Barriers and opportunities for process heat decarbonisation of SMEs in Auckland

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Climate Connect Aotearoa

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Executive Summary

This study provides insights into the decarbonisation of process heat within Small and Medium Enterprises (SMEs) in the Auckland region. The investigation has been driven by the increasingly urgent need for industries to transition towards more sustainable, net-zero-carbon emission technologies, with a focus on practical, market-available solutions.

The report begins with an analysis of process heat emissions and energy use in the Auckland region, setting the stage for understanding the local context and its unique requirements. It then offers an examination of the existing national policy and action plans aimed at reducing emissions, with a special focus on the initiatives established by the New Zealand Government, EECA, and the Climate Change Commission. These include the Energy Transition Accelerator, Regional Energy Transition Accelerator, Government Investment in Decarbonising Industry fund, and Emission Trading Scheme. The report underscores the importance of these initiatives in providing the necessary support for SMEs in their transition to sustainable energy solutions.

The main body of the report is dedicated to exploring market-available decarbonisation solutions, namely energy efficiency measures, heat pumps, electric and electrode boilers, and biomass boilers. The report provides a detailed evaluation of these technologies, with emphasis on their relevance to SMEs, and identifies leading technology providers in the Auckland region and beyond.

In addition, there exist notable technical and non-technical barriers preventing SMEs from fully embracing the decarbonisation journey. An examination of these barriers is presented, highlighting the specific challenges faced by SMEs and the factors that might impede their progress towards a low-carbon future. The study provides recommendations that could be investigated to overcome these barriers. The following are the summarised recommendations:

- Establish sector-based energy decarbonisation consortiums to share access to technical expertise and case studies, possibly co-funded by government agencies. In addition, it would provide a platform for SMEs to share information and experiences and collaborate on common non-competitive challenges. This could include comprehensive education and awareness programs about the benefits of transitioning to net-zero-carbon energy sources.

- Understand the capacity of existing grid and distribution infrastructure for electricity delivery. Co-design strategies with government and electricity authorities to modernise the electricity grid and distribution networks. Implement long-term planning, update grid codes and standards, encourage regulatory frameworks that incentivize infrastructure upgrades, and adopt innovative solutions such as smart grid technologies, renewable energy integration, and energy storage.
- Consider Energy-as-a-Service (EaaS) providers to handle all aspects of the system, including its installation, operation, maintenance, and upgrades.
- Establish green investment funds to support SMEs' decarbonisation efforts through low-interest loans or grants for projects that contribute to the transition to net-zero-carbon energy. Utilise existing schemes administered by EECA.

Contents

1 Introduction

1.1 Background

Small and medium-sized enterprises (SMEs) are important contributors to the Auckland region's economy, providing employment opportunities and driving economic growth. However, the increasing need to invest and implement net-zero-carbon energy initiatives presents a significant economic and technology challenge that deviates from business-as-usual for these companies.

Net-zero-carbon energy refers to practices, technologies and fuels that deliver the required energy without a net-zero release of greenhouse gases, like carbon dioxide, over their lifetime. Transitioning from consuming fossil fuels to net-zero-carbon energy is often referred to as decarbonisation due to the reduction in greenhouse gases emissions. It is critical for everyone, including SMEs, to play critical roles in transitioning to clean, renewable and sustainable energy to ensure a sustainable future for the regional and national economies as well as the environment.

Decarbonising energy in SMEs is often a complex process that requires significant investment, time, and resources beyond business-as-usual. Some of these challenges include the lack of technical and engineering expertise to identify the least-cost transition pathway and the high investment cost of implementing net-zero-carbon energy technologies, particularly challenging for smaller businesses with limited budgets. SMEs operate across a broad range of sectors, and no one solution is appropriate for all companies.

Despite the challenges, decarbonising process heat in SMEs is an essential step in aligning businesses with regional and national sustainability objectives and commitments. Business can obtain competitive advantages that yield benefit in the long run, including:

- **Operational Cost Savings:** Switching to renewable energy sources for process heat can lead to significant operational cost savings over time. Technologies such as heat pumps, for instance, can be three-to-four times more efficient compared to traditional fossil fuel systems.

- **Enhanced Reputation:** As consumers and investors increasingly favour companies that demonstrate commitment to sustainability, SMEs can enhance their reputation and competitive advantage by decarbonising. At the same time, this makes their business models more sustainable in the long run.
- **Compliance and Government Investment:** The Government is increasingly implementing more stringent carbon emission reduction regulations and opportunities. By decarbonising process heat, SMEs can stay ahead of these regulatory changes, avoiding potential penalties while taking advantage of significant co-funding and government investment schemes.

Transitioning process heat to net-zero-carbon sources in SMEs is not merely a response to the growing environmental challenges but it's also a proactive strategy to secure future economic viability and competitive advantage.

