DISTRICT HEATING SCHEME CASE STUDY, TAUPŌ, NEW ZEALAND

Celia Wells[1], Smrithi Talwar [1], Phil Glassey[1] and Anya Seward[2]

[1]First Affiliation with full contact address and country name

[2] Second Affiliation with full contact address and country name

c.wells@gns.cri.nz

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ABSTRACT

Research from Europe demonstrates the multi-faceted benefits for society from investing in district heating schemes. The technology provides reliable heating and cooling that has proven positive impacts on health and wellbeing. As the source of energy is the earth as opposed to an electricity provider, it addresses growing energy poverty hardship as there are minimal running costs to maintain a high level of comfort year-round. The reduced burden on the electricity grid also contributes to the government's sdecarbonisation and 100% renewable electricity generation targets by reducing the overall total of how much is produced.

A GNS facilitated a workshop in Taupō in July 2021 will explore the opportunities and barriers for investing in residential heating technology in New Zealand. A wide range of stakeholders were invited to the discussions: central and local government, iwi, engineers, developers and green finance. Discussions centred around an actual case study (a 2,200 lot subdivision and retirement village in Taupō), but the technology discussed is scalable and replicable across New Zealand.

This paper will summarise the workshop findings and analyse the barriers and opportunities to extending this initiative to other parts of the country.

1. WHY CONSIDER DISTRICT HEATING SCHEMES FOR TAUPŌ

1.1 Strategic alignment with Taupō District Plan

In mid-2020, GNS Science was engaged by Taupō District Council to investigate geothermal opportunities that could contribute to their vision for Taupō "to be the most prosperous and livable District in the North Island by 2022."[1] GNS' research, and consequent report, highlighted that geothermal energy is an important factor in shaping the district's character and could play a role in enabling the "compact, adaptable and vibrant communities" the council sought. GNS recommended that council should look to embed "longer-term planning around geothermal / ground source energy use" into their planning to achieve societal benefits. Elsewhere in the world, geothermal direct use has resulted in significantly lower power bills[2]and therefore sincentivises households to move toward warm and dry homes that are known to result in improved health outcomes for families.

Following this report, Amplify Taupō invited GNS to host a workshop at Geothermal Weeks on district heating. The workshop brief was to identify the barriers and opportunities for geothermal / ground source energy use in Taupō by discussing a feasibility study for a 2,200 lot development in Taupō.

1.2 Climate

Taupō has an oceanic or marine climate in accordance with the Koppen classification providing cool winters and mild summers. Average maximum temperatures range from 11C in July through to 22.7C in January for an average maximum of 16.9C. With respect to a DTES, the climate conditions indicate a dominant heating system with a minimal requirement for cooling in residential dwellings.

1.2.1 Social Benefits

In May 2021, the University of Auckland's "Growing up in New Zealand" longitudinal study collaborated with BRANZ to capture the indoor temperatures of New Zealand homes. The study presents initial evidence for an ideal minimum (19 degrees C) and maximum (Humidex=28) indoor climate range for soptimising child and health and wellbeing (Morton et al 2021). It also demonstrates that young children are more likely to be exposed to poorer indoor climate conditions if their families are living in poverty (ibid, at page 54). 2,000 of the study's participants surveyed their indoor temperatures and found that "60 per cent lived in homes with temperatures and humidity levels outside of the World Health Organization recommended range. More than half of those

[1] Great Lake Taupo. *Taupo 2050.* District Plan reporting found online here: Taupo District 2050 District Growth Management Strategy.pdf (taupodc.govt.nz). Accessed 2021.

[2] Richer, A. *Geothermal energy giving Iceland lowest heating costs in the Nordics*. ThinkGeoEnergy - Geothermal Energy News. Found online here: https://www.thinkgeoenergy.com/geothermal-energy-giving-iceland-lowest-heating-costs-in-the-nordics/. Accessed 2021.

