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Lookahead from Kawerau, New Zealand: the Largest Geothermal Industrial Direct Use Complex in the World

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ABSTRACT

Kawerau in New Zealand has been home to the largest industrial geothermal direct use operations in the world since the 1950s, utilizing geothermal energy from the Kawerau Geothermal Field (KGF) supplied by Ngāti Tūwharetoa Geothermal Assets Ltd. (NTGA) for different industrial processes: pulp and paper, wood products processing, timber drying, clean steam production, among others. This paper provides a look-back on the milestones achieved and a lookahead on the opportunities and challenges for increased geothermal energy direct use in Kawerau and in New Zealand.

1. INTRODUCTION

The Kawerau Industrial Complex located at Kawerau, New Zealand is the largest and one of the longest-running industrial geothermal direct heat users in the world. Direct geothermal energy use in Kawerau has been ongoing since the start-up of the Tasman Pulp and Paper Mill in 1957 up to the present set of process industries in the area that uses process heat from geothermal steam. In 2018, the complex utilized around 5.3 PJ of geothermal energy per year, equivalent to about 1.93 million tonnes of geothermal steam per year. Direct use in the complex is expected to rise due to planned increased geothermal process heat utilization at Oji Fibre Solutions, an existing kraft pulp processing plant, and Waiu, a newly constructed dairy processing plant.

Ngāti Tūwharetoa Geothermal Assets Ltd. (NTGA), a Maori-owned geothermal operator supplies geothermal energy to the Kawerau Industrial Complex through its steamfield assets in the Kawerau Geothermal Field. In addition, it also owns and operates the 21MW_{net} binary cycle power plant (TOPP1) utilizing geothermal steam and a large volume of separated geothermal water (SGW).

Figure 1 below shows the current lay out of the Kawerau Industrial Complex and nearby power plants in relation to the town of Kawerau.

Figure 1. The Kawerau Industrial Complex in Kawerau, New Zealand as viewed from the north (Waiu Dairy still under construction, KGL power plant owned by Mercury).

1.1 The Kawerau Geothermal System

The Kawerau geothermal system is in the northeastern region of the Taupō Volcanic Zone (TVZ) of New Zealand (Figure 2). It has an area of around 22 km^2 over a liquid-dominated, alkali-chloride reservoir with fluid temperatures reaching up to 310 °C.

The Pūtauaki volcano is the system's likely heat source. Hot geothermal fluid flows up through the faults and fractures of the greywacke basement around the southern part of the field, then flows laterally through the overlying volcanic and sedimentary layers, mixing with groundwater as it flows through to the surface outflows and into the plains to the north as shown in Figure 3. Additional details about the Kawerau geothermal system are discussed by Bignall and Milicich (2012) and Milicich et al. (2016).

