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Geothermal Use Inventory Update – Data, Visualisation and Information

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ABSTRACT

Direct geothermal use in New Zealand spans sectors (e.g. tourism, industrial, agricultural, commercial, residential) and includes a broad range of energy use technologies from high-temperature industrial-scale processes to low temperature small-scale installations. Access to reliable and accurate direct use data informs sound decision making by resource managers, to ensure the effects of use on geothermal systems are well understood. Robust data also informs adaptive management, as users and regulators seek more efficient, sustainable and effective use of geothermal resources.

Large industrial uses have metering associated with their facilities, with reliable energy, take and discharge data being captured, often as part of their permits to operate. However, different challenges are faced in other sectors where there are often multiple single users with relatively small-scale use. These challenges include (i) developing monitoring systems that are accurate, versatile, and cost effective, and (ii) capturing reliable and accurate data where smaller privately-owned entities are often unaware of the thermal capacity or the energy delivery from their heat producing facilities.

The Bay of Plenty Regional Council (BOPRC) has recently focussed on improving the reliability of geothermal usage data on the Rotorua Geothermal Field in a way that is easily transferable across the many users, to inform a review of the management of the Rotorua Field.

GNS Science has been cataloguing available take and use data through the development of a New Zealand-wide graphical and searchable, interactive web-based “geothermal use” database. Their aim is to provide information to landowners, businesses and councils on what geothermal resources there are in their area, and the various ways it is being used.

This paper summarises these complementary activities and charts the progress of New Zealand’s goal to better understand the extent of its direct geothermal energy use – seeking to better inform geothermal management policy, and to foster, as appropriate, the uptake of direct geothermal energy use.

1. INTRODUCTION

Geothermal energy is energy derived from natural heat within the earth and in New Zealand, includes all geothermal water, classified as water above 30°C (Resource Management Act (RMA), 1991). The nation is well-endowed with geothermal resources in zones of high heat flow associated with volcanic and tectonic activity in the central and upper North Island (Figure 1; Climo et al., 2016; White and Chambefort, 2016). Outside of the volcanic region many thermal springs are found throughout both the North and South Islands (Mongillo and Clelland, 1984; Reyes, 2015). Ambient ground heat resources are even more widespread.

New Zealand’s geothermal energy use data for 2019 is summarised in Table 1. Geothermal electricity generation, which is well quantified but not the focus of this paper, accounts for about 15% of New Zealand’s electricity supply (MBIE, 2019a).

Table 1: Geothermal energy use in New Zealand for 2019 [MBIE, 2019b; Seward and Carey, 2020; Daysh et al., 2020]

Type of Use	Primary Energy (PJ/annum)	Consumer Energy (PJ/annum)
Geothermal Electricity Generation	~200	26.5
Geothermal Direct Use	~16	9.7
Geothermal (Ground-source) Heat Pumps	< 0.5	< 0.5

This paper is focussed on direct geothermal energy use. Direct use applications include traditional Māori cultural uses such as cooking and bathing, as well as mineral bathing facilities. These uses are especially common in areas where there is surface expression, like Taupō and Rotorua, where a significant geothermal tourism economy has developed. New Zealand’s direct uses also include timber drying, pulp and paper processing, milk processing, horticulture, aquaculture, minerals (silica) processing, space heating and cooling, and water heating for both domestic and commercial uses.

Industrial process heat is the largest geothermal heat use of any sector (Climo et al., 2016; White and Chambefort, 2016), with the Kawerau Geothermal System supporting notable industrial direct heat use, particularly in wood processing and paper making. Direct use data in the industrial sector is well quantified. Direct use is less well quantified in the commercial and residential sectors. Geothermal energy potential is considered significant for all sectors and some improved quantification should assist in overall policy direction, improved management and the increased uptake of ground energy use in New Zealand.

