economic, or cultural. The consideration of these dimensions is dependent on the sector that is subject to analysis. Within the educational or health sectors, social and economic indicators may be analysed, while within the tourism and energy sectors, social, economic, and environmental indicators may need to be analysed. However, in many countries, and certainly in Aotearoa, all these sectors have been increasingly concerned with cultural values. Many organisations in the energy sector have shown interest in incorporating cultural values into their practice. This interest is evident in new regional policies (Bay of Plenty Regional Council, 2018) and energy industry action plans and strategies (Climo et al., 2017) that mention a need to accommodate cultural values.

4.1 Merging cultural indicators with western indicators

When considering the introduction of cultural indicators to the current methods of impact assessment adopted by the energy sector, it is unproductive to simply assemble a set of Māori-valued indicators and then analyse such indicators independently of the analysis of western-valued indicators. That is, if one were to undertake a triple-bottom-line analysis to assess the impacts upon the environment, the society, and the economy, and then undertake a cultural impact assessment (CIA), it would often be difficult to adjust the conclusions made from the triple-bottom-line assessment to accommodate the impacts identified in the CIA. Consequently, the impacts identified in the CIA are often overlooked, negotiated, or manipulated to be less intrusive on the conclusions made from the triple-bottom-line assessment (Hikuroa, Slade, & Gravley, 2011). These issues mean that it is necessary to assemble the cultural indicator set in a parallel manner to the assembly of the environmental, social, and economic indicator sets. Furthermore, the definitiveness, the metric, and the scale with which to measure the cultural indicators need to match those used to measure the other indicators to allow the four indicator sets to be analysed concurrently and to allow the extent of cultural impacts to be consistently referenced against that of the other indicators (Morgan, 2006).

Morgan (2006) illustrated an interconnectedness between the four indicator dimensions (see figure 3). This figure suggests that some indicators can indeed be relevant in multiple dimensions. The figure shows that environmental changes can impact culture, society, and the economy because the environment encompasses all other dimensions.

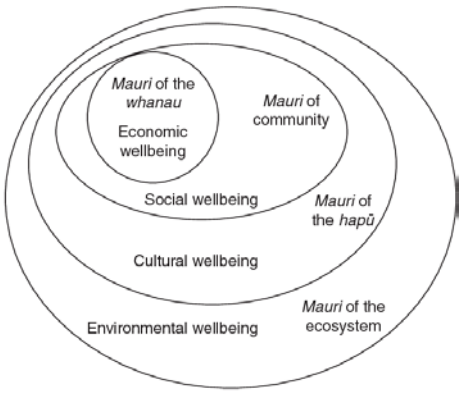

Figure 3: Venn diagram representation of the Mauri Model (nested dimensions of well-being) (Morgan, 2006)

4.2 Cultural indicators of sustainability

The list of cultural indicators presented herein consists of three cultural indicator components: wairuatanga

(spirituality), customary geothermal benefits, and governance and identity politics.

4.2.1 Wairuatanga (Spirituality)

The indicators within the wairuatanga component (see table 1) were derived from Māori belief systems where Rūaumoko, the god of geothermal, earthquake, and volcanic activity, generates underground forces whenever he pleases. It is believed that Rūaumoko resides underground with his mother, Papatūānuku the earth-mother, and that when he becomes agitated or spiteful towards human-intervention, he will respond by inflicting damaging forces to the ground above. These indicators were also derived from ancient Māori legends of ancestral geothermal exploits. Examples of such legends are those of Maui, who fished-up Aotearoa's North Island, and Ngātoroirangi, who called upon his demigod sisters to bring underground heat to the central North Island (Stokes, 2000). These indicators, therefore, influence Māori behaviour and respect towards geothermal resources to maintain Rūaumoko's acceptance of geothermal utilisation, and to uphold the memory of Māori ancestors.