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children slept in rooms that were too cold, and reported poorer overall health." Cold, damp homes contribute to worsening respiratory illness, and in New Zealand, Māori children are hospitalised with asthma at twice the rate of non-Māori children.[3]

These findings are widely reported in New Zealand and are an indictment on years of underinvestment in quality housing, something the current government has committed to reversing. The health statistics related to cold and damp homes for Taupō are reflective of the cold, damp climate, but also poor housing and evident energy poverty; Taupō is placed second in the country for Asthma hospitalisations (0-14 years), lower respiratory tract infection hospitalisations (0-4) and chronic obstructive pulmonary disease hospitalisations (45+). [4]

2. FEASIBILITY DESKTOP REVIEW

2.1. Report Intention

GNS Science engaged GeoExchange Australia Pty Ltd (GXA) to conduct a desktop feasibility assessment for a proposed District Thermal Energy System (DTES) for the planned Taupō East Urban Lands development. Taupō East Urban Lands (pictured below) is council owned land earmarked in the district plan for 2,200 homes. The land is intended to be sold in stages to private developers, presently, the Village Neighbourhood Centre has been sold to developers.

The intention of the desktop feasibility is to assess whether renewable thermal energy (RTE) is an option as the energy source for the DTES and then to consider the suitability of various DTES models that could be applied to the site. The findings of this report were presented and debated at a workshop held in Taupō at the end of July 2021. The workshop and workshop participants are detailed in section 3.

2.2 Taupō East Development, Taupō District Plan, 2050

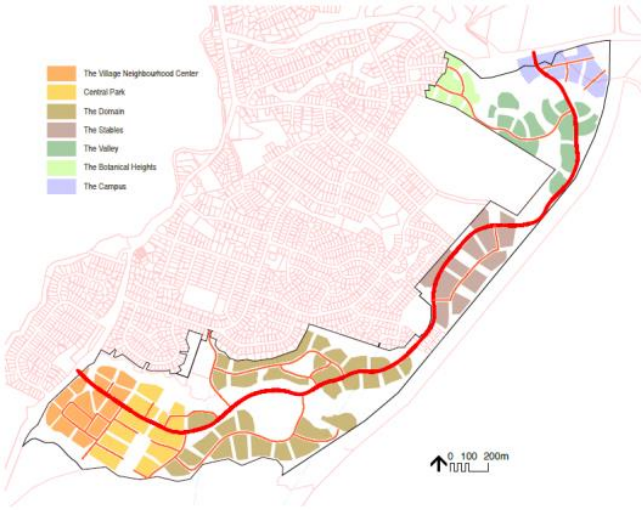

Figure 1: Master plan development area is approximately 674 100 m2 and runs approximately northeast to southwest for approximately 4 km and up to 1.2 km across at its widest point

2.3 Report findings:

Climate data for the project site indicates a heating dominant climate. Although the historical climate data indicates that cooling may not be necessary, especially in residential dwellings, future climate scenarios indicate that cooling should be available to all buildings across the development and has therefore been included in all models.

The investigation identified the potential for the use of shallow ground and groundwater temperatures in the 15 to 30 °C range, increasing towards 50 °C towards the north of the site. This could be utilised as a source of RTE. With respect to the design of a DTES, these geothermally enhanced temperatures will provide higher heating efficiencies and lower cooling efficiencies. It may also

[3] University of Auckland, Growing Up in New Zealand. *Children "Scientists" in world-first study looking at health and indoor climate.* Report found online here: https://www.growingup.co.nz/Children-scientists-in-world-first-study-looking-at-health-and-indoor-climate. Accessed 2021.

[4]Massey University, Health Space: Puna Ora. Statistics found online here: https://healthspace.ac.nz/health-topics/health-status/. Accessed 2021.

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mean that direct heat transfer (via heat exchanger) is possible for heating towards the north of the site, potentially negating the need for heat pumps.

In addition to the potential for RTE to be sourced from (geothermally enhanced) ground and groundwater, Lake Taupō also provides significant potential as a thermal source.

