Sustainable action for a better tomorrow

Climate Change Commission

NZ Process Heat Decarbonisation

Final Report

20/10/2023

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1	3/10/2023	Draft for Client Review	JB/KS	JDB	DT
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Executive Summary

The urgency to address decarbonisation is growing globally as countries approach deadlines for mandates and commitments. In New Zealand, process heat has been identified as a focus for decarbonisation. While industry stakeholders have expressed the possibility of achieving process heat decarbonization by 2037 through their efforts and investments, formal research to substantiate this claim is limited, as is the understanding of the market's capacity to facilitate this transition.

This report aims to assess New Zealand's capability to execute process heat decarbonization and establish a realistic timeline for its achievement.

Limitations of This Analysis

This study provides a thorough review of the process heat decarbonisation challenge that lies ahead. However, there were limitations to this analysis that could not be overcome as they were difficult to predict at this time, or outside of the scope of this study.

1. Throughout this report, decarbonisation of process heat is treated in isolation. Hence, competing factors, external to process heat decarbonisation, such as transport electrification, economic growth, housing development, materials shortage, global markets, etc. were largely ignored. However, these will have a significant impact on the ability of New Zealand to decarbonise process heat by 2037.
2. Conducting analysis on this scale is challenging, assumptions made create inaccuracies at a site/regional level, but this was the trade-off to creating a realistic picture of process heat decarbonisation on a national level.
3. Further consideration and study in ensuring the redundancy and reliance of the electrical grid system once process heat is decarbonised is required. Due to this, consideration of N vs N-1 security for electrical network upgrades is key.

Capacity for Decarbonisation

The quantum of work identified to decarbonise process heat was estimated to be achievable (in isolation of other decarbonisation efforts within NZ) by 2048, which is 11 years later than the target. The main headwind in this effort is the availability of key personnel.

- In the labour market, electricians and design engineers were most constrained, but only electrical engineers had the capacity to achieve process heat decarbonisation in the desired timeframe as seen in Figure 1.
- The ability of Electricity Distribution Businesses to implement the network upgrades required to facilitate decarbonisation is also a risk but further investigation is required to understand their constraints.
- Suppliers of key equipment indicated that manufacturers could supply the equipment required for decarbonisation but are already constrained by the availability of skilled workers for installation and materials such as copper.

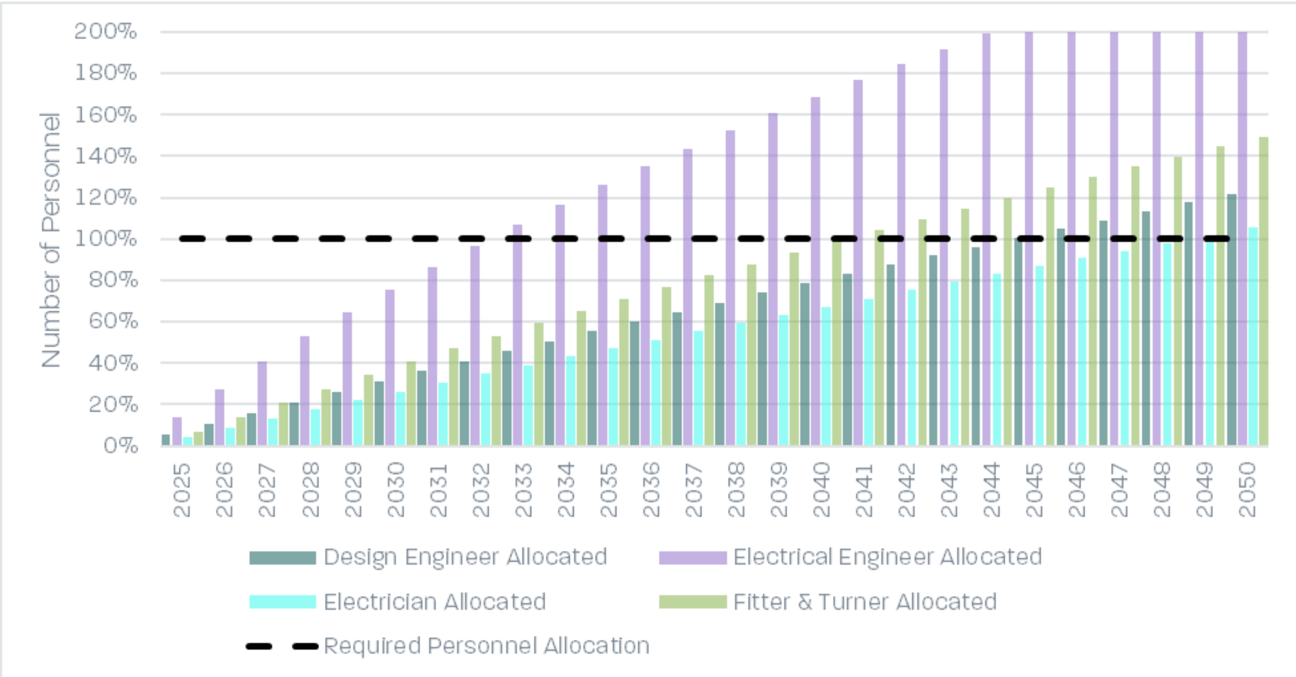

Figure 1 – Decarbonisation Profession Allocation Timeline

Next Steps

- Availability of key personnel has been identified as the main constraint from this study. Pressure needs to be applied on the government to invest in apprenticeship schemes and incentivise skilled professionals to stay in the country.
- Identifying energy efficiency and decarbonisation opportunities will be key to achieving decarbonisation targets for the country; investment by EECA into energy audits should be continued.
- The capability of EDBs to implement the network upgrades required in the desired timeframe is uncertain; EDBs should be encouraged to improve capital budget forecasting to better accommodate for new market factors such as process heat decarbonisation and transport electrification.
- As mentioned throughout this report, factors external to process heat decarbonisation will have a significant impact on the ability of New Zealand to decarbonise process heat by 2037. How these factors all interact, and their net impact will be difficult to measure, however, further investment into studies of this nature for sectors/industries/technologies that have connection to process heat decarbonisation will help us to better understand the entire picture and plan/execute more effectively.

1. Introduction

The necessity of a response to climate change is growing globally. In New Zealand, process heat has been identified as a focus for decarbonisation, making up one third of New Zealand's overall energy use and contributing ~8% to gross emissions[1]. Process heat refers to the thermal energy required for processes such as heating, drying, and cleaning, usually supplied as steam or hot water.

While significant work has been conducted to understand the targets of decarbonisation and how they align with New Zealand's commitments; there has been limited work undertaken to assess the timeframe of process heat decarbonisation and the potential to achieve this earlier than required. Industry has indicated they may be able to achieve a 2037 timeframe from their own efforts and investment, however, there has been limited formal research to back this assumption.

There is limited knowledge of the market's capacity to develop, and deliver, the decarbonisation of process heat. This report assesses whether New Zealand has the capability to execute this and when it is achievable by. This analysis has been split into three sections:

Section A – Process Heat Decarbonisation
This section focuses on determining the quantum of work required to decarbonise process heat in New Zealand. This section aims to understand and estimate the required projects to decarbonise the generation of process heat in New Zealand.

The current energy and fuel demand of process heat are quantified using data from prior work undertaken by DETA and a gap analysis approach. Replacement to low carbon emission technologies for each end use are assumed and proposed based on the understanding of already known and proven technologies. The resources required to undertake these replacements are investigated by estimating the following for each project:

- Capital costs – accounting for equipment, electrical and mechanical installation, civil construction, design, and project management.
- Engineering and project support staff requirements.
- Fuel/electricity requirements.
- Number and capacity of key equipment required (heat pumps, boilers, transformers).
- Electrical network upgrades required.

[1] https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/low-emissions-economy/decarbonising-process-heat/

Section B – Estimation of Capacity

This section assesses the capability of the New Zealand market and supply chain to support and execute the required decarbonisation projects by 2037. Evaluations on the availability of required personnel, capability to execute electrical network upgrades, and ability to procure/manufacture key equipment were conducted.

This section aims to understand when decarbonisation is likely to be achievable, if the 2037 target cannot be realised. Headwinds and tailwinds in the decarbonisation effort are identified and investigated in this section to understand the levers to pull to expedite and support the decarbonisation of process heat.

Section C – Scenario Modelling

The section takes the output from Sections A and B to further assess the capability of the New Zealand market to decarbonise process heat. Scenarios are developed based on the headwinds and tailwinds identified in Section B to determine the effectiveness of affecting these factors.

This section aims to understand the effect of each bottleneck and makes recommendations as to where the overall rate of decarbonisation may be accelerated.

2. Methodology

2.1 Section A – Process Heat Decarbonisation

This section aims to understand the quantum of work required to decarbonise process heat in New Zealand. The required number of heat pump, biomass boiler, and electrode boiler projects are estimated. The resources required to undertake these installations were also estimated – assets/equipment, capital costs, staff support required, and electrical network upgrades.

2.1.1 General Process

- Lists of currently operating boilers have been taken from boiler databases, developed for individual Electricity Distribution Businesses (EDBs) as part of another project. These lists have been produced by DETA, in partnership with the Energy Efficiency and Conservation Authority (EECA), to map boilers and develop the Regional Heat Demand Database (RHDD) that was initiated in November of 2020.
- For areas that have not previously been considered, or the research is currently underway/pending, corrections have been made, as per the assumptions outlined in Section 2.1.2.
- For boilers that were not captured as part of the previous database generation work (due to several factors, such as having limited site access), corrections have been made to account for these, see working assumptions in Section 2.1.2.
- Where possible, information on known fuel switching projects has been taken from work previously conducted by DETA, such as from EDB Thermal Fuel Transition Impact Assessments, Energy Audits, and Energy Transition Accelerators.
- A gap analysis was conducted to complete the dataset, assigning decarbonisation projects to every site.
    - Where boiler capacities and utilisation data were missing; averages were taken from the available data on a sector basis to estimate (i.e. average capacity of a meat processing boiler is **2 MW** and observed utilisation is **34%**).
    - Where a decarbonisation pathway was not identified, the pathway was chosen by a series of elimination criteria **(as outlined in Section 2.1.4 below).**
- Capital costing data was then collated from previous DETA projects and external online sources to develop cost factors for each project type, accounting for: supply and install of equipment, associated civil works required, LV electrical & controls, ancillary mechanical works, HV electrical network upgrades, as well as design and project management fees and appropriate contingency allocations typical for projects of this nature **(refer graphs in Section 2.1.6 below).**
- As with all studies such as this, there are some unavoidable gaps in the data. To account for this, a comparison has been made against the NZ Emission Tracker[2] and a correction added to the list to account for these discrepancies, as far as is reasonably practical **(refer process outlined in Section 2.1.5 below).**

[2] https://emissionstracker.environment.govt.nz/#NrAMBoEYF12TwClByBTALo2wBM4eg4xwCcSW0QA

2.1.2 Working Assumptions

Table 1 – Summary of working assumptions for Section A

Assumptions	
Data	All by-product boilers, i.e. those boilers that utilise heat from other systems, do not need to transition.
	Sites with unknown capacities have been assigned the same capacity as the average for their sector.
	For sites with an unknown boiler size, in industries with large variability in boiler sizes (e.g. Dairy, Meat, Other Manufacturing), a 2MW boiler size has been assumed. 2 MW is a suitably sized average based on the observed data.
	Sites with unknown fuel types were assumed to consume the same fuel type as the most common type in their region.
	Sites with unknown boiler utilisation / fuel consumption have been assumed to have the same boiler utilisation as the average of their sector.
	Sites with an unknown boiler output end-use: - Assumed to require HW <100 °C for Education, Correctional & Detention Services, Hospitals, Council, Accommodation, Retirement Village, Pool Heating, Military Base, Meat Processing, Buildings, Horticulture - Assumed to require steam, i.e. >100 °C for Wood Processing, Dairy Processing, Food Processing, and Other Manufacturing sites
	Every site was assumed to have 10% demand reduction available for opportunities related to energy efficiency. There are undoubtedly some sites with less (newer, more advanced sites) and some with more efficiency opportunities available. 10% is regarded as a conservative estimate, based on our experience with previous projects.
	Assumptions related to data correction for sites without allocated decarbonisation projects / pathways is outlined in detail below.
	It has been assumed the largest available transformer size is 1.5MVA, as this is typically what EDBs use.
	For electrical capacity upgrades larger than 6MW, the cost of transformers has been allocated fully to the EDBs, as they would likely be installed at the substation level rather than local to the new equipment, on site. This cost is then passed through to the sites as part of the electrical network upgrades.
Capital Costing	Heat pumps less than 0.5MW do not require a new plant room to be built. This is predominantly found to be the case and is based on previous experience where this new plant can use the space of old equipment being removed or sit alongside existing equipment.
	Electric boilers less than 2MW are assumed to not require a new plant room to be built.
	Civil costs for heat pumps (≥0.5MW) and electric boilers (≥2MW) are based on a scaled equation derived from previously completed projects. This correlation results in a linear cost relationship between civil cost / MW installed.
	Civil costs for biomass boilers are significant due to the large building envelope required and the storage / loading area of the biomass fuel being used. This is

	true even for a relatively small biomass boiler (1MW) and has been assumed to have a fixed base cost and then to scale linearly per MW installed capacity.
	Heat pump and electric boiler projects of 0.5MW and above will require a site supply capacity upgrade.
	Mechanical costs (i.e. integration of piping systems, additional pipe bridges / pipe supports to run pipes, etc) are averaged to be an additional 20% on the equipment supply costs.
	Low Voltage Electrical and System Automation / Controls costs are assumed to be 40% of the equipment supply costs.
	Woodchip and Wood Pellet boiler conversions are assumed to be 30% of full replacement cost. Conversion to biomass boilers has been assumed to only be possible for existing coal boilers.
	Project management fees are assumed to be 8% of the direct project costs (i.e. the sum of all equipment, civil, electrical, automation, and mechanical costs). Typically, across industry, PM costs can range from between 4 to 10% depending on many factors – for brownfield site developments, with multiple contractor engagements to coordinate, 8% is a reasonable assumption.
	Design costs (e.g. detailed site mechanical and electrical design to integrate with existing site systems) are assumed to be 4% of direct project costs.
	Contingency allocation is an essential component of all capital project costing scenarios to account for unanticipated project costs that need to be expended to complete the project; 20% of total project costs has been assumed.
Labour Required	The labour hours have been estimated using historic project information and an assumed hourly charge out rate (charge out rate of personnel outlined in Section A summary spreadsheet).
	The cost for Mechanical, Electrical and Controls labour has been estimated at 50% of the total cost for that respective cost factor.
Correction	Correction for sites where there is no information on the boiler has been estimated by comparing the NZ Emission tracker against total emissions currently identified; process further outlined in Section 2.1.5.

2.1.3 Data

The table below displays the number of sites in each sector and their average utilisation; this information has been sourced from the RHDD and was used for gap analysis.

Table 2 – Number of sites and average utilisation by sector

Sector	Count	Average Utilisation
Schools	123	5%
Other Education	22	23%
Wood Processing	56	95%
Dairy Processing	50	46%
Hospitals	47	35%
Meat Processing	73	34%
Other Manufacturing	146	59%
Council	40	7%
Correctional and Detention Services	9	15%
Venues	3	5%
Food Processing	45	31%
Buildings	27	24%
Retirement Village	7	30%
Pool Heating	5	12%
Horticulture	8	50%
Oil & Gas	1	93%
Military Base	5	31%
Accommodation	9	26%

2.1.4 Project Allocation Process

For sites that did not indicate a fuel switching project or were not covered in the RHDD, projects were allocated by a series of elimination process, as laid out below. The reality is that there is nuance in decarbonising process heat and site characteristics dictate what low-carbon alternative is best. The process outlined below aims to give the most accurate representation of the national process heat decarbonisation.

