Update of Direct Geothermal Energy Use Inventory and Management for New Zealand

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ABSTRACT

As New Zealand transitions away from fossil fuels, more emphasis is being placed on renewable energy solutions. The technological, economic and environmental benefits of direct geothermal use are well demonstrated globally. In New Zealand, direct geothermal use spans sectors (tourism, agriculture, aquaculture, residential, commercial and industrial) and includes a broad range of energy use technologies from high-temperature industrial processes to low-temperature small-scale installations. Access to reliable and accurate direct use data informs decision making on resource management, assisting with determining the appropriate balance between utilization and the protection of special natural features at the surface of geothermal systems.

As a means to monitor, promote and inform on the potential of utilizing New Zealand's natural geothermal resources, GNS Science has been cataloguing geothermal direct energy use activities, through the development of an online tool. This paper summarises recent geothermal energy use in New Zealand, recent drivers for uptake, and showcases some new initiatives.

1. INTRODUCTION

Geothermal energy, derived from heat within the Earth, is a resource that New Zealand possesses in abundance. Geothermal heat has been used for centuries prior to European settlement by Māori, who utilized waiariki (warm pools) and ngawha (boiling pools) for cooking, healing, bathing and ceremonial use, considering geothermal resources taonga (treasures). Direct geothermal heat and water use has sought to be fostered in recent years, with the growing urgency to decarbonize energy sources in the face of climate change (Climo et al., 2015; Climo et al., 2022). Geothermal direct use includes all applications of geothermal heat energy such as the examples shown in Figure 1, excluding electricity generation.

Compilation of geothermal direct use data provides a means to monitor, promote and inform on the potential of utilizing New Zealand's natural geothermal resources for direct use. As part of global geothermal community, New Zealand produces updates of geothermal use for the International Energy Agency Geothermal Technology Collaboration Programme (e.g. Bromley, 2022) and contributes a country update to the World Geothermal Congress (e.g. Siratovich et al., 2023).

This paper summarises:

- drivers for the uptake of geothermal direct use in New Zealand
- updates made to the New Zealand geothermal direct use database since 2021
- current direct use in New Zealand
- four case studies of recent direct use initiatives.

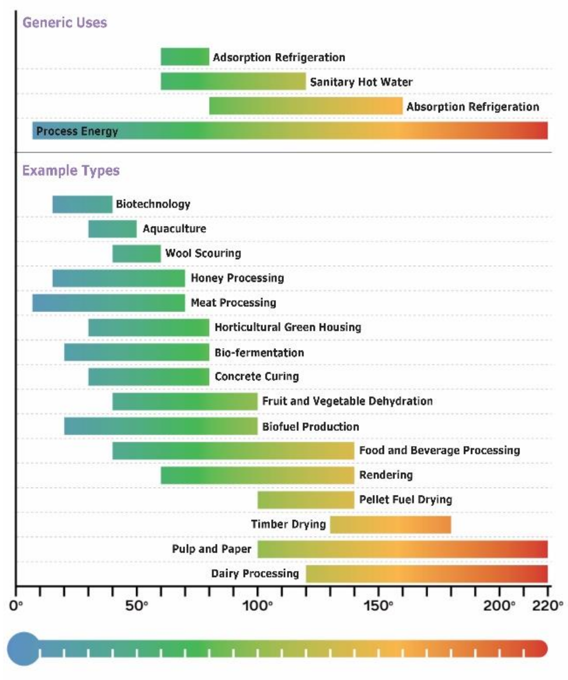

Figure 1: Potential applications of direct geothermal heat use and at differing fluid temperatures (modified from Climo et al., 2022)

2. GEOTHERMAL DIRECT USE IN NEW ZEALAND

2.1 Drivers for uptake of geothermal direct use

In 2019, New Zealand committed to achieving net-zero emissions by 2050 under the Climate Change Response (Zero Carbon) Amendment Act. As of October 2021, this includes a 2030 waypoint goal of 50 percent reduction of net emissions below the gross 2005 level. This was followed by several initiatives and legislative reforms across various sectors of government, several of which could positively influence the uptake of geothermal direct use. These include:

- Replacement of all coal boilers in primary and secondary schools by 2025, under the state sector decarbonization fund
- Reforms to the existing Emissions Trading Scheme (ETS) enacted in June 2020, including the phasing out of industrial allocations of carbon credits, auctioning of units and the introduction of penalties for non-compliance (Ministry for the Environment, 2020).
- New Zealand's first emissions reduction plan (ERP) published in May 2022, comprising strategies, policies and actions including emissions budgets, in 5-yearly increments (Ministry for the Environment, 2022).

