Low-Temperature geothermal – a decarbonising solution for covered crop growers in New Zealand?

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ABSTRACT

Low-temperature geothermal energy can provide a low-carbon, energy efficient solution for low-temperature heat users in New Zealand. Many places in the world are already utilising their ambient and low-temperature geothermal resources for space heat and cooling, including residential and commercial buildings, district heating systems, retirement villages, schools, swimming pools, and greenhouses.

The Netherlands is a standout example of converting their greenhouses from using natural gas to utilising their natural deep 80°C water resources (located at ~2-3km depths). The Netherland has set a target of 43% of greenhouse heating to be sources by geothermal by 2030, removing more that 30PJ of natural gas combustion on an annual basis.

Many covered crop growers in New Zealand, are seeking means to decarbonise their operations and are investigating the potential of utilising geothermal for their heating needs. GNS Science is working with New Zealand's horticulture industry to investigate the potential of low-medium temperature geothermal resources to meet heating demands for covered crop growers. Initial work will focus on understanding the potential of ambient groundwater systems. These cool groundwater temperatures remain stable throughout the year, providing an ideal heat source for ground-source heat pump systems to convert to an optimum space heating temperature to distribute through the soil and air within the glasshouse. Other sources of stable low-grade temperatures include the natural thermal gradient of the shallow sediments and rocks, and surface water (including seawater, lakes and rivers).

This paper discusses the opportunities of using geothermal resources in New Zealand, for decarbonizing the horticulture industry.

1. INTRODUCTION

1.1 Covered crops in NZ

Covered cropping is an integral part of New Zealand's food system, enabling New Zealanders to access freshly grown vegetables from a local supplier throughout the year; provides resilience within the domestic food system; and is important for risk management at a national level.

There are approximately 256 hectares of covered / indoor crops in NZ, with a large amount located in the Auckland and Waikato regions, with some located on the South Island (Tasman, Marlborough and Canterbury). The horticulture industry in New Zealand has a value of >$6 billion per year, with crops grown for the domestic and international markets (HortNZ, 2021a). Tomatoes, capsicum, eggplant, cucumber, lettuce, chillies and herbs are the dominant crops grown in greenhouses, where stable temperatures and sunshine hours are important for growth.

Greenhouses are a highly efficient food production system, optimising the use of land, water, and nutrients. They utilise techniques including CO_2 enrichment, soilless cultivation and heating to maximise production of crop. Compared to outdoor production, greenhouses use less water and grow higher volumes for the same production area. For example, tomatoes grown in a high-tech greenhouse can produce 100 kg / m^2 yr, equal to 1,000 tons / ha yr. This is 10 - 20 times more than the production of any field-grown crop. In addition, the greenhouse crop will use four times less water than the outdoor crop (Futuristic farms, 2019).

1.2 Energy demand and current sources

EECA's Energy End Use database (https://www.eeca.govt.nz/insights/data-tools/energy-end-use-database) suggests that covered crops accounted for 9.7% of coal use and 4.3% of natural gas use amongst low and medium temperature heat users (e.g. using boiler systems for heating/cooling) in New Zealand, in 2019 (HortNZ, 2021). Heating has multiple functions that provide efficiency and quality in produce production. Space temperature regulates the rate of photosynthesis, budding, ripening and plant growth rate. Heating also allows for space conditioning, managing air humidity (which reduces onset and spread of disease, reducing demand for chemicals, and increase fruit quality). Space heating is also crucial for year-round growing. Seed germination, cutting production and growth are also temperature dependent.

A recent industry survey conducted by Tomatoes New Zealand and Vegetables NZ of their members indicated that the most common form of greenhouse heating is natural gas (62%), followed by coal (15%). The survey also highlighted regional differences in fuel source:

- Natural gas is limited to the mid and upper North Island (there is no reticulated gas network in the South Island).
- One large grower in Central North Island uses geothermal energy.
- Diesel/oil heating was found in all regions but is slightly more common in the South Island.
- Biomass was only being used in the South Island, but is the most commonly-considered alternative fuel.
- One small grower was using electricity to heat their greenhouse

Energy demands for covered crop growing vary depending on the location, climate, greenhouse, crop and other variables. Each hectare of covered crops may require ~10,000 GJ of renewable energy for heating in winter and

CO_2 production in summer. At 95% of 256ha of covered crops, this equates to 2,432,000 GJ energy demand without accounting for any sector growth.