1. If temperature requirements are below 100 °C, the site is transitioning to **heat pumps**.
2. If temperature requirements are above 100 °C and the site is in an urban area, the site is transitioning to an **electric boiler**. If the site has more than 10 MW of installed capacity, then a 50/50 allocation between an **electric boiler** and **wood pellet boiler** is assumed.
3. If temperature requirements are above 100 °C, the site is in a rural area, installed capacity is less than 10 MW, and the site utilises coal; the site is converting their existing boiler to a **wood pellet boiler**.
4. If temperature requirements are above 100 °C, the site is in a rural area, installed capacity is less than 10 MW, and the site utilises anything but coal; the site is transitioning to a **woodchip boiler**.
5. The remaining 18 sites were analysed on a site-by-site basis; utilising DETA's internal knowledge and external connections to determine the appropriate fuel switching project.

Regional biomass availability was also assessed as part of this process, based on DETA's published green paper *New Zealand's Process Heat Future Fuel Part 1: South Island*[3] and ongoing work to develop Part 2 for the North Island. Due to the indication of sites electrifying process heat through our work to develop the RHDD and the assumption that sites with temperature requirements less than 100 °C will transition to heat pumps; there was a significant allocation to electrification before biomass was considered. This means that biomass was not constrained in any region and did not have to be considered as a limitation when allocating fuel switching projects.

[3] File attached

2.1.5 Emissions Correction Process

After completing our modelling, the industrial and commercial emissions were compared against the New Zealand Emissions Tracker. It was expected that there would be unaccounted for emissions as:

- The RHDD has not yet been completed for all North Island regions,
- There are bound to be sites that were missed due to our bottom-up analysis, and
- Boilers under 500 kW were not included.

The difference in emissions is summarised below and sectors were grouped as follows.

Industrial - Dairy, Food, Horticulture, Meat, Oil & Gas, Other Manufacturing, Wood.
Commercial - Accommodation, Buildings, Correctional, Council, Hospitals, Military, Other Education, Pool Heating, Retirement Village, Schools, Venues.

Table 3 – Comparison between modelled emissions and NZ Emissions Tracker reported emissions

	Modelled Emissions (ktCO_2e)	Emissions Tracker (ktCO2e)	Difference
Industrial	3,281	4,478	1,197
Commercial	274	1,073	799

Once the difference in emissions was quantified, fossil fuel statistics from the Ministry of Business, Innovation, and Employment (MBIE) were used to align the coal[4] and natural gas[5] consumption with the real market. The Climate Change Commission also supplied their gas demand profiles from ENZ modelling which was used as another reference point. The remaining missing emissions were split by fuel source based on the process heat analysis conducted by MBIE in 2016[6]. As these resources use a top-down approach (allocating the observed fossil fuel consumption to different industries), they were deemed to be a better representation of the NZ market and hence our modelled emissions were aligned.

The decarbonisation of these additional fossil fuels was allocated to project types and capacity sizes based on the trends of the rest of the model.

2.1.6 Capital Costing

The below charts display the approach to estimating cost of equipment (exclusively), on a $/MW and $/MVA basis. There is large variation between costs in some cases, due to the inherent differences in site characteristics (including factors such as location) as well as the variations

[4] https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-statistics/coal-statistics/
[5] https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-statistics/gas-statistics/
[6] https://www.mbie.govt.nz/dmsdocument/152-process-heat-current-state-fact-sheet-pdf#:~:text=Process%20heat%20accounted%20for%2035%25%20of%20New%20Zealand's%20energy%20consumption.&text=Around%2055%25%20of%20process%20heat,mainly%20coal%20or%20natural%20gas.&text=Around%2068%25%20of%20process%20heat%20was%20made%20using%20boiler%20systems.

between how the equipment is being integrated into the site. This undoubtedly leads to "overs and unders", which will be averaged out to some degree across the breadth of work required.

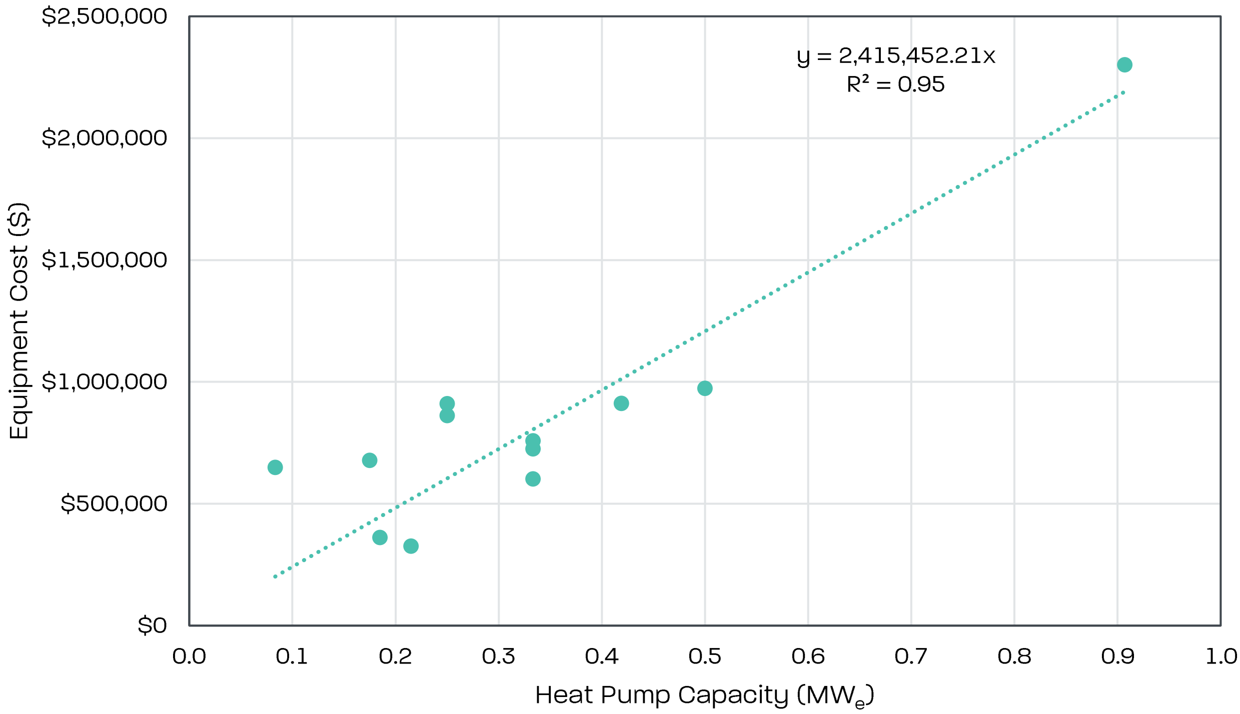

Figure 2 – Correlation between equipment cost and heat pump capacity.

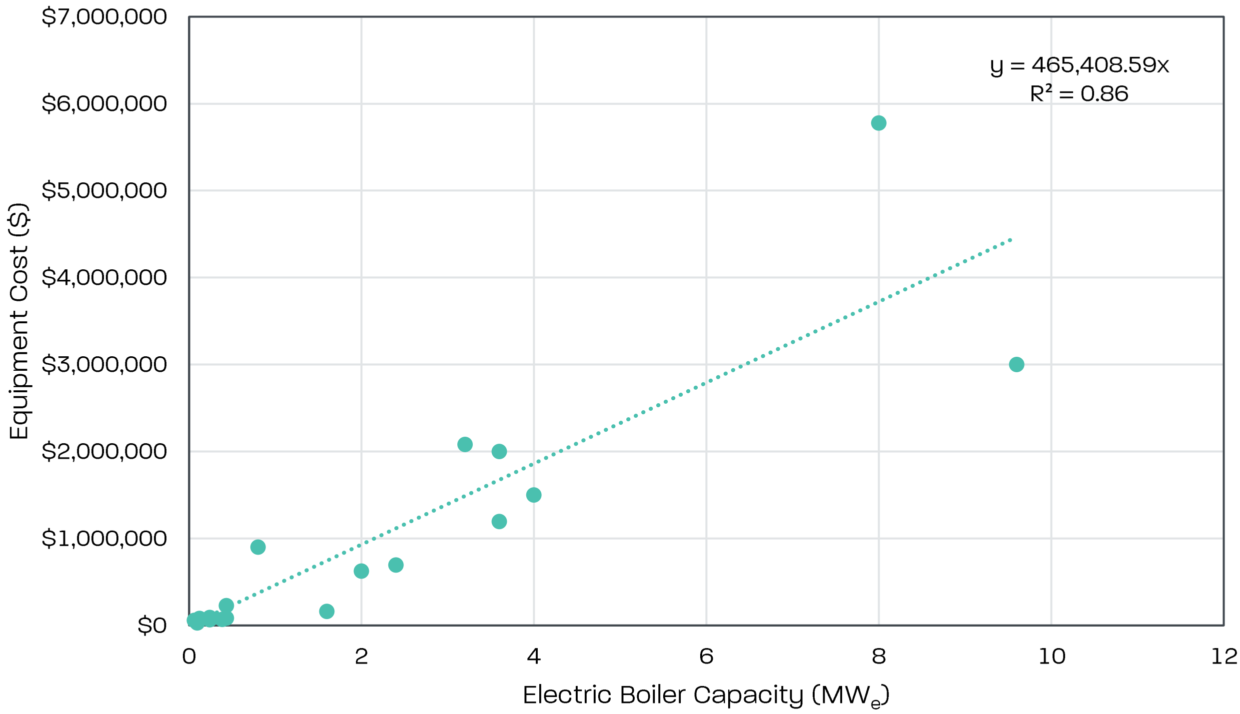

Figure 3 – Correlation between equipment cost and electric boiler capacity.

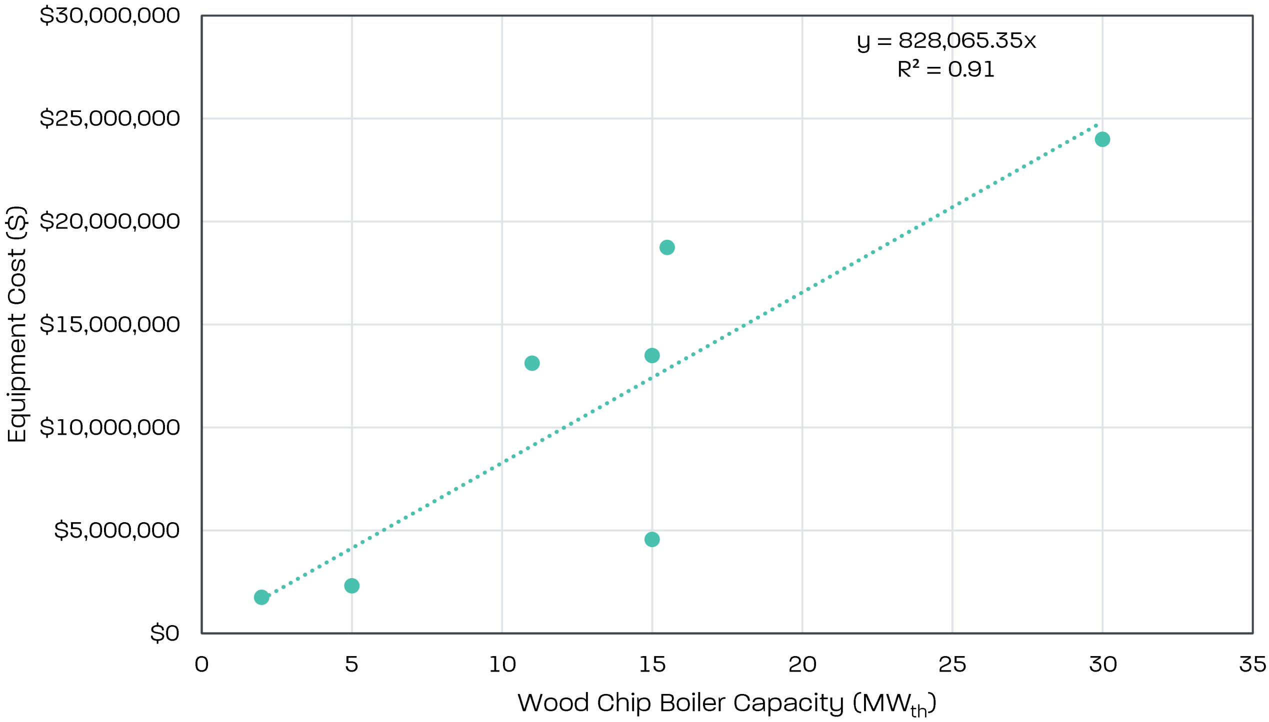

Figure 4 – Correlation between equipment cost and wood chip boiler capacity.

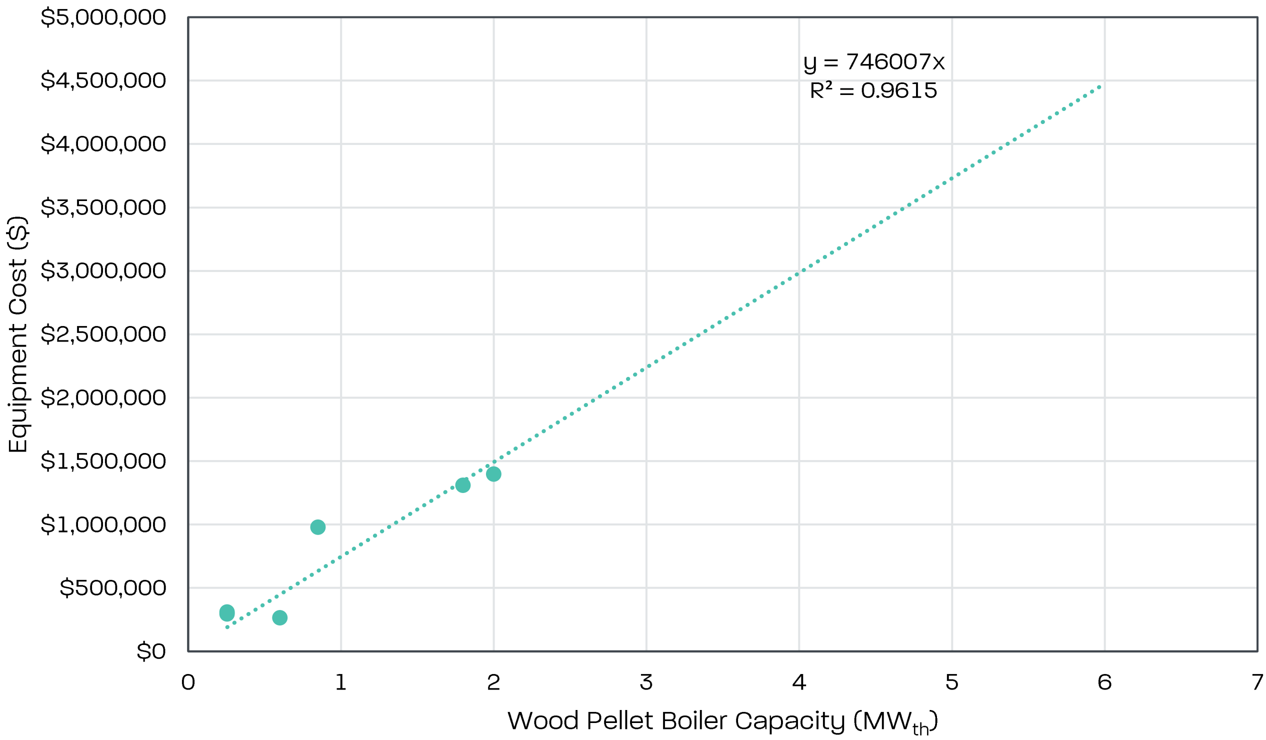

Figure 5 – Correlation between equipment cost and wood pellet boiler capacity.

