Combining Low Grade Geothermal Heat with Heat Pumps, An Opportunity to Decarbonise Industrial Districts

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ABSTRACT

In Aotearoa New Zealand, district heating networks for commercial and industrial applications are notably scarce. Prominent examples, such as Kawerau and He Ahi, leverage site specific high-temperature geothermal resources to support industrial processes. However, the concept of shared thermal energy infrastructure is overlooked, despite its potential to offer significant economies of scale and cost efficiencies for businesses.

Low-grade geothermal heat is widely available across Aotearoa New Zealand but remains underutilised, partly due to perceptions of limited applications and its overshadowing by high-temperature systems primarily used for electricity generation. Recent advancements in industrial ground source heat pump (GSHP) technology are shifting this paradigm. Modern GSHPs can now deliver process heat at temperatures up to 160°C, with prototypes reaching 180°C and expectations of achieving 200°C within this decade. These developments position low-grade geothermal resources as viable and valuable for a broader range of industrial applications.

The high capital investment required for individual GSHP systems can be a barrier to adoption. This paper proposes that district scale low-grade geothermal infrastructure could mitigate these costs, thus maximising uptake and impact. There is opportunity for public investment in such infrastructure, as it supports the electric transition being promoted by the Government by reducing reliance on the national electricity grid, particularly during peak demand periods. A private model, where heat is supplied as a service to industrial customers, is equally viable and has been commercially implemented internationally.

This paper will explore regions where district geoheat presents the most compelling potential and examine the roles that both the geothermal community and government can play in facilitating its development.

1. BACKGROUND

District heating involves generating or accessing heat in a centralised location and then distributing it to residences, businesses and / or industry in a local area.

District heating networks offer great potential for efficient, cost-effective and flexible large-scale use of low-carbon energy for heating (IEA, 2025), with later generations now also including provisions for cooling too. Greater deployment of district heating networks can play a pivotal role in addressing climate change by enabling the widespread adoption of renewable energy sources (Dang et al, 2024). When utilising a local heat source, like geothermal, they also offer greater energy independence and security.

A number of district heating markets have seen increased dynamism recently, particularly in Europe. Since 2022, policy support for district heating has grown in response to energy security concerns sparked by the crisis following Russia's invasion of Ukraine.

Globally, there are many residential district schemes, however, 40% of the heat generated globally in district heating plants is consumed by industry (IEA, 2025). This paper's focus is on the opportunity for Aotearoa New Zealand industrial areas to collectively benefit from local heat sources, especially geothermal, in the form of a district heating and cooling network.

District schemes are not a feature of the New Zealand energy eco-system, however, a number of externalities are currently in play that mean the case for district schemes, especially for industry, is building. This includes gas supply constraints, energy price volatility, electricity grid constraints, national and international carbon taxes, and internal sustainability commitments.

According to the Ministry of Business Innovation and Energy (MBIE, 2022), process heat makes up one-third of Aotearoa New Zealand's overall energy use and contributes approximately 8% of gross emissions. 56% of process heat is supplied using fossil fuels, mainly gas and coal. Two-thirds of process heat is used for low (less than 100 °C) and medium (100-300 °C) temperature requirements (MBIE, 2022); highlighting the opportunity to switch more of these operators to low temperature geothermal.

The benefits of district heating schemes extend beyond direct benefit to industry. The United States Department of Energy highlight the national benefits, these include greater grid stability by reducing peak demand (enabled by aggregating loads and shifting peak demand with thermal energy storage), fewer natural gas peaking stations and lower transmission and distribution costs (US DoE, 2021).

In countries with less obvious and available geothermal resource than Aotearoa New Zealand's, significant investment in geothermal for district heating networks is underway. For example, the Aarhus district energy scheme in Denmark is in development to extract 60-80 °C hot geothermal water from 2-3km depth. The warm geothermal water is pumped up to the surface, where the heat is harvested and transferred to the water in the district heating network in a closed circuit, supplying critical baseload heating (Richter, 2022).

Internationally, innovation in district heating networks is currently pursuing several different avenues, such as exploring the integration of different heat sources (includes secondary heat sources like data centres, metro tunnels, industry, electrolysers, nuclear power plants) either directly or supported by heat pumps and storage systems (IEA, 2025).