The engineer and report authors acknowledge that ownership of Taupō waters was vested in the Tūwharetoa Māori Trust Board, on behalf of Ngāti Tūwharetoa under a Deed with the Crown in 2007.[5] Therefore, ideas presented here in regards to using the lake in an open or closed-loop system are for discussion only. Using Lake Taupō as an open or closed-loop system

A closed water loop is an option when a suitable water body is located nearby. The minimum requirements for a suitable water body are a minimum water depth of two metres and sufficient water volume to accommodate the load to be applied. Lake Taupō could be utilised as either a closed or open loop system and would require lake access through the existing township;

Figure 2: Open loop using a body of water such as a lake

An open-loop DTES using Lake Taupō provides a lower cost and higher efficiency DTES than a closed-loop system. An open loop system could be potentially incorporated with the town water supply as it also extracts from the lake. It is noted that Lake Taupō is the water source for the township, and as such, there is significant local experience with extracting water from the lake for human utility. Compared to water supply, the difference with a DTES is that the water is extracted, utilised for heat exchange, and returned to the lake. There is no chemical treatment, and the only modification to the water is a small change in temperature.

Accessing the shallow groundwater within the Oruanui Formation

Although groundwater depths, yields and temperatures (noting the deeper geothermal influence) vary across the site, the shallow groundwater has good potential for a DTES. This would be achieved via a network of paired open loops at depths of around 50m that would each serve their immediate area with some interconnectivity to assist with redundancy. Direct heat exchange (i.e. without a heat pump) has not been considered at this stage as the maximum temperatures are expected to be in the 40-50C range. While such temperatures are typical in an underfloor heating system, they are not sufficiently high for direct use in a DTES. Noting that higher temperatures than this would be required for radiators and hot water systems.

Figure 3: Paired boreholes to a nominal depth of 50m

Shallow groundwater in the Oruanui Formation underlying the development ranges in temperature from ~15 to 20C at the south of the site up to ~50C towards the north of the development.

[5] Tuwharetoa Maori Trust Board. Information found online here: https://www.tuwharetoa.co.nz/commercial-operations-and-events/. Accessed 2021.

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These geothermally enhanced groundwater temperatures are unique to the area and are the result of proximity to the Tauhara Geothermal Zone that is associated with local geothermal energy generation. The assessment indicates that it is possible to access these enhanced temperatures without compromising the local geothermal energy system. This will need to be verified through further investigation and consultation.

Accessing this shallow groundwater through a network of paired boreholes to a nominal depth of 50m provides both the lowest cost source of RTE as well as the highest system efficiencies.

Pending the recommended investigations and consultations, the geothermally enhanced shallow groundwater within the Oruanui Formation provides the greatest potential for a viable DTES for the proposed development. The geothermally enhanced temperatures present are not sufficiently high for direct heat exchange, and as such, heat pumps will be required on the DTES. Heat pumps are to be located on a per building basis and would replace conventional air sourced heat pumps;

The DTES will provide up to a 51 % reduction in annual electricity use across the development, which equates to $2210 per annum at the household level and approximately $4 million at the development scale. In terms of maximum electrical demand (EMD), the DTES provides up to a 44% reduction. This has the potential to reduce electrical infrastructure such as substations and transformers across the development.

Financial estimates

As the CAPEX estimates relate to the cost of the DTES, they would be initially borne by the system installer and not by the individual building owner. Capex estimates are for comparative purposes only and address only the DTES and not the heat pumps or building services.

