MBIE Resources Feedback Team,

Submission on "From the Ground Up – a draft strategy to unlock New Zealand's geothermal potential"

Thank you for the opportunity to comment on "From the Ground Up - a draft strategy to unlock New Zealand's geothermal potential." I would also like to thank Minister Shane Jones for highlighting this document at the recent New Zealand Geothermal Association Seminar held in Taupo on 30 July 2025.

I am making this submission as an individual rather than on behalf of any organisation or company.

About Myself - Brian White

My name is Brian White, I am a professional mechanical engineer, and I have been active in the geothermal industry then wider energy industry since the late 1970's and continue to be active to the present. My experience includes:

- Labouring on the Wairakei operational field in the 1970s,
- Working as an engineer on the Wairakei operational field
- Specialist geothermal studies at the University of Auckland Geothermal Institute
- Being part of a New Zealand Electricity design team initially working on Huntly thermal boilers then on Ohaaki geothermal steam turbo-generators during respective project construction periods,
- Being part of an investigations team in the Ministry of Works and Development Head Office (an office previously responsible for some of the regulations around geothermal use and that had coordinated initial New Zealand international aid using geothermal technology) in a team that managed huge amounts of geothermal information covering exploration and drilling, with my focus on Kawerau, including responsibilities for some of the government direct use projects. This included introductions and passing on key information that saw the development of the first New Zealand binary cycle geothermal power station at Kawerau
- Being a private geothermal consultant to Works Wairakei (focusing on Kawerau and Ohaaki), the Gas and Geothermal Trading Group (range of fields and issues), and DesignPower (the old design arm of ECNZ) looking for new development opportunities both in New Zealand and internationally,
- Leading a mechanical design team at DesignPower while being principal geothermal engineer with a focus on potential New Zealand, Philippine and Indonesia geothermal developments. This also covered introduction of binary cycle technology for Wairakei and investigations into an alternative sub-atmospheric flash technology for low temperature development. This included first due diligence exercises on geothermal assets including review of non-conventional operating modes for geothermal power
- Initially leading the DesignPower effort in the development of the Wayang Windu geothermal field in Indonesia, New Zealand's largest private investment in international geothermal projects and one of the few geothermal projects to see significant advancement through the Asian Financial Crisis
- Returning to New Zealand to a range of projects including identification of fields that could form a new geothermal business after the transfer of ECNZ geothermal assets to

Contact Energy - this new portfolio became the basis for Mighty River Power/Mercury geothermal assets

- Transferring to East Harbour Energy for a variety of consulting work. One early study in partnership with Motu saw the first studies of carbon emissions for geothermal development, while other studies looked at national potential and costs for both geothermal electricity and heat, and potential emissions targets for geothermal development
- Being seconded to Ministry of Economic Development (MBIE predecessor) initially as an acting regulator for both gas and electricity networks, then in a range of energy technical roles, including being on the 2006 Officials Review of the Electricity Market, introduction of Low Fixed Charge tariffs, and for the transfer of Crown Kawerau geothermal assets to Mighty River Power/Ngati Tuwharetoa Geothermal Assets
- Sitting on various committees allocating Government research funds
- Sitting on the Board of the New Zealand Geothermal Association at various times in various roles (the latest including being chair of an Information and Advocacy Committee). I was the first Executive Officer of the NZGA holding the office from 2005 until 2016, and maintain deep connections into the geothermal community
- Being appointed by Cabinet to a Board of Inquiry in 2010 into the Tauhara geothermal development (approved and recently developed)
- Working with the World Bank principally on the encouragement of geothermal development in Indonesia starting with a "Breaking the Deadlock" report in partnership with Castalia in 2006, then giving technical support for the Ulubelu 3 & 4 and Lahendong 5 & 6 (Tompaso) developments (partly to stimulate private investment), and now giving support to what are sometimes referred to as government drilling programmes, government drilling having been a key to risk mitigation and the previous development of New Zealand geothermal fields. Indonesia has now achieved status as the second largest developer of geothermal electricity in the world. Some of New Zealand's largest geothermal aid programmes in Indonesia (after Kamojang) have been linked to these projects
- Working with the New Zealand Ministry of Foreign Affairs initially as an external consultant (frequently on projects linked to Vanuatu or Indonesia) but then on a two-year contract leading renewable energy efforts partly through COVID-19 years. MFAT geothermal programmes related to Indonesia, the Caribbean and East Africa.
- Subsequent years have been back with East Harbour Energy with multiple geothermal direct use projects frustrated by risk associated with lack of past drilling in the places of interest
- Working with WPS on a "Battery" role for geothermal energy in New Zealand in which geothermal has a more flexible generation profile
- Over the years I have written a number of papers often in partnership with others. Through my period as Executive Officer of NZGA many of these related to the current status of geothermal development in New Zealand and could be referred to. Some selected wider papers include:
    - White, B.R. (November 1983) The Performance of Bottom Outlet Cyclone Separators ("Wairakei"-Type). Geothermal Institute Report 83.27 – this technology opened the door for wet field development (most New Zealand and international fields)
    - Thain, I.A. and White, B.R. (November 1993) Wairakei Power Development Efficiency Studies. Proceedings of the 15th New Zealand Geothermal Workshop - easiest gains in generation are through efficiency efforts
    - White, B., Bauer, H., Morris, G. and Torrens, S. (May 1995) Steamfield Development Opportunities Supplying Process Heat Industries. Proceedings of

the World Geothermal Congress 1995 - highlighting the attractiveness of direct heat applications