The opportunity to innovate in Aotearoa New Zealand by utilising low temperature geothermal that is supported by heat pumps and storage systems, including consideration of additional waste heat sources, is the focus of the remainder of this paper.

2. DISTRICT ENERGY DEFINITIONS

The United States Department of Energy defines district energy as a "system that benefits its connected buildings by delivering high-efficiency heating and cooling services, providing fuel and technology flexibility brought on by economies of scale, and opening up additional productive space in the buildings themselves by eliminating individual boilers, chillers, and cooling towers" (US DoE, 2021).

Further classification of district systems has adopted numbered generations that have evolved over time, starting as early as the 1880s (Figure 1).

Generation	Heat Source	Temperatures	Pipeline material
First (1880s)	Coal and waste	Steam (>150 °C)	Concrete / steel
Second (1930s)	Coal, waste, and oil	Pressurised hot water (>100 °C)	Steel
Third (1970s)	Coal, waste, biomass, geothermal and solar	Pressurised hot water (< 100 °C)	Pre-insulated steel
Fourth (Current)	Mainly renewable energy	Hot water (< 80 °C)	Pre-insulated twin flexible plastic
Fifth (Current)	Low temperature water	Near ambient ground (< 45 °C)	Uninsulated plastic

Figure 1: Classification of district energy generations (Dang et al, 2024)

Ngāti Tūwharetoa Geothermal Assets' direct heat supply to industry in Kawerau aligns with the definition of First and Second Generation district heating schemes, however, noting it is a renewable source of low carbon heat. They supply "geothermal process steam at pressures of 7 to 16 bar, with around 2.8 GJ of thermal energy per tonne of steam. We also supply process water at a temperature of 170 °C (7 bar), with around 0.7 GJ of thermal energy per tonne of water" (Tūwharetoa Geothermal, 2025).

Utilising geothermal heat in this way has immense impact, however, it is location specific to high temperature geothermal zones like the Taupō Volcanic Zone (TVZ). Whereas Third, Fourth and Fifth Generation district schemes have wider applicability across Aotearoa New Zealand and are defined as follows.

2.2 Third Generation

Third Generation district heating systems use pressurised hot water as the heat carrier, with prefabricated insulated pipes buried under the ground to transfer the heat and hot water supplied at around 90 °C.

Low-temperature geothermal systems with resource temperatures between 90°C and 150°C do exist in parts of Aotearoa New Zealand. These resources are arguably less geographically constrained than the high-temperature systems of the TVZ and Ngawha. While there are currently no known district heating schemes in Aotearoa New Zealand operating within this temperature range, such geothermal systems could technically supply heat directly to a third-generation district heating network.

2.3 Fourth Generation

Fourth Generation district heating refers to advanced district energy systems that operate at low supply temperatures (typically less than 80°C), are highly energy efficient, and are designed to integrate a wide range of renewable and low-grade heat sources (e.g., geothermal, solar thermal, waste heat, and heat pumps).

To address significant heat losses in previous generation systems, Fourth Generation district schemes include excess heat utilisation, novel thermal storage solutions, decentralised components, and the integration of renewable energy sources such as geothermal (Dang et al 2024). However, these systems have some limitations. For example, it is currently not possible to use a single pipe to provide both heating and cooling services to buildings simultaneously (Dang et al 2024). To address this issue, the concept of Fifth Generation district heating and cooling has been introduced.

2.4 Fifth Generation

Fifth Generation does not represent sequential development following Fourth Generation; instead, both technologies are evolving concurrently. As a result, the two complement each other (Dang et al, 2024).

Fifth Generation is a highly innovative and integrated energy system providing superior efficient and sustainable heating and cooling solutions. It combines a set of advanced technologies, including centralised and decentralised heat pumps, large-scale thermal storage, smart grid systems, and thermal networks, to enable flexible energy generation, distribution, and utilisation. Unlike previous generations of district heating and cooling, Fifth Generation focuses on optimising energy efficiency and reducing carbon emissions (Dang et al, 2024).

