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Energy transition: the potential of geothermal energy use through industrial symbiosis in New Zealand

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ABSTRACT

New Zealand electricity generation is currently 82% renewable, however electricity represents only about 25% of consumer energy demand. Most of the other energy demand is used for transport and process heat sourced from fossil fuels. An opportunity to promote renewable energy use and reduce dependence on energy imports exists in primary processing industries.

This paper presents one outcome of the New Zealand government-funded "Wood Energy Industrial Symbiosis" project that focused on identifying New Zealand-wide opportunities. Industrial symbiosis engages traditionally separate industries, clustering in a collective approach, where wastes and by-products from one facility can become the raw material for another. Available energy resources are used to identify opportunities where industrial heat might be supplied from renewable geothermal and/or woody biomass energy sources. Woody biomass is widely available in New Zealand and under-utilised, and there is significant potential to increase the use of geothermal energy. Energy from geothermal can also free up wood processing residuals that might otherwise be burnt in a bio-mass boiler opening up other potential revenue streams.

Opportunities vary by region; based on the wood supply, existing wood processing demand, geothermal resource location and non-forestry industrial heat demand. Mapping the co-location of industrial heat consumers with these two energy sources identifies opportunities that can contribute to the renewable energy transition that is occurring in the New Zealand's process heat sector.

1. INTRODUCTION

New Zealand seeks to be an energy efficient, productive and low emissions economy in a context of increasing energy demand, increasing energy costs, substitution for CO_2 rich fuels, and changing social attitudes to energy use. One key aspect to achieving the proposed targets is to better utilize the natural energy resources available in the country and encourage growth of businesses in an integrated and more efficient manner. This paper focuses on the regional potential for industrial symbiosis involving major process heat users and renewable sources of energy, in particular woody biomass and geothermal energy (New Zealand government-funded project -Wood Energy Industrial Symbiosis – Aim 3).

Industrial Symbiosis is, by definition, the association between two or more industrial facilities in which wastes or byproducts become the raw material for another. Industrial symbiosis enables operating cost reductions whilst also providing opportunities for new businesses, economic growth and employment. The opportunity for New Zealand is: (i) to co-locate industries requiring and providing renewable heat energy, (ii) to improve process efficiency, (iii) generate economic benefit and (iv) increase the level of process heat produced from renewable energy as part of New Zealand's energy transition to a low carbon economy.

The nation's electricity generation is 82% renewable (MBIE, 2018), however electricity is only about a quarter of consumer energy demand (Figure 1). Most of the other energy used, mostly for transport and process heat, is sourced from fossil fuels such as oil, coal and gas. Around half of New Zealand greenhouse gas (GHG) emissions are directly due to the burning of fossils fuels. One of many opportunities to reduce New Zealand dependence on these fuels, meet our future energy needs and lower GHG emissions is through improving energy efficiency and switching to renewable heat sources in the industrial sector (Figure 1).

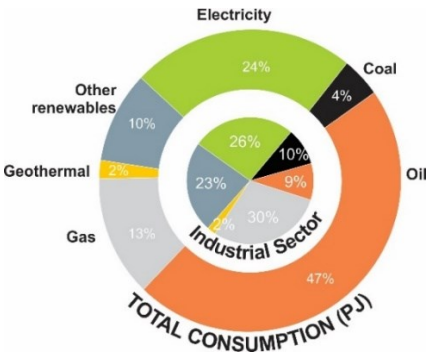

Figure 1: New Zealand total energy consumption, and energy consumption within the industrial sector, by fuel type as of 2017 (MBIE, 2018).

2. NEW ZEALAND NATURAL RESOURCES

New Zealand is rich in natural resources (Figure 2). Coal is extensively available with most coalfields located in the Waikato, West Coast and Southland regions (Figure 2 Black Areas). Oil and gas resources are also available with producing fields located in the Taranaki Basin (Figure 2 North Island Orange Areas). Gas resources are distributed across the North Island by pipelines (Figure 2 Orange lines) but there are no gas transmission pipelines in the South Island. Existing gas fields are in decline, and in the absence of new development or discoveries, gas supply to industrial users is eventually expected to rely on imports.

High temperature geothermal fields are concentrated in the Taupo Volcanic Zone (TVZ), with one high temperature field found in the Northland Region. However, medium to low temperature resources are indicated by warm to hot springs occurring in many regions of the North Island and along the main mountain range (Southern Alps) of the South Island.