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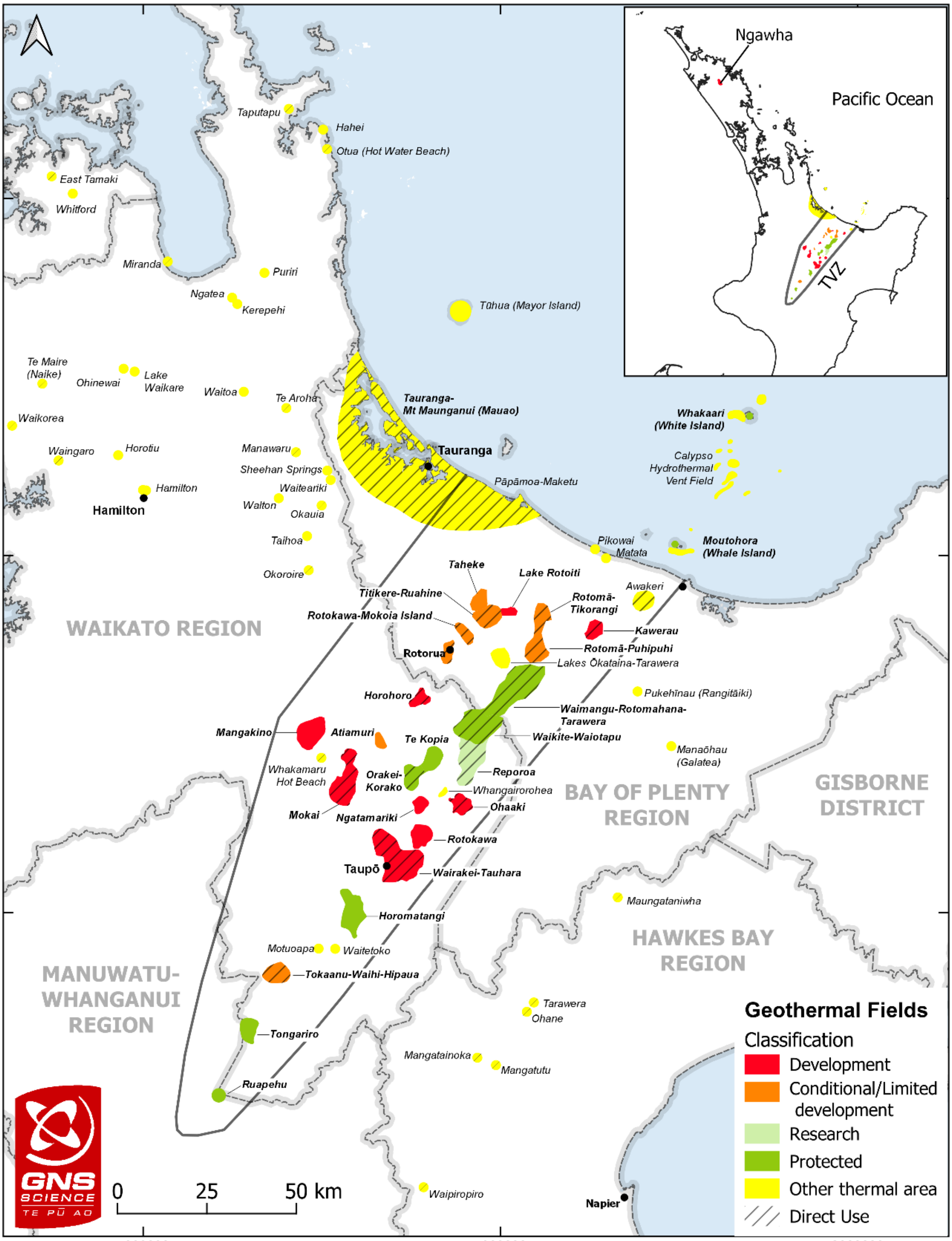

Figure 2: High temperature geothermal fields and other thermal areas in New Zealand's North Island. After Climo et al. (2020a). Coordinates are in NZGD2000/New Zealand Transverse Mercator 2000.