Table 1: Cultural indicators of Wairuatanga (Spirituality)

Wairuatanga (Spirituality)	
Wairuatanga: Spiritual and ancestral connection	Access to culturally important and spiritually significant sites
	Ability to practice culture with aid of geothermal features
	Recognition of ancestral memory
Wāhi Tapu: Sacred sites (used or unused)	Recognition of culturally important and spiritually significant sites
	Modification, removal or destruction of culturally important and spiritually significant sites
Tikanga/Kawa: Māori protocol and procedure	Following of correct protocol in use of geothermal resources and in researching geothermal resources
Whakapapa: Ancestral belonging	Recognition of hapū relationship and connection to place
	Recognition of hapū relationship and connection to other hapū

4.2.2 Customary geothermal benefits

The second component of cultural indicators (see table 2) concerns the values associated with cultural practices and customary uses of geothermal resources that reflect the historical and current practical benefits afforded to the Māori communities of Te Ārawa and Ngāti Tūwharetoa.

Table 2: Cultural indicators of customary geothermal benefits

Customary geothermal benefits	
Mana Rauemi: Equipment integrity	Integrity of tools and facilities used to utilise geothermal resources – includes bore connection pipes for private extraction, private baths, and private steam boxes.
	Integrity of traditional resources – includes kānuka (white tea tree), kōkōwai (red ochre), and rongoa (medicinal minerals).
Mahinga Kai: Food preparation	Adequacy of geothermal features (includes flora) as cooking resources
	Consent to use geothermal features (includes flora) as cooking resources
	Diversity of ways to use geothermal features (includes flora) as cooking resources
Whanaungatanga: Iwi/ hapū/ whānau social connection	Equity of benefits from geothermal resources
	Looking after other people of iwi/hapū
Oranga Māori: Māori way of life	Change from current access and use of geothermal resources
	Change from current perception and behaviour around geothermal resource
Hauoratanga: Health and safety	Safety of Māori in proximity to geothermal features or development
Whakahauora: Medicinal/therapeutic properties	Adequacy of geothermal features' (includes flora) medicinal or therapeutic properties
	Consent to use geothermal features' (includes flora) medicinal or therapeutic properties
	Diversity of geothermal features' (includes flora) medicinal or therapeutic properties
Ātāhua: Iwi/hapū scenic beauty	Pleasance of appearance of geothermal land or development
	Naturalness and indigeneity of land
Whenua atu: Adjacent Māori land	Impact on any other indicator associated with adjacent land
	Access to adjacent land

4.2.3 Māori governance and identity politics

In today's context, where a multi-worldview spectrum of stakeholders exists and where a competitive field of economic goals typically overrides cultural sustainability goals, there is a need for cultural indicators to reflect the importance of Māori representation in geothermal governance, and the importance of Māori relevance and identity in their regions' societies and political systems. The indicators below (see table 3), therefore, ensure that Māori do not lose out on opportunities or fall-behind in Aotearoa's economic growth through geothermal development. The Māori governance and identity politics component captures the concerns of Māori de-colonialists, who have suffered trauma from marginalisation or land-confiscation and want to oppose western development. Such traumas are certainly not exclusive to Aotearoa, with indigenous marginalisation occurring, or having occurred, in places such as Hawaii (Edelstein & Kleese, 1995), Japan (Ellington, 2009; Yamada, 2009), and Yellowstone National Park (Hall, 2018). This component of Māori governance and identity politics indicators also captures the aspirations of Māori who want to participate equally in geothermal harnessing opportunities to the extent that non-Māori participate. However, not for the personal benefit of such Māori, but for the benefit of entire Māori communities.

Table 3: Cultural indicators of Māori governance and identity politics

Māori governance and identity politics	
Rangatiratanga: Māori ownership, government, authority and autonomy	Ownership of land and associated geothermal resources (White, Morris, & Lumb, 1995)
	Authority to develop own geothermal resources (C.S. White, personal communication, 20 June 2018)
	Authority to approve or deny resource consents

	Capability to undertake Māori-led cultural impact assessment (CIA)
	Obligations under Te Tiriti o Waitangi recognised in ongoing participation of Māori (Faaui, 2017)
	Equity in benefits or profits in partnership
Mana Whakahono: Joint benefits	Māori representation in partnership
	Māori influence on decisions (voting system)
Kaitiakitanga: Responsibility of guardianship	Māori autonomy and capability in ecosystem, land, and water action management
	Māori autonomy and capability in ecosystem, land, and water monitoring
	Protection of geothermal features from vandalism and misuse
	Iwi/hapū acknowledgment of traditional role as kaitiaki (guardians)
	Acknowledgment of Rūaumoko (atua of earthquakes) and Papatūānuku (earth mother)
Mōhiotanga Māori: Māori traditional knowledge	Recognition and active search of Māori traditional knowledge associated with geothermal feature
	Preservation and conservation of Māori traditional knowledge
	Promulgation of Māori traditional knowledge to wider community and younger generations
Iwi Mōhiatanga: Māori community knowledge and awareness	Awareness and understanding of iwi/hapū of matters affecting their geothermal resources
	Opportunities for youth to pursue technical knowledge of geothermal engineering
Iwi Āheinga: Māori community capabilities and opportunities	Employment opportunities for iwi/hapū
	Access to private geothermal features
Ahurea tuakiri: Cultural identity	Preservation of original geothermal features' names
	Pride in being Māori associated with geothermal features