Woody biomass is another resource available. Unused residuals such as logging residues in harvested plantation forests were identified by Hall and Gifford (2008) as the largest biomass resource available to New Zealand. The plantations are widespread, but some areas with significant concentration occur in the Central North Island, Gisborne, Northland, Tasman, Otago and Southland Regions. The limitation of biomass energy supplies are that they require long term management as wood supply varies over time; based on the age class distribution of the plantings, the area of the plantings and the harvesting occurring (Hall et al., 2016). The long run supply of woody residues was summarised (Hall, 2017) as being in the order of 18.8 PJ per annum.

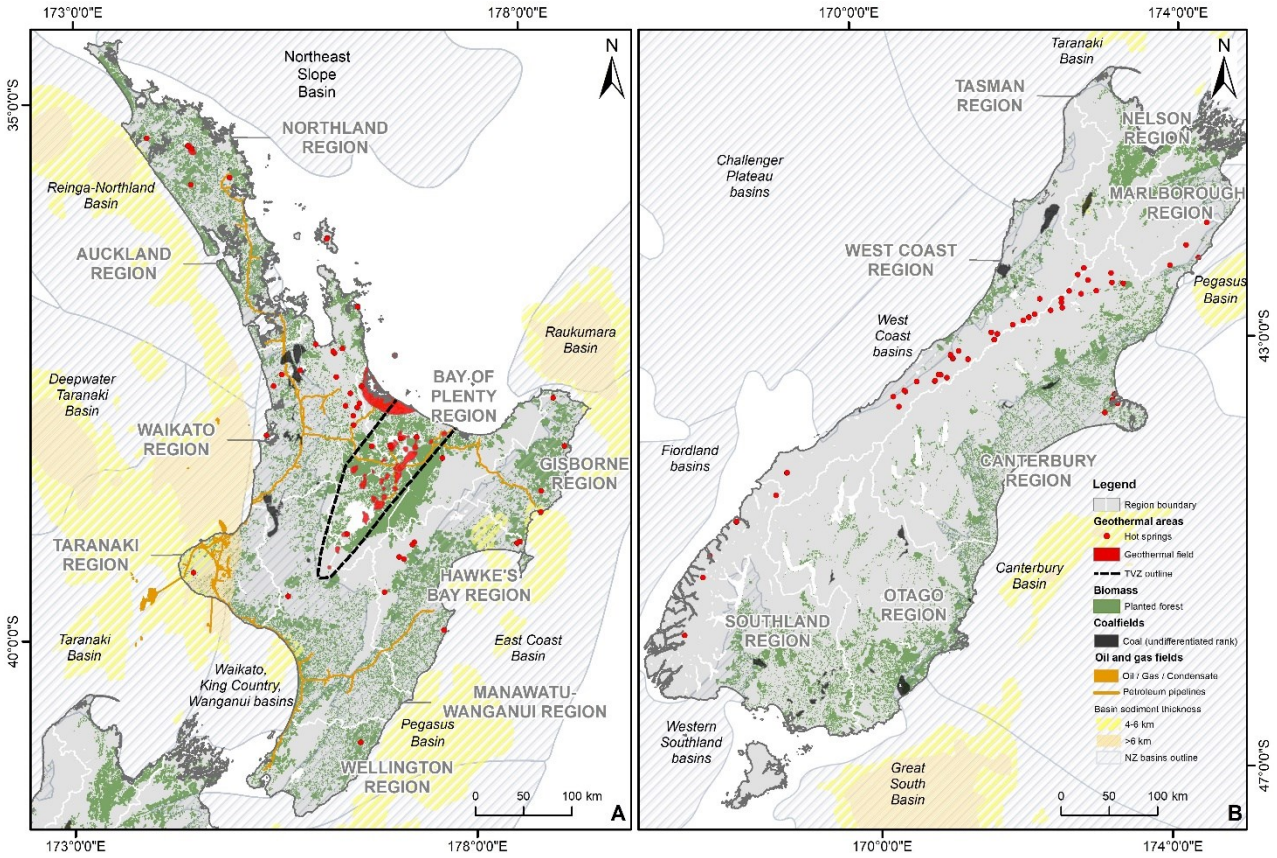

Figure 2: Summary map of natural resources of New Zealand, including fossil fuels (coal, oil and gas fields) and renewables (geothermal resources and planted forest as the main biomass resource).

3. NEW ZEALAND HEAT DEMAND

The larger heat users data is compiled from the New Zealand Heat Plant Database (EECA, 2014) updated to May 2016 for the wood processing section, dairy processing data and geothermal heat use. The companion Energy End-Use Database (EECA, 2012) was used to derive demand for fuel by industry and end-use (Figure 3). Based on both databases, it was possible to examine fossil fuel by region and industry (Figure 3). This data was then used to highlight industries worthy of greater focus for renewables.