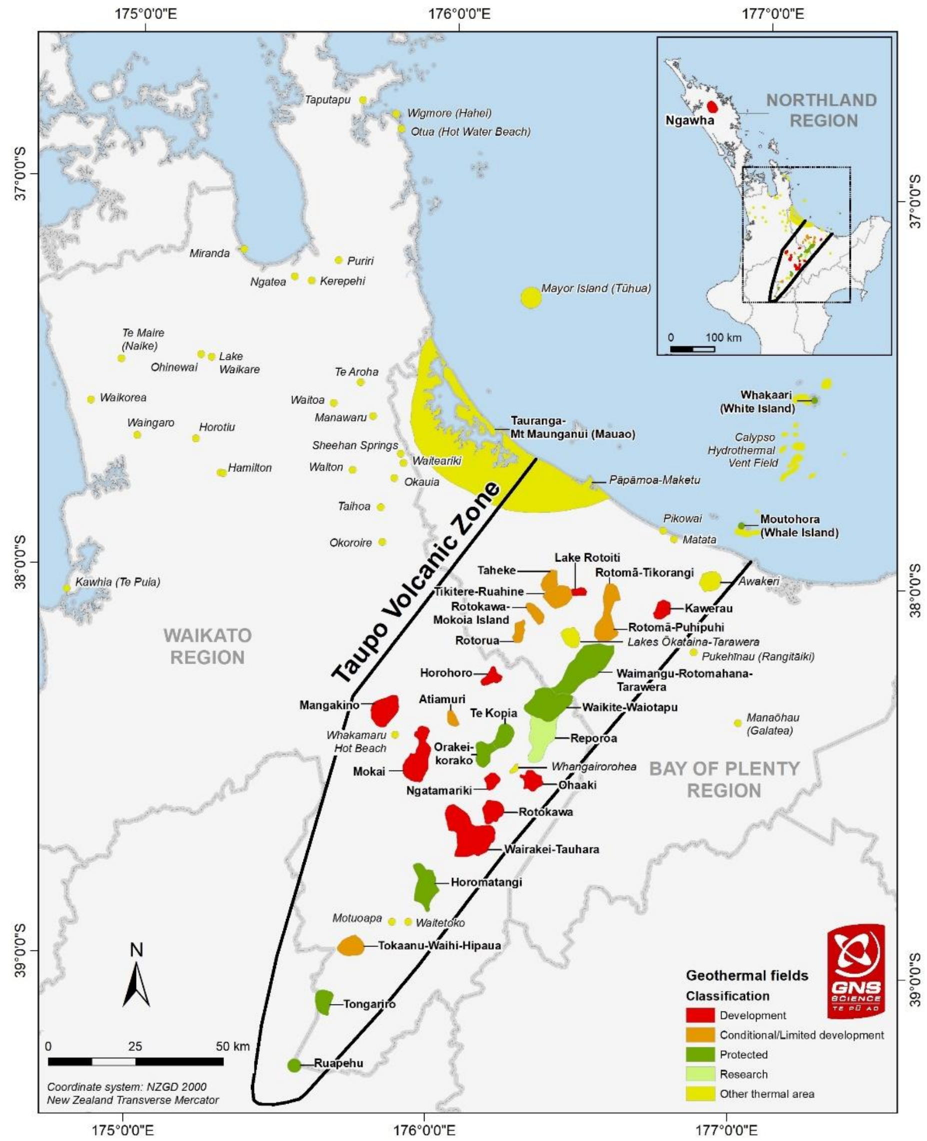

Figure 1: High temperature geothermal fields and other thermal areas in New Zealand's North Island.

2. DRIVERS FOR DATA COLLECTION

2.1 Resource Management

Reliable and accurate use data is important for supporting sustainable management of geothermal resources and in the ambient temperature domain (<30°C) for ground water management.

In New Zealand, geothermal use is managed at a regional scale by regional councils, including the allocation of geothermal fluid heat and energy, and discharges to land, air and water. The type of development/use allowed in/on a particular geothermal system is detailed in regional planning and policy framework documents developed under the RMA (Climo et al., 2016; BOPRC, 2008; BOPRC, 2014; WRC, 2007). These include regional policy statements, which set the overall management framework (e.g. system categorisation), and regional plans that contain detailed rules for use.

Under regional plans, a resource consent (or permit to use) is required for taking (and using) geothermal water, unless specifically provided for by a rule in a regional plan. Each geothermal development activity will have an activity status, determined by the applicable plan (EMS, 2011), which sets the level of enquiry a consent application will have, and the matters that are considered when assessing that application. The activity status categories are Permitted, Controlled, Restricted discretionary, Discretionary, Non-complying, and Prohibited.

Most resource consents for geothermal fluid abstraction are discretionary, with the level of information required for an application influenced by the different values of the particular geothermal system, the scale of the activity, and the potential effects of the proposal. Large industrial scale activity consent applications require comprehensive assessments of actual and potential effects and often these applications are publicly notified, providing the opportunity for potentially affected parties and the community to make submissions on the proposal and to influence the final outcome.

Methods to avoid, remedy or mitigate adverse effects are applied through conditions of a consent, often including provisions around adaptive management and monitoring, especially for larger scale operations. Large takes and discharges often have consent timeframes granted for up to the RMA maximum of 35 years.

Under section 35 of the RMA, regional councils have a duty to obtain information and generally monitor the environment to the extent necessary to effectively carry out their functions, and this is through resource consent monitoring (e.g. use data) and “State of the Environment” monitoring programmes and reporting. Resource managers therefore work to ensure the effects of resource use on geothermal systems are understood and that robust data informs decision making as part of policy, plans and resource consents.

