BEYOND BASELOAD: THE FUTURE OF GEOTHERMAL

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Keywords: *Geothermal, economic development, employment, water access, food security, indigenous engagement, direct use geothermal, resource use, renewable energy*

ABSTRACT

Historically, the benefits of geothermal energy developments are discussed in terms of megawatts and revenue and these benefits are balanced against the environmental impacts of development. More recently, discussion has expanded into areas such as decarbonisation, community economic development, and cultural significance. While financial benefits are usually an important part of sustainable activities, simple binary thinking that 'success equals making money' is not adequate to assess performance.

Geothermal developments and their impacts, (both positive and negative), are complex and diverse and require careful consideration; in that all effects should be considered and synthesised into the decision-making process. In New Zealand, The Resource Management Act (RMA) allows for consideration of a wide range of effects, however, discussion is often polarised into 'binary' conversations meaning there are two opposing views and one is 'right' and one is 'wrong'. The reality is that opposing points of view can both be correct (e.g. what may be 'wrong' for maximising revenue, may be 'right' for employment and vice versa). It is essential then to understand the complete benefits and impacts of geothermal developments.

Geothermal energy use must be viewed through a more universal lens, in that it can help provide solutions to some of the world's most pressing problems: limited access to water, lack of food security, decarbonisation, low employment, poverty, economic oppression, and the marginalisation of indigenous peoples (not forgetting it is also an abundant and reliable source of renewable energy). The full value of geothermal development is only obtained when these additional benefits are unlocked.

Geothermal is more than a simple substitute for other energy sources, it can change how people live for the better. This paper will discuss the above, providing examples, and discussion on why we should be talking about geothermal differently and how to change the discussion to its inclusive benefits.

1. INTRODUCTION

Global electricity sources are experiencing significant paradigm challenges because of the focus on decarbonization which is changing the ways that electricity is generated. This has catalysed significant growth in the renewables sector; specifically, in the wind and solar power developments (Figure 1). Capital costs of renewable installations are being driven down by technological innovation with over 1 TW of new installed capacity since 2004 with wind and solar being the dominant technologies deployed (Frankfurt, 2018).

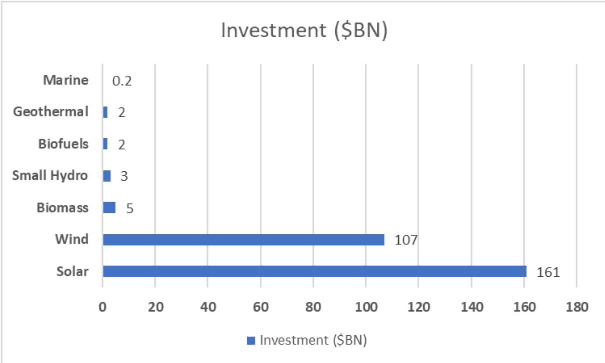

Figure 1: Global New Investment in Renewable Energy by Sector (2017) (Frankfurt, 2018)

Geothermal energy has also seen growth in this period but, as Frankfurt (2018) points out, geothermal is a small portion of the global market share. Geothermal electricity generation continues to stay competitive through reducing capital costs to build and construct but the long run marginal costs (LRMC) are dependent on geothermal plants maintaining high availability to cover the high capital costs to build and construct. The high upfront cost of geothermal (as compared to other renewables), lengthy timeframe to generation (>5 years from greenfield to production), general lack of understanding about the technology, and overall risk of success makes it difficult to convince industry outsiders and communities about the significant long-term benefits that come with geothermal developments.

Geothermal has long been championed as the go-to baseload renewable energy, but this position is rapidly changing as energy storage options evolve and the intermittent availability of solar and wind generation will soon be smoothed by technological innovations in and reducing cost of battery technologies (Figure 2). If we continue to talk about geothermal in terms of baseload and fuel substitution all the competitive advantages related to geothermal energy will not be realized.

