NEW ZEALAND'S GEOTHERMAL DIRECT USE INVENTORY AND OPPORTUNITIES

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ABSTRACT

The success of direct geothermal use is well demonstrated both domestically and internationally. Geothermal direct use in New Zealand includes timber and milk processing, geothermal tourism, balneology, and commercial and domestic heating.

There is growing interest from the geothermal industry, economic development agencies, regulatory authorities and others to develop new direct use projects in New Zealand. However, to date, much of the direct use and lower temperature geothermal research has been ad-hoc, and eclipsed by the focus on high temperature resources and electricity generation.

There is a considerable need for access to robust information on existing direct use operations, available resources and their characteristics, knowledge of the regulatory environment, and economic data.

This paper presents the development of a national geothermal direct use database. The focus is on commercial and industrial opportunities, where the energy demand and economic development potential is considerable.

This project continues GNS Science's goal of raising awareness of geothermal resources and the potential breadth of uses for this renewable, reliable, and accessible source of heat energy.

1. DIRECT USE OPPORTUNITIES

1.1 Potential Uses

Direct use refers to the use of geothermal heat energy in applications other than the generation of electricity. Most processes which need the input of heat can successfully use geothermal energy directly, instead of, or as a supplement to, electricity and/or fossil fuels. The processes or applications that can be supported by direct use depend primarily on the temperature of the geothermal fluid available (Figure 1).

Installations can be stand-alone (i.e. one heat source, one use) or cascaded - where applications are set up in series, each using the discharged fluids/heat from the previous process. Cascaded direct heat use after power generation may be problematic in New Zealand, where cooling of high temperature resources presents a silica management issue. However, reverse cascades (using heat for direct use first and then for binary power generation) or parallel supply for direct use and generation offer valuable alternatives for commercial use of this high quality heat source.

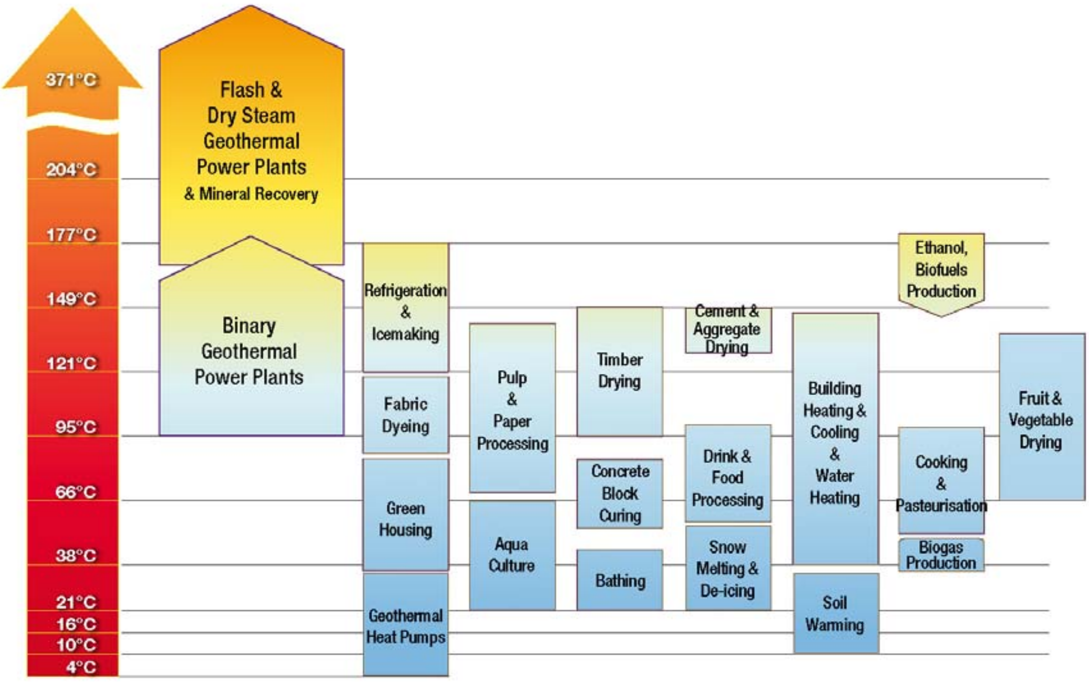

Figure 1 Lindal diagram showing examples of potential uses for geothermal resources, as a function of the temperature required for the process.