Table 7: CAPEX Estimates for DTES Options

Scenario	Thermal Capacity (kW)	Lake: Closed Loop	Lake: Open Loop	Groundwater: Open Loop[1]
Single Dwelling	12	$23 760	$11 760	$8700
The Village Neighbourhood Centre	3100	$6 138 000	$3 038 000	$2 247 500
Central Park	3700	$7 326 000	$3 626 000	$2 682 500
The Domain	6600	$13 068 000	$6 468 000	$4 785 000
The Stables	2800	$5 544 000	$2 744 000	$2 030 000
Botanical Heights	1100	$2 178 000	$1 078 000	$797 500
The Valley	2500	$4 950 000	$2 450 000	$1 812 500
The Campus	1800	$3 564 000	$1 764 000	$1 305 000
Total: Taupō East Development	21 600	$42 768 000	$21 168 000	$15 660 000
Note 1: Cost applicable to both temperature options				

An electricity cost of 33c kWh-1 has been adopted and amortised allowance is provided for service and replacement of conventional systems within a 20-year life cycle. It is important to note that the energy savings in this section are those that the system provides and are not those which would be realised by an individual building or homeowner. Rather, the energy savings would typically be distributed between the owner of the DTES and the homeowner. The exact ratio of the shared savings will depend on the model adopted for the operation of the DTES.

Table 11: OPEX Estimates and Savings for Option 5b - Open Groundwater Loop (20C)

Scenario	Thermal Capacity (kW)	Conventional System Cost	Option 5b Groundwater: Open Loop (20C)		
			Year 1 Cost	Savings	Payback (Years)
Single Dwelling	12	$4308	$2097	$2210	3.9
The Village Neighbourhood Centre	3100	$1 112 885	$541 849	$571 036	
Central Park	3700	$1 328 283	$646 723	$681 560	
The Domain	6600	$2 369 369	$1 153 614	$1 215 755	
The Stables	2800	$1 005 187	$489 412	$515 775	
Botanical Heights	1100	$394 895	$192 269	$202 626	
The Valley	2500	$897 488	$436 975	$460 513	
The Campus	1800	$646 192	$314 622	$331 570	
Total: Taupō East Development	**21 600**	**$7 754 298**	**$3 775 464**	**$3 978 834**	

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3. GEOTHERMAL WEEK WORKSHOP

3.1 Participation and agenda

The District Heating Workshop was an invite-only event. It was part of the busy Geothermal Week schedule organised by Amplify Taupō. The workshop was attended by 58 people, representing local iwi, Council, the Waikato Regional Council (WRC), EECA, commercial developers, drillers, energy companies and other interested participants from the community.

The first half of the morning workshop involved a scene-setting presentation from the University of Otago, Centre for Sustainability on energy poverty and distributed energy solutions in New Zealand, this was followed by Yale Cardin of GXE presenting an introduction to ground source heat pump technology and the findings of the desktop feasibility assessment for the Taupō East development.

After a morning tea break, the participants were required to actively participate in structured workshop activities and feedback to the wider group for discussion on why New Zealand would benefit from investment in district heating. Following the high-level analysis of 'why,' this is important, participants moved to groups that were of interest - or to which they had expertise in - and discussed the interest and viability of the presented case study and potential opportunities to overcome barriers to achieve a successful pilot installation.

3.2 Key discussions

Maori/ iwi partnership

The group discussion recommendations were firm on not just consulting Maori, but instead aspiring for co-management use of the resource. Incorporating a Maori world view of geothermal activity was also raised with one participant commenting, "therein lies the pathway to the future". The group had disparate opinions in relation to resource use. One person raised concerns on the possible use of lake water, whereas Maori trust land developers present commented that the 'case study was excellent and relevant to us as land developers (iwi)", the disparate opinions aired reinforced the requirement for engagement to ensure entire tribe support.

They requested leadership on such schemes and felt that policy should prioritise communities that live with, and on, the resource so it can benefit their communities, those contributing these views were generally from the Rotorua region and are considering direct geothermal use options. They urged for thorough due diligence on long-term ownership and management models before committing to district heating opportunities.

Economics/ Costing

The group discussing the economics provided more questions and scrutiny for discussion than answers, but considering that lower operating cost is sold as the opportunity and upfront capital cost is the main barrier identified, this feedback was somewhat expected. They were quick to point out that proof of concept is required for the desktop feasibility and was keen to question the rationale for 12kw home heating systems selected by the engineer. There was a sense that the return on investment was very attractive but required further analysis. They also explored different funding models for the $15M Capex, with community, government or private models, to be considered.