1.2 Auckland Council and Climate Connect Aotearoa

Auckland Council has set an ambitious target to reach net-zero carbon emissions[1] by 2050. The council recognises the urgent need to address climate change and continues to take significant steps to reduce the region's carbon footprint. As a result, one of its key priorities is to decarbonise the energy use across residential, commercial, and industry sectors, which is responsible for a significant portion of the city's GHG emissions.

To support the council's decarbonisation efforts, Climate Connect Aotearoa was established as a non-profit, innovation hub with the goal of bringing together individuals, businesses, and organisations to work collaboratively towards a low-carbon future. Climate Connect Aotearoa's mission is to accelerate the transition to a net-zero-carbon, resilient, and equitable Aotearoa through education, collaboration, and action. The organisation collaborates with Auckland Council and other stakeholders to identify and implement effective strategies for decarbonisation, including the promotion of renewable energy, the adoption of energy efficiency measures, and the reduction of carbon emissions in transport. Climate Connect Aotearoa plays a crucial role in facilitating the necessary collaboration and

[1] https://www.aucklandcouncil.govt.nz/plans-projects-policies-reports-bylaws/our-plans-strategies/Pages/te-taruke-a-tawhiri-ACP.aspx

knowledge-sharing to achieve the council's ambitious decarbonisation targets, as well as promoting climate action throughout the wider Auckland community.

As part of their efforts, Climate Connect Aotearoa identified the need to better identify and analyse the barriers and opportunities for decarbonising process heat in SMEs in Auckland. SMEs represent a diverse range of businesses that often face technically challenging pathways to decarbonise, but lack the engineering capability and financial resources to make the transition. To address this need, Climate Connect Aotearoa initiated this report as a first step in supporting Auckland SMEs on their individual decarbonisation journeys.

1.3 Purpose of this work

This study aims to identify key pathways for decarbonising process heat in Auckland with a focus on SMEs. It reviews and analyses the existing market for electric heat pumps, electric boilers and biomass boilers in New Zealand relevant for SMEs. The report further identifies key technology providers and manufacturers, including those located within the Auckland region, assesses the current state of technologies for various process heat applications, provides a qualitative assessment of key barriers to uptake, and concludes with recommendations for addressing local challenges and decarbonising process heat in Auckland SMEs.

The report draws on the expertise and experience of the authors, as well as academic and industrial literature, in assessing the current state of affairs in Auckland SMEs, net-zero-carbon energy technology options, and the equipment manufacturers and suppliers of these technologies.

1.4 Report structure

The remainder of the report is organised as follows. **Section 2** delves into the nature of process heat emissions and energy usage within the Auckland region, underpinning the need for decarbonisation. In **Section 3**, we examine the current national policy and action pertaining to energy decarbonisation. This includes an exploration of the Energy Transition Accelerator (ETA), the Government Investment in Decarbonising Industry (GIDI), the Emission Trading Scheme and the Climate Change Commission. **Section 4** details market-available decarbonisation solutions for process heat, encompassing measures such as energy efficiency, heat pumps, electric hot water, electrode boiler, biomass boilers, thermal storage technologies, process and manufacturing electrification technologies, and on-site renewable electricity systems. **Section 5** identifies the potential barriers to the uptake of these decarbonisation solutions, segregating them into technical and non-technical categories for a more granular understanding. In **Section 6**, policy interventions that could address these barriers and expedite the transition to low-carbon process heat are discussed. Finally, **Section 7** draws the report to a close with a summary of recommendations for SMEs and policymakers, followed by concluding remarks.

2 Process heat emissions and energy use in the Auckland region

The report[2] "Process Heat Emissions & Energy Use in the Auckland Region" presents the findings and recommendations of a study conducted to assess greenhouse gas (GHG) emissions and potential mitigation methods within the industrial sectors in Auckland. The study demonstrated that industrial processes relying on natural gas for process heat contribute to emissions of 1.36 million tonnes of $CO_{2\text{-eq}}$, with the NZ Steel Glenbrook mill accounting for over 60% of these emissions.

It was estimated that emissions could be reduced by 13% using industrial heat pumps utilising renewable electricity. These heat pumps can supply process heat below 100°C at high coefficients of performance (COP)[3] and sectors with relatively low temperature heat demands like food and meat processing, have the greatest reduction potential. The report also indicates that although biomass could substitute natural gas for process heat, issues such as availability, cost, and distribution hinder widespread fuel switching in the Auckland region.

The report covered a wide range of industrial sectors although there was a large focus on the larger industrial emitters. Three data sources were used - EECA End-use Database (2012), Modified EECA Heat Plant Database (2016) and the Auckland City Council Industrial Emissions Inventory (2011). One of the issues encountered was a lack of reliable data regarding energy usage and emissions. The lack of reliable data is particularly a problem for small and medium sized enterprises and includes reliable data on energy usage, temperature demands, energy costs and emissions.

