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Energy Markets Policy Building, Resources and Markets
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SUBMISSION ON THE DISCUSSION DOCUMENT ACCELERATING RENEWABLE ENERGY AND ENERGY EFFICIENCY.

Thank you for the opportunity to make a submission on the discussion document. This submission is from the New Zealand Geothermal Association (NZGA), with major input to the submission coming from the Geoheat Strategy Action Group, which is a grouping of NZGA members, member organisations and other interested parties driving the Geoheat Strategy for Aotearoa NZ 2017 – 2030.

The NZGA Action Group submitted material on 22nd February 2019 to EECA and MBIE on the PHiNZ document; Opportunities and Barriers to lowering emissions. Through the course of 2019 there has been useful interaction with EECA / MBIE leading to the Action Group providing additional thoughts and commentary in a 4th October 2019 ideas paper to EECA / MBIE on the PHiNZ initiative. These two documents are included here as **Appendix 1** and **Appendix 2** respectively.

Geothermal Energy is a significant opportunity for New Zealand yet much more needs to be done if we are to grasp this opportunity for the benefit of New Zealand. In particular, we point to the greater deployment of geothermal in the process / stationary energy area as an effective means for the nation transition to low carbon energy. The NZGA has been examining possible pathways for a greater deployment of geothermal energy over a number of years and has developed the Geoheat strategy and Action Plans in advance of the release of the MBIE PHiNZ initiatives.

The Geoheat Strategy for Aotearoa NZ 2017 – 2030 can be download from : https://nzgeothermal.org.nz/app/uploads/2017/06/Geoheat_Strategy_2017-2030__Web_Res_.pdf.

The 2018 -2019 Action Plan can be downloaded from : https://docs.zoho.com/file/0gw4j3499b6a5bd2442d89d715d9614403c03

The most recent Action Plan for 2020 – 2021 released in February 2020 identifies action that will further support the achievement of the overarching Geoheat Strategy goals. Not only does this plan set out activity by industry players for the 2020 – 2021 year, it also reviews some of the direct geothermal use achievements through 2018 – 2019. The 2020-2021 Action Plan is attached as **Appendix 3** to this submission. We recommend this document as providing insight into near term activity and opportunities available to New Zealand to reduce the carbon intensity of its process and manufacturing industries.

This submission answers question Question Q2.9 (p33) of the MBIE December 2019 document
In your view, how can government best support direct use of geothermal heat? What other options are worth considering?

NZGA in answering this question consider there are four important aspects that MBIE needs to pursue and resource.

1) Business Case Writing.

There is much more that can be done in the large-user and industrial-heating space with geothermal energy. There is sufficient geothermal energy in existing fields to materially expand industrial scale applications. However, the feasibility of geothermal use remains a commercial decision for firms exploring de-carbonisation options.

If existing business is to transition to geothermal energy, then in most cases it is not just a shift in energy source that is needed but the energy intensive part of the business will need to relocate. A business will not normally look to relocate unless a properly structured business case can be presented. This capacity does not normally reside within small to medium business and thus in order to facilitate these companies to actively seek to de-carbonise their business, we consider resourcing business case writers and support expertise, to selected businesses, to write relocation business cases at no cost to the business. This activity will also provide a very useful means of engaging NZ industry with geothermal providers and thus opening up currently unrealised opportunity.

The NZGA 2020 – 2021 Geoheat Action Plan in Priority Action 4 (p11) suggests targeting 10 business cases in the next two years. If 5 lead business case writers can be resourced, then each can cover two businesses over the 2020 – 2021 period. It could be anticipated that these business case writers will need other input to the cases they prepare that is beyond their expertise and this technical support should also be resourced by MBIE.

2) Wood and Geothermal Energy Symbiosis Opportunities.

Nature's Flame, Taupo, a wood fuel pellet producer converted to geothermal heat in November 2019. The heat is supplied by Contact Energy from the Tauhara Geothermal Resource.

The synergy demonstrated here between geothermal energy and the timber industry is remarkable. The use of geothermal energy enables increased pellet production from the plant in that more wood residue is available for manufacturing into pellets as the wood residue is not now used to power the residue drying process. Geothermal energy use thus acts to create greater value from the incoming wood residue stream. Additionally, the biofuel pellets are readily transportable providing a way for geothermal energy to be transported in a climate friendly fuel many 100's of kilometres from the site of the geothermal resource.

Subsequently Fonterra announced that their Te Awamutu Facility will be powered by biomass pellets produced from the Nature's Flame Taupo production facility commencing in the 2020 - 2021 dairy season.

The success of this Nature's Flame conversion is recorded in the 2020 – 2021 Geoheat Action Plan (page 14).

This success, and others, reinforces the need to further identify processes that geothermal energy use can assist in releasing additional value. We suggest that this topic warrants further attention and effort to bring to reality.

An unanswered question is what has come of implementation of the SCION Industrial Symbiosis work completed a number of years ago? This work identified a range of forestry-based supply chains which we suggest might benefit from a geothermal energy supply to release additional value. The work could be relooked at and the most promising pursued with business cases being developed for identified companies.

We think there is much to be done to further foster geothermally powered wood processing leading to exporting higher value wood products. Surely additional processing in NZ can be fostered by Government initiatives that lead to reducing the volume of unprocessed log exports.

Also, the Natures Flame example assists in identifying the opportunity for geothermal energy to be transported over much greater distances as embedded energy than is conventionally considered possible through geothermal energy carrier pipelines. What other opportunities exist for this to occur? What are the merits of converting logs into pellet bio-fuel using geothermal and exporting fuel rather than exporting unprocessed logs?

3) Fund Studies in the Geothermal Supply Pipeline

There is opportunity for geothermal energy supply operations to grow in New Zealand and further thought as to how this is might be quantified is required. Accordingly, we suggest additional studies to help identify what the next steps might be to release additional potential from NZ's geothermal resources over the medium term. For simplicity sake we have termed this potential as an indicated geothermal resource "supply pipeline".

Such a study would build on previous earth sciences / technical work undertaken in NZ with a specific focus on the indicated geothermal "supply pipeline" out, to say 2030.

In this regard as a first step we support the option of producing a map or database of potential renewable energy generation and demand points - including geothermal energy, **Option 10.7.** Any information that makes decision makers aware of renewable/geothermal energy options is extremely valuable.

4) Climate Change Emissions Initiatives in the Geothermal Sector.

A recent paper by Mclean and Richardson (2019) provides emissions data from New Zealand's geothermal power stations up to the end of 2018. The paper contextualises these emissions relative to natural emissions through the ground surface from three areas in the Taupo Volcanic Zone. This paper is included in **Appendix 4** as it provides quality information on geothermal emissions.

In November 2018 NZGA responded to a request from the Interim Climate Change Commission staff to provide a perspective in relation to a Stocktake of Geothermal Resources for use in their modelling at the time. We have not provided all of this information as it was provided in confidence at the time, however MBIE may be able to access this directly from the Climate Change Commission? We have included a broad summary overview table as **Appendix 5.** Geothermal is an important element for NZ in achieving its emission targets through reducing carbon energy emissions.

Additionally, NZGA consider it is important to prepare the New Zealand geothermal sector for carbon recycling and CO_2 emission reductions targeting some implementation and adoption after 2030.

Carbon recycling of the CO_2 in the geothermal discharge emissions basically gives two uses of the carbon for one emission, in essence halving the emissions intensity. Carbon Recycling International in Iceland has developed a semi-commercial scale plant (https://www.carbonrecycling.is/) that reuses CO_2 and hydrogen produced from renewable electricity converting it to methanol, with a further larger facility planned.

Atmospheric emission reduction techniques need to be identified and taken through to full scale operation in order to enable continued use of NZ's geothermal resources in the net carbon "zero" world beyond 2050.

Government funding support for industrial scale activity and trials is recommended by establishing an **Industry – Government Consortium** to develop, select and test technologies at the pilot plant level. It is recommended that the government works in conjunction with the willing large geothermal users and interested parties such as: Contact Energy, Mercury, Tuaropkai, Ngati Tuwharetoa Geothermal Assets and Baseload Power NZ to establish this consortium. Once established the consortium will work to develop, jointly resource and implement geothermal carbon emissions reduction initiatives. This might, for example, extend to government agreeing to underwrite development of a geothermal energy supply system in a key location, making the energy available to multiple process heat users.

We would be pleased to present and discuss the contents of this submission, and explore further opportunities for fostering renewable geothermal energy use in New Zealand, should you so desire.

We obviously will bring a strong geothermal emphasis to those discussion, out of NZGA's view that New Zealand's renewable energy transition will require the use of the complete range of renewable opportunities that New Zealand is endowed with. Geothermal is but one component but a component that the nation is significantly endowed with and with the opportunity to significantly benefit from.

We trust these thoughts and ideas assist moving NZ along on this path accelerating renewable energy uptake and the uptake of energy efficiency initiatives.

In our view to move aspects further forward in timely fashion requires funding, both government funding and some from industry. It's time for New Zealand to get moving, and for us as a nation to see real activity on the ground.

Thank you

Stephen Daysh
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Brian Carey
NZGA Geoheat Action Group
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Appendices

Appendix 1 - **Submission on the Process Heat in New Zealand Document – 22 February 2019**

Submission on the Process Heat in New Zealand Document – Opportunities and Barriers to lowering emissions.

Date : 22 February 2019

This submission comes from the Geoheat Action Group, which is the New Zealand Geothermal Association (NZGA) Group that has been driving the Geoheat Strategy for Aotearoa 2017 – 2030.

Thank you for the opportunity to make a submission.

Geothermal Energy is a significant opportunity for New Zealand to grasp in the process / stationary energy area as we as a nation transition to low carbon energy. The NZGA has seen this from a way out and has developed strategy and actions in advance of this PHINZ work.

We would be pleased to come and discuss the contents of the submission and also explore further opportunities for fostering renewable direct heat use in New Zealand if that would be useful to you. We will bring a geothermal flavour to those discussion, out of a position that the renewable energy transition will require using the complete range from the renewables basket. Geothermal is but one component.

This submission does not follow the questions in the document but is more of a general commentary on aspects canvassed. You will find some broad philosophy discussed in several places and there are three aspects we specifically note below:

1) **Broader Emissions Context** - The focus of the activities considered here is that process heat sits within the broader NZ emissions context. The broader context must always be considered as there may be other lower hanging fruit that will see gains that are as good as can be achieved with less investment than by the more narrow focus of the PHINZ work. For instance are there are wins in greenhouse gas absorption or agricultural areas that might provide easier wins than to lowering emissions in the stationary energy area.
2) **Smaller Installations** - In the process heat area there maybe smaller uses / boilers (say less than 1 MW thermal) that are not under direct pressure to reduce emissions and to adjust their processes. Energy management / efficiency advice provided to these smaller installations could be a way of cost effectively lowering emissions and assisting these users (and NZ). The larger installations have consultants that are assisting them and likely don't need advisory support. Small boiler installations raising hot water or steam are unlikely to have such support and coordinated investment in advice is suggested.
3) **Strategic** - The renewable energy label is going to become progressively more important for consumers over time. The appetite for products that are made with renewable energy will rapidly develop and consumer change is swift whilst energy system change is slow. Waiting for consumers to change is really not an option for a business that wishes to maintain and grow a customer base. Business needs to be adopting renewable energy over an orderly time frame now so the box is ticked for tomorrows consumer. Maybe some awareness material for smaller businesses would assist so they can plan for this energy transition that their consumer base will start to demand. The businesses will ask "So what do I do ?" so some advisory material would be useful for them.

The biggest area of potential gain in the direct heat utilisation area is possibly in the industrial use of process heat. There is much more that can be done in the large user and industrial heat use space with geothermal energy. There is energy available at Kawerau and Tauhara on quite short delivery timeframes for businesses now. There is opportunity for geothermal energy supply operations to grow in New Zealand and some thought as to how this is might be quantified seeking to assist in identifying what the next steps are to releasing **more potential**, whether that be at Kawerau, Tauhara or at other geothermal fields would be useful. Call this the supply pipeline if you like.

Looking beyond the current proven geothermal resources there is, deeper down, much more energy beyond the depths that drilling currently reaches that will in time become accessible. The drivers for this will be the increasing cost of energy, the advances in knowledge around the deeper "beyond todays geothermal resources', the hotter fluids that can reasonably be expected and research that is going on that will more generally release energy from engineered geothermal systems from broader areas than New Zealanders currently consider prospective for geothermal energy.

Temperature of supply is a crucial aspect. Industrial processes have developed around carbon based fuels since the industrial revolution on the basis of energy density and temperatures achievable from carbon fuels underpinning many of the design of processes. It will be beneficial for there to be change in thinking around how processes are engineered focussing on using lower temperature energy sources. This is rather than the other way around which is how can a renewable source provide energy in the same way as the existing carbon source - which appears to be a common approach.