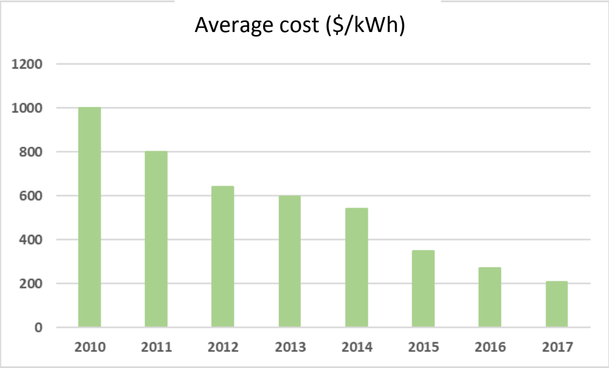

Figure 2: Lithium-Ion Battery Pack Price (Global Average) (Frankfurt, 2018)

Therefore, the time is right for the geothermal industry to look beyond just electricity generation and begin to leverage the other opportunities that geothermal energy can afford. It is imperative that we shape global perception, promote intrigue, and challenge thinking around geothermal energy through dynamic thought leadership and innovative thinking. An aligned and coherent conversation needs to elaborate on the wide range of meaningful contributions that geothermal developments can bring to society.

Geothermal developments can have significant impact through:

- Access to various water sources
- Provision of food security
- Support decarbonisation efforts
- Employment opportunities
- Economic development of poor, rural and isolated communities
- Increased prosperity of indigenous peoples and local communities

To remain relevant and economically favourable, the geothermal industry must stop repeating old narratives focused on electricity generation and start adding to the geothermal story. The industry must work to actively pursue the additional possibilities that geothermal can bring and foster enthusiasm with others outside the industry.

The change in thinking however will only come from leadership. And thought-leadership comes from strategic differentiation. This involves the risk of allowing new ideas to flourish, looking at things differently, and being brave enough to have smart people challenge assumptions and reshape the status quo. How would we use energy if it was unlimited? Would we live differently? Would we heat our garage floors, keep our houses warm all day, every day, in winter? What does that mean to us, our families, friends and communities, health, wellbeing and general happiness?

Only by changing the conversation will geothermal remain globally relevant.

2. GLOBAL PROBLEMS

Increasing population, climate change, economic disparity, environmental decline and reliance on fossil fuels are large and difficult issues.

The population is predicted to grow significantly in the next 80 years (Figure 3 below). This has considerable implications on resources required to feed and water a population of this size.

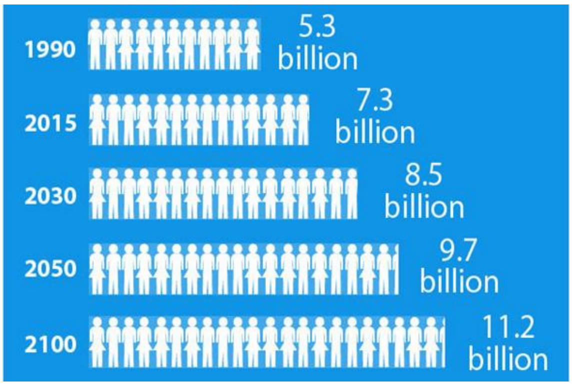

Figure 3: World Populations projected to 2100 (United Nations Department of Economic and Social Affairs, 2015)

Geothermal is a relatively niche industry, and the potential benefits associated with its use and how it can help to alleviate social, economic and environmental problems is not widely understood. Governments, not-for-profits, commercial and other groups in pursuit of solutions should consider geothermal energy in their decision-making processes.

2.1 Water

Water is one of the critical issues facing the modern world for agricultural, hygienic and basic human consumption purposes. Indeed, there is enough fresh water for everyone on Earth. However, due to bad economics or poor infrastructure, millions of people (most of them children) die from diseases associated with inadequate water supply, poor sanitation and un-hygienic water supplies (UN, 2018).

Oceans are a major alternative source of water. Seawater desalination is an energy intensive proven technology. The Kimolos Project, which began in the 1998 on Kimolos island in the Cyclades group of islands in Greece, successfully demonstrates the use of low enthalpy geothermal energy (470 kWe generator) to power a multiple-effect distillation (MED) process to desalinate seawater. The unit uses ~61ºC (well head temp) fluid at a 50 m^3/h flow-rate to produce on average 3.24 m^3/h of fresh water (SETIS, 2016).

Figure 4: Kimilos geothermal desalination plant (source: www.slideplayer.com/slide/5806970/

Geothermal energy provides the following advantages for desalination (Awerbuch, 2016):

1. Stable and reliable baseload supply of energy
2. The technology to extract hot water from underground reservoirs is mature.
3. Temperatures ranging from 70-90°C are ideal for desalination
4. Cost effective with high availability
5. Geothermal requires relatively less land footprint than other renewables

Geothermal developments can provide access to water through production wells via previously inaccessible aquifers; as well as condensates from steam turbines. While not usually potable directly in these forms, the application of practical engineering solutions can provide the means to make these waters fit to meet basic needs of human consumption, suitable for bathing and cleaning, fit for raising basic food stocks and potentially even growing crops, livestock and recreational uses.

