

Taking the climate heat out of process heat

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Introduction

In 2018, Transpower published a comprehensive analysis of New Zealand's future energy options. *Te Mauri Hiko* looked forward to 2050 and, via modelling and scenario analysis, considered the opportunity for the country's energy options to drive the emergence of a low carbon economy.

Te Mauri Hiko found that New Zealand enjoys an almost unparalleled opportunity to lead the world in decarbonising its economy. New Zealand's abundance of renewable energy options can displace the country's dependence on fossil fuels across all areas of the economy and enable us to meet our significant international climate change commitments.

Achieving this vision hinges upon the electrification of the New Zealand economy, which could require a doubling of current electricity generation levels by 2050. With approximately 80 per cent of New Zealand's electricity generation already produced through renewable sources, and with that level steadily increasing, the *Te Mauri Hiko* vision requires significant changes to New Zealand's primary sources of fossil-fuelled energy consumption – namely transport and industrial process heat applications.

This paper is part of an ongoing suite of analysis and reports that collectively make up the *Te Mauri Hiko* work programme. It follows the overall *Te Mauri Hiko – Energy Futures* analysis and subsequent papers on both solar and wind contributions to New Zealand's energy future.

Taking the Climate Heat out of Process Heat is focused on precisely that: the opportunities facing New Zealand businesses, the national economy and the country's climate change commitments that can come through replacing fossil fuels with renewable electricity for a wide range of industrial process heat applications.

While invisible to many of us, process heat is any heat generated to heat a space or water, or to manufacture a product – with more than 65 per cent of New Zealand’s process heat used by energy-intensive industries. It is used right across our economy – from hospitals and schools, to dairy and food processing plants. Process heat is critical to much of what we consume everyday: how we keep warm, sterilise equipment, cook and pasteurise our food, and produce staple economic commodities.



Successfully transitioning from fossil-fuelled applications to renewable energy sources will be fundamental to decarbonising the New Zealand economy and leading the global effort to avoid unmitigated climate change.

This paper discusses the role of process heat in New Zealand, including its scale and contribution – both to the economy and to our collective emissions profile. It assesses alternatives to current process heat technologies, the economics of various alternative options and addresses some of the misconceptions that have built up around process heat and the potential conversion opportunities.

As with all of the *Te Mauri Hiko* work, this paper seeks to stimulate discussion and debate in service of New Zealand realising the unique opportunity to transform our economy through our energy choices.

Transpower believes that in order for New Zealand to realise this opportunity, we need to work together to build a clear, common context and a vision for the future. As part of this commitment we have worked with the Energy Efficiency and Conservation Authority (EECA) on parts of this paper and with Powerco on case study four. We thank them for their contribution to it.

We look forward to feedback on this document to further our thinking and modelling on process heat, and to continuing this important conversation.

The *Te Mauri Hiko* team

Transpower's *Te Mauri Hiko – Energy Futures* is available at www.transpower.co.nz

Executive summary

Over the past 150 years, electricity has been steadily replacing the on-site combustion of fossil fuels to provide energy. Initially, electricity was mainly used in replacing oil and gas to provide lighting. However, over a relatively short space of time, it has replaced coal, wood and fossil fuels in many aspects of our daily life.

With New Zealand's electricity already primarily generated from renewable sources, the two main areas left to electrify are transport and the application of process heat (process heat), including drying products by evaporating water. Many people will be surprised as to how significant process heat applications are to New Zealand's overall carbon emissions profile.

Process heat is New Zealand's biggest user of the most carbon intensive fossil fuel – coal. Process heat applications consume 90 per cent of New Zealand's total annual coal demand.¹

To meet New Zealand's commitments under the Paris Agreement, the appropriate electrification of process heat is just as important as the electrification of transport. Process heat makes up over a quarter of New Zealand's energy-related emissions. Emissions from process heat have also increased by around 45 per cent over the past 25 years.

¹ <https://www.mbie.govt.nz/assets/d7c93162b8/energy-in-nz-18.pdf>, page 20, including industrial, other transformation, co-generation, commercial and residential. Note this percentage includes industrial processes and products use (IPPU) emissions from manufacturing steel (approximately 20 per cent).



The appropriate electrification of process heat is just as important as the electrification of transport. Process heat makes up over a quarter of New Zealand's energy-related emissions.



Historically, coal, gas, and even diesel and LPG were cheap, easy to manage, and capable of quickly achieving very high temperatures. But as attention turns to their environmental cost, new technologies are offering credible alternatives to fossil fuels. Just as heat pumps have transformed home heating, industrial heat pumps are a credible option for higher heat processes. Other options include biomass (already used in the timber industry) and even converting a steel plant to run on hydrogen.²

The ease of conversion of fossil-fuelled applications to electrical alternatives spans the full spectrum. Some present significant challenges and there is also some low hanging fruit, particularly in applications with lower temperature demands. Even electrifying low temperature process heat applications can deliver significant and important carbon emissions reductions. Overall, a wide range of electrical alternatives are emerging quickly and promise improved efficiency and economics.

Electrifying significant process heat applications will obviously require more electricity to be generated and then distributed via the transmission and local lines company networks. There will be implications and challenges for every element of the electricity sector, including for distribution assets in terms of capacity, forward investment and maximising network utilisation, and through using emerging technologies such as batteries. Our case study on page 21 on electrifying process heat in Eastern Waikato highlights some of these challenges.

² <https://interestingengineering.com/steel-plant-in-sweden-set-to-operate-entirely-on-hydrogen-fuel>

Section one

Why process heat is critical to our future

In addition to heat used to support chemical reactions for the production of petroleum products or to manufacture aluminium and steel, process heat often takes the form of creating steam, hot water or hot gasses. For example, traditionally hospitals and schools would burn gas or coal to heat water in order to heat buildings while dairy factories use gas or coal to pasteurise and dry milk. Horticultural greenhouses burn coal or gas to provide heat and carbon dioxide to increase plant growth.