Geothermal is a lower temperature energy source compared to carbon energy. Industrial processes have developed over time around the temperature achievable from carbon fuels. A driver has been that the higher temperatures from carbon fuels push the kinetics and productivity gains that are achievable relative to lower temperature processes. In the geothermal space there is thinking around using mechanical vapour recompression. This is sound because in some circumstances this will enable the temperatures attainable with geothermal sources to be increased. Fundamentally however the approach follows the line seeking to make geothermal match the carbon fuels profile.

A suggestion is to selectively study processes and focus on reengineering the process for use of the temperature profile available from geothermal energy. Then disseminate the results.

Thinking about other sectors there may be approaches and technologies from the geothermal sector that can be applied or adopted in those sectors. One example is the work on low temperature power generation using source temperatures from 60 to 120 C developed in Sweden (Climeon). These systems are being used not only in the geothermal sector (on low temperature geothermal systems in Iceland), but in electricity production through energy recovery in ships (flues and engine cooling systems) and in other industrial energy recovery.

Traditionally processing facilities have adopted a fuel fired boiler plus electricity to supply the process. There is a move to multiple fuels supplying one site. An example of this is the Roquette Freres starch plant in France. The total plant thermal load is some 100 MWth. There is a diversified energy supply from a 40 MWth biomass boiler, production of biogas from industrial sludge and a 24 MWth geothermal supply. For this plant the geothermal energy is transported in a pipe loop that has a 15km length from the geothermal heat supply to the use at the plant.

The message is geothermal can be transported a little way it doesn't have to be used at site. It depends on the size of use and the prevailing energy economics as to how distant. Certainly, energy and temperature losses for a thermal supply of 20 plus MWth over 20km are anticipated to be acceptable. Smaller uses say 5 MW would likely need to be within 5km of the heat supply and small uses say 1 MWth would need to be close to supply.

Appendix 1 - **Submission on the Process Heat in New Zealand Document – 22 February 2019**

New Zealanders view of what geothermal energy is and what it can be used for is an impediment to the adoption of a range of new thermal ground technologies. The past experience limits the thinking on the future. In Europe, for instance, where 50% of the thermal energy is used in facilities heating there is significant activity occurring to develop lower temperature interconnected energy systems, which share energy between facilities along with the interconnected system being connected with a ground energy storage component. Here the ground is being used as a thermal battery. Large reductions in carbon emissions are predicted to be achieved with these systems that are being implemented on a large scale in several European cities. There are two aspects that emerge. New Zealand's approach to energy management is usually on an individual site by site basis. What opportunities are there for energy sharing between adjacent sites - The concept of heat parks ? The other aspect is that of using the ground as a thermal battery to manage fluctuating energy demand.

Conservatism in adoption of new technologies is an impediment. This is noted in the document. Our general view is energy systems in New Zealand are engineered using current known solutions, faster design is achieved, and project delivery shorter with the use of time proven devices engineered to have low consent / permit exposure. Designing for novelty has the potential for time delays to be introduced into the project timeline or additional conditions to be introduced by for instance a permitting authority (if consents are required) which add to the project cost. Engineering is focussed on a low liability, fast solution delivery from the engineering team – this results in the past engineering approach dominating tomorrows installations.

Thinking and work on how to more quickly deploy innovative and new solutions to assist New Zealand in our energy transition would be useful. Energy vision is needed but also processes that facilitate bold engineering enabling engineering and industry to more quickly embrace new solutions. It is how we get to this position that is the challenge. Funding might need to be allocated to push likely winners into the deployment phase. European, EC and country of origin, investment in large deployment projects results in working examples at the industrial scale that then others can emulate. The deployment, scaling up from the research phase, has been de-risked.

There is thinking on the world stage into how geothermal energy might assist in providing more food for the worlds population by reducing food waste. This may be more related to the agri-food sector than the process heat sector but processing will be needed. The document has come out of IRENA in the last month (Accelerating geothermal heat adoption in the agri-food sector: Key lessons and recommendations, January 2019)

There is much going on in the European and US context. This includes smart thermal grids based on energy sharing and Engineered Geothermal Systems. The European Union and the US Department of Energy are spending significant sums on geothermal research. With the large levels of expenditure that are going on over the next five years advances are going to occur, and quite rapidly, and NZ needs to keep abreast of these.

The International Energy Agency Technical Collaboration Programmes (IEA Geothermal for geothermal) could be a way of bringing new information and ideas into New Zealand. There are a number of IEA renewable energy Technical Collaboration Programmes that New Zealand participates in and a workshop with presentations from the New Zealand member from each of the TCP's could be a useful way of sharing some of the knowledge from the world stage.

Please note that the url on page 26 of the PHINZ document no longer works as the New Zealand Geothermal Association has moved to a new web site. The working address is given here - Geoheat

Appendix 1 - **Submission on the Process Heat in New Zealand Document – 22 February 2019**

Strategy url https://nzgeothermal.org.nz/app/uploads/2017/06/Geoheat_Strategy_2017-2030__Web_Res_.pdf

Also there is an Action Plan associated with the Geoheat Strategy that has a shorter operational focus. The url for the current Action Plan for 2018 – 2019 is https://docs.zoho.com/file/0gw4j3499b6a5bd2442d89d715d9614403c03

We wish to reiterate Geothermal Energy is a significant opportunity for New Zealand to grasp in the process / stationary energy area as we as a nation transition to low carbon energy. Lets make the most of what we as a nation have in our renewable basket.

We trust these thoughts and ideas assist you and as indicated earlier we would be happy to come and talk with the team if you think that that would be useful for you.

Thank you

Brian Carey
(email : Privacy of natural persons)

For Geoheat Action Group

22 February 2019

Appendix 2 - 4 October 2019 - Ideas Paper for EECA / MBIE re PHiNZ – from NZGA Geoheat Action Group

Background :

The Geoheat Action Group have engaged with the EECA / MBIE team on the 14th May 2019 at MBIE Stout St, Wgtn and Michael Henry from EECA joined the Geoheat Action Group meeting on the 9th July in Taupo, came on a site visit to Natures Flame (Taupo), Geo40 (Ohaaki), NTGA (Kawerau) and Asaleo Care (Kawerau) with GNS Science and GeoSilica representatives from Iceland on 10th July 2019 and joined the Geoheat Action Group meeting on the 5th September 2019 (video conference).

As part of the Process Heat in New Zealand Initiative that EECA and MBIE are developing they have asked about barriers that might impede the uptake of the process heat use of geothermal energy. The few pages of notes here provide some thoughts and ideas that have been circulated around the New Zealand Geothermal Association Geoheat Action Group.

The context for PHiNZ has a focus on only process heat in New Zealand, and primarily two aspects; fuel substitution and energy efficiency.

This material has been put together by the New Zealand Geothermal Associated Geoheat Action Group who would be pleased to discuss the ideas further with MBIE / EECA if that is considered useful.

Commentary:

The question that is exercising the mind is that geothermal energy has been used for a long time for process heat in New Zealand. In fact New Zealand leads the world in geothermal process heat use. So are there really any barriers ? It is happening now and has done so for the last 60 years.
Are we not creating barriers simply by labelling them as such and putting words on a list.

Isn't the issue around awareness ?

The right people in the places where business decisions get made don't know about geothermal, it possibly is not on their offering sheet or if it is it is not a high enough priority on their capital spend list.

It is our recommendation that the term *barrier* **not be used** with regard to geothermal energy for industrial process use.

Some aspects for consideration by the PHiNZ Team follow.
Please note that the term business as used in the material is more focussed towards a specific business but it might be that there is applicability to a more generic "type of business".

Renewable Energy Substitution

Moving a business to geothermally rich location for fuel substitution

1. *Awareness of the possibilities around Geothermal Energy*

Business are working hard to keep their heads above water in day to day activities and the potential for geothermal energy use to substitute for more carbon rich fuels will likely be below the consideration agenda for most businesses.

Geothermal is more than just substitution and additional advantages from using geothermal might exist for a business. It might be possible to operate the business a little differently. Might get some additional marketing credentials, etc.

Suggestion– Select a number of businesses that could benefit from low carbon geothermal, work with them and develop a business case for each of them for their consideration, including additional advantages that might accrue for the business. MBIE / EECA / Climate Change Commission to provide or fund business case writers that work to assess the business relocation.

2. *People and housing*

People and housing are aspects that need to be available to attract businesses i.e. if a large business (50-100 people) is writing the business case for moving to say Kawerau, how they attract, retain and house staff is a major issue. In Taupo this might not be such an issue, where differing opinions exist on availability of houses for purchase however limited rental accommodation in Taupo is a constraint.

Over to MBIE and EECA for ideas - No ideas forth coming from our group

3. *Context of the Location at which Geothermal Energy is available*

Energy substitution occurs as part of other business requirements and not in isolation as to what is available at a given location. Such as transport networks, available workforce, availability of land, availability of fresh water / ground water, waste water and waste management facilities, the planning regime in play at the location.

Suggestion - For different locations (Initially Kawerau, Tauhara and Wairakei) develop an offer sheet around the elements listed above (and others that might get added).

4. *Identify and work to remedy priority weaknesses at the location*

From 3 above work to remedy identified weaknesses and / or work to identify which businesses a specific element is not a weakness for.

Rail and transport networks were raised as part of the EECA, NTGA, GNS Discussions on the field trip on the 10th July at NTGA Kawerau. There are some businesses for which the absence of rail link will not be weakness for others it might.

5. *Targeted awareness raising to appropriate businesses*

Communicate – target appropriate businesses and embark on a geothermal energy substitution road show. EECA / MBIE to resource – Communication undertaken in conjunction with organisations such as the Bay of Connections, Contact Energy, Tauhara North Number 2 Trust and Ngati Tuwharetoa Geothermal Assets.

Resource Management Act

National Policy Statements (NPS) are a powerful means of signalling intent. There is an NPS for Renewable Electricity Generation. An NPS on renewable energy in general would signal government intent and could be developed – the uptake of renewable energy, including more geothermal energy is crucial for NZ to meet its emissions targets.

Regional Policy and Plans Review – Central Government agencies to submit for further enabling Renewable Energy and RE use provisions to be embodied in these planning documents.

Consent Hearings where renewable energy is involved as a significant factor in permitting a facility – Appropriate central government agencies to submit so the governments intentions are clearly expressed in decisions and in permits granted.

Access to fresh or ground water

Ability to access freshwater is constrained in the Waikato catchment, and other catchments also. In a number of places groundwater is also constrained. Many businesses need water, the RMA allocation is a first in best dressed parade. May be an over lay is needed that provides better allocation mechanisms in support of renewable energy use businesses (We are not thinking of hydro power generation here) that facilitate reasonable levels of FTE's in their enterprises. This is an economic development overlay on sustainability.

It is also clear that the interest in water and its availability will become even more important (critical) if Hydrogen is adopted in a major way as an energy carrier. H_2 doesn't come from electrolysers without clean H_2O. Maybe water for non-hydro energy use is an aspect for consideration and for policy.

Energy Efficiency

Process redesign studies

Consider selected process redesign studies with the aim of lowering the temperature required for a given process use that might use geothermal energy. Process energy use has been developed over the years around the temperature available from carbon rich fuels. The future for geothermal energy available for process use is around how lower temperatures might be used say less than 210 ^oC.

There is also an amount of energy available at Kawerau now (5PJ/annum) that is extracted from the ground that is not being used ahead of it being discharged back underground / at the surface. How might this energy (which is at reasonable temperatures of up to 180 ^oC) be used, resulting in improved efficiency from already abstracted energy.

Suggestion – EECA /MBIE to develop a scope of what this might look like in the context of PHiNZ. Prioritise and fund the priority studies.

Current Process Uses for Geothermal Resources

Include for:

- Paper manufacture (Tissue and newsprint)
- Milk Processing
- Kiln drying sawn timber
- Drying mill shavings and sawdust for biofuel pellet production
- Glasshouse heating
- Brewing and distilling
- Crop drying
- Aquaculture
- Bathing, therapeutic and spa
- Honey processing
- Facilities heating / cooling
- Minerals production – silica sol

Further Dialogue

Please feel free to dialogue further with the NZGA through its Geoheat Action Group if that is useful to the PHiNZ team. Please use Brian Carey as the conduit in the first instance.

