OPPORTUNITIES FOR INDUSTRIAL CO-LOCATION TO IMPROVE RENEWABLE ENERGY USE AND EFFICIENCY

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ABSTRACT

This paper is an update on the New Zealand opportunities for industrial co-location, where there are wood resources, natural energy sources and process heat demand. Industrial symbiosis engages traditionally separate industries, clustering in a collective approach, for mutual advantage. Wastes and by-products from one facility become the raw material for another. Potentially available energy resources have been used to identify opportunities where industrial heat might be supplied more efficiently from renewable geothermal or woody biomass energy sources. Mapping the co-location of industrial heat consumers with these two key energy sources identifies opportunities that can contribute to the renewable energy transition that is occurring in the New Zealand's process heat sector.

1. IDENTIFYING NEW ZEALAND'S INDUSTRIAL SYMBIOSIS OPPORTUNITIES

Industrial Symbiosis is the association between two or more industrial facilities in which wastes or byproducts of one become the raw material for another. Industrial symbiosis enables operating cost reductions whilst also providing opportunities for new businesses.

The outcomes sought for New Zealand are to co-locate industries requiring and providing renewable heat energy, to improve process efficiency, generate economic benefit and increase the level of process heat produced from renewable energy as part of New Zealand's energy transition.

Steps in achieving this include:

1) Inventory energy sources and opportunities
2) Optimise existing processing clusters
3) Identify and share success stories, and
4) Develop proof of concept for new ideas.

Identifying national industrial symbiosis opportunities (bullet 1) above) is the focus of one component of a New Zealand Government-funded Research Programme: Wood Energy Industrial Symbiosis (2014-2018). Research partners include Scion, GNS Science, and the University of Waikato. Industry partners and/or co-funders include EECA, Oji Fibre Solutions, Sequal Lumber, Norske Skog, HRL Morrison, Kawerau District Council, Ngāti Tuwharetoa Geothermal Assets and Grow Rotorua.

The specific goal of this component is to develop an understanding of economic processing and product mix options where there is coincidence of wood resources, natural energy sources and process heat demand across regional New Zealand.

A particular focus was on identifying opportunities for:

1) geothermal as an energy source for wood processing, and
2) woody biomass as an energy source in an industrial cluster.

2. ENERGY RESOURCES & DEMAND

New Zealand seeks to be an energy efficient, productive and low emissions economy (MBIE, 2017). This is relevant in the context of future growth in energy demand, increasing energy costs, substitution for CO_2 rich fuels, and changing social attitudes to energy use. This section identifies the existing spatial distribution of energy resources in New Zealand, and the demand/use of these supplies.

The nation's electricity generation is currently around 80% renewable, however electricity is only about 25% of consumer energy demand (MBIE, 2015). The majority of the other energy that is 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. There are many opportunities to reduce New Zealand dependence on fossil fuels to meet our future energy needs (RSNZ, 2016). Improving energy efficiency and switching to renewable heat sources are key opportunities for the process industry to lower its GHG emissions and reduce dependence on energy imports (MBIE, 2017).

2.1 Fossil Fuels

Coal is widely available both in the North and South Island, in particular in the Waikato, West Coast and Southland regions (Figure 1). Oil and gas resources are scarcer and current producing fields limited to the Taranaki basin, though exploration is ongoing in other basins (PEPANZ, 2017). Petroleum based resources are readily transported nationwide, especially gas through the pipeline running through the North Island.

Recoverable, in ground fossil reserves are estimated at:

- Coal: 147,500 PJ
- Oil and Condensate: 680 PJ
- Gas: 2,330 PJ

While coal will be available in the long term, oil and gas resources in New Zealand are limited and the supply is predicted to decline in future decades in the absence of new discoveries (MBIE 2015).

2.2 Renewable Options

New Zealand is a nation seeking to grow its geothermal and biomass energy use. These low-carbon, low GHG, renewable energy sources promote a clean, green identity, offering a viable pathway to transition towards a greater proportion of renewable energy use in the stationary process heat sector.