- White, B., Morris, G. and Lumb, T. (May 1995) New Zealand Geothermal Resource Ownership - Cultural and Historic Perspectives. Proceedings of the World Geothermal Congress 1995 - an early paper emphasising the close relationship of Māori with geothermal resource
- White, B.R. and Daysh, S.G. (September 1996) Environmental Permitting for the Wayang Windu Power Development Project - A Case History. Geothermal Resource Council Transactions, Volume 20 - a paper setting out lessons learned from Indonesia consenting processes in comparison with New Zealand experience
- White, B., Morris, G. and Taylor, C. (November 1998) Wairakei - A Fresh Look at Rejected Technologies. Proceedings of the 20th New Zealand Geothermal Workshop - drawing insights into technologies that may have been before their time
- White, B.R. (November 2006) An Assessment of Geothermal Direct Use in New Zealand. Proceedings of the 28th New Zealand Geothermal Workshop - looking at direct use as opposed to electricity generation
- White, B.R. (November 2013) A Brief Review of Geothermal Health and Safety Regulations Following the "Pike River Inquiry". Proceedings of the 35th New Zealand Geothermal Workshop - a paper reviewing H&S regulations (including the 1961 regulations referenced in this strategy document) and the level of risk associated with geothermal development
- Climo, M., Milicich, S. and White, B. (January 2016) A History of Geothermal Direct Use Development in the Taupo Volcanic Zone, New Zealand. Geothermics Vol 59, Part B, pp215-224 - historical perspective of direct use in TVZ, New Zealand
- White B.R. and Chambefort, I. (January 2016) Geothermal Development History of the Taupo Volcanic Zone. Geothermics Vol 59, Part B, pp 148-167 - an abbreviated history from Māori to 2015 covering geothermal electricity development including international outreaches during development hiatuses
- White, B.R. (November 2016) Te Wharewaka, Wellington - A Case Study in Geothermal Heat Pump Applications Beside a Large Body of Water. Proceedings of the 38th New Zealand Geothermal Workshop - a case study of geothermal heat pumps at the edge of "geothermal" development
- White, B.R., Bramantyo, E.A. and Cahyono, Y.D. (November 2018) Old Lessons Applied to Modern Separator Station Design. Proceedings of the 40th New Zealand Geothermal Workshop - re-visioning separator design - a key to wet field development
- White, B. (November 2021) Lost in the Jungle - A Review of the Still-Radical Geothermal Development at Kiabukwa, DR Congo. Proceedings of the 43rd New Zealand Geothermal Workshop - a review of a development that preceded Wairakei using sub-atmospheric flash technology (alternative to binary cycle at low temperatures)
- White, B.R. (November 2024) Stored Heat Calculations - Time for Review. Proceedings of the 46th New Zealand Geothermal Workshop - a look at some of the methods for field capacity assessment, with a correction applied (low temperature resources have been previously underestimated), calling for coordinated revision of methodologies.

Draft Geothermal Strategy

For reviewing the draft geothermal strategy, I find the tables on page 4 and spanning pages 20 and 21 to be an excellent stimulus for discussion of some of the issues around geothermal development here.

Improving Access to Geothermal Data and Insights

I support the prime goal of improving access to geothermal data and insights.

It is worth noting that of the 32 New Zealand geothermal electricity generation projects identified on the New Zealand Geothermal Association website, every one without exception has been associated with past scientific exploration backed up by a Government drilling programme that ceased in 1986. To date, no New Zealand field has been developed outside this original core of information and reservoir insight, with legacy wells and published papers having gone a long way to reduce development risk to acceptable levels for the developers of the day and subsequent developers. Some of the early science has been superseded and some field sectors have needed extended exploration (then development drilling), but groundwork had been done to give developers confidence to proceed with particular fields. This underlines the critical role that field information based on government science and drilling and accessible information can play, first in reducing risk then in giving developers confidence to proceed.

I note that a non-Crown well was drilling by Fletchers on Tikorangi in the 1980s without progress on the project since then, and that there has been recent private drilling on the Taheke field with a project now set for development.

I have been an advocate for assisted exploration programmes in Indonesia. Indonesia has progressed to be the second largest developer of geothermal electricity generation in the world, partly on the back of some excellent high temperature fields. However, the next tranche of fields for development are likely to be somewhat cooler. The Indonesian Government progressively releases fields for development using a bidding process but, until recently, information on which to bid for fields was limited. The Indonesian Government exploration and drilling programme will mean that fields can receive well-founded informed bids by serious developers to continue or accelerate Indonesia's good progress.

I do not believe that New Zealand's exploration drilling efforts should have finished (or at least they should now be revisited). Through the 50's, 60's, 70's and 80's the dominant technology for generation development was flash cycle technology (steam turbines and condensers - perhaps in multiple stages using flash plants in the steamfield to deliver steam at necessary pressures). Required reservoir temperatures for this technology were around 230ºC or higher. Binary cycle technology is now an established technology that can use lower temperature fluids combined with good well flows made possible by downhole pumps that can handle temperatures up to near 200ºC, combined with larger diameter wells and deliver massive flows per well. There are 20 examples (see https://www.nzgeothermal.org.nz/geothermal-in-nz/what-is-geothermal/) in New Zealand of binary cycle plants (some recently retired because of age and some linked to hybrid flash technology or higher temperature fields) with benefits such as ability to have full reinjection including gas. Many fields around the world are developed in the 120-160ºC reservoir temperature range using this binary cycle technology. On this basis there are now several other fields that should be explored to open up geothermal development.

New Zealand developers have had a focus on high temperature fields, and previously had field capacity estimate methods that essentially wrote off fields with reservoir temperatures below 180ºC. The dominant model for fields in New Zealand was based around a field that had boiling fluids virtually to the surface (boiling point for depth or BPD) with a tendency by developers to discount fields if this was not the case. Alternative field examples came right at the end of the

Government drilling programme in 1986 with 600m deep wells drilled at Horohoro and Whakatane. All showed linear temperature increases to the bottom hole temperature in the range 45-86°C, these being written off as the most "ungeothermal" wells (in comparison with the BPD model) drilled in New Zealand to that time. But since that date, drilling for enhanced geothermal systems (EGS) has progressed globally, and the temperature gradients found in the Horohoro and Whakatane wells represent outstandingly good conditions compared with trial EGS or commercial systems developed in Europe or the US. It should be noted that similar exceptional gradients have been found at Whataroa near the Alpine Fault in the South Island, and this has been highlighted as an area of exceptional heat flow in the consultation map on page 9.

As an aside, the actual temperature gradient for Horohoro and Whataroa is close to 120°C/km, so if these or similar areas were targeted in the supercritical geothermal programme then necessary temperatures may be achieved with conventional drilling depths of 3km or so.