4.3 Western-valued indicators of sustainability

The term 'western-valued' may be misleading, as indeed, many of the indicators within the western-valued indicator lists are valued by Māori culture also. Nonetheless, because these lists have been adopted in most western-based assessment frameworks, the term 'western-valued' helps to differentiate the lists from that of the cultural indicators, which are valued almost exclusively by Māori (I. Morehu, personal communication, September 19, 2018). There are three lists of western-valued indicators: environmental, social, and economic, all of which are presented herein as draft lists to be further refined in continuing consultations. Each of the lists are separated into three components to highlight in closer detail the different western-valued aspects within each dimension.

4.3.1 Environmental indicators of sustainability

The components of the environmental indicators list are geothermal activity, which focuses on development impacts on both geothermal systems and geothermal features; ecology, which focuses on the impacts upon habitats of flora and fauna; and atmosphere, which focuses on the spatial properties in the region of development (see table 4).

Table 4: List of environmental indicators

Geothermal activity	
Geothermal feature	Area and distribution of geothermal land and features
	Diversity of geothermal features
	Security and longevity of live geothermal features
	Allowance of naturally occurring change of geothermal features
Geysers and intermittent or hydrothermal eruption craters	Height of geyser, or size of eruption
	Frequency and duration of geyser or eruption
Mud geysers	Height, frequency and duration of mud geyser eruption
Fumaroles	Size and distribution, discharge capacity, and discharge temperature of fumarole
Flowing springs and mixed springs, and ejecting mud pots	Discharge capacity, temperature, and mineralogy of flowing spring, mixed spring, or ejecting mud pot
Steaming ground	Discharge capacity and temperature of steaming ground
Non-flowing pools, mixed pools, and mud pools	Size and depth, temperature, and mineralogy of non-flowing pool, mixed pool or mud pool
Heated ground	Area and distribution, temperature, and hardness of heated ground
Geothermal system	Multiple system connectivity and interdependence
	Allowance for natural discharge from system
	Rate of extraction from system compared to regeneration of system temperature, pressure, and capacity
	Estimated productive lifetime of geothermal system
Ecology	
Native vegetation	Area and distribution, diversity, and security of native vegetation
Native ecosystem	Area and distribution of land and vegetation, geothermal features, and water ecosystems
	Threat to native ecosystems during construction of development
	Diversity, and security of native ecosystems
Non-geothermal water (underground/surface water)	Quality, temperature, and eutrophication of water
	Capacity and use of water for geothermal developments
Land foundation	Seismicity and landslides induced in region of development
	Erosion, subsidence, and drainage of land
	Quality and stability of soil
Land, water, geothermal feature waste	Land area required for waste removal/dumping
	Material/waste spill into water, and geothermal land or features

	Temperature of hot water released into environment
	Concentration of metals (Hg, Cr, Cu, As, Pb, Zn, Ni, Cd, etc.) in vicinity of development
	pH of effluent released into environment
	Concentration of chlorides and sulphides released in effluent
Atmosphere	
Land usage	Land area required to support geothermal development - well field, substation, access roads, and auxiliary buildings etc.
Hydrothermal pollution	Temperature of air in vicinity
Anthropogenic air contaminants	Greenhouse gas emissions from geothermal development
	Concentration of SO_2 and H_2S in vicinity of plant
Land coverage from sunlight	Height of plant and sky coverage from steam plume
Catastrophic events	Environmental impact from unexpected events - well blowouts, phreatic explosions, ruptured steam pipes, turbine failures, and fires

4.3.2 Social indicators of sustainability

The components of the social indicators list are: education, which focuses on community skills and knowledge associated with geothermal development; security, which focuses on self-sustaining capabilities and resilience of the community; and quality of life, which focuses on community happiness (see table 5).