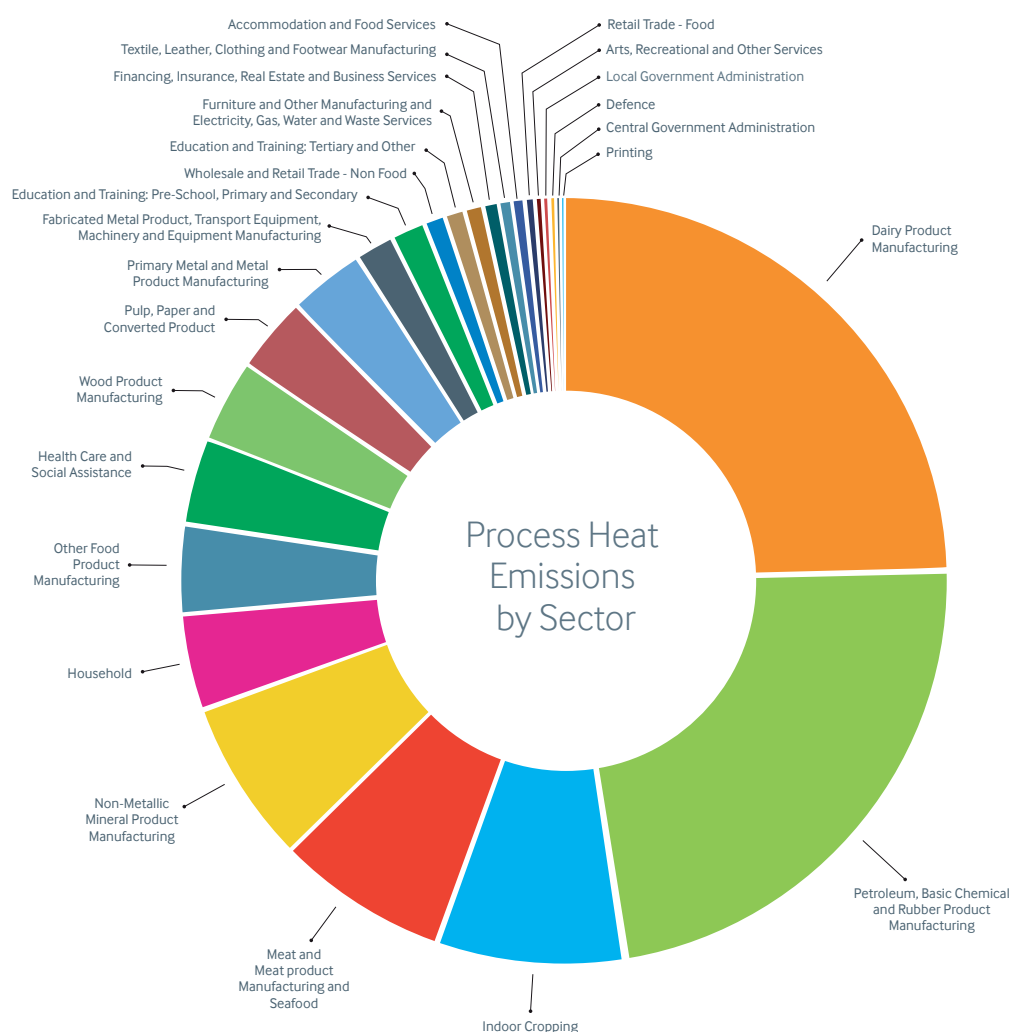


SECTION ONE: Why process heat is critical to our future

Process and industrial heat is one of the largest sources of New Zealand's energy-related emissions (second behind transport), responsible for 28 per cent of all energy-related greenhouse gas emissions in 2017.³ The Productivity Commission has recently highlighted emissions from process heat grew 45 per cent between 1990 and 2016.⁴

Meeting New Zealand's Paris Accord commitments and decarbonising our economy will require a concerted and coordinated effort to address emissions from process heat. Figure 1 below shows the breadth of sectors responsible for New Zealand's process heat emissions, reinforcing this is not a challenge for just one sector to address; rather all sectors need to take responsibility for tackling this issue and their contribution to it.

Figure 1: Process heat emissions by sector⁵



³ Gross emissions – see www.mbie.govt.nz/assets/8c89799b73/process-heat-current-state-fact-sheet.pdf

⁴ New Zealand Productivity Commission final report on low-emission economy, available at www.productivity.govt.nz/inquiry-content/3254?stage

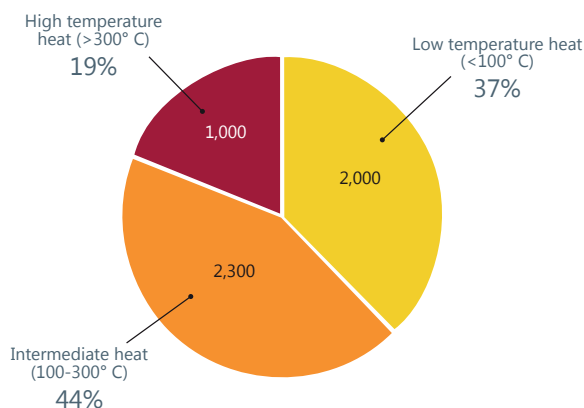
⁵ Emissions intensity from Ministry for the Environment (MfE) 2015. Energy end use data sourced from EECA energy end use database <https://www.eeca.govt.nz/resources-and-tools/tools/energy-end-use-database/> Note that data used for analysis is the 2012 dataset as this is the most complete dataset available.

SECTION ONE: Why process heat is critical to our future

There are many ways to achieve the transition away from fossil fuels – from electrification (on which we largely focus) to improved efficiency measures to the increasing use of biomass.

Some process heat applications are much easier to decarbonise than others – it's important to look at the temperature required in the relevant process. For low temperatures, heat pumps (like the one you may have at home) offer a cheap, reliable alternative to the use of coal or natural gas for heating. Other processes requiring very high temperatures, such as in steel manufacturing, may be much more challenging. The good news is that 37 per cent of carbon emissions from process heat are from low temperature applications, which can be relatively easily substituted for standalone low temperature applications, or where embedded with higher temperature systems can be reduced via energy efficiency efforts (including through heat recovery which further enhances the economies of emission reductions). Gas may be used by some as a transition fuel to electricity.

Figure 2: Process heat emissions by temperature band⁶



As a trade-focused country, aspiring to grow export value, there could be a significant opportunity for our businesses to lead the world in providing decarbonised products. New Zealand already has one of the most sustainable electricity systems in the world so decarbonising process heat through electrification could be another way for companies and businesses to maintain their international competitiveness (both in providing and marketing 'greener', lower carbon products and offsetting concern around 'food miles'). Additionally, if New Zealand can successfully capture zero carbon production techniques through reliance on renewable energy sources, there is the opportunity to not only boost the domestic manufacturing sector, but also attract other manufacturing companies to New Zealand that seek to produce climate friendly goods for an increasingly discerning world.

Tackling process heat emissions through energy efficiency and electrification also provides a valuable opportunity for elements of the agriculture sector, which traditionally find emissions reductions challenging to achieve, to take important steps towards lowering the carbon intensity of production – for example, through the use of process heat in production of milk powder, as discussed further in this paper.

⁶ Delivered energy figures by Fuel, Sector, End Use and Technology for 2012 from data sourced from EECA augmented with Transpower analysis. Emissions conversion figures from 2012 MBIE published data. Updated 2016 data is not regionalised – it shows a similar story with a larger magnitude of emissions across all temperatures and a slightly different distribution between the temperature brands. Regardless, the opportunity to reduce low temperature emissions remains high.

Section two

Taking the heat out of process heat misconceptions

The conversation around process heat is gathering pace but it is not widely understood and there are many misconceptions surrounding it. This section addresses some of the more common misconceptions to provide a clear, common context on the future for process heat.

SECTION TWO: Taking the heat out of process heat misconceptions**MISCONCEPTION ONE:****The technology doesn't exist to electrify process heat**

Technology to provide process heat – even at high temperatures – is now established in the market, with various solutions capable of providing for heat applications up to very high temperatures.

This is no longer true. Technology to provide process heat – even at high temperatures – is now established in the market, with various solutions capable of providing for heat applications up to very high temperatures. A broad range of technologies have been developed and implemented over the past decade including industrial heat pumps, microwave, dielectric (radio frequency) heating, infrared, plasma, and induction heating systems. These supplement direct resistance electrical heating.