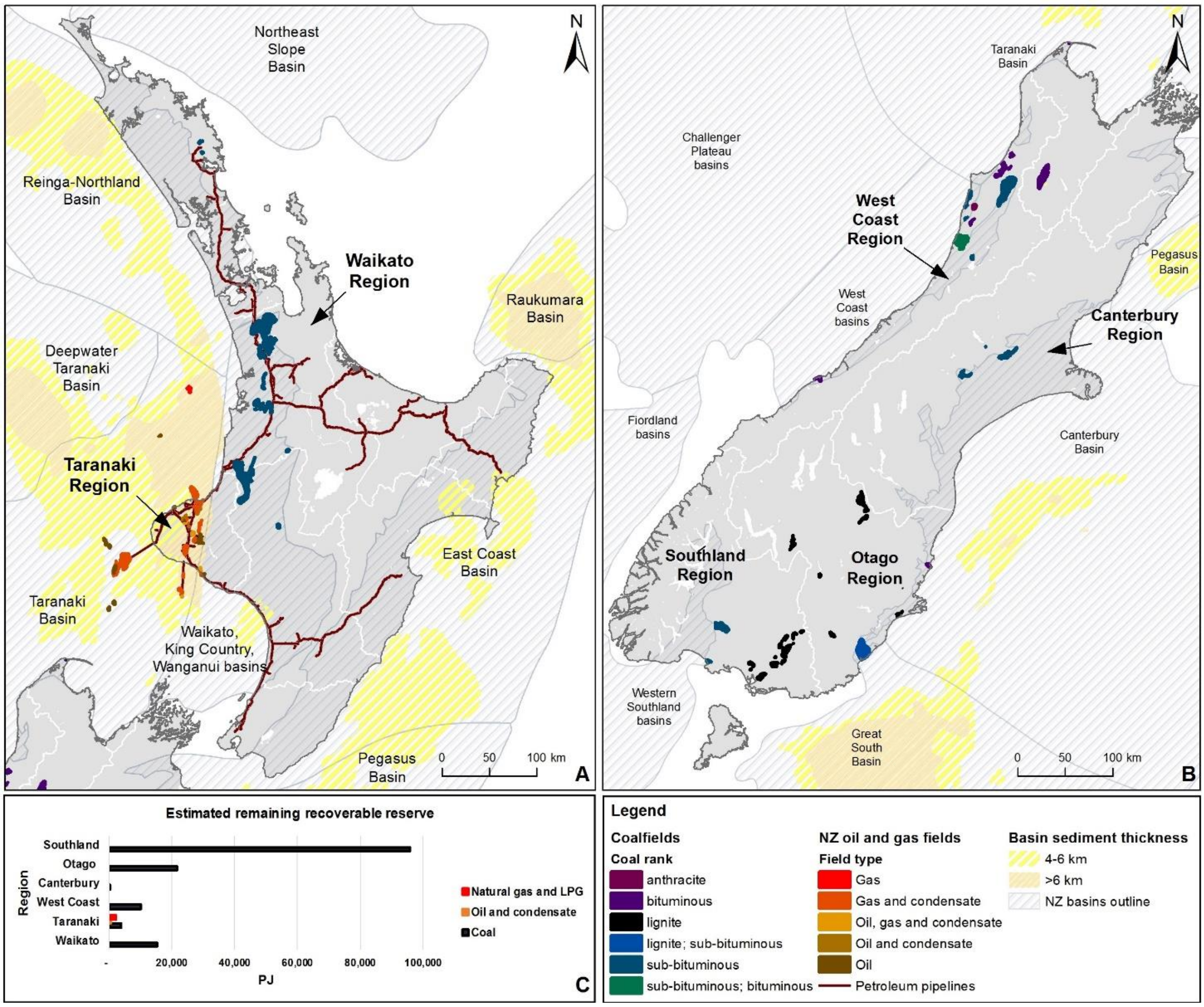

Figure 1: Distribution of existing producing oil and gas and sedimentary basin potentially hosting further resources (courtesy of GNS Science), and location of coal fields, in the North Island (A) and South Island (B). C: Estimated remaining capacity per region hosting fossil fuel resources (Source: Oil and gas: MBIE, 2015; Coal: adjusted from Barry et al., 1994).

Hot springs are common in New Zealand across both islands, but high temperature geothermal fields suitable for industrial process energy use are only found in the Central North Island, through the Taupo Volcanic Zone (TVZ), and in the Northland Region (Figure 2).