Table 5: List of social indicators

Education	
Geothermal workforce capabilities	Physical and mental capability of community to work in geothermal development construction or operations
	Opportunity for community to upskill in geothermal workforce
Gender diversity	Gender diversity in geothermal workforce in management and non-management roles
Qualifications	Opportunity for youth to gain geothermal related qualification through either apprenticeship, internship, or university education
Primary/ secondary school engagement	Outreach effort by development parties to teach geothermal related sciences and engineering
Public participation and transparency	Degree of public participation in geothermal development impact assessment and decision-making
	Degree of geothermal-development information released to public - including impacts, and decisions
	Effort made to resolve concerns of the public
Research and Innovation	Level of research and innovation towards more sustainable solutions
Knowledge sharing	Documentation of all geothermal-development information
	Incorporation of lessons learnt
	Unity and collectiveness of efforts and solutions from multiple professional sources
	Contribution of geothermal development to larger scheme of national goals
Tourism education	Correctness of geothermal information shared to tourists
Security	
Geothermal labour market	Demand, availability, and accessibility of geothermal related jobs to community - impact on job availability in community
	Job security
Income of geothermal workforce	Average income level of non-management and management workforce
	Gender/ethnicity income equality
Consumption of geothermal development product	Availability, affordability, and security of geothermal development product to community
Community perception and trust	Community perception of, and trust in, the local council and other community representative authorities, power companies, and owners
Health and Safety	Degree of health and safety precautions for public in proximity to geothermal development
	Degree of health and safety precautions of geothermal workforce - including isolation of catastrophic events
Property	Impact on property prices in the region
	Percentage of community residents that must be relocated due to geothermal development
Community resilience	Community resilience to natural disaster, natural resource or food crisis, or energy crisis
Natural resources for community	Accessibility, availability, adequacy, and security of natural food resources in the region
	Adequacy and security of geothermal feature (includes geothermal flora) as cooking and medicinal resource
Tourism industry	Impact on geothermal tourism
Quality of life	
Local access to natural resources for recreation	Public or local access to geothermal resources, public land, or waterbodies for recreational use
Outdoor space quality	Community satisfaction with geothermal features for recreation
	Freshness of air in geothermal development region
	Cleanliness, drinkability, and swim-ability of water
	Aesthetics of environs to facilitate mental and spiritual health
	Noise pollution from geothermal development
Age diversity	Diversity of age-groups in community

Community arts	Demonstration of creative arts in community
Work−life balance	Satisfaction with work-life balance, leisure time and holiday time
Telephone and internet access	Connection of community to internet and telecommunication

4.3.3 Economic indicators of sustainability

The components of the economic indicators list are: the financial viability from the developer's perspective; contribution to national and regional economic well-being and national energy goals; and the national and regional demand for energy (see table 6).

Table 6: List of economic indicators

Financial viability	
Total energy supply	Projected total energy supply from geothermal development
Total company profits	Total company profit from return of assets remaining after total company expenses
Total company expenses	Development, operations and distribution costs, sales and operation taxes, and royalties
Start-up expenses	Up-front expenses (expenses up to the point of operation and distribution start-up)
Specific investment expenses	Total expenses for each partner of company compared to each ownership percentage
Total compensation expenses	Total expenses to cover compromise of environment, society, and culture
Company debt	Short term debt to total debt ratio
Financial risk	Contingencies for accidents and insufficient resource extraction
Market value	Impact on market value of energy
Project life-time	Duration in which operations continue to provide profit
Productivity	Efficiency of production inputs such as labour and generation system to produce and distribute outputs of energy
National and regional contribution	
Gross domestic and regional product (GDP and GRP)	Sum of product produced in region
Consumers price index (CPI)	Average price of goods and services in region
Producer price index (PPI)	Change in price of goods and services
Balance of payments (BOP)	Overseas trade index, currency strength, deficit or surplus of imports, and net energy imports
Contribution to renewable energy supply	Percentage of geothermal energy supply to total renewable energy supply of New Zealand
Contribution to total energy supply	Percentage of renewable energy supply to total energy supply
Contribution to future energy security	Percentage of projected future energy demands satisfied by geothermal production
Stocks of critical fuels	New Zealand stock of oil and gas, and percentage of demand of critical fuels to total demand
Small business start-ups	Number of locally owned businesses in region
National and regional demand	
Energy use per capita	Energy use or consumption of electricity per capita
Energy demand from industry	Energy use or consumption, and demand for electricity, from manufacturing, agriculture, commercial retail, and transport