2.2 Increasing Geothermal Energy Use

Comprehensive information and data (and reporting) helps to increase awareness of geothermal resource use opportunities.

New Zealand is one of a number of nations seeking to grow geothermal energy use sustainably. Direct use applications are being emphasised in national renewable energy policies as effective in reducing greenhouse gas emissions (MBIE, 2017; MED, 2011) and in driving economic development, including employment growth (MBIE et al, 2015). Geothermal (ground source) heat pumps are a growing area of use in the commercial sector, utilising ambient shallow geothermal energy in underground strata and water bodies (Seward and Carey, 2020).

New Zealand will benefit in moving to lower carbon energy supply, and the New Zealand Geothermal Association (NZGA) has been active in promoting and developing work streams that foster the uptake of geothermal direct-use, through the development of the Geoheat Strategy for Aotearoa NZ, 2017 – 2030 (Climo et al., 2017). This strategy targets increased geothermal energy use and associated geothermal industry jobs. Shorter timeframe action plans (e.g. Climo et al., 2018) foster engagement that enables agencies, geothermal fluid suppliers and potential users to connect, and also have intermediate steps that cumulatively will build towards the 2030 Geoheat Strategy targets. In order to track progress, reliable data is necessary on both energy use and employment for projects established. More detail on the Geoheat Strategy and the implementation approach can be found in Climo et al., (2020).

Low awareness is a substantial barrier to increasing the diversification of geothermal resource use in New Zealand (Carey and Climo, 2012). Showcasing existing applications is one way to raise awareness, promoting potential business uses and opportunities. One recent example is the potential use of geothermal energy through industrial symbiosis (Alcaraz et al., 2020).

Successful implementation of direct use development also requires financial data on economic viability, market drivers and sound business cases to be developed by the potential user. Quantifying the economic value of geothermal resources (e.g., Barns and Luketina, 2011; Conroy and Donald, 2013; Luketina et al., 2016) provides policy makers with a framework for considering the impact of resource management decisions and assists economic development agencies and investors to better understand the opportunities. Direct use data can be used to support economic studies, as well as the creation of multipliers for industries where quantitative information is less readily available, for example, horticulture, fish farming and honey processing.

3. HISTORY OF DATA COLLECTION

Historically, geothermal research and data collection in New Zealand has focused on high temperature resources and electricity generation, while direct use and lower temperature geothermal research has been more ad-hoc. However, this has changed over the past 5-10 years, with an emerging focus on direct geothermal use.

3.1 Reporting

Regionally, all geothermal resource users, particularly the large-scale industrial uses, collect and provide data to regional councils for consenting and (permit to use) compliance purposes (see section 2.1). Information is first required as part of consent applications, to demonstrate sustainable resource management and appropriate management of environmental effects. The information informs the decision making and the conditions of any resource consents granted. Consent holders may then be required to carry out certain monitoring through the lifetime of the consent, to demonstrate compliance with the specific conditions of the consent and monitor identified potential adverse effects on the receiving environment.

Nationally, electricity data and summary reports, including geothermal data, are regularly compiled (quarterly and annually) by the New Zealand Government, currently via the Ministry of Business, Innovation and Employment (MBIE). Various organisations also collect, collate and present data, including the NZGA (e.g., White, 2009; Carey et al 2015).

Broader published reviews of geothermal energy use in New Zealand include Speden and Allis’s (1997) review of 50 years of geothermal use in NZ, Hunt and Lund’s (2002) summary of direct geothermal use, and Climo et al.’s (2016) history of geothermal direct use development in NZ’s Taupō Volcanic Zone.

Internationally, New Zealand reports to the International Geothermal Association (e.g. Harvey et al., 2010; Carey et al., 2015; Daysh et al., 2020) through a country update paper at each World Geothermal Congress (WGC). New Zealand, as a member of the International Energy Agency Geothermal Implementing Agreement (IEA Geothermal) contributes annual updates for their statistical archive (e.g., Bromley and White, 2011; Bromley 2019). The data used for these analyses is the MBIE geothermal electricity data and available direct use information. There is no regular data collection as part of these workstreams, they simply report what is available.

Internationally, there is a need for robust information that can be shared, along with experience, to support geothermal development through regional and international cooperation, including financing, technology development, data sharing, training, and geoscientific surveying. IEA Geothermal and IRENA (International Renewable Energy Agency) work programmes (IEA-GIA, 2019; IRENA, 2019) are two international organisations where collaborative benefits are realised through sharing geothermal use data, information and experience. Data compilation and reporting are two tasks of these collaborations, for instance IEA Geothermal has Working Group 10 which collates and reports information (Weber and Wissing, 2020).