1.2 Fossil Fuel Heat Demand in New Zealand

Over the next thirty years substantial increases in oil and gas prices can reasonably be expected, with reducing availability of fossil fuels and increasing demand for energy. Industries that use coal, oil, and natural gas for their thermal energy needs may be able to replace or supplement their current systems with geothermal heat.

In 2011 fossil fuel use equated to an energy consumption of 115 PJ in the agriculture, industrial and commercial sectors; that is 40 PJ of oil, 23 PJ of coal, and 52 PJ of natural gas (MED, 2012). The combined fossil fuel use by sector for 2011 is shown in Figure 2; a total annual use of 238 PJ (MED, 2012).

This analysis excluded primary energy supply (i.e. production, imports, exports etc.) and excluded transport use. The transport sector consumed an additional 206 PJ in 2011, dominated by imported oil use. Geothermal energy can not be directly used for transportation, but it could play a role in domestic biofuel production.

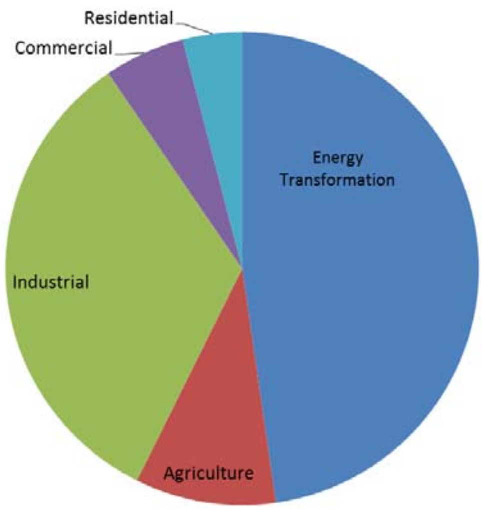

Figure 2 Fossil fuel energy use, comprising natural gas, oil, and coal, by sector for 2011 (data from MED, 2012). This data excludes the transport sector, and excludes the primary energy supply (e.g. production, imports, exports).

Electricity generation, including cogeneration, accounts for the largest domestic use of fossil fuels (excluding transport). Geothermal resources are already a key component of New Zealand's energy scene, capable of providing an even greater contribution to electricity generation, as well as industrial, commercial and residential heating and cooling into the future.

Industrial fossil fuel uses, where geothermal energy could potentially play a larger role, include (but are not limited to) mining, cement, lime and plaster, meat, dairy and other food processing, wool, timber, pulp and paper products, textile manufacturing, and petrochemical industries. Commercial use is mainly in space heating, such as hospitals, rest homes and educational institutions. Lesser amounts are consumed in the agricultural and residential sectors.

1.3 Existing Direct Use in New Zealand

Existing direct use applications in New Zealand include timber drying, paper and pulp processing, space heating and cooling, bathing, milk drying, greenhouse heating, and prawn cultivation in aquaculture ponds.

The energy usage from geothermal direct heat applications in New Zealand in 2012 was estimated as 9.4 PJ/yr (unpublished data). This figure is predicted to significantly reduce for 2013 due to the closure of one of two paper machines in Kawerau (White, 2012).

Industrial process heat is New Zealand's largest geothermal direct heat user by energy extracted (Figure 3). The Norske Skog Tasman (NST) paper and pulp facility in Kawerau, established in 1957 (Bloomer, 2011), is the primary consumer of direct use geothermal energy in New Zealand.

Carter Holt Harvey Wood Products uses steam supplied by NST for further manufacturing of processed timber products (Wolfe, 2013). The newest addition of direct use geothermal energy in Kawerau belongs to Svenska Cellulosa Aktiebolaget (SCA) Hygiene Australasia, who use a high temperature and pressure, clean (gas-stripped) geothermal steam supply for tissue manufacturing (Lind *et al.*, 2013; Bloomer, 2013).