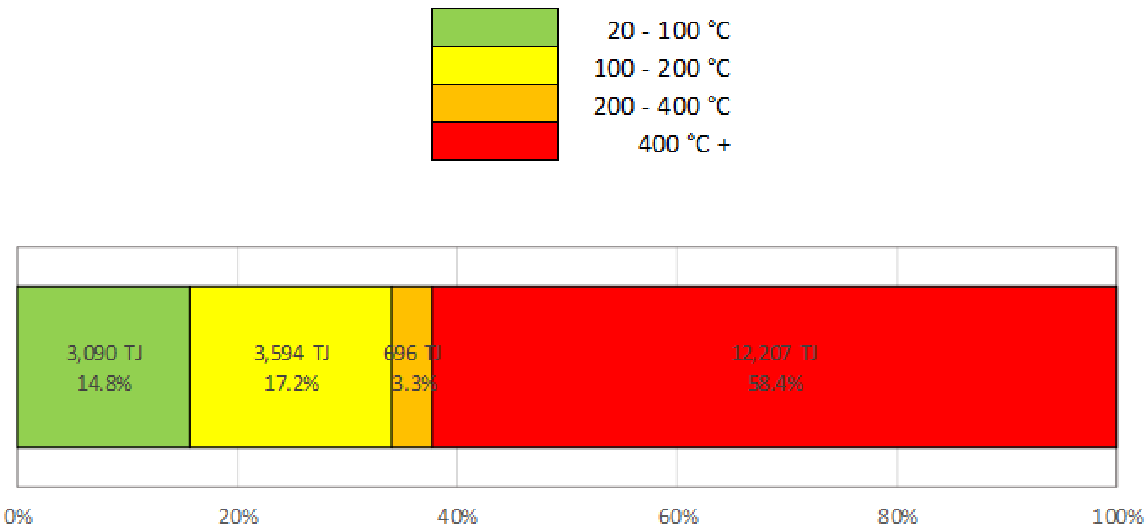
Based on the findings, the study provides several recommendations to facilitate emissions reduction in the industrial sector. These include setting clear sector-based emissions reduction targets, implementing low-carbon measures in council-owned businesses and facilities, promoting and supporting companies that implement emissions reduction projects, encouraging engagement with experts to assess reduction potential during equipment upgrades, monitoring developing technologies like industrial heat pumps, promoting best-available-technologies, and supporting

[2] Atkins, M., 2018. Process Heat Emissions & Energy Use in the Auckland Region, University of Waikato.
[3] COP is the ratio of the amount of useful heating or cooling that is supplied by a heat pump to the work required.

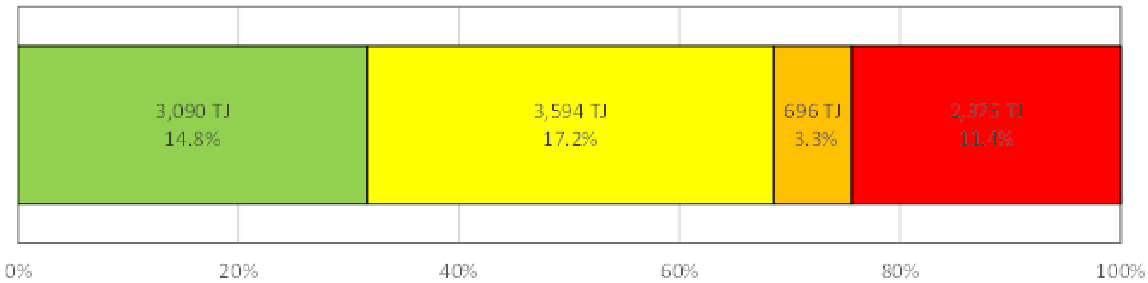
the development of low-carbon building materials and streamlined consenting processes for low-carbon building options.

Figure 1 shows the estimated process heat demands for the Auckland region at different temperature levels. NZ Steel dominates the overall process heat energy demand and also has high temperature demand due to the steelmaking process.

Table 1 summarises the estimated overall energy demand due to process heat related emissions by sector in the Auckland region.



a) with NZ Steel



b) without NZ Steel

Figure 1. Overall temperature demand profile for the industrial heat sector in the Auckland Region[2].

Table 1. Emissions data by industry sector and fuel type for the Auckland Region[2].