3.2 Data Quality & Information Gaps

A fundamental limitation to reporting, past reviews and geothermal energy use assessments in New Zealand, has been that the direct use data sets are incomplete, much is estimated and the data is of variable quality. The most accurate data is associated with the larger use industrial installations, where flow (and energy) metering are often linked to industrial/commercial supply contracts and/or resource consent monitoring (Table 2).

Commercial, domestic and small mineral bathing uses are the least well defined, less monitored (Table 2), with estimates often based on consented take, coupled with known resource and use characteristics.

Table 2: Generalised monitoring requirements for geothermal energy use at different scales.

Scale	Broad Characteristics	Likely Monitoring Requirements
Industrial	Temperature: >160°C Capacity: up to 100 MW Well depth: up to 3500 m	• Downhole data • Monitoring of actual use (production and injection) • Chemical sampling, tracer testing • Surface monitoring as applicable (features and Subsidence) • Groundwater monitoring • Cultural impact monitoring • Council usually holds discretion to require additional monitoring
Light Commercial	Temperature: 100-200°C Capacity: 50 kW-5 MW Well depth: <1000 m	• Downhole data on drilling • May require monitoring of actual use but might only be infrequent intermittent measurements • Some down hole testing may be required, but irregular • Council usually holds discretion to carry out additional monitoring on wells if considered necessary
Domestic & Small-Scale	Temperature: 30-100°C Capacity: <50 kW Well depth: <150 m	• Downhole data on drilling • Quite limited monitoring of actual use, with intermittent measurements maybe required once or twice through the lifetime of a consent • Council usually holds discretion to carry out additional monitoring on wells

3.3 What is Fit-for-Purpose?

Direct geothermal use in New Zealand spans a number of sectors (e.g., tourism, industrial, agricultural, commercial, residential) and includes energy use technologies ranging from high temperature industrial-scale processes to low temperature small-scale installations and includes heat pumping technology.

The question to consider is: *what is fit for purpose direct geothermal use data monitoring?*

Large industrial uses account for about 70% of the national total. Any inter-year trends will likely be captured in changes in the large contracted supplies, with changes in smaller usage being much less important for reporting on national trends. But the cumulative usage on a local scale from a large number of small takes can be locally important for resource management and resource sustainability.

Capturing reliable and accurate use data is problematic. Smaller users are often unaware of the thermal capacity or the daily to annual energy delivery from their heat producing facilities. Also, for ‘Permitted’ uses (or any other uses that are unconsented), there is usually no requirement to submit monitoring data. While these takes are generally small, they are still an important part of overall accounting in a geothermal system, especially in ‘vulnerable’ systems, or in a local area.

National statistical data is collected by Statistics New Zealand and a range of other government departments. The geothermal data that informs the national consumed energy use dataset (e.g. Figure 2) is likely adequate simply because the geothermal direct use contribution to the energy use data is less than 1.5% of the total (i.e. 8 PJ out of 590 PJ for 2017, Figure 2). The total consumed geothermal energy data is overall expected to be accurate to within an error margin of +/-20%. It is unlikely that significant additional effort to reduce this error margin would be meaningful; a few PJ will have little effect on the overall data.

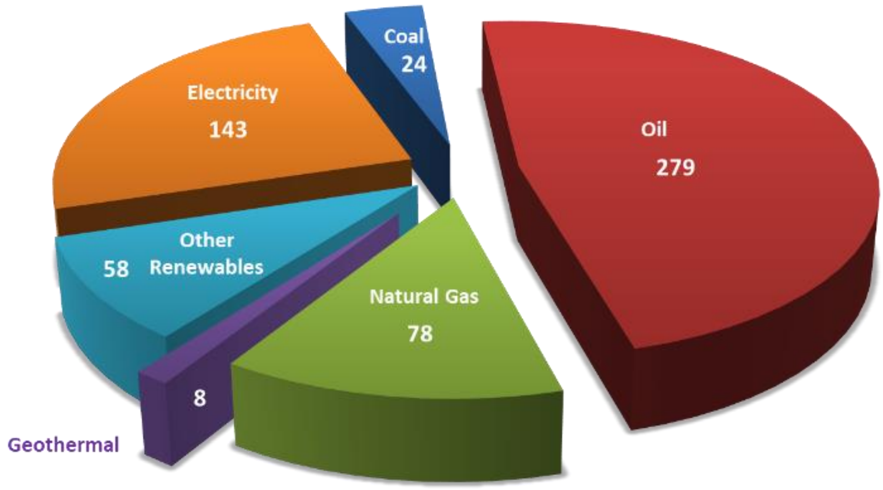

Figure 2: Consumed energy by fuel type for 2017 (PJ) – Total 590 PJ (MBIE, 2019b).