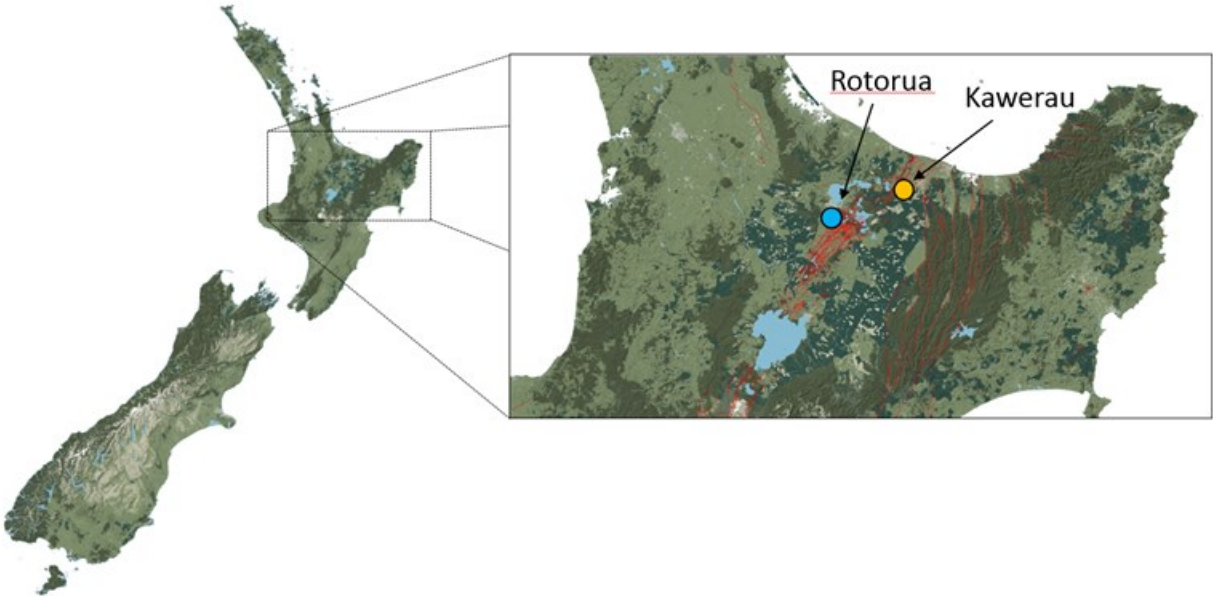

Figure 2. The Kawerau Geothermal Field in the Taupo Volcanic Zone (TVZ) of New Zealand (modified from the New Zealand Active Faults Database (Langridge et al., 2016) accessed through http://data.gns.cri.nz/af/).

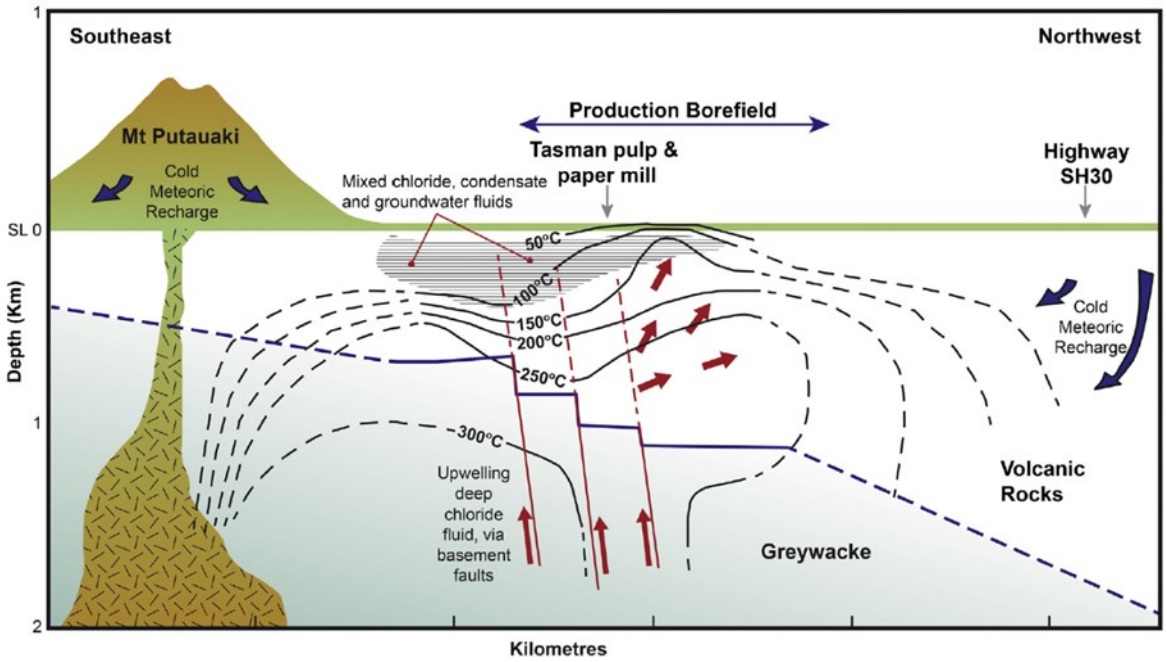

Figure 3. The Kawerau Geothermal System from Milicich et al. (2016).