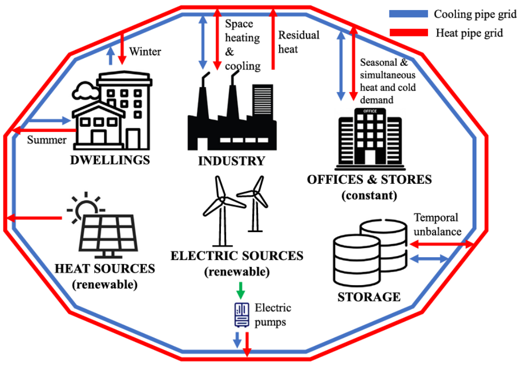

Figure 2: Schematic of a Fifth Generation district scheme showing multiple energy and heat sources, plus cooling. (Dang et al, 2024)

The low-temperature nature of Fifth Generation district energy offers several advantages, including minimal heat loss, reduced insulation costs, and the ability to utilise urban and industrial waste heat as well as various renewable heat sources, especially geothermal.

3. AOTEAROA NEW ZEALAND'S LOW TEMPERATURE GEOTHERMAL SYSTEMS

Geothermal water is designated by the Resource Management Act (RMA) as water with temperatures exceeding 30°C. The lower end of the geothermal spectrum (<150 °C) can be utilised for Third, Fourth and Fifth Generation district energy systems. However, geothermal development in Aotearoa New Zealand has been focused mainly on power generation in two regions of recent volcanism, the TVZ and Ngawha in Northland, where temperatures >300 °C were intersected by drilling (Reyes, 2015). The focus of this study are low-temperature regions in Aotearoa New Zealand, therefore outside the TVZ and Ngawha which most often feature in geothermal discourse.

Thermal spring systems with lower temperature ranges and mass flows, occur in regions with Holocene arc-type (Taranaki), intraplate (Auckland) or pantelleritic (Mayor Island) volcanism; Miocene to Pleistocene volcanism in the Coromandel Peninsula; and hot mantle diapirism in parts of Northland and, possibly, in the Hauraki Rift Zone (Reyes, 2017). Thermal springs also occur in non-volcanic environments e.g., along the rapidly rising Southern Alps of the South Island and along the active forearc in the Hikurangi Accretionary Prism where hot aqueous solutions rapidly ascend (Reyes, 2017).

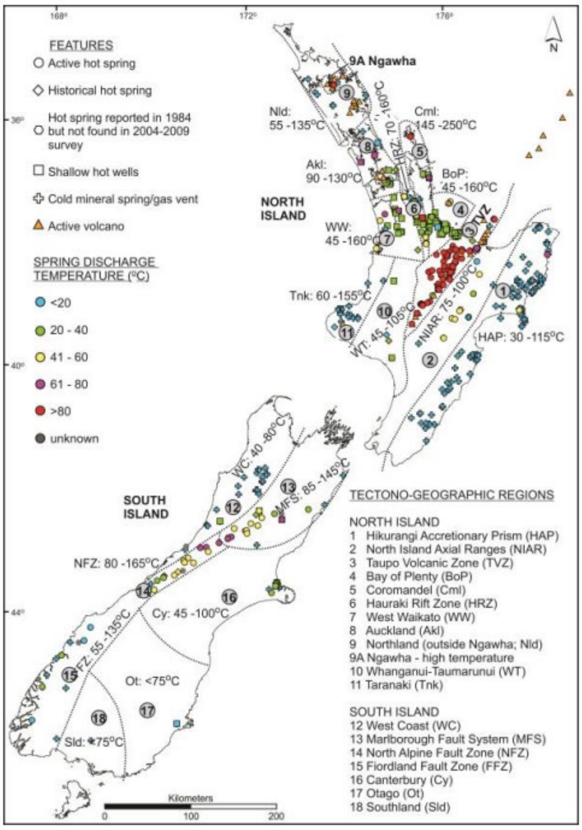

Figure 3: Map showing the distribution of springs and their discharge temperatures in the 18 major tectono-geographic regions of New Zealand and estimated median subsurface temperatures for each region, except the TVZ (3) and Ngawha (9A) which are a high-temperature geothermal regions (Reyes, 2017)

Accessing low-temperature geothermal heat (15–80 °C) for Fourth and Fifth Generation district schemes is particularly feasible in Aotearoa New Zealand due to its favourable geological setting. In regions like the western Bay of Plenty and the Hauraki Plains, >30 °C can be accessed at relatively shallow depths. For example, the Tauranga Geothermal System (TGS) has a maximum recorded temperature of 70 °C at approximately 700 meters (GeoExchange NZ, 2024). However, 77°C was recorded at a depth of ~330 meters near Te Puke soon after the GeoExchange NZ, 2024 reference (BOPRC pers com 2024). This stands in contrast to many European systems, where similar temperatures require deep drilling to 2–3 km and beyond, significantly increasing capital costs.