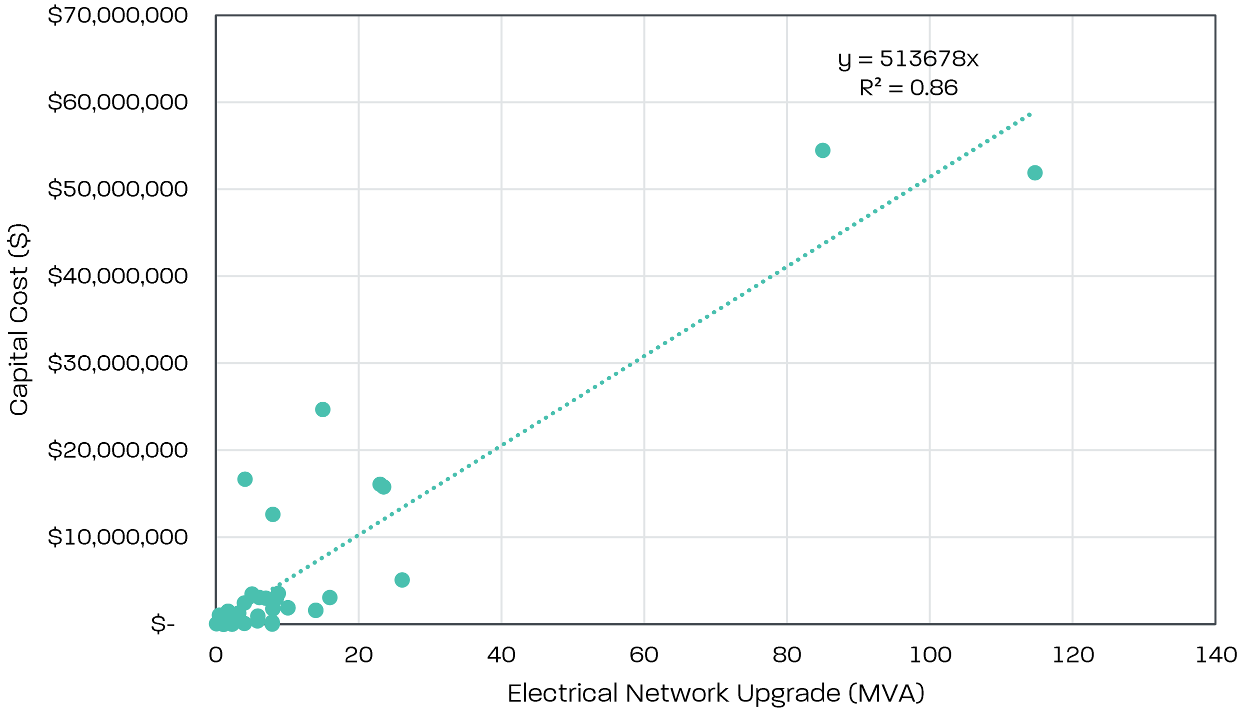

Figure 6 – Correlation between equipment cost and electrical network upgrades.

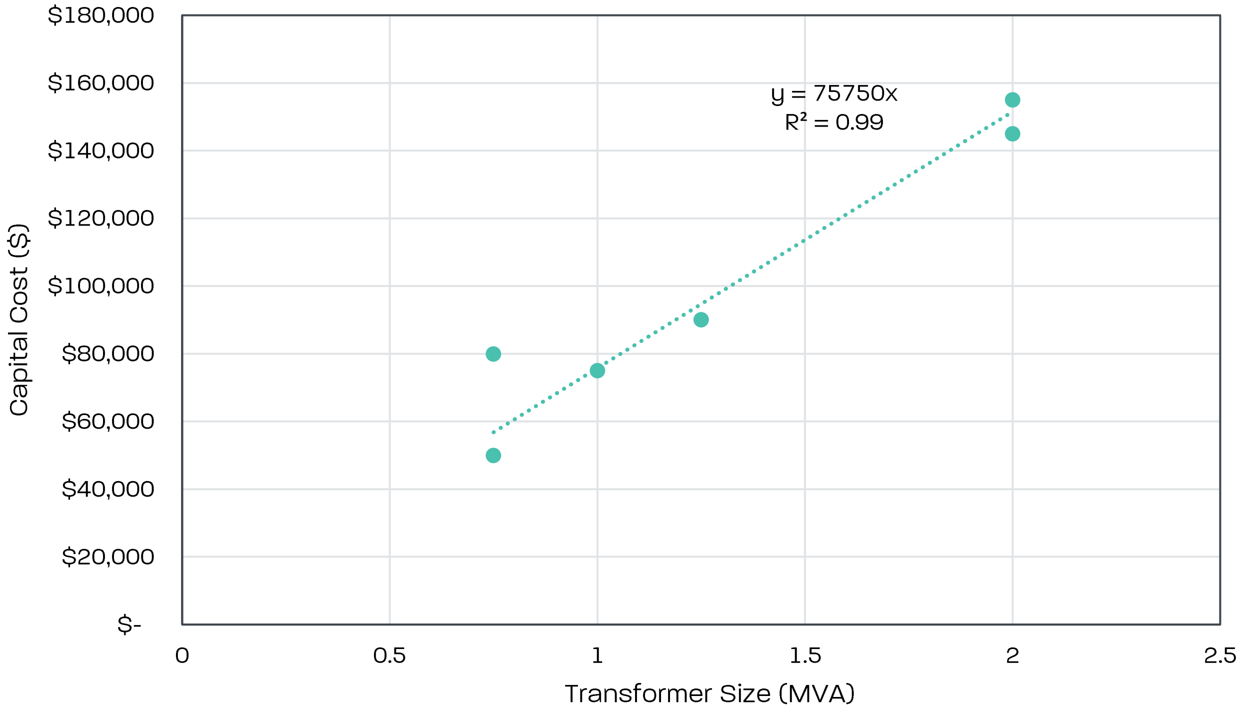

Figure 7 – Correlation between capital cost and transformer size.

2.2 Section B – Estimation of Capacity

This section aims to understand whether New Zealand's supply chain can support the required quantum of decarbonisation efforts, as identified within Section 2.1. The aspects of New Zealand's market that were assessed in this part of study were:

- Personnel availability.
- Electricity distribution businesses capital allocation.
- Equipment suppliers' capacity.

These aspects were selected as they were expected to provide the most sizable opportunities, as well as the greatest threats, in the effort to decarbonise New Zealand's process heat.

2.2.1 Capable Personnel Availability

Table 4 below outlines the estimated required personnel to facilitate the decarbonisation of process heat for New Zealand, as identified in Section A of this study. This was normalised to the 15-year window from 2023 to 2037 to estimate the yearly personnel demand for each profession type to deliver the 2037 target.

The estimated yearly required personnel were compared to the 2018 census data for New Zealand[7] to understand the proportion of the personnel in each profession type that will be required for the decarbonisation effort. Table 5 outlines the occupations and the number of people that were allocated to each profession type from the 2018 census data.

The quality of census data for occupation is deemed was deemed high by Stats NZ after the update in 2020[8]. The occupation data was answered by 80% of the participants and Stats NZ added the 20% imputation based on their quality framework. Due to this, the quality of the profession count was deemed complete[9].

Table 4 – Personnel requirement from quantum of work established in Section A

Profession Type	Total number of people-years required	Number of people required per year	Proportion of total personnel in each profession type required for process heat decarbonisation
Design Engineer	1,060	76	8%
Project Manager	1,696	122	3%
Electrical Engineer	895	64	25%
Electrician	2,214	159	10%
Controls Engineer	1,107	80	9%
Fitter & Turner	2,214	159	22%
Total	**9,186**	**660**	**8%**

7 https://www.stats.govt.nz/information-releases/2018-census-totals-by-topic-national-highlights-updated
8 https://www.stats.govt.nz/information-releases/2018-census-totals-by-topic-national-highlights-updated
9 https://www.stats.govt.nz/reports/overview-of-data-quality-ratings-interim-coverage-and-response-rates-and-data-sources-for-2018-census#variables

On average, 8% of each profession type is required for process heat decarbonisation. Electrical Engineers and Fitter and Turners seemed to be the most constrained as the quantum of work would require 25% and 22%, respectively, of each profession's total personnel. However, the ability of the work force to support the continued process heat and the current activities will play a more significant role in the decarbonisation pathway than the overall numbers in 2018.

Table 5 – Personnel in required professions in 2018 based on census data.

Occupation	Allocated profession type	Count
Construction Project Manager	Project Manager	9,777
Project Builder[10]	Project Manager	34,344
Program or Project Administrator	Project Manager	16,101
Fitter (General)	Fitter & Turner	5,832
Fitter and Turner	Fitter & Turner	1,470
Fitter-Welder	Fitter & Turner	2,802
Electrical Engineering Technician	Electrician	2,475
Electrician (General)	Electrician	20,016
Electrician (Special Class)	Electrician	3
Chemical Engineer	Design Engineer	471
Electrical Engineer	Electrical Engineer	3,576
Mechanical Engineer	Design Engineer	12,177

To assess the ability of the New Zealand work force to support the decarbonisation effort, the required yearly work force replenishment was estimated. A yearly economic growth and retirement rate of three percent were assumed to estimate the required replenishment rate to the work force for business-as-usual activities. This BAU number, was then added to the number of people required per year for decarbonisation (660), as shown in Table 4, to estimate the total number of personnel requirement for that year.

The number of personnel available to cover the requirement each year was then estimated using the data provided by tertiary education providers to the Ministry of Education outlining the number of graduates for each relevant specialisation[11] and the estimated personnel from net migration. The NZQF levels included were between level 3 (certificate) and level 8 (honours, and postgraduate certificates and diplomas). The levels below level 3 were deemed lacking enough expertise for the work required for decarbonisation and the levels above level 8 were deemed to predominantly pursue academia and further studies over working in industry. The field of studies that were selected are "Mechanical and Industrial Engineering and Technology" and "Electrical and Electronic Engineering and Technology" as the definition[12] of these fields were deemed the most appropriate.

10 https://skillshortages.immigration.govt.nz/project-builder/#:~:text=ANZSCO%20level%201,or%20licensing%20may%20be%20required.

11 https://www.educationcounts.govt.nz/statistics/tertiary-participation

12 https://www.educationcounts.govt.nz/data-services/code-sets-and-classifications/new_zealand_standard_classification_of_education_nzsced/nzsced_detailed_fields_of_study

The net yearly migration data was compared to the population[13] of New Zealand to assess the effect of migration on the total population of the country. Table 6 below outlines the net migration as a percentage of population. The average of the percentages of net migration was then multiplied to the average percentage of population for each profession type to estimate the effect of migration across each. Note that 2021 and 2022 net migration data was removed from consideration due to the lockdown caused by COVID-19. The net effect of migration and qualification attainment numbers were compared to the population of New Zealand to assess the interaction and uptake of the population to the relevant fields of study.

Table 6 – Population and migration statistics

Year[14]	Population count	Net migration	Net migration as percentage of population
2013	4,436,000	809	0.02%
2014	4,501,100	33,462	0.74%
2015	4,591,900	53,427	1.16%
2016	4,695,000	64,613	1.38%
2017	4,796,700	59,533	1.24%
2018	4,886,100	48,995	1.00%
2019	4,965,300	52,101	1.05%
2020	5,082,800	84,836	1.67%
2021	5,107,900	-6,585	not considered
2022	5,115,100	-17,613	not considered
2023	5,199,100	86,772	1.67%

For the years where the available replenishment is less than the required level, it is assumed that the available personnel will be split to each requirement category in the same proportion that each category makes up in the total requirement. As an example, if 200 personnel in total are required (100 for retirement, 60 for economic growth, and 40 for process heat decarbonisation) but there are only 100 available personnel, then these available personnel will be split as 50 for retirement, 30 for economic growth and 20 for process heat decarbonisation. The cumulative sum of personnel allocated to process heat decarbonisation from the start of decarbonisation effort to that specific year was compared to the quantum of work required. The year that the cumulative sum of process heat personnel allocated equals or became more than the quantum of work requirement, is assumed to be the year that decarbonisation is achieved.

2.2.2 Electricity Distribution Businesses (EDB)

A significant portion (45%) of the current process heat energy use is estimated to switch to electricity. This equates to 1,446 MVA of energy that needs to be electrified. The capacity of the Electricity Distribution Businesses (EDBs) to support this electrification was assessed by

[13] https://www.stats.govt.nz/topics/population

[14] Financial year from April to March the following year.

comparing the capital requirement to supply this electrification, estimated in Section 2.1 against the capital allocation of the EDBs.

The capital expenditure forecast of each EDB was obtained from their submitted Asset Management Plan (AMP) to the Commerce Commission[15]. AMPs submitted to the Commerce Commission forecasts a 10-year window up to 2032. The capital estimates from 2033 to 2037 were extrapolated using the AMP capital values from 2026 to 2032. These values are selected as the capital forecast appeared stable during this 7-year window, as seen in Figure 8.

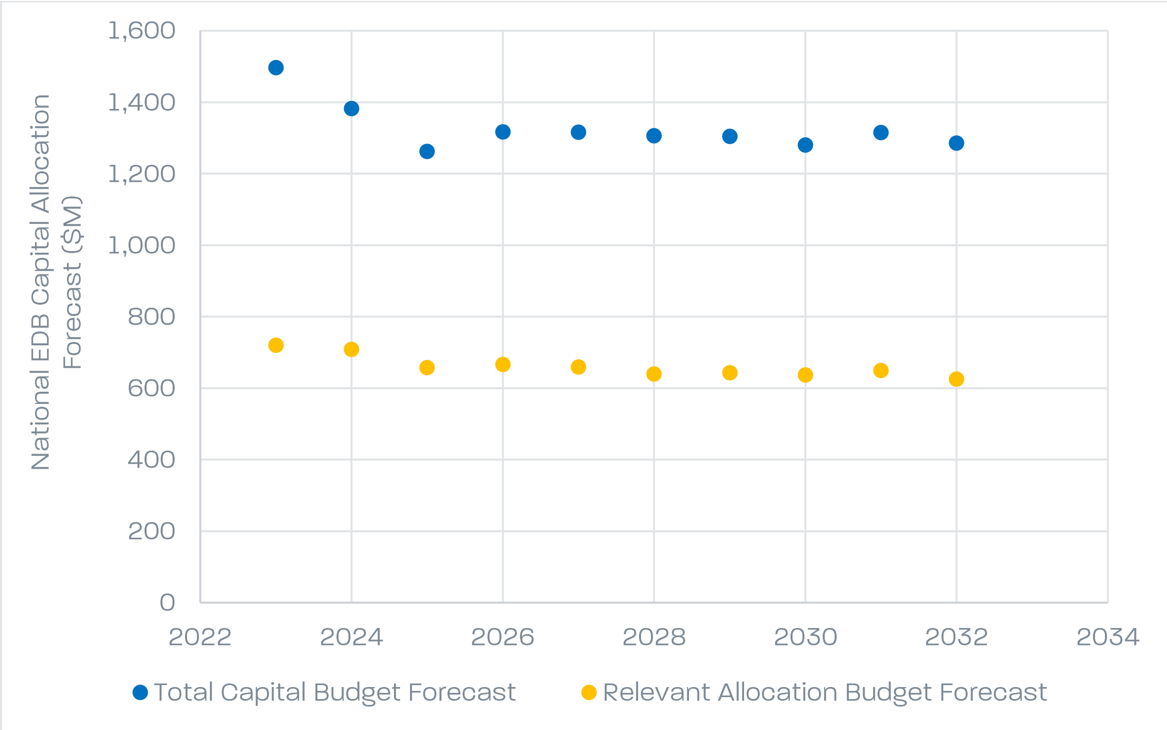

Figure 8 – National capital budget forecast for EDBs

Not all capital allocations were deemed relevant to support the decarbonisation of process heat. The capital allocations that were selected and used for this analysis are shown below, a breakdown of the categories outlined in the AMP is in Appendix A. These were selected based on prior work with EDBs, and in consultation with a particular EDB.

- System growth.
- Consumer connection.
- Reliability, safety, and environment.

In addition to capital spending, timeframes for executing upgrades will play a key factor in the rate of decarbonisation. Figure 9 below shows the spread of estimated timeframes for capacity upgrade projects that were investigated by EDBs. Projects that are greater than 3 MVA were grouped together as they vary greatly in duration due to the intensity of civil work required and the sensitivity of this civil work to the local terrain.