1.2 Brief History of Kawerau Geothermal Development

The use of geothermal energy, especially for direct heat applications, have a long history in Kawerau. Prior to industrial development in the 1950s, the Kawerau geothermal area, then known as the Onepu hydrothermal area (Studt, 1958), was already being utilized by the local Tūwharetoa iwi (Maori tribe) for various purposes, most of which would be considered sustainable geothermal direct heat use/applications such as for healing and recuperation, cultivation of plants, space heating, cooking, breeding ground for fish, bathing, and source of sulphur for traditional medicine (Adlam and King, 2015).

1.2.1 Industrial Direct Use

In the 1950s, the Kawerau geothermal area was chosen to be developed for industrial geothermal direct heat use for the Tasman Pulp and Paper mill. The mill developed an innovative geothermal condensate treatment plant to steam strip dissolved gases from the geothermal condensates and generate a higher quality feed water for the boilers and the heat exchangers in the mill (Carter and Hotson, 1992; Hotson, 1994).

By the 1990's, majority of the geothermal steam supplied to the pulp and paper mill was fed through clean steam heat exchangers or reboiler units to produce process steam suitable for use in the paper making equipment, i.e., minimal gas content (Carter and Hotson, 1992). Geothermal industrial direct heat use in Kawerau increased over time due to increased energy demand from the pulp and paper mill.

1.2.2 Power Generation Development

While the geothermal fluid in Kawerau was primarily used for process steam at the pulp and paper mill, a portion of the steam has been used to generate 8MW of electricity in a backpressure turbine (turbo-alternator) for the mill. The most recent turbine was installed in 2004, replacing a turbine installed in 1966 (Bloomer, 2015). The exhaust steam from this turbine have been used as process steam for the mill but may also be discharged to the atmosphere.

In contrast to other geothermal fields, Kawerau's geothermal energy was initially used mainly for industrial process heat. Power generation outside the mill were through binary cycle power plants using the separated geothermal water from the two-phase separation plants.

Two small Ormat binary power plants, the 2.4 MW TG1 and 3.5 MW TG2, were commissioned in 1989 and 1993, respectively to utilize separated geothermal water for electricity generation. Both binary cycle power plants used around 180 ºC separated geothermal water. The TG1 plant has been decommissioned and TG2 plan is currently not-operational.

In 2008, Mercury built and commissioned the 100MW Kawerau Geothermal Ltd. (KGL) double-flash plant and new set of production and injection wells to become another tapper in the field. Around the same time, Geothermal Development Ltd. (GDL) also commissioned an 8MW binary cycle power plant and became the third tapper, ushering in a multi-tapper arrangement in the Kawerau Geothermal Field.

In 2012, Norske Skog Tasman (NST) commissioned the 21MW_{net} TOPP1 binary cycle power plant supplied with geothermal steam and water from NTGA.

The most recent power generation development was the 24MW_{net} binary cycle power plant by Te Ahi O Maui (TAOM), the fourth geothermal reservoir tapper, commissioned in 2018 commissioning and supplied by new production wells drilled at the western part of the geothermal field.

2. MILESTONES AND UPDATES TO NTGA GEOTHERMAL OPERATIONS SINCE WGC 2015

The last Kawerau geothermal direct heat use data was provided by various authors during the 2015 World Geothermal Congress (WGC) at Melbourne, Australia (Adlam and King, 2015; Bloomer, 2015; Carey et al., 2015; Climo et al., 2016; Lund and Boyd, 2016). In the following years since the 2015 WGC, geothermal direct heat use remained stable, underpinned by upgrades and optimization of NTGA steamfield operations. This section summarizes the activities carried out by NTGA to ensure uninterrupted steam supply to the geothermal direct heat users.

2.1 Steamfield Assets Additions, Upgrades, and Repairs

NTGA carried out steamfield upgrades and asset maintenance activities to ensure the reliability of geothermal energy supply to the Kawerau industrial complex. These projects include the drilling and completion of new production wells (KA54 and KA57), the successful repair and maintenance of two production wells (KA27 and KA47), upgrades to the anti-scalant system and the clean steam plant, and the new supply or increased supply of process steam to new direct geothermal users such as Sequal Lumber's kiln dying process, Waiu's dairy processing plant and Oji Fibre Solution's kraft pulp processing.