In this study, we focused on coal energy as the principal fossil fuel for substitution due to its higher contribution to GHG emissions, and of co-firing technologies that allow the use of a percentage of biomass in the traditional coal boiler. We also assess the current demand for geothermal heat to assess where further development could be promoted.

3.1 Coal energy demand

In the North Island coal resources and production are centred on the Waikato region (Figure 2). Most of the coal demand (Figure 3) is closer to the coal fields, but there are substantial demands in Hawke's Bay, Manawatu-Whanganui and Northland. The principal user in Northland is a cement producer that also uses wood residues to maximum co-firing capacity in the cement kiln. In the South Island coal use is widespread as it is a major source for heat energy (Figure 3).

Industrial sectors with significant coal use are: dairy, indoor cropping, meat processing, other food processing and wood processing (Figure 4). The dairy industry requires a lot of process heat and appeared as a realistic target for transitioning from coal to biomass energy. The meat industry also has significant and wide spread coal demand.

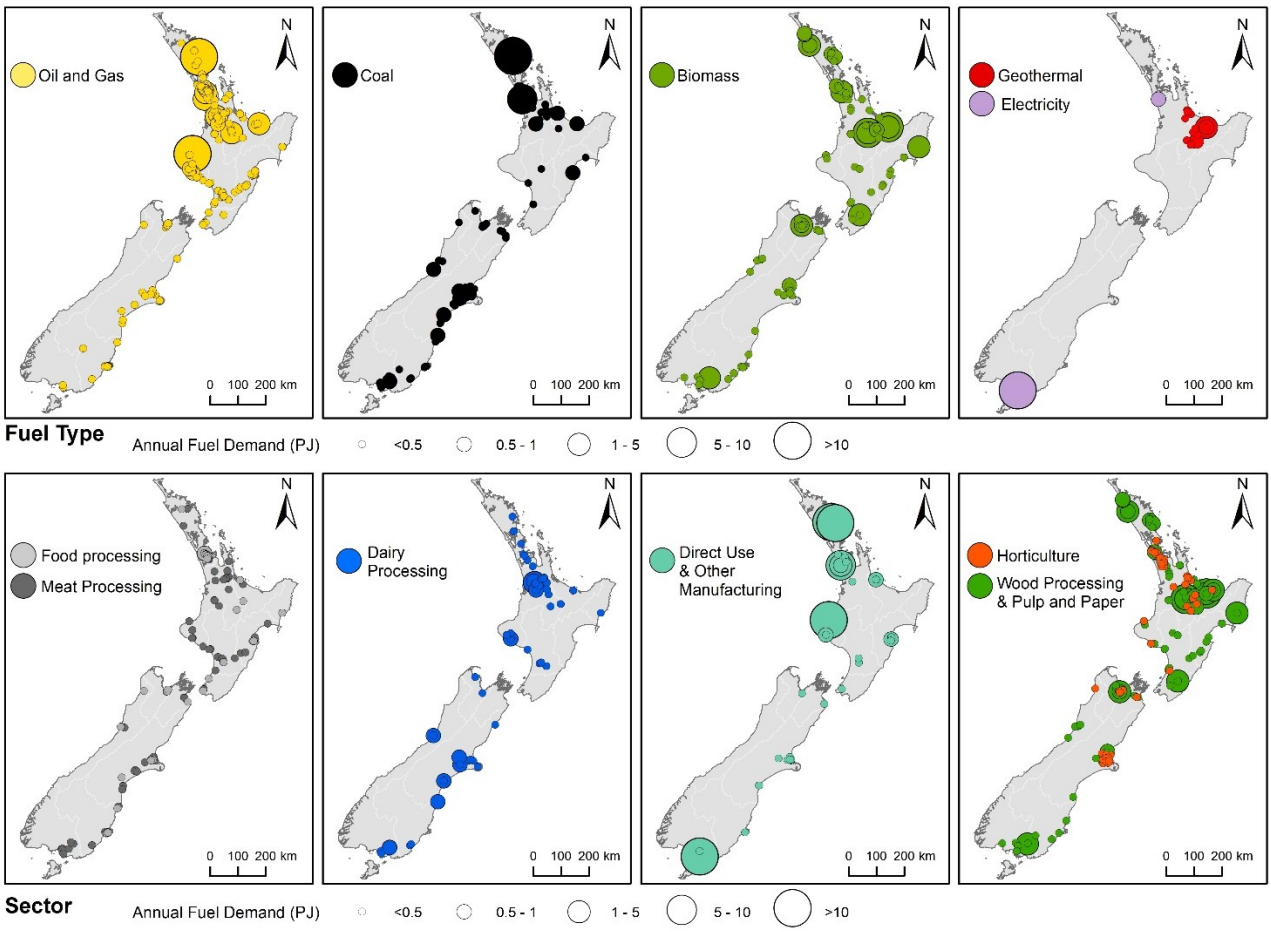

Figure 3: Annual fuel demand (PJ) by fuel type (top maps) and by sector (bottom).