15 https://comcom.govt.nz/regulated-industries/electricity-lines/electricity-distributor-performance-and-data/information-disclosed-by-electricity-distributors

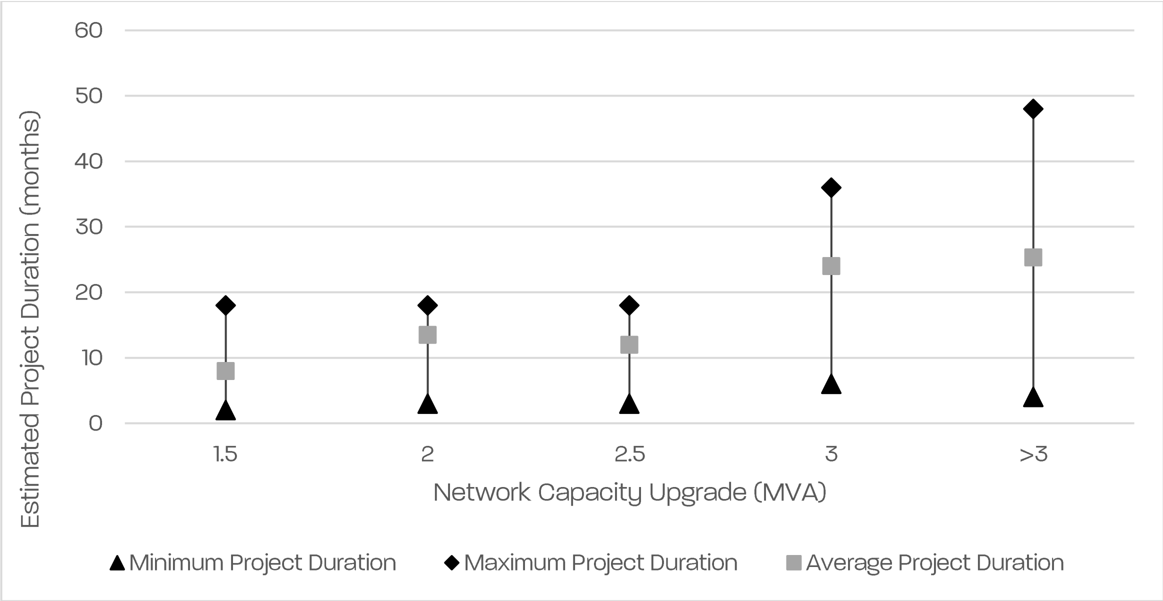

Figure 9 – Potential timeframes of electrical network upgrades

2.2.3 Equipment Suppliers

Key suppliers of process equipment required to facilitate process heat decarbonisation were consulted to assess the capacity of the market.

During the consultation, the companies were asked if they can supply the necessary level of key equipment into New Zealand for the decarbonisation of process heat. Companies were asked what they observe as the main bottlenecks for the implementation of these projects and any major risks in the current market climate.

2.3 Section C – Modelling Headwinds and Tailwinds

This section aims to understand the headwinds and tailwinds of process heat decarbonisation. Sensitivity analysis was conducted to understand the key factors and how they influence the rate of decarbonisation. For all following scenarios, the required number of personnel estimated from Section A was treated as the base case quantum of work. The available personnel demand profile from Section B was treated as the base case personnel availability profile.

The results from the scenario modelling can be found in Section 3.

2.3.1 Demand reduction change

Demand reduction is the process of sites becoming more efficient with the way the use their energy. One of the key elements that dictates the quantum of work for process heat decarbonisation is the level of demand reduction that industry undertakes prior to investing in large-scale, fuel-switching decarbonisation projects. The impact of varying demand reduction on the timeline of decarbonisation was investigated.

Demand reduction rates of 0%, 10%, and 20%, were used in the model for Section A. The effect of the demand reduction rate on equipment requirements, capital cost estimations, and personnel requirements was then recorded. These recorded parameters were then treated as an input in the model for Section C.

The change in demand reduction varied the quantum of work required but the base case yearly personnel demand was used in each scenario to simulate the impact of demand reduction on the decarbonisation timeline.

2.3.2 Timeline variation

The deadline to decarbonise process heat for the base case scenario was 2037 as outlined in the proposal by the Climate Change Commission. However, the mandate from the New Zealand government only specifies that coal be phased out by 2037 and for the country to be net zero by 2050. A scenario was investigated where coal users were decarbonised by 2037 and the deadline for the other fossil fuels was extended to 2050 to align with the current regulations of the country. The capability of decarbonising the coal users were also modelled by reducing the quantum of work to coal users only.

2.3.3 Personnel rate changes

The availability of personnel to deliver process heat decarbonisation is key to achieving the desired deadline. Table 6 outlines the setpoints of the factors impacting the labour market for each scenario modelled, where workforce entry inflation factor increases the total quantity of people entering a given profession each year. The effect of these factors on the timeline to decarbonise was compared to the base case.

Table 6 – Personnel rate factors

Scenario	Economic Growth Rate	Retirement Rate	Migration Rate	Workforce Entry Inflation Factor
Base Case	3%	3%	1%	0%
Economic Growth Rate Increase	▲ 5%	3%	1%	0%
Economic Growth Rate Decrease	▼ 1%	3%	1%	0%
Retirement Rate Increase	3%	▲ 5%	1%	0%
Retirement Rate Decrease	3%	▼ 1%	1%	0%
Migration Rate Increase	3%	3%	▲ 5%	0%
Migration Rate Decrease	3%	3%	▼ 0.25%	0%
Workforce Entry Increase	3%	3%	1%	▲ 10%
Workforce Entry Increase	3%	3%	1%	▲ 20%

2.3.4 Electricity demand reduction

Adoption of new technology such as steam heat pumps could expedite the decarbonisation journey for New Zealand. The extent to which these technologies impact the timeline is not certain, as they are not yet commercially viable and will likely not be economically competitive initially. Adoption of more efficient technology can reduce the personnel demand to decarbonise however, installation and commissioning of such technology is a specialised trade. This means that even though the demand for required personnel may be lower due to more efficient technology, the pool of people that can implement such technology is more limited.

The scenario of adopting new technology is modelled by reducing the demand on the electricity grid. The electricity upgrade requirement was reduced up to 30%, in 5% increments, from the base case scenario. The effect of this reduction on the timeline for EDBs to execute the upgrade was investigated.

An analysis of the duration of network grid upgrades that EDBs have investigated was also completed. A total of 39 EDB upgrades of varying MVA capacity was used for this analysis. The maximum, minimum, and average duration for each project was calculated and plotted. The normalised metric of MVA per month was calculated by dividing the capacity and the average duration it takes for that MVA capacity upgrade.

3. Results

3.1 Section A – Process Heat Decarbonisation Results

The current fossil fuel use in New Zealand is estimated in Table 7. Natural gas and coal are the predominant fossil fuels accounting for 60% and 30%, respectively.

Table 7 – Current Fossil Fuel Use

Fossil Fuel	Contribution (TJ)
Coal	20,085
Natural Gas	40,416
Diesel	5,688
LPG	1,013
Total Energy	67,202

Hard-to-abate sectors such as cement and steel production do not currently have economically feasible options to decarbonise process heat, causing there to be fossil fuel use remaining after our modelling, summarised below.

Table 8 – Remaining Fossil Fuel Use After Decarbonisation

Fossil Fuel	Contribution (TJ)
Coal	286
Natural Gas	2,734
Diesel	-
LPG	-
Total Energy	3,020

Low carbon emitting technologies are already used to generate process heat. The current level of use of these technologies is shown in Table 9. By-products, such as wood waste and waste oil, and electricity consumption make up more than 90% of the energy used to generate low carbon process heat.

Table 9 – Current Low Carbon Emission Fuel Use

Technology	Contribution (TJ)
Electricity	30,826
Wood-Chip	506
Wood-Pellet	793
By-Products	33,380
Total Energy	65,505

If the projects identified in this analysis were completed, the future split of low carbon energy is shown below. Wood chip boilers are expected to play a key role in providing process heat.

Table 10 – Future Low Carbon Emission Fuel Use

Technology	Amount use (TJ)
Electricity	51,609
Wood-Chip	30,844
Wood-Pellet	6,548
By-Products	33,380
Biogas	677
Total Energy	**122,381**

The estimated emissions reduction from process heat decarbonisation is shown in Table 11. Wood chip boilers are expected to contribute 46% of the total emissions reduction. Of the remaining emissions, 57% is attributed to electricity use from process heat decarbonisation, assuming a grid emissions intensity of 0.074 $kgCO_2e$ per kWh. If New Zealand's electrical grid continues to decarbonise as projected the remaining emissions will decrease accordingly.

Table 11 – Estimated Process Heat Decarbonisation

Description / Decarbonisation component	Emission (tCO_2e)
Current Process Heat Emissions	6,167,500
Demand Reduction	- 484,300
HTHP	- 698,900
Electrode Boiler	- 945,700
Wood-Chip	- 1,982,900
Wood Pellet	- 183,300
Biogas	- 19,100
Remaining	**1,853,300**

The estimated cost of decarbonisation is shown in Table 12.

Table 12 – Estimated Cost of Decarbonisation

Cost Component	Estimated Cost ($M)
Heat Pump	$ 1,190
Electric Boiler	$ 615
Wood-Chip (Conversion)	$ 5
Wood-Pellet (Conversion)	$ 4
Wood-Chip	$ 1,670
Wood-Pellet	$ 328
Biogas	$ 123
Civil Costs	$ 683
Electrical & Control Costs	$ 1,520
Mechanical Costs	$ 762
Electrical Network Upgrade Costs	$ 893
Transformer Costs	$ 32
Design Costs	$ 313
Project Management	$ 626
Contingency (15% allocation)	$ 1,565
Total	**$ 10,300**

The key equipment required for process heat decarbonisation is shown below. Low-capacity equipment, <2MW_{th}, is expected to make up 67% of the quantity of equipment required to decarbonise process heat.

Table 13 – Key Equipment Breakdown

Equipment Type	0-1 MW_{th}	1-2 MW_{th}	2-5 MW_{th}	5-10 MW_{th}	10-20 MW_{th}	20-40 MW_{th}	40+ MW_{th}
Heat Pump (no.)	229	131	55	72	32	4	0
Electric Boiler (no.)	168	119	70	38	15	4	6
Wood-Chip (Conversion) (no.)	0	2	1	0	1	0	0
Wood-Pellet (Conversion) (no.)	0	2	1	0	1	0	0
Wood-Chip (no.)	111	135	65	22	27	18	13
Wood-Pellet (no.)	72	25	8	10	12	1	0
Biogas (no.)	0	0	5	0	2	0	0
Electrical capacity (MW)	323	244	354	347	153	83	220

The estimated personnel requirement is shown in Table 14. The number of electricians and fitter/turners required accounts for 48% of the total personnel requirement.

Table 14 – Personnel Requirement

Profession Type	Total Cost	Charge out Rate ($/hr)	Total Hours Required	Hours per year (hr/p/y)	Number of people years required
Design Engineer	$ 317,999,000	$ 200	1,589,995	1,500	1,060
Project Manager	$ 635,997,000	$ 250	2,543,988	1,500	1,696
Electrical Engineer	$ 268,420,000	$ 200	1,342,100	1,500	895
Electrician	$ 387,534,000	$ 100	3,875,340	1,750	2,214
Controls Engineer	$ 387,319,500	$ 200	1,936,598	1,750	1,107
Fitter & Turner	$ 387,534,000	$ 100	3,875,340	1,750	2,214
Total	**$ 2,384,803,500**	**$ 175**	**15,163,361**	**9,750**	**9,186**

3.2 Section B – Estimation of Capacity Results

This section outlines the findings from investigating the capacity of the New Zealand market to support the decarbonisation of process heat. These results were also treated as the base case scenario for further modelling of headwinds and tailwinds, as outlined in Section 3.3.

3.2.1 Capable Personnel Availability

Figure 10 shows the trends of people entering the profession types relevant to process heat decarbonisation in New Zealand over the past 10 years.

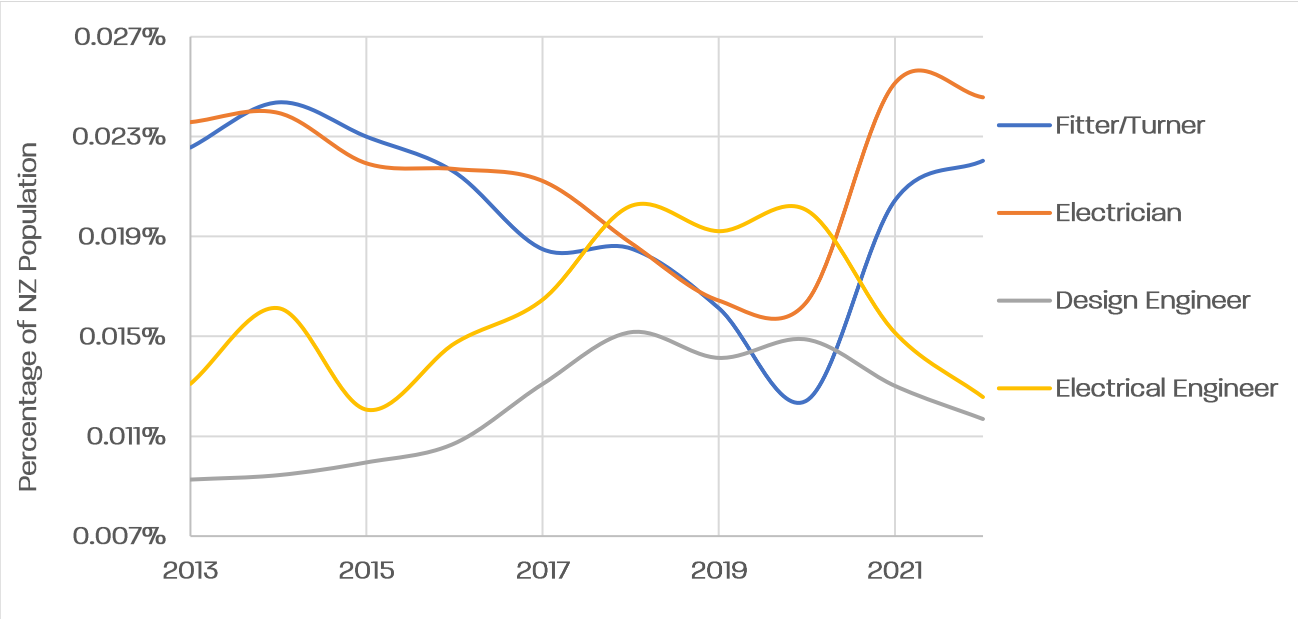

Figure 10 – Proportion of population entering key professions required for decarbonisation.

Electrician and Fitter/Turner apprenticeship completion has seen an upward trend since 2020 due to the Targeted Training and Apprenticeship Fund that was implemented by the government in July 2020[16]. However, this funding ended in December 2022, and the percentage of people entering these trades has only just returned to 2013 levels; it is expected that the number of people entering these disciplines will decline in absence of the fund. The proportion of population enrolled in programmes that can potentially supplement Electrical and Design Engineers was on an upward trend until 2020 but is now declining.

From the quantum of work established in Section A, the annual demand for key personnel was estimated by dividing the total quantum of work by the desired timeline for decarbonisation (2024 – 2037). Due to the competing factors in the labour market, such as economic growth and retirement, the personnel demand for process heat decarbonisation could not always be met. Electricians and Design Engineers were identified as the bottlenecks in the labour market to achieve decarbonisation.

[16] https://www.tec.govt.nz/funding/funding-and-performance/funding/fund-finder/targeted-training-and-apprenticeship-fund/

Figure 11 and Figure 12 show the profile of cumulative allocation of design engineers and electricians to process heat decarbonisation against the quantum of work, signified by the dotted total personnel requirement line. It is estimated that design engineers will need until 2045, while electricians will need until 2048 to complete all the decarbonisation effort outlined. These are both later than the targeted 2037 deadline.