The NZGA has been challenged by the question of understanding statistically robust trends in geothermal use across New Zealand, including the uptake of geothermal (ground sourced) heat pumps. This led NZGA to open dialogue with Statistics New Zealand seeking to have several geothermal energy questions entered into the five yearly New Zealand general census or possibly in specific sector sampling that Statistics New Zealand undertake irregularly. The dialogue resulted in Statistics New Zealand advising that the information gained would not be statistically significant because, with the methods they use, the data population size is too small. In essence, significance would not be evident.

It would be ideal to have accurate data to inform the New Zealand public about the trends occurring in geothermal energy use and regional geothermal development over time. Used in the right way, the data would raise awareness which would open up new ideas and opportunities for further uptake of geothermal technologies. Unfortunately, the costs associated with monitoring and regular data collection at this scale are a real issue. There is a challenge in developing data capture systems that are adequately accurate, versatile, and cost effective across all sectors.

The following two sections record two complementary ways to address some of these difficulties. The first offers a broad view of geothermal energy use, but only records limited detail (a national database), while the second approach is a detailed investigation of direct use data at a local geothermal field-scale in Rotorua.

4. A NATIONAL GEOTHERMAL USE DATABASE

GNS Science have developed a New Zealand-wide graphical and searchable web-based geothermal use database (GNS Science, 2019; Climo and Hall, 2013). A similar geothermal prospector mapping tool has been developed for geothermal energy use in the United States (NREL, 2019). Also, several groups have established online mapping and information tools for power plants and geothermal energy (e.g. AGID, 2019; PETA, 2019).

The aim of New Zealand's geothermal use database is to provide qualitative information to landowners, businesses and councils on the geothermal resources in their area, and the various ways that the energy is being used. This database displays New Zealand's geothermal energy use, with categories including aquaculture, agriculture, bathing, industrial process heating, tourism and space heating/cooling, as well as electricity generation and geothermal (ground-source) heat pump installations. These categories are consistent with the requirements for the WGC country update reporting (Lund et al., 2010), and is aligned with the approaches used in New Zealand geothermal assessments (e.g., White, 2009; Bromley and White, 2011).

4.1 Data Sources

The data for this GNS Science web-based database (e.g. Figure 3) has been sourced from:

1. Published literature, conference proceedings, publicly available reports and websites;
2. Geothermal consent data from regional councils; and
3. Direct contact with owners and operators, by telephone, email, web-based survey and some site visits.

The first phase was high-level collection of any and all information on geothermal users, determining their location, contact details and categorising type of use. Some operations have more than one category (e.g. a spa operation could be categorised under bathing and tourism). Thus, secondary categories were introduced, where appropriate, to assist in analysis of the data.

The second phase gathers available technical information on each operation.

Regional councils resource consent records allows for the easiest capture of data for the national database, though this still requires research with each regional council as to consents lodged in their region. Data collected from this source still requires verification of use, with a combination of web searches, direct contact, and web surveys used to determine if the consented take was an accurate view of actual use. In some cases, there was no evidence of a lodged consent having any active take, in which case the record would be removed from this geothermal use database.