Power plants are installed in several geothermal fields and direct uses are well established, from small to industrial scale. Heat is used for bathing, aquaculture, horticulture, dairy and wood processing (Climo et al., 2016). Geothermal energy, if properly managed, is a sustainable resource available at all times, independent of environmental/climatic factors which influence renewable sources such as solar and wind.

Woody biomass is widely available (Figure 2) and under-utilised. 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. These plantations are widespread across New Zealand, but there are some areas with significant concentration, such as; the Central North Island, East Coast, Northland, Tasman, Otago and Southland. The potential to expand the wood processing industry was assessed by taking data from wood availability forecasts (MPI, 2016), and comparing this to the demand for logs required for the existing wood processing infrastructure (Scion, 2015). The limitation of biomass energy supplies is 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).

2.3 Identifying Large Heat Users

Identification of the larger heat users was undertaken using EECA's Heat Plant Database (EECA, 2014). The database was updated for all large scale users bringing it up to date to May 2016. Scion updated the wood processing section taking into account major changes in the wood processing sector that have occurred in recent years. These changes mostly involved closure of sawmills that were using their own wood residues for heat for drying lumber. University of Waikato updated the dairy processing data. GNS Science updated and expanded the information on the use of geothermal heat.

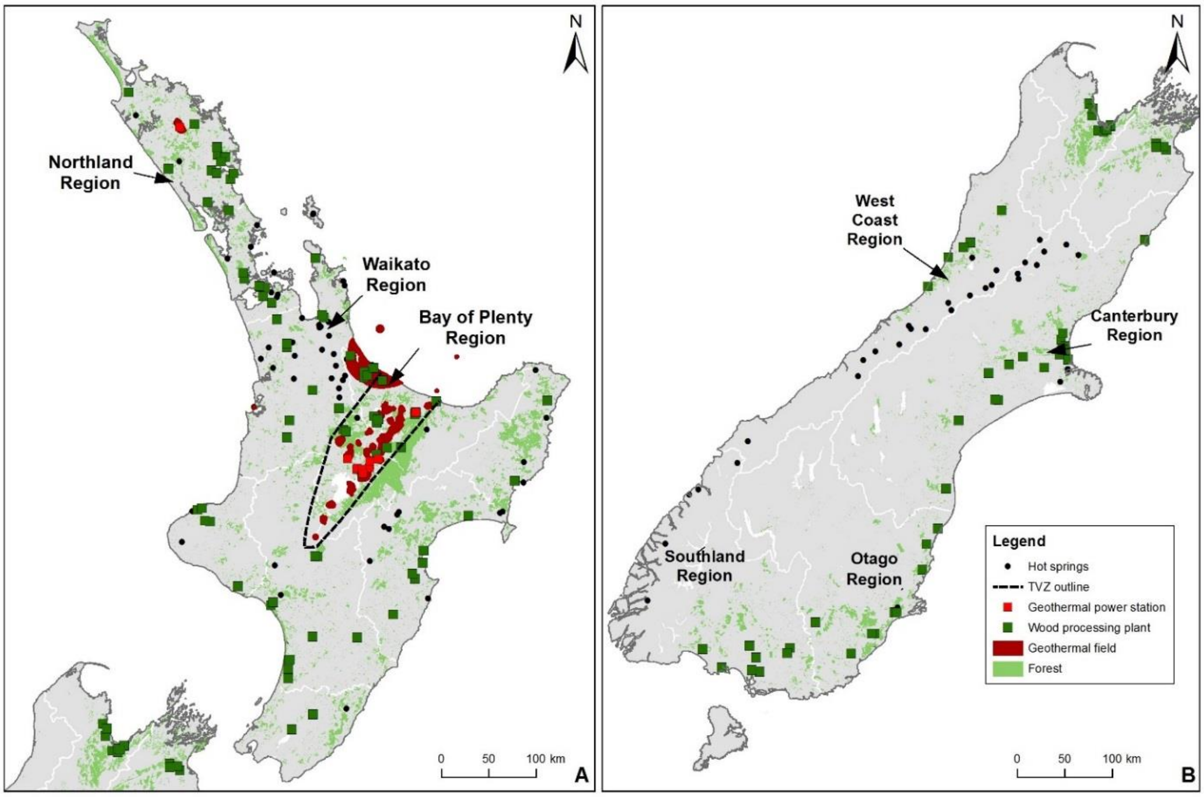

Figure 2: Distribution of geothermal fields, geothermal power stations, planted and exotic forest (LCDB, 2015) and wood processing plants (Jack et al., 2013). Hot springs are from Reyes et al. (2010).