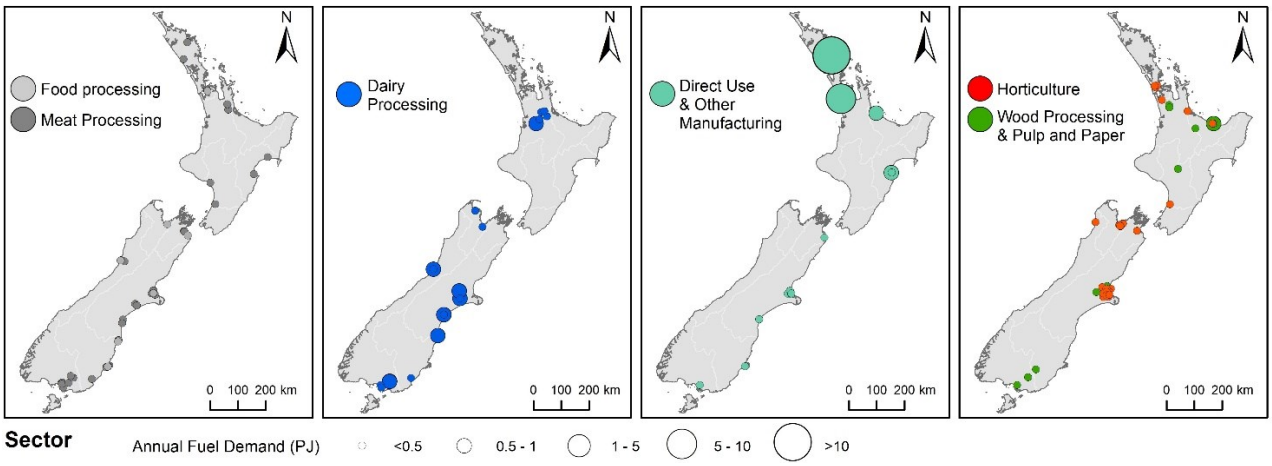

Figure 4: Annual coal fuel demand (PJ) by sector.

Heat sourced from coal could be met by in-forest residues in Northland, Bay of Plenty, Taranaki, Manawatu-Wanganui and Wellington (Hall et al, 2016; Hall and Alcaraz, 2017). Coal demand in the Waikato and Hawke's Bay exceed the regional supply. In the latest assessment, wood supply is sufficient to meet around 85% of coal demand. East Coast has a substantial volume of wood residues, but no coal demand. In the South Island there is insufficient wood from forest residues to meet the coal demand in the Canterbury, West Coast or Southland Regions. Marlborough has sufficient residues to meet coal demand from in-forest residues whilst Nelson wood processors are in residue deficit and residues are already extracted from forests to meet wood processing heat demand.

3.2 Geothermal uses

Geothermal fields are managed by the Regional Council's some of whom who have classified the resources based on their natural values and the most suitable management approach. The classification aims to balance development of the resources (e.g. power generation and / or direct uses) with the protection of valued surface features. Geothermal fields are classified as:

- Protected (no further development allowed since the Resources Management Act system policies were put in place)
- Limited/Conditional development (development under certain conditions can be allowed)
- Development

Most of the fields categorised for development have geothermal power stations and direct uses in place. Industrial and commercial uses of geothermal heat are well established, in particular at Taupō, Wairakei, Ohaaki, Mokai and Kawerau (Figure 5). The annual total geothermal heat demand for the Waikato Region sits at 3.03 PJ, and 4.82 PJ for the Bay of Plenty Region. Uses for geothermal energy are diversified in the Waikato region, including wood, food and dairy processing and horticulture (Figure 5) as well as electricity generation. Geothermal applications are also diverse in the Bay of Plenty, but its use is strongly dominated by the pulp and paper industries, principally by the Kawerau industrial cluster.