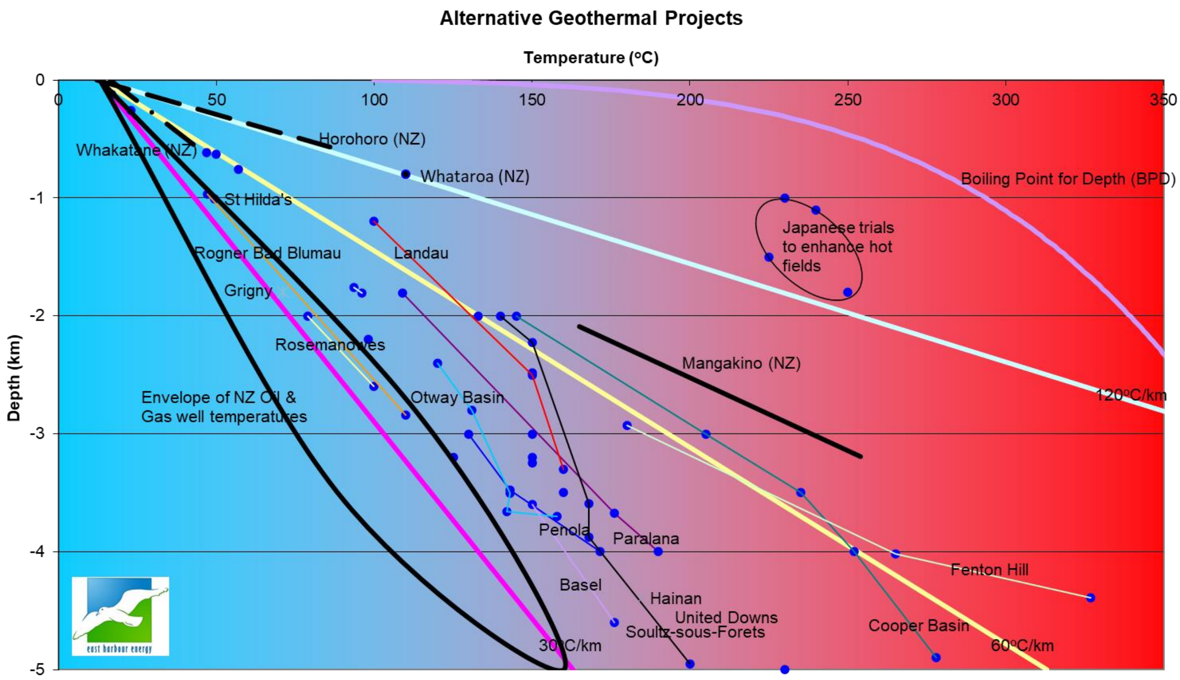

Figure 1: Graph showing temperatures in EGS sites and low temperature commercial developments compared with some New Zealand resources (shown in black)

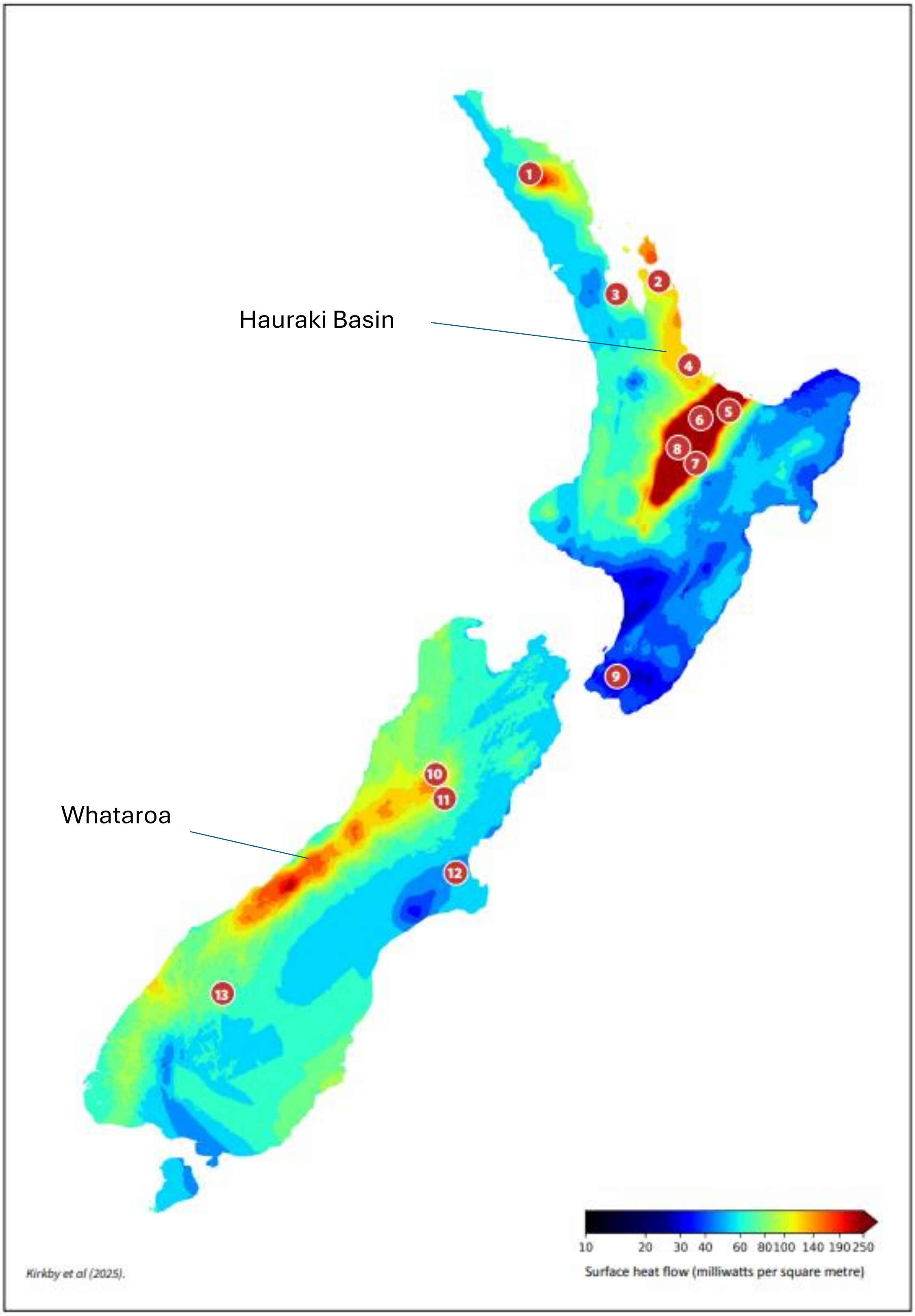

Figure 2: A surface heat flow map across New Zealand [Source: page 9 of consultation document]