	Natural Gas	Coal	LPG	LFO	Diesel	Petrol	Wood	Electricity	Uncertain	Total
Energy Use (TJ/y)	10,718	7,297	57	34	262	20	421	600	177	19,587
Emisssions (t_{CO2}/y)	568,074	729,711	4,093	2,309	18,211	1,422	842	24,960	9,381	1,359,005

Sector	Energy (TJ/y)									
	Natural Gas	Coal	LPG	LFO	Diesel	Petrol	Wood	Electricity	Uncertain	Total
Construction	0	0	0	0	10	3	-	-	-	**12.4**
Dairy Product Manufacturing	288	-	2	-	55	-	-	-	-	**344.9**
Electricity, Gas, Water and Waste Services	50	-	-	15	-	-	-	-	-	**64.5**
Fabricated Metal Product, Transport Equipment, Machinery and Equipment Ma	251	-	-	-	-	-	-	-	-	**250.5**
Furniture and Other Manufacturing	302	-	-	-	-	-	-	-	-	**301.6**
Furniture and Other Manufacturing and Electricity, Gas, Water and Waste Serv	40	158	1	0	-	-	-	-	-	**199.5**
Meat and Meat Product Manufacturing and Seafood	205	209	-	-	-	-	-	-	17	**431.0**
Mining	0	0	-	0	3	0	-	-	-	**2.7**
Non-Metallic Mineral Product Manufacturing	2,770	-	-	-	-	-	-	-	-	**2,770.0**
Other Food Product Manufacturing	3,167	-	50	-	122	-	-	-	160	**3,499.1**
Petroleum, Basic Chemical and Rubber Product Manufacturing	808	-	-	-	57	-	-	-	-	**864.4**
Primary Metal and Metal Product Manufacturing	2,332	6,900	-	-	-	-	-	600	-	**9,831.8**
Printing	1	-	-	0	0	0	-	-	-	**1.6**
Pulp, Paper and Converted Paper Product Manufacturing	326	-	-	-	-	-	-	-	-	**325.7**
Textile, Leather, Clothing and Footwear Manufacturing	129	30	4	19	16	17	-	-	-	**215.0**
Wood Product Manufacturing	51	-	-	-	-	-	421	-	-	**472.0**
Grand Total	**10,718**	**7,297**	**57**	**34**	**262**	**20**	**1,354**	**600**	**177**	**19,586.8**

Sector	Emisssions (t_{co2}/y)									
	Natural Gas	Coal	LPG	LFO	Diesel	Petrol	Wood	Electricity	Uncertain	Total
Construction	2	2	7	1	696	195	-	-	-	**902**
Dairy Product Manufacturing	15,251	-	117	-	4,019	-	-	-	-	**19,387**
Electricity, Gas, Water and Waste Services	2,626	-	-	1,016	-	-	-	-	-	**3,642**
Fabricated Metal Product, Transport Equipment, Machinery and Equipment Ma	13,279	-	-	-	-	-	-	-	-	**13,279**
Furniture and Other Manufacturing	15,986	-	-	-	-	-	-	-	-	**15,986**
Furniture and Other Manufacturing and Electricity, Gas, Water and Waste Serv	2,141	15,799	64	7	-	-	-	-	-	**18,011**
Meat and Meat Product Manufacturing and Seafood	10,886	20,878	-	-	-	-	-	-	889	**32,654**
Mining	1	0	-	1	194	2	-	-	-	**198**
Non-Metallic Mineral Product Manufacturing	146,809	-	-	-	-	-	-	-	-	**146,809**
Other Food Product Manufacturing	167,853	-	3,633	-	8,000	-	-	-	8,492	**187,978**
Petroleum, Basic Chemical and Rubber Product Manufacturing	42,806	-	-	-	4,117	-	-	-	-	**46,923**
Primary Metal and Metal Product Manufacturing	123,587	690,000	-	-	-	-	-	24,960	-	**838,547**
Printing	61	-	-	0	7	25	-	-	-	**92**
Pulp, Paper and Converted Paper Product Manufacturing	17,262	-	-	-	-	-	-	-	-	**17,262**
Textile, Leather, Clothing and Footwear Manufacturing	6,830	3,032	272	1,284	1,179	1,200	-	-	-	**13,798**
Wood Product Manufacturing	2,694	-	-	-	-	-	842	-	-	**3,536**
Grand Total	**568,074**	**729,711**	**4,093**	**2,309**	**18,211**	**1,422**	**842**	**24,960**	**9,381**	**1,359,005**

3 Current national policy and action

The New Zealand Government, EECA and the Climate Change Commission play leading roles in advising, setting and actioning national climate policy. They have implemented several programs to encourage emissions reduction. Key initiatives include the Energy Transition Accelerator (ETA), the Regional Energy Transition Accelerator (RETA), Government Investment in Decarbonising Industry (GIDI) fund, and the Emission Trading Scheme (ETS). These programmes are designed to support both small, medium and large energy-consuming organisations and regional stakeholders in transitioning towards net-zero-carbon energy. While initially focused on larger businesses, recent efforts to offer generalised, region-specific advice has extended support to SMEs, recognising their unique challenges in achieving emissions reduction.