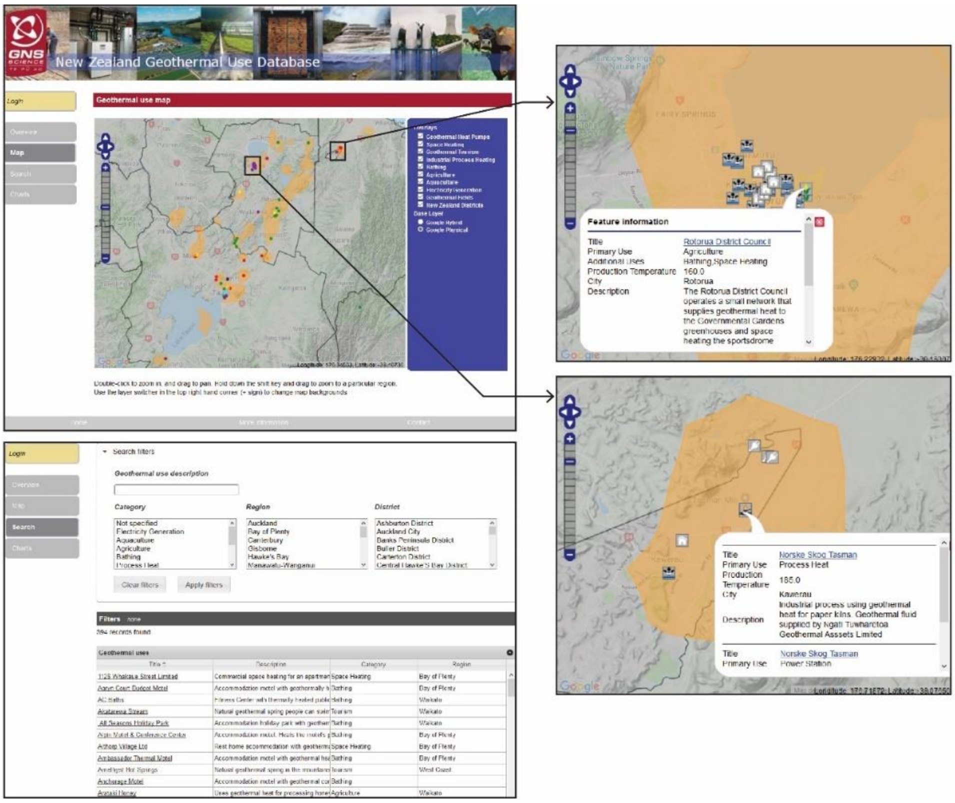

Figure 3: Example map-view and associated tabulated data of geothermal resources and uses in Rotorua and Kawerau from the GNS Science New Zealand Geothermal Use Database. Data can be searched by use type category (e.g., aquaculture, space heating), or location (region or district), with query results able to be exported from the catalogue.

4.2 Successes, Difficulties and Future Plans

Table 3 provides a status of the data collection by region as of January 2019, the number of users identified and an assessment of the overall quality of the data for that region[1]. Initial efforts were focused on the Waikato and Bay of Plenty Regions (Figure 1) in the Taupō Volcanic Zone, where the amount of direct geothermal users is greatest (>300 users), followed by other regions (Table 3).

Difficulty 1: Accuracy

a) qualitative data in many cases is missing, or of lower quality
b) quantitative data based on measurement is substantially missing

Generally, regions with fewer users should have a higher accuracy in the data record, as it requires less effort to verify the data. In contrast, regions such as the Bay of Plenty, which includes a large number of users in the Rotorua and Tauranga Geothermal Fields, were much more challenging to collect and verify data on ‘number of users’, although the total number of consent holders will be accurate.

Also, in many cases, smaller users did not know either their actual take (fluid quantities or energy), or information on discharge quantities or reinjection temperatures for instance. In other areas of the Bay of Plenty, while fluids being taken are classed as from a low-temperature reservoir, the fluids were not specifically being used for an energy use application, but for irrigation of orchards for instance. In these cases, the take is limited in time say to the summer months, meaning the consented take aggregated over a year is not a realistic representation of the actual use.

It is also worth noting that customary direct heart uses by Māori (e.g. bathing, cook boxes) generally do not require a resource consent and as such records of these uses is very limited.

[1] Note that in some cases the data is based on number of resource consents granted by regional councils, rather than ‘users’. For example, one resource consent could service multiple users, with different end uses.

Table 3: Data collection by region.

Region	Data Collection (as at Jan. 2019)	Number of users	Accuracy
Northland	Completed	4	High
Auckland	In progress	11	Medium
Bay of Plenty	Completed	266	Medium
Waikato	Completed	63	Low
Gisborne	Completed	1	High
Hawke's Bay	Completed	3	Medium
Taranaki	In progress	1	High
Manawatu-Wanganui	In progress	0	Medium
Wellington	In progress	3	Medium
Marlborough	Completed	2	Medium
Nelson	Completed	2	Medium
Tasman	In progress	4	Medium
Canterbury	In progress	76	Medium
Otago	In progress	27	Medium
West Coast	Completed	4	High
Southland	Completed	9	High

Difficulty 2: Timeliness

a) there is an absence of temporal control on data
b) ongoing updates are time intensive

Collection of data of this type provide a 'snap-shot in time', and with the data collection being spread over several years (and ongoing), not all data is up-to-date for all the regions. This means that data is as accurate as possible at the time of entry but becomes less accurate (outdated) as new users are consented and as other users cease operations or change use. This lack of temporal control on the data is a limitation of a database of this type.

Future Plans

Capturing better quantitative data records might allow for analyses of key criteria for estimating future trends, such as heat energy used, economics, number of existing installations and planned developments.

To obtain more accurate data, a possibility for the future would be for all the regional councils to change the consent reporting requirements to seek more accurate monitoring and reporting of actual use for all consents, including seasonal or temporal patterns of use (e.g. for seasonal horticultural uses). However, the costs and benefits of this would have to be considered within the context of the RMA (i.e., are the costs of this requirement reasonable and commensurate with the level of take and the end use of the data?). In some cases, the costs of gathering more accurate data will outweigh the benefits, and accurate record keeping will remain problematic.