The discussion above has focused on electricity generation. However, there is now strong interest in direct use of geothermal for heating. Clearly there is some opportunity to use heat at the back end of power stations. Geothermal brines after use, even for binary cycle projects can have temperatures of around 80°C which is more than adequate for glasshouse or similar projects. It should be noted that Ngawha Generation has considered secondary heating projects in their recent consent applications, potentially opening opportunities for higher employment in the Far North. Contact Energy has been a long-term advocate for direct use linked to their electricity generation projects, and have examples linked to Wairakei, Tauhara and Ohaaki developments. Tuaropaki at Mokai has diverse examples of direct use development (including a green hydrogen plant and milk treatment plant) both upstream and downstream of their station. Ngāti Tūwharetoa Geothermal Assets at Kawerau has multiple examples of direct use with the Kawerau Mill being the largest direct use in the world until the mill closure – some of this steam is now being redirected to electricity generation.

RETA has performed some interesting studies recently linking direct use and geothermal energy. The RETA database of heat plant has no geothermal use examples outside the Bay of Plenty (despite large commercial/industrial applications in Taupo, or the wide range of applications (including green hydrogen production developed at Mokai). Consequently, RETA is largely blind to the national opportunities.

On the basis of the discussion above, I believe that further government exploration (including drilling) is warranted:

- Potentially at or near Whataroa – with a view to direct use applications on the West Coast. Such drilling may not be warranted given the risk of Alpine Fault activation.
- In the Hauraki Basin – this could have transformational value in terms of glasshouse development or other food processing (there are multiple examples of existing food processing developments in the area). Measured temperatures from shallow wells suggest temperature gradients in the range 60-100°C/km, which combined with estimates of depth to basin being 1-2kms suggests a greywacke basement reservoir like Ngawha with a temperature over 120°C (also partly supported by some spring chemistry). If temperature and permeability are adequate then electricity generation may be possible. Again, if these qualities are adequate, this could be one of the largest capacity fields in New Zealand (and potentially globally if the field and permeability extends under the Basin). Food and electricity could then be available on Auckland's doorstep. The Basin is traversed by rail which then links to the ports of Auckland and Tauranga to bring in equipment or to export food. Relevant technologies are all proven, though pumped wells would be new for New Zealand and will broaden our experience.

Consideration could also be given to extended exploration at Horohoro and Whakatane to see if use can be made of the exceptional temperature gradients there. If fractures can be found then heat can be brought to the surface for use. If there is no permeability then this is an ideal environment for some downhole heat exchange technologies.

Further, direct use application linked to existing geothermal stations through the Waikato, Bay of Planty and Far North can be promoted through highlighting of existing geothermal developments, along with case studies of commercial developments using geothermal energy.

Not discussed until now, but broad data on shallow subsurface properties can help with the promotion of geothermal heat pumps. Heat pumps can also be used anywhere where there is ground water, surface water (rivers, lakes or harbours or even golf course water hazards).

<u>Government Attitudes to Geothermal Information</u>: Two examples will be given here – those of EECA and Treasury.

Unfortunately, the RETA reports are part of EECA strategy and EECA as a rule is blind to geothermal. EECA's intent on policy is to remain technologically agnostic. A search through many of their documents on "geothermal" in previous years has yielded zero references, while there are references to wind, solar and biomass as examples. This reflects negative bias rather than agnosticism.

Back in the 1980's, Treasury had a negative view of the geothermal industry, thinking that much advantage had simply been given away internationally through open sharing of government-led research. What is now Earth Sciences New Zealand regularly published papers on field research or new areas of science. New Zealand-sourced textbooks on reservoir engineering or geochemistry were available, and papers were published on the separators that enabled wet field development that applied to most fields developed since then (see my papers 1983, 1998, 2018). Our consultants travelled the world sharing how to make projects happen. Subsequently, we helped provide international training through the University of Auckland Geothermal Institute and other university Masters courses and PhD projects. The annual New Zealand Geothermal Workshop with its papers has been running since 1979, linked to the Institute. New Zealand engineers and scientists have been publishing papers in international settings to the present. These consultants are commercially available to assist clients anywhere. Treasury view was that advantage had been lost. Perhaps their taking on the Crown's geothermal assets (many of the Government-drilled wells and the Kawerau steamfield assets supplying the Kawerau mill) in the late-1980s was their way of controlling information flow. Treasury still holds some Crown wells. Treasury and industry information regimes now stand in stark contrast:

- Treasury. About 1990, Treasury appointed Rankine and Hill as their geothermal adviser. The company had no geothermal expertise but has retained its contract for the last 35 years unchallenged. They merged with Connell Wagner in 1992, then eventually with Aurecon in 2009. The Treasury contract has carried through to Aurecon since then.
  Aurecon and its predecessor have had multiple decades in which to develop geothermal expertise. They do not attend industry conferences or offer candidates for the industry Association board and are largely unknown to members of the industry. The Aurecon website (at the time of writing) contained no claim of competence in geothermal matters. In theory, Aurecon is the doorman past which requests for information associated with Crown wells must travel. Aurecon has developed a policy on sale of information at some discounted price to original capture.
  Aurecon staff are not competent to assess the real value of collective information held. There is valuable information on the cost and cost spread of wells that can be related to depth, production casing diameter and through simple escalation (then adjustments for some modern practices including deviated well drilling). There is also information that can be extracted on well production that can relate feed temperature and depth, mass flow and well diameter to enable comparisons between fields and assessments of likely production range within individual fields. It is not clear how much of this information may be left. Copies of this information (and additional historical material) had been held by the Ministry of Works and Development (MWD) and was transferred to Wairakei (what is now MB Century) in 1988 when MWD was disestablished. This information has since been lost with three stories about its end: still in MB Century sheds (not found); donated to the Geothermal Institute (not found); sent to landfill (most likely).
  It should be noted that no development of geothermal assets took place while under Treasury stewardship, though wells were monitored and maintained (and some may have been permanently sealed). One policy recognised that wells and assets may have value as part of Treaty of Waitangi settlements. In practice, development only occurred when assets could be acquired off Treasury. Good examples enabling development include well sales to Tuaropaki (Mokai field) and Tauhara North No 2 Trust (Rotokawa field). Kawerau asset sales were a particular case that may not have involved Aurecon at all. Norske Skog had outlined their commercial needs to Ministers, after which Treasury arranged commercial back-to-back Kawerau asset transfers through Mighty River Power to Ngāti Tūwharetoa Geothermal Assets (NTGA) linked to a Treaty settlement. NTGA has been exemplary in optiimising use of assets and trying to develop

more. Arrangements at the time gave Mighty River Power (now Mercury) confidence to proceed with their Kawerau geothermal development.

- Industry. In practice, New Zealand engineers and scientists have been making their extensive experience available internationally, but this has been to our gain. Sharing of science and engineering experience through published papers has helped stimulate international geothermal development (initially very much in its infancy). Subsequently New Zealand companies have brought our experience to many specific projects internationally with many millions of dollars earned through consultation. New Zealand companies and individuals still have a high profile and are seen to be sound sources of guidance, successfully competing with international companies. This consulting scene is dynamic with players rising and falling with time, new talent rising while others may retire or be absorbed in other consultancies. New Zealand's MFAT has been able to use this World-leading knowledge to lift countries, and this has been for its own strategic purposes for the benefit of New Zealand. New Zealand is already seen as a "centre of excellence" as proven by many international geothermal specialists relocating here. They bring additional experience with them, adding to the pool of knowledge and experience that we have, that we bring to our own projects and bring to the World. Any New Zealand geothermal meeting is rich with this international experience and perspective. If our people had not been so free with information in the first place then the international growth in geothermal would have been much slower, our own experience would have been more limited, and these international people adding to our numbers and experience may never have been nurtured.

In advocating for access to information, it should be borne in mind that there are both industry and government biases that need to be countered.

Ensuring Regulatory and System Settings are Fit for Purpose

Risk and uncertainty are two key words when considering development. As such, radical change, even with good intent, can be a hurdle. Enhancements can always be identified for existing regulatory systems, and clear guidance can be given to ensure inspectors are consistent and appropriate in their recommendations. The industry can be a great guide to what is needed and it is expected that some of these areas will be highlighted through this consultation process (see a discussion of drilling codes in the next section as an example).

One area of concern for me is Health and Safety. I am satisfied with the genuine culture of Health and Safety present across the industry and measures taken to ensure this. I have previously written about these H&S issues (White, 2013). There are potential special issues with hydrothermal eruptions (which may have a natural cause, independent of development or not) and with gas emissions (some rare occasions that must be managed), but WorkSafe should not equate geothermal risk with oil and gas risk because of the common use of drilling rigs. This is particularly so for drilling into lower temperature resources.

Note that while industry and the NZGA can play a role around sound regulatory settings, there is a cost to this work. The NZGA has limited funds which it must juggle across many initiatives. Consideration should be given to some means of cost offset to enable such work to be prioritised.

Advancing Knowledge and Uptake of Geothermal Technologies

I fully support this intent.

Note that industry working with the New Zealand Geothermal Association (NZGA) has already been involved with several relevant initiatives.

- Many years ago, a drilling code was developed that has become an internationally referenced standard. It initially followed the disestablishment of the Ministry of Works and Development to help capture the wealth of geothermal knowledge and experience resident within MWD and industry drilling staff. The Association and industry came together again several years ago to revise the standard. The Code helps ensure sound and safe drilling practices.
- Recently and currently, the NZGA and industry have been working together in efforts to reduce greenhouse gas emissions from geothermal stations. Reinjecting non-condensable gases back into their reservoirs is becoming more common. The most radical change was effected by Ngawha Generation which has moved Ngawha from one of the highest geothermal emitters per MWh generated to a zero emitter. In turn this should lead to improved perceptions of geothermal energy by public and officials.

I note the very substantial work done by what is now Earth Sciences New Zealand in publishing case studies and setting up website maps with locations of demonstration projects. At one time, the New Zealand Geothermal Association (NZGA) had some of this information on its website. NZGA continues to advocate a GeoHeat Strategy through an Action Group (strongly assisted by Earth Sciences NZ) with a view to increased direct use. This diagram helps with discussion but emphasises the strong alignment between government draft strategy and industry strategy.