- The Government Investment in Decarbonising Industry (GIDI) fund was established by the Energy Efficiency and Conservation Authority in 2020 – focusing on industrial processes and process heat use seeking to assist businesses transition to a lower carbon footprints (https://www.eeca.govt.nz/co-funding/industry-decarbonisation/about-the-government-investment-in-decarbonising-industry-fund/). As of July 2023, funding for one geothermal direct use-related project (Essity Australasia Geothermal heat Project - Kawerau Paper Machine hood conversion to geothermal energy) has been approved over the first 3 rounds of funding.
- Ara Ake, a government funded energy development centre launched in 2020 to assist with the development of clean energy technologies (https://www.araake.co.nz/).
- The Māori and Public Housing Renewable Energy Fund, which prioritises projects led by Māori-affiliated or Māori-run organisations. As of July 2023, two geothermal-related projects have been approved for funding (https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/low-emissions-economy/energy-efficiency-in-new-zealand/maori-and-public-housing-renewable-energy-fund/)

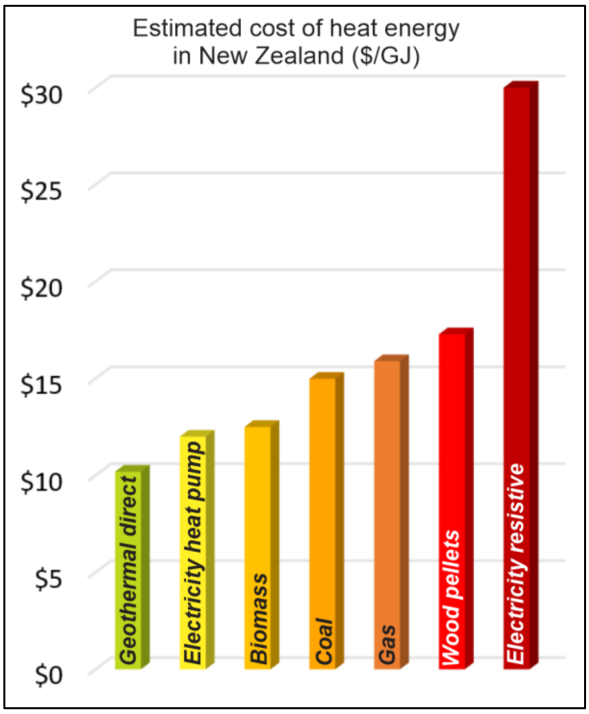

Figure 3: The estimated cost of heat energy in New Zealand, accounting for carbon costs associated with electricity and emissions factors (data from Climo et al., 2022 and references therein)

2.2 Regulation and management of direct use

Regional councils are the governing bodies for regulation and management of geothermal use, which is primarily accomplished through the Resource Management Act (RMA). At the time of writing this the RMA is undergoing major reform which will see it repealed and replaced with three new Acts: the Spatial Planning Act (SPA), the Natural and Built Environment Act (NBA) and the Climate Adaptation Act (CA) (https://environment.govt.nz/assets/publications/rm-reform-an-overview-v2.pdf).

Under existing legislature (the RMA), the taking of geothermal water and energy is prohibited unless:

1. permitted through regional or district plan rules, national environmental standards or granted resource consents, or
2. "in accordance with tikanga Māori (Māori custom or culture) for the communal benefit of the tangata whenua and does not adversely affect the environment" (Kissick et al., 2021).

In the major geothermal regions (Waikato and Bay of Plenty), geothermal fields are classified based on system temperature, existing use, significant geothermal features and their vulnerability, and the level of scientific understanding of the system (Figure 3; Climo et al. 2020a; Kissick et al., 2021). These classifications dictate the level of development (or lack thereof) permitted in a particular field (Figure 2).

Resource consents for direct use are usually based on a daily volume of water take which is based on the capacity needs of the user, efficiency and potential impacts on the geothermal resource and the surface environment. They are also required for the construction of new wells, taking or use of geothermal energy, taking or use of heat or energy from material surrounding geothermal water, and discharge of geothermal water (Kissick et al., 2021). For larger scale commercial or industrial use, the consent process requires thorough assessments of potential effects, consultation with potentially affected parties and the preparation of documentation that assesses the environmental effects.