Brian Carey, For NZGA Geoheat Action Group

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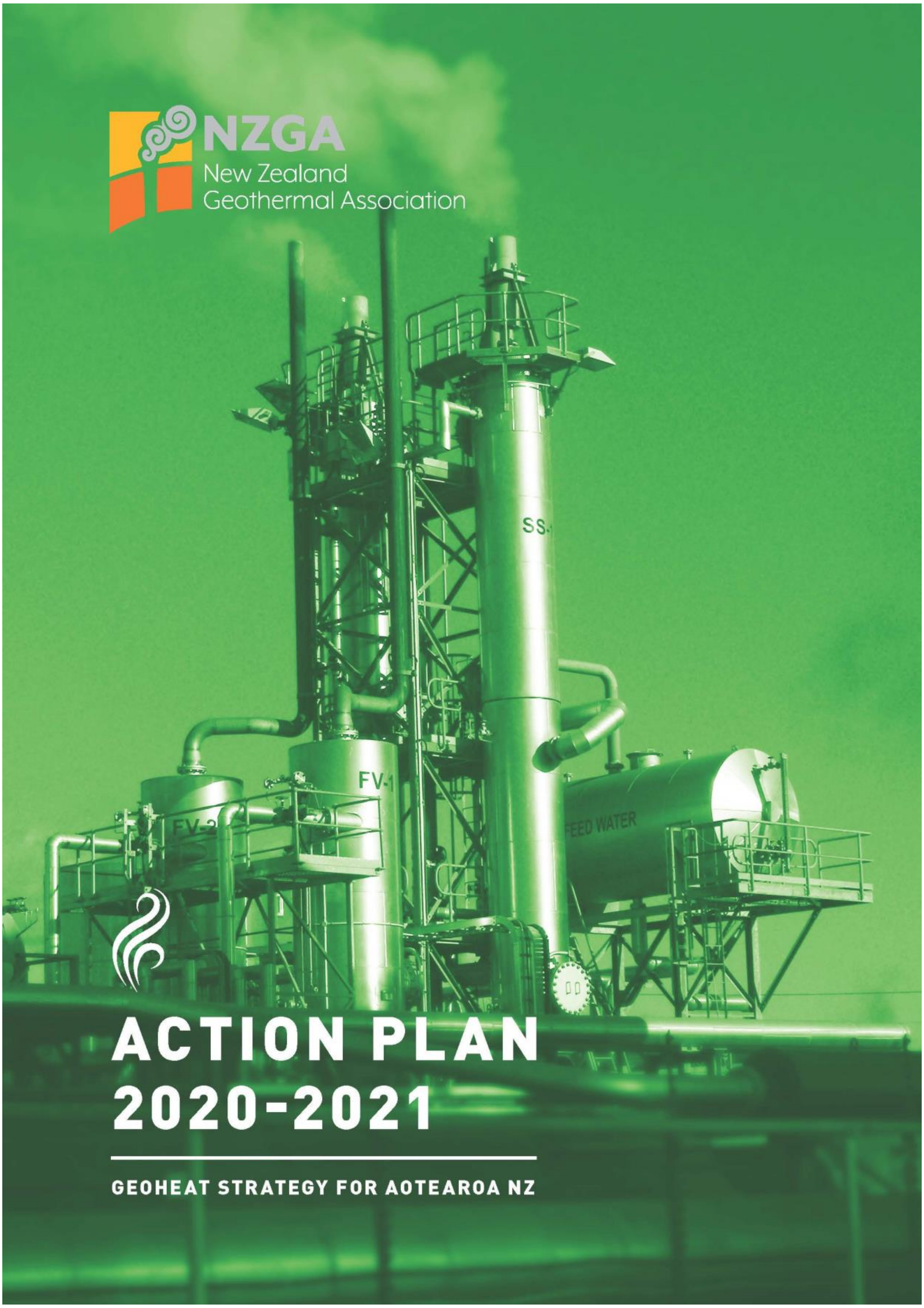
Appendix 3 – NZGA Action Plan 2020 – 2021



NZGA
New Zealand
Geothermal Association

ACTION PLAN 2020-2021

GEOHEAT STRATEGY FOR AOTEAROA NZ

FOREWORD

On behalf of the New Zealand Geothermal Association, it is with pleasure that I introduce you to the Geoheat Strategy Action Plan 2020 – 2021; the second Action Plan to be produced under the Geoheat Strategy for Aotearoa NZ 2017– 2030.

The Association is proud to be taking a lead role in delivery of the Geoheat Strategy. We are encouraged by the continued support for the Strategy, and particularly acknowledge the work undertaken through the Bay of Connections and the work of the funded Geothermal Business Development Lead.

The Geoheat Strategy seeks real gains in the short to medium term by assisting the energy sector to move to a low-carbon future through increased use of geothermal energy and, importantly, jobs that come with that use. The Strategy is designed to be directive, yet flexible, evolving through Action Plan activity as effort reveals the best next steps.

Significant 2018 – 2019 accomplishments are reported in this Action Plan, including the creation of more than 150 fulltime jobs in new businesses using geothermal energy. We are now looking to build on that success.

One of the critical components for continued achievement is to secure ongoing funding for strategy coordination. Dedicated resources for connecting businesses with direct geothermal use opportunities are vital to move this important work forward.

Working with our partners, we will continue to drive the Strategy forward for the benefit of all New Zealanders. Please join with the New Zealand Geothermal Association, share the vision, and help us to realise a geothermal future for New Zealand by actively growing direct geothermal use.

Stephen Daysh
Chair – Geoheat Strategy Governance Group
President – New Zealand Geothermal Association

REALISING GEOTHERMAL POTENTIAL

EXECUTIVE SUMMARY

This is the second Action Plan developed to focus and drive outcomes in the implementation of the Geoheat Strategy for Aotearoa NZ, 2017 – 2030.

The objectives of the first Action Plan (2018 – 2019) were exceeded; more than three new businesses have established, with more than 150 full time jobs associated with these businesses that are either now using or setting up to use geothermal energy.

This second Action Plan (2020 - 2021) identifies two new objectives:

Objective 1:

New direct geothermal projects, generating at least 80 new FTE jobs, are committed to and in development by the end of December 2021.

Objective 2:

Secure funding to continue to drive Strategy implementation for the next two years (ca. NZD 300,000).

Four Priority Actions will be driven by the Strategy coordinator:

Priority Action 1: Deliver Funding Strategy

Priority Action 2: Partner with Māori Organisations

Priority Action 3: Partner with Central Government

Priority Action 4: Deliver Business Cases

In support of these priority tasks, the New Zealand Geothermal Association (NZGA) Geoheat Action Group will also advance a range of other complementary activities.

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JANUARY 2020

Bibliographic Reference

Climo, M., Blair, A., Carey, B., Bendall, S., 2020, Action Plan 2020–2021; Geoheat Strategy for Aotearoa NZ., New Zealand Geothermal Association

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Available in pdf format from www.nzgeoheat.nz

Acknowledgement of the financial support from the GNS Science research programme "New Zealand's Geothermal Future" for organisation of the Geoheat Action Group and for funding publication of the 2020 – 2021 Action Plan.

Acknowledgement to Sarah Milicich, Brian Carey and GNS Science photo library for photographs used in the publication.

PURPOSE

This 2020 - 2021 Action Plan, prepared to advance the Geoheat Strategy for Aotearoa NZ, 2017 – 2030, reviews the effectiveness of activity through 2018 - 2019 and sets future actions for 2020 - 2021 to further advance Strategy goals.

Regular Action Plan updating seeks to ensure that Strategy implementation is effective and nimble, responding to changing circumstances and new opportunities.

OVERVIEW: GEOHEAT STRATEGY FOR AOTEAROA NZ, 2017–2030

The Geoheat Strategy for Aotearoa NZ, 2017 – 2030 was launched in 2017 as an NZGA initiative, with support from GNS Science.

The Strategy sets two overarching goals for geothermal direct use in New Zealand:

1. Annual direct primary geothermal energy use is increased by 7.5 PJ in new projects in the period 2017-2030; and
2. Geothermal direct use business operations are employing (directly and indirectly) an additional 500 people associated with new projects in the period 2017-2030.

By assisting the New Zealand energy sector to transition to a low-carbon energy future, the Strategy is firmly aligned with the direction set by the Climate Change Response (Zero Carbon) Amendment Act 2019. The Act provides a framework for New Zealand to develop and implement climate change policies that contribute to the global effort under the Paris Agreement and allows New Zealand to prepare for, and adapt to, the effects of climate change.

The Strategy document and associated resources can be accessed via the links below:

GEOHEAT STRATEGY FOR AOTEAROA NZ, 2017 – 2030	CLICK HERE
GEOHEAT ACTION PLAN, 2018 - 2019	CLICK HERE
GEOHEAT STRATEGY LAUNCH VIDEO, 2017	CLICK HERE

[1] Refer to Glossary on page 15 of this Action Plan for references and website addresses

EFFECTIVENESS REVIEW: 2018–2019

The first Action Plan, released in March 2018, identified priorities and focussed activity for a two year period with an overarching objective and priority actions (see green box below).

A Geothermal Business Development Lead (BDL) was contracted for a two year period from December 2017. Funded by the Bay of Connections (BoC), MBIE, NZGA and industry, the BDL was tasked with identifying, contacting and engaging with potential geothermal heat users domestically and abroad. The BDL leveraged key networks to identify industries, investors and potential partners of organisations that could potentially use geothermal resources as part of their business. The aim was to attract businesses and create significant job opportunities.

Achievement exceeded the targets set in the 2018 – 2019 Action Plan. The overarching objective was achieved, and substantially exceeded.

2018 - 2019 OBJECTIVE

STATUS ACHIEVED

OBJECTIVE:

Three new medium to large scale (minimum 30 jobs) direct geothermal projects are committed and in development by December 2019.

Status Report: At least seven businesses have adopted geothermal resource use, with more than 150 FTE's involved in those businesses (see Table 1, page 8).

2018–2019 ACTION PLAN - PRIORITY ACTIONS

PRIORITY ACTION 1:

Action: Develop a stocktake of supply side assets, infrastructure and geothermal resources to create a communicable picture of geothermal opportunities in New Zealand.

PRIORITY ACTION 2:

Action: Target commercial and industrial scale projects on brownfield sites where geothermal capacity exists in association with an existing project and/or a resource consent for the extraction of geothermal heat.

PRIORITY ACTION 3:

Action: Undertake domestic and international market analysis for large heat users capacity exists.

PRIORITY ACTION 4:

Action: Develop market value propositions for geothermal heat suppliers.

TABLE 1 Summary of New Direct Use Geothermal Projects 2018 – 2019

Business	Type	Location	Activity	Capital Investment NZD Million	FTEs[1]
Rogue Bore Brewery	New	Wairakei	Brewing	5	~24
Waiu Diary[2]	New	Kawerau	Milk processing	33	~40
Nature's Flame[2]	Conversion	Tauhara	Bio-fuel wood pellet production	2010 investment of 34 Million. 2019 conversion cost not known	~50
GEO40[2]	New	Ohaaki	Silica sol production	15	~30
Wai Ariki[3]	New	Rotorua	Balneology / Spa	30	n/a
Pink and White Gin	New	Rotorua	Distilling	unkown	~10
Oji	Conversion	Kaweau	Pulp Production	unkown	n/a

[1] FTEs - Full Time Equivalents. These are estimated by the businesses involved, and include people working onsite at the facility using geothermal fluid / energy, but exclude the geothermal fluid supplier, contractor and other indirect FTE's created.
[2] From Climo et al (2020)
[3] From Stuff (2017)

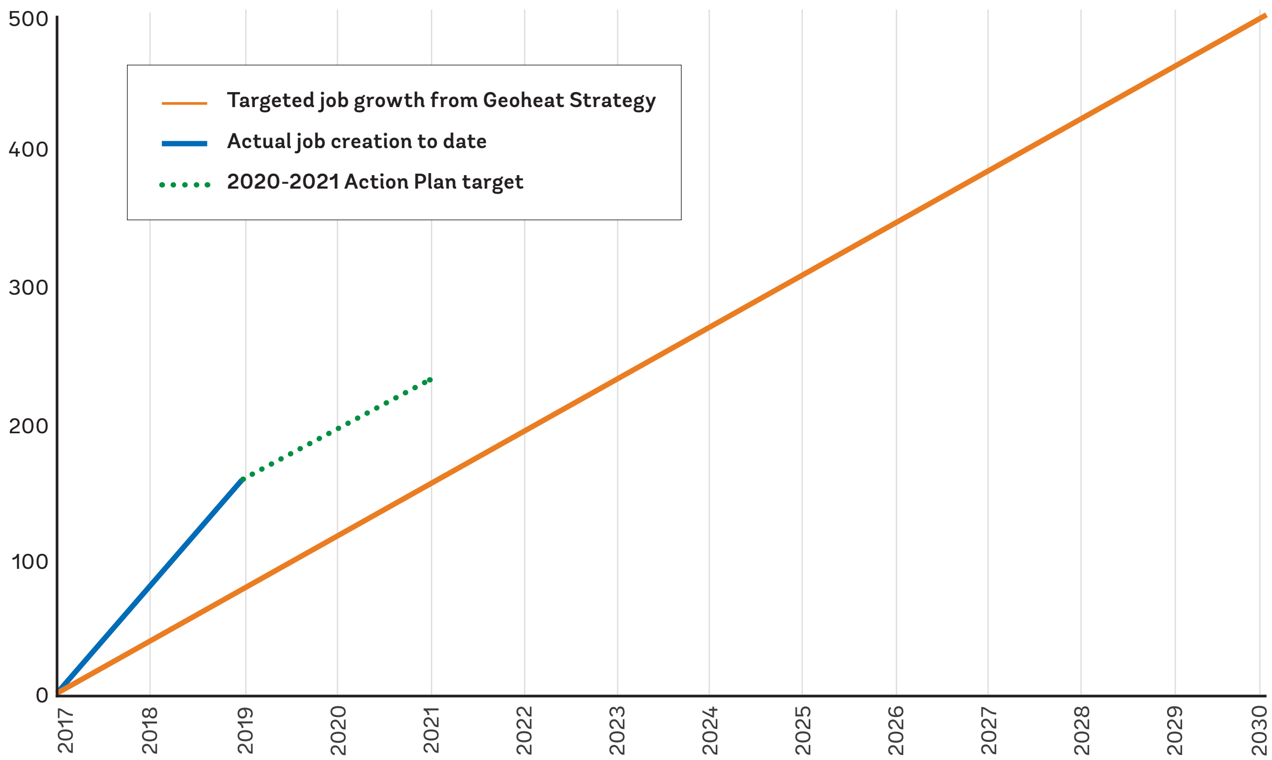

FIGURE 1 plots actual FTE generation since strategy inception and compares this with a linear projection of job growth out to the Strategy target of 500 new FTE's created by 2030. Figure 1 shows that actual FTE's are tracking ahead of the linear projection.