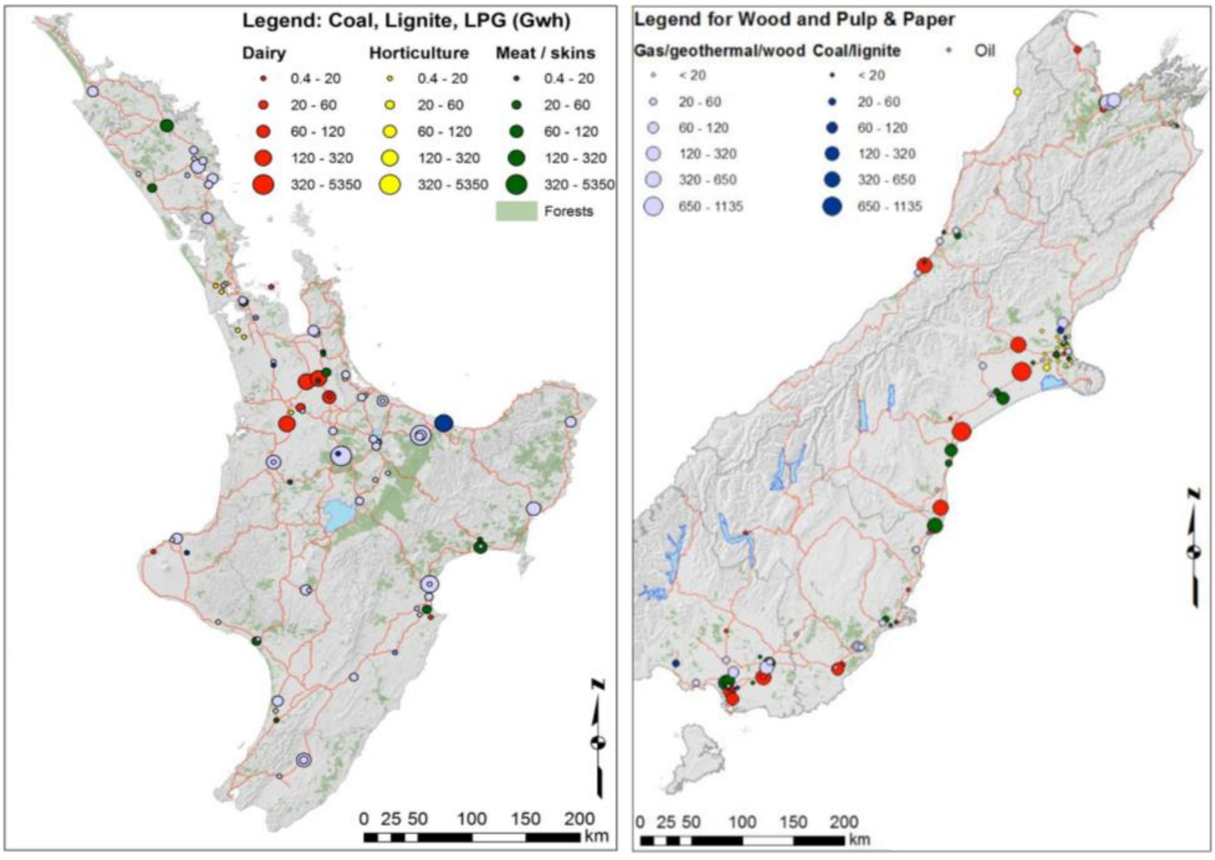

Figure 3: Heat demand by industry and site (Hall et al., 2016).

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 of these databases, it was possible to examine fossil fuel, in particular coal demand by region and industry. This data was then used to highlight industries worthy of greater focus for renewables. These were industries with high fuel demand for heat in a given geographic location, including dairy, indoor cropping, meat processing, seafood processing, non-metallic minerals and wood processing.