Frameworks for management of direct use in smaller commercial and residential operations vary substantially across regional councils and within regions depending on field classification. The comprehensiveness of a management plan usually correlates with the amount of direct use in that field and recognized effects on its features. For example, the process and information required to receive or renew a geothermal consent in the Rotorua Geothermal Field is more rigorous than in less developed fields in the bay of Plenty Region, due to the system management plan implemented in 1991 following the recognition of degradation of surface geothermal features (Scott et al., 2016; Kissick et al., 2021).

2.3 Take and use data collection

Major users of direct heat have significant measurement and reporting requirements associated with their consents, however until recently, actual geothermal take for smaller users (i.e. residential and small-scale commercial) has not been recorded systematically. Currently, levels of data collection vary between councils and different geothermal fields. Major consents require data collection that captures water and energy taken and the data is available to regional councils and the public. However, commercial contracts for the sale of water and energy are private, and smaller-scale data collection is scarce.

Most consent conditions require several measurements of flow rate and possibly temperature during the consented period. In Rotorua a trial was undertaken in 2017 of a mobile metering system that measures mass flow rate, and the Bay of Plenty Regional council is working towards metering of more medium and large consented takes (Barber et al., 2017; Zuquim et al., 2021; Zuquim et al., 2022). Estimates of country-wide geothermal direct use are based on compilations of available data by the Regional Councils, the Ministry of Business, Innovation and Employment (MBIE) and GNS Science.

2.4 Drivers for further data collection

Thorough data collection and analysis assists in geothermal system management by identifying discrepancies between allocated water takes or heat use and actual usage. This allows more appropriate resource allocations that better match the needs of end users whilst resulting in a more efficient use of the resource.

Increasing monitoring, reporting requirements and a streamlined data compilation workflow will make data more accessible and useable across government, research and business sectors. Temperature, pressure and flow measurements will assist in field-wide monitoring, by tracking the effects of direct use over time, thus identifying usage patterns and seasonal trends (Zuquim et al., 2021). These data will also contribute to reservoir models of field capacity, which provide an estimate the potential energy of geothermal systems and how much can be used sustainably. (e.g. Pearson et al. 2014). The insights gained from these will:

- Inform future decisions in system management and resource allocation
- Mitigate potential negative effects of direct use on the geothermal resource and surface features
- Provide valuable learnings for future development of other fields, both in New Zealand and internationally

Data collection on the categories of geothermal direct use on smaller scales (i.e. residential or commercial space heating, water heating, bathing) may help to identify trends in current usage, as well as potential opportunities for future use. These data can be used to promote the capabilities of direct use, and ultimately grow direct use as a sustainable and renewable energy source.

3. DATABASE UPDATE

The GNS Science New Zealand geothermal direct use database (https://data.gns.cri.nz/geothermal/index.html) contains records of direct users across the country. Users are categorized into commercial, industrial and residential, with usage types categorized into space heating, water heating, process heat, bathing, agriculture and aquaculture. Consenting information, borehole data and measured/metered usage is also included where available.

The current database consists of records generally corresponding to resource consents for water and heat/energy takes from bores and surface features in the major and small fields / areas, or representing small-scale usage of natural features (e.g. natural hot pools and springs used for bathing).

The database is undergoing a restructure to transform it from a ‘flat’ (single sheet) system containing individual records, to a ‘relational’ (linked multi-sheet) system. Users will be assigned a unique identifier and be linked via this identifier to separate sheets containing information such as borehole data, usage and metering and consent information.

With relational databases data records can be on a one-to-one or one-to-many basis, avoiding repetition of data. For example, multi-user consents can be stored as a single record that is linked to each of the users, rather than repetition of consent information for each user record. This should improve the accuracy of calculations of usage volume and heat energy, and result in a cleaner database overall.

This style of database can be easily updated with new data and the format can be modified if the needs of the user change. It is also queryable, meaning that records can be extracted on an as-needed basis containing only the fields or information relevant to the query.

3.1 Data collection and availability

Records have been compiled by GNS Science by sourcing information from New Zealand Government data portals (e.g. https://catalogue.data.govt.nz/dataset), regional councils, published literature, MBIE and directly from users (Climo et al., 2013; 2020). As of July 2023, data has been collected and updated, and is available online (https://data.gns.cri.nz/geothermal/).

Data availability varies depending on the Regional Council, geothermal field and operation in question. In some cases, information on industrial takes is commercial and has therefore been withheld from public data portals. In other cases, data such as metered flow or temperature measurements are non-existent or incomplete.