In the TGS, notably high gradient increases have been observed, ranging from 4 to 22.5 °C per 100 meters when descending from the surface. It is these high gradients, attributed to residual heat from past tectonic and magmatic activities, that provide the notably elevated near subsurface temperatures (GeoExchange NZ, 2024). Where enhanced heatflow is observed, high vertical permeability, due to either fracturing or faulting is the likely cause (Simpson, 1987). This natural advantage positions Aotearoa New Zealand to develop cost-effective, low-carbon district energy networks that align with Fourth and Fifth Generation principles — integrating renewable heat, operating at lower temperatures, and being compatible with future-ready infrastructure.

4. HEAT PUMP TECHNOLOGY

The integration of heat pumps in district networks is not new, but it is playing an increasingly important role to decarbonise these systems and to enable sector coupling. In addition to a geothermal resource, heat pumps can harvest waste heat from sources such as water bodies, data centres, metro tunnels, industrial facilities or electrolysers (IEA, 2025)

Heat pumps are used when the temperatures required for the heating or cooling application are not matched by the geothermal resource. For example, a 50 °C geothermal resource may be used i) directly to heat a swimming pool or hot spring and / or ii) indirectly with a heat pump to boost to 80 °C for a hot water process or to 120 °C for a steam application.

Industrial heat pumps can provide energy at temperature levels of up to 160°C. Prototypes are operating at around 180°C and industry experts expect temperatures of 200°C and beyond in this decade (EHPA, 2024).

They can be located within the system, either in a central energy plant such that hot or chilled water is pumped around the network, or in a distributed manner at each building such that the heat or cool is only created where and when required.

They are especially of value when the geothermal resource is at ambient conditions which enables cooling to more readily be a product of the system.

5. STRATEGIC RELEVANCE TO AOTEAROA NEW ZEALAND

In January 2024, MBIE estimated Aotearoa New Zealand had about 8.5 years worth of gas reserves (1,300 petajoules) at 2023 rates of consumption (MBIE, 2024), but analysis of current consumption rates with most recent reserve forecasts, suggest the figure is more likely 5.5 years (MBIE a, 2025). Gas shortages, coupled with soaring prices, have sparked warnings from both the Electricity Authority (EA) and the Gas Industry Company (GIC). As the country braces for increased demand, the risk of energy disruptions looms larger (B2B News, 2025). Transitioning to affordable, sustainable and secure energy supply is now a matter of operational viability.

As Aotearoa New Zealand's gas supply declines, discussions around renewable fuel alternatives for industry have tended to focus on biofuels, biomass, and electrification via air source heat pumps or electric boilers. However, there is growing recognition of geothermal heat as a viable option outside of its most known applications within the TVZ. For example, in July 2025 MBIE released a draft geothermal strategy, ‘From the Ground Up’ that proposes a doubling of geothermal energy use by 2040 (MBIE b., 2025).

While limited awareness has historically been a barrier to uptake, this is now being addressed through advocacy and guidance. A more significant barrier, however, is the high upfront capital cost of geothermal system development. This is why this paper proposes district energy models, which enable economies of scale by spreading infrastructure costs across multiple users. Typically, these systems are owned and operated by a heat utility, with energy delivered through a heat-as-a-service model.

Shifting to district systems not only improves the economic viability of geothermal heat, but also ensures more sustainable and efficient use of the resource, delivering broader impact by transitioning multiple businesses simultaneously to renewable heat sources.

Modern high-efficiency district energy systems combine district heating and cooling with elements such as central heating plants (CHP), thermal storage, geothermal heat pumps, deep lake cooling, and local microgrids. According to the US Department of Energy, CHP’s can deliver electricity and thermal energy services at overall efficiencies of 65% to 80%, an improvement over the national average of 51% for these services when provided separately by central station power generation and on-site boilers. Aggregating the thermal and electricity loads across multiple sites leads to an economy of scale, thereby bringing benefits to energy users that may not have had sufficient heating or cooling loads to implement this technology on their own. (US DoE, 2021).