At lower temperatures, the expansion of heat pump technology is now very well established. In the same way this has transformed home heating over the past 15 years, it is already transforming low temperature industrial applications. Industrial heat pump technology can now provide for process heat up to 165°C and is expected to become increasingly commercially available, covering a major component of New Zealand's process heat requirements.

At higher temperatures, technology also exists that can be deployed today. Options such as dielectric and induction heating, electrical resistance heating and electric furnaces are all commercially available and already have existing industrial applications. While these higher temperature technologies are less common in New Zealand (due to a lack of adoption or short-term economics rather than technical limitations), they still offer both substantial energy savings and process efficiency gains. We recognise this can be more challenging for existing sites, and explore this further in *Misconception four*.

International case studies have been able to demonstrate the improvements these technologies offer, both in terms of energy and process, efficiency.

MISCONCEPTION TWO:**The cost of electricity makes electrification unaffordable**

It is tempting to compare the current cost per gigajoule (GJ) of delivered electricity with a cost per GJ for natural gas (or coal) and conclude that gas – being three to five times cheaper on this measure⁷ – is more economic. However, the commercial reality is more complex, as the inherent efficiency of electricity means less energy (fuel) is required. As technology evolves and improves, and carbon prices rise (discussed below), the economics will increasingly favour electrification for many process heat users in New Zealand.

This paper accounts for the efficiency by which fuel – electricity, coal or gas – can be converted into usable process heat, through a measure known as the Coefficient of Performance (CoP). Lower temperature processes can take advantage of commercial and industrial-scale electric heat pump technology with CoPs of between three and seven (so 3-7 units of useful energy are produced for every unit of electricity). Even high-temperature processes can exploit this technology for highly efficient pre-heating.

Higher temperature processes can take advantage of electricity's versatility in, for example, applying the optimum temperature for the process, and transferring heat directly to, and only to, the target material.⁸ By comparison, using a central gas or coal-fired boiler to produce steam can have a CoP of only 0.5, so only half the energy is used, and half is wasted.

⁷ MBIE's 2018 annual average prices – methodology for their variorisation is not stated: www.mbie.govt.nz/assets/Data-Files/Energy/energy-quarterly-statistics/a0285022ed/prices-statistics.xlsx.

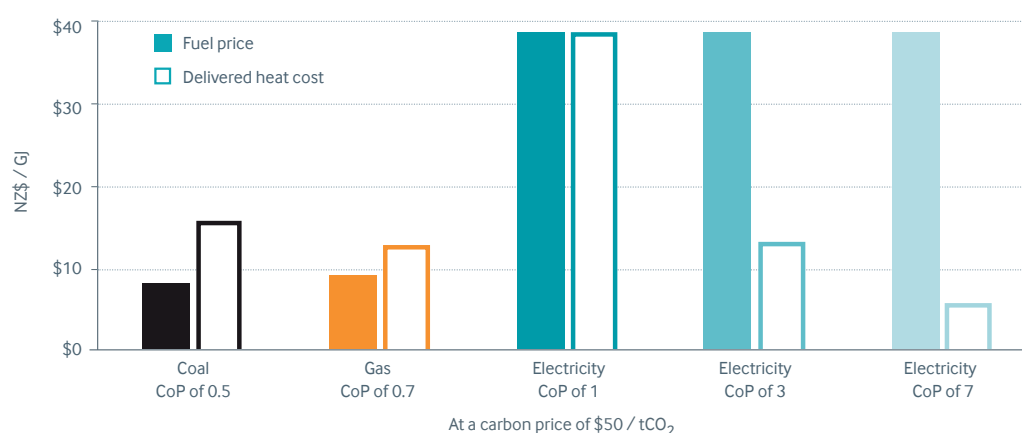
⁸ The Australian Beyond Zero Emissions' report *Electrifying Industry – Zero Carbon Industry Plan* has a useful and detailed discussion of these technologies. bze.org.au/research/manufacturing-industrial-processes/electrifying-industry/.

SECTION TWO: Taking the heat out of process heat misconceptions

Electricity experiences losses too, in generation, transmission and distribution, but these occur before entering the site, so are already accounted for in the customer's price. As a result, electricity can have a strongly positive efficiency multiplier, whereas gas and coal have a strongly negative one.

The following chart illustrates the possible impact of CoPs on fuel prices and delivered heat costs for industrial users, assuming a \$50 per tonne carbon price (being an incremental increase from the current carbon price towards the Productivity Commission's suggested carbon price of \$100 or more):

Figure 3: Comparison of fuel prices and delivered heat costs⁹



As technology evolves and improves, and carbon prices rise (discussed below), the economics will increasingly favour electrification for many process heat users in New Zealand.

There are other factors to consider in electrification decisions. Boilers, heat pumps and other process heat equipment are long-lived assets. The investment decisions around these depend on the changing economics and risks over the equipment's physical lifetime, including on the capital costs and the forward expectation of prices for fuel, for carbon and for the capital items.

The expected increase in the carbon price to more than \$100 per tonne (as suggested by the Productivity Commission¹⁰) will directly and materially enhance the fuel cost advantages of electricity but the cost of boilers, heat pumps and electrical connections will also be important considerations.

Electrification has several other financial advantages: it is often modular so can be extended, there is no need for expensive ash handling and no need to hold fuel inventory (which can require considerable committed capital, space and specialist skills). All these benefits favouring electrification will increasingly be a part of the business case considerations for process heat applications and help make the total cost comparison very favourable, particularly for lower temperature processes.

The International Energy Agency (IEA) has completed a substantial volume of research on industrial heat pumps and their performance¹¹, with the results showing substantial energy efficiency gains and typical investment payback periods of fewer than seven years.

⁹ Average 2018 industrial gas and electricity prices from MBIE, coal prices from Transpower analysis, emissions factors from MBIE, fuel prices and costs only: excludes capital and non-fuel operating costs.

¹⁰ New Zealand Productivity Commission, Low-emissions economy, final report August 2018, available at www.productivity.govt.nz/inquiry-content/3254?stage=4. The Commission reported modelling by Concept Consulting that showed New Zealand can move to a low-emissions economy at an emissions price rising to between \$75 and \$150 a tonne of CO₂e by 2050, and decarbonise towards net zero GHG emissions at emissions prices in the range of \$150 to \$250 a tonne of CO₂e by 2050 (in New Zealand dollars).

¹¹ See www.iea.org/tcp/end-use-buildings/hpt and heatpumpingtechnologies.org.