Projects are underway to develop better uses of woody biomass for a variety of exportable products, which would require an increase in industrial process heat from geothermal resources (Jack, 2013).

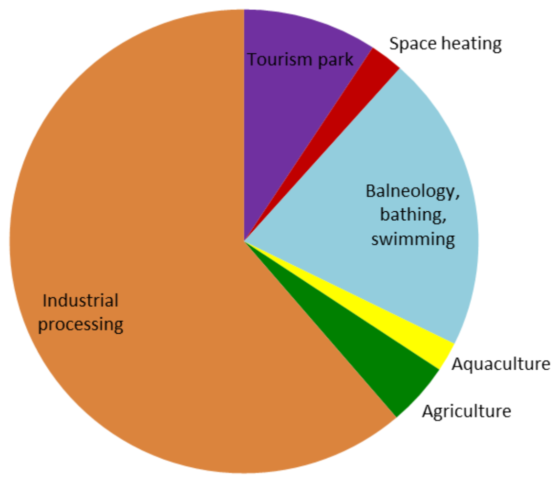

Figure 3 Extracted energy (2012) for different categories of geothermal direct heat use in New Zealand. This figure excludes domestic use, geothermal heat pumps and non-commercial bathing.

Bathing and swimming is New Zealand's largest use by total number of operations (Figure 4). Maori traditionally used hot springs for bathing and cooking. Scientific studies of hot springs in the 19^{th} and 20^{th} centuries focussed on the balneological (bath science) and therapeutic properties of the hot water (Bradshaw and Faulkner, 2011). Sanatoriums were built around springs like Te Aroha and Hanmer Springs, as well as the Queen Elizabeth Hospital in Rotorua. Hot pools continue to be a major use of geothermal resources.

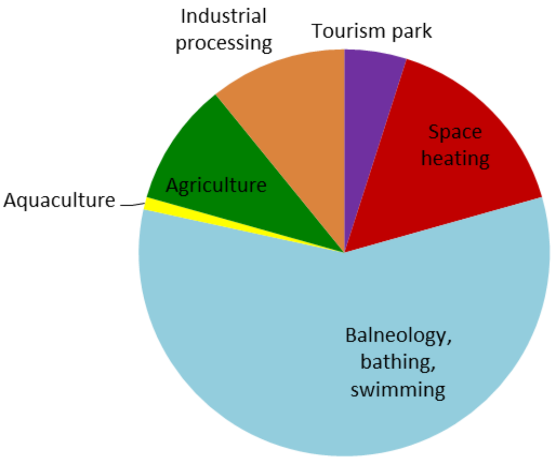

Figure 4 Relative number of installed geothermal direct use operations (2012) in New Zealand (updated from Reyes, 2007 and White, 2009). This figure excludes domestic use, geothermal heat pumps and non-commercial bathing.

2. AVAILABLE RESOURCES

New Zealand is well-endowed with geothermal resources. The areas in New Zealand best suited for geothermal direct use projects are in the localised zones of high surface heat flow (Figure 5) that occur with high volcanic and tectonic activity (Reyes, *et al.*, 2010; White, 2009). Faults, fractures and permeable formations act as channels for fluid movement, and transmission of heat towards the ground surface.

Figure 5 Areas of high heat flow (orange areas) associated with tectonic, volcanic and geothermal activity in New Zealand (revised from White, 2009).

There are obvious manifestations of this type of geothermal energy in areas such as Rotorua, Taupo and Ngawha, associated with high temperature geothermal systems. In addition, there are many more thermal springs in both the North and South Islands (Reyes, 2007; Reyes *et al.*, 2010).

Extractable energy from these conventional geothermal heat sources, and "waste" heat from cascaded and parallel use, has been projected at 265 PJ, (Reyes, 2007; Reyes, 2011). It is estimated that New Zealand is using <5% of these potential resources.

Direct use technologies can utilise both high (>150°C) and lower (<150°C) temperature resources. However, heat needs to be used where there is demand in vicinity of the resources, as transport of heat over longer distances has economic limitations. This presents opportunities for enhanced local/regional economic development around geothermal resources.