2018 - 2019 PRIORITY ACTIONS PROGRESS REPORT

PRIORITY ACTION 1:

STATUS PARTIAL

Action: STOCKTAKE OF RESOURCES

Description: Develop a stocktake of supply side assets, infrastructure and geothermal resources to create a communicable picture of geothermal opportunities in New Zealand.

Status Report: Stocktake commenced and preliminary information compiled. Focus shifted to specific opportunities and solutions, which was considered more effective.

PRIORITY ACTION 2:

STATUS ACHIEVED

Action: TARGETED PROJECTS

Description: Target industrial and commercial scale projects on brownfield sites where geothermal capacity exists in association with an existing project and/or a resource consent for the extraction of geothermal heat.

Status Report: Significant new projects committed and in development, with at least seven businesses adopting geothermal use with more than 150 FTE's recorded (Table 1).

PRIORITY ACTION 3:

STATUS PARTIAL

Action: MARKET ANALYSIS

Description: Undertake domestic and international market analysis for large heat users.

Status Report: Collaboration was strengthened between geothermal fluid/heat suppliers, NZTE and MBIE to identify and connect with high potential domestic and international investment targets. Connections were made with target industry groups (e.g. wood processing) to promote the benefits of geothermal use. This work moved from broad market analysis to a tactical approach, whereby an opportunity was identified by a heat supplier and support was provided, which included market insight, information and connections.

PRIORITY ACTION 4:

STATUS ACHIEVED

Action: CONNECT SUPPLIERS AND TARGETS

Description: Develop market value propositions for geothermal heat suppliers.

Status Report: Significant progress made in establishing connections between heat users, heat suppliers, funding sources, investors and information. Confidentiality requirements prevent full reporting, however large-scale new projects are in development through connections made. Assistance provided in writing Provincial Growth Fund[2] applications (worth > NZD 60M)

OTHER 2018 - 2019 HIGHLIGHTS

- An engaged Strategy Action Group, meeting regularly with approximately 20 active members from multiple sectors / professions;
- Supportive Minister of Energy and Resources (Hon Megan Woods) who understands the industry, especially the multiplier effect of direct heat and other opportunities (e.g. hydrogen);
- The potential for geothermal mineral extraction is now on the central government radar;
- Increased engagement with and awareness within other industries and businesses outside of the geothermal sector;
- Wider New Zealand interest (outside of the Taupō Volcanic Zone) in direct use geothermal is growing, including Northland and the West Coast;
- Increased data and information is available in the public arena for use in wider discussions . This includes eight conference papers, five external industry presentations, and three international geothermal industry presentations (Mexico, Iceland, USA);
- Key groups are starting to pull together; moving in the direction aligned around the geothermal direct use vision. Groups include BoC, central government, geothermal operators, NZGA and economic development agencies.

[2]The Provincial Growth Fund is the three billion dollar New Zealand Government investment fund for regional economic development over the three-year period 2018-2020. (https://www.growregions.govt.nz/about-us/the-provincial-growth-fund/)

2020–2021 ACTIONS TO GROW DIRECT GEOTHERMAL USE

The primary focus for activity under the 2020 - 2021 Action Plan is to continue the momentum of converting business connections into tangible projects.

A critical element to achieving this is to secure adequately funded resources to implement Strategy initiatives, most importantly the work of the Strategy Coordinator.

The focus for the 2020 - 2021 Action Plan continues to be on the utilisation of geothermal resources in the Taupō Volcanic Zone (Figure 2).

ACTION PLAN OBJECTIVES

OBJECTIVE 1

New direct geothermal projects, generating at least 80 FTE jobs, are committed to and in development by end of December 2021.

The creation of at least 80 full time equivalent (FTE) jobs more than doubles the target set by the 2018-2019 Action Plan. However, this goal is considered realistic given the results achieved in 2018-2019 (Figure 1 and Table 1). In a continuation of the current approach, activity will focus on energy and fluid capacity available at existing geothermal sites (brownfield), where geothermal resources can be readily accessed and new opportunities created.

OBJECTIVE 2

Secure funding to drive Strategy implementation for the next two years (ca. NZD 300,000).

Without dedicated resources, Strategy implementation will falter.

The successes to date have been realised through the creation of the BoC funded Geothermal BDL role.

As a truly independent role, funded by multiple funding sources, matters such as project confidentiality, intellectual property and proprietary technologies have been able to be effectively managed. This has allowed greater project support and close relationships to be developed.

A minimum of NZD 300,000 has been identified as the lowest level of investment required to maintain current momentum. This is based on salary and associated project costs for engaging a person with the necessary experience to deliver on targeted outcomes. Experienced individuals with dedicated time to drive implementation are limited.

FIGURE 2 Taupō Volcanic Zone: The focus area for the 2020–2021 Action Plan

PRIORITY ACTIONS

The four priority actions aim to provide building blocks for achieving the two 2020 – 2021 objectives . Flexibility is retained to pursue avenues of greater impact, if identified during implementation.

PRIORITY ACTION 1: FUNDING STRATEGY

Description: Develop and implement a funding strategy to secure funding for 2020 -2021 and beyond.

Rationale: Multiple funding sources are important for independence and role functioning of the Geothermal BDL / Strategy Coordinator. Rapid implementation of the funding strategy is crucial, as the current contract funding for the Geothermal BDL concludes in mid 2020.

Approach: We will target central government, industry, NZGA, regional economic development agencies and Māori organisations. Outcomes sought by funders will need to be clearly identified, and a business case for funding from each source developed.

PRIORITY ACTION 2: PARTNER WITH MĀORI ORGANISATIONS

Description: Establish / develop productive working partnerships with willing Māori organisations to assist in the achievement of aspirations for geothermal energy use and development.

Rationale: Specific geothermal expertise is not always available to assist in the realisation of geothermal developments, however there is significant potential for Māori organisations, who are geothermal developers, and/or owners of geothermal resources / land, to actively lead aspects of geothermal utilisation in New Zealand.

Approach: A partnership approach will be taken to explore, develop, and ultimately realise geothermal development potential by piloting two specific activities:

(a) Support for Toi Kai Rawa – The Strategy Coordinator will provide support for the direct geothermal use initiatives that Toi Kai Rawa develop through 2020 - 2021. The Strategy coordinator will seek expertise and advice from the Geoheat Action group as may best fit the initiatives.

(b) Direct support to one Māori organisation each year to organise a targeted tactical workshop (as opposed to strategic). The criteria for choosing the organisation will be developed as an early phase workstream.

PRIORITY ACTION 3: PARTNER WITH CENTRAL GOVERNMENT

Description: Partner with central government agencies to find geothermal solutions to support greenhouse gas emission targets and job creation strategies.

Rationale: Multiple emissions reductions and increased employment outcomes can be achieved from geothermal energy use projects.

Approach: We will take a solution-oriented approach, combining expertise provided through and under the Geoheat Strategy with resources available through central government.

PRIORITY ACTION 4: DELIVER BUSINESS CASES

Description: Produce at least 10 funded business cases for geothermal conversion for targeted existing business and for new business opportunities.

Rationale: Choosing to use geothermal energy over another energy source becomes a question of economics and feasibility. Access to tools, information, and assistance to answer feasibility questions is expected to encourage more businesses to go geothermal, especially where conventional energy sources may be simpler to pursue. Business cases will be particularly valuable for small to medium enterprises, who are likely not to have this expertise in-house.

Approach: A group of geothermal business case writers will be assembled to assist in business case development for targeted companies / organisations considering new start-up enterprises or the conversion of existing business to geothermal energy. Business cases will be confidential to each business in question and will not be made public, allowing a full exploration of the benefits of geothermal energy for each particular project. Development of the business case will be at no cost to the particular business, however co-funded opportunities will be explored.

GEOHEAT ACTION GROUP ACTIVITIES

Activity in supporting work streams can be initiated and progress made at any time, should a champion/group step forward who is willing to drive that action area.

ONCE OFF ACTIVITY - 2020

	Activity	Description
1	**Strategy Consultation**	Given the high level of engagement in Strategy implementation and the successes achieved to date, the approach is to seek continued engagement, interest, input and involvement, rather than a full Strategy review. Through various opportunities provided for industry interaction (e.g. New Zealand Geothermal Workshop), this Action Plan and the Strategy will be discussed for feedback.

ONGOING ACTIVITY - 2020 - 2021

These tasks are business as usual, or need to be maintained to continue implementation momentum.

	Activity	Description
2	**Action Group**	Continue to maintain and grow clusters of 'like minds' to assist with growth of geothermal energy use. Strive for connected and cooperative industry to affect far greater change than individual efforts.
3	**Network & Connect**	Maintain and grow connections and networks to raise the geothermal profile. Establish services and mechanisms to provide interaction between potential geothermal heat users and heat suppliers. Develop broader targeted engagement with identified Māori organisations.
4	**Process Heat in NZ**	Actively participate in the MBIE / EECA Process Heat in New Zealand and Accelerating Renewable Energy and Energy Efficiency initiatives through 2020 - 2021.
5	**Showcase**	Actively showcase existing success stories in geothermal energy use to increase awareness and stimulate further development. Share information. By sharing lessons learned, future projects can learn from and build on past successes. Success breeds success. Collect data that enables effective monitoring of the Strategy goals.
6	**Education and Training / Skills Shortages**	There is a strong focus on job creation under this Strategy; skilled workers are required for those jobs. Look for opportunities to create skills / learning programs for new professionals entering the geothermal industry. Look for opportunities to create cadetships within existing companies / organisations, develop, as appropriate, specific courses (including developing scholarship opportunities for those courses) in partnership with university or other training organisations.
7	**How-to Guides**	Develop 'how-to' reference guides. At the smaller scale, the complexity of developing a geothermal use can be a barrier. Plain language advice and information on regulatory requirements, technology and resource information could assist to reduce barriers and enhance connections.

BEYOND 2021

Lower priority tasks, possibly more complex and/or requiring substantial funding, or currently beyond the mandate and interest of organisations and individuals involved.

	Activity	Description
8	**Greenfield Development**	Link greenfield site developers with potential energy users. Greenfield resources offer potential future energy supplies in support of economic development, but are further from business, infrastructure and market realisation.
9	**Logistics and Infrastructure**	Advocate for improved infrastructure. Direct use geothermal energy is not transportable over large distances (i.e. more than 30 km); strategic transportation connections for products to reach markets for areas rich in geothermal energy opportunities will boost the competitiveness of businesses seeking to utilise this resource.
10	**Policy Alignment**	Improve policy alignment in regards to geothermal energy use. Regulatory barriers, particularly for small- to medium-scale developments, can be reduced through improved Policy Statements, Regional Plans, and to some extent, District Plans. A National Policy Statement on renewable energy would show Central Government intent. There is also more potential for enabling non-regulatory documents, such as Energy Strategies.