SECTION TWO: Taking the heat out of process heat misconceptions**MISCONCEPTION THREE:** Increasing the carbon price will drive electrification

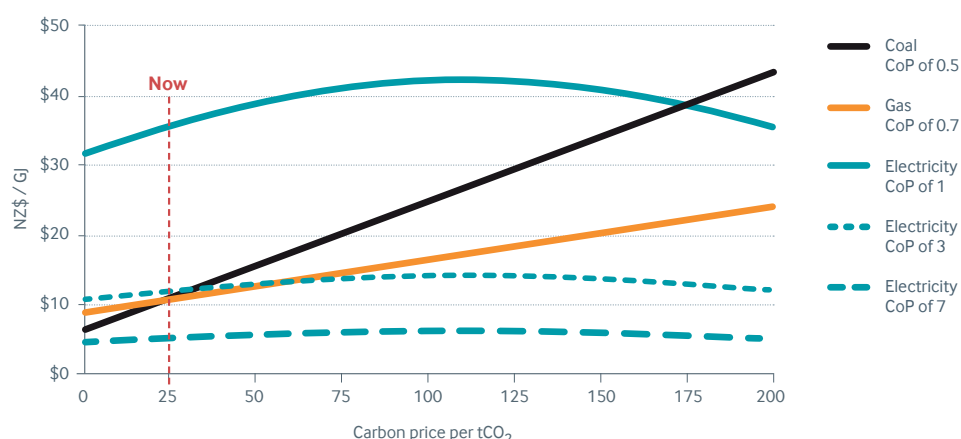
This is true in New Zealand, although in the short- to medium-term this effect may be more muted than expected.

As the carbon price rises, the cost of coal, gas or other fossil fuels used in process heat applications will naturally also rise. However, electricity prices are also affected by a rising carbon price. Electricity prices are set by the marginal producing unit – in New Zealand this is currently typically coal or gas or hydro generators, with the latter valuing the cost of its water against the former.

On the other hand, higher carbon prices will encourage more investment in renewable generation and the decommissioning of fossil-fuel generation, leading to an evolution of the generation mix towards a higher proportion of renewables. This is already occurring in the New Zealand market with generators lining up renewable portfolios. As thermal plant continues to be displaced – or reserved for dry-year rather than normal-year operations – the carbon-price component of the electricity price can be expected to fall.

It is difficult to predict the interplay of these factors, but one can expect the impact of carbon prices on electricity prices to be close to linear initially but to fall off – potentially rapidly – at higher carbon prices and in the medium- to long-term. By contrast, the impact of carbon prices on gas and coal is purely linear, without let-up. The diagram below illustrates one possible future of this relationship, assuming that the base prices of coal, gas and electricity remained constant:

Figure 4: The impact of carbon price on the cost of delivered heat¹²



Given the uncertainty over how much of the carbon price will be reflected in the electricity price over different horizons, thought should be given to what additional measures could catalyse the commercial incentives to electrify.

¹² To illustrate this point, we have taken average 2018 industrial gas and electricity prices, coal prices from Genesis Energy published data, emissions factors from MBIE, assuming conservatively that gas peakers set the marginal price of wholesale electricity 100 per cent of the time now, with a purely illustrative assumption that this reduces linearly to 0 per cent as the carbon price increases to \$200/tCO₂.

SECTION TWO: Taking the heat out of process heat misconceptions**MISCONCEPTION FOUR:** We can wait for better technology in the future

There are some easy gains to be made. For example, with more than 350 separate public sector facilities consuming 6 PJ of gas or coal for process heat today (including at least 60 schools), the public sector could lead the way to a cleaner, more climate friendly and economically sustainable future. ■■

If electric process heat is feasible, and becoming ever more economic with time, what's holding it back? It is inevitable technology and its resulting benefits (such as improved efficiency and lower capital costs) will continue to improve over time, potentially rapidly as the world increasingly seeks low carbon energy solutions, and carbon prices rise.

For process heat industries, where plant investments (in boiler replacement for example) are big ticket items, the temptation could be to wait.

Industry in particular needs to bridge the gap between installed process heat technology (generally a non-electrified process) and the ultimate future state of a given facility (likely to be significantly electrified) as plant reaches its economic end-of-life. This necessary transition requires more focus and commercial attention. There may be significant opportunities in food processors and others using cool stores to re-direct heat from refrigeration plant to drive a high temperature heat pump. A programme to scrap old boilers (to ensure they head out of circulation) and using EECA funding grants¹³ can play a role here too.

Most of all, New Zealand needs to build capability and start reducing process heat emissions today. The technology exists, the economics increasingly stack up and there are some easy gains to be made. For example, with more than 350 separate public sector facilities consuming 6 PJ of gas or coal for process heat today (including at least 60 schools), the public sector could lead the way to a cleaner, more climate friendly and economically sustainable future.

MISCONCEPTION FIVE: Electricity is more complicated and less reliable than fossil fuels

This is simply not true. However, it's important to note that changing something as fundamental as a fuel source for a process that is critical to a business's production can be challenging. Managing gas or coal today requires significant attention – from resource consents, to stockpiles, to specialised health and safety management. Managing electricity is much simpler – there's no stockpile on-site to be managed or replenished, and you can switch it on and off without the warming up and cooling down losses on-site. The risk of uncontrolled explosion of fuel is removed.

Reliability can be the other key concern. Electricity is extremely reliable with customers across all distribution networks experiencing availability of 99.96 per cent, and direct transmission customers experiencing availability of 99.996 per cent. What about the 0.004 per cent? Part of that fraction stems from planned outages which can be timed and managed. While it is difficult to access data on this point, existing boilers and fossil fuel heat systems experience outages. It should also be considered that the time to re-start plant with electrical equipment is much faster and safer than with coal or gas.

¹³ For investigations, audits, monitoring and other similar operating costs. These grants do not cover capital costs.

Case studies

the changing face of process heat

While emissions from process heat applications have increased by 45 per cent since 1994, over the past decade, EECA and New Zealand businesses have worked to reduce emissions through improving process efficiency.

A few pioneering examples have started to show what an electric future for process heat could look like.

CASE STUDY ONE:

Dairy factory electrification¹⁴

synlait™
making more from milk

Earlier this year, with support from EECA through its Technology Demonstration programme, Synlait commissioned New Zealand's first large-scale electrode boiler.

Synlait is New Zealand's third largest dairy company and in June 2018 made a commitment not to install another coal-fired boiler at any of its sites. It also committed to reducing off-farm greenhouse gas emissions by 50 per cent by 2028. Synlait's installation of an electrode boiler is a significant step towards lowering its emissions footprint.

The boiler is located at Synlait's Dunsandel site in Canterbury. It stands seven metres tall with a diameter of 2.7 metres and provides renewable process heat to Synlait's advanced dairy liquids facility. The boiler uses electrodes that are submerged in water with electricity flowing through the electrodes, vaporising the water into steam to create renewable process heat. The steam from the electrode boiler will be used to pasteurise and sterilise milk, clean production lines and help form product packaging.

At this stage, the capacity of the electrode boiler is 6 megawatts (MW) with the option for Synlait to double this capacity to 12 MW. The local electricity distributor, Orion, upgraded its network capacity to provide the necessary power for the electrode boiler and its upgrade investment is sufficient to cater for the potential doubling of boiler capacity.

While the operating costs for the electrode boiler were higher than some of its other options, over a 10-year period, Synlait considered it to be the best option. The electrode boiler is 99 per cent efficient, which is up to 30 per cent more efficient than coal burners. The carbon saving of this 6 MW electrode boiler – compared to a coal alternative – is around 14,000 tonnes CO₂/year. That's roughly the same emissions reduction as removing 5,300 cars from the road.