3.1 Energy Transition Accelerator and Regional Transition Accelerator

EECA administers several programs aimed at promoting energy efficiency and reducing emissions. The Energy Transition Accelerator (ETA), which specifically targets large energy-consuming businesses and public sector organisations. The ETA assists these entities in developing a strategic plan or roadmap to guide their transition towards emission reduction. An external expert conducts an assessment that identifies new technologies, efficiency opportunities, and fuel switching options, providing a potential transition roadmap.

While EECA co-funds up to 40% of the assessment cost (up to a maximum of $35,000), the program was not originally designed with small and medium enterprises (SMEs) in mind, and the cost has been prohibitive for them.

Recognizing this limitation, EECA has recently developed sector decarbonization pathways to offer SMEs generalised, sector-specific advice on how to decarbonize their operations. As of May 2023, pathways have been released for the aged care and retirement living, brewing, coffee, commercial buildings, and covered cropping sectors. EECA plans to release pathways for hotels and expanded polystyrene plastics in 2023.

An issue with developing energy transitions is the lack of reliable information on several important factors such as future energy prices, availability of biomass supply and electrical infrastructure capacity. EECA has attempted to improve the evidence base for transition planning by introducing the Regional Energy Transition Accelerator (RETA) programme. The programme undertakes an in-depth analysis on a regional basis with the aim to "develop and share a well-informed and coordinated approach for regional decarbonisation"[4]. Relevant stakeholders are included in the gathering of information and development of the document. As of June 2023 RETAs are available for the Southland[5] and Mid-south Canterbury[6] regions.

3.2 Government Investment in Decarbonising Industry

Another significant initiative is the Government Investment in Decarbonising Industry (GIDI) fund, initially established with a fund size of $79 million. The GIDI fund provides co-funding of up to 50% for projects that achieve substantial decarbonization of process heat. In May 2022, the fund was expanded to $650 million and became a contestable fund. The eligibility criteria were broadened to include projects facilitating process heat decarbonization (such as upgrading electricity infrastructure), installation of high-efficiency equipment (like electric motors and heat pumps), and space and water heating for commercial buildings. An analysis of the funded GIDI projects within the Auckland Council boundaries is presented below.

Overall, EECA's programs, including the ETA and the GIDI fund, aim to support businesses and organisations in their efforts to reduce emissions and increase energy efficiency. While the ETA program has primarily focused on larger entities, EECA's recognition of the challenges faced by SMEs has led to the development of sector-specific decarbonization pathways. The expansion of the GIDI fund has also provided additional opportunities for businesses to access funding for decarbonization projects. These initiatives demonstrate the government's commitment to promoting sustainability and decarbonization in various sectors of the New Zealand economy.

[4] https://www.eeca.govt.nz/co-funding/regional-decarbonisation/about-reta/
[5] https://www.eeca.govt.nz/co-funding/regional-decarbonisation/southland-regional-energy-transition-accelerator/
[6] https://www.eeca.govt.nz/co-funding/regional-decarbonisation/mid-south-canterbury-regional-energy-transition-accelerator/

3.3 Analysis of GIDI projects in Auckland

As of April 2023 there have been four rounds of GIDI funding with 66 projects being funded. Nine projects in the Auckland region from a total of 66 projects (14%) have received a total of $4.08 million out of a total of $79.54 million (5%) committed in those rounds.

In late May 2023 it was announced that New Zealand Steel Glenbrook would build a new $300 million electric arc furnace to replace the existing oxygen steelmaking furnace and two out of the four coal fuel kilns. The project is being part funded by GIDI fund up to $140 million. The emissions reduction is estimated to be around 800,000 $t_{CO_2\text{-}e}$ and the goal is to have the furnace operational by January 2027. The funding is conditional on the full feasibility study.

The $140 million funding is arranged in three parts[7]:

a) Base funding to support the installation of the electric arc furnace;
b) An additional payment of $10 million commissioning incentive if the furnace is commissioned by January 2027; and,
c) A bonus payment of an additional $20 million if another 800,000 $t_{CO_2\text{-}e}$ reductions over and above the baseline amount (800,000 $t_{CO_2\text{-}e}$) set out in the funding agreement.

The NZ Steel project demonstrates the current Government's commitment to supporting large scale emissions reductions. This one project has an estimated lifetime emissions reduction of over 16 million $t_{CO_2\text{-}e}$ and represents a 1% reduction in New Zealand gross emissions per year.

A list and details of the GIDI projects announced for the Auckland region are summarised in Table 2. A breakdown summary of the allocated funding by primary decarbonisation technology and sector is provided in Figure 2 (NZ Steel excluded). Horticulture (4 projects) received a large proportion of the funding ($1.74 million) reflecting a large horticulture industry in the region. Food and meat processing (3 projects) received $1.24 million. Efficiency and heat recovery projects received the most funding at $1.68 million for 4 projects followed by heat pumps with $1.3 million for 3 projects.