This use of novel water sources is exemplified by El Salvador's, Grupo CEL who use cooling tower condensate from the Berlín geothermal power plant to water coffee and cacao plants for commercial distribution. Project Vida employs ~600 women from local impoverished communities to cultivate, tend and process plants for domestic and export markets. The plants, fluid and soil are monitored and regularly tested to ensure no harmful constituents contaminate the plants. Without access to the geothermal water this project would not exist.

Figure 5: David Lopez, President of Grupo CEL, and Vida Project workers (source: www.cel.gob.sv/exitosa-ofensiva-ecologica-del-proyecto-vida/)

Even in locations where fresh water is plentiful, water derived from geothermal sources can have specific desirable characteristics. For example, geothermal separated water contains minerals which have long been interesting as feedstock for extractive processes, which are recently receiving renewed interest and success. Geothermal condensate contains no dissolved oxygen, making it an ideal water source for many industrial processes.

2.2 Food

'By 2050, the world must feed 9 billion people. Yet the demand for food will be 60% greater than it is today' (Breene, 2016a).

Cultivation and processing of food is an energy intensive process if food is to be produced in commercial quantities. Geothermal energy can (and does presently) play a role in the security of food supplies. In regions that are non-OECD and on the cusp of geothermal development, the deployment of geothermal energy as an energy source for food production can provide the impetus and improvement that these regions so desperately need and further provide economic stimulus through further diverse applications of geothermal energy.

Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life (Shaheen, 2017).

Food security and nutrition is one of the biggest concerns for developing countries, including small island developing states and landlocked countries, which are endowed with geothermal energy resources.

Geothermal heat can be used for drying and preserving foods, heating green houses, sterilising soils, and refrigeration. It enables the growing of foods where local environments are unable to provide the necessary growing conditions and can be used in the preservation of food to eat later or to sell to consumers.

Some examples of geothermal energy being used in food production and processing include:

Growing:

- Friðheimar in Iceland grows Piccolo, Flavorino and Plum tomatoes inside a 5,000 m^2 glasshouse using 95°C fluid from a 200 m deep borehole onsite. Approximately 100,000 tons of fluid is used annually.
- Huka Prawn Park, near Taupō, is the only geothermally-heated prawn farm in the world. Discharge water from the Wairakei geothermal power station heat 15 production ponds and 4 fishing ponds to between 27-31°C, the optimum temperature for Malaysian freshwater prawn (Macrobra-Chium Rosenbergii) growth (GNS Science, 2018). 7.8 t/yr of prawns are produced from 2.75 ha of ponds (GNS Science, 2018). Prawns are grown for consumption in the onsite restaurant which is also a major tourist destination.

Preservation:

- At the Domo de San Pedro geothermal field in Mexico fruit, including pineapple, mango, papaya and guava, are dried using large industrial dryers heated with geothermal energy. Temperatures are maintained at 60°C reducing the moisture content of the fruit from 80 to 20 percent in 24hours (Nguyen, 2015). The fruit is then packaged and sold commercially.
- The Māori-owned dairy company Miraka, based near Taupō, is the first milk drying facility in the world to use geothermal energy. Miraka use both heat (for clean steam) and electricity generated from geothermal fluid. It has the capacity to process more than 300 million litres of milk into powders and Ultra High Temperature (UHT) long-life milk products every year (GNS Science, 2018). The milk supply comes from 100 local farms, around 60,000

cows, within an 85-kilometre radius of the factory (GNS Science, 2018).

- One of the main industries in Iceland is fishing and fish processing. Additional to the fillets and other fish products, Iceland uses geothermal energy to dry fish heads and backbones and export the much-needed protein to Nigeria. Exports of 13 million tons of dried fish heads and cuts equated to $69 USD in 2012 (Gissurarson, 2018).

