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Kawerau Geothermal Field – Making the Most of What We Have

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ABSTRACT

New Zealand's current level of geothermal energy production has the potential for expanded energy utilisation, especially in the area of industrial process heat. Increasing geothermal energy utilization efficiency has the potential to push geothermal energy even further ahead of other renewable energy types as the energy source of choice in the decarbonisation of the power and process industries in New Zealand. The current level of energy utilisation at the Kawerau Geothermal Field in New Zealand is analysed to identify potential for energy efficiency improvements. The prospect of additional geothermal energy benefits from separated geothermal water as part of a symbiotic New Zealand geothermal energy park is considered.

1. INTRODUCTION

The Kawerau Geothermal Field (KGF) is the northernmost developed geothermal field in the Taupo Volcanic Zone (TVZ) of New Zealand. The KGF covers an area of around 22 km^2 and produces from a liquid-dominated, alkali-chloride reservoir with fluid temperatures reaching up to 310 °C. The Pūtauaki volcano is the system's likely heat source, with geothermal fluid upflowing through the faults and fractures of the greywacke basement around the southern part of the field, 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 (Bignall and Milicich, 2012; Milicich et al., 2016)

The KGF supports industrial direct heat use of around 170 MWth (5.3 PJ/year) at the Kawerau Industrial Complex, the largest single location of industrial geothermal direct use in the world, and supports four geothermal field and power plant operators with a combined installed capacity of around 153 MWe (161 MWe including the back-pressure turbine at the Norske Skog paper mill). The Kawerau geothermal network configuration as of 2018 is shown in Figure 1, but this does not include the newly commissioned Te Ahi O Maui (TAOM) power plant.

The four geothermal field operators are as follows:

- Ngati Tuwharetoa Geothermal Assets Ltd. (NTGA) supplies geothermal energy for industrial direct heat use and power generation. NTGA supplies steam to Norske Skog for industrial process heat. Norske Skog uses a portion of this supply to operate an 8-MW back-pressure steam turbine to generate electricity for mill use. The exhaust steam is available as process steam for the mill. NTGA also owns and operates the 21-MW TOPP1 binary cycle power plant, purchased from Norske Skog.

- Mercury NZ operates the 100-MW Kawerau Geothermal Ltd (KGL) double-flash power plant using geothermal fluid from its own steamfield assets.

- Geothermal Development Ltd (GDL) operates the 8-MW GDL binary cycle power plant using geothermal fluid from KA24.

- Te Ahi O Maui (TAOM) operates the newly commissioned 24-MW TAOM binary cycle power plant using geothermal fluid from its own steamfield assets at the western part of the KGF.

The Kawerau geothermal operators utilize the geothermal resource within the parameters of their own resource consents (permits). The operators and the regional regulatory authority, the Bay of Plenty Regional Council (BOPRC), developed and subscribe to a joint Operational System Management Plan that aims to ensure the sustainable management and development of the Kawerau geothermal resource. While the Kawerau Geothermal Field is a sustainably managed reservoir, there is still potential for increased geothermal energy utilization through improved utilization efficiency.

In this paper, the KGF is used as an example to highlight the potential and the challenges for increased geothermal energy utilization in a developed geothermal field through improvements in energy utilization efficiency. Due to the scarcity of publicly available data, the energy values and efficiency estimates are to be treated as gross figures and are only meant to illustrate the opportunity.