The current energy cost for covered crops from either coal or natural gas ranges from $10-20/GJ – or $100,000 - $200,000 per Ha. The transition to renewable energy has a range of costs (including new capital demands) from $30/GJ to transition to wood fuels up to $50/GJ for direct electric heating, or 3x to 5x current energy costs. This will lift energy costs from $300,000 to $500,000 per Ha.

1.2 Alternative renewable energy sources

Currently growers have a range of renewable technologies available as alternatives to fossil fuels for generating heat in greenhouses.

The first option which is available for growers is biomass. The type of biomass used by growers is typically wood chip or wood pellets, and the type used depends on the size of the boiler. Larger boilers typically go for woodchip due to the high volumes required, while smaller applications will likely use wood pellets to reduce the storage and transport requirements. Biomass is also favorable for growers due to the ability to convert existing coal boilers to biomass relatively cheaply when compared to other fuel switching methods. The major disadvantage for biomass is the increased transport and storage requirements due to additional volume being required. The storage also needs to be enclosed as the biomass fuels need to remain dry, increasing the capital cost.

The other option growers consider for their sites is electrification, this comes in the form of either an electric boiler or an air-source heat pump. Electric boilers have low capital costs, but they have much higher ongoing operational costs as they don't obtain the high efficiencies available for air-source heat pumps. Air-Source heat pumps have the opposite problem where they can suffer from high capital costs depending on the size, while obtaining lower operating costs because of the high coefficient of performance (COP) of between 2 and 3. The main disadvantage of electrification which is limiting the uptake of these technologies is the infrastructure required for large scale electrification. Many growers have poor electricity infrastructure due to their location making power cuts a major problem for the site, while others will not have the capital available to upgrade their electrical infrastructure.

Switching fuel use from coal and natural gas to biomass and electricity requires further investigation and research on alternative fuel supply and technology availability by region and capacity. Electrification requires the building of more power stations to address supply constraints, and both electricity and hydrogen will require growers to write-off their investment in their current boilers. Biofuels could be used with modifications to existing boilers so these capital assets are better utilized. If electricity is used, then a back-up system is needed as growers cannot rely on electricity alone during times of peak loads (so a hybrid system will be needed).

Geothermal energy could provide an alternative for space conditioning of greenhouses. A variety of technology exists for accessing the subsurface heat and transforming it to useable heat. A match between operation demand and natural resource at site can be made through technology and engineering design. The major disadvantage for geothermal at the moment is that growers are not necessarily aware of the opportunities and are often daunted by the upfront costs and current lack of use, outside of one or two growers located within the geothermal regions. This is new to growers in New Zealand and they are seeking information regarding the opportunities. The following sections provide an overview of research being done to map and quantify different sources of geothermal heat throughout New Zealand, and a range of typical techniques that are commonly used to access the heat for use.

2. WHAT ARE THE OPTIONS FOR GEOTHERMAL HEATING OF GREENHOUSES IN NZ?

2.1 Overview of geothermal heat resources in NZ

Geothermal energy is any energy stored in or derived from the Earth. It is not limited to places with "hot ground", for example Taupo or Rotorua, but it is a resource available nationwide. It is derived from three major sources: (1) volcanic systems (e.g. the high temperature systems located within the Taupo Volcanic Zone), (2) stored energy from the sun (e.g. ambient ground temperatures stored in shallow rocks and soils), and (3) heat generated by radioactive decay within the Earth's Crust.

Figure 1 shows the locations of New Zealand's known high temperature geothermal systems. These systems are volcanic in origin and are in areas where high temperature fluids are present.