Once our gas reserves end, Aotearoa New Zealand - as an isolated island nation - will be exposed to the supply risks of importing natural gas (natural disaster and geopolitical risks). Therefore, greater utilisation of local heat sources, like geothermal, contributes to greater energy security and resilience.

District heat networks have exceptionally high reliability, often providing electricity and thermal energy (both heating and cooling), even during unexpected grid outages. For example, a 48 MW district energy CHP system provides resilient electricity, chilled water, and steam to 18 healthcare facilities on the Texas Medical Center campus in Houston, Texas. This system was able to continue operating during Hurricane Harvey and its aftermath in 2017, allowing the campus to meet patients’ needs during the storm (US DoE, 2021). Such security and resilience is essential in a warming climate.

6. POTENTIAL APPLICATIONS IN AOTEAROA NEW ZEALAND

6.1 Christchurch

Christchurch city overlies a series of confined aquifers ranging in depths from 5 m to greater than 200 m. These aquifers are highly productive, with yields in excess of 100 L/s possible from a single well (Seward et al, 2017). Due to these flowrates, the capital cost per kilowatt of thermal energy delivered from GSHP infrastructure is significantly lower than in other parts of the developed world. Groundwater temperatures remain within the 12-13°C range providing an ideal source for heating and cooling (Seward et al, 2017).

As the city looked to rebuild itself after the 2011 earthquakes, one option considered was to provide electrical energy, heating and cooling to the city center as a district energy scheme, with a centralised plant fueled by sustainable energy sources. A network of pipes would then transport the energy from the plant into buildings around the city, enabling owners to dispense with their own plant and the associated space requirements. But, the process for developing this centralised system was too lengthy given the business and government drivers for rebuilding Christchurch and ultimately did not eventuate (Seward et al, 2017). The Justice Precinct, comprising of three commercial buildings, did proceed with connecting to a central 3MW GSHP system (Seward et al, 2017).

The nature of the geological conditions in Christchurch are favourable for a Fifth Generation district energy scheme. Open loop systems would supply ambient temperature groundwater to each building and then heat pumps within each building would provide its heating, cooling and hot water requirements..

Due to the thermal source being shallow ambient groundwater, this is replicable across most of Aotearoa New Zealand.

6.2 Western Bay of Plenty

The Tauranga Geothermal System (TGS) covers an area of approximately 875 km^2 in the western Bay of Plenty, stretching from Waihi Beach in the north to Te Puke- Maketū in the south east. The TGS is a low-temperature geothermal system, with a maximum recorded temperature of approximately 77°C at a depth of ~330 meters (BOPRC pers com 2024).

In GeoExchange’s ‘The Geoheat Potential of the Tauranga Geothermal System’ report (2024), an assessment on the potential for district schemes was produced that was based on combining available geological data and regional growth plans.

Due to the relatively shallow and warm resources, assessments made for the region determined ‘good’ prospectivity in most future growth locations, this included Rangiuru, where a significant commercial / industrial greenfield development is underway. Rangiuru is in the southeast of the TGS, where the warmest known temperatures are located. This is a good candidate for a Fourth Generation district heating scheme, where industry could use the supply of 70 °C for base load heating or as the source for their industrial GSHP. The waste heat generated by industry could also be captured and provide additional heat supply to the district loop. Further, an absorption chiller could be used to supply chilled water.

The report also made a positive assessment for decarbonising industry in the Mount Maunganui industrial area. There is an existing concentration of heat users and due to the polluted airshed classification that already exists, industry cannot switch to biomass without strict particulate capture. Further to this, Transpower has announced significant electrical infrastructure upgrades are scheduled to account for anticipated electrification of Mount Maunganui industrial operations (Transpower, 2025).

However, this industrial area sits atop of known 50 °C groundwater at ~300 meters. The GeoExchange NZ report concluded that a system delivering this warm resource to heat users was viable (GeoExchange NZ, 2024). Such a system would provide sustainable, reliable and affordable heat to multiple users and if planning is coordinated strategically, this could reduce part of the required investment in electrical upgrades in the region.

6.3 Taranaki

Evidence of the subsurface temperatures in Taranaki's sedimentary basin are known due to the extensive oil and gas exploration that has occurred. The highest recorded temperature is 172 °C in central New Plymouth at 4.45 km deep. Which is consistent for a thermal gradient of 35 °C /Km for the region (Reyes, 2007).