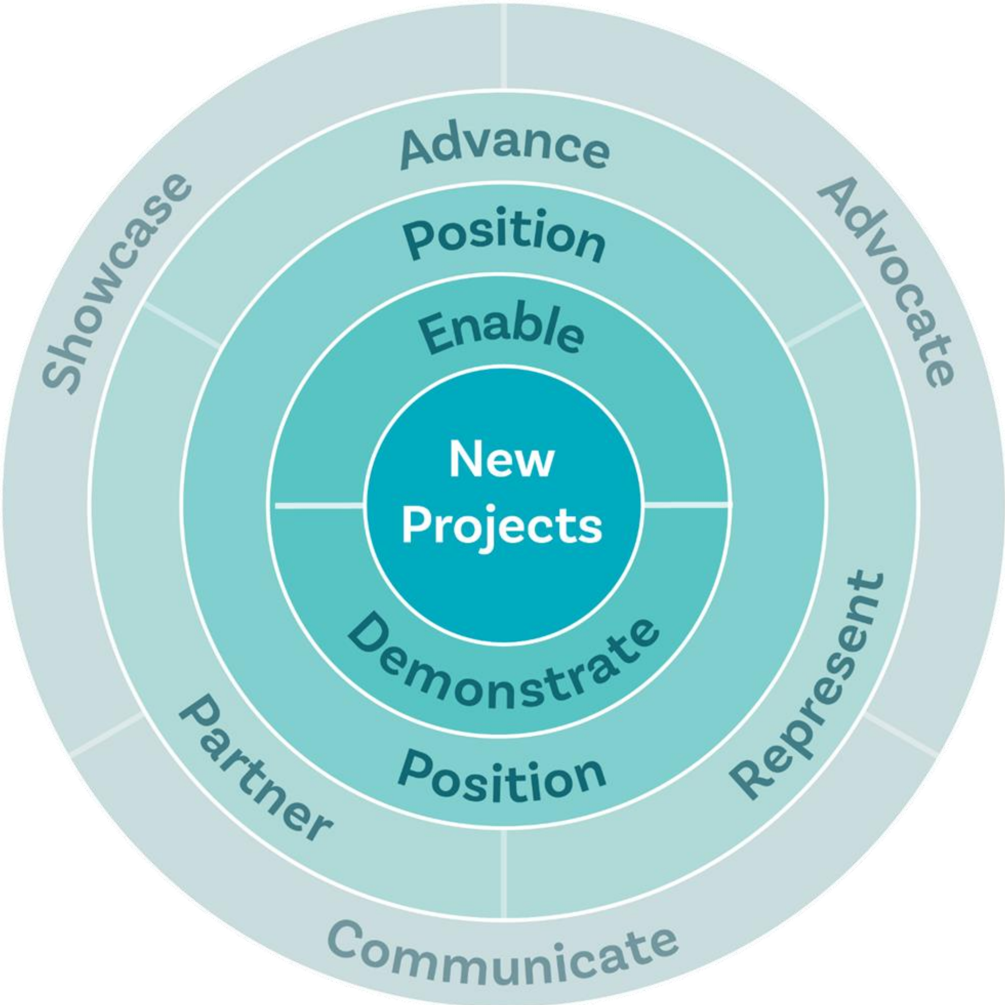

Figure 3: Key discussion points for a geothermal heat strategy

The GeoHeat strategy will likely be discussed in detail by NZGA.

I do want to bring out two other areas of specific knowledge development (this could also be discussed in the "Driving science, R&D ..." section).

Two-Phase Flow Regimes in Horizontal Pipes. If you visit a geothermal facility you will see a lot of horizontal pipes, some carrying a mixture of steam and brine (called two-phase flow). New Zealand engineers did some early research on this in the 1950s. You might think that details have been sorted, but they have not. Essentially pipe designers want a steady flow in pipes rather than a pulsing flow that could damage supports or displace the pipe. Various flow regimes have been identified by researchers though there is little description consistency between them. Different flow regime charts are used depending on the dominant national paradigm: US designers will rely on the 1954 Baker chart while NZ designers commonly use the 1974 Mandhane chart. Both were developed using air-water test rigs with diameters much smaller than is commonly designed for. Corrections are applied to match geothermal conditions. The Baker and Mandhane charts can be plotted on common axes as shown below (from White et al, 2018).

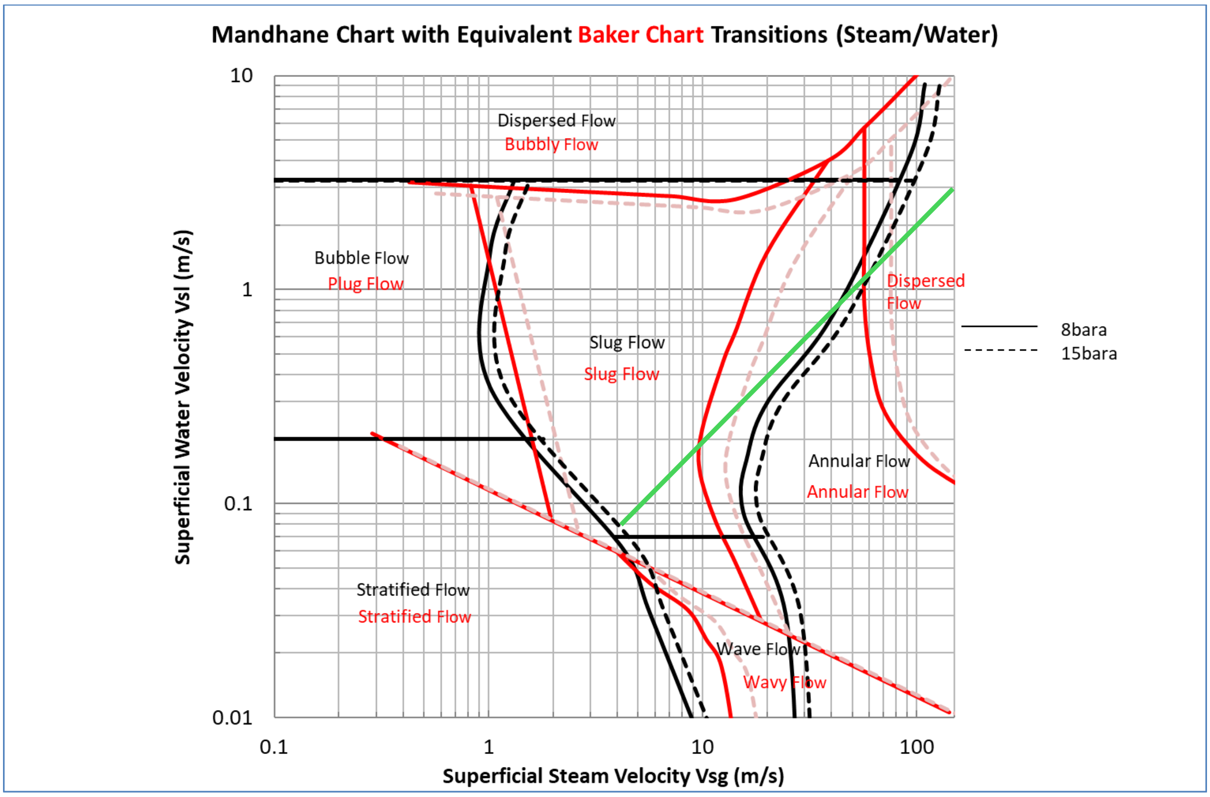

Figure 4: Comparison of Mandhane and Baker horizontal flow regime charts.