[7] https://www.thelawyermag.com/nz/news/general/bell-gully-backs-eeca-on-history-making-emissions-reduction-project/446719

The lifetime emission reductions per dollar of GIDI fund committed is about $ for the Auckland projects. The average $/t_{CO2-e}$ reduction is $10.66/$t_{CO2-e}$, whereas the national average is $15.31/$t_{CO2-e}$. The weighted average for rounds 1 - 4 of GIDI is $9.79/$t_{CO2-e}$. NZ Steel[8] is even lower with $7.56/$t_{CO2-e}$ with the overall reduction cost including the company's contribution being estimated at $16.20/$t_{CO2-e}$.

Note the actual reduction cost of the other GIDI projects is not known as the company's financial commitments have not been disclosed (although it needs to be at least 50% of the total project costs to qualify). Another important point to make is that these reduction costs per tonne of CO_2 are not the same and the marginal abatement cost (MAC) because it does not include the time value of money or changes in operational costs from the project. In some cases such as fuel switching, operational costs may actually be increased. The marginal abatement cost will likely be much higher than the reduction cost per tonne in Table 2.

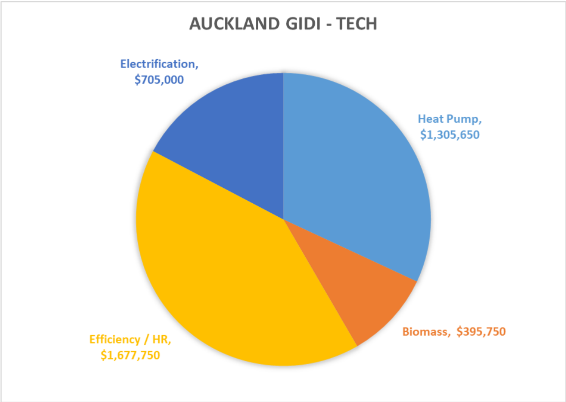
The reason for this greater "value for money" from Auckland projects could be due to a number of factors. These include:

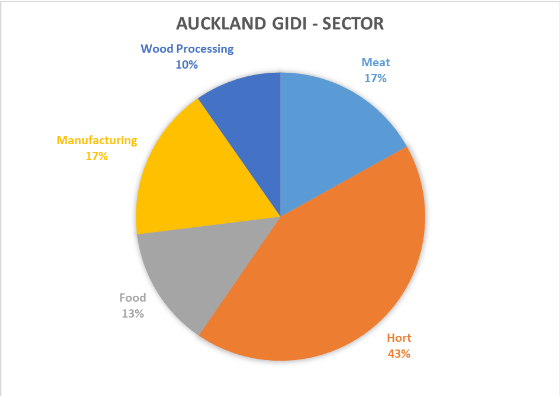
- The relatively small size of the projects (with the exception of NZ Steel). The average emissions reduction of projects in the Auckland region was 55 kt_{CO2-e} while the national average was 123 kt_{CO2-e}. The relationship between emissions reduction and GIDI funding is illustrated in Figure 3.
- The industry mix in Auckland is somewhat different than most other regions being focused on horticulture, manufacturing and food processing.
- Auckland based industries and/or sectors are less efficient allowing cost effective projects to be implemented providing emissions reduction at low cost.

[8] https://environment.govt.nz/news/government-partnership-with-nz-steel-set-to-unlock-massive-emissions-reductions/

Table 2. GIDI projects and funding committed to the Auckland region.

Company	Project Type	GIDI Funding	Lifetime Reductions [tCO2-e]	Sector	GIDI Round	GIDI Cost of Reduction [$/$t_{CO2-e}$]
Auckland Meat Processors	Heat Pump	$690,750	142,850	Meat	R3	$4.84
Gourmet Paprika	Efficiency / HR	$575,250	56,420	Hort	R3	$10.20
NZ Starch	Efficiency / HR	$150,000	16,075	Food	R1	$9.33
NZ Steel	Electrification	$140,000,000	18,518,638	Manufacturing	Special	$7.56
NZ Sugar	Heat Pump	$400,000	55,340	Food	R2	$7.23
Pacific Coilcoaters	Electrification	$705,000	71,825	Manufacturing	R2	$9.82
Papakura Timber	Biomass	$395,750	33,475	Wood Processing	R3	$11.82
Southern Paprika	Efficiency / HR	$330,000	26,680	Hort	R2	$12.37
Turners and Growers Fresh	Efficiency / HR	$622,500	37,950	Hort	R4	$16.40
Van Lier Nurseries	Heat Pump	$214,900	15,400	Hort	R2	$13.95