3.2 Barriers to data compilation

Difficulties in data compilation result from the variability in data availability and formats between the organisations collecting/holding data. These issues include:

- Non-uniform data field names – prevents efficient and accurate merging of data from different sources
- Ambiguous naming of data fields – e.g. unclear units for numeric fields
- Non-tabulated data - e.g. PDF or Word, scanned documents that need to be individually opened and read to extract information
- Updated naming systems – some boreholes have new IDs, with changes not clearly documented between data sources

Some resource consents cover multiple users, with one volume of consented water take from one or two wells shared between several domestic residences or commercial establishments. In these cases, tabulated (spreadsheet) data usually exists for the consent and main consent holder, but information on other users is only available in written consent documents. Accurate data on the actual number of direct geothermal users is difficult to collect, and not all users are represented in the figures discussed in later sections.

Many of the issues listed can be overcome but will require a significant amount of time and effort to manually extract or digitize data. Ultimately the best solution for future data collection and storage would be the specification and implementation of a standardised metering and digital data collection system across all regions and geothermal fields.

4. RECENT DIRECT GEOTHERMAL USE IN NZ

4.1 Usage and changes since 2021

Geothermal direct use is documented in 9 of New Zealand's 16 regions, and the Waikato and Bay of Plenty Regions account for the majority of users, comprising 498 of the 645 users currently listed in the database. Since data for actual metered water or heat usage is rare this section quantifies non-industrial direct use based on number of users rather than heat or power output. This reflects trends in the uptake and type of geothermal direct use in each field or region.

Process heat remains the largest geothermal direct user by energy usage and is estimated at 7.4 PJ. This is ~0.4 PJ lower than 2020 due largely to the 2021 closure of the Norse Skog Tasman paper mill in Kawerau that utilized ~2.4 PJ per annum (MBIE 2022a; 2022b). Businesses in the Kawerau Industrial Estate supplied by Ngati Tuwharetoa Geothermal Assests (NTGA) use an estimated 4 PJ per annum for timber drying and processing at Carter Holt Harvey and Sequel Lumber, milk processing at Waiū Dairy, paper and pulp manufacturing at Oji Fibre Solutions and Essity tissue paper manufacturing (Carey, 2018; Climo et al., 2022). Approximately 1.1 PJ per annum is used from the Wairakei-Tauhara field for kiln drying timber by Tenon and wood pellet manufacturing by Natures Flame (Contact Energy, 2022). Remaining major direct geothermal process heat users are Miraka milk drying plant and Gourmet Mokai greenhouses (Mokai field), and the Ohaaki Heat timber drying facility (Broadlands-Ohaaki field).

Non-process heat uses (e.g., bathing, space heating and water heating) account for a small proportion of direct use by heat output but include a large and growing number of individual users. Users in the Bay of Plenty region account for the majority of these, primarily in Rotorua and Tauranga, and a

Rotorua is the most developed geothermal field for direct use for non-process heat, with at least 109 active resource consents. Many consents in the Rotorua geothermal field cover multiple users from the same geothermal bore or surface source, so the actual number of users is greater than the number of consents. An exclusion zone extending 1.5 km from the significant geothermal features in the Whakarewarewa and Arikikapakapa geothermal areas is in place, which prohibits the extraction of geothermal fluid in the southern portion of the field. This area is dominated by consents for downhole heat exchange systems in residential dwellings, at least 10 of which have been granted consent since early 2020. Geothermal direct use also contributes to