Refrigeration:

- The use of a vapour absorption machine running on water/ammonia mixture as the working fluid, can provide the necessary refrigeration at about 0°C, which is sufficient for meat preservation (Kiruja, 2012)

Cooking:

- Canning of beef entails precooking it and packing it in sterilised containers using hot water or steam at about 140°C (Kiruja, 2012)

Low cost heat from localised geothermal sources unlocks the ability to produce foodstuffs for communities and commercial groups that wouldn't have been viable otherwise.

2.3 Carbon

Greenhous gas emissions (GHG), especially CO_2 emissions, are considered the main causes of global warming. In 2017, the amount of carbon dioxide (CO_2) in the atmosphere achieved levels of 406.5 parts per million (ppm), up 2.3 ppm since 2016, and 37 ppm since the year 2000 (Frankfurt, 2018).

Emissions at current levels appear to be high enough to keep pushing up the CO_2 proportion by about 2 or 2.5 ppm per year (Frankfurt, 2018).

Global protocols, reductions targets, penalties and other measures are being implemented.

The global replacement of traditional fuels with renewables led to around 1.8 gigatons of carbon dioxide emissions being avoided last year – the equivalent of removing the entire US transport system (Frankfurt, 2018); geothermal resources play a critical role in this replacement not only through electricity generation but also through other means of direct utilization of geothermal resources.

In New Zealand, geothermal developments have supported significant decarbonisation efforts; 'Geothermal displacement of gas/coal generations is the single biggest reduction to date in New Zealand's emissions profile – two million tonnes CO_2 per year' (Clarke, 2016)

Geothermal resources in New Zealand are utilised across a range of sector activities with the emissions profile spanning no accountable emissions through to modest greenhouse gas emissions.

Whilst some CO_2 emissions result from geothermal operations there is a spectrum of geothermal applications with negligible greenhouse emissions, such as:

- Low temperature direct uses from cool to hot waters and the ground
- Low to moderate temperature uses that use separated geothermal water
- Pumped system that can keep dissolved gases in solution
- In ground thermal storage

Use of higher temperature geothermal fluids for electricity generation or process heat result in modest greenhouse emission intensity relative to fossil fuels. Figure 6 is the 2015 Ministry of Business, Innovation and Employment (MBIE) data for the GHG Intensity g CO_2e / kWh of electricity produced by using geothermal energy, natural gas and coal.

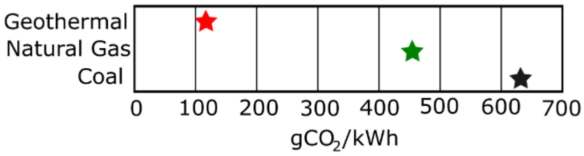

Figure 6: NZ Electricity Generation g CO2e / kWh by fuel type MBIE data for 2015.

Most geothermal sector operations also have greenhouse emissions associated with construction, ongoing maintenance and transportation associated with a facility through its asset lifetime. These emissions are not included in the data in Figure 6.

GHG emissions from high temperature geothermal fluid use spans a range depending on the geological context, how the fluid is brought to the surface and the energy conversion technology applied.

Where geothermal fluid is boiling as part of underground or surface processes, a portion of the gas dissolved in the water is released into the vapour (steam) phase. When energy is extracted from the vapour (steam) phase the gases accumulate, either re-dissolving as the fluids cool or being removed or released from the process. This is process dependent.

The range of GHG emissions are from very low emission up to the levels found in geothermal electricity generation from Ngawha (~400 g CO_2e / kWh (NZ Gazette, 2017)) which is similar to the GHG emission level from an efficient gas fired power plant. The overall electricity sector GHG intensity in New Zealand is about 115 g CO_2e / kWh (MBIE, 2015). This is about one quarter the intensity for gas fuelled generation.

Replacing fossil fuel energy operations with geothermal generation provides those countries with exploitable geothermal resources the opportunity to significantly reduce their CO_2 emissions.

2.4 Employment

The scale of the employment challenge is vast. The International Labour Organization estimates that more than 61 million jobs have been lost since the start of the global economic crisis in 2008, leaving more than 200 million people unemployed globally (Breene, 2016b).