4. 4 Discussion of indicator sets

The above indicator sets have each been subject to one iteration of a feedback and revision process to ensure that each indicator is relevant to geothermal resource development and that each indicator description is contextually specific to avoid any vagueness and possible misinterpretation. Further iterations of feedback and revision, and a Delphi Iteration process (Shortall & Kharrazi, 2017) undertaken with focus groups, are necessary to finalise the indicator sets and insert them into the processes of the impact assessment framework. These additional iterations will filter-out the indicators that are considered as being beyond the scope of what geothermal developments will substantially impact. An example of such an indicator may be the 'Small business start-ups' indicator in the 'National and regional contribution' component of the economic indicators set. Consideration should be given to whether a geothermal development will indeed influence small businesses in the region on a significant level.

As many of the above indicators are described qualitatively, before the indicators can be inserted into the processes of the impact assessment framework, each indicator also needs to be accompanied by threshold descriptions that describe the correlation between the indicators and their numerical or physical measurements. Additionally, the scale in which the numerical or physical measurements are placed must be consistent across the entire selection of indicators.

5. INDICATORS IN IMPACT ASSESSMENT

The indicators above are fitted into an impact assessment framework in which the state of each indicator, as impacted by the pre-determined construction and operation effects of a geothermal development, is measured. An adapted version of the Mauri Model decision-making framework (Morgan, 2006) will be developed to accommodate the measure and application of the above indicators into final design and execution phases of geothermal developments.

The Mauri Model decision-making framework complies with a range of requirements as set-out by The Bellagio Sustainability Assessment and Measurement Principles (Pintér, Hardi, Martinuzzi, & Hall, 2012) and in a comparative study among other frameworks such as the Cultural Health Index and the State of the Takiwā framework, the Mauri Model was the preferred option for the impact assessment of matters involving cultural sensitivities (Faaui, 2017). The Mauri Model was developed within the Māori context of Aotearoa to empower Māori communities in decisions made by corporates that may affect Māori. Within the model, indicators are measured in terms of 'mauri,' the Māori concept that describes the link between physical objects and their spiritual life-force (Morgan, 2006). Therefore, this model is the preferred option from which to construct the impact assessment process required to empower Māori communities within geothermally active regions in decisions regarding geothermal development.

6. CONCLUSIONS

Concerns regarding the underrepresentation of Māori-valued goals of cultural sustainability have been presented, and acknowledgement of the historically dominant presence of such Māori values before the arrival of non-Māori to Aotearoa has been expressed. The goal of this study was to revitalise the importance of Māori cultural values associated with geothermal resources. A set of cultural indicators of sustainability was compiled in parallel with environmental, social, and economic indicators and presented herein.

It was identified that the cultural indicators originated from three aspects of the Māori worldview: spiritual, customary benefits, and identity politics. Geothermal development impacts on these three aspects were addressed by their embedded selection of indicators. The environmental, social, and economic indicator sets were each separated into three components to highlight the different western-valued aspects that may be impacted by geothermal development in closer detail. There is still a requirement for the indicator sets to be further refined through iterative methods to establish a clear scope of geothermal development impacts that are necessary to be considered.

ACKNOWLEDGEMENTS

We would like to acknowledge the representatives of Rotorua, Kawerau, and Taupō Māori communities, and the Ngāti Mākino Iwi Authority, New Zealand Geothermal Association, and GNS Science organisations, for providing insight towards the development of the indicator sets.

REFERENCES

Bay of Plenty Regional Policy Statement (2018).

Bertani, R. (2016). Geothermal power generation in the world 2010–2014 update report. *Geothermics, 60*, 31-43.

Boast, R. (1995). Geothermal resources in New Zealand: A legal history. *Canterbury Law Review, 6*, 1-24.

Climo, M., Bendall, S., & Carey, B. (2017). Geoheat Strategy for Aotearoa NZ, 2017–2030: New Zealand Geothermal Association.