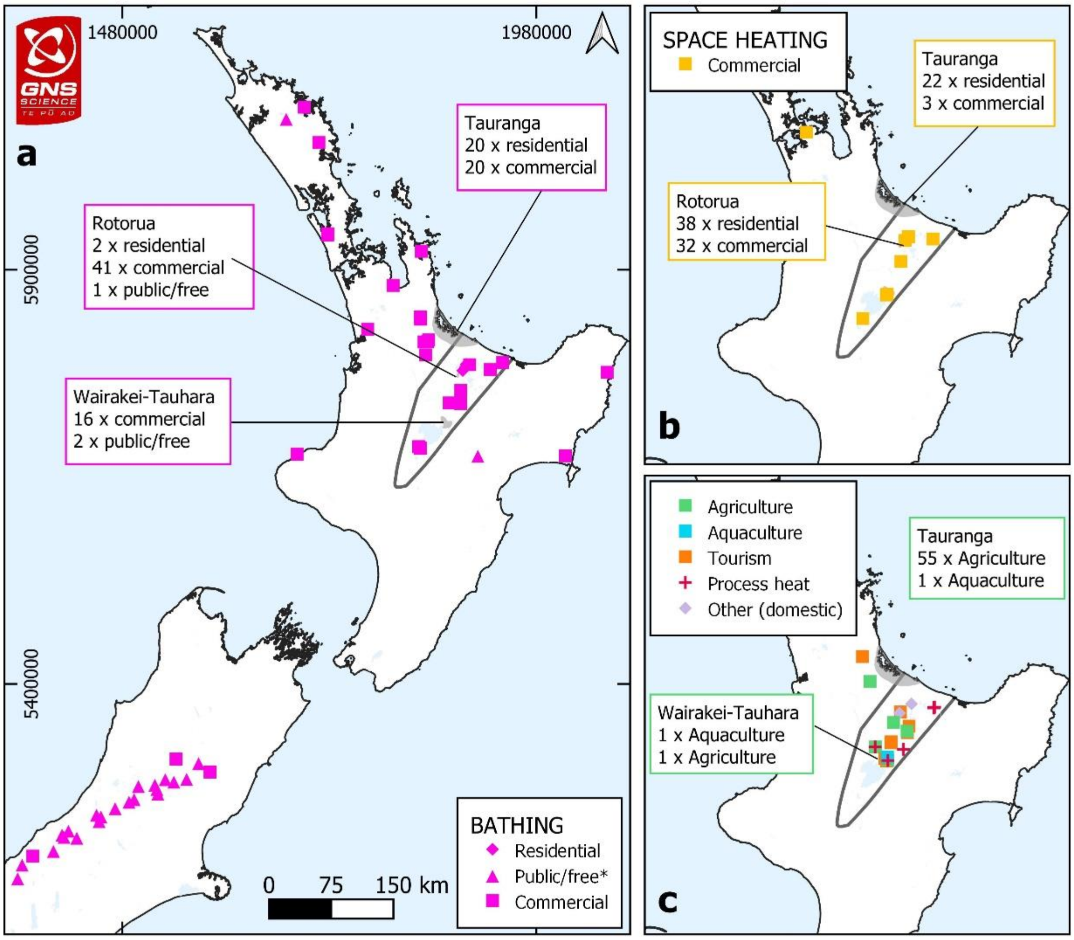

Figure 4: Primary uses of geothermal water/heat for a) bathing, b) space heating (majority of users for space heating also use for water heating), and c) other uses including agriculture, tourism and process heating. Fields with a large number of users are indicated in callout boxes. *'Public/free' includes natural undeveloped hot springs that may be used for bathing.

the tourism industry in Rotorua, with several tourist parks and attractions, and at least 45 tourist accommodation facilities using geothermal heat and water for bathing, space heating or water heating.

The Tauranga warm water (30-70°C) geothermal field has a larger number of geothermal direct use consents than the Rotorua field (146 consents), 72% of which are for residential and commercial bathing, space heating and water heating. It does appear that this number has increased over recent years, for both water takes from bores and heat/energy use from downhole heat exchange systems, however this may partially be attributed to improved data collection. The remaining 28% of consents are for water take for agriculture, most of which do not use the energy content of the fluid as most irrigation or frost protection does not require warm water.

In the Wairakei-Tauhara field there are 31 resource consents, including two for downhole heat exchanger systems. Most users are tourist attractions, tourist accommodation or domestic residences using geothermal water for bathing, space heating and water heating. Other major commercial users include the Wairakei Resort Hotel, the Taupō Hospital, Taupō Intermediate School and Huka Prawn Park (aquaculture).

Other New Zealand geothermal fields currently have limited direct use. In the TVZ there are four consents for residential space or water heating at Tikitere-Ruahine and Lake Rotokawa-Mokoia. Remaining use is by commercial users for bathing, space heating, tourism (i.e. geothermal tourist parks), and for agriculture at Horohoro (greenhouses) and Waiotapu (honey production). Outside of the TVZ, direct use is exclusively in commercial bathing facilities at Ngawha (Northland), Parakai (Auckland), Te Aroha (Waikato), Hamner (Canterbury) and several other small areas / fields. Natural hot springs that are free for use by the public are also listed as direct use in the GNS Science database, including several in the South Island's West Coast region and at a number of locations across the North Island.

