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A history of geothermal direct use development in the Taupo Volcanic Zone, New Zealand

Melissa Climo[a,*], Sarah D. Milicich[a], Brian White[b]

[a] GNS Science, Private Bag 2000, Taupo 3352, New Zealand
[b] East Harbour Energy, PO Box 11-595, Manners Street, Wellington 6142, New Zealand

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ABSTRACT

New Zealand's direct geothermal energy use is focussed in the Taupo Volcanic Zone, with the majority being commercial and industrial installations near Rotorua, Taupo and Kawerau. Bathing is the oldest and most numerous use of geothermal resources, but industrial process heat uses the most energy. Historical growth of direct use has not shown a trend of steady growth or constant development over time. Rather, geothermal energy use has had periods of growth, decline and little or no change. This paper examines four phases of growth over the past 60+ years, and reviews some of the developments that have occurred.

1. Introduction

This paper reviews the history of geothermal direct use development in New Zealand's Taupo Volcanic Zone (TVZ, Fig. 1). An overview of published studies is included, as well as information on the geothermal resource availability in the TVZ, and the existing and potential uses of the energy. Four periods of development are described, with examples focussing on industrial and commercial-scale operations. The data provided includes installation name, location, start/end dates, and type of use.

This review of direct use applications focuses predominantly on bathing (the largest use by number of installations), and process heat operations (the largest use by energy consumed). Motels, hotels and other commercial holiday accommodation also use geothermal energy for water/space heating and bathing in the TVZ. These users account for a significant number of installations, estimated to be ca. 80 (BOPRC, 2005). However, commercial accommodation operators were not included in this study, except for key historic developments where published data was available. The study has also not considered natural hot springs and streams that have not been developed. Geothermal (ground-source) heat pump installations and domestic uses have also been excluded.

Previous studies of direct use applications in New Zealand are summarised in conference papers, journal articles, Government updates and international reviews. For the past 30 or so years, country updates have been on an approximately five yearly cycle, highlighting the major geothermal developments during the preceding 5 years. The major papers reviewing geothermal direct use developments in New Zealand include Freeston (1985), Lund and Clelland (1990), Thain and Freeston (1995), Thain and Dunstall (2000), Dunstall (2005), Harvey et al. (2010) and Carey et al. (2015). Additionally, New Zealand geothermal use updates have been presented in various conference proceedings (e.g. White, 2006a; Harvey and White, 2012; Bromley, 2012).

Data and summary reports are compiled at least annually for and by the New Zealand central government (currently via the Ministry of Business, Innovation and Employment). Various associations also collect, collate and present data, including the New Zealand Geothermal Association (e.g. White, 2006b, 2009), International Geothermal Association (e.g. Harvey et al., 2010) and International Energy Agency—Geothermal Implementing Agreement (e.g. Bromley and White, 2011). Broader reviews of geothermal energy use in New Zealand also include Speden and Allis's (1997) review of 50 years of geothermal use in New Zealand, and Hunt and Lund's (2002) summary of geothermal use.

The literature also contains descriptive case studies of geothermal direct use installations in New Zealand. Examples include Rotorua Hospital (Steins and Zarrouk, 2012), Taupo Hospital (Febrianto et al., 2013), Broadlands Lucerne Co. (van de Wydeven

* Corresponding author.
E-mail addresses: m.climo@gns.cri.nz (M. Climo), s.milicich@gns.cri.nz (S.D. Milicich), brian.white@eastharbour.co.nz (B. White).

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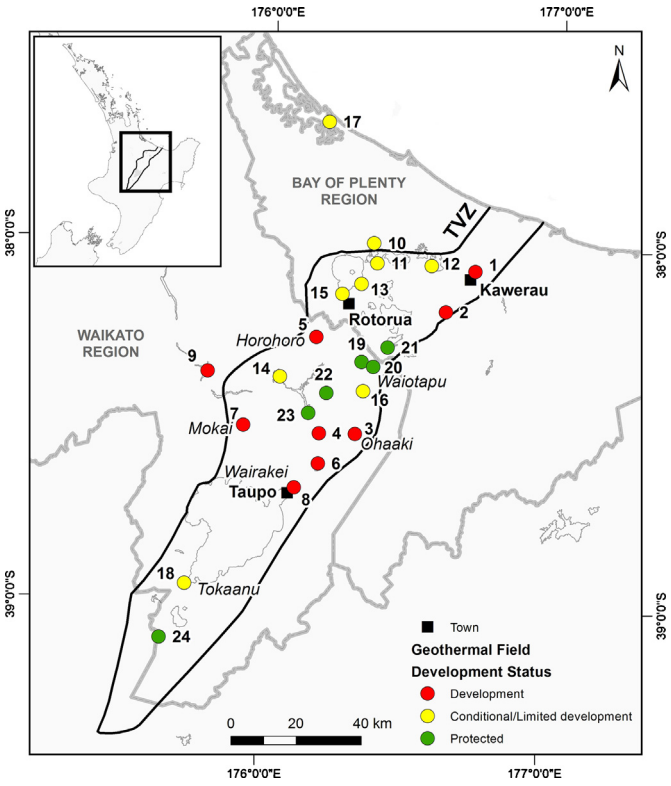