SUCCESS STORIES

Asaleo Care - Kawerau

In 2010, Asaleo Care converted from a natural gas fired boiler to geothermally produced process steam supplied by Ngāti Tūwharetoa Geothermal Assets, reducing their annual carbon footprint by 39% (~ 22,000 tonnes per year).

Commended in the 2012 EECA Business Awards (EECA 2012), the judges commented that the conversion achieved "An impressive reduction in CO_2 emissions. It shows a good partnership model with iwi and ongoing leadership and intent as part of their sustainability commitment."

Geothermal energy is an enabler for Asaleo Care, significantly reducing their carbon footprint (as of 2019 the reduction is 46% annually (Asaleo Care 2019)) and providing them with a competitive advantage from low carbon renewable energy.

Asaleo Care is continuing to actively invest in upgrades to their Kawerau facility, confident in the benefits of geothermal process heat in a low-carbon future. An NZD 60 million state of the art tissue converter line expansion was installed in 2014 (TVNZ 2014) and in late 2019 Asaleo Care completed installation of an NZD 23 million Forte converter line that enables product enhancements, improves packaging, reduces waste, and increases functionality.

Sid Takla, Asaleo Care's Managing Director, says that the company has invested in the future of the manufacturing sector, in the economy and in jobs in Kawerau and the Bay of Plenty. "New Zealand is an attractive and compelling country to invest in, and with our well-established site, our hard-working and dedicated team, our strong, long-standing partnership with the Ngāti Tūwharetoa iwi, there is no doubt – this is the right place to be for [our] next phase of growth." (Asaleo Care 2019).

Nature's Flame - Taupō

The largest wood pellet plant in the Southern Hemisphere was opened by Nature's Flame in 2010. Located at Taupō in the heart of the New Zealand timber industry, Nature's Flame manufactures premium wood pellet fuel for New Zealand and international consumption.

The pellet fuel is a carbon neutral fuel alternative to coal. Wood fibre in the form of sawdust and shavings is obtained from sawmilling operations; the fibre is dried, resized and then compacted to form a dense fuel which burns efficiently and cleanly.

In 2019, Nature's Flame replaced an aging undersized biomass boiler used for drying the wood fibre with a geothermal heat supply. The geothermal heat is supplied by Contact Energy.

John Goodwin, Nature's Flame Operations Manager said "We are thrilled by the outcome of this deal with Contact. With our new energy supply system getting to operational status, we are able to increase to 100% of capacity (pellet manufacturing capacity), creating new jobs in the Taupō region. We are now receiving 18MW of heat continuously, which is fuelled by a low carbon renewable source." (Contact 2019).

James Kilty, Chief Generation and Development Officer for Contact Energy said, "Partnerships like this one with Nature's Flame are at the core of our ambition to lead the energy sector to a low-carbon future. We believe climate change is real and the greatest challenge of our time, but also our greatest opportunity. We want to be working with other commercial and industrial customers to form partnerships that help to reduce emissions for New Zealand." (Contact 2019).

GLOSSARY

BDL: Geothermal Business Development Lead for the Bay of Connections.

BoC: Bay of Connections, Regional Development Agency for the Bay of Plenty Region and the Taupō District.

Direct Use: Refers to the use of geothermal energy / fluid directly. Essentially this is any application of geothermal energy use other than converting geothermal energy to electricity.

EECA: Energy Efficiency and Conservation Authority.

Geothermal energy: Energy sourced from the ground.

Greenfield Site: Site considered to be prospective for geothermal resources that has limited information available or is unproven and no resource consents are in place to allow the take of geothermal fluid.

MBIE: Ministry of Business, Innovation and Employment.

NZTE: New Zealand Trade and Enterprise.

NZGA: New Zealand Geothermal Association.

PJ: Peta Joule, a unit of energy equal to 10^{15} Joules. A larger scale glasshouse (approx. 12 ha) might use less than 0.3 PJ / annum.

Primary Geothermal Energy: The total amount of geothermal energy supplied to a process. This will be greater than the actual amount of energy consumed in the process.

Strategy Coordinator: Role established under the Geoheat Strategy for Aotearoa NZ, 2017 – 2030 to drive strategy implementation. This role for 2018 – 2019 was delivered by the BoC Geothermal Business Development Lead.

Toi Kai Rawa: Māori development agency promoting Māori economic development within the wider Bay of Plenty. (http://www.toikairawa.co.nz/).

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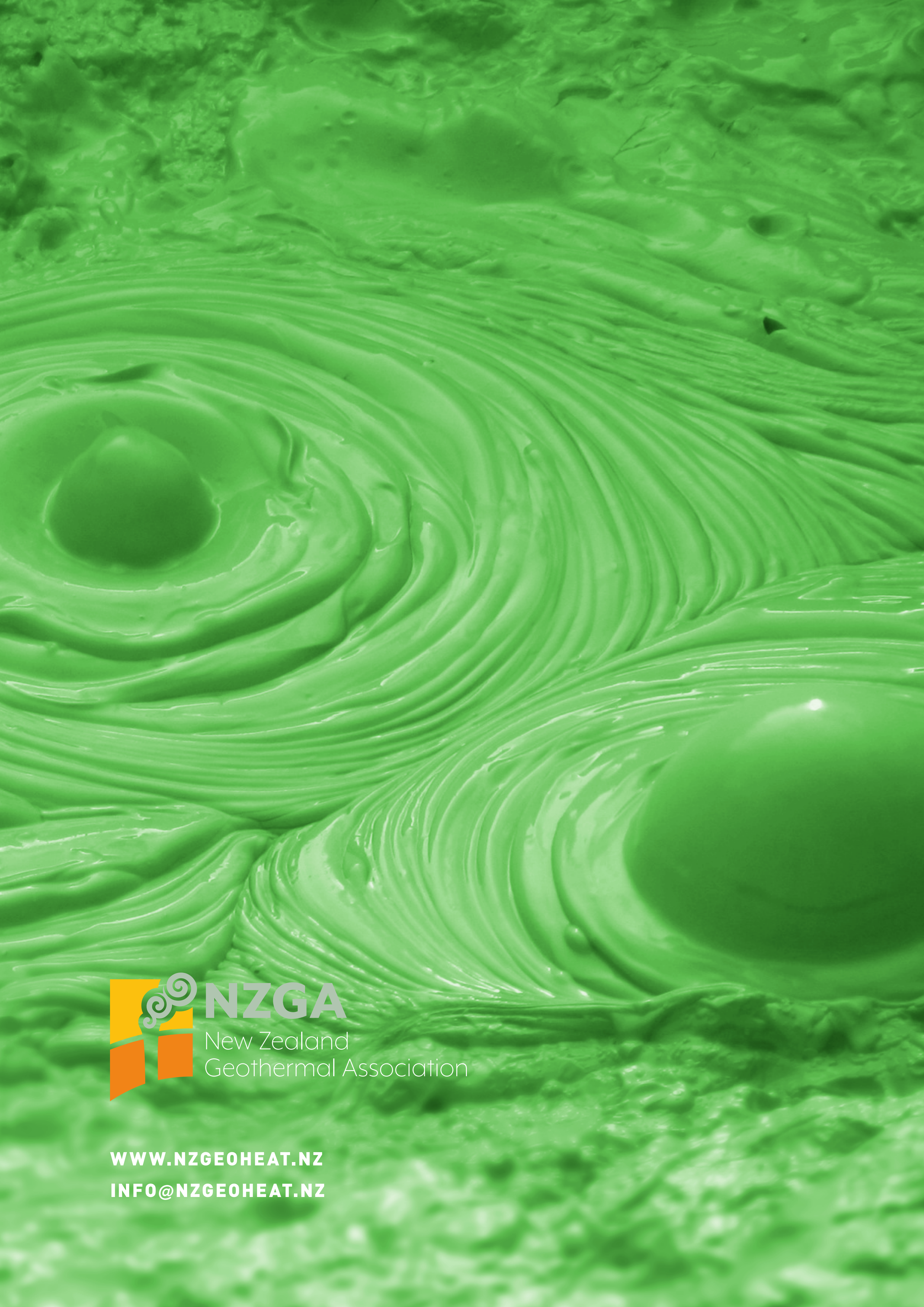

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Appendix 4 – Mclean, K., Richardson, I., 2019. Greenhouse Gas Emissions from New Zealand Geothermal Power Generation in Context.

Mclean and Richardson (2019) provides data on Greenhouse Gas emissions from New Zealand's geothermal power stations, contextualises the emissions relative to natural emissions from Rotorua, White Island and Rotokawa. The paper is a source of quality data. The paper is part of the Proceedings of the 41st New Zealand Geothermal Workshop held in Auckland in November 2019.

Reference : Mclean, K., Richardson, I., 2019. Greenhouse Gas Emissions from New Zealand Geothermal Power Generation in Context. Proceedings 41st New Zealand Geothermal, 25-27 November 2019, Auckland, New Zealand.

GREENHOUSE GAS EMISSIONS FROM NEW ZEALAND GEOTHERMAL POWER GENERATION IN CONTEXT

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Keywords: *Carbon dioxide, CO_2, methane, CH_4, greenhouse gas, geothermal, emissions.*

ABSTRACT

Conventional geothermal systems are complex natural features, usually comprising a deep heat source such as a magma chamber, and above this a convecting system of hot water/steam. There are often natural features at the surface indicating the presence of these geothermal systems underground, including fumaroles, hot springs, geysers and steaming ground. There are many geothermal fields in New Zealand, mostly associated with volcanism within the extensional Taupo Volcanic Zone of the North Island.

From these geothermal surface features, there is a significant natural flux of CO_2 and methane (CH_4) through the ground surface and into the atmosphere. These gases are transported to the surface by hot geothermal fluids, though the original source of the gases is not yet known and is the subject of current research by GNS. When geothermal fields are developed for electricity generation, CO_2 and methane are released during the power generation process, while the natural flux of these gases is thought to diminish.

CO_2 and methane emissions data during plant operation (combined as CO_2-equivalent) are presented for the major geothermal plants in New Zealand. There is a focus on the most recent emissions for the calendar year 2018, followed by a review of how these emissions have changed over the period 2010-2018. The tendency of geothermal emissions intensity to decrease over time is shown, as well as the effect of plant/operational changes. The geothermal emissions intensity is compared to typical values for other clean energy sources, and also to fossil fuels.

1. INTRODUCTION

Greenhouse gases are emitted by most geothermal power stations during the power generation process. In the underground reservoir, the hot geothermal fluid contains carbon dioxide (CO_2) and methane (CH_4), which are then transported to the surface when the fluid is extracted. The gases separate into the steam phase which goes to the power plant where it is condensed in a heat exchanger (condenser). The greenhouse gases do not condense, and along with some others are referred to as non-condensable gases (NCGs) and would accumulate in the condenser where they would compromise efficiency if they were not removed. Removed gases are typically released to the atmosphere, though in a few cases are compressed and reinjected (Kaya and Zarrouk, 2017) or purified and used for industrial purposes such as production of methanol (Halper, 2011).

Significant fluxes of greenhouse gases are emitted via these natural surface features, and also as flux through the soil. The net effect of the power station development on all greenhouse gas emissions - from both power generation and the natural surface features - is arguably a more valid measure of the carbon impact of a geothermal development.

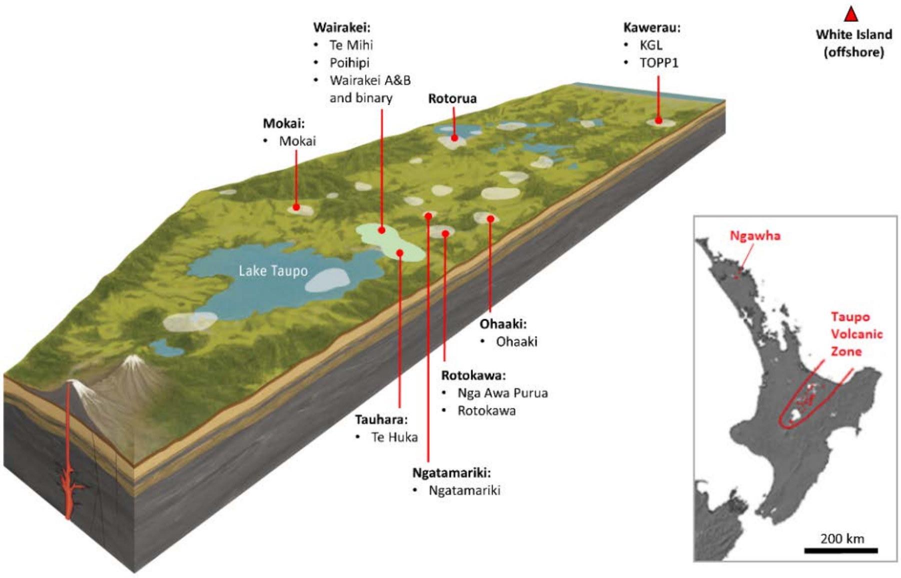

Figure 1: Map of the Taupo Volcanic Zone (TVZ) indicating the 23 known geothermal systems, associated power stations (bullet points), and other locations discussed in this paper. Inset: map of the north island, indicating the location of Ngawha geothermal field and TVZ.