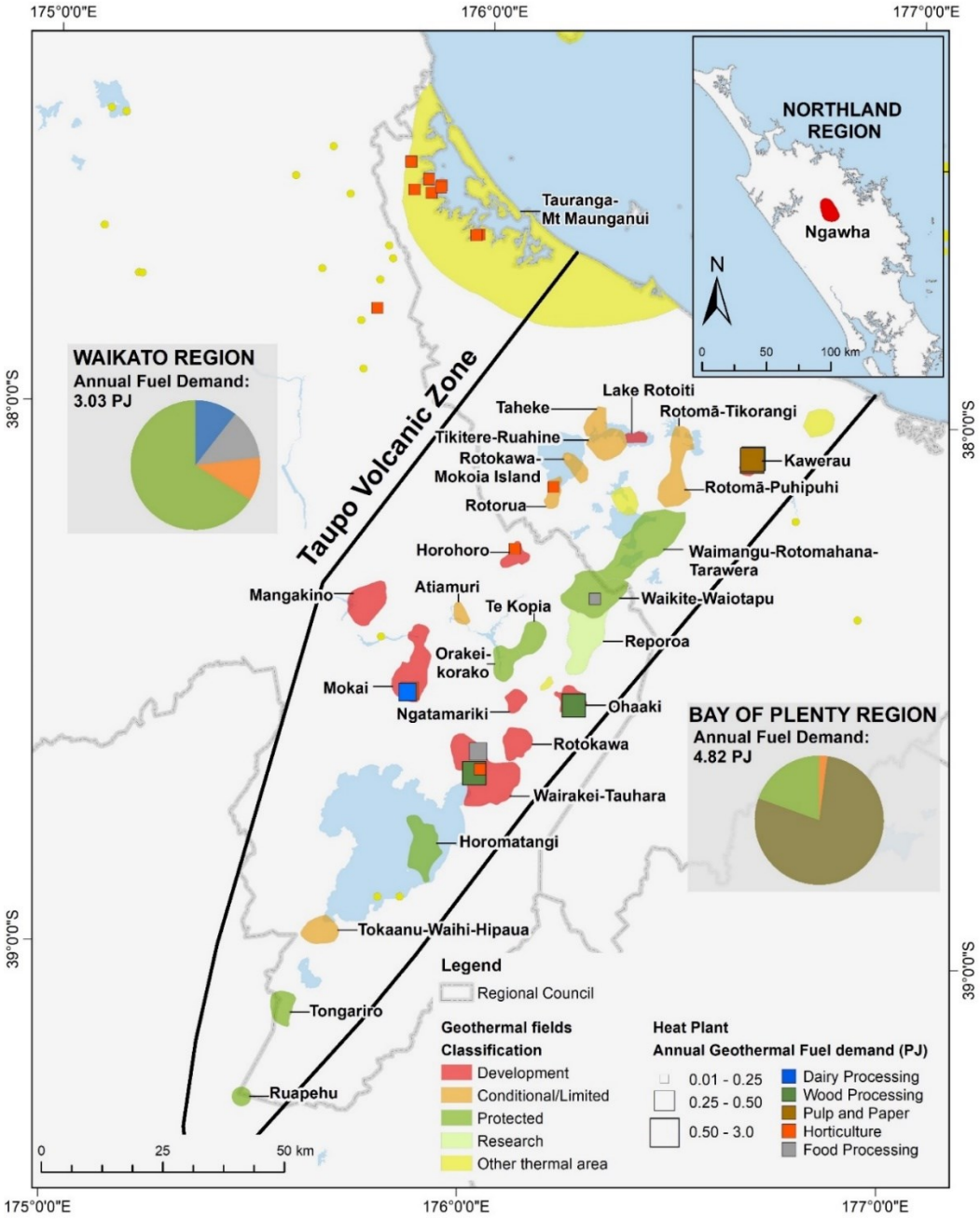

Figure 5: Geothermal heat use summary (modified from Alcaraz et al, 2017).

There is significant potential to increase the use of geothermal energy in process industries. The New Zealand Geothermal Association through the Geoheat Strategy for Aotearoa NZ (Climo et al, 2017) and the Bay of Plenty Regional Council through the Regional Economic Development Agency, the Bay of Connections are working to foster the uptake of Geothermal energy for the economic

and employment benefits. Aspects of this work including outcomes achieved since the end of 2017 are discussed in Climo et al (2020).

Use of geothermal heat is constrained by the fact that the energy in the form of steam and hot water is not a readily transportable commodity, unlike coal or biomass, but development of industrial clusters in the vicinity of resources can remove this impediment. The remaining stored heat in place for New Zealand's principal geothermal fields has been back calculated from New Zealand Geothermal Association Data (NZGA, 2014) in order to plot in Figure 6, in an over simplistic way, locations where geothermal energy might be available.

The back calculation used the assumptions from Lawless (2002) to reproduce the heat in place, without assumptions on recoverability. The calculated data enables comparisons between fields (Figure 6) and the total stored heat in place taking into account historical production of the New Zealand fields to be estimated (38,500PJ). The fields with highest stored heat are Taheke-Tikitere, Kawerau, Tokaanu and Tauhara (>5,000PJ each), followed by Rotokawa (>2,000PJ). Protected fields (e.g. Waiotapu, Orakeikorako, Te Kopia Waimangu) have environmental restrictions that preclude development were not assessed. Tauranga was not assessed.