2.1.1 New Production Wells Drilled

NTGA drilled and connected production well KA54 in 2016. At start-up, the well had a capacity to produce up to 174 MWth or 27.8 MWe at a wellhead pressure of 30 barg. This additional well enables NTGA to reliably supply energy while other production wells are shut-in for well testing and repairs. Its high wellhead pressure also enables it to supply the high-pressure clean steam plant with 22 barg 'raw' geothermal fluid to generate 16 barg 'clean' or degassed process steam to satisfy downstream process heat requirements.

NTGA also drilled KA57 in 2019 at the southern and hottest part of the Kawerau Geothermal field. The well is yet to be tested and if productive, will be connected to NTGA's steam gathering system to provide geothermal supply reliability to the industrial complex.

2.1.2 Successful Well Work-overs and Anti-Scalant Upgrades

NTGA successfully carried out the work-overs on two production wells, KA27 and KA47.

NTGA re-lined KA47 to repair a casing issue, ensuring the reliability of 131 MWth (21 MWe) production capacity. This repair utilized a smaller oil and gas rig and the project provided alternative options for carrying out future geothermal well repairs in New Zealand (Figure 4).

Figure 4. KA47 well casing repair on a tight well pad using Webber's Nova-1 rig.

Kawerau's geothermal fluid has a potential for calcite scale deposition. Anti-scalant inhibition systems using downhole injection of scale inhibitors through tubes have been in place since the 1990s. The anti-scalant system in NTGA has been successful in mitigating the effects of wellbore calcite scale deposition. However, as these anti-scalant systems age, their maintenance and replacement become more complicated.

In a recent anti-scalant tubing pull-out and maintenance activity in production well KA27, the tubing that was in place for many years was found to be scaled up from years of residual scale build up. An acid-flush plan and a mechanical clean-out plan were required to bring the well back in service. The acid-flush plan was required to ensure that the anti-scalant tubing can be pulled out even with residual calcite scale reducing the available wellbore clearance. The mechanical clean-out plan was required to recover maximum wellbore clearance and remove any significant scale deposit that may block the well from flowing. These plans were successfully carried out and the "live" or non-quenched mechanical clean-out ensured a quick return-to-service for KA27 (Figure 5). The successful activity ensured the continued reliability of 48 MWth (7.4 MWe) production capacity. Additional details of the KA47 and KA27 work-overs are discussed by Clements and Quinao (2018).

Figure 5. KA27 "live" clean-out using Western Energy's coiled-tubing unit (CTU).

2.1.3 Clean Steam Plant Upgrades

NTGA operates a 60-t/hr high-pressure (16 barg) clean steam plant (CSP) that uses stripped geothermal condensate as feedwater. It is fully redundant, which means maintenance shutdowns and inspections can be carried out without interrupting the clean steam supply to the customer.

The CSP is based on a geothermal reboiler technology that has been pioneered in the Kawerau Industrial Complex (Carter and Hotson, 1992). However, the NTGA plant is the first high-pressure application of this technology. Moore (2011) and Bloomer (2015) describe the CSP's design concepts and details.

After eight years of operation, the CSP continues to provide reliable, high-pressure clean steam to Asaleo Care for the manufacture of tissue products. Recent modifications include the addition of a caustic-dosing equipment to effectively manage the pH of the system and mitigate the risk of corrosion (Figure 6).

The CSP is also set to supply clean steam to the milk drying process of the new Kawerau Dairy plant and to Oji Fibre Solutions' kraft pulp processing in 2019.

Figure 6. Tube bundle from one of the Clean Steam Plant heat exchangers during a recent routine maintenance and inspection. The fully redundant plant ensures clean steam supply was uninterrupted during this maintenance activity.

2.1.4 Reinjection System Upgrades

NTGA has five reinjection wells, three shallow in-field wells and two deep edge-field wells, that relied on the system pressure and gravity for reinjection pressure.