Designers will try to avoid the pulsing Slug Flow regime, increasing the velocity in the pipe until the flow is Annular. The design line will be parallel to the green line shown in Figure 4, which matches a condition of constant ratio of steam to brine. However it can be seen here that New Zealand designers may be sizing pipes for up to 5 times the velocity that a US designer will design for (to cross the annular flow transition line). This could be a pipe size just less than 50% of the US designer but with a significantly increased pressure drop and with a throttled well as a result. Throttled wells imply more wells (or earlier replacement wells) may be needed for the New Zealand designer than the US designer, but both designers ae working to convention rather than hard data.

In order to optimise design a programme of field data capture is required, and this can be achieved without significant commercial data disclosure. Operators could walk the lines and report when surging flow is observed (based on sound). Engineers could then assess flow parameters (pressures and mass flow) and assess superficial velocities to plot a point that is inferred to be slug flow. Similarly, non-surging lines might be inferred to be annular flow. It is expected that pipelines can eventually move off design, say due to well rundown or changing pressures. Data acquisition could be accelerated if a pipeline is deliberately throttled at a downstream valve. When sufficient transition points are plotted and shared across industry then a refined flow transition can be plotted for future optimised design. While pipeline cost will increase, this should be less of an effect than reduction of well numbers on overall development cost. This could be a task for NZGA to coordinate, in a similar manner to which they secured industry cooperation on gas reinjection. Publication of results could assist geothermal uptake both in New Zealand and internationally through reduced costs.

Simple Assessment of Field Capacity. Many parties are interested in field capacity, from developers to government for planning purposes. For developed fields the most comprehensive means is through a major series of measurements in response to operation then processed into a numerical reservoir simulation. Superimposed on this are new conventions that reflect confidence levels. However, before wells are drilled or fields have limited testing, then cruder methods have been used that go back to first principles.

The most common means are referred to as stored heat calculations (this had a New Zealand origin in the 1950s but has wide international acceptance now though with different conventions affecting calculations – it looks at how much heat can be recovered from a volume of hot rock and water) and power density calculations (this looks at how much heat can be recovered from an area of hot rock). These are discussed in White 2024. Generic results can be plotted on common axes and this is shown in Figure 5. It should be noted that corrections to the stored heat calculations were required and have been done for the graph, and are explained in the paper.

Figure 5 emphasises that a range of estimate methods are coalescing around common curves and data. Some of the data points require correction, being based on only the area associated with production (rather than full area) or based on first stage production (rather than full sustainable capacity of a field). The extrapolation of the power density curve for high temperature resources may not be justified. It is now time for a more detailed international review of methodologies to improve the usefulness of such methods. Ideally, calibration of existing fields should be done against the modelling of sustainable capacity from the numerical reservoir simulations. This review should be tied into United Nations Framework Classification for Geothermal Projects and can be led by the special geothermal expert group within this, for which there are New Zealand delegates.

The end result should be more useful and consistent basic capacity assessment methods for early-stage field investigations. Some government funding to take this forward may be necessary as industry has talked about revising methodologies for many years without progress – attention has been on format for expressing confidence in calculations rather than the calculations themselves.

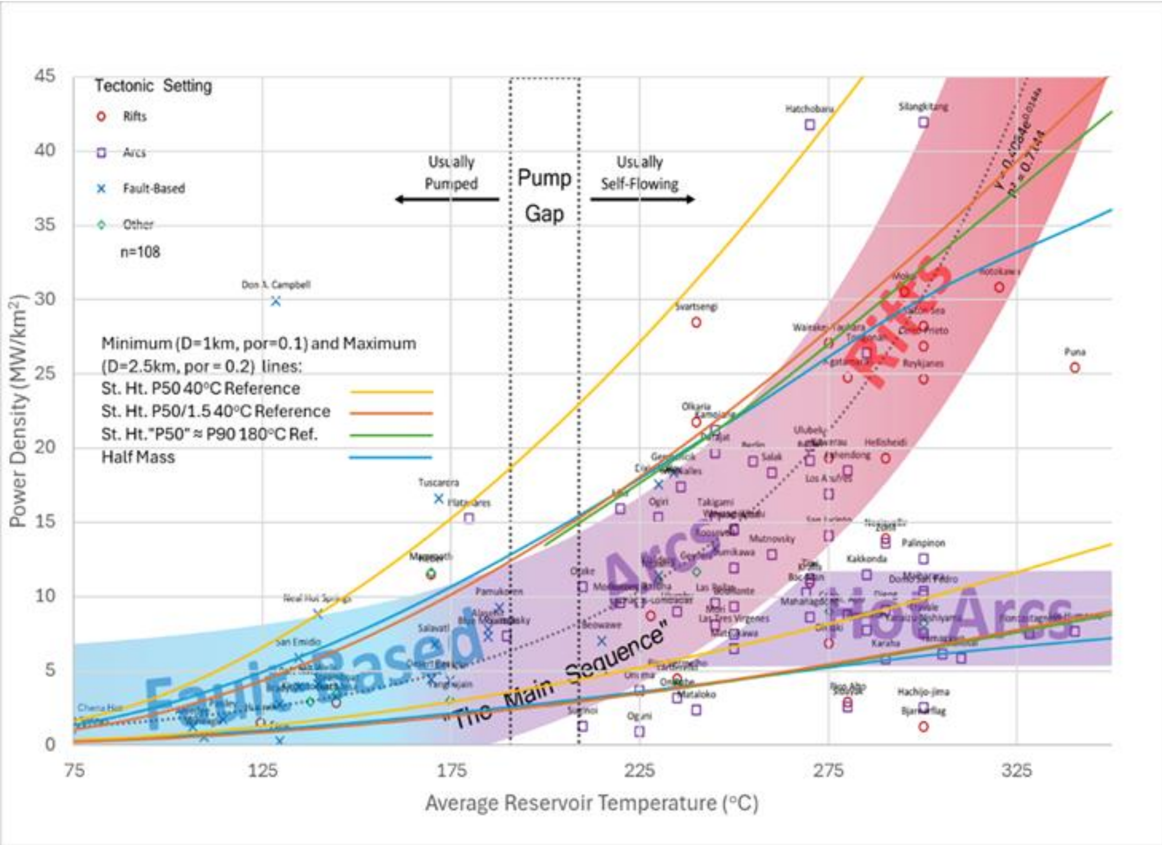

Figure 5: Plot of corrected stored heat estimates vs Wilmarth et al power density curves [Source: White 2024}