Fig. 1. Geothermal resources in New Zealand's Taupo Volcanic Zone (TVZ), indicating the development status of each. Boundaries are shown for the Waikato and Bay of Plenty Regions. Field numbers refer to Table 1.

and Freeston, 1980; Pirrit and Dunstall, 1995), Prawn Park (Lund and Klein, 1995), geothermal orchids (McLachlan, 1998), and Kawerau's timber drying (Scott and Lund, 1998), glasshouses (Dunstall and Foster, 1998) and the Tasman pulp and paper mill (Hotson, 1994, 1997).

Some published papers have provided a short descriptive summary by geothermal area, such as Taupo (Koorey, 1996), Rotorua (Lund, 1976; Anderson, 1998) and Kawerau (Bloomer, 1997, 2011, 2015). Example of engineering-focussed studies, which discuss heat exchangers, equipment, controls and systems for direct use installations, include Drew (1988), Gudmundsson (1988), Steins et al. (2012) and Dunstall and Freeston (1989).

2. Geothermal resources in the TVZ

Geothermal systems are present throughout New Zealand with high temperature fields (>225 °C) generally magmatic-related sources and localised, such as the TVZ. The more widely scattered moderate (125–225 °C) to low (<125 °C) temperature resources can be related to young volcanism, or non-magmatic origin related to deep faults and tectonic features. The latter can be found throughout New Zealand, with many located on along the Alpine Fault in the South Island (Hochstein, 1990; Reyes et al., 2010).

The TVZ (Fig. 1) is an area of high heat flow with geothermal, volcanic and tectonic activity. It is situated above a subduction zone, where the Pacific plate is westwardly subducted beneath the Australasian plate (Wilson et al., 1995). The Earth's crust is estimated to be only 15 km thick beneath the TVZ (Wilson et al., 1995). Deeply circulating groundwater is heated and channelled to the surface through faults, fractures and permeable pathways, generating the natural geothermal energy. The high temperature geothermal areas in the TVZ (Fig. 1) predominantly span three Districts (Taupo, Rotorua and Kawerau) and two Regions (Bay of Plenty and Waikato).

Māori legend tells that the geothermal fields in the North Island were birthed when Te Pupu and Te Hoata, tipua (goddesses) of fire, surfaced from the Earth in search of Ngātoroirangi, who had been exploring through to Mount Tongariro and was dying of cold. They carried kete (baskets) filled with glowing embers. Where they emerged from underground on their way from Whakaari (White Island) to Mt. Tongariro, they created geysers, hot springs and mud pools, leaving a path of geothermal activity that remains today (Gregg et al., 1960; Tauhara Geothermal, 2015).

2.1. Legislative framework

In New Zealand, geothermal resources are not owned by the Government like petroleum and mineral reserves are (CMA, 1991). There is no present royalty payment charge over the extracted geothermal energy. The sole right to tap and use geothermal energy, falling short of explicitly conferring ownership, is vested in the Government. Geothermal resources are treated as water, and their use is managed at a regional level through the Resource Management Act (1991). Geothermal systems have been classified (Fig. 1, Table 1) in the regional planning and policy frameworks (BOPRC, 1999, 2008; WRC, 2007) into management groups, directing the type of development allowed in/on a particular geothermal system. A summary of these regional classifications is found in Table 2.

Options range from permitted for high capacity developments, limited capacity developments, to protected from development. However, it should be noted that limited direct use is allowed across most of the classifications.

2.2. Electricity generation

Geothermal electricity generation began in New Zealand in 1958 when the Wairakei Power Station began operation. Electricity generation from geothermal resources is well-established in 2015, with