In 2018, reinjection pumps were installed to increase the capacity of the deep reinjection system and ensure reinjection pressure is available for the 4km connecting pipeline between the production area and the deep reinjection wells. Shallow reinjection wells are also planned to be installed in 2019 to increase the capacity and flexibility of the shallow injection system.

2.2. Industrial Geothermal Direct Heat Use Updates from the Kawerau Industrial Complex

The overall energy consumption for industrial geothermal direct use in Kawerau is currently at around 5.3-5.4 PJ per year in the last three years. This is equivalent to the industrial direct heat utilization of around 170 MW thermal energy, still the largest industrial geothermal direct heat utilization in the world.

The current industrial geothermal direct use in the Kawerau Industrial Complex is still dominated by Norske Skog Tasman's (NST) pulp and paper operations even after the decommissioning of one of the two paper machines at NST in 2013 (Norske Skog, 2014). A snapshot of the 2018 industrial geothermal steam usage summary is shown in Figure 7.

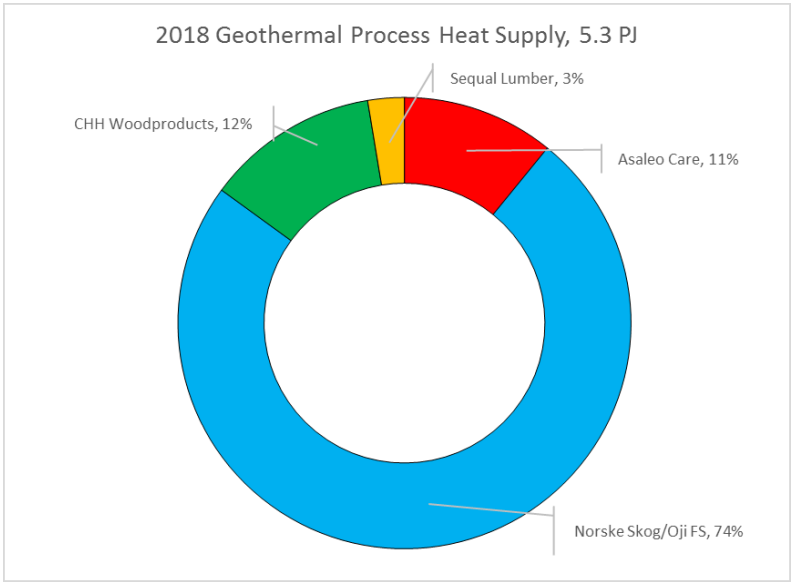

Figure 7. Proportion of industrial geothermal direct heat usage in the Kawerau Industrial Complex.

In 2018, NTGA had the capacity to produce a total of around 14.8 PJ of geothermal energy (at 87 ºC reference temperature), with the potential to increase this to around 18 PJ by increasing well production flows. Around 35% of NTGA's current geothermal energy capacity is supplied to the Kawerau Industrial Complex, while around 28% is supplied to a 21-MW binary power station as shown in Figure 8 below. The rest of the produced energy is reinjected or released to the atmosphere through atmospheric separators and cooling channels.