3. POTENTIAL TARGETS FOR RENEWABLE ENERGY SUPPLIES

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, geothermal resource location and non-forestry industrial heat demand. Potential expansion of wood processing is part of the analysis, along with associated displacement of fossil fuels used for heat.

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 site.

3.1 Geothermal Energy Industrial Symbiosis

This study focuses on large scale industrial process heat applications that require high temperature energy.

There are no geothermal resources in the South Island that could sustain industrial co-location.

Industrial and commercial uses of geothermal heat are well established in the Central North Island, in particular at Taupō, Wairakei, Ohaaki, Mokai and Kawerau (Figure 4). The annual total geothermal heat demand for the Waikato Region currently sits at 1.58 PJ, and 3.58 PJ for the Bay of Plenty Region (calculated from EECA, 2012). Uses for geothermal energy are diversified in the Waikato region, including wood, food and dairy processing and horticulture (Figure 4). Geothermal applications are also diverse in the Bay of Plenty, but energy use is strongly dominated by the pulp and paper industries, principally by the Kawerau industrial cluster (Figure 4).

There is significant potential to increase the use of geothermal energy. As part of this study, the remaining stored heat in place for each of New Zealand's principal geothermal fields has been back calculated from New Zealand Geothermal Association Data (NZGA, 2014). The back calculation used the assumptions from Lawless (2002) to reproduce the heat in place, without assumptions on recoverability. As this data has been published it was considered better to use this available data than to calculate new estimates for this study. The calculated data enables comparisons between fields and the total stored heat in place taking into account historical production of the New Zealand fields to be estimated (38,500PJ, Table 1).

Based on the back calculated numbers, 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 and Tauranga was not assessed.

Table 1: Estimated remaining stored heat energy in geothermally-rich regions.

	Remaining Stored Heat (PJ)	
Bay Of Plenty	17,300	(45%)
Waikato	19,800	(52%)
Northland	1,400	(4%)
Total	**38500**	

Geothermal heat can effectively be piped up to 5 km from a geothermal well. Figure 4 plots the distance identifying where process heat end users might be co-located to take advantage of geothermal energy.

3.2 Wood Energy Industrial Symbiosis

Wood availability from forests is variable by region and over time and this needs to be considered in any analysis. Current levels of harvest will be available in most regions for around twenty years, but with fluctuations (Hall et al., 2016). Regions with potential to expand wood processing based on existing resources are Northland (0.7M m^3), Central North Island (5.0M m^3), East Coast (1.5M m^3), Hawkes Bay (0.8M m^3), and Otago / Southland (1.0 M m^3).

There is potential for the use of wood residues from a rising volume of wood for harvesting as well as potential for new wood processing with associated residues (Hall et al., 2016).

Industries with symbiotic regional opportunities for using wood energy include (Hall et al., 2016):

- Dairy processing: Northland, Waikato / Bay of Plenty, Otago / Southland;
- Meat processing: Northland, Hawkes Bay, Manawatu, Otago, Southland, Waikato;
- Indoor cropping: wide spread across New Zealand.