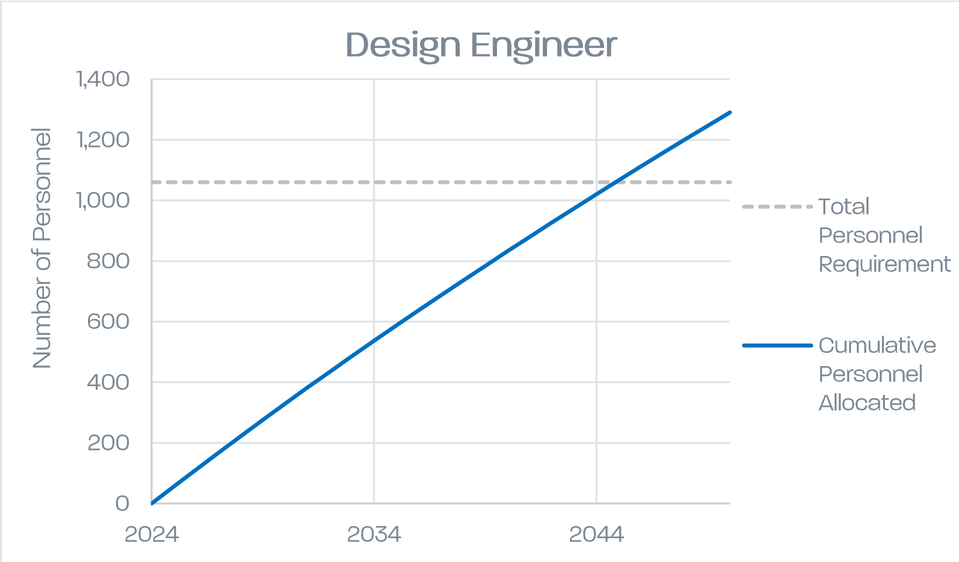

Figure 11 – Design engineer labour market timeline to meet process heat decarbonisation requirements.

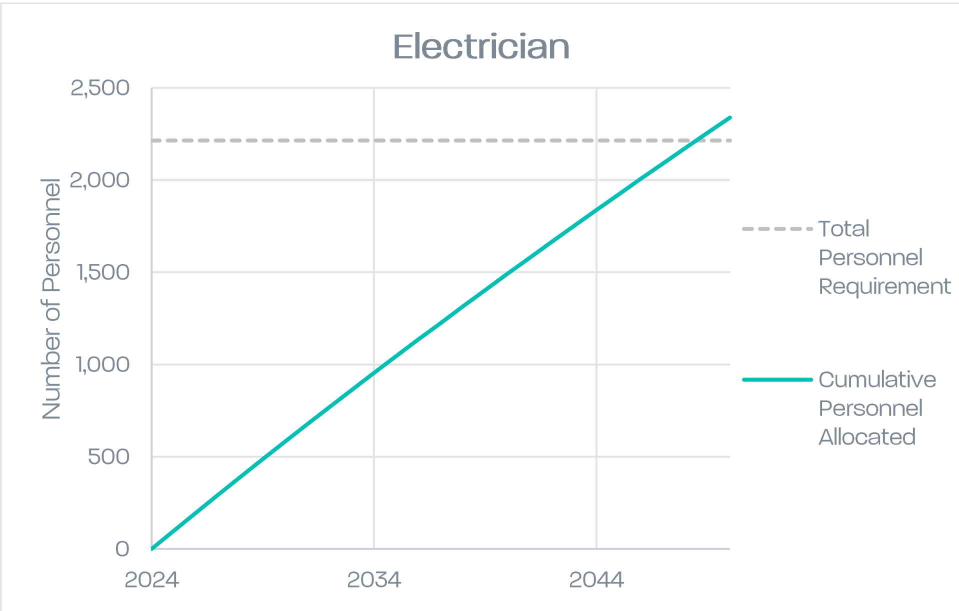

Figure 12 – Electrician labour market timeline to meet process heat decarbonisation requirements.

Figure 13 shows the same pattern for fitter and turners which would require until 2040 to complete the quantum of work required.

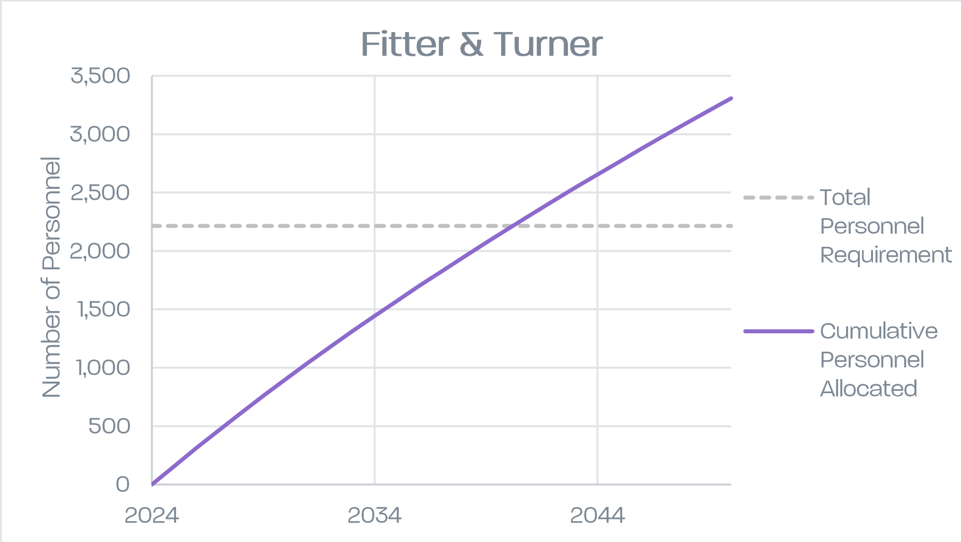

Figure 13 – Fitter & Turner labour market timeline to meet process heat decarbonisation requirements.

Electrical engineers are the only profession type that can hit the 2037 target. It is estimated that this profession type has capacity to complete the quantum of work by 2032, excluding external factors not accounted for in this analysis.

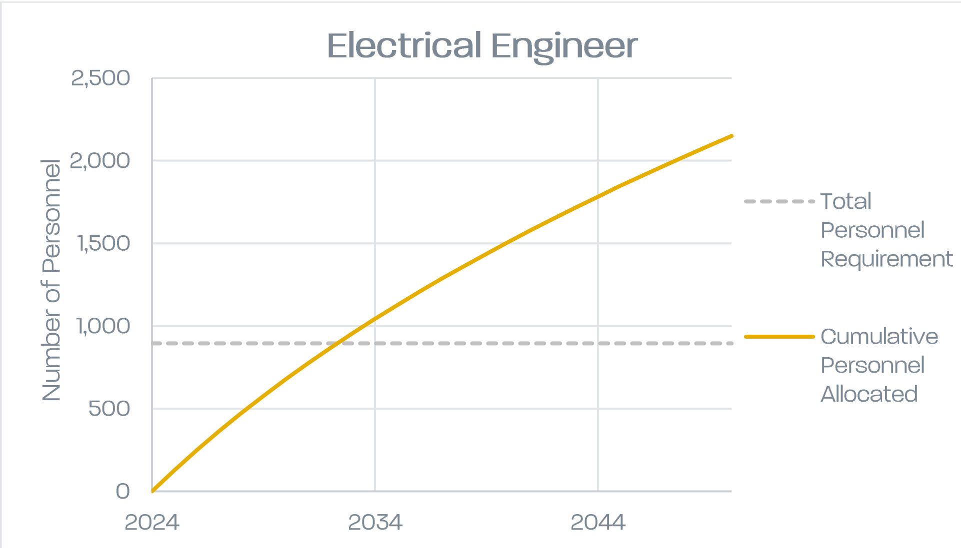

Figure 14 – Electrical engineer labour market timeline to meet process heat decarbonisation requirements.

Figure 15 shows the overall timeline for all profession types. As mentioned in the earlier part of this section, see Figure 12, 2048 is when decarbonisation of process heat is expected to be delayed until, due to the availability of Electricians.

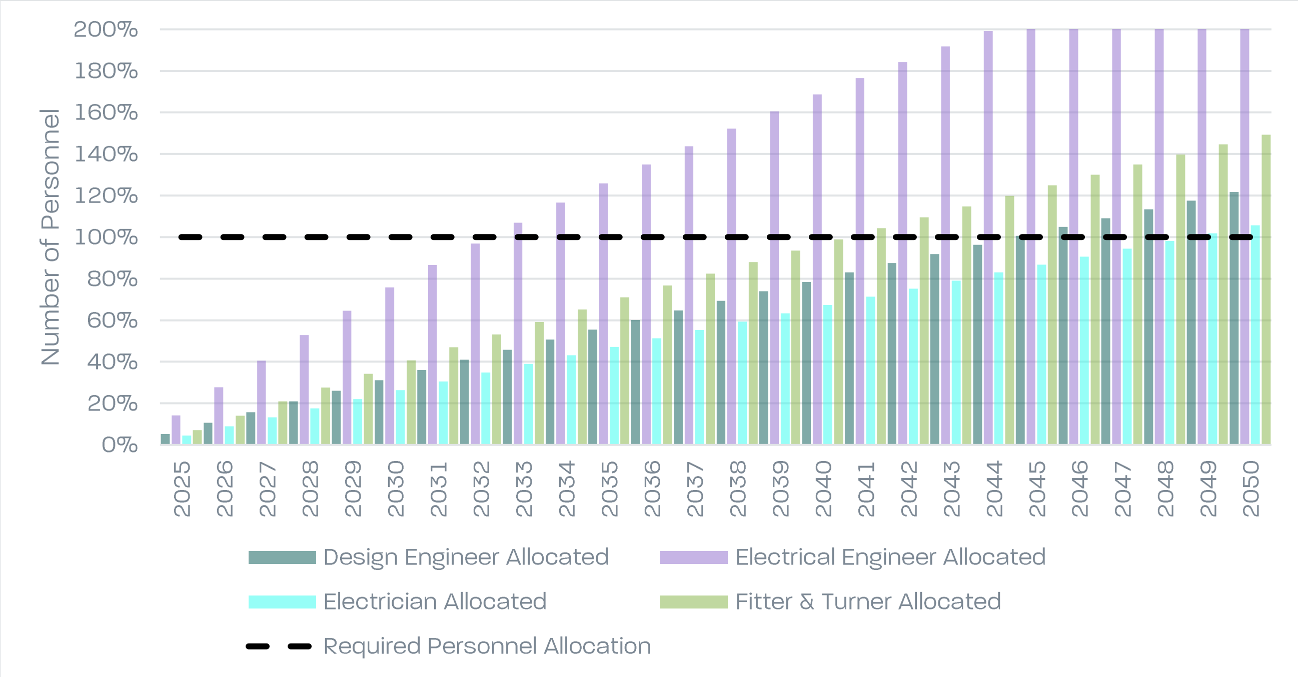

Figure 15 – Personnel Allocation Overall Timeline

3.2.2 Electrical Distribution Businesses (EDBs) analysis results

The EDBs' total capital estimate for the relevant allocations is $9.7 billion over the next 15 years; the capital requirement of network upgrades estimated in this study would equate to 13% of this.

Table 15 – Ability of EDBs to accommodate modelled capital implications of process heat decarbonisation

Description	Amount
EDB Capital Forecast to 2037 ($M)	$ 19,663
EDB Relevant Allocation Forecast to 2037 ($M)	$ 9,687
Percentage of Total Capital Forecast Required for Decarbonisation	6%
Percentage of Relevant Allocations Forecast Required for Decarbonisation	13%

While this is a relatively small increase in additional work, some EDBs could potentially struggle if they are a small region with large-scale industrial process. For example, the region covered by Alpine Energy is estimated to require capital expenditure of $53 million for electrical supply upgrades to decarbonise process heat. This equates to a significant portion (65%) of the relevant capital allocations of Alpine Energy. Similarly, Westpower could face the same issue as it is estimated that the electrification to support the decarbonisation effort in its region would require 87% of its 15-year capital investment estimate. Appendix A shows a breakdown of the estimated proportion of the capital forecast of each EDB to complete decarbonisation of process heat in their region. It is important to note that the capital implications of network capacity upgrades are sensitive to factors such as existing infrastructure and local geography; the estimates in this analysis could result in inaccuracies at a site and regional level. There is also a significant amount of emissions, and hence projects, that were included as part of the gap analysis which haven't been allocated to a particular EDB.

Based on the data collected, a 2.5 MVA upgrade will take 10 months on average. Due to the duration and expected capital cost; it is estimated that each EDB could only undertake one new network upgrade project each year. The number of projects per year each EDB can complete has been estimated from previous experience but has significant uncertainty and dictates the timeline for the work to be completed. Using these assumptions, it will take 17 years to implement the 1,446 MVA of capacity upgrades estimated in Section A as shown in Table 16.

Table 16 – Timeline for EDBs to complete process heat decarbonisation work

Description	Amount	Unit
Total upgrade requirement	1446	MVA
Number of EDBs	27	
Preferred MVA capacity installed per project	2.5	MVA
Estimated project per EDB	1	per year
Duration of preferred MVA	9.4	months
Estimated duration to realise requirement	201	months
# of years required to realise upgrade	17	Years

3.2.3 Equipment suppliers results

As part of this analysis, key suppliers of equipment required for process heat decarbonisation were consulted to gauge the capacity of the market and identify risks to future production. For confidentiality, names of suppliers have been excluded and the commentary below summarises the key points of conversations had. It was highlighted by all suppliers that having an estimate of the future demand for equipment allows them to create stock to better manage availability and lead times.

Heat Pumps

- Heat pump supply into the country could be ramped up by offshore manufacturing to meet the additional requirements of process heat decarbonisation.
- New Zealand will be competing with the global market for heat pump supply as demand is increasing globally.
- Estimating the future demand of heat pumps is valuable to suppliers as they can stock the required equipment, increasing availability and reducing lead times.
- Installers of heat pumps are the main constraint. Currently, installers from Australia are used to supplement the New Zealand market. Based on the results in Section 3.2.1, this will continue to be an issue unless there are significant changes to the labour market.

Electric Boilers

- Lead times for importing electric boilers are, in early 2023, 6 – 10 months for 1 – 10 MW and 5 months for <1 MW.
- Similar to heat pumps, there is the off-shore production capacity to accommodate for increased demand from process heat decarbonisation.
- The key constraints for electric boiler supply are availability of personnel for installation and material availability. There has been growing concerns globally with the supply of copper, which is key for boiler manufacturing.

Biomass Boilers

- Biomass boiler manufacturing is the most constrained out of the key equipment identified. The New Zealand market can only supply 70 – 80% of the required biomass boilers, due to the limited number of boiler makers in this country and the difficulty of importing units (particularly for large boilers).
- Suppliers identified a lack of boiler makers entering the market as an issue; stating that private companies must develop their own apprenticeship programme to have personnel to employ.
- Copper supply was also identified as a risk going forward.

Transformers

- Manufacturers in New Zealand have enough staff/production capacity to accommodate the additional transformer requirement of process heat decarbonisation. However, availability of materials will be a constraint. Magnetic core steel sourced from China is already in short supply globally, with lead times of 6 – 10 months and getting worse. Copper supply is also a risk, as identified by other suppliers.
- There has been a significant increase in the demand for 300 kVA transformers across New Zealand from new housing developments. If this trend continues and transport electrification continues as expected; the competition for transformers may become a constraint.

3.3 Section C – Modelling Headwind and Tailwind Results

3.3.1 Demand Reduction

The level of demand reduction achieved by industry will have a significant impact on the timeline of decarbonisation of process heat. Figure 16 to Figure 19 outlines the effect of changing demand reduction to the timeline of achieving decarbonisation of process heat for each profession type. Reducing the demand reduction resulted in more quantum of work and hence a delayed realisation of decarbonisation. The reverse is found when demand reduction is increased.