Edelstein, M. R., & Kleese, D. A. (1995). Cultural relativity of impact assessment: Native Hawaiian opposition to geothermal energy development. *Society & Natural Resources, 8*(1), 19-31.

Ellington, L. (2009). *Japan*: ABC-CLIO.

Faaui, T. N. (2017). *An Integrated Assessment of New Zealand's Worst Environmental Maritime Disaster: The 2011 Grounding of the MV Rena on Otāiti (Astrolabe Reef), Bay of Plenty*. University of Auckland.

Hall, S. (2018). Yellowstone Supervolcano Could Be an Energy Source. But Should It? Retrieved from https://www.nationalgeographic.com/science/2018/08/news-yellowstone-supervolcano-geothermal-energy-debate-iceland-hawaii/

Hikuroa, D., Slade, A., & Gravley, D. (2011). Implementing Māori indigenous knowledge (mātauranga) in a scientific paradigm: Restoring the mauri to Te Kete Poutama. *Mai Review, 3*

Kawharu, M. (2000). Kaitiakitanga: a Maori anthropological perspective of the Maori socio-environmental ethic of resource management. *Journal of the Polynesian Society, 109*(4), 349-370.

Love, M. T. W. (2001). Ten years of the Resource Management Act for Māori. *An address to the Resource Management Law Association (Auckland Branch)*

Lund, J. W. (2003). Direct-use of geothermal energy in the USA. *Applied energy, 74*(1-2), 33-42.

Lund, J. W. (2004). 100 years of geothermal power production. *GHC Quarterly Buelletin, 25*(3), 11-19.

Lund, J. W., Freeston, D. H., & Boyd, T. L. (2011). Direct utilization of geothermal energy 2010 worldwide review. *Geothermics, 40*(3), 159-180.

Maxwell, P. (1990). *The Maori Use of Geothermal Energy* (W. Tribunal Ed.). Rotorua Library Te Ārawa Heritage and Research Collection, New Zealand: Waitangi Tribunal.

Morgan, T. K. K. B. (2006). *Decision-support tools and the indigenous paradigm.* Paper presented at the Proceedings of the Institution of Civil Engineers-Engineering Sustainability.

New Zealand Legislation. (1881). *Thermal Springs Districts Act 1881*: Parlimentary Counsel Office

New Zealand Legislation. (1952). *Geothermal Steam Act 1952*: Parlimentary Counsel Office

Resource Management Act, Parlimentary Counsel Office, Ministry of the Environment § 67 (1991).

Pihama, L., Smith, G., Moewaka-Barnes, H., Mahuika, R., Smith, L. T., Mika, C., . . . Taylor, J. (2015). *Kaupapa Rangahau: A Reader: A collection of readings from the Kaupapa Rangahau Workshop Series* (L. Pihama, S.-J. Tiakiwai & K. Southey Eds. 2 ed.). Hamilton, New Zealand: Te Kotahi Research Institute.

Pintér, L., Hardi, P., Martinuzzi, A., & Hall, J. (2012). Bellagio STAMP: Principles for sustainability assessment and measurement. *Ecological Indicators, 17*, 20-28.

Shortall, R., & Kharrazi, A. (2017). Cultural factors of sustainable energy development: A case study of geothermal energy in Iceland and Japan. *Renewable and sustainable energy reviews, 79*, 101-109.

Stokes, E. (2000). *The legacy of Ngatoroirangi: Maori customary use of geothermal resources*. Hamilton, New Zealand: Department of Geography, University of Waikato.

Taute, N., Fa'aui, T., & Ingham, J. (2019). *Rūaumoko: More than just a symbol.* Paper presented at the 2019 Pacific Conference on Earthquake Engineering, Auckland, New Zealand.

The Waitangi Tribunal. (1993). *Preliminary report on the Te Arawa representative geothermal resource claims*. Wellington: Waitangi Tribunal.

Warhurst, A. (2002). Sustainability indicators and sustainability performance management. *Mining, Minerals and Sustainable Development [MMSD] project report, 43*, 129.

White, B., Morris, G., & Lumb, T. (1995). *New zealand geothermal resource ownership: Cultural and historical perspective*. Paper presented at the World Geothermal Congress, Florence, Italy.

Yamada, M. (2009). Westernization and cultural resistance in tattooing practices in contemporary Japan. *INTERNATIONAL journal of CULTURAL studies, 12*(4), 319-338.