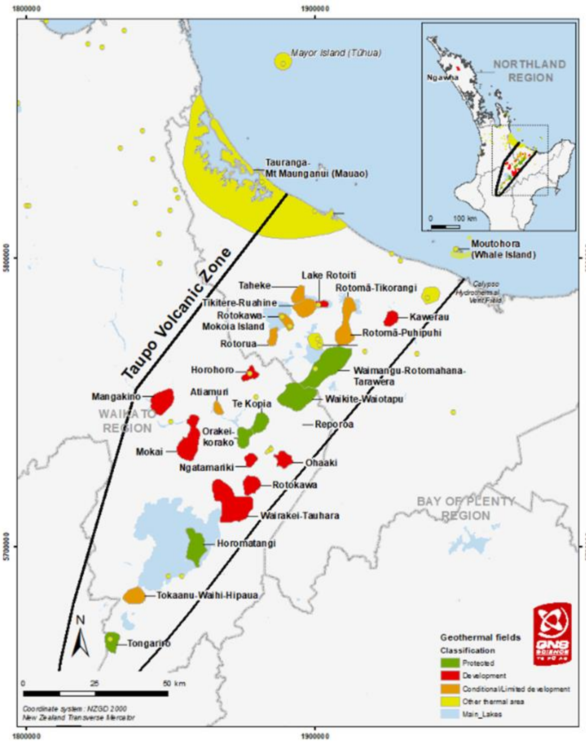

Figure 1: Locations of New Zealand's Volcanic-driven geothermal systems. Colours indicate the classification of use of each system, defined by the Waikato Regional Council and the Bay of Plenty Regional Council.

Figure 2 shows the average annual soil temperatures across New Zealand (Tait and Zheng, 2007). This provides an indication of the solar heat is stored in the shallow ground, which can be easily accessed and used for space heating and cooling of buildings and infrastructure.

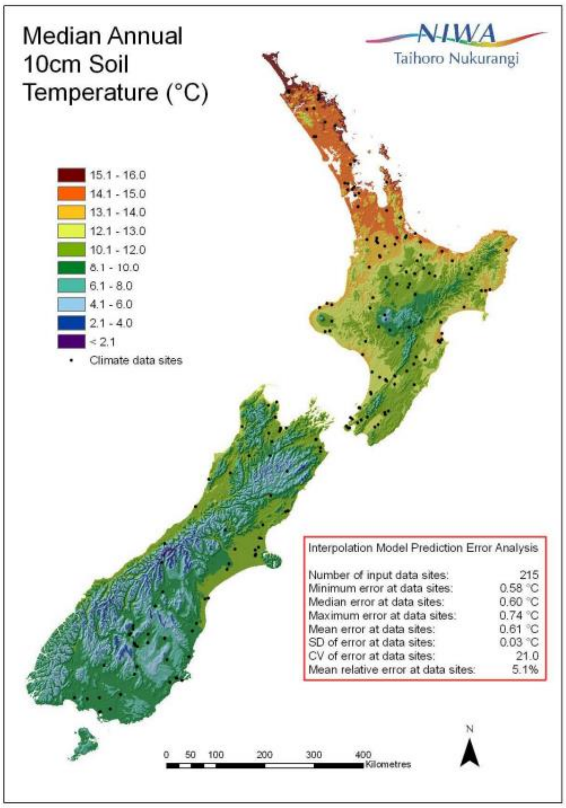

Figure 2: New Zealand's mean shallow soil temperatures (Tait and Zheng, 2007).

Figure 3 shows contoured estimated heat flow for New Zealand, based on temperature-depth profiles measured in accessible bores and wells (Funnell et al, in prep; Seward et al, 2023). Areas of higher heat flow are shown in red colours, and indicate areas where elevated ground-temperatures can likely be found at shallower depths. A heat flow model is currently being developed, which will provide better estimates of heat flow in areas where there are no measurements (see Kirkby et al, paper #47 (this volume)).

Additionally, heat is stored and transported through subsurface water. Figure 4 shows the catchment zones of large known aquifer systems beneath the North Island. Colours indicate permeability of the host rocks. The darker red colours indicate a better subsurface flow. This research is still ongoing with the hydrological unit map currently being developed for the South Island. These maps will then be combined with other datasets, including recharge rates, water flow, depth to water table and water temperature (where available).