To illustrate the full geothermal greenhouse gas emissions picture, available CO_2 and CH_4 emissions data have been collected from both natural surface features and from the 12 major power stations in New Zealand (Figure 1). These data are presented as CO_2-equivalent.

2. BACKGROUND

2.1 Major geothermal power stations in NZ

There are 12 major geothermal power stations in New Zealand, located at 8 geothermal fields (Figure 1). All but one are located within the Taupo Volcanic Zone, which is a wedge of volcanism through the north island resulting from crustal extension and melting associated with subduction of the Pacific tectonic plate under the Australian plate. The exception is Ngawha geothermal field, which is located in the far north (Figure 1).

2.2 Geothermal emissions: natural state vs development

In their natural state (pre-development) geothermal systems emit CO_2 and CH_4 (and also H_2S and other gases) via natural surface features which include fumaroles, steaming ground, hot pools, and flux through the soil (Figure 2).

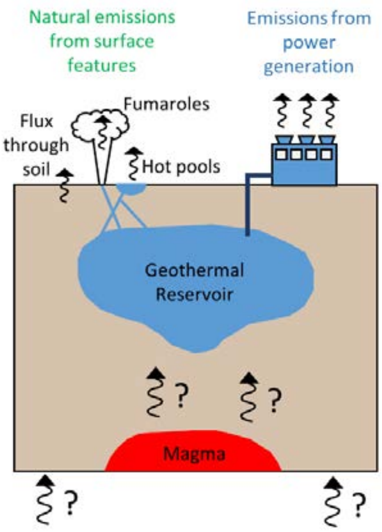

Figure 2: Schematic showing a geothermal reservoir with natural greenhouse gas emissions via surface features and from power generation.

These emissions are significant, and while this has not been studied extensively, or for all geothermal fields, some examples are (t/day of CO_2 only, does not include CH_4):

- Rotorua: at least 1000 (Werner and Cardellini, 2006)
- Rotokawa: 441 (Bloomberg et al., 2014)
- Crater floor of White Island volcano: 124 (Bloomberg et al., 2014)

When a geothermal field is developed, fluid is extracted from the reservoir and emissions of CO_2 and CH_4 are released from this fluid during the power generation process (Figure 2), along with other non-condensable gases which are removed from condensers in the power station and then released.

There is a lack of research into the effect that this geothermal fluid extraction has on the emissions from surface features. If it could be shown that the power generation resulted in a measureable decrease of the emissions from surface features then a case can be made to use this decrease to offset the power generation emissions (Bertani and Thain, 2002). In other words, it is the net effect of the development that is important (the balance of surface feature and power generation emissions).

There are few studies of CO_2 and CH_4 natural flux from geothermal systems in New Zealand, however this is the subject of a three-year Royal Society Te Aparangi Marsden project which commenced this year (led by Isabelle Chambefort, GNS, Chambefort et al., 2019, this volume). A goal of the project is to create a CO_2 flux map for the whole Taupo Volcanic Zone, including both inside and outside the known geothermal areas. Another goal is to identify the deep source of the CO_2 in geothermal reservoir fluids, which is not currently known (Figure 2).

2.3 Global geothermal emissions intensity survey

Bertani and Thain (2002) compiled CO_2 emission data from 85 geothermal power plants in 11 countries, representing 6643 MWe (net) of generation, which was 85% of the global generating capacity at the time. The global MW-weighted average emissions intensity was 122 gCO_2/kWh with a very wide range of 4 – 740 gCO_2/kWh. Also 73% of the plants had a MW-weighted emissions intensity of 55 gCO_2/kWh. This study does not mention CH_4.

2.4 Operational vs life-cycle emissions

To fully understand the impact of a development a life-cycle assessment is necessary, which includes all emissions from construction, operation and decommissioning. This paper examines the operational emissions from geothermal power stations: construction and decommissioning are beyond the scope of this paper. However, lifecycle analyses (LCAs) are examined for different energy sources by the Intergovernmental Panel on Climate Change (IPCC, 2011). Median values for emissions intensity in gCO_2/kWh are as follows: coal = 1001 and natural gas = 469, and the renewables: solar PV = 46, geothermal = 45, wind = 12 and hydro = 4 (IPCC, 2011).

2.5 Emissions measurement methodology

Under the Climate Change (Stationary Energy and Industrial Processes) Regulations 2009 (Schedule 2, Table 6), each site is allocated a default emissions factor (DF) which is the fraction of $CO_{2\text{-eq}}$ present in the steam ($tCO_{2\text{-eq}}$/t steam). An emissions factor (EF) is multiplied by the total annual mass of steam (t) to calculate the total annual mass of $CO_{2\text{-eq}}$. (t) (Equation 1).

$$mass\ CO_{2-eq}(t) = EF\left(\frac{tCO_{2-eq}}{t\ steam}\right) \times mass\ steam\ (t) \tag{1}$$

Geothermal power companies can also apply for a unique emissions factor (UEF) under the Climate Change (Unique Emissions Factors) Regulations 2009 (Clauses 14-17). Circumstances in which a UEF might be applied for/used includes if the emission factor drops below the default emissions factor (DF), and for all geothermal power stations built since the regulations, as the DF for new developments is very high. Hence the emissions factor "EF" in Equation 1 can be either the DF or the UEF. This is described in more detail in a letter from GNS Science to the NZGA (Carey, 2010). The UEF is usually a flow-weighted average of the sampled $CO_{2\text{-eq}}$ contents of the various steam lines supplying the power station, which is then verified by an auditor before reporting to government. Sampling for the UEF is completed by GNS Science. Some internal sampling also occurs.

In this paper all emissions factors are actual measured emissions factors (either UEF or internal sampling), not default emissions factors (DF). In some cases the emissions factors in this paper might correspond with the "official" UEF, though the UEF is only updated if the data shows a statistically significant change from the previous year, and so the finer details of the change with time are lost.

Emissions intensity ($gCO_{2\text{-eq}}$/kWh, which is the same as $tCO_{2\text{-eq}}$ /GWh) is a measure of how much greenhouse gas is emitted per unit of electrical energy generated (Equation 2). It is useful for comparison between different types of power stations, as it is independent of the fuel source.

$$Emissions\ intensity\ \left(\frac{gCO_{2-eq}}{kWh}\right) = \frac{mass\ CO_{2-eq}(g)}{energy\ (kWh\ net)} \quad (2)$$

The effects of carbon dioxide (CO_2) and methane (CH_4) are combined into one value: carbon-dioxide-equivalent ($CO_{2\text{-eq}}$), which is the amount of actual CO_2 plus a calculated amount of CO_2 to represent the methane, which has 25 times more effect than carbon dioxide. For example, the emissions factor (EF) as measured at a particular sampling point on a steam line is calculated using Equation 3 (Climate Change (Unique Emissions Factors) Regulations 2009, Clause 15(1)(d)):

$$EF\ \left(\frac{tCO_{2-eq}}{t\ steam}\right) = MMF\ CO_2 + (25\ \times MMF\ CH_4) \quad (3)$$

Where: MMF CO_2 – mean mass fraction of CO_2 in the steam sample, and MMF CH_4 is the mean mass fraction of CH_4.

2.6 Emissions intensity from fossil fuel plants

Emissions factors for fossil fuel plants are expressed as $tCO_{2\text{-eq}}$/TJ, rather than geothermal emissions factors which are $tCO_{2\text{-eq}}$/t steam. Therefore an estimate of the emissions intensity of fossil fuel plants (used in Figure 4) can be calculated by multiplication with the heat rate (the inverse of efficiency) (Table 1).

Table 1: Calculation of estimated emissions intensity for fossil fuel power stations.

Fuel	Emissions factor*	Heat rate**		Emissions intensity
	$tCO_{2\text{-eq}}$/TJ	kJ/kWh		$gCO_{2\text{-eq}}$/kWh
Natural gas	53.64	OCGT	9,800	525
		CCGT	7,307	390
Coal	87.68	Coal	10,900	955

*Climate Change (Stationary Energy and Industrial Processes) Regulations 2009 (Schedule 2, Tables 1 and 4).
** PB Power (2009).

3. RECENT EMISSIONS INTENSITY (2018)

A recent snapshot of geothermal emissions for the calendar year 2018 is presented in Table 2 for the 12 major geothermal power stations in New Zealand, including emissions factor, total mass of steam, average generation and the calculated emissions intensity. There are various ways to calculate an overall number to represent this dataset:

- Not all power stations are the same size, and this is accounted for by calculating a MW-weighted average for the dataset of 76 $gCO_{2\text{-eq}}$/kWh (net).
- Standard median and inter-quartile range: median 61 and range 45-93 $gCO_{2\text{-eq}}$/kWh (net).

A straight average (unweighted) is not a valid representation of this skewed dataset due to the presence of significant outliers (Ohaaki and Ngawha). For example, in this case the average would be 103 $gCO_{2\text{-eq}}$/kWh (net), which is outside the inter-quartile range.

The dataset and statistical representations discussed above and in Table 2 are shown graphically in Figure 3, which clearly shows the skewed nature of the dataset with the two outliers of Ohaaki and Ngawha. When the geothermal numbers are compared to fossil fuels (Figure 4) it is clear that overall geothermal emissions are an order of magnitude less than emissions from fossil fuel plants.

Table 2: Geothermal power stations operational emissions intensity for 2018.

Power station	Geothermal field	Emissions factor	Total mass of steam	Average generation	Emissions Intensity	Annual emissions	Emissions rate
		t $CO_{2\text{-eq}}$ / t steam	t steam	MWe (net)	g $CO_{2\text{-eq}}$ / kWh (net)	t $CO_{2\text{-eq}}$	t $CO_{2\text{-eq}}$ / day
Wairakei A&B and binary	Wairakei	0.002300	9,287,157	116	21	21,360	58
Te Mihi	Wairakei	0.005100	11,703,800	157	43	59,689	163
Poihipi Road	Wairakei	0.004800	3,208,715	46	38	15,402	42
Ohaaki	Ohaaki	0.036300	2,552,176	31	341	92,644	254
Te Huka	Tauhara	0.007000	1,239,798	22	45	8,679	24
Rotokawa	Rotokawa	0.014540	1,683,626	33	84	24,480	67
Nga Awa Purua (NAP)	Rotokawa	0.009947	7,798,462	141	63	77,571	212
Mokai	Mokai	0.004600	5,615,613	56	52	25,832	71
Ngatamariki	Ngatamariki	0.013352	3,765,219	90	64	50,273	138
Kawerau (KGL)	Kawerau	0.017082	6,557,855	104	123	112,021	307
TOPP1	Kawerau	0.012100	929,196	21	60	11,243	31
Ngawha (all plants)	Ngawha	0.083950	735,127	23	304	61,714	169
				MW-weighted average	**76**	**Σ 560,909**	**Σ 1536**
				Median	**61**		
				25th percentile	**45**		
				75th percentile	**93**		

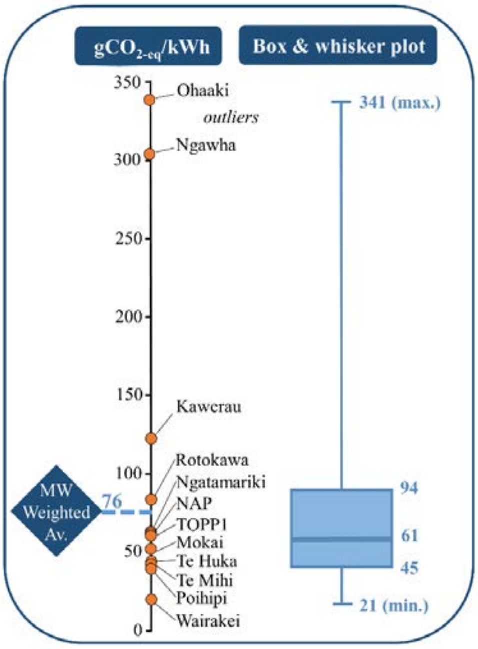

Figure 3: Graphical representation of operational emissions intensity from geothermal power stations data, and statistical representations of that dataset (Table 2).