Regulatory/ consenting

One of the benefits highlighted by this group (which included WRC planners and councilors) is that a scentralised system is beneficial for resource use over ad-hoc individual systems that are close to each other. The engineer spoke at the ease in which pipes can run alongside other civil infrastructure and suggested road reserves could be used to run pipes, this group identified that road reserves don't easily classify as "utilities" (such as this) and it may overlap with multiple pieces of legislation. The group of experts were prepared to investigate to ensure this wasn't a regulatory barrier. They acknowledged that; "There's a lack of clarity in the minds of the community regarding resource use, resource management and the regulatory environment."

Enabling Business Systems

This group suggested that a beneficial next step would be to produce a business case and management plan for owning and running a district scheme as a utility or provide successful models from overseas. One participant commented, "There is huge potential here, with many people and groups wanting to be involved. We need a strategic plan with a project team, which is multi-functional with good/respected leadership, connected with strong networks." These comments reflect that New Zealand may not have the technical eco-system to easily make a district heating scheme happen, there should be technical and expert training provided to support those wanting to consider these schemes.

Social Engineering/ Behaviour Change

This group was supportive of these systems but could identify the barriers to New Zealanders adopting community facilities and also accepting a higher standard of home heating. There was a strong call for leadership "We must change our thinking from 'this might be a nice thing to do and visualise a better way of living. Our future grandchildren are relying on us" to "How do change and momentum occur?" and "We need leadership." They urged for more public education with examples of international district heating schemes to be shared so more could understand the larger social benefit.

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Environmental issues

The idea that this form of district heating supports the decarbonisation agenda was supported by this group, "Groundwater is not seasonal in the way that hydro is", but they warned caution as to whether it was truly sustainable use of resource and urged more investigation of the possible impact on the environment, especially surface features (feasibility study required on natural cycle and link to health of surface features) and possible land subsidence concerns.

4. POST WORKSHOP ANALYSIS

4. 1. Next steps and outcomes

The workshop has generated interest in the use of earth energy for home heating, and the following summarises some key outcomes:

- The majority of workshop participants indicated via feedback forms that they would like to remain involved as a group to continue discussing the opportunity for Taupō East development, but also for other district heating schemes in New Zealand, GNS will facilitate this group remaining in contact;
- Stage 1 of the Taupō East development, which is part of the case study used for discussion, has been sold to a developer, and they participated in the workshop. They have indicated an interest in the shallow open groundwater loop option and may possibly engage the engineer for a full feasibility design. If this were to go ahead, it provides excellent proof of concept opportunity;
- The General Manager of a Maori lands trust in Rotorua that was present and is managing a 5,000 home development has engaged with GNS Science to provide a similar feasibility report for direct geothermal use at their development;
- GNS Science is planning to relaunch the Ground Source Heat Pump Association NZ (GHANZ) in November 2021.

5. CONCLUSION

With wellbeing and climate change mitigation at the centre of current Government agendas, there is momentum to raise the standard of home heating and to invest in distributed renewable energy systems. However, district heating and ground source heat pumps are not widely considered for new developments in New Zealand. The purpose of the Taupō East feasibility study and workshop was to generate awareness but also to get a pulse reading as to whether Iwi, central and local government, and the general public would be interested in New Zealand investing in these schemes. The participants approved of higher standards of home heating that were renewable and affordable for the homeowner. However, the idea mostly remained conceptual with different opinions voiced as to who should lead a project like this but with no one taking ownership of it. The idea of community shared facilities for heating and cooling was foreign to New Zealanders, and some workshop participants wanted to see more examples of these types of schemes from overseas to prove the benefits. There is interest in a small proof of concept project at the Taupō East site, and the workshop has generated interest with developers in Rotorua and Queenstown. From here, GNS will continue to run educational workshops on the opportunity through the relaunch of GHANZ and are continuing to engage central government agencies.

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