¹⁴ Dairy Factory Electrification – sourced from Synlait.
www.synlait.com/news/synlait-has-switched-on-new-zealands-first-large-scale-electrode-boiler/;
and www.synlait.com/wp-content/uploads/2019/03/Synlait-Electrode-Boiler-fact-sheet_March-2019.pdf;

CASE STUDY TWO:

Northland hospitals¹⁵NORTHLAND DISTRICT
HEALTH BOARD

The Northland District Health Board (DHB) runs several small hospitals that have historically used fossil fuel-fired central boiler systems to provide heat and hot water. Over the past five years the DHB has been progressively converting these to electric heat pumps – saving money and reducing emissions.

Kawakawa hospital was the first at which modern, efficient heat pumps replaced boilers. The project was so successful that it was quickly replicated at Kaitia and Dargaville Hospitals. The \$700,000 investment in making the switch across all three hospitals was funded through a loan from EECA and generated target cost savings of \$300,000 per annum. This represents a compelling investment case: including a two-year capital pay-back period and the ongoing annual savings able to be redirected into core health services.

Kaitia and Dargaville Hospitals provide a clear example of the value of the change. Each hospital's central boiler was run on diesel (burning a combined 127,000 litres of diesel per annum) while the new electric heat pump system is 3.5 times more efficient and enables superior levels of control.

For example, the heat pump-based system enables separate control of hot water and heating, enabling individual buildings to be managed based on occupancy. This makes a huge difference as only one ward is used day and night and historically the whole system had to be run on the diesel system. This is a typical example of the dual focus on electrification and efficiency – using less energy from cleaner sources to generate savings.

Overall, the DHB has cited “clear financial benefits” and “reducing our carbon footprint” as the core reasons behind the change.



CASE STUDY THREE:

Food processing

VERKERKS

- TRADITIONAL EUROPEAN SMALLGOODS -

Ashburton Meat Processors (AMP) is run by A. Verkerks to make cured meats. It is typical of food processors in New Zealand, with the exception of the company's commitment to both electrification and energy efficiency.

AMP used to run its heating and refrigeration systems on light fuel oil and an old 'Freon' (CFC) coolant. As it looked to replace its heating and refrigeration systems it also sought to electrify its energy sources to significantly reduce its carbon footprint.

The business worked with Christchurch firm Active Refrigeration to replace its refrigeration and heating systems with a new ammonia-based heat pump. The new system provides simultaneous cooling and high temperature heating, offering a significant step-change in efficiency. The switch not only reduced emissions but also generated annual savings of over \$200,000. The plant has been able to comfortably provide increased capacity and has reduced overall emissions by 42 per cent.

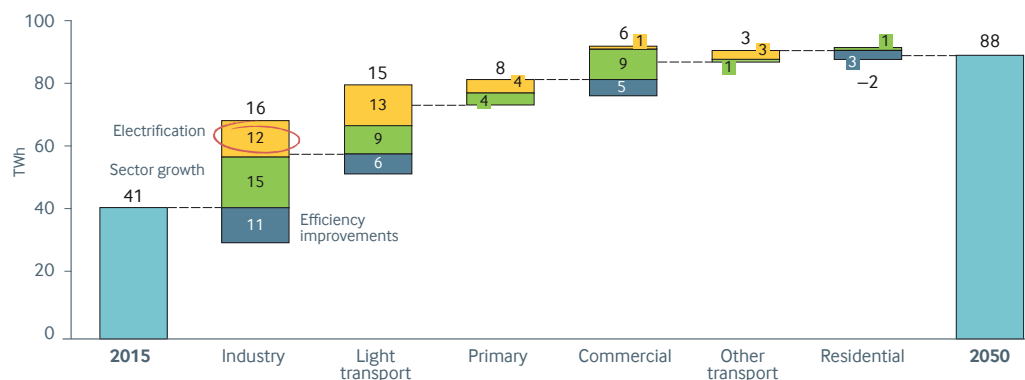


¹⁵ Northland Hospitals – sourced from Northland District Health Board.
www.northlanddhb.org.nz/assets/about/Carbon-Footprint-to-2018.pdf

Section three

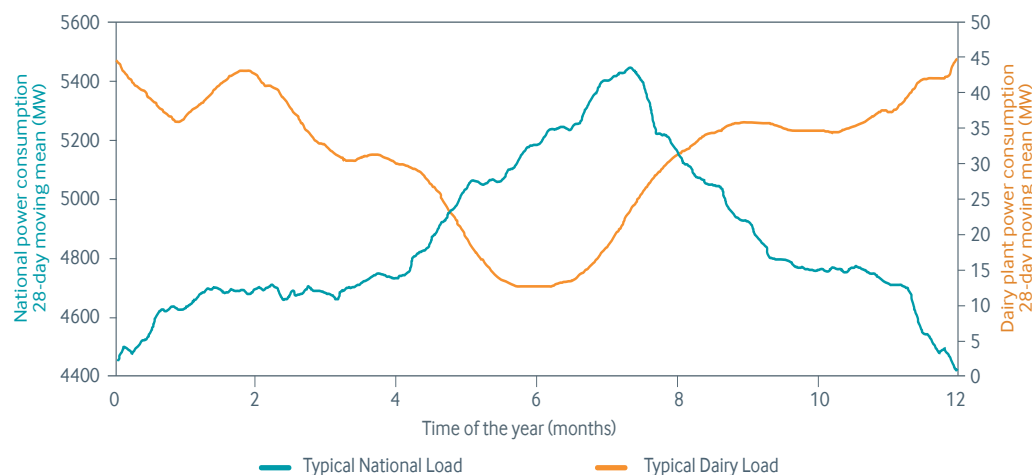
The challenge for transmission and distribution companies

Given the technology, economics, environmental imperative to act and the reliability and efficiency that electrification of process heat can offer, Transpower expects significant new loads on the grid and across local networks over the coming decades. The base case scenario in the original *Te Mauri Hiko* estimates national electricity demand could double by 2050, a large part of which is due to the expected electrification of process heat applications.

SECTION THREE: The challenge for transmission and distribution companies**Figure 5: Process heat is a significant part of electricity growth in the *Te Mauri Hiko* base case scenario**

New investment in transmission and distribution assets and services will be required to enable this electrification of process heat. Headroom in network capacity varies across both the national grid and at the distribution level. This means the location of the plant being electrified and existing headroom capacity in the nearby lines is key when considering investment size, timing and connection location, as well as whether it would be most efficient for the connection to be at the distribution network or, for larger plant, directly into the national grid.

Electrification of process heat offers both significant opportunities and challenges for the broader electricity system. Demand from dairy factories, meat works and other seasonal industries can help to smooth the overall seasonality of New Zealand's electricity demand. For example, dairy plant power consumption increases in the spring and summer milking season and drops in winter, providing an inversion and balance to New Zealand's overall energy consumption, which rises in winter. This potentially valuable opportunity to smooth national electricity demand could help underpin year-round renewable supply and contribute to reducing the current dry-year electricity supply gap.

Figure 6: Seasonality of current dairy factory electricity consumption is complementary to New Zealand's existing winter electricity peak

SECTION THREE: The challenge for transmission and distribution companies

A further opportunity with increasing process heat load is to increase New Zealand's network utilisation. Energy distribution companies are now starting to work to enable new technology (such as batteries and other distributed energy resources) and to develop new potential service offers.