Also, in some cases data is commercially sensitive and can be treated as such under New Zealand law, meaning that not all data will be readily available. However if consent data could be integrated directly with the database, it would provide the most accurate and timely measure of direct use nationally. This in itself is a challenge, and would need to include agreed protocols with regional councils around data reporting and aggregation, and subsequent processes put in place to feed data into a centralised database.

5. A FIELD-SCALE VIEW OF GEOTHERMAL USAGE DATA

5.1 Rotorua Geothermal System

Bay of Plenty Regional Council (BOPRC) has recently focussed on improving the reliability of direct geothermal usage data on the Rotorua Geothermal Field (Figure 4) in a way that is easily transferable over many sites. The Rotorua Geothermal Field covers an area of approximately 12 km^2. Wells are generally shallow, and temperatures range from 90°C to 200°C (Barber et al., 2017). The field is managed to protect its unique geothermal surface features, while allowing some direct heat use. Current uses of geothermal fluid include bathing and wellness, space and water heating for commercial, domestic and municipal properties, and heating for over 400 homes. There is currently no geothermal electricity generation or industrial-scale direct heat use in Rotorua.

There are approximately 130 consents for the take and use of geothermal water and energy, about 76 for production/injection systems and 38 for down hole heat exchangers, and a number of takes from surface features (BOPRC, 2019). Consented use varies between users, from 2 t/day to up to 600 t/day, with a total consented take from the field of approximately 10,000 t/day. The majority of takes are under 200 t/day, and 33% of consent holders account for 80% of total consented take (Doorman and Barber, 2017).

While Rotorua use is small in comparison say to large industrial takes on 'Development' fields like Kawerau, it is still significant in the context of sustainable management of the Rotorua Geothermal Field, including the protection of significant surface features.

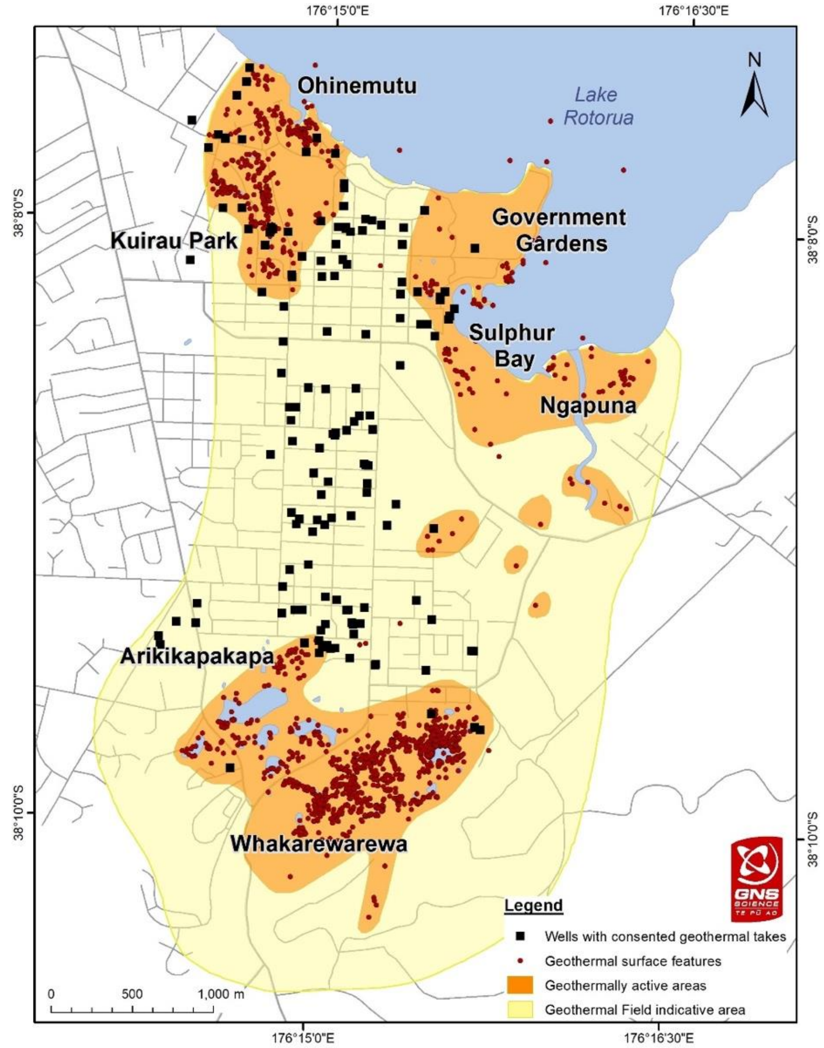

Figure 4: Rotorua Geothermal Field, consented / permitted geothermal wells/bores and geothermal surface features.