4. INDUSTRIAL SYMBIOSIS

Both geothermal and biomass are proven energy sources for process heat applications. Opportunities vary by region; based on the wood supply, existing wood processing demand (Scion, 2018), geothermal resource location and non-forestry industrial heat demand (Alcaraz and Hall, 2018). Figure 6 illustrates the existing and potential spatial convergence between energy source and energy end-users.

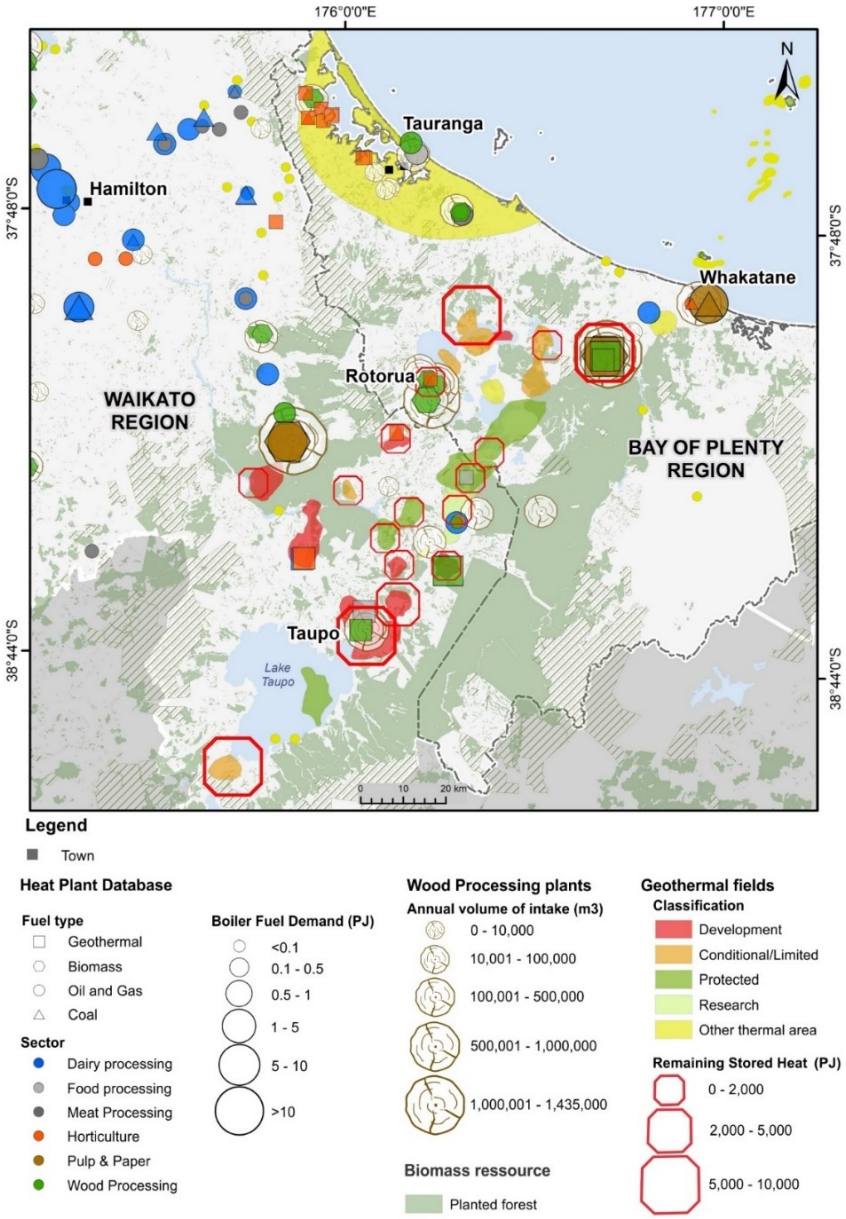

Figure 6: Summary map of natural resources and existing heat users' location in the Bay of Plenty and Waikato regions. This is used to highlight potential opportunities for further development of industrial clusters based on the spatial convergence of resources and potential users.

The section that follows describes successful industrial symbiosis developed at the Mokai Geothermal Field and possible initiatives for the Kawerau and Ngawha geothermal fields.

4.1 The Mokai example

An excellent example of holistic use of resources is found at the Mokai Geothermal Field where the use of the land, water and geothermal resources are well integrated through businesses that operate under the umbrella of the Tuaropaki Trust (http://www.tuaropaki.com/). An ethos evident in the activities of the trust is its responsibility as kaitiaki (guardian) of resources.