Research efforts into modelling these various heat resources is complicated by New Zealand's dynamic and varying geology, and the temporally variability of non-conductive heat flow regimes. Efforts are being made to quantify the shallow, accessible low-temperature geothermal resources to provide useful information for potential end users and encourage smart, sustainable use of these natural renewable energy resources for heat and cooling purposes.

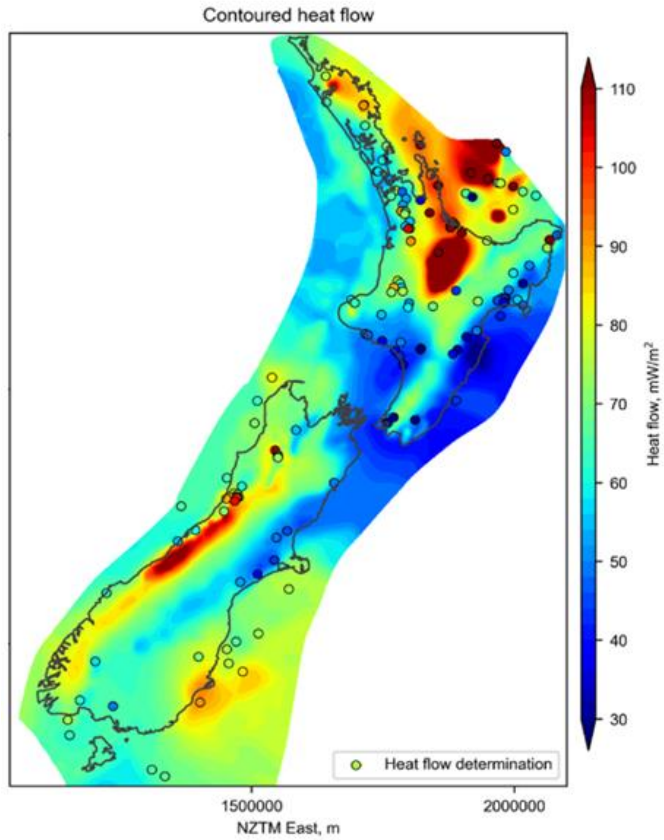

Figure 3: Estimated heat flow across New Zealand (Funnell, in prep., Seward et al, 2023)

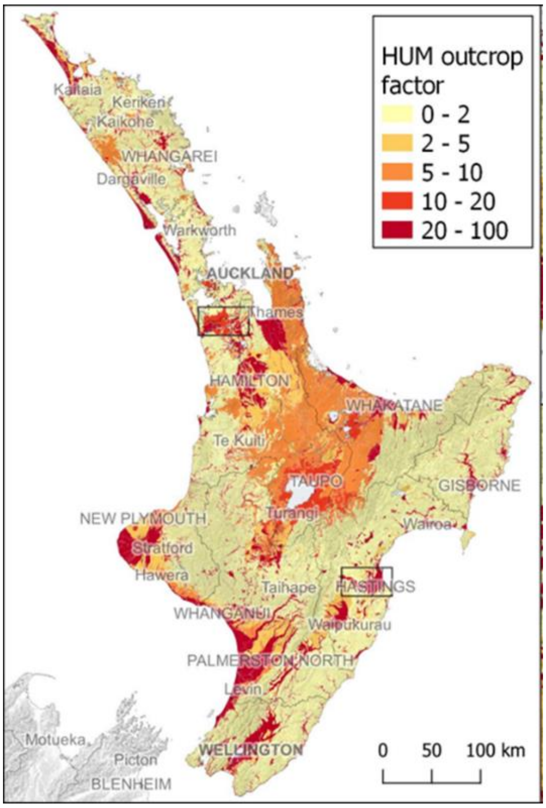

Figure 4: Maps of hydrological units. (Seward et al, 2023)