It is important to note that resources (time, capital, personnel) will still be required to identify and implement demand reduction. The relationship between the resource costs and the amount of demand reduction is expected to follow a non-linear relationship. The effort to identify opportunities to reduce demand becomes labour intensive and specialised the higher the requirement becomes. The cost of implementing higher proportions of demand reduction is expected to be higher, in per percentage basis, due to the complexity of the solution. Quantifying these resources is difficult and the identification of opportunities has been deemed as out of the scope of this project. Regardless, investment into demand reduction will have a net positive impact on New Zealand's timeline to decarbonise process heat, along with other benefits such as reduced energy consumption and a lower requirement for new power stations.

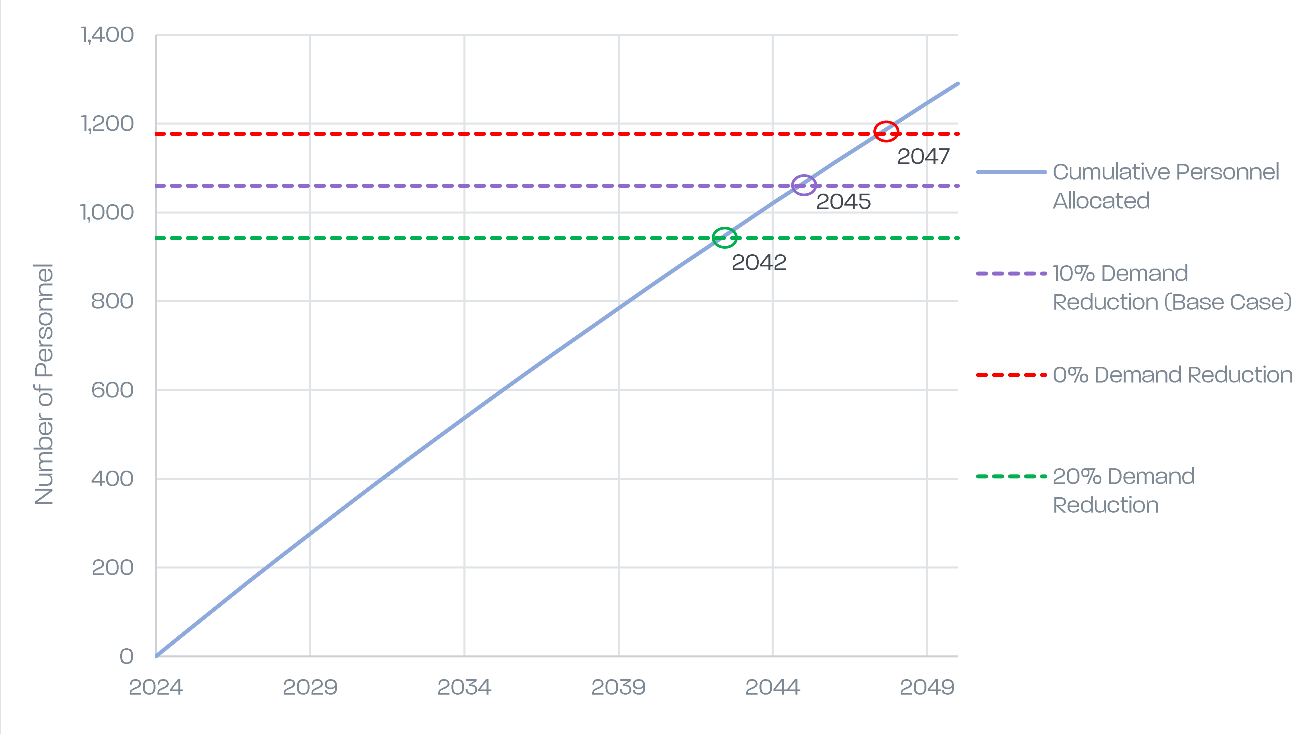

Figure 16 – Impact of demand reduction on design engineer labour market timeline to meet process heat decarbonisation requirements.

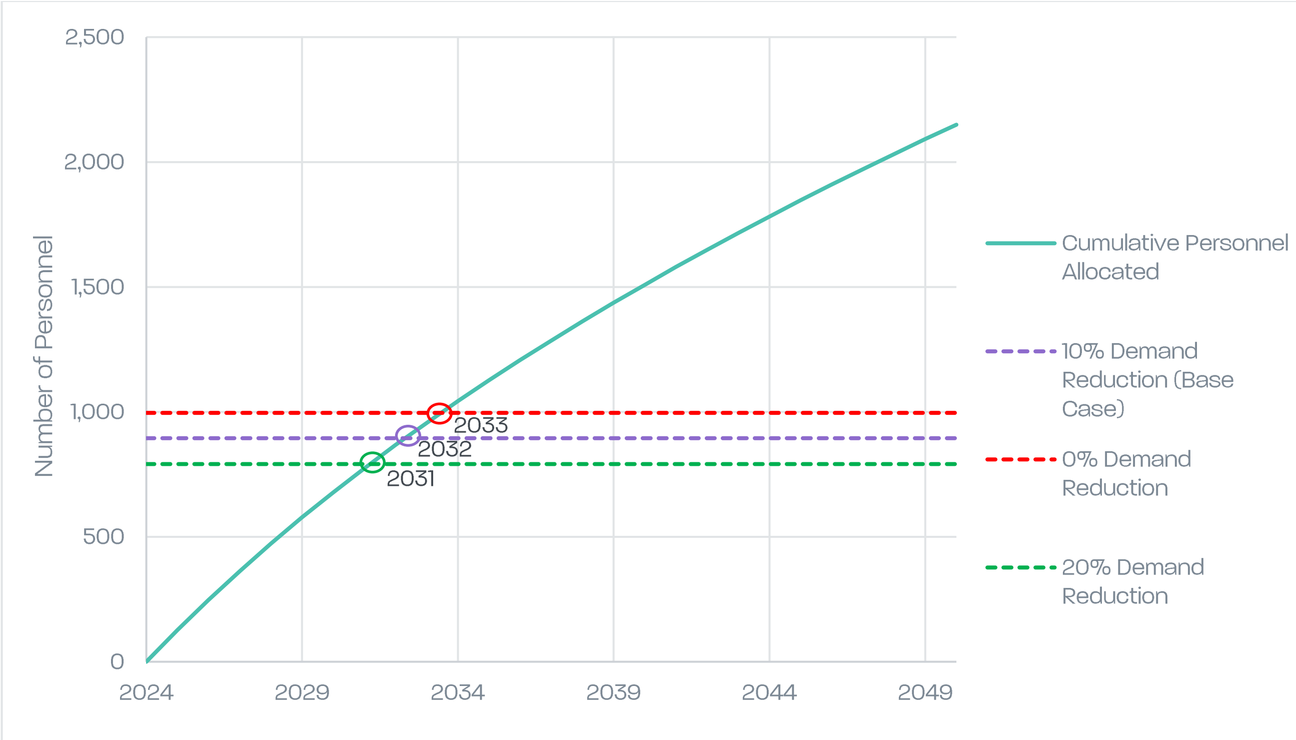

Figure 17 – Impact of demand reduction on electrical engineer labour market timeline to meet process heat decarbonisation requirements.

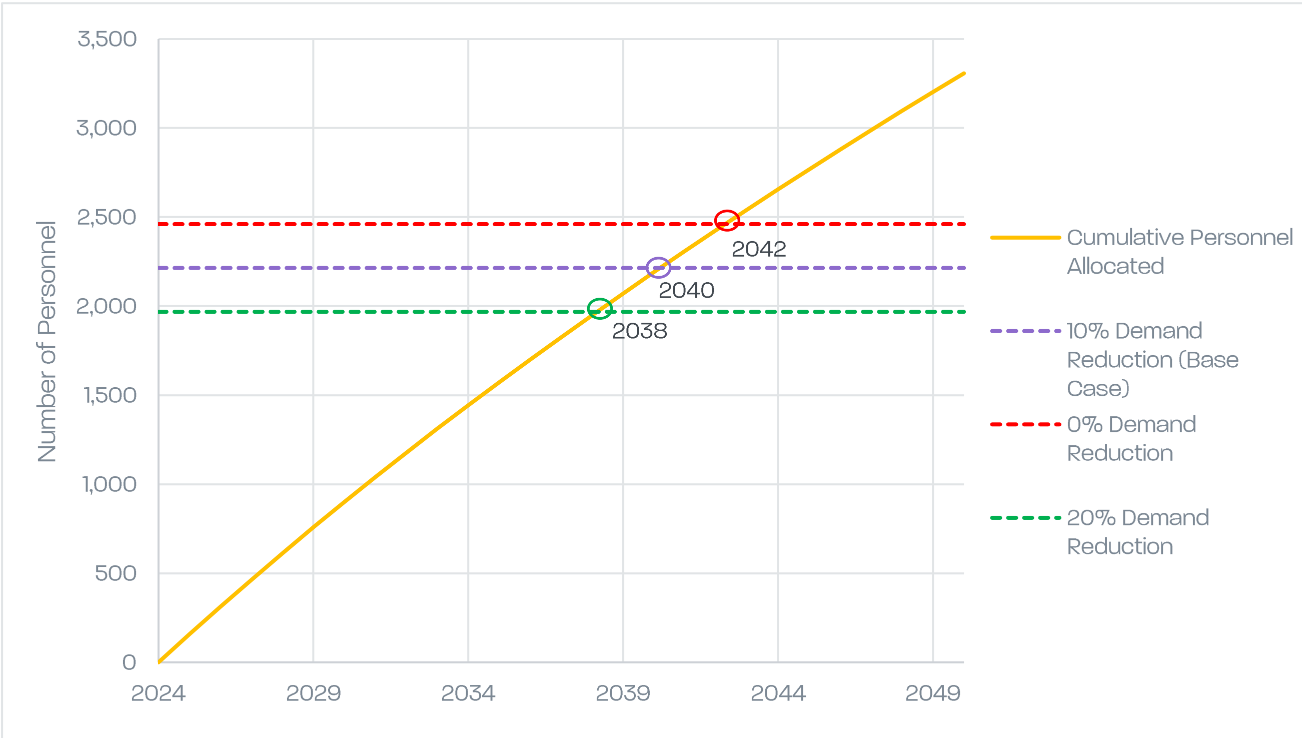

Figure 18 – Impact of demand reduction on fitter & turner labour market timeline to meet process heat decarbonisation requirements.

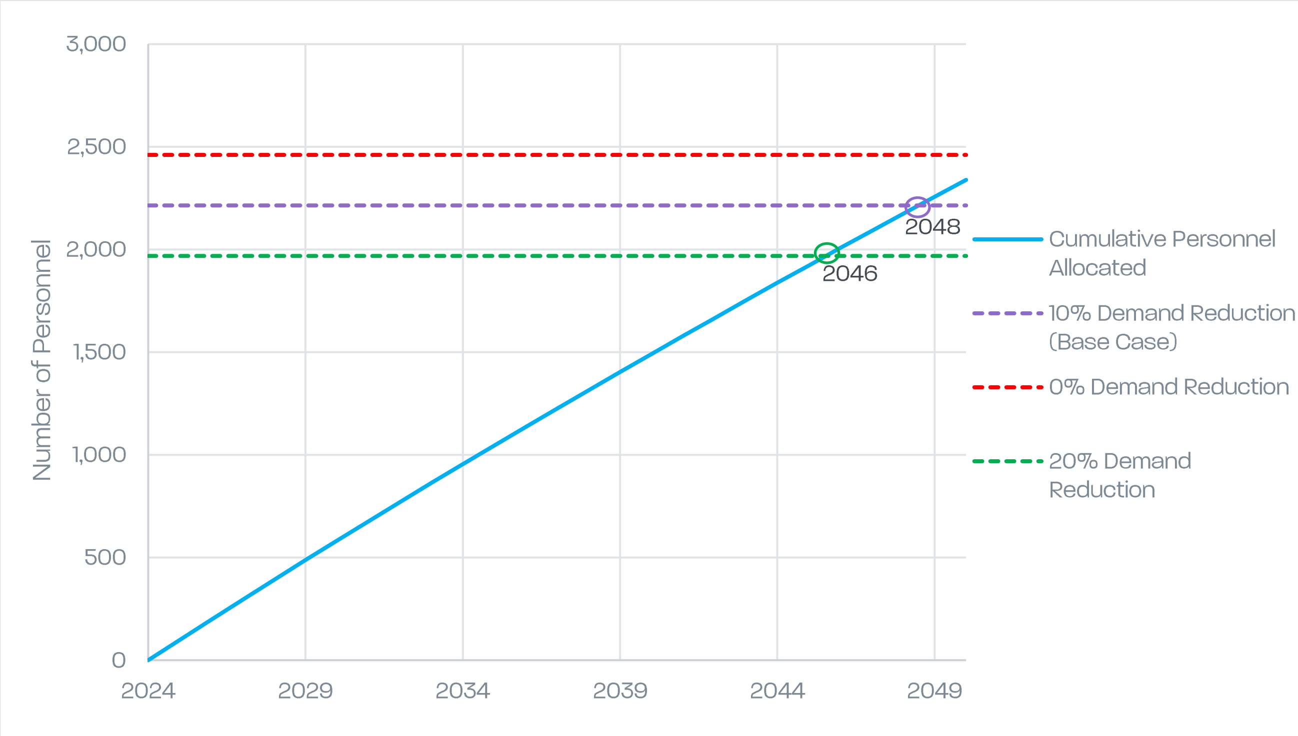

Figure 19 – Impact of demand reduction on electrician labour market timeline to meet process heat decarbonisation requirements.

3.3.2 Timeline Variation

Due to the base case scenario not meeting the required target deadline of 2037, any softening of the requirement will result in further slippage of timeline. Due to this, the timeline effect of changing the due date for the non-coal fossil fuels was not pursued. A coal only case was modelled to confirm whether the 2037 target to decarbonise coal is achievable. Figure 20 shows that the coal timeline can be achieved by 2030. This is possible with a concentrated effort to decarbonise coal users only.

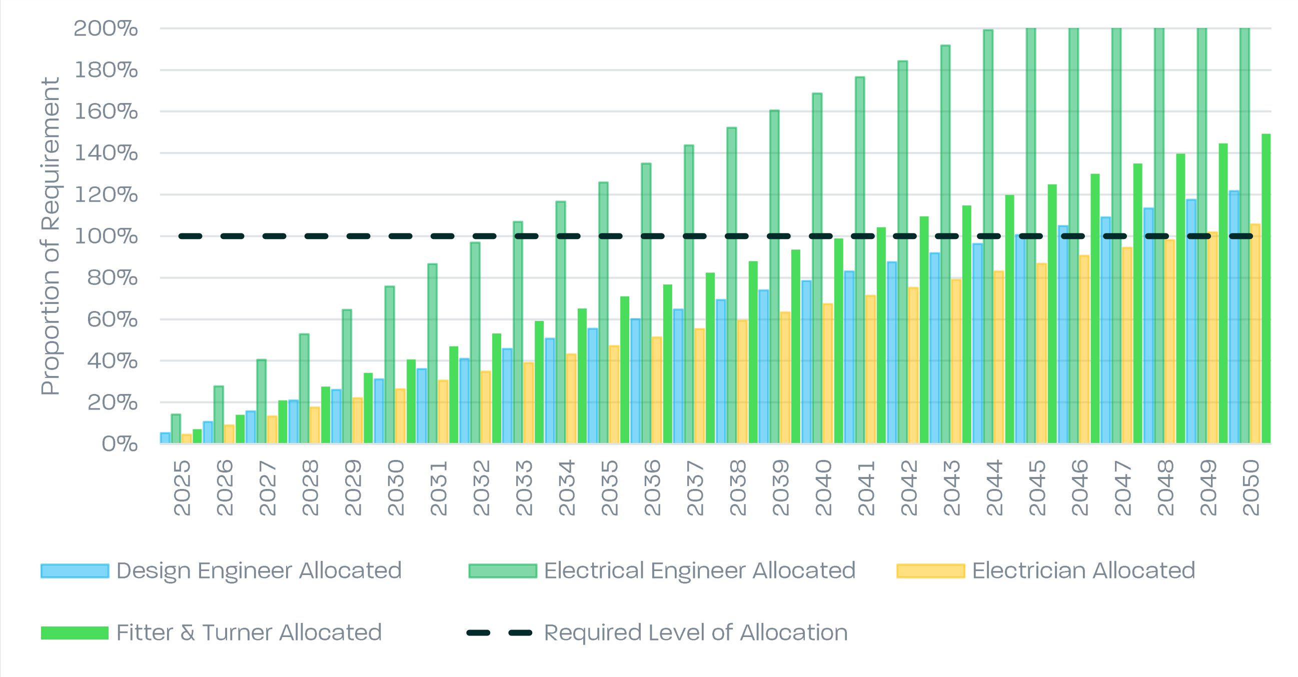

Figure 20 – Coal Decarbonisation Personnel Allocation Timeline

3.3.3 Labour Market

The effects of changing the labour market can be seen in Figure 21 to Figure 24, Table 17 below summarises the setpoints of the factors for each modelled scenario. Any change that would result in less people every year to work on process heat decarbonisation (i.e. higher economic growth, higher retirement rate, and lower migration rate) resulted in the prolonging of the realisation of process heat decarbonisation. The reverse is true for any factors that increase the number of people available to support the process heat decarbonisation effort.