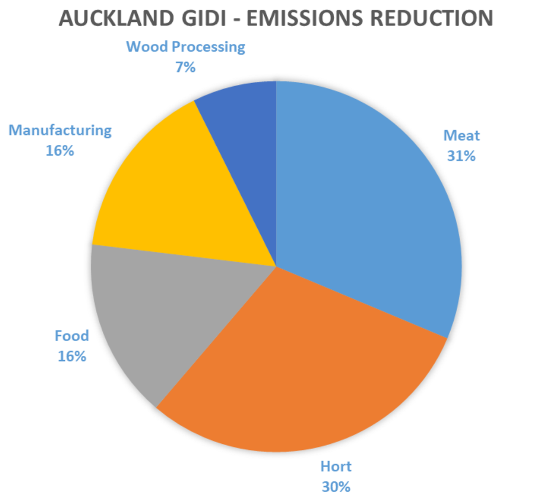


Figure 2. GIDI projects and funding committed to the Auckland region by technology and sector (NZ Steel excluded).

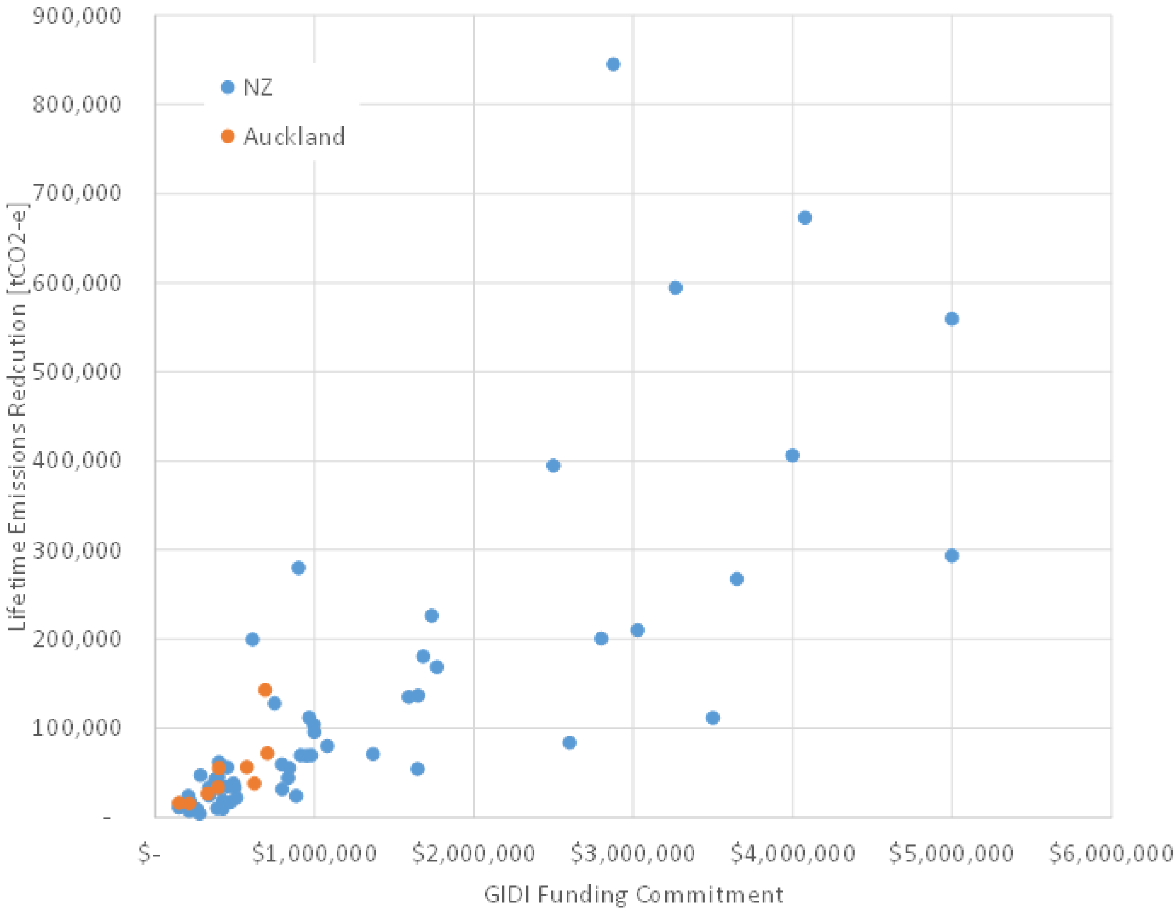


Figure 3. Relationship between emissions reduction and GIDI funding for individual projects.

There are some obstacles possibly preventing SMEs applying for GIDI funding for projects. The minimum project cost is $300,000 and GIDI funding will only provide up to 50% of the project. GIDI funding must be used toward the capital costs of the project and the project must be implemented and commissioned within 2 years of the application being approved. Depending on the SME, decarbonisation projects may not meet the minimum funding threshold, struggle to provide or finance the remaining capital cost, or get the project operational within the 2 year timeframe. GIDI fund requirements have changed significantly since the programme was first announced and it is possible the conditions could be modified or a complementary fund started to target SME decarbonisation.