These initiatives are important in considering transmission alternatives to assist with managing load and the achievement of the maximum potential for converting a process to electricity, in the most economically efficient manner.

Many process heat sites pose challenges to distribution and transmission systems due to their remoteness and energy intensity. In some cases, large plant – e.g. electrified dairy plants – could be supplied from the 220 kV transmission grid backbone as a more efficient alternative to upgrading existing regional 110 kV or 66 kV distribution systems. In other cases, the economics of electrifying plant in its existing location may – in conjunction with other commercial drivers – make it more economic to relocate to a greenfield site with optimised plant closer to transmission assets and other infrastructure.

The network planning challenge exists at both the distribution and transmission level. As our Waikato case study shows (see page 21), existing networks have significant capacity that can be utilised but continuing growth will also require further network investment. The challenge for network companies is to estimate the amount and timing of increasing demand in order to investigate if, what and when investment would be needed to ensure sufficient capacity and reliability.

In some cases, while large sites can be electrified in months, the timeline to build a new transmission line can be as long as seven or more years if resource consenting is required. In some cases, Transpower may need to upgrade other assets so early discussions are critical. Transpower has already held discussions with potential customers for industrial sites as large as 50-80 MW and their load can be incorporated with relatively straight-forward upgrades – early communication and joined up thinking is the key to successful developments.

The challenge at the distribution level is, in some respects, harder than at the transmission level. It is likely electrification, particularly at large energy-consuming sites, would occur in stages. There is a risk of large plants initially connecting to distribution networks for the early stages of electrification, only to find these networks cannot support their full electrification. Once connection costs are balance sheet items for these customers and distribution companies, it may become harder to electrify further without connecting to the transmission network – raising the risk of future stranded distribution network assets and sunk cost.

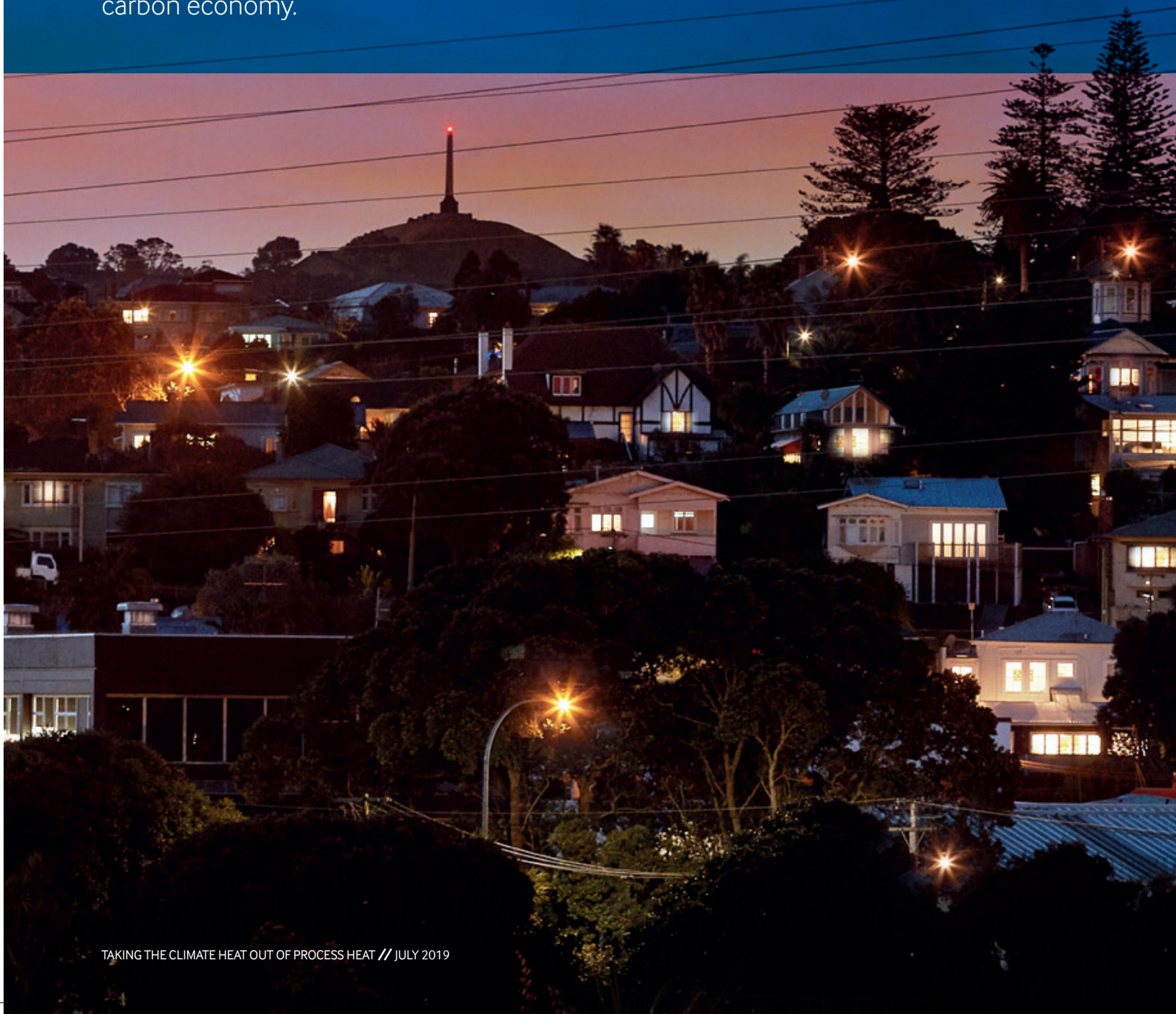
These challenges require the transmission and distribution operators to take a holistic approach to transmission planning for a region, working closely not only with the local distribution company, but also with customers with significant current and / or potential electricity loads. The thinking and conversations around process heat electrification need to be occurring now.

“
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Section four

Implications and challenges to resolve

Te Mauri Hiko describes an energy future in which New Zealand meets its international climate change commitments and leads the world through cutting carbon emissions and leveraging its abundant and diverse renewable resources to build a low carbon economy.



SECTION FOUR: Implications and challenges to resolve

Fundamental to this change is New Zealand's current process heat systems – the core engine of our manufacturers and primary producers, and heating our schools and hospitals.

This paper has identified four critical issues that need to be addressed collaboratively to realise the opportunity to electrify process heat for the benefit of New Zealand's industry and economy:

1. Capability building and getting started now

Process heat is a technical topic, one that requires expert advice. There is a need to provide leadership in building capability in this space so that the renewal, capital planning and maintenance conversations at thousands of locations across the country are infused with a sense of what's possible and the benefits of being among the first movers. Our manufacturers can lead the world in meeting the requirements of consumers who are increasingly demanding environmentally sustainable products.

New Zealand needs its engineers and consultants to have the experience of the latest electric heat technology. EECA's business programmes¹⁶ have been making a difference here but rely on willing first-movers both to adopt new technology and then showcase it.