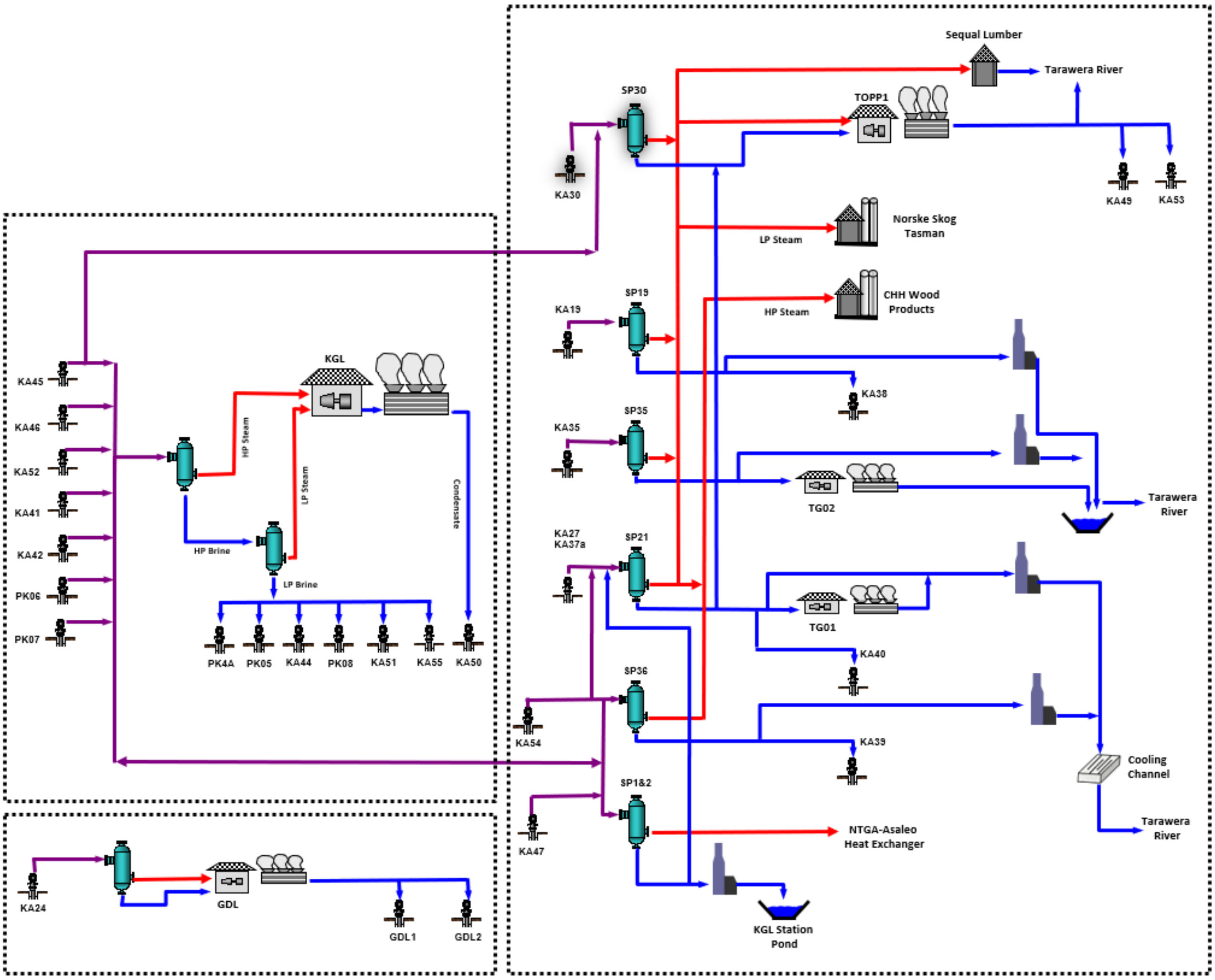

Figure 1. The geothermal energy supply and use at the Kawerau Geothermal System from the Kawerau System Management Plan (BOPRC, 2018). TAOM not included.

2. GEOTHERMAL ENERGY UTILIZATION AT THE KAWERAU GEOTHERMAL FIELD

2.1 Geothermal energy production

The total geothermal energy produced from the Kawerau Geothermal Field (KGF) was estimated using publicly available information on each of the geothermal operator's activities and resource consents.

The Kawerau System Management Plan (SMP) states that the combined field operators could abstract up to 174,680 tonnes/day of geothermal fluid from the KGF (Bay of Plenty Regional Council (BOPRC), 2018). In 2018, NTGA only utilized 54,600 tonnes/day out of a total resource consent to abstract 89,400 tonnes/day. Assuming the rest of the geothermal operators fully utilized their consented abstraction rates, this results in a field total of 139,880 tonnes/day.