Table 17 – Personnel rate factors

Scenario	Economic Growth Rate	Retirement Rate	Migration Rate	Workforce Entry Inflation Factor
Base Case	3%	3%	1%	0%
Economic Growth Rate Increase	5%	3%	1%	0%
Economic Growth Rate Decrease	1%	3%	1%	0%
Retirement Rate Increase	3%	5%	1%	0%
Retirement Rate Decrease	3%	1%	1%	0%
Migration Rate Increase	3%	3%	5%	0%
Migration Rate Decrease	3%	3%	0.25%	0%
Workforce Entry Increase	3%	3%	1%	10%
Workforce Entry Increase	3%	3%	1%	20%

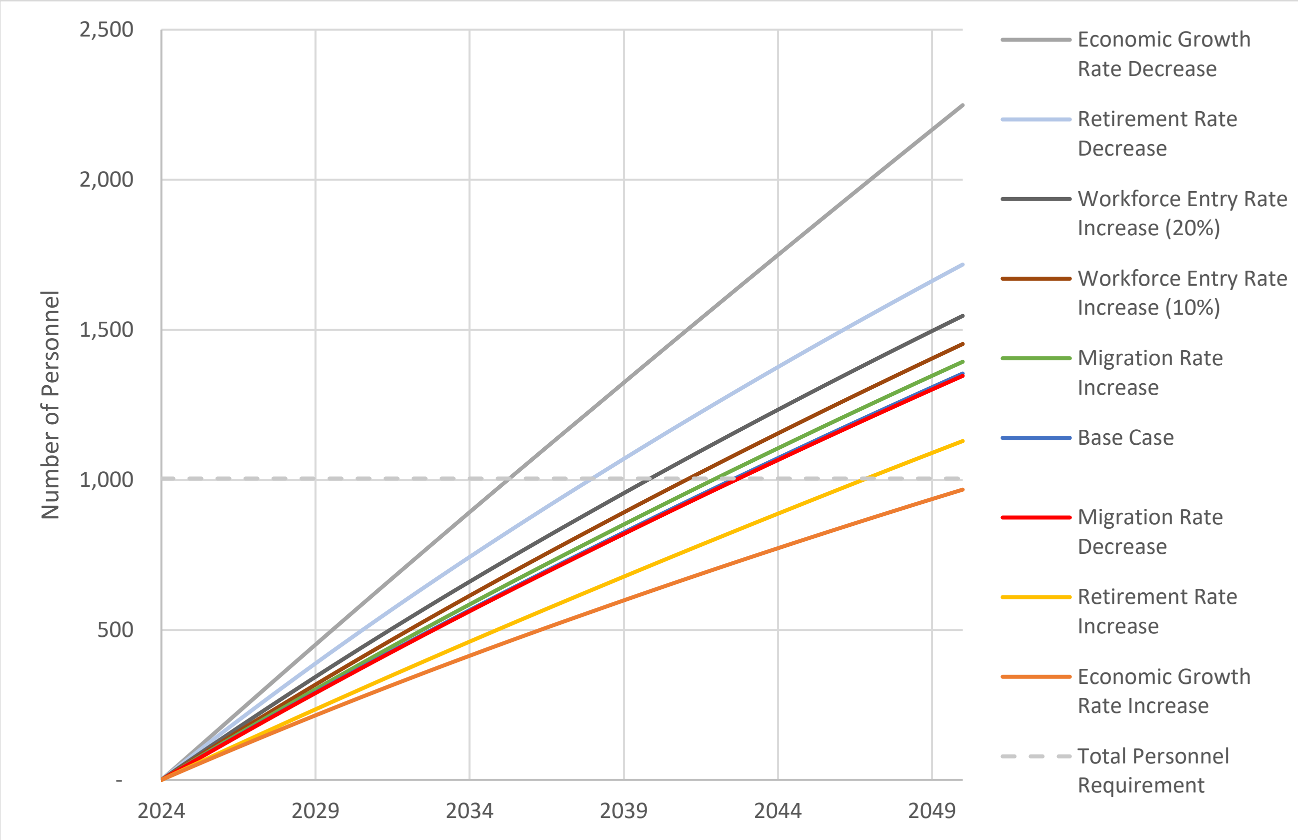

Figure 21 – Impact of market changes on design engineer labour market timeline to meet process heat decarbonisation requirements.

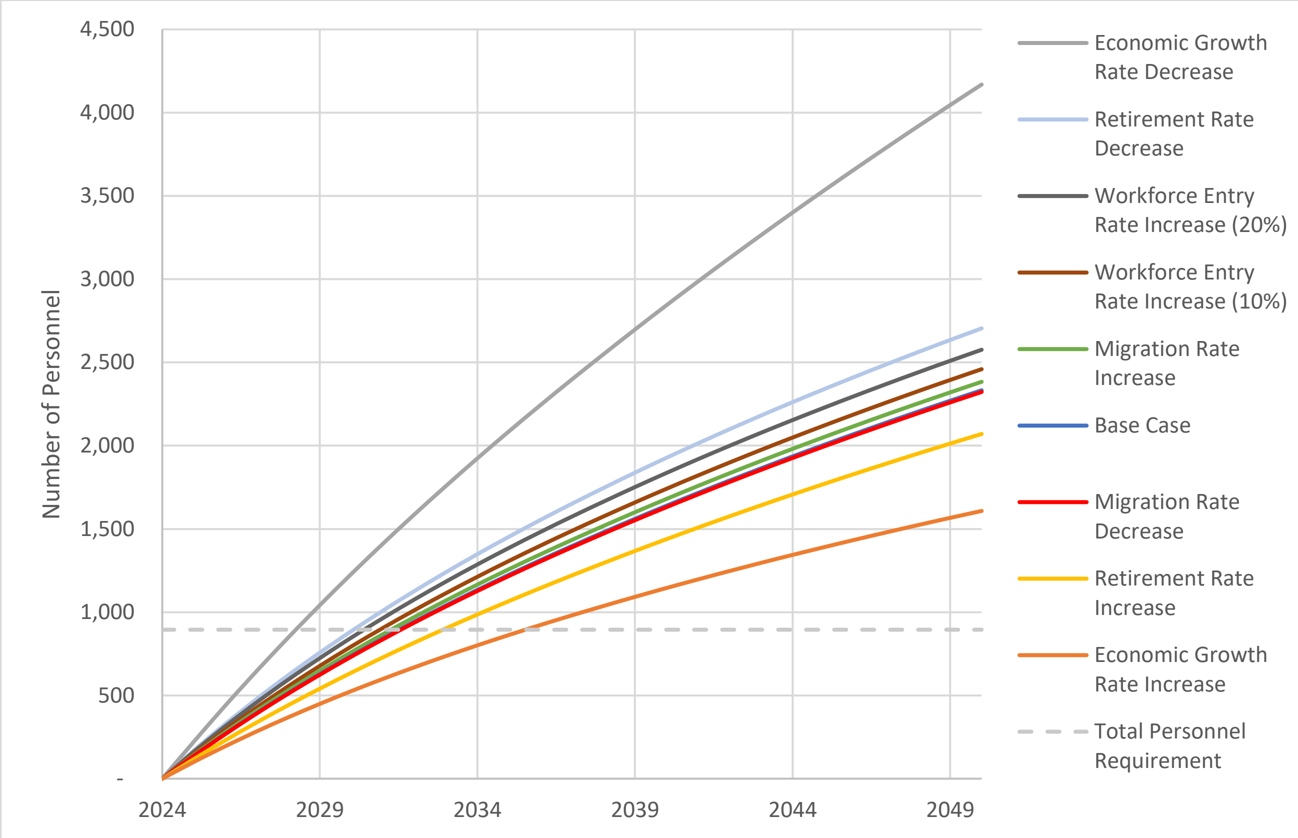

Figure 22 – Impact of market changes on electrical engineer labour market timeline to meet process heat decarbonisation requirements.

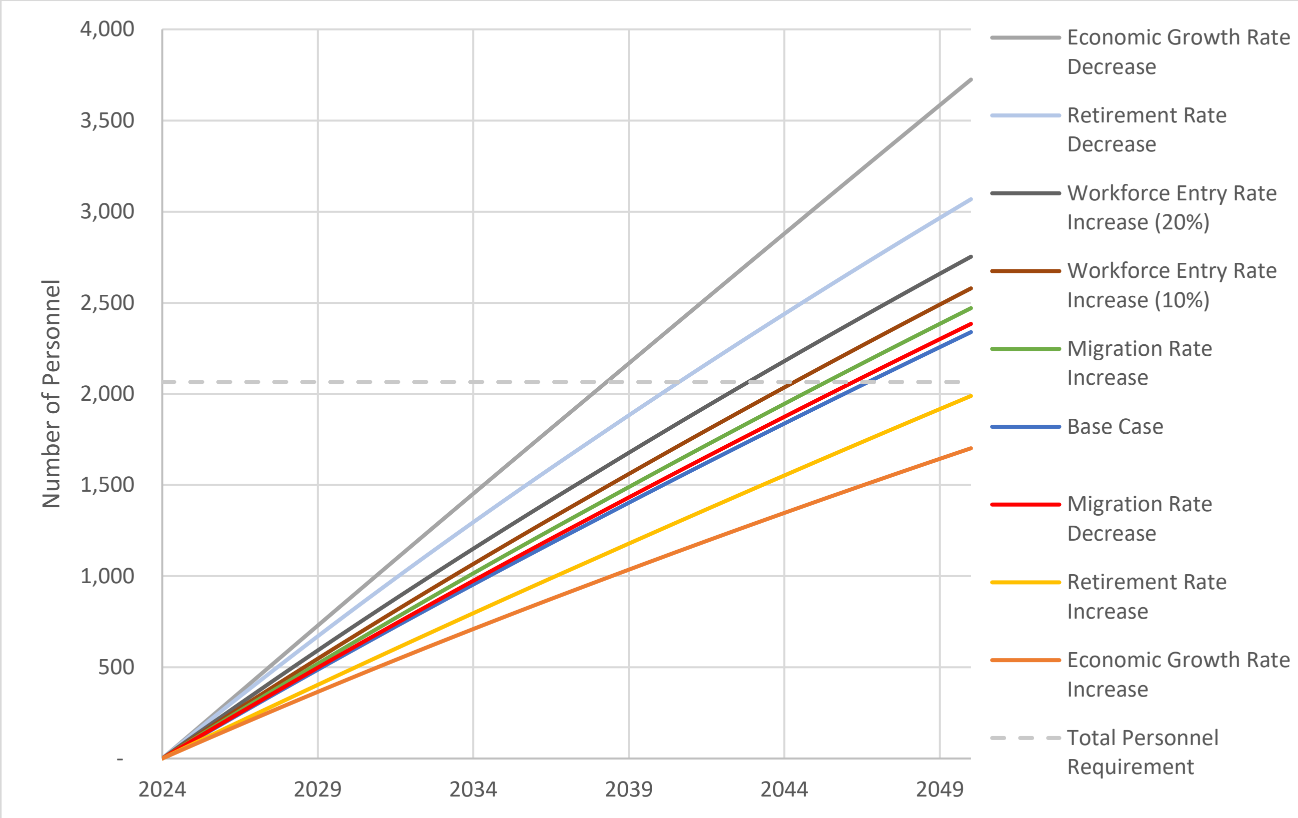

Figure 23 – Impact of market changes on electrician labour market timeline to meet process heat decarbonisation requirements

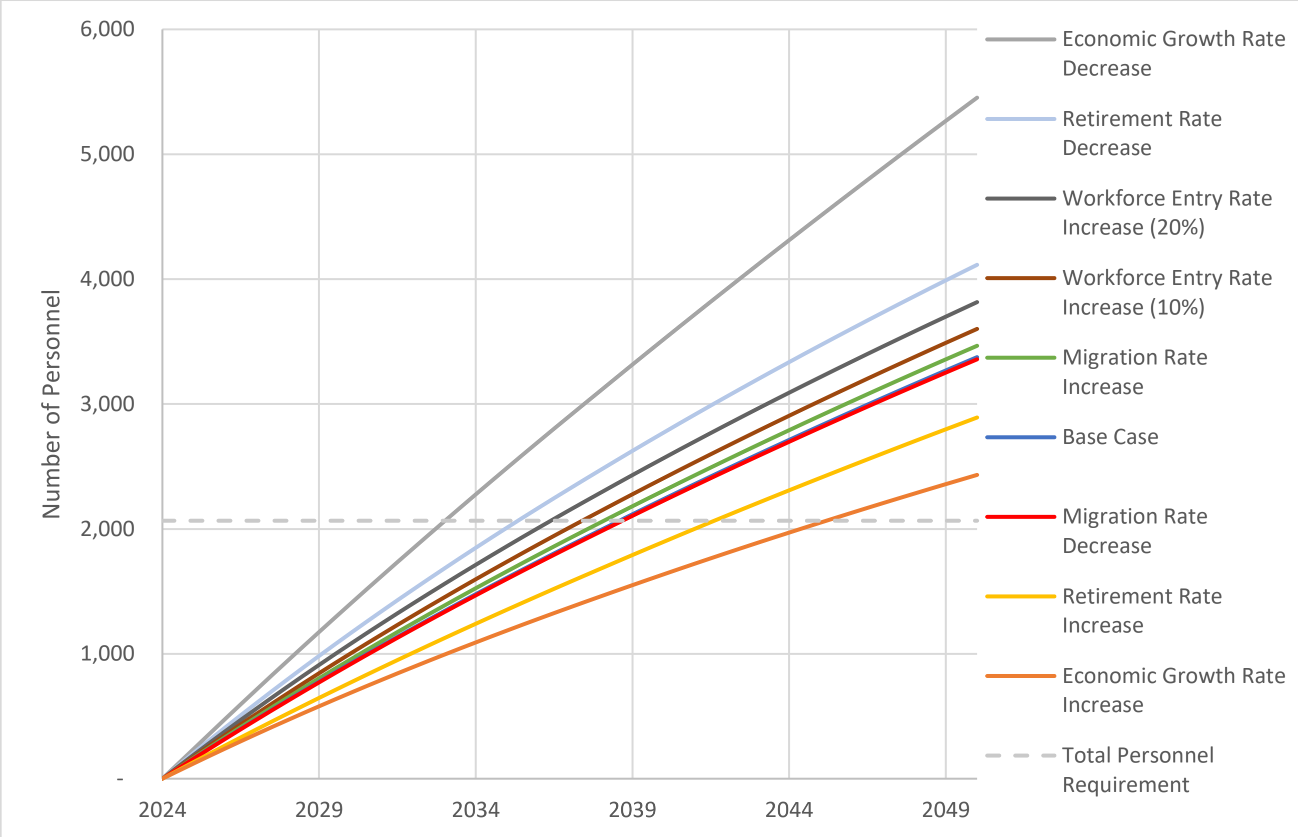

Figure 24 – Impact of market changes on fitter & turner labour market timeline to meet process heat decarbonisation requirements

3.3.4 Electrical Technology Uptake

From previous work undertaken by DETA, a list of electrical network upgrade projects were obtained. The expected duration of each project compared to the magnitude of the capacity upgrade is shown in Figure 25. There is greater certainty in the duration of smaller projects as more data points were available. Although larger projects may deliver capacity to the grid faster on a MVA basis; these are not always possible and depend on the existing grid infrastructure and local demand of end users.