2. Replacement cycles and scrapping

A key aspect of fuel change in process heat is the replacement cycle for boilers and high-cost capital equipment. These assets last for decades and once the high upfront cost has been spent on say a coal boiler, the commercial incentive can be to simply keep using it. A critical challenge is getting this plant decommissioned, which will require innovative thinking around incentives to either scrap old fossil fuel plant or invest in clean electric plant. Every year about three per cent of the country's traditional thermal boilers come up for renewal and it is vital that these are decarbonised. Otherwise we are locking in high intensity carbon emissions – and their costs – for the next 30 years, perhaps much longer.

3. Collaboration and network planning

The electricity system is a network, so with the substantial new loads envisaged here it becomes very important to have line-of-sight to what load will likely be added and when – particularly large chunks of demand. New Zealand is blessed with an abundance of low-cost renewable energy resources but the time to add generation, transmission and distribution resources can be longer than the time to install an electric boiler. This highlights the need for collaborative network planning. The location and timing of this new electricity demand will influence planning and preparation, and make sure the network is in place to reliably support new plant when it is commissioned.

4. Leveraging the carbon price for incentives

In this paper's misconceptions section it noted that an increase in carbon price can lead to an increase in electricity prices in the short- to medium-term, even when more renewable electricity is being added (as the marginal units set the price). As observed in this section, this mutes the incentive for companies to transition to electricity based on carbon price expectations alone. Thought should be given to what additional measures could catalyse the commercial incentive to electrify.

¹⁶ www.eecabusiness.govt.nz/assets/Uploads/EECA-Business-Programme-Summary-June-2018.pdf



CASE STUDY FOUR:

Eastern Waikato electrification of process heat applications – network and transmission considerations (in collaboration with Powerco)

The *Te Mauri Hiko* team worked with Powerco to consider some of the known energy users in the Eastern Waikato and Thames Valley area with heat-based, non-electric processes that could potentially be electrified. The Eastern Waikato is a particularly useful example as it includes several dairy, meat and other production plants as well as regional centres and long-serving infrastructure. This case study focuses on the challenges faced for transmission and distribution around additional electrical load. It also considers how the initial, partial transition to electrification might potentially play out at existing plants.

This joint snapshot is set out in Figure 7. It reflects current known facilities and is intended to be illustrative rather than comprehensive.

The major energy user in the region is the Waitoa dairy factory, which is one of three Fonterra factories in the North Island that currently uses coal. This site has a relatively new UHT plant, which can process year-round, so it has a steady load across winter and summer (this differs from most dairy factories, which are more summer-weighted).

The next largest energy users are the timber processors, which generally use their own wood wastes as fuel. This case study assumes the timber processors will continue to do so and subsequently, they have been excluded from any further consideration for conversion to electricity.

The region also includes several cheese making and meat processing plants, many using LPG or diesel as fuels for process heat. There are several schools in the region as well as a hospital and other small facilities also understood to be using fossil fuels.

Based on a number of assumptions, this paper estimates an initial 40 MW increase in electrical load on the network after switching some fossil-fuelled processes to electrified process heat in this area. This represents those parts of existing processes that would be the easiest and most efficient to convert to electricity in the short- to medium-term – not the full scale of existing heat and process loads at these plants. The full heating load at these plants is substantially larger and, should they be fully electrified, would run into hundreds of MW (an exact figure is difficult to determine, as a one-to-one electricity substitution for alternative heat sources is not expected and the actual load figure would depend on how future industrial processes may be planned).

The distribution utility perspective

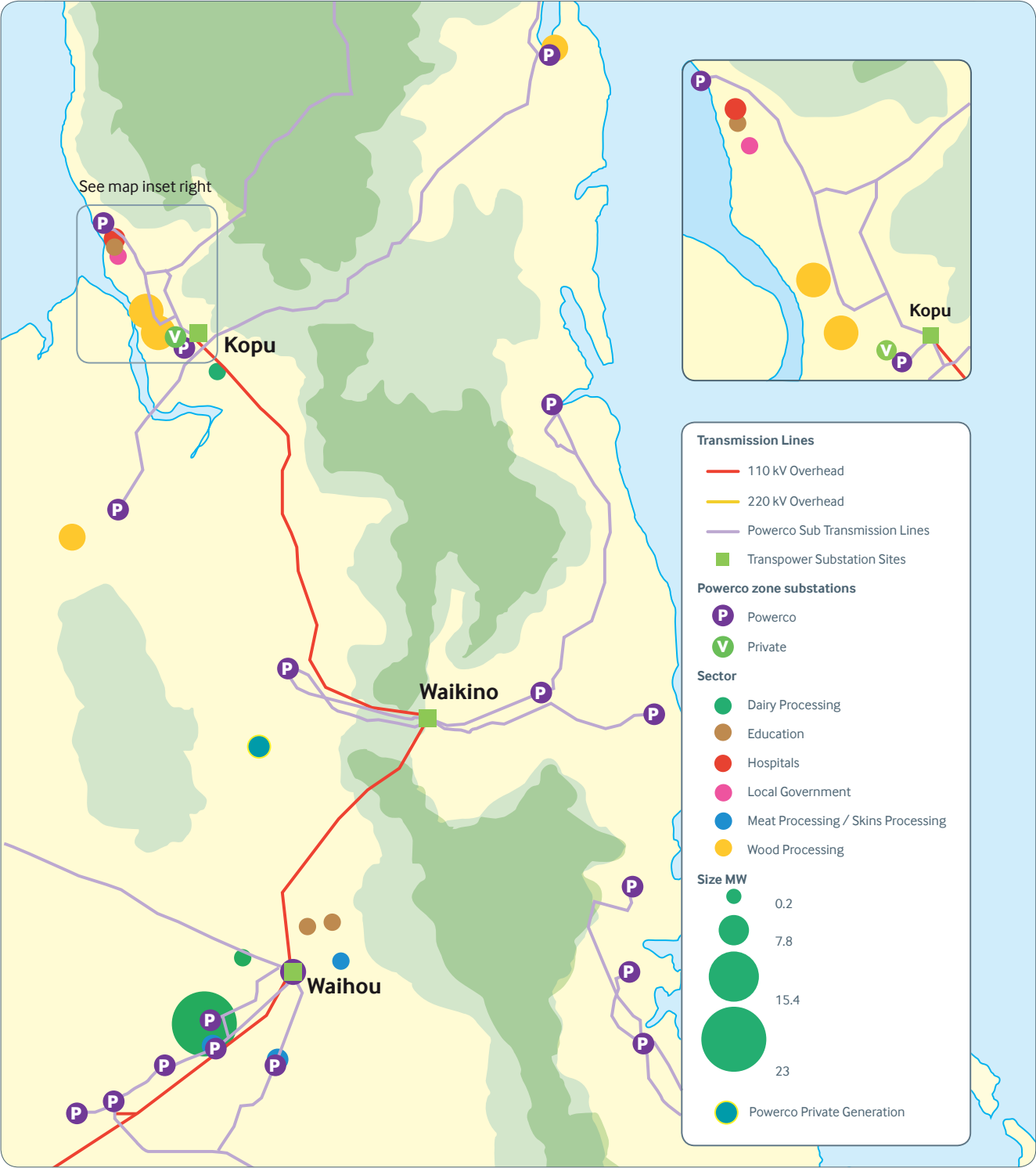
Powerco could accommodate all of the potential 40 MW capacity uplift, for the expected initial conversion of heat loads, on its sub-transmission circuits and distribution circuits.