Pastoral farming is a core activity on the 3410 hectares of trust land, with dairy farming operations forming a significant part of the farming activities. The milk produced is supplied to the Miraka processing facility at Mokai. Some wastes from the dairy unit are composted through the Ngaire George Sustainability Centre which is discussed below. Plants produced at that facility are used in riparian management on the farm lands.

Geothermal energy production from the Mokai Geothermal Field supports power generation, process steam production for the Miraka milk processing facility and heat to the Gourmet Mokai greenhouses. Power generation capacity is ~110 MWe in a combination of steam turbine and organic rankine cycle power plants. Ownership is shared with 75% in the Tuaropaki Power Company and 25% in Mercury NZ Ltd. Mercury operate and maintain the facilities.

Miraka, a milk processing company, is a joint venture between several Maori Trusts, including Tuaropaki and Wairarapa Moana, and Vinamilk. The facility commenced processing milk in 2011 and up to 20 MWth of process steam used by Miraka is generated from geothermal steam produced from the Mokai geothermal field. The process steam plant is operated from the geothermal power plant control room. Organic plant waste from Miraka is composted through the Ngaire George wormfarm.

Gourmet Mokai Ltd (http://nzgourmet.net/gourmet-mokai.html) is a joint venture between Gourmet New Zealand and the Tuaropaki Trust that has been operating since 2002. An 11.7-hectare greenhouse operation producing tomatoes and capsicum was developed in two stages; 5.5 hectares in 2002 followed by 6.2 hectares in 2007. A 24 MWth geothermal heat supply provides the energy for temperature control in the greenhouses. The plant waste is composted through the Ngaire George Sustainability Centre.

The Ngaire George Sustainability Centre integrates waste management from several business activities working to minimise environmental impact whilst producing superior environmental outcomes. Waste from the Gourmet Mokai glasshouses, the dairy unit, and the Miraka milk processing plant are processed in a large wormfarm. The nutrient rich vermicompost produced is recycled. A native plant propagating nursery forms part of the centre producing trees and plants that are being used to enhance riparian margins of the Trust land and obtain carbon offsets.

Tuaropaki is the owner of the geothermal and energy services company MB Century (http://www.mbcentury.co.nz/). MB Century capability is in engineering, project management, power plant refurbishing and deep well drilling. MB Century portfolio includes three drilling rigs, one of which is an automated Drillmec HH350 drilling rig, and well wireline services including high temperature pressure temperature spinner (PTS) tools with associated winches and data acquisition systems.

As shown in Figure 7 upstream business feeds downstream business, which enables value adding through the chain. The integrated and symbiotic approach enables competent parties to contribute value for Tuaropaki. Local employment opportunities emerge as do opportunities for environmental enhancement and carbon emission offsets.

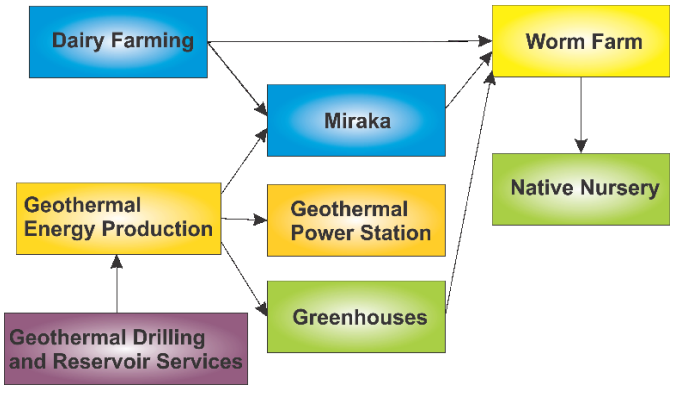

Figure 7: Integrated Tuaropaki business operations at Mokai.

4.2 Kawerau example

Kawerau has a large existing wood processing cluster with extensive use of geothermal heat for wood processing and power generation. A wood use / economic process model along with scenarios runs have been developed to identify potential processing opportunities (Fahmy, 2017). This cluster includes a Kraft pulp mill, a newsprint mill, a tissue plant and two sawmills. The processing plants together take approximately 2,23 M m^3 of logs per annum. The sawdust from the two sawmills go to a wood pellet plant about 80km away as it is not required as process heat fuel.

The use of geothermal heat within a traditional wood processing plant changes the processing opportunities that are possible (Hall et al. 2017). The residual material can be used for manufacture of added value products such as wood pellets, bark briquettes, tannins,

resins, particle board etc.; instead of being used for fuel for process heat. The residue could also be used as a solid fuel at non-wood industrial processing sites with heat demand distant from the Kawerau site.