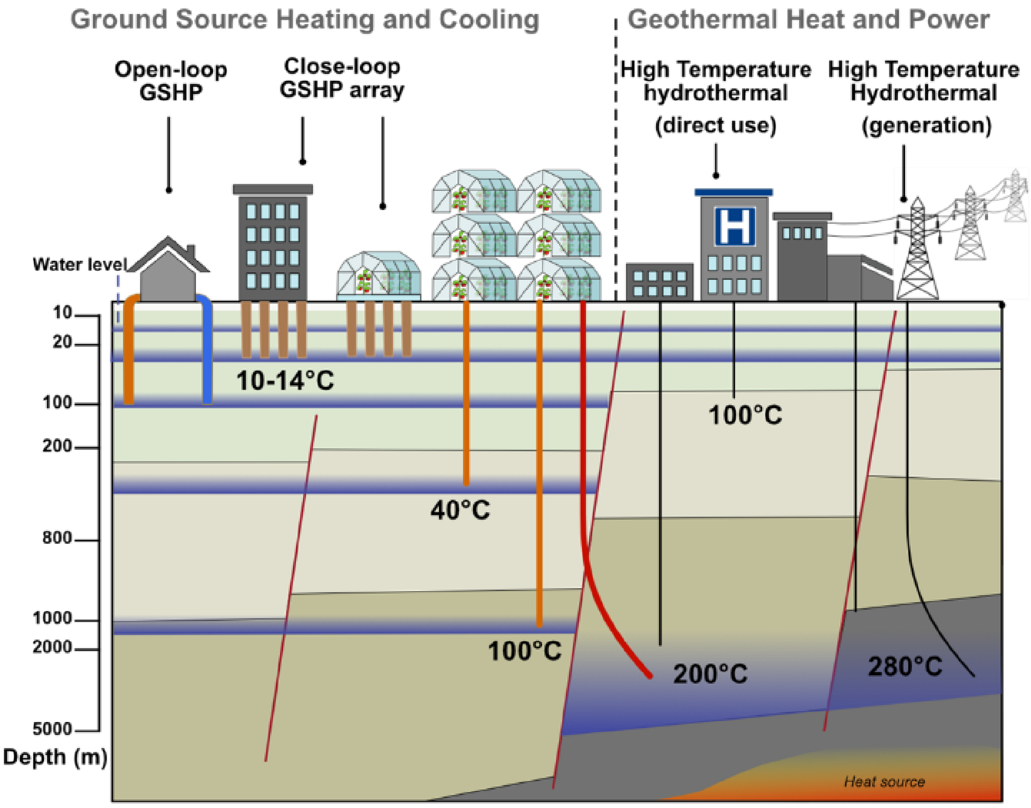

Figure 5: Illustration of subsurface heat sources and potential means for access and use.

2.2 Low-temperature geothermal technologies

There are several different ways to access and use geothermal resources. These include using the heat (or cool) directly or indirectly depending on the resource at a location and demand of the use (Figure 5). Indirect methods include accessing the subsurface heat and enhancing it to usable heat energy through ground-source heat pumps technologies. Direct methods include accessing low-temperature heat directly for heating.

Directly using subsurface can be achieved by either extracting fluids for use, or transferring the heat through a heat exchanger so that no fluid is extracted. Indirect heat use technologies include heat pumps / heat exchange technologies, where subsurface temperatures are enhanced to higher grade useable heat. These ground-source heat pumps (GSHP) or geo-exchange system harness the lower temperature geothermal energy stored in the soils, rocks and subsurface (or surface) waters, and enhances it for heating needs.

End-use demand can generally be met in most locations through good understanding of (1) the available resource, (2) demand needs and (3) smart design of ground loops and heat pump. Figures 6a and b, illustrate a couple of ground loop designs options, with 6a showing the layout of a series of shallow vertical closed-loop bores which have a working fluid circulated through the pipes absorbing heat from the soils, rocks and any subsurface water as is travels round the loop. Figure 6b show an open-loop systems where bores extract water from a subsurface aquifer.