Assuming a generic production enthalpy of 1200 kJ/kg, the total thermal energy that was produced from the KGF in 2018 is around 1,880 MWth/hour or 59.3 PJ/year. Of this total, at least 170 MWth or 5.3 PJ/year would be used for industrial process heat at the Kawerau Industrial Complex as reported by another paper in this congress (McClintock et al., 2020). The remaining 1,710 MWth would be used to generate around 161-168 MWe of electricity. These are summarized in Table 1 below.

Table 1. Estimate of geothermal energy produced from the Kawerau Geothermal Field

Total consented take, tonnes per day	174,680
Estimated actual take as of 2018, tonnes per day	139,880
Total geothermal energy produced (at 1200 kJ/kg), MWth	1,880
Energy for direct use, MWth	170
Energy for power generation, MWth	1,710

2.2 Geothermal energy utilization and gross efficiency

The gross energy utilization efficiency of the KGF is estimated as the ratio of the produced thermal energy utilized by the operators to the total produced thermal energy from the field. This ratio highlights whether there are opportunities for improving the field's utilization efficiency.

Out of the total estimated 1,880 MWth produced by the field, around 170 MWth of steam is used in the industrial complex as process heat. Steam condensate exits the complex at around 50 ºC and assuming all the steam supplied exits at this temperature, the geothermal direct use in Kawerau has a gross energy utilization efficiency of around 94%.

The remaining 1,710 MWth is available for power generation and supports around 161-168 MWe of electricity generation. According to the Kawerau System Management Plan, separated geothermal water from power plants in Kawerau is reinjected at an average temperature of 120 ºC. At this exit temperature, the gross energy utilization efficiency of the geothermal energy for power generation is around 57%.

The fraction of unutilized energy from the exit streams available for use is dependent on the refence temperature assumed. In this exercise, the 20 ºC ambient temperature was chosen. These results are summarized in the Table 2 below.

Table 2. Gross energy utilization efficiency and the estimated thermal energy currently unutilized at Kawerau.

Parameters	Totals	Utilized energy	Gross efficiency	'Available' energy above 20 ºC, MWth
Energy for direct use, MWth	170	157	93%	8
Energy for power generation, MWth	1,710	967	57%	619
Total geothermal energy produced (at 1200 kJ/kg), MWth	1,880	1,124	60%	627 (~20 PJ)

It should be noted that the direct use efficiency in the KGF example is high because the industrial complex is supplied geothermal steam for process heat and the exit stream is steam condensate. The gross energy utilization efficiency would be lower if the supply is two-phase or hot geothermal water.

3. OPPORTUNITY FOR INCREASED UTILIZATION AND IMPROVED EFFICIENCY

The ~ 20 PJ of 'available' thermal energy from the Kawerau Geothermal Field presents the opportunity for increased geothermal utilization efficiency from a single geothermal field. It is important to note that this 'available' energy is likely impractical or technically infeasible to achieve at present. However, even just recovering a fraction of this available energy is an opportunity worth exploring.

3.1 Option to utilize hot geothermal water for process heat (industrial and cascade uses) or power generation

At present, the separated geothermal water (SGW) produced from NTGA's two-phase separation plants are not utilized in the Kawerau Industrial Complex for process heat. The SGW used to support power generation from TG01 and TG02, with the latter's exit stream used in cascade to maintain the thermal characteristics of a geothermal lagoon and for use in hot bathing pools.

On the industrial process heat side, there is an opportunity to develop heat exchangers that could efficiently use hot geothermal water in the process industries. Hot water heat exchangers are already a fixture in binary cycle power plants and its extension to other process industries should be explored.

Additional power generation using hot water should be revisited either through more efficient binary cycle power plants or the improving technology of thermoelectric generators (TEGs).

The thermal energy is also available for further cascade uses, especially for lower-grade heating purposes.

3.2 Option to increase power generation efficiency by improving silica management

The gross energy utilization efficiency of the geothermal energy used for power generation could be improved if the range of temperature available for generation is able to be lowered from the current 120 ºC average.