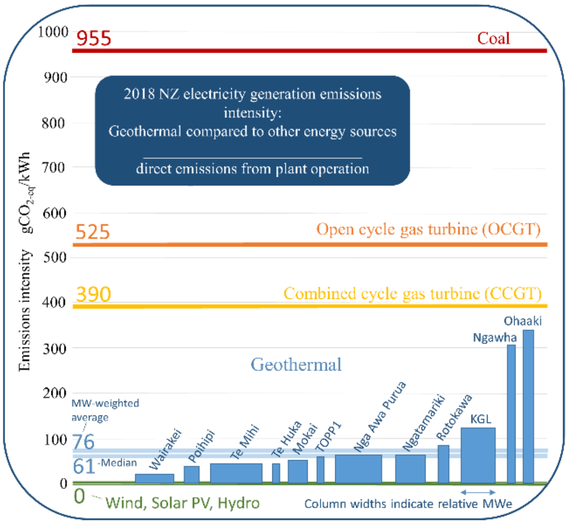

Figure 4: Graphical chart comparing the operational emissions intensity of geothermal power stations in New Zealand (Table 2) to other types of electricity generation (Table 1).

The emissions rate from each geothermal power station is also given in Table 2 as tonnes per day (t $CO_{2\text{-eq}}$ / day) for comparison with the emissions rates from three areas of natural surface features (Section 2.2). This comparison is shown graphically in Figure 5, and shows that total natural surface feature emissions exceed the total geothermal power station emissions, even though the three estimates represent only a small fraction of the total surface feature activity in the TVZ (23 known geothermal systems, Figure 1). Also CH_4 is not included in these estimates of natural surface feature emissions, if it was they would be greater.

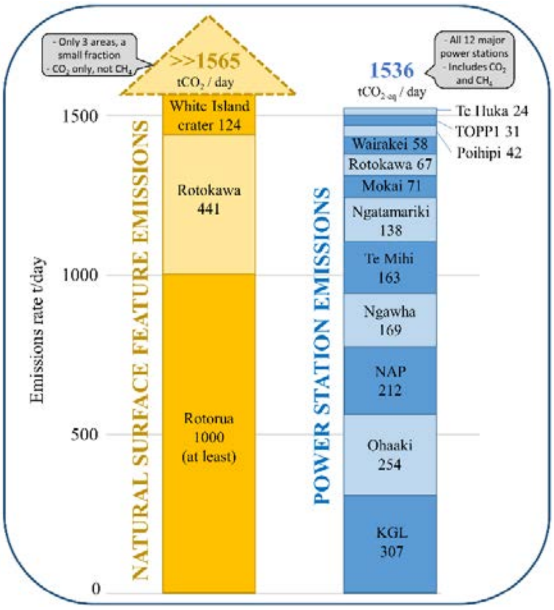

Figure 5: Comparison of emission rates from 3 areas of natural geothermal surface feature activity to the 12 major geothermal power stations.

4. CHANGES TO EMISSIONS INTENSITY 2010 – 2018

The previous section was a snapshot of geothermal emissions for the calendar year 2018. Geothermal emissions intensity is not constant through time, and while it generally declines over time due to degassing of the geothermal reservoir fluid, if there are operational changes to the steamfield or plant it can sharply increase or decrease. Emissions data is available for most geothermal power stations over the time period 2010 to 2018. Available emission data from Mercury operated power stations is given in Table 3, Ngawha and TOPP1 owned by Top Energy and NTGA, respectively in Table 4, and Contact Energy power stations in Table 5.

4.1 Decline due to degassing

4.1.1 Rotokawa

The Rotokawa field hosts both the Rotokawa and Nga Awa Purua power plants, where emissions intensity has been declining over time (Figure 6a).

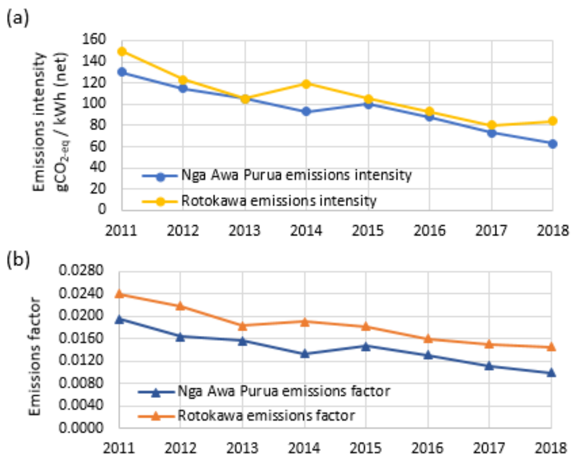

Figure 6: Rotokawa and Nga Awa Purua power stations 2011-2018: (a) emissions intensity; (b) emissions factor (Table 3).

This decline is predominantly a result of lower concentrations of CO2-eq in the steam at the two stations as shown in Figure 6b. There are some years where the emissions intensity has increased slightly from the previous year, this is typically a result of operational changes (well contributions). It is expected that the gas in steam concentrations at the Rotokawa field will continue to decline as the field degasses as a result of both development and natural surface feature emissions. It is interesting to note that Rotokawa is the only geothermal field in New Zealand for which emissions values for both power generation and natural surface feature emissions are available, and the total emissions from the two power stations in 2018 (67 + 212 = 279 $tCO_{2\text{-eq}}$/day, Table 2) are significantly exceeded by the natural surface feature emissions of 441 tCO_2/day (which does not include methane, Section 2.2). Continued degassing of the field is expected to further reduce the emissions intensity of these power plants.

4.1.2 Ngatamariki

The Ngatamariki power plant was commissioned in 2013, and the Ngatamariki geothermal field is one of the latest in New Zealand to be developed for power generation. The Ngatamariki field has shown early signs of decreasing emissions intensity due to decreasing gas in steam concentrations (emissions factor) (Figure 7).

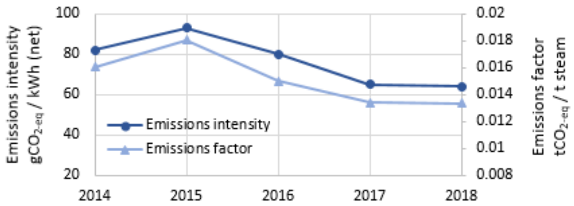

Figure 7: Ngatamariki power station 2014-2018: (a) emissions intensity; (b) emissions factor (Table 3).

Table 3: Emissions intensity and source data for Mercury power stations

Station	Year	Emissions factor [tCO_2(eq)/t steam]	# sample sets	Mass steam [kt]	Generation [GWh (net)]	Emissions intensity [gCO_2(eq)/ kWh(net)]
Mokai	2011	0.0058	*	*	*	35
	2013	0.004356	6	5,555	815	30
	2014	0.004033	6	5,722	876	26
	2015	0.0036	8	6,159	851	26
	2016	0.004599	8	6,215	852	34
	2017	0.004155	8	5,910	848	29
	2018	0.0046	12	5,616	492	52
Ngatamariki	2014	0.016062	8	3,220	629	82
	2015	0.01805	8	3,792	733	93
	2016	0.015	8	3,716	699	80
	2017	0.01342	10	3,873	801	65
	2018	0.013352	12	3,765	785	64
Nga Awa Purua (NAP)	2011	0.019449	*	*	*	130
	2012	0.016329	12	8,076	1145	115
	2013	0.015633	12	7,449	1106	105
	2014	0.013356	12	7,369	1063	93
	2015	0.014663	12	7,359	1083	100
	2016	0.01309	12	7,915	1170	88
	2017	0.011181	12	7,576	1170	73
	2018	0.009947	12	7,798	1239	63
Rotokawa	2011	0.024004	*	*	*	150
	2012	0.02174	6	1,614	284	123
	2013	0.01829	6	1,636	284	105
	2014	0.018994	6	1,603	256	119
	2015	0.018205	6	1,581	273	105
	2016	0.015991	8	1,620	280	93
	2017	0.014966	8	1,551	289	80
	2018	0.01454	12	1,684	292	84
Kawerau (KGL)	2011	0.017358	*	*	*	136
	2012	0.020443	12	6,647	842	161
	2013	0.018352	12	6,231	813	141
	2014	0.019471	10	6,857	901	123
	2015	0.02226	12	7,001	902	173
	2016	0.019153	12	6,676	853	150
	2017	0.017288	12	6,947	961	125
	2018	0.017082	12	6,558	912	123

*Source data for some of the Mercury power stations was not readily available for 2011, only the final results.

Table 4: Emissions intensity and source data for Top Energy (Ngawha) and NTGA (TOPP1) power stations.

Station	Year	Emissions factor [tCO_2(eq)/t steam]	# sample sets	Mass steam [kt]	Generation [GWh (net)]	Emissions intensity [gCO_2(eq)/ kWh(net)]
TOPP1	2017	0.0122	15	920	187	60
	2018	0.0121	12	929	187	60
Ngawha	2010	0.09700	26	361	101	348
	2011	0.09252	4	683	193	328
	2012	0.08902	4	735	203	322
	2013	0.08839	6	769	197	345
	2014	0.08640	10	783	194	348
	2015	0.08119	4	784	192	332
	2016	0.08490	12	770	203	322
	2017	0.08314	6	726	198	306
	2018	0.08395	4	735	203	304

Table 5: Emissions intensity and source data for Contact Energy power stations

Station	Year	Emissions factor [tCO_2(eq)/t steam]	# sample sets	Mass steam [kt]	Generation [GWh (net)]	Emissions intensity [gCO_2(eq)/ kWh(net)]
Wairakei	2010	0.0048	1	13,105	1,359	46
	2012	0.0065	2	13,202	1,324	65
	2013	0.0062	1	13,018	1,262	64
	2014	0.002	1	11,630	1,156	20
	2015	0.0022	1	11,540	1,113	23
	2016	0.0026	13	10,387	1,119	24
	2017	0.0026	12	9,581	1,045	24
	2018	0.0023	8	9,287	1,017	21
Te Mihi	2014	0.0059	12	6,107	756	48
	2015	0.005	8	10,627	1,262	42
	2016	0.0048	8	10,169	1,188	41
	2017	0.0052	10	12,121	1,410	45
	2018	0.0051	9	11,704	1,376	43
Poihipi	2010	0.006	1	3,208	385	50
	2012	0.0014	2	3,651	448	11
	2013	0.0013	1	3,471	450	10
	2014	0.0019	1	3,136	394	15
	2015	0.0020	1	2,464	322	15
	2016	0.0020	1	3,069	398	15
	2017	0.0041	3	3,215	413	32
	2018	0.0048	11	3,209	403	38
Te Huka	2010	0.0087	1	1,254	210	52
	2011	0.0079	1	779	133	46
	2012	0.0046	12	1,216	210	27
	2013	0.0047	6	1,020	176	27
	2014	0.0057	1	1,373	213	37
	2015	0.0059	10	1,221	195	37
	2016	0.0059	9	1,210	191	37
	2017	0.0055	10	1,188	207	32
	2018	0.007	8	1,240	193	45
Ohaaki	2010	0.0555	1	3,892	411	525
	2011	0.0493	1	3,480	392	438
	2012	0.04875	2	3,077	346	434
	2014	0.0463	1	2,597	272	443
	2015	0.0411	1	2,982	326	376
	2016	0.0494	12	3,103	331	463
	2017	0.0392	10	3,230	338	375
	2018	0.0363	9	2,552	272	341

4.1.3 Ngawha

A declining trend is observed in the emissions intensity from Ngawha due to decreasing emissions factor as the field degasses (Figure 8). The other factor affecting the emissions intensity is the efficiency of the plant which is higher at high utilisation, such as in 2012, accounting for the dip in emissions intensity at this time (Paul Doherty, Top Energy, personal communication). The efficiency of binary plants is a lot more variable than the larger power stations. However the plant efficiency does not affect the emissions factor, which is a simple fraction of greenhouse gas in the produced steam. By also plotting the emissions factor (Figure 8) the effect of efficiency is removed and the 2012 dip disappears.

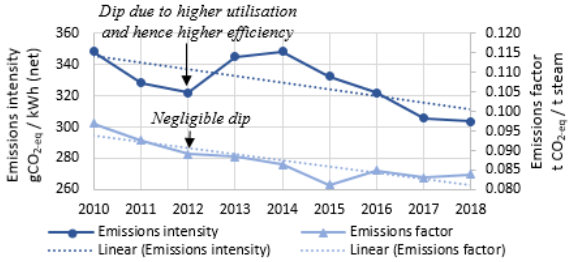

Figure 8: Ngawha binary station 2010-2018: (a) emissions intensity; (b) emissions factor (Table 4).

4.2 Operational changes

4.2.1 Wairakei/Te Mihi/Poihipi

The Wairakei A&B and binary, Te Mihi and Poihipi power stations are all owned by Contact Energy and are located in Wairakei geothermal field. They are interconnected via the above-ground steamfield and some wells can be switched between stations. If all wells in this field had the same emissions factor then the well switching would have no effect, the emissions factor of each station would be the same. The emissions intensity of each station would differ only slightly depending on the plant conversion efficiency between energy in the steam and electrical energy. However, some wells have a higher emissions factor than others, particularly some wells drilled into the shallow steam cap above the deeper liquid Wairakei reservoir.