The unprocessed log supply that flows past Kawerau for export from Tauranga is substantial, in excess of 1 million m^3 per annum in the long term (25 to 30 years). Large scale expansion of primary wood processing integrated with the existing processors and utilising residues from both could allow substantial volumes of value adding processing of these materials (e.g bark to tannins and solid fuel briquettes, sawdust to resins, terpenes and wood pellets).

4.3 Ngawha example

The Ngawha Geothermal Field is a significant energy resource producing fluid at 230 to 240°C (Burnell, 2016). The installed capacity of the Ngawha Power Station is currently 25 MWe and currently under expansion with a further 28 MWe scheduled to be operational by 2021. Under the resource consent granted to the resource developers, a second expansion stage of 28 MWe could take place from 2026.

The Ngawha Geothermal Field does not currently support any process heat utilisation. Direct heat use is currently for bathing at the Waiariki Pools and Ngawha Springs where the natural geothermal fluids fill various bathing pools.

There is the potential for geothermal heat to be available at Ngawha for industrial processes depending on the level of the development for electricity production that is pursued. An industrial cluster model of primary and secondary processing of timber was developed along with simple financial analysis for some cluster options (Hall et al., 2017; Carey et al., 2018).

The wood resource in Northland is currently at the peak of production (MPI, 2016) and harvest volumes are expected to reduce over time however, wood processing capacity in Northland does not consume all of the current and potential future harvest (Hall et al., 2017). An important consideration when locating wood processing is the transport distance from the plantation to the processing site, and the distance from the processing site to the export port. The Ngawha site is centrally located in Northland, adjacent to a number of plantation forests and approximately 120 km from the deep-water Marsden Point port. There is also potential to expand Northland wood processing capacity to increase added value processing reducing the volume of raw log exports.

Primary solid wood processing based on Ngawha geothermal heat would significantly reduce the demand for the wood processing residuals to be burnt for process heat, allowing this material to be processed into value added products. Processes that show promise under conditions as of late 2016 are:

- OEL™ (engineered structural lumber product); 100,000 m^3 per annum log in
- Plywood (industrial grade); 350,000 m^3 per annum log in
- OSB (reconstituted panel product); 345,000 m^3 per annum of log and plywood mill residues in
- Wood pellets plant with resin and terpene extraction

This cluster operation would consume around 0.7 M m^3 of logs per year, annually producing 185,000 m^3 of residues (used for making wood fuel pellets etc). A capital weighted ROCE of ~ 23% was estimated. This cluster would consume a significant proportion of the electricity from one of the proposed 28MWe expansion stage along with 170MWth of geothermal heat. There is probably sufficient geothermal heat resource in the field to run the current 25MWe power plant, one of the additional 28MWe power plants and to provide the 170MWth heat demand for the forestry processing cluster.

5. SUMMARY

This paper presents some of the outcomes of the New Zealand government-funded "Wood Energy Industrial Symbiosis" project, which sought to develop an understanding of economic processing and product mix options where there is convergence between wood resources, adjacent renewable energy resources and current process heat demand in regional New Zealand.

The finite nature of the existing gas reserves, the current lack of infrastructure to import gas and uncertainty about the timing of new discoveries and development of those new fields creates a fundamental reason for considering the use of a renewable low GHG fuels such as wood in industrial processing. Whilst replacing coal with wood has a greater impact on GHG emissions, from a business perspective coal is cheap and abundant. Gas is a more expensive fuel and supply may be a constraint within the planned life of any new plant.

From current and predicted energy resources and the location of large heat users the study has identified opportunities where industrial heat can be supplied from renewable geothermal and woody biomass energy resources.

A key opportunity in the Central North Island is the convergence of geothermal resources with the large plantation forest estate and associated wood processing industry. There is already development of geothermal heat use in wood processing at Kawerau and Taupo but there is potential for more development.

For example, sawmills and other primary solid wood processors typically use their residuals (sawdust, bark, shavings, sander dust, trimmings) as boiler fuel to provide heat to their lumber drying kilns. In both Taupo and Kawerau the use of geothermal heat in sawmill drying kilns means the wood residues are available for manufacture of other products (e.g particle board and wood pellets).

Ngawha is the only site, outside of the Central North Island in New Zealand, with likely industrially exploitable geothermal resources. The findings highlight the potential to leverage wood resource processing opportunities by clustering them along with geothermal energy at Ngawha, using the residuals for value added processing instead of burning them for fuel. There is expected to be sufficient geothermal heat resource in the field to run the current 25MWe power plant, one of the additional 28MWe of power generation facilities and to provide the 170MWth heat demand for the timber / wood processing cluster outlined above.

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