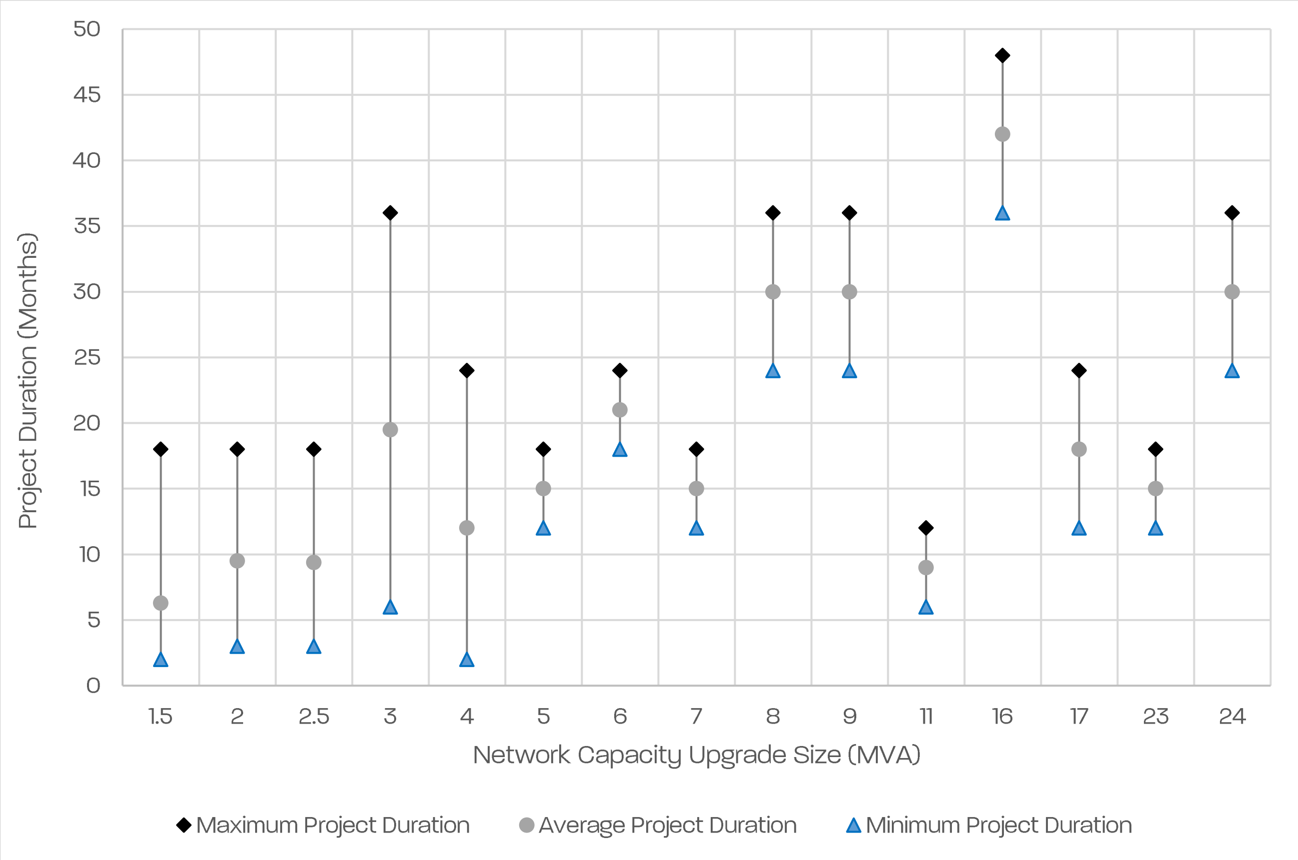

Figure 25 – Projected timeline of network capacity upgrades

Figure 26 shows the impact of adopting more electrically efficient technologies in the decarbonisation of process heat. The effect of the reduction in electricity demand due to more efficient technology vs the time to complete network upgrades were plotted. Three different capacities were used in the model to assess the effect of capacity in the timeline.

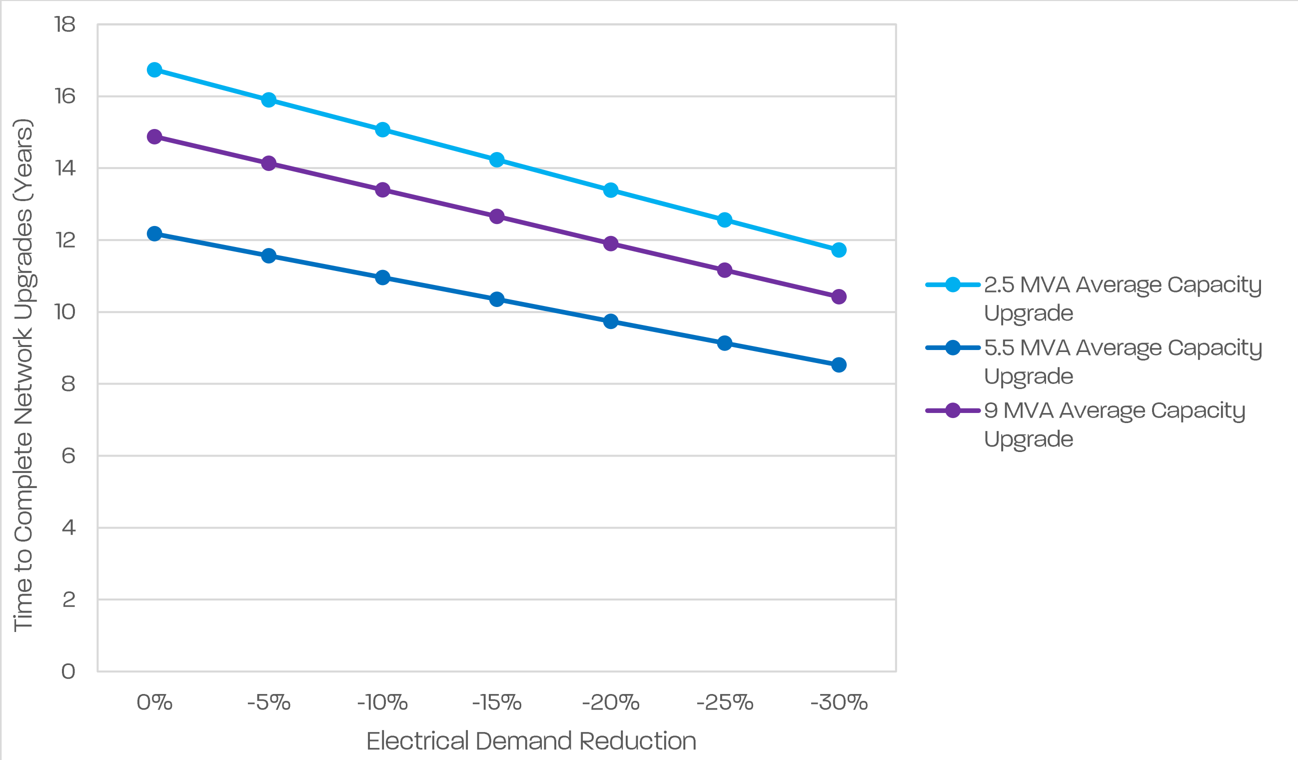

Figure 26 – Impact of new electrical technology adoption on network capacity upgrades required for process heat decarbonisation

4. Discussion

The decarbonisation of process heat will play a key role in New Zealand's response to climate change. Process heat makes up one third of the country's energy use and contributes 8% to its gross emissions. Whilst substantial work has been completed to understand the targets of decarbonisation, assessments on the timeframe of process heat decarbonisation has been limited. This study aimed to understand whether the goal of decarbonising process heat is achievable by 2037 and to perform a quantitative analysis on factors that could impact the timelines associated with this goal.

The quantum of work identified to decarbonise process heat was estimated to be achievable (in isolation of other decarbonisation efforts within NZ) by 2048, which is 11 years later than the target. The main headwind in this effort is the availability of key personnel. Information from online sources on economic growth, retirement, migration, current personnel in key professions, and graduation into key professions was collated to assess the current state of the labour market. This analysis indicated that most of these professions are already struggling to keep pace with BAU activities and don't currently have the capacity to complete additional process heat decarbonisation work in the desired timeline. Personnel issues were even highlighted by suppliers of key equipment who indicated that they have the manufacturing capacity to supply the additional demand but are already short of installers for BAU.

Electricians and Design Engineers were identified as the bottlenecks in the labour market, but only Electrical Engineers have the capacity to meet the 2037 deadline. It was highlighted earlier that although Project Managers and Controls Engineers will be key to this work; there was not information available to conduct the above analysis. From our understanding of the industry, Project Managers are unlikely to be a constraint due to the many professions that transition to Project Managers as they progress through their career and the skillset of project management being transferable between industries. Control Engineers are likely to be another bottleneck to decarbonisation due to the limited number of people currently working in the industry and the skillset required to enter.

Factors such as economic growth and worker retirement rates have the largest impact on the labour market and hence the availability of personnel, however, these factors are difficult to predict and impossible to control. A reduced rate of economic growth has been estimated to have the most impact on reducing the timeline required for decarbonisation – however, this is not a desirable outcome and reducing economic growth is unlikely to be pursued given the many other negative outcomes.

Another factor that will play a key role in achieving the decarbonisation target is the ability of EDBs to facilitate the necessary electrical upgrades to provide an extra 1,446 MVA of capacity to the grid. Using the assumptions on this study, it will take the EDBs 17 years (in isolation) to provide the required extra capacity for the process heat decarbonisation effort. This is later than the expected target of 2037. However, as highlighted previously, the capacity of EDBs to execute projects has only been provisionally estimated and should be investigated further. Capital budget forecasts of EDBs across New Zealand was compared to the modelled capital implications of network upgrades from process heat decarbonisation. This indicated that the EDBs do have the capital capability to accommodate the upgrades.

In addition to developing understanding of the timeframe for capacity upgrades, identifying and implementing demand reduction opportunities will be key to achieving national process heat decarbonisation. Increasing the average demand reduction across sites by up to 20% could reduce the necessary electricity upgrade by EDBs as well as improve the timeline required by the electrician labour market (the bottleneck) by 3 years. The adoption of new technologies such as steam heat pumps could have a significant impact on the EDBs ability to accommodate for network upgrades and on process heat decarbonisation as a whole. However, the future impact of these technologies is difficult to predict and should not be relied upon when developing plans.

In summary, decarbonisation will not be achievable by 2037 (in isolation, let alone once other decarbonisation work is included) if the current track is followed. Availability of qualified staff is the main headwind in the decarbonisation effort followed by the potential risk of the capability of EDBs to complete the electrical upgrades required to facilitate decarbonisation in the necessary timeframe.

4.1 Limitation of analysis

This study provides a thorough review of the process heat decarbonisation challenge that lies ahead. However, there were limitations to this analysis that could not be overcome as they were deemed to require a substantial amount of time to uncover and understand, were difficult to predict at this time, or were outside of the scope of this study. Some of these limitations are outlined in the following paragraph.

1. Conducting analysis on this scale is challenging, assumptions made create inaccuracies at a site/regional level, but this was the trade-off to creating a realistic picture of process heat decarbonisation on a national level.
2. Further consideration and study in ensuring the redundancy and reliance of the electrical grid system once process heat is decarbonised is required. Due to this, consideration of N vs N-1 security for electrical network upgrades is key. This would have a substantial impact on the cost of electrical upgrades. Based on the observed projects used as data points in this study, securing N-1 redundancy generally costs two to four times more than the N supply.
3. Throughout this report, decarbonisation of process heat is treated in isolation. Hence, competing factors, external to process heat decarbonisation, such as transport electrification, economic growth, housing development, materials shortage, global markets, etc. were largely ignored. However, these will have a significant impact on the ability of New Zealand to decarbonise process heat by 2037. For example, the electricity requirement for transport electrification is estimated to be four times more than for process heat – this will have a major impact upon a range of factors, such as availability of transformers, ability of EDBs to provide upgrades and availability of personnel to design and install electrification solutions.

4.2 Next Steps

- Availability of key personnel has been identified as the key constraint from this study. Pressure needs to be applied on the government to invest in apprenticeship schemes and incentivise skilled professionals to stay in the country.
- Identifying energy efficiency and decarbonisation opportunities will be key to achieving decarbonisation targets for the country; investment by EECA into energy audits should be continued.
- The capability of EDBs to implement the network upgrades required in the desired timeframe is uncertain; EDBs should be encouraged to improve capital budget forecasting to better accommodate for new market factors such as process heat decarbonisation and transport electrification.
- As mentioned throughout this report, factors external to process heat decarbonisation will have a significant impact on the ability of New Zealand to decarbonise process heat by 2037. How these factors all interact, and their net impact will be difficult to measure, however, further investment into studies of this nature for sectors/industries/technologies that have connection to process heat decarbonisation will help us to better understand the entire picture and plan/execute more effectively.

Appendix A – Further information from EDB Asset Management Plan

Below is a breakdown of the estimated required proportion of the capital forecast of each EDB to complete decarbonisation of process heat in their region. Please note that due to the broad assumptions used in this study, there is expected to have a moderate level of inaccuracy once for analysis that is done on a regional level.

EDB name	Total cost (000,000 NZD)	% of total 15 year CAPEX forecast	% of total 15 year Relevant Field forecast
EA Networks	8.36	5%	7%
Otago Net and Power company	89.29	13%	38%
Alpine Energy	53.34	21%	65%
Orion NZ	35.26	2%	5%
Aurora Energy	1.53	0%	1%
Network Waitaki	13.77	7%	11%
Network Tasman	14.56	6%	8%
The Lines Company	4.47	2%	5%
Marlborough Lines	4.05	2%	10%
MainPower NZ	-	0%	0%
PowerCo	149.67	4%	7%
Nelson Electricity	3.00	13%	42%
Buller Electricity	0.99	4%	35%
Westpower	14.27	56%	87%
Electra	-	0%	0%
CentraLines	-	0%	0%
Counties Energy	3.34	1%	2%
Firstlight Network	1.20	1%	5%
Horizon Energy	6.97	4%	14%
Northpower	20.21	7%	15%
ScanPower	-	0%	0%
Top Energy	3.66	1%	2%
Unison Networks	27.52	3%	7%
Waipa Networks	1.36	1%	2%
Wellington Electricity	18.57	2%	4%
WEL Networks	142.14	11%	15%
Vector Lines	244.88	6%	11%

The categories that fall under capital expenditure in the EDBs' asset management plans are shown below.

Category description
Expenditure on assets
Asset relocations
Asset replacement and renewal
Assets commissioned
Capital expenditure forecast
Consumer connection
Cost of financing
Energy efficiency and demand side management, reduction of energy losses
Overhead to underground conversion
Research and development
Expenditure on network assets
Expenditure on non-network assets
Legislative and regulatory
Other reliability, safety and environment
Quality of supply
Total reliability, safety and environment
System growth
Value of capital contributions
Value of vested assets
Capital contributions funding system growth
Distribution and LV cables
Distribution and LV lines
Distribution substations and transformers
Distribution switchgear
Other network assets
Subtransmission
System growth expenditure
System growth less capital contributions
Zone substations
Asset replacement and renewal expenditure
Asset replacement and renewal less capital contributions
Capital contributions funding asset replacement and renewal
Class B
Class C