3. BARRIERS TO INCREASED USE

Geothermal energy is a key strength, capability and competitive advantage for New Zealand, aligned with national energy targets and goals for economic growth.

The success of direct geothermal use is well demonstrated both domestically and internationally and there is growing interest from the geothermal industry, economic development agencies, regulatory authorities and others to develop new direct use projects in New Zealand.

So, why has this potential not yet been realised?

While for electricity generation from geothermal energy is well known and its potential quantified, the scale and breadth of the geothermal direct use opportunity remains unclear. There is a considerable need for access to robust information on existing direct use operations, available resources and their characteristics, and knowledge of the regulatory processes. Additionally, for successful implementation, direct use developments require financial data on economic viability and market drivers.

To date, much of the direct use and lower temperature geothermal research has been ad-hoc, and eclipsed by the focus on high temperature resources and electricity generation. However, the published literature does include a number of introductory reports (e.g. Reyes, 2007) and "how-to" guides (e.g. Lund *et al.*, 1998; Thain *et al.*, 2006) for developing direct use applications.

Additionally, country reporting has identified past trends in direct use development and identified areas of change (e.g. White, 2009; Harvey and White, 2012). However, a fundamental limitation to these assessments has always been that the databases remain incomplete.

4. GEOTHERMAL USE INVENTORY

GNS Science is compiling a national geothermal use database that includes existing direct uses, as well as power generation and geothermal (ground-source) heat pump installations.

This inventory will support a number of goals, including:

1. *More robust estimation of New Zealand's geothermal use for national and international reporting:* Regular reporting of geothermal use is undertaken for central government (Ministry of Business, Innovation and Employment - Economic Development) as well as international associations such as the International Geothermal Association and International Energy Agency – Geothermal Implementing Agreement (IEA-GIA). Additionally country updates are presented at conferences, including the World Geothermal Congress (WGC) (Harvey *et al.*, 2010), African Rift Geothermal Conference (Harvey and White, 2012) and the Australasian Institute of Mining and Metallurgy Conference (Bromley, 2012).

2. *Increased awareness of the opportunities for geothermal resource use:* Showcasing existing applications for geothermal energy would promote new business opportunities, in turn supporting economic growth. Awareness is a substantial barrier to increasing the diversification of geothermal resource use in New Zealand (Carey and Climo, 2012). Generating power is the most commonly understood use of geothermal resources for New Zealanders, but less is known of the direct heat use or geothermal heat pump opportunities (Doody and Becker, 2011).

3. *Valuing geothermal use:* Geothermal resources are a valuable asset, particularly in contributing to regional economies through tourism, electricity generation and direct uses. Quantifying their economic value (e.g. Barns and Luketina, 2011) 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 opportunity. The direct use inventory could support micro- and macro- 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 (Luketina, 2013).

4.1 Methodology

The methodology used to develop the geothermal use inventory included obtaining geothermal use data, qualitative and quantitative where available, from:

- Published literature, conference proceedings and publically available reports;
- Geothermal consent data from Regional Councils; and
- Direct contact with owners and operators, by telephone, email, web-bases survey and site visits.

The first phase was to collect the qualitative information. This includes developing a complete national list of all users of geothermal resources, determining their location, contact details and categorising their type of use.

The second phase was to gather technical information on the resources and each operation, where appropriate, to allow for quantitative analyses of key criteria for estimating future trends, such as heat energy used, economics, number of existing installations and planned developments.

Site visits will be on-going and undertaken as required, particularly where owners do not know sufficient technical information about their geothermal installations, both surface and subsurface systems, to respond to a survey questionnaire.

4.2 Categories of Use

The collated data will be divided by the major use:

1. Bathing (including balneology and commercial pools and spas);
2. Space heating/cooling (including district heating and water heating);
3. Industrial process heating (including timber and food processing);
4. Agriculture (including greenhouses, open ground heating and animal husbandry);
5. Aquaculture;
6. Geothermal Tourism (including commercial and non-commercial) ;
7. Geothermal (ground-source) heat pumps; and
8. Domestic use (including home space and water heating and domestic pools).