As with other geothermal fields, silica scaling and the field's ability to manage or inhibit silica deposition limit the temperature range available for power generation. Resolving the silica deposition risk through cost-effective solutions around chemical inhibition or removal of silica presents a notable opportunity to increase the geothermal field's energy efficiency. Technologies that remove silica from the SGW currently being developed by organizations like Geo40 could provide opportunities for efficiency improvements while providing an alternative source of revenue.

4. GEOTHERMAL ENERGY EFFICIENCY FOR A LOW-CARBON ECONOMY

According to New Zealand's Ministry of Business, Innovation and Employment (MBIE, 2018), 82% of New Zealand's electricity supply was from renewable sources in 2017. Modelling and forecasts presented by New Zealand's Interim Climate Change Committee (ICCC, 2019) in their Electricity inquiry – Final Report estimates that by 2035, the renewable electricity generation would rise to 93% under a business-as-usual (BAU) scenario, with a recommended prioritization of an accelerated electrification of transport and process heat to reduce green-house gas (GHG) emissions rather than pursuing 100% renewable electricity.

Accelerated electrification and GHG emissions reduction in process heat are major opportunities for increased geothermal energy utilization, especially for geothermal fields like Kawerau where industrial complexes are co-located with geothermal power plants. Geothermal energy is already a mature and established renewable energy supplier to New Zealand's energy demand both in the electricity and in the process heat space (see Figure 2). The reliability and baseload characteristic of geothermal energy provides the necessary stability of supply unlike the weather-dependency of other renewable energy sources.

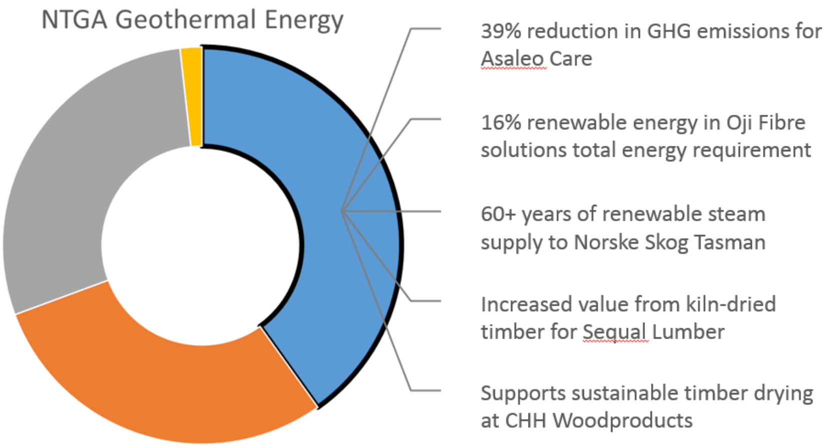

Figure 2. Geothermal process heat advantages, an example from NTGA at the Kawerau Geothermal Field

Operational geothermal fields should be the first to explore and review their gross energy utilization efficiencies to evaluate whether a significant portion of their 'available' thermal energy is able to be utilized either as process heat or additional power generation, with minimal modifications and interruptions to operations. An industry-wide effort to resolve technical limitations, especially around scale management, should be pursued to increase geothermal's energy utilization efficiency and keep geothermal competitive in a low-carbon future.

5. CONCLUSIONS

The global drive towards a low-carbon world presents a major opportunity for increased geothermal energy utilization, especially in operating geothermal fields. The Kawerau Geothermal Field (KGF) was used as an example to evaluate potential opportunities for increased geothermal energy utilization through efficiency improvements rather than increased geothermal fluid production. Based on this exercise, there is probably another 20 PJ of thermal energy available in the unutilized hot separated geothermal waters that is currently either reinjected or discharged at the surface.

Options to utilize this 20 PJ thermal energy includes power generation from binary cycle power plants or increased process heat utilization through efficient hot water heat exchangers. Another option to utilize the remaining thermal energy is to explore solutions to mitigate, inhibit or manage silica deposition in separated geothermal water and enable a wider temperature range for power generation.

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