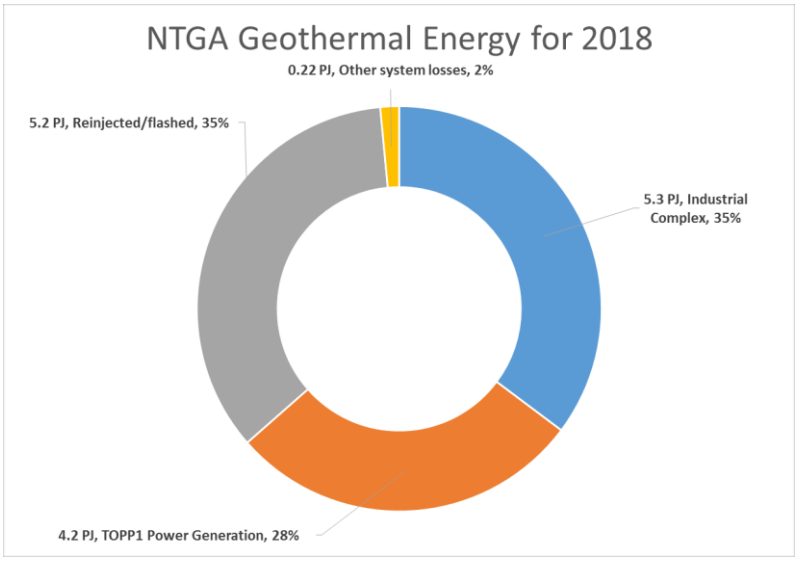

Figure 8. NTGA geothermal energy production capacity distribution in 2018.

2.3 Potential for Increased Utilization of Geothermal Energy in Kawerau

There is a large potential for additional geothermal energy production in Kawerau based on current operations and the resource consent (permit) granted to NTGA as shown in Figure 9. New geothermal energy consumers like Waiu Dairy are set to benefit from the co-location of available energy supply and infrastructure in the Kawerau Industrial Complex.

At present, there is already around 5.2 PJ of underutilized thermal energy at surface that is currently reinjected or released to the surface environment. A portion of this energy, contained in the 180 ºC separated geothermal water, was previously used in two

binary cycle power stations TG1 and TG2 (5.9 MWe combined capacity) that are now both shut. A portion of the hot water is used to maintain a thermal lagoon and bathing pool before flowing into the adjacent Tarawera River. The rest of the thermal energy could be further utilized through additional geothermal direct heat cascade uses or power generation.

NTGA was granted resource consent to abstract additional geothermal fluid from the KGF that has the potential to produce an additional 10.6 PJ of thermal energy. Combined with the existing 5.2 PJ geothermal energy potential in the separated geothermal water at surface, NTGA is well-placed to ensure that Kawerau remains a world leader in industrial geothermal direct use.

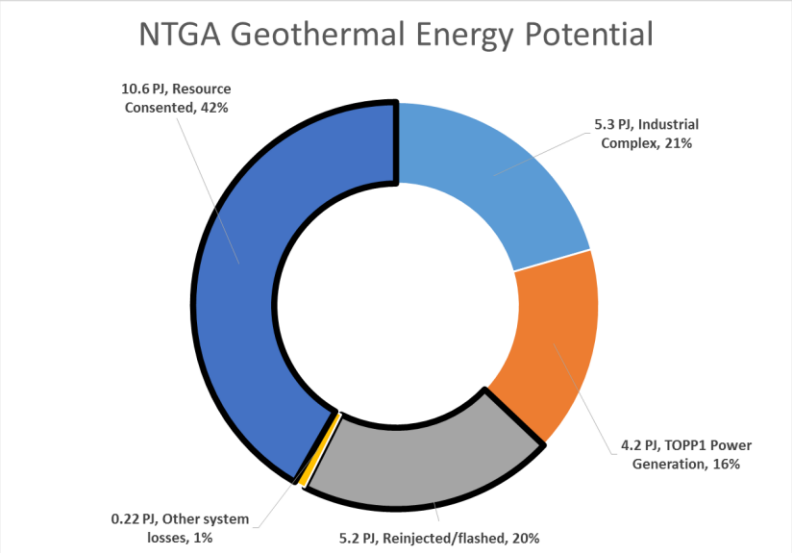

Figure 9. NTGA's potential geothermal energy production capacity at full resource consent utilization.

3. CONCLUSION

The Kawerau Industrial Complex currently uses around 170 MWth (5.3 PJ/year) of geothermal process heat and with planned additional utilization in 2019, would still be the largest single location for industrial geothermal direct heat use in the world.

The reliability of industrial geothermal direct heat supply to the Kawerau Industrial Complex is enabled by NTGA's continued investment in the upgrade and maintenance of its steamfield assets and the geothermal reservoir.

NTGA has the potential to increase its geothermal energy production from the Kawerau Geothermal Field, providing reliable and long-term energy supply to existing and future energy customers at the Kawerau Industrial Complex.

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