These oil and gas wells serve two functions in regards to geoheat.- the first is it improves certainty of expected temperature ranges at certain depths, which derisks new drilling exercises for future direct use, including district schemes. The second is that the abandoned oil and gas wells can be repurposed and used to supply heat to district schemes.

Two abandoned wells (Bell Block 1 and 2) do exist in close proximity Bell Block industrial, which has light industry that would be suited to the 45-54 °C heat supply (Reyes, 2007). But it does also raise opportunity for new industrial zones in rural areas with abandoned wells. The repurposing of oil and gas wells is widely researched internationally, Are Ake are leading a consortium of researchers to look into the feasibility of this for the Taranaki region.

7. HOW MIGHT FOURTH AND FIFTH GENERATION DISTRICT SCHEMES BE IMPLEMENTED

The future of Fourth and Fifth Generation district schemes in Aotearoa New Zealand that leverage our abundant low-temperature geothermal resources is most likely to advance through the involvement of commercially motivated utility owners, however public sector support is required. Internationally, such systems are often owned by public utilities or developed through public–private partnerships. The majority of international examples of district energy schemes involve the public sector to some degree, whether it is with planning strategies, incentivising development, or in many cases, the public sector has partial or full ownership of the project (UN Environment Programme, 2016)

In the Aotearoa New Zealand context, iwi are well-positioned to lead the ownership and operation of these systems, particularly in regions with hot geothermal resources. The Tuwharetoa Geothermal energy park in Kawerau is a strong example of how government, the private sector, and iwi can collaborate over time to deliver a functioning district energy system.

The first geothermal wells at Kawerau were drilled by the New Zealand government in the 1950s to support industrial development, such as the Tasman Pulp & Paper mill and early electricity generation; these initial bores were later deepened by the Ministry of Works in the 1960s to sustain production, and while the assets were originally Crown-owned, they were transferred to Mighty River Power in 2005 as part of a Treaty settlement before being sold to Ngāti Tūwharetoa Geothermal Assets (NZGA, 2025)

Policy levers are another effective way to incentivise this type of development. In the United Kingdom, in March 2023, the Energy Security Bill introduced a heat networks regulation to enable heat zoning. It's a government-led planning tool designed to identify areas where low-carbon heat networks (like district heating) are likely to be the most cost-effective and beneficial. The Climate Change Committee has estimated that around 18% of heat consumption in the United Kingdom could be supplied through heat networks by 2050 (IEA, 2025).

National heat plans can support policy implementation, and many countries are starting to follow this practice. For instance, in February 2022, the Sustainable Energy Authority of Ireland published a National Heat Study looking at 2050 opportunities for district heating, and Germany is discussing a Heat Planning Act. (IEA, 2025) Combining such heat demand mapping exercises with known low temperature geothermal resources in Aotearoa New Zealand, would also unlock the opportunity.

8. CONCLUSION

District geoheat systems represent a strategic opportunity for Aotearoa New Zealand's transition to a low-emissions economy. While high-temperature geothermal resources have long supported industrial heat applications in a district system at Kawerau, the potential of low temperature geothermal resources remains underexploited. Advances in GSHP technologies now make it feasible to deliver process heat at commercially relevant temperatures using low-grade geothermal sources, offering a scalable, flexible alternative for decarbonising industrial heat.

This paper has highlighted the viability of integrating low temperature geothermal energy into Fourth and Fifth Generation district networks. Such schemes can significantly reduce upfront costs through shared infrastructure while enhancing energy resilience and grid independence. Public or private ownership models are both viable, and international precedents demonstrate the commercial potential of heat-as-a-service business models.

Three locations were examined to illustrate the range of opportunities available in Aotearoa New Zealand. Christchurch demonstrates the potential to use the shallow, ambient groundwater with GSHPs within an urban context. In the Western Bay of Plenty, the TGS has temperatures ranging from 30 – 77 °C at relatively shallow depths in some commercially strategic locations. Meanwhile, in Taranaki, abandoned oil and gas wells present a unique opportunity to access deep, warm geothermal reservoirs without the need for new exploration. Together, these case studies reflect conditions that are representative of many other regions across the country.

These findings underscore the strategic value of district geoheat systems in unlocking underutilised renewable resources, promoting industrial decarbonisation, and supporting regional development across Aotearoa New Zealand.

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