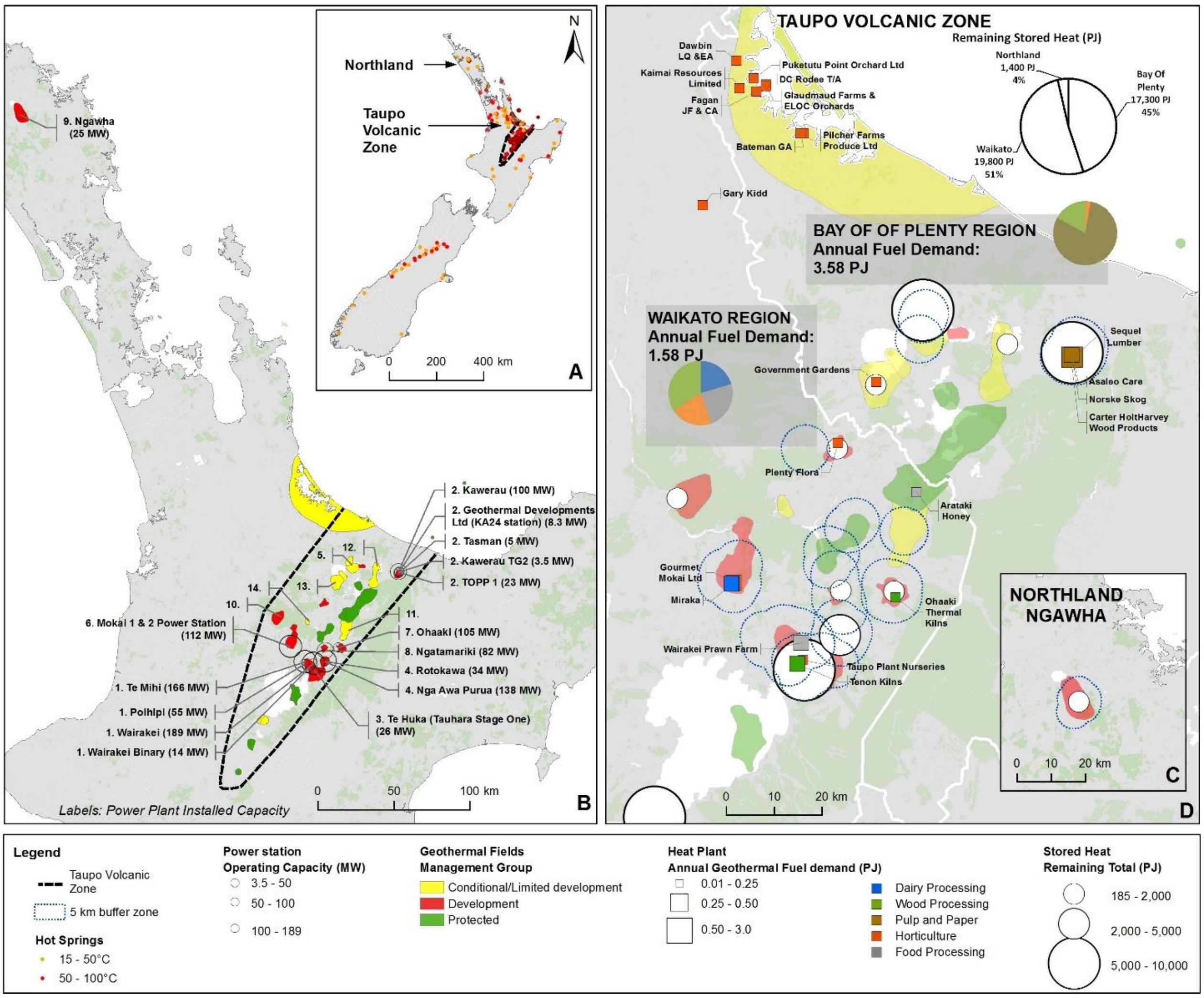

Figure 4: Geothermal summary map. Hot springs distribution (A) from Reyes et al. (2010). Power plant installed capacity (B). Existing installed capacity process heat uses of geothermal energy in Northland (C) and the Central North Island (D) colour coded per industry and calculated remaining stored heat in place for each field. Geothermal resource data is sourced from Carey et al. (2015) and Climo et al. (2016).

3.3 Northland Case Study

Geothermal energy

The Ngawha Geothermal Field is a significant energy resource producing fluid at 230 to 240°C (Burnell, 2016). The data analysis delineates a known hot region of around 12 km^2.

The installed capacity of the Ngawha Power Station is 25 MWe and it consistently produces about 70% of the electricity consumed in the Far North. The facility reduces exposure of the Far North to National Grid disruption / failures to the south. Known direct heat uses are bathing at the Waiariki Pools, Ngawha Springs, where the natural geothermal springs fill various bathing pools. The Ngawha Geothermal Field does not currently support any process heat utilisation.

The field capacity has been assessed using reservoir simulation techniques and consented for up to 75 MWe of installed power generation capacity. Top Energy obtained consent in 2015 (Appeal resolved in April 2016) to install an additional 50 MWe in two 25 MWe stages. Investigations are assessing the appropriate approach for the upcoming development up sizing.