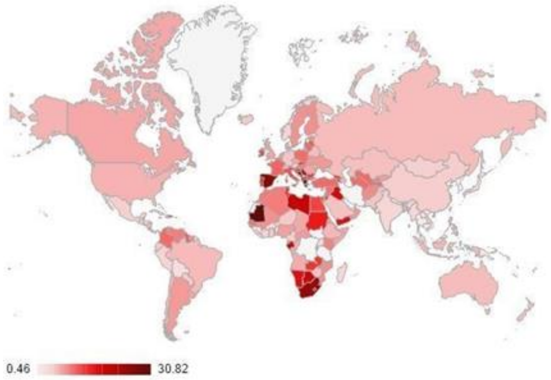

Figure 7: Unemployment rate (% workforce unemployed) per Country 2015 (International Labour Organisation, 2015)

However, many industries are facing difficulty hiring suitably qualified staff. Globally, 38% of all employers are reporting difficulty filling jobs, a two-percentage point rise from 2014 (Manpower Group, 2015).

Put simply, we need jobs for the hundreds of millions of unemployed people around the world, and we need the skilled employees that businesses are struggling to find (Breene, 2016b).

Whilst geothermal electrical power stations, once built, require few but relatively high qualified staff (0.5-2 persons per MWe) (Thorhallsson, 2006), geothermal direct use projects typically require much larger employment numbers (Figure 8). It is important to note that to make most direct use projects economically viable the initial costs associated with accessing the fluid, etc. are covered through the development of geothermal electricity plants first.

Geothermal developments are often located in remote areas, where opportunities for employment are relatively low; geothermal electricity installations provide economic impetus for a unique few, while installations that employ a cascade use of geothermal fluids can bring more meaningful and significant employment to these remote regions (e.g. those seen in Figure 8).

Business Name	Activity	Size of operation	FTE*
Miraka	Milk processing facility	~300ML/year milk processed into milk powders and UHT	~120
Tenon	Timber Drying	150,000m3/year of timber dried	265
Huka Prawn Park	Aquaculture tourism (Prawns)	~7.8 tonnes of prawns produced per year	60
Asaleo Care	Tissue & Toilet Paper Manufacturing	~50,000 tonnes/year of tissue product	~200
Norske Skog	Paper production (Newsprint)	~150,000 tonnes/year paper production	161

Figure 8: Examples of New Zealand Industrial Direct Use Operations – Size and Employment (Blair, 2018). (* FTEs = Full Time Equivalents. Including all people working onsite at the operation, and excluding suppliers of steam and other contractors e.g. maintenance etc)

2.5 Economic Development

The push for economic growth in recent decades has led to substantial increases in wealth for large numbers of people across the globe. But despite huge gains in global economic output, there is evidence that our current social, political and economic systems are exacerbating inequalities, rather than reducing them (Breene, 2016c).

Large scale conversion of geothermal heat energy into electricity relies on a transmission grid to transport the finished energy product to market. However, energy or other attributes of geothermal can be encapsulated into other products and services that transmit value through different channels. For example, road infrastructure provides inward access for tourism and outward paths to market after value has been added to products through processing. New products and services can be created from geothermal fluids alongside or after processing for electricity. Embedding geothermal characteristics or energy into other products allows geothermal to be transported by truck, by post, or over the internet, opening new markets.

Geothermal energy can be used directly to create environments that are different from their host location opening up new markets and revenue streams. An example of this is the 50-hectare Oserian flower farm in Kenya (Figure 9). Oserian uses the energy from a well leased from KenGen to provide an energy source to provide optimal growing temperature and conditions that would otherwise not be possible in this region. Today, Oserian is the largest producer of flowers in Kenya, with major exports to Europe.

Figure 9: Oserian Flower Farm (Source: Harvestflowers.co.uk)

The greatest benefits that geothermal energy provides in these applications can be found in delivering additional benefits to economic activities that already exist in the area; the co-location of such industrial processes along-side electricity production allows for significant realization of economic benefits. An example of this type of co-location is the interaction of the New Zealand forestry industry, with the geothermal resources of the Taupō Volcanic Zone (TVZ) which hosts New Zealand's largest plantation forests. Figure 10 illustrates the proximity of the geothermal resources and forestry assets in the Taupō Volcanic Zone (TVZ).