Powerco and Transpower have jointly assumed the increasing electrification, even for these initial conversions, will occur incrementally. To achieve these incremental uplifts, it will be necessary to frequently upgrade parts of existing circuits and substations. Depending on the size of the increased capacity required, the cost of such upgrades could range from a few hundred thousand dollars for a distribution line reconductoring; approximately \$7 million for a new zone substation with associated feeders; and up to \$15-30 million for new sub-transmission circuits and a zone substation.



CASE STUDY FOUR:

Figure 7: Capacity of heat-based, non-electric processes that could potentially be converted to electricity in the Thames Valley Area¹⁷



¹⁷ Note that the load indicated in the chart is not the full heating and process loads of the various plant. Instead, it refers to that portion of the process load that would likely be relatively easy and efficient to convert to electricity in the first instance.

CASE STUDY FOUR:

Powerco would not necessarily need to make all these investments to accommodate the total uplift. There is some existing headroom in capacity to absorb the smaller increments of electrification, and some degree of demand-side management or network reconfiguration could unlock further capacity.

The challenge, as with the transmission network, is attaining sufficient certainty to remain ahead of the needs of customers, ensuring sufficient network capacity is available and unlocked by the time it is needed.

The order of any incremental investment is dependent on discussions with customers. For large customers currently connected at sub-transmission level, such as dairy factories, Powerco envisages upgrade investments matched to the customer needs, with investment being made in consultation with customers and aligned to their growth path. Where the investment solution is in the realm of conductor upgrades, determining how to proceed is relatively straight-forward. It is more challenging for Powerco where the customer growth path is long, and the upgrades are for investments such as transformer capacity. Under these circumstances, it may well be economic to stage the investment.

For the smaller, diverse customer groups in this region, such as schools, the investments would be more likely to follow the load increases as they occur, with minimal large step-change investments being undertaken unless the demand forecast is relatively certain to warrant the need for such upgrades. This strategy is adopted to avoid the risk of over-investing. Big step-change investments would therefore only be made where there is very clear indication of the demand increase. This is a risk trade-off – between the risk of over-investing and demand not arising, and the risk of investing incrementally with a resulting inefficient investment path over the long-term. In the event a large step-change in load should arise in this region – such as a new electrified dairy plant or a full conversion to electricity of one of the existing large plants, particularly where the total electrical load is in the 30 - 50 MVA or higher range – Powerco considers it would generally be most efficient for such a site to connect directly to the transmission system.

Transmission utility perspective

Any increasing load in the distribution system could mean an increase in the amount of electricity to be supplied at peak times from the transmission system to the point it connects with that distribution line. As such, Transpower is most concerned with whether there is sufficient headroom in transmission capacity, and no voltage issues, arising from the potential increased load.

The current line from Hamilton to Kopu has around 150 MW capacity in total; it is at near-full capacity at peak times. It appears there is 40 MW of additional initial load that may arise from the initial electrification of known process heat plants along the spur but in the longer term it could end up being significantly more.

There is an ability to handle some incremental load growth, with relatively small investments (\$3-5 million) for improving voltage quality on the spur but this will trade-off security or require new approaches. For example, off-peak capacity enabled by flexible demand, the use of intelligent technology to enable greater capacity (though with a low probability security trade-off), or operating the transmission lines at greater capacity (considering changing seasonal and temporal ambient conditions).

If growth is larger, then transmission options could include a new substation east of Hamilton and new transmission to the load (either 110 kV or 220 kV). If new transmission is required, a seven-plus year process is potentially required to secure the necessary property rights, designations and resource consents and then build and deliver the new infrastructure.

A key challenge is to understand the cost/benefit of incremental investment compared to a step-change investment of reconductoring or, if needed, a new transmission line and associated assets. Herein lies the fundamental challenge of uncertainty. If Transpower is certain all the load to reach the trigger would eventuate, it could make the bigger investment that potentially has a lower whole-of-life cost; but with uncertainty the challenge is determining the approach that will enable the transition while minimising the risk of investing in capacity for which the need may not eventuate.

Transpower's traditional approach to managing uncertainty is to plan and invest incrementally, but as demand increases, an incremental approach can mean inefficient investments over the longer-term. Consideration should be given to investing proactively and prudently to unlock likely future capacity constraints while recognising the risks associated with such investments.

Consideration should also be given to new generation that could connect to this line, for example Ventus Energy's proposed Kaimai wind farm. New generation balances load so this would reduce the amount of power flow on the line from the west. If the generation proposed can match local demand it would then ease the need for transmission investment, but this would require new tools and platforms to manage intermittency in an energy future in which demand flexibility and batteries will play a bigger role.

Summary

Te Mauri Hiko has been consistently highlighting that New Zealand has a unique opportunity to lead the world in transforming its economy through the energy choices it makes over the next 30 years.

New Zealand has a renewable electricity base that is the envy of the rest of the world and is blessed with an abundance of other new renewable energy options. New Zealand can build a low carbon economy that sets an example to the rest of the world, supports the kiwi brand and provides a unique opportunity to market climate-friendly products to an increasing consumer conscious world.

Even with the abundance of renewable energy options that New Zealand has, transforming an economy will require vision and a great deal of leadership: leadership from our political decision makers, leadership from energy consumers, leadership from our energy industry and, as highlighted in this paper, leadership from business.



Changing the way things have always been done is never easy, and all sectors of the economy are grappling with the climate change challenge and the energy choices available to them.



Many people will likely be surprised to learn just how much industrial heat processes – processes we rarely see or, even less, consider – contribute to New Zealand's emissions of climate changing gases. Yet, in many cases, the way we heat our schools and hospitals, process our food and manufacture the goods we consume and export has not changed much in 150 years. We burn oil, coal and gas in relatively simple, traditional boilers, as we have done since the industrial revolution.

As electric vehicles make their way onto our streets and into our suburbs in increasing numbers; as coal and gas-fired power stations are increasingly being retired and moved into reserve plant; and as more and more renewable energy projects are developed across our country and in our homes and businesses, our industrial heat processes also now need to move with the times.

The price of carbon, the long-term drivers behind the prices for fossil fuels and, most importantly, the rapid evolution of technology, now provides for clean, efficient and economically viable electric technology options for the purpose of process heat.

This brings us back to leadership. If we are to avoid a climate crisis and leave a world to enjoy for future generations, every sector of the economy needs to lead and replace its use of fossil fuels with clean alternatives as quickly as it can.

One of the challenges with leadership is being prepared to make early decisions – to lead the rest of the field. The purpose of this paper is to highlight that there are now rapid technological and economic advances occurring in the process heat space that is providing more and more options for businesses wishing to pursue a cleaner, climate-friendly future.

Changing the way things have always been done is never easy, and all sectors of the economy are grappling with the climate change challenge and the energy choices available to them. Realising New Zealand's economic opportunity through making the right energy choices will require not only leadership, but a willingness to also share ideas, work together and pursue a common vision.

This paper seeks to make a contribution to these goals in service of realising our unique opportunities.



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