5.2 Geothermal Use Data

In reviewing its policies for management of the Rotorua Geothermal Field, BOPRC sought accurate data on use. Knowing the actual use of energy from the field, and improved tracking of this over time, will allow BOPRC to understand trends in use, more accurately predict and model effects of this use, and also to consider opportunities for future allocation.

To date, BOPRC only required actual use measurements twice over the lifetime of a resource consent. The data is submitted to BOPRC as a condition of consent, recorded in BOPRC's consent and compliance database and is publicly available. However, the data is not always reliable, is usually only a 'spot measurement' rather than flow / energy measurements over an adequate period of time, and between users the data is not collected in a consistent manner, so robust actual information on field wide use is lacking.

5.3 A New Method for Data Collection

To address these data deficiencies, BOPRC developed a pilot flow testing programme to determine the current actual (rather than consented) take on the system (Barber et al., 2017). A particular challenge was the large number of wells, and the poor condition of many wellheads and casings. Also, many Rotorua wells exhibit two phase flow, slug flow, gas, and scaling - making accurate measurements challenging, and the maintenance of meters and monitoring equipment costly. Wells are often close to dwellings and buildings so access is also an issue.

A flow testing programme evolved through a range of field trials over several years, leading to the development and refinement of a method that includes (i) fitting a separator loop with an inline flow meter near the reinjection well, (ii) venting gas before flows are measured and (iii) temperature measurements being made before and after energy is extracted by the user.

This loop system was trialled and refined on 15 wells. A calorimeter test was performed simultaneously to calibrate results, with the system proving very accurate (over 95% accuracy). A key difference between calorimeter and the flow loop measurements was the measurement of continuous data over a reasonable period of time using the flow loop, as opposed to short term measurements that do not reflect temporal or seasonal variation in use from the calorimeter. Data logging/telemetry was an important element in developing the technique.

5.4 Successes, Difficulties and Future Plans

The new method allowed BOPRC to measure total use of energy for a given well. While only 15 wells were tested using this method, the results indicated that actual use is, in many cases, substantially lower than consented quantities. This information allowed BOPRC to review the assumptions around actual use for all other wells on the system. In addition, the information collated provided data suitable for future compliance monitoring purposes.

This method was found to be accurate, affordable, robust and transferable across multiple small wells. BOPRC could extend their data set by obtaining continuous flow data on more wells and improve the aggregated data on actual direct heat use over time.

Constraints include the cost of fitting the loop system to wells and the cost of running the equipment, assessed against the value of the data obtained. It is likely that priority will be on the consents that represent the largest takes on the system, and that the smallest takes on the system will continue to use the intermittent 'spot measurement' method. While the ongoing costs of running the monitoring programme are matters that BOPRC has yet to confirm, the approach will provide BOPRC with better data on actual use and significantly improve the accuracy and robustness of the geothermal energy use data on the Rotorua Geothermal Field.

6. SUMMARY

There are opportunities to grow and further diversify New Zealand's geothermal direct use, to create new businesses, and to relocate existing businesses into geothermally-rich regions to benefit from this renewable heat energy supply. There may also be potential to convert other industries from fossil fuels to geothermal energy. To support these opportunities, and the sustainable management of geothermal resources, it would be beneficial to improve the data quality and to better capture energy use data across all sectors.

New Zealand is working towards filling known data gaps, as well as incorporating a wider range of technical data. A national database offers a broad overview of existing geothermal uses, but is limited in both qualitative and quantitative data. The flow loop method for measuring geothermal well use, trialled in Rotorua, offers excellent data quality, suitable for compliance reporting, but is cost and labour intensive and even in Rotorua is likely to only be used on larger wells.

For national scale reporting, the current level of accuracy in the geothermal direct use dataset is likely adequate because (i) the geothermal direct use contribution is small (less than 2% of the national consumed energy use dataset), and (ii) this geothermal data is dominated (~ 70%) by a handful of large industrial users who already closely monitor their energy use.

For local reporting and resource management (e.g. at a field- or regional scale), more robust quantitative data would allow for analyses of key criteria for estimating future trends, such as heat energy used, economics, number of existing installations and planned developments. However, it is necessary to assess the costs of collecting and maintaining such data against the intended data use, the context of resource management legislation, and the scale of the potential economic, environmental and social benefits, which in our view are location specific.

The future of geothermal data monitoring, collection and management is not a one-size-fits all approach. It is not practical, nor affordable, to collect highly detailed data on all operations on a national scale, and to maintain temporal data on either a continuous or even semi-continuous basis for all users. The key consideration for the design and implementation of a geothermal data management regime is to ensure the approach is fit-for-purpose.

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