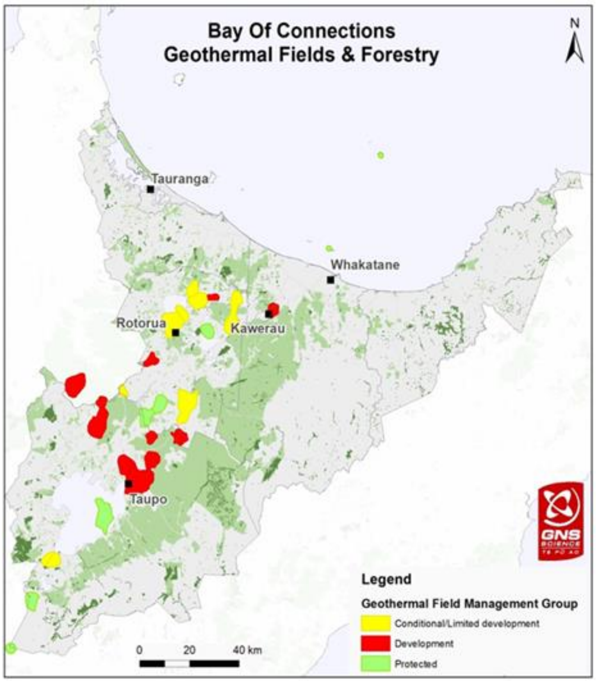

Figure 10: Map showing co-location of forestry and high temperature geothermal resources (and their development classifications) in the TVZ (Blair, 2017).

Wood processing businesses use large amounts of heat. A typical timber drying facility might use on the order of 1 PJ / annum of direct primary geothermal energy use, where a glasshouse might use less than 0.05 PJ / annum. The heat supplied from geothermal energy can come at a much-reduced cost when compared to other sources of heat (e.g. coal, natural gas) in addition to the low-carbon impact. As a result, organisations that align themselves to utilize geothermal energy in their processes are offered significant cost savings when geothermal energy is available to them. Moving from gas to geothermal energy for Tenon's softwood pine batch kiln drying operation in Taupō, saves over $1.2M/year on energy costs, increases timber drying capacity by 5%, and reduces 28,000 tons of CO_2 emitted to the atmosphere (Taupō Times, 2007).

Other forestry operations using geothermal energy:

- Asaleo Care: clean steam for tissue paper
- Ouji Fibre Solutions: steam for pulp and paper products
- Sequel Lumber: sawn lumber drying
- Ohaaki Thermal Kilns: contract timber drying

Using geothermal heat directly can provide localised jobs, profits are spent in local communities, and due to the worlds increasing focus on socially responsible product manufacturing, products embedded with geothermal energy provides significant opportunity to capitalise on 'green' brand premiums.

Geothermal fluids are not only a source of energy, they also contain gases, dissolved solids and microbes which can be extracted for commercial applications.

A recent advance in obtaining further value from the geothermal process at Ohaaki Power Station has come from a commercial silica extraction operation led by GEO40, in conjunction Contact Energy and land owners Ngati Tahu Tribal Lands Trust. GEO40 extracts commercially valuable forms of silica from the separated geothermal fluid, thereby reducing the concentration of silica in reinjected fluids, which benefits Ohaaki Power Station operations. The operation provides new income streams for the Ngati Tahu Tribal Lands Trust, along with employment for local people, as well as providing a more natural appearing fluid through the Ohaki ngawha (hot pool).

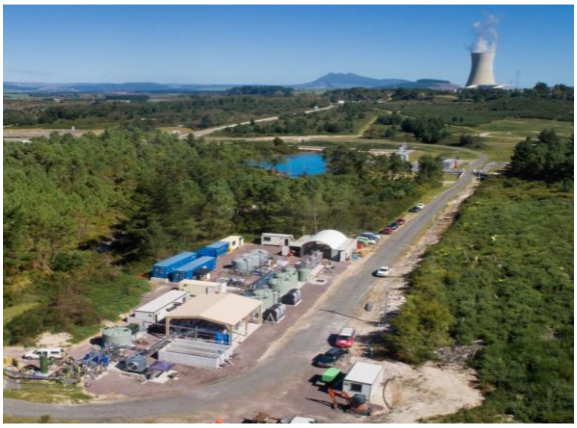

Figure 11: GEO40's demonstration plant at Ohaaki (Source: geo40.com/ohaaki).

Supporting existing industry, enabling new industry and added competitive branding advantages, geothermal energy provides a platform for economic growth and prosperity.

2.6 Indigenous Peoples

Indigenous communities are often located in isolated rural locations which are also qualities that are often associated with geothermal manifestations. Indigenous communities also greatly value geothermal as places of spiritual, economic or practical significance.

New Zealand provides an excellent example of where indigenous peoples have benefitted for centuries from the use of geothermal resources.