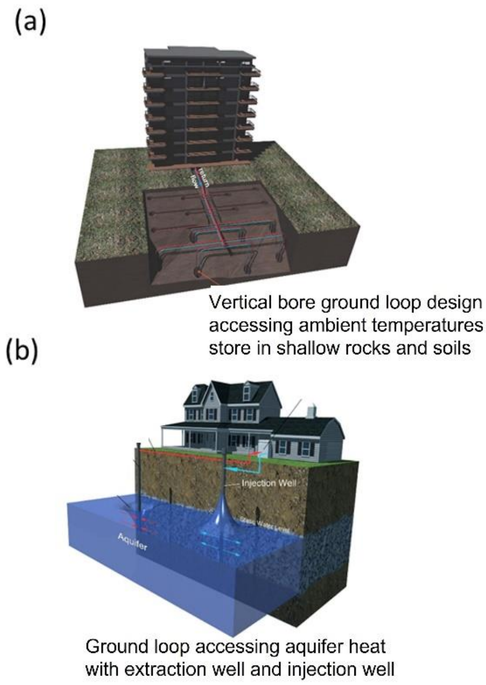

Figure 6: Illustrations of a couple of ground loop designs for heat pump systems. (a) shows a close loop system of vertical bores. (b) show an open-loop system where water is extracted from a subsurface bore.

GSHP systems can provide many benefits over other heating alternatives, including:

- Reduced operating costs due to high efficiencies in both heating and cooling modes
- No outdoor equipment which improves aesthetics and reduces maintenance costs
- Can also dehumidify
- No greenhouse gas emissions

Current barriers to uptake of heat pump technology are:

- The technology is relatively unknown in NZ
- High upfront costs
- Awareness of this technology as a clean, renewable energy

Additionally, awareness that geothermal heat exists outside of the Taupo Volcanic Zone and is an option for direct heat use is also relatively unknown, although users are become more aware of direct heat use as an option.

3. OVERSEAS TRANSISTIONS

Transitioning to a low-carbon future is a global task, with transitions to smart energy use being a focus globally. Several large, multi-national research programmes have been funded to better investigate the geothermal resources available for decarbonization efforts, through large research programmes such as those funded through Geothermica (www.geothermica.eu; e.g. GEOFOOD, GEO-URBA, HEATSTORE, and RESULT).

These programmes all focus on better understanding of the subsurface geothermal systems and clean energy use, and are not alone in their efforts. However, as well as, advances in mapping, modelling and understanding the resource, there needs to be support and drive from government. Two governments in Europe, who are supporting the efforts to decarbonize through geothermal energy use, are France and the Netherlands. Although neither are particularly known for the geothermal resources, both countries are leading the way in supporting and de-risking investment into the use of geothermal energy.

3.1 France

The French geothermal risk guarantee scheme is an established, successful model for dealing with risk associated with investing in geothermal. It has been adopted by the Dutch for horticulture and other sectors, by other countries in Europe, and is one of the recommended priority actions in the IRENA's 'Powering agri-food value chains with geothermal heat. A guidebook for policymakers' (IRENA, 2022).

The scheme has existed since the 1970s and was developed to address the geothermal risk quandary, that being a successful drilling project depends on the properties of the geothermal resource, but these are only known at the end of drilling work. Traditional insurance policies do not offer any specific solutions for this type of risk, and with no insurance for large capex projects, financial organisations are unlikely to invest (Bezelgues-Courtade and Jaudin, 2008).

The government run incentive and insurance scheme was based on a risk guarantee, drilling projects received 30% subsidy towards their project and the remaining 70% was provided as a loan. If a project was unsuccessful, developers were only accountable for 10% of their loan. The scheme is self-sufficient because successful drilling projects loan repayments paid for any drilling failures the government encountered (Boissavy, 2017). Thanks to the very low rate of failure in well-resourced regions (like the Paris Basin), wells entailing higher risks can be drilled in regions where little exploration has been conducted (Bezelgues-Courtade and Jaudin, 2008). The scheme has since evolved but the principles have been applied in many other European countries, with the model being so successful in some cases that private insurance have replicated the scheme.

Risk mitigation schemes and insurance programmes is one of the main policy instruments designed to attract investment to and facilitate the development of the geothermal direct-use projects, no such schemes exist in New Zealand and if included with heat tariffs or subsidy mechanisms, accelerated uptake in primary industries could be expected.