Geothermal Heat Pump Funding. In advancing knowledge and uptake of geothermal technologies, thought can also be given to funding mechanisms. A challenge for any renewable energy technology is its high initial capital cost, though this is offset by low operating/fuel cost. A spread of capital costs over multiple years may accelerate uptake of domestic technologies such as geothermal heat pumps. I have recently learned that Westpac offers what they call “Greater Choices Home Loans”. It enables costs to be spread over a period of five years with no interest to enable a mor efficient home. The loan specifically covers “heat pumps, including hot water heat pumps”. The description is slightly unusual, apparently referring to geothermal/ground source heat pumps even though these use local average temperature ground or water. Westpac is not aware of domestic applications for this technology. However it does highlight that a mechanism for funding is already in place. Presumably, this is backed by a government fund for which Westpac (and possibly other banks) are implementing agents. In this case there may be a need to help banks understand their own products and to help the public understand the opportunity available to them to spread costs.

Enabling Place-based Geothermal Clusters

To an extent, clustering (in terms of breadth of development) on a site is up to the commercial inclination of whatever developer is out there. However there is a need to make potential developers aware of what is possible at a geothermal site and potentially some of the co-benefits from clustering. Iceland has set a good example in this. Clustering in terms of numbers of developments on a site can be encouraged through the publishing of case studies and articles.

Driving Science, Research and Innovation, Including Supercritical Geothermal Technology

I support the supercritical research that has commenced, including the planned drilling. This gives New Zealand scientists and engineers the opportunity to be at the leading edge of development in the geothermal space, having partly missed similar opportunities in EGS research. Having accessed supercritical conditions through drilling, the challenge will then be to deal with the engineering challenges that result, including well integrity issues. However, the presence of the supercritical environment will then help draw in further researchers from here and overseas to address the issues.

I have already drawn attention to the need for additional government drilling and exploration of fields in this submission, and pointed out the key role that legacy government wells have played in all New Zealand geothermal development (outside of small scale commercial and domestic home and pool heating) to date. The following figure highlights the need for this action. Until the first wells are successfully drilled and tested, risk levels can be too high for private investment. Whereas the earlier focus was solely for high temperature electricity production, technology now allows commercial development of fields with temperatures down to 120°C or so, and attention is now shifting to decarbonising industry or opening up new industry with low emissions geothermal heat. The same issue with risk and cost applies to this new environment, but more fields become candidates for this government investment. Suggestions for drilling and exploration have been made earlier in this submission, but it is not a long list.

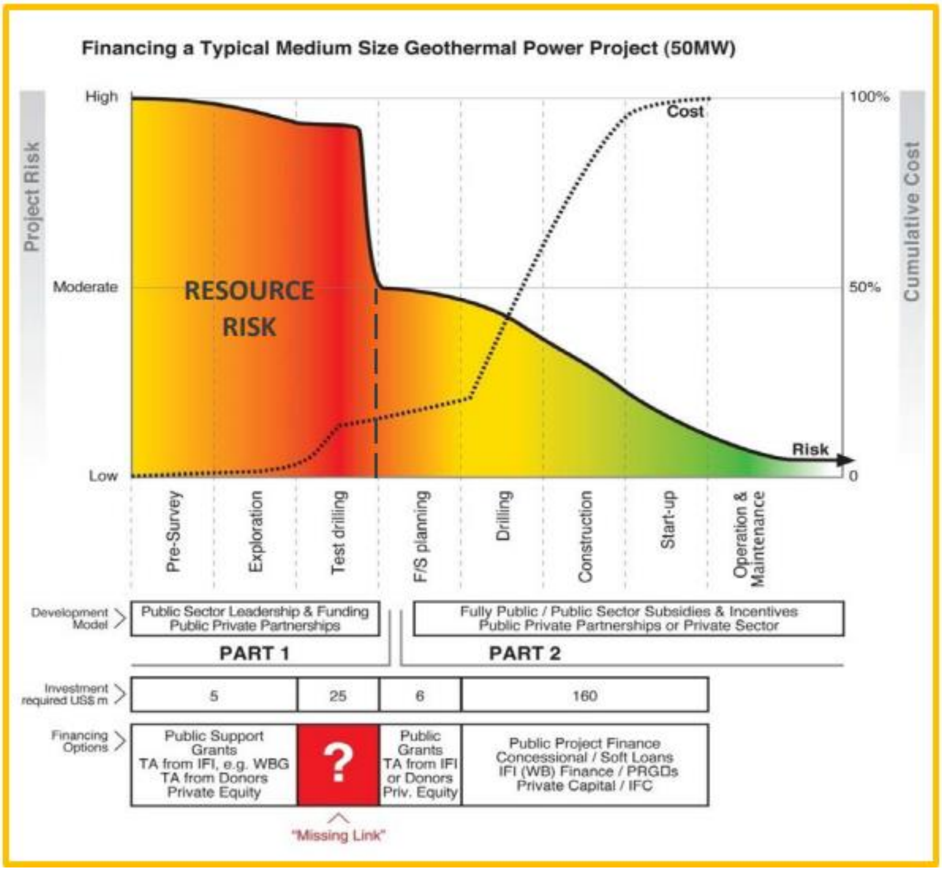

Figure 6: Graph showing changing project risk and cumulative project cost. Risk prior to any test drilling is normally too high to justify the cost to a private developer, and this normally requires government intervention. [Source: ESMAP/World Bank 2012. Graph was heavily based on work by Jacobs New Zealand].

I look forward to hearing responses to this consultation and seeing further stimulation of New Zealand geothermal resources.

I am happy to discuss any of these aspects.

Regards

Brian White