The simulation modelling used to assess the energy available for the two by 25 MWe increments is significantly more sophisticated than the remaining stored heat assessment recorded in Table 1. For each 25 MWe power plant usable energy available at the surface (not heat in the ground) from the 25,000 tonnes per day of geothermal fluid to be extracted from the field per unit is about 15 TJ/day (175 MWth or 5.5 PJ / annum) with the fluid re-injected at 85 °C.

The current 25MWe power generation plant draws around 1050 tonnes per hour of fluid. Around 99% of this fluid is reinjected at 85 to 95°C. Some additional fluid (18 t/hr of water) is supplemental injection to assist in maintaining field pressure.

The draw on the field from this geothermal power use of 1050t/h gives a calculated energy content of around 8.7 to 8.8 PJ per annum (Burnell, 2016). The additional power generation which is proposed and consented would be in two 25MWe stages spaced several years apart.

Top Energy has expressed interest in possibly developing a Heat Park for direct heat use after the next 25 MW power generation increment is operational. The industrial use could be to support processing timber (Martin Jenkins 2015). A combination sawmill and thermo-mechanical pulp mill was analysed in a little detail by Indufor (2016).

Biomass resource

The wood resource in Northland is currently at a peak of production (MPI, 2016) and harvest volumes are expected to drop over time. Scion's wood processing database (Scion, 2015) is used to estimate the demand from the existing wood processing mills in Northland. This study shows that the processing capacity in Northland does not consume all the current and potential future harvest.

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 port at Marsden Point. There is also potential to expand Northland wood processing capacity to increase added value processing reducing raw log exports.

Symbiosis Opportunities

Geothermal data is used to determine the potential of the Ngawha Geothermal Field to provide industrial heat and power; and / or the use of the waste heat from a power plant for low-grade heat (Hall et al., 2017).

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 was developed by Scion and financial analysis for some cluster options performed.

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 at Q4 2016 are;

- OEL™ (engineered structural lumber product)
- Plywood (industrial grade)
- OSB (reconstituted panel product)

This cluster operation would consume around 0.7 M m^3 of logs per year, producing 185 k m^3 of residue. A capital weighted ROCE of ~ 23% was estimated. This cluster would consume a significant proportion of the electricity from one of the proposed 25MWe stages along with 170MWth of geothermal heat. There is estimated to be sufficient geothermal heat resource in the field to run the current 25MWe power plant, one of the additional 25MWe power plants and to provide the 170MWth heat demand for the cluster.

3.4 Other case studies

The project focused on identifying national opportunities where biomass and/or geothermal energy can be used symbiotically with industries requiring large amounts of heat as part of their processing chain.

From a geothermal perspective, the Ngawha case study is a great example of symbiotic opportunity.

The project also investigated the existing Kawerau wood processing cluster, developing a process model and running scenarios to identify potential processing opportunities (Fahmy, 2017). Kawerau has a large existing wood processing cluster with extensive use of geothermal heat for wood processing and power generation. 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).

Other case studies focus principally on wood biomass as an energy source. A case study of the Gisborne area (East Coast) has been completed and a Southland/Otago case study will be developed in 2018. These will identify opportunities in these regions.

4. SUMMARY

The wood energy industrial symbiosis project is assessing the opportunities for industrial co-location of wood resources, energy sources, including renewable energy sources and process heat demand.

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.

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

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REFERENCES

Barry, J.M., MacFarlan, D.A.B., Duff, S.W. (1994). Coal resources of New Zealand. Energy and Resources Division, Ministry of Commerce, 1994.

Burnell J. (2016). Statement of evidence of Dr John Burnell for Northland Regional council and far North Distract Council hearing concerning a resource consent application by Ngawha Generation Limited for expanded operation of Ngawha geothermal filed; public hearing in Kerikeri on 10-14 August 2016.

Carey, B., Dunstall, M., McClintock, S., White, B., Bignall, G., Luketina, K., Robson, B., Zarrouk, S. (2015). 2010-2015 New Zealand Country Update, Proceedings World Geothermal Congress 2015, Melbourne, Australia, 2015.

Climo, M., Milicich, S., White, B. (2016). A history of geothermal direct use development in the Taupō Volcanic Zone, New Zealand. Geothermics, 59, 215-224.