This manner of presentation is consistent with the requirements for the WGC country updates (Lund *et al.*, 2010), and is aligned with the approaches used in New Zealand geothermal assessments (e.g. White, 2009; Bromley and White, 2011).

Some operations will have more than one category (e.g. the Polynesian Spa in Rotorua would be categorised under bathing and tourism). Sub-categories will also be introduced where appropriate to assist in analysis of the data. For example, space heating sub-categories might include district heating, water heating, schools, hospitals/health, commercial buildings (e.g. office blocks, shopping centres) and accommodation.

4.3 Web-Accessible Map

A web-based map is being developed in parallel to the database. It is intended that selected high-level summary information, that has no commercial sensitivity, will be made publically available to showcase the breadth of geothermal use in New Zealand.

Summary data might include descriptive information (e.g. type of use, owner, year, photograph) as well as selected technical data (e.g. temperature, flow rate, capacity, annual energy use).

Figure 6 shows an example of a map showing a range of geothermal uses in the Taupo area.

A similar mapping application has been developed for geothermal energy use in the United States (http://geoheat.oit.edu/dusys.htm). Also a number of groups have established online mapping and information tools for power plants (e.g. map.thinkgeoenergy.com; www.energynews.co.nz).

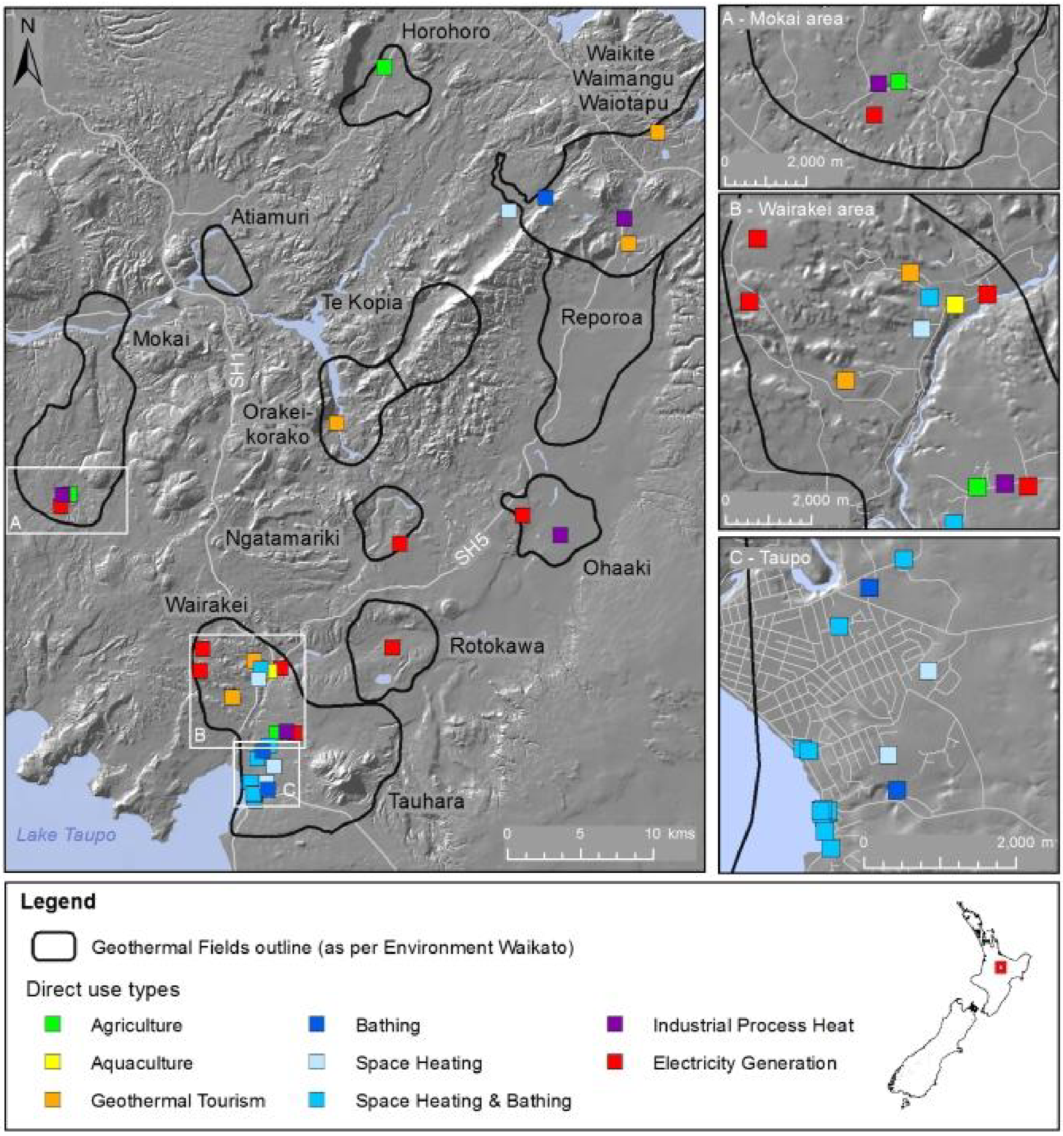

Figure 6 Mapping example of some of the geothermal uses in the Taupo area, excluding domestic use and geothermal heat pumps.

5. INTERNATIONAL CONTEXT

New Zealand is one of many nations seeking to grow their geothermal energy use. Direct use geothermal applications are being emphasised in national renewable energy policies as effective measures for curbing greenhouse gas emissions (Holm *et al.*, 2010).

International growth in geothermal projects has been attributed to international and multi-lateral support for development in new locations, and is often driven by financing from regional institutions (e.g. African Rift Geothermal Energy Development Facility; European Bank for Reconstruction and Development). However, other forms of support, other than financing, are also being endorsed to facilitate geothermal development through regional and international cooperation. Examples include technology and data sharing, training, and geoscientific surveys.

New Zealand shares its internationally-recognised experience and expertise in high temperature geothermal development to assist other countries exploring their geothermal potential (for example - www.geothermalnewzealand.com). However, New Zealand is not at the forefront in leadership of most direct use applications or geothermal heat pump developments (Carey and Climo, 2012)