3.2 Netherlands

The Netherlands is the world's second largest exporter of agricultural products by value behind the United States (Reiley, 2021). Geographically they're similar in size to Canterbury and produce 20% of Europe's tomatoes, capsicums and cucumbers, all grown in covered crop facilities and predominantly heated by natural gas. The Netherlands faces an important task: CO_2-equivalent emissions (CO_2-eq) must be reduced by ~40% in 2030 compared to 2015, and by ~95% by 2050. This means not just 95% sustainable electricity, but also 95% sustainable heat. Around 40% of Dutch emissions are due to heat consumption, much from the agri-food sector (EBN 2019).

To address climate change targets and yet sustain existing industry, the Dutch horticulture industry has innovated by initiating a transition to geothermal direct use, in most cases drilling over 2km to access 70°C heat. Whilst capital investment is high, the reliable, low-cost energy supply is so attractive that the industry is targeting 65% conversion to geothermal energy by 2050 (Figure 7).

This is an ambitious strategy that the industry can not achieve on its own, this development has been supported up to now by the Ministry of Agriculture, Nature and Food Quality and LTO Glaskracht Nederland within the public/private partnership Kas Als Energiebron (EBN, 2019; Greenhouses as Energy Source).

One of the key deliverables to de-risk and communicate the opportunity has been mapping of subsurface resource by public scientific research institute, TNO. They created ThermoGIS which is a public, web-based geographic information system that displays the regional potential of geothermal energy in the Netherlands using a number of subsurface maps (https://www.thermogis.nl/en). The maps show what the achievable flow rate can be, but also the temperature of the production water, or the geothermal capacity. Finally, they indicate what, approximately, the costs are, compared to the price of grey energy. Other initiatives include access to subsidies, a government risk and insurance scheme similar to the French model, and favourable regulatory changes.

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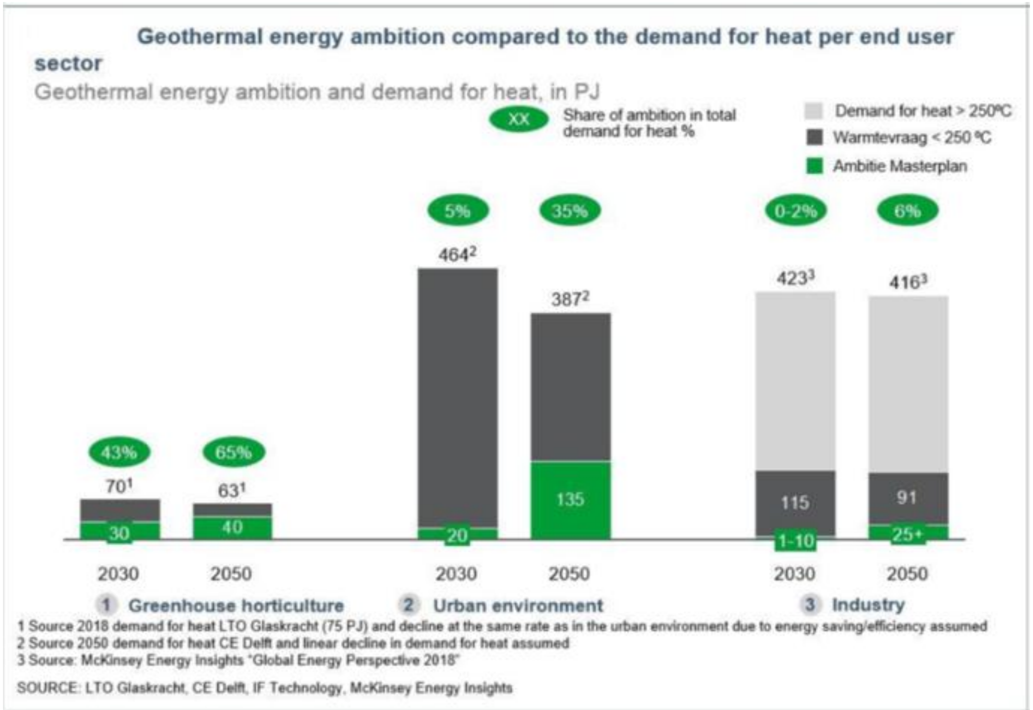

Figure 7 The Netherlands Geothermal energy ambition compared to the demand for heat per end use sector (Figure 4 from EBN, 2019).