Climo, M., Hall, J.P., Coyle, F.J., Seward, A.M., Bendall, S., Carey, B.S., White, B. (2015). Direct use: opportunities and development initiatives in New Zealand. paper no. 28010 In: Horne, R.; Boyd, T. (eds) *Proceedings, World Geothermal Congress 19-24 April 2015, Australia-New Zealand.*

EECA (2014). EECA Heat Plant database Obtained from EECA in 2015 and updated.

EECA (2012) EECA Energy End-use database. https://www.eeca.govt.nz/ resources-and-tools/tools/energy-end-use-database/ Energy data used is for the 2012 calendar year.

Fahmy, M. (2017). Aim 1 – Kawerau Industrial Cluster Model. Identifying new wood processing opportunities. Scion Wood Energy Industrial Symbiosis Stakeholders Workshop 28 July 2017.

Hall, P., Gifford, G. (2008). Bioenergy Options for New Zealand. Situation analysis; biomass resources and conversion technologies. Scion.

Hall, P., Hock, B., Alcaraz, S., Climo, M., Heaphy, M. (2016). Wood Energy Industrial Symbiosis 2016 Progress Report - Aim 3. Scion Internal Report to MBIE.

Hall, P., Alcaraz, S., Carey, B., Hock B. (2017). Assessment of wood processing options at Ngawha - incorporating geothermal energy; Wood Energy Industrial Symbiosis project. Scion Internal Report to MBIE.

Indufor (2016). Pre-feasibility of a Mechanical pulpmill complex in Northland; local impact component, Resource analysis, market analysis. MPI technical paper 2016/72. Prepared for MPI by Indufor.

Jack, M., Hall P., Goodison A., Barry L. (2013). WoodScape study - summary report. Scion contract report for the Wood Council of New Zealand. http://www.woodco.org.nz/strategic-plans/woodscape

Lawless, J.V. (2002). New Zealand's geothermal resource revisited. New Zealand Geothermal Association Annual Seminar, Taupo.

LCDB – Land Cover Database (2015). Landcare Research New Zealand Ltd. GIS file. https://lris.scinfo.org.nz/layer/48423-lcdb-v41-land-cover-database-version-41-mainland-new-zealand/

Martin Jenkins (2015). Tai Tokerau Northland Growth Study. Opportunities Report February 2015. Published by Ministry of Primary Industries. www.mpi.govt.nz/document-vault/5428

MBIE - Ministry of Business, Innovation and Employment. (2011). Developing Our Energy Potential: New Zealand Energy Strategy 2011-2021 and NZ Energy Efficiency and Conservation Strategy 2011 – 2016. Available at: www.mbie.govt.nz and www.eeca.govt.nz. ISBN 978-0-478-35894-0

MBIE - Ministry of Business, Innovation & Employment. (2015). Energy in New Zealand in 2015. http://www.mbie.govt.nz/info-services/sectors-industries/energy/energy-data-modelling/publications/energy-in-new-zealand. Reserves data tables Accessed June 2016.

MBIE – Ministry of Business, Innovation & Employment. (2017). Unlocking our energy productivity and renewable potential. Draft Energy Efficiency and conservation strategy. Retrieved 3 July 2017 from: www.mbie.govt.nz

MPI - Ministry of Primary Industries. (2016). Regional wood supply forecasts. https://www.mpi.govt.nz/news-and-resources/open-data-and-forecasting/forestry/

NZGA – New Zealand Geothermal Association. 2014. Assessment of New Zelanad's High Temperature Geothermal Resources. http://nzgeothermal.org.nz/geo_potential/

PEPANZ – Petroleum Exploration & Production Association of New Zealand. (2017). New Zealand's Energy Mix. http://www.energymix.co.nz

Reyes, A.G., Christenson, B.W., Faure, K., (2010). Sources of solutes and heat in low-enthalpy mineral waters and their relation to tectonic setting, New Zealand. J. Volcanol. Geotherm. Res. 192, 117–141.

RSNZ – the Royal Society of New Zealand. (2016). Transition to a low-carbon economy for New Zealand. https://royalsociety.org.nz/

Scion (2015). Scion Wood Processing Database (unpublished).