Geothermal energy in New Zealand has been used by Māori for cooking, balneology, ritual/spiritual cleansing and burial, as well as the use of geothermal muds for medicinal purposes.

Māori investments strategies are based on intergenerational returns (not solely on short term cashflow) which harmonizes with the long-term project life of geothermal power plants i.e. 30+ years. Commercial shareholdings and ownership in geothermal projects have allowed the growth of successful businesses that have enabled significant social investment in their people (e.g. finance, health, wellbeing, education, cultural, and recreational). The benefits of geothermal projects for Māori have extended far past financial return to shareholders.

The direct use operations outlined in Figure 8 all exist in small towns with relatively high Māori populations, so the impact and benefit of these operations are amplified (Blair, 2018) i.e. populations of Taupō and Kawerau are 32,907 (27% Māori) and 6,363 (55% Māori) respectively (Statistics NZ, 2013).

Not only is geothermal able to provide employment for indigenous communities in rural locations, but it also offers both electric and non-electric commercial opportunities.

Tauhara North No. 2 Trust (TN2T) landowners at the Rotokawa Geothermal Field, are listed fifth on the Deloitte top nine Māori business entities (Gibson, 2015). TN2T earn revenues from royalties and distributions related to steam field and geothermal power plant assets. Due largely to the vision of the original Trustees and followed by good commercial governance the asset base has grown from cash reserves of $64k in 1993 (Campbell, 2017) to ~$500M in 2015 (Gibson, 2015).

Annually, revenues ($millions) from the commercial operations is invested through grants and social programmes for the owners and descendants of the trust.

The success of Māori in New Zealand to foster, protect and benefit from geothermal resources is being shared with other indigenous communities around the world. In 2017, as part of a United States Energy Association funded project, representatives of Ngati Tahu Tribal Lands Trust and Contact Energy met with the Maasai (Kenya) and KenGen (Kenya) to share their experiences, lessons and to provide guidance on strategies and tools to support the growth of long-term positive relationships between them at the Olkaria Geothermal Field.

“Indigenous communities have unique relationships and values when it comes to geothermal resources and the natural environment and that recognising this, alongside the unique aspirations of the community are critical to building meaningful relationships into the future.” (Campbell, 2018)

From this exchange the Maasai have developed a strategic plan to 2050 to support their social, environmental and economic aspirations, and KenGen is formalising a community engagement framework to support the Maasai achieve their goals.

Figure 12: Maasai and Māori exchange a hongi (traditional Māori welcome) at Olkaria, Kenya. (source: Caitlin Smith, US Energy Association, 2017)

Geothermal high temperature systems are globally rare, and they offer indigenous communities that live above them employment and economic opportunities which will increase the prosperity of their people. Success in these initiatives requires vision of those involved in electricity developments to see the broad spectrum of possibilities and to recognise that the strength of their own businesses can be enhanced through wider participation in the projects.

4. CONCLUSION

The geothermal industry will not survive if we continue to think about geothermal energy as a ‘baseload substitute’ for other generation options. Geothermal is more than a simple substitute it can transform the livelihood of communities through application of diverse processes alongside electricity generation schemes. Other renewables lack this competitive advantage.

“By investing in renewables, countries can power new communities, improving the lives and livelihoods of the people who live in them, and at the same time cleaning up the air they breathe.” (Gabbatiss, 2018)

The world faces significant challenges which, of course, cannot be solved by geothermal alone. However geothermal can provide solutions and opportunity.

As we have discussed, there are several installations worldwide that benefit from the use of geothermal energy to aid in economic development, water supply, food security and myriad other industrial uses. However, there are still many areas for growth and expansion to further cement geothermal energy’s role in an increasingly dynamic global market.

Geothermal is more than electricity, more than energy. The natural and man-made processes associated with the formation and use of geothermal fluids provides a plethora of unique, interesting and compelling opportunities that if we broaden our thinking, will ensure that the geothermal industry will continue to thrive in a rapidly changing world.

ACKNOWLEDGEMENTS

The authors would like to thank Aroha Campbell and Nick Clarke for providing quotes, Sarah Milicich for the preparation of Figure 11, and Dorothy Raroa (pictured on right) and Caitlyn Smith for the great photo in Figure 12. Kia ora koutou.

We’d also like to acknowledge the fantastic work that La Geo, Grupo CEL, and WING El Salvador are doing for women working in the geothermal industry in El Salvador and encourage them to keep up the good work!

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