4.2 New initiatives

In this section four 2022 direct use initiatives are featured:

4.2.1 Whakapoungakou Iwi Geothermal Energy Grid, Rotokawa, Rotorua

In March 2022 funding was granted to the Ngāti Uenukukopako Iwi Trust by the Māori Housing Renewable Energy Fund to provide low-income Māori households proximal to the Lake Rotokawa-Mokoia geothermal field with geothermal water for space heating. (https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/low-emissions-economy/energy-efficiency-in-new-zealand/maori-and-public-housing-renewable-energy-fund/maori-housing-renewable-energy-fund/list-of-funded-projects/)

4.2.2 Te Waiāriki o Ōhinemotu (Sacred waters of Ōhinemotu), Rotorua

A feasibility study investigating the use of geothermal energy systems in households at Ōhinemotu, Rotorua, was granted funding from the Māori and Public Housing Renewable Energy Fund in March 2022. These households traditionally accessed geothermal taonga for heating, cooking and bathing, and this project would integrate traditional ways of life with modern technologies and lifestyles (https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/low-emissions-economy/energy-efficiency-in-new-zealand/maori-and-public-housing-renewable-energy-fund/maori-housing-renewable-energy-fund/list-of-funded-projects/).

4.2.3 He Ahi Eco-Energy Park and He Tipu centre, Taupō

A 45 ha industrial area, He Ahi Eco-Energy Park in Tauhara, Taupō, was opened in July 2022 by Te Pae o Waimihia, a collective representing six hapū (Māori family groups) in Taupō district, in partnership with Contact Energy (https://www.nzgeothermal.org.nz/downloads/4-HeAhi---GeoWeek-Seminar.pdf). The park includes lots for lease that will be supplied with geothermal energy from nearby wells in the Tauhara Geothermal Field for process heat use. This initiative opens the way for small to medium sized commercial enterprises to access geothermal energy which would not otherwise be possible because of the capital hurdle of accessing geothermal energy for the size of enterprise.

Adjacent to He Ahi is He Tipu, the site of the former Taupō Native Plant Nursery that as of September 2021 is under the management of Te Pae o Waimihia (https://www.tepaeowaimihia.com/projects). The site is to be redeveloped into a social, environmental and cultural centre with an emphasis on Māori values, starting with a food and plant nursery that will directly utilize geothermal heat in its greenhouses (reopening in 2023). This will be followed by an iwi Māori-based wellbeing centre with geothermal mineral pools, and a training centre.

4.2.4 Essity paper drying machine rebuild, Kawerau

Supporting funding of NZD 1.65 million granted from the GIDI fund to repurpose a paper machine drying hood that was previously heated by natural gas. This is the first paper machine in the world to have the drying hood heated by geothermal steam. The total cost of the project is NZD 15.5 million with a reduction of some 6200 tonnes per annum of carbon dioxide anticipated. Essity has been using geothermal energy at their Kawerau site since 2010 in lieu of natural gas fired boilers this transition to geothermal already has reduced their carbon dioxide emissions by 37% year on year.

5. CONCLUSIONS

Geothermal direct use in New Zealand is growing rapidly as global move to decarbonise energy has driven the government to introduce programs that incentivise transitions to low-carbon energy. With this growth comes the mounting need to quantify geothermal heat and water takes at all scales, to improve our understanding of the geothermal resource and inform data-driven decision making for system and environmental management.

This is a transitional period for resource management with RMA reform and regional plans undergoing major review. Historically, data collected on geothermal direct use has varied in quality and quantity, but in the last decade this has begun to improve, notably with new metering programmes introduced in Rotorua. Challenges remain in collecting and compiling data, particularly across multiple regions and geothermal fields where there is variability in data format and availability. The GNS Science New Zealand direct use database is being updated to ensure it is more fit for purpose, readied to be more accessible and to accommodate an increasing volume of data.

Several geothermal direct use initiatives are in development across multiple sectors, particularly manufacturing and housing. Many of these are a result of government-funded programmes such as GIDI and the Māori and Public Housing and Renewable Energy Fund. The NZGA has taken steps in promoting direct use through the Geoheat Strategy and Action Plans having assisted several businesses with their transitions plans to direct geothermal use, and a pipeline for future uptake. These programmes and initiatives speak to the growing desire at national and regional levels to enmesh geothermal direct use in New Zealand's energy future, the outcomes of which will be evident in the coming years.

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