4. SUMMARY

There is an increased need to seek sustainable, low-carbon energy sources for New Zealand's covered crop sector. Growers and their industry bodies are seeking better understanding of what geothermal resources are available and accessible to meet heating and cooling demands of their operations. Efforts are being made to better understand and delineate differing sources of heat throughout New Zealand to aid in decision making and awareness of the opportunities that different geothermal energy can provide.

Overseas nations are going through similar transition, with differing approaches and success rates. Global advances in understanding and mapping the geothermal heat resources and improving technology for accessing and transferring heat for use is being supported through large research and development funds, with additional incentives from government. France and the Netherland provide great examples of government initiatives and support to encourage uptake of geothermal heat. The Netherlands, in particular, have connected heat-users, geologists, technology specialists and funds to de-risk the uptake and transition from natural gas to geothermal with great success rates. They are on track to met the targets set of 40% reduction by 2030.

Overseas examples show that it is important for industry bodies, researchers and government to work together to support and incentivize efforts to decarbonize. Geothermal energy has great potential in New Zealand, inside and outside of the areas of high temperature systems to support the transition. This paper brings together research efforts focused on understanding our non-conventional geothermal resources, and end users needs. Efforts are now being made to bring the information together in a useful manner for end-user and decision makers to make smart, informed decisions regarding energy transition to renewable resources.

REFERENCES

Bezelgues-Courtade, S., and Jaudin, F., 2009. The French geothermal risk guarantee system. In Proceedings of Workshop on Geoligical risk insurance, World Bank Geothermal Energy Development Program (GOFUND), 11-12 November, 2008 Karlsruhe, Germany

Boissavy E.C., 2017, The Successful geothermal risk mitigation system in France from 1980 to 2015. European Geologist 43. The successful geothermal risk mitigation system in France from 1980 to 2015 - Eurogeologists

EBN, 2019. Master Plan Geothermal Energy in the Netherlands – A broad foundation for sustainable heat supply. Master Plan Geothermal Energy in the Netherlands - A broad foundation for sustainable heat supply - Energy.nl

Funnell, R. [in prep], New Zealand Heat Flow Data – North Island version. GNS Science Report

Futuristic farms, 2019. https://www.youtube.com/watch?v=KfB2sx9uCkI

HortNZ, 2021a. Submission on Climate Change Commission 2021 Draft Advice for Consultation, March 2021. https://www.hortnz.co.nz/assets/Environment/National-Env-Policy/Climate-Change/HortNZ-CCC-Advice-Submission-March-2021.pdf

HortNZ, 2021b. Submission on Phasing out fossil fuels in process heat, May 2021. www.hortnz.co.nz/assets/Environment/National-Env-Policy/Climate-Change/HortNZ-Submission-Phasing-out-process-heat-31-May-2021.pdf

IRENA, 2022. Powering agri-food value chains with geothermal heat: A guide book for policy makers. Interational Renewable Energy Agency, Abu Dhabi

Kirkby, A., Funnell, R., Scadden, P., Sagar, M., and Seward, A.M., *2023 this volume*, Towards a national temperature model for New Zealand, paper 47, In Proceedings of New Zealand Geothermal Workshop 2023

Reiley, L., 2021. Cutting-edge tech made this tiny country a major exporter of food, The Washington Post. Netherlands is the second-largest exporter of agricultural products - Washington Post

Seward, A.M., Kirkby, A., Funnell, R., Reyes, A., Carson, L., Pearson-Grant, S., Wells, C., White, P., and Taves, M., 2023, GRC Transactions vol 47, 2023

Tait A., and Zheng, X., 2007. Analysis of the Spatial Interpolation Error associated with Maps or median Annual Climate Variables, National Institute of Water and Atmosphere Research Ltd. 2007. https://niwa.co.nz/sites/niwa.co.nz/files/import/attachments/Climate_Maps_Error_Analysis.pdf