The emissions intensity from these three stations must be considered in combination (Figure 9) as many of the sudden changes in the individual power stations emissions intensity are balanced by an opposite change in another station, as wells are switched between the two. This can be clearly seen as emissions at Wairakei rose in 2012, and dropped at Poihipi, when the higher-emitting dry-steam wells were switched to Wairakei as a new flash plant was completed (FP16) with liquid-fed lower-emissions wells, and the steam from this plant was used for Poihipi.

When Te Mihi started generating in 2014, the higher-emitting dry steam wells were switched there from Wairakei, causing the Wairakei emissions to drop (Figure 9). Those wells were priortised to Te Mihi as they are located near the station and transmission losses are minimised.

In 2017 there was an increase in emissions intensity at Poihipi and Te Mihi (Figure 9) due to two factors: fluid production increased (enabled by annual rather than quarterly accounting of fluid mass take), and also two new dry steam wells were connected.

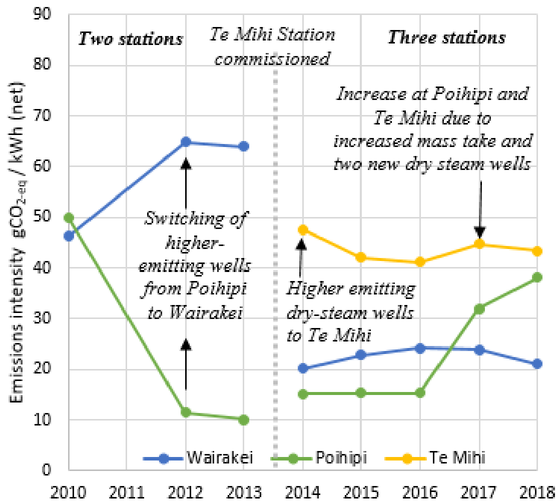

Figure 9: Wairakei A&B and binary, Poihipi, and Te Mihi power station emissions intensity 2010-2018.

4.2.2 Te Huka

There are only two wells supplying steam to Te Huka binary power station: TH14, which has higher enthalpy and higher emissions, and TH20 which has lower enthalpy and lower emissions, even though the wells are very close. The combined output of the wells is more than is required to run the plant. The proportion of steam coming from each of the two wells has been changed over time to maximise the electrical power output within the constraints of the plant control system TH14 and TH20 have different output characteristics, and so they are fed into different pressure reducing trains. The valve position of TH20 is fixed, while the valve position of TH14 automatically adjusts to the requirements of the plant, which vary throughout the day. The fixed valve position of TH20 is an indication of the proportion of flow coming from TH20 (Figure 10b).

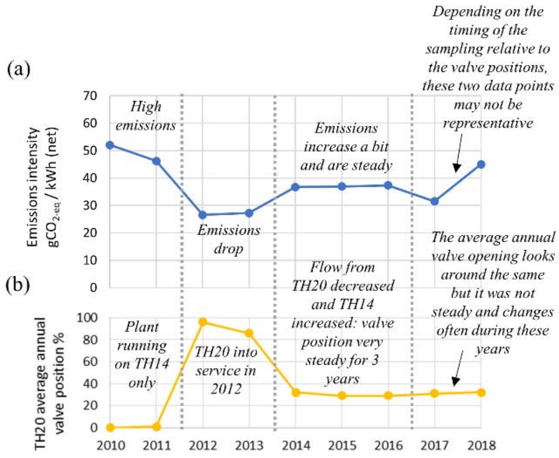

Figure 10: Te Huka binary station 2010 – 2018: (a) emissions intensity; (b) TH20 estimated average annual valve position.

When Te Huka first started generating, during 2010 and 2011, the plant was run on TH14 only (TH20 valve position is zero, Figure 10b), and emissions were relatively high (Figure 10a). TH20 was brought into service in 2012 and supplied the majority of steam to the plant for two years, and so emissions dropped. The valve opening of TH20 was increased to ~30% in 2014 (Figure 10b) for two reasons: the highly throttled state of TH14 during 2012-2013 caused operational issues that could trip the plant, and also calcite scaling in TH20 let to installation of a calcite inhibition system which required the well to be operated at a higher pressure. The result was that emissions increased in 2014 (Figure 10a). The valve opening of TH20 was then steady during 2014-2016, very rarely changing from 30%, and emissions were also steady. For the final two years (2017 and 2018) the valve opening data (which is an annual average) looks unchanged, but actually was quite variable over the year. Hence the emissions sampling could have been unwittingly biased depending on the timing of the sampling relative to the timing of the valve changes, which could explain the change in the 2017 and 2018 emissions compared to 2014-2016 (Figure 10a).

4.2.3 Ohaaki

Multiple factors are influencing the emissions intensity from Ohaaki power station over the 2010-2018 period (Figure 11).

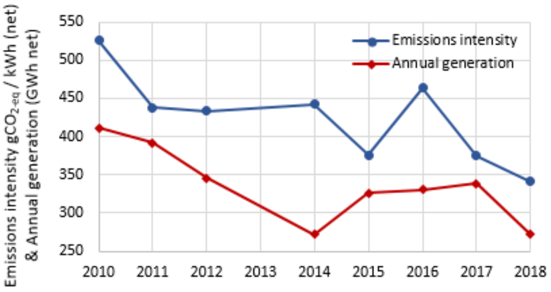

Figure 11: Ohaaki power station 2010-2018: (a) emissions intensity; (b) annual generation.

The generation has decreased as fluid production has been cut back to the long-term sustainable levels indicated by numerical modelling. There has also been a new focus on production from the previously-untapped deep reservoir under the West Bank (starting in 2007/2008). This new production initially caused a large spike in emissions (which were still high in 2010) as pressure dropped significantly in the deep reservoir. However now the pressures have partially recovered and stabilised, there is less pressure drawdown and therefore less boiling and degassing, so emissions are lower.

5. MBIE EMISSIONS DATA

Commencing in 2008, with the commissioning of Mercury's (then Mighty River Power) Kawerau geothermal power plant (KGL) the New Zealand electricity market has seen a significant addition of geothermal capacity over the last 10 years. During this period the Kawerau geothermal power plant, Te Huka, Nga Awa Purua, Ngatamariki, Te Mihi and Te Ahi O Maui geothermal plants have been commissioned. Together these power plants have added over 500 MW of renewable generation capacity to the New Zealand electricity system.

If this increased geothermal generation capacity is used to supply electricity that otherwise would have been generated from fossil fuels, an estimate of the corresponding reduction in CO_{2eq} emissions can be made. Since 2007, annual geothermal electricity generation has increased by over 4000 GWh. An assessment of the expected CO_{2eq} emissions of this increased generation is shown in Table 6.

Table 6: Estimated CO_{2eq} emissions for 4000 GWh generated by: coal, gas and geothermal.

Fuel	Emissions Intensity (gCO_{2eq}/kWh)	Annual Emissions (tCO_{2eq})
Coal	955	3,820,000
Gas OCGT	525	2,100,000
Gas CCGT	390	1,560,000
Geothermal	76	304,000
Δ Emissions (coal – geothermal)		3,516,000
Δ Emissions (CCGT – geothermal)		1,256,000

As can be seen in Table 6, displacing 4000 GWh of coal fired generation with geothermal is estimated to reduce CO_{2eq} emissions by approximately 3,500,000 tonnes per year. If geothermal displaced CCGT gas generation this would reduce emissions by more than 1,250,000 tonnes per year.

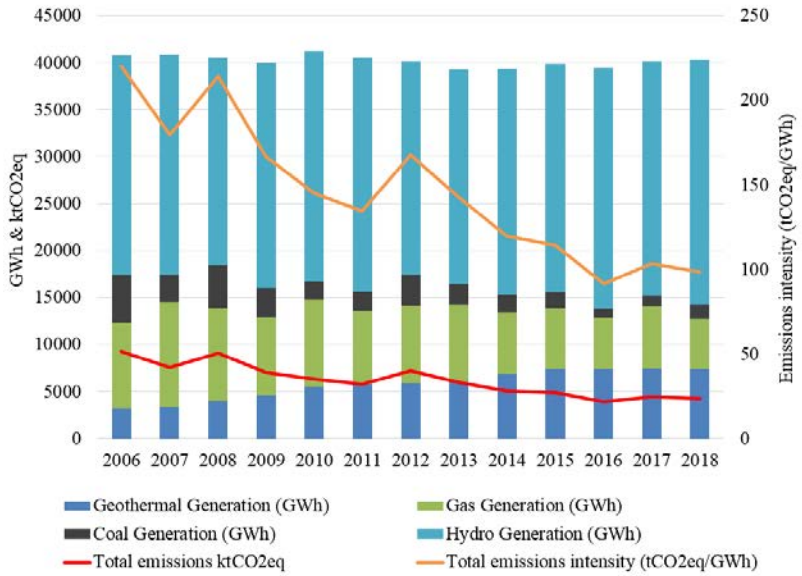

Figure 12: New Zealand electricity generation and CO_{2eq} emissions data (MBIE Electricity statistics, 2019 and MBIE New Zealand energy sector greenhouse gas emissions, 2019).

The impact of the increase in geothermal generation on New Zealand's electricity generation emissions is illustrated in Figure 12. It can be seen that as geothermal generation has increased and fossil fuel based generation has decreased over the last 10 years, the overall emissions intensity of the electricity generation sector has approximately halved, along with the total emissions.

6. CONCLUSIONS

- For the 12 major geothermal power stations in New Zealand in 2018:
  - The MW-weighted average operational emissions intensity is 76 $gCO_{2\text{-eq}}$/kWh (net).
  - The median and interquartile range for operational emissions intensity is: median 61 and range 45-93 $gCO_{2\text{-eq}}$/kWh (net).
- Operational geothermal emissions are higher than many other renewable energy sources, but much lower than fossil fuel plants.
- Emissions from geothermal power stations are outweighed by emissions from natural surface features. The effect of development on this natural flux of greenhouse gases is not known, and is required in order to know the net effect of development on emissions.
- Decline in emissions intensity due to degassing has been shown at several New Zealand geothermal fields, with Rotokawa perhaps showing the most dramatic decline in emissions intensity over the last 10 years.
- It has been shown that emissions intensity is variable at several New Zealand geothermal power stations due to operational reasons. These increases and decreases are due to well switching between stations, new wells being connected, and changes in the proportion of flow from existing wells.
- The increase in electricity generated from geothermal sources has made a significant contribution to major reductions in emissions from New Zealand's electricity industry over the last 10 years.

ACKNOWLEDGEMENTS

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Appendix 5 – Summary of Key Messages provided to ICCC in November 2018

Key messages for ICCC quantitative analysis

There are reasonably consistent expectations about the amount of electricity that geothermal is expected to provide in the future. Direct use could grow but regulatory frameworks will play a mitigating role.

Scale of impact:

- MBIE analysis expect geothermal generation to double from 7.5 TWh in 2017 to almost 15 TWh by 2050. Over this projection, geothermal generation is forecast to increase from 17.4% to between 20-25% of total electricity generation.
- To support the projected increase in generation, geothermal power capacity must double from the current 1,005 MWe to around 2,010 MWe. Such an expansion will be difficult to realise. The existing inventory of brownfield developments plus feasible new field developments together total less than half the required growth. The balance of the new capacity forecast is speculative.
- While direct use is relatively minor compared to electricity generation, the industry plans to expand supply form 4.0 PJ in 2017 to 7.5PJ by 2030 as part of de-carbonisation policy initiatives.

Degree of uncertainty and risk reduction:

- While New Zealand scientists and engineers are world leaders in geothermal exploration and development, the calculus of adding new geothermal generation capacity is complicated. Investors require alignment on energy policy, economics, regulations, access to the HV transmission system, and technical conditions. So both the timing and quantity of future capacity additions is problematic.
- Wholesale electricity prices, carbon prices, and foreign exchange rates are three of the volatile variables likely to impact the timing of geothermal development. While generation technologies are mature, incremental improvements by manufacturers should continue to lower the real unit costs of capacity. Despite these trends, regulatory frameworks and incentives may be required to accelerate both new generation and direct use.
- Modelled levelised electricity costs for new geothermal capacity range from 7-10 cents per kWh, depending on whether the projects are brownfield or greenfield. Reflecting this range, recent reported capital costs vary from $4,300 to $6,000 per kW.

Conclusions:

- In the upside case, new geothermal resources might generate another 1,000 MWe by 2050. However, it seems unlikely that even half this will be realised by 2035. The contribution of geothermal generation will depend heavily on external factors such as the cost of alternative green power, the cost of thermal fuel, electricity prices, carbon prices, and foreign exchange rates.