The IEA-GIA and IRENA (International Renewable Energy Agency) work programmes (see below) are two international examples where collaborative benefits can be realised through sharing of geothermal use information and experience.

5.1 IEA-GIA Direct Use Annex

The IEA-GIA was established in 1997 to promote international collaboration cooperative research, analysis and information sharing concerning the sustainable development and utilisation of geothermal energy. This agreement has recently been extended for a further five year term (2013-2018).

New Zealand (via GNS Science) has recently joined the IEA-GIA's Annex VIII: Direct Use of Geothermal Energy. This group aims to promote the wider direct use of geothermal energy and to learn from the experiences of participants. The forward tasks in direct use are:

1. Innovative and novel direct use applications.

2. Communication: developing handbooks and compiling data on known direct use applications.

3. Standards and regulations: translating, paraphrasing and sharing technical design standard documents.

4. Reporting direct energy use.

New Zealand's geothermal use inventory is a foundation activity that will support all of these tasks, with particular relevance to tasks 2 and 4.

5.2 IRENA Global Atlas

IRENA was founded in 2009 to promote the widespread adoption and sustainable use of all forms of renewable energy. It seeks to integrate country profiles, technology information, plant simulation tools, economic modules and socio-economic indicators into their database platform.

A technical working group of geothermal members is being established, and international geothermal data, including contributions from New Zealand, will be introduced into IRENA's GIS-based Global Atlas (www.irena.org).

6. CONCLUSIONS

Increasing geothermal energy use in New Zealand is a sound opportunity to support a drive towards climate-friendly renewable energy sources in meeting expected increases in energy costs, growing energy demand and social change towards energy use.

The development of a publically-available database and web-based mapping application of geothermal applications is one initiative that will assist in supporting increased geothermal energy use. This project will raise awareness of existing geothermal use in New Zealand, while also showcasing the breadth of potential applications and resources.

The project aligns with international direct use and geothermal data management initiatives.

The collated data will support more robust quantification of energy use, economics and other useful indicators for both country reporting and for catalysing economic development opportunities and growth.

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