3.4 Emission Trading Scheme

The Emissions Trading Scheme, ETS, is the country's longest standing tool for meeting international and domestic emission targets. The scheme was introduced in 2008 and now operates as a 'cap and trade' system, which places a price on greenhouse gas emissions to encourage their reduction.

Under the ETS, the government sets a cap on total emissions allowed within certain sectors. Businesses or entities that emit greenhouse gases as part of their operations are required to acquire and surrender emissions units, NZUs. Each unit represents one tonne of carbon dioxide (equivalent). Figure 4 presents the carbon price from the first quarter of 2010 till mid-2023.

Figure 4: Trend in the Emission Trading Scheme NZU price[9] since 2010. Each marker indicates the start of the year, 1 January.

The ETS has undergone several changes since it was first introduced. Many of these changes have had a significant impact on the price (Figure 4). For example, the

[9] Data retrieved from http://www.carbonnews.co.nz/ on a weekly basis.

‘crash’ in the carbon price in 2013 was the result of the market being flooded with international units that businesses in New Zealand were allowed to purchase and surrender at the time. The Government began making significant changes to the ETS in 2015 to address the issue of low carbon prices. These reforms were designed to increase the price of carbon and provide a better incentive for businesses to reduce emissions.

In 2016, the Government announced that businesses participating in the ETS could no longer use international carbon credits to offset their emissions. Another key change was the decision to phase out the 'one-for-two' obligation, which allowed some businesses to surrender one unit for every two tonnes of emissions, effectively halving the price of carbon for these businesses. The phase-out began in 2016 and was completed by 2019. As a result the price rebounded in 2016 and began to steadily increase.

There were several factors contributing to the sharp rise in carbon prices in 2021 resulting from additional changes to the scheme in the Climate Change Response (Emissions Trading Reform) Amendment Act[10] 2020. Here is a summary of key changes:

- **Cap on Emissions:** The cap limits the number of units that can be auctioned, which effectively puts a limit on the total emissions allowed within the scheme. This cap introduced more certainty about the environmental outcome of the ETS and contributed to upward pressure on prices.
- **Cost Containment Reserve:** The 2020 reforms also included the creation of a cost containment reserve. This allows additional units to be auctioned if prices exceed a certain level, replacing the fixed price option. The price level at which the reserve is triggered is initially set higher than the previous fixed price level, encouraging a rise in price.
- **Auctioning of Units:** The introduction of regular auctions of NZUs in 2021 provided a more transparent and predictable supply of units.

The combined effect of these changes likely fueled hedging of NZUs due to the uncertainty impact of the new rules. However, 2023 has seen a calming of the market as the price has fallen to levels that reflect a more steady increase.

[10] https://legislation.govt.nz/bill/government/2019/0186/latest/LMS143384.html

3.5 Climate Change Commission

To reduce the politics in the climate change debate, the Government established the Climate Change Commission under the Climate Change Response (Zero Carbon) Amendment Act[11] of 2019. The commission serves as an independent advisory body tasked with providing expert advice based on the latest science to the government on climate change mitigation and adaptation.

Key responsibilities of the Commission include:

1. **Setting Emissions Budgets:** The Commission advises the government on setting carbon budgets, which are legally binding caps on the amount of greenhouse gases that can be emitted over a five-year period.
2. **Climate Change Policy:** The Commission helps in developing and reviewing New Zealand's climate change policies. This includes providing advice on the country's Nationally Determined Contributions under the Paris Agreement.
3. **Progress Tracking:** The Commission monitors and reports on New Zealand's progress towards its emissions reduction targets and adaptation to climate change.
4. **Public Engagement:** The Commission is tasked with enhancing public understanding of climate change and the need for mitigation and adaptation efforts. They achieve this through regular communications and consultations.
5. **Risk Assessment:** The Commission also plays a role in preparing national climate change risk assessments, which help the country prepare and plan for the impacts of climate change.

Both the ETS and the commission play significant roles in the country's regulatory landscape around greenhouse gas emissions. The ETS has direct financial implications for SMEs. Understanding how the ETS works can help SMEs manage and potentially reduce these costs. The recommendations and advice given by the commission are expected to shape future climate policy. Keeping up to date with the work of the CCC can provide SMEs with valuable foresight for strategic planning and help them anticipate and prepare for changes in regulations. All of which can contribute to SME's long-term success and sustainability.

[11] https://environment.govt.nz/acts-and-regulations/acts/climate-change-response-amendment-act-2019/

4 Market-available decarbonisation solutions for process heat

Developing the most effective decarbonisation strategy for an SME often involves a combination of low- and net-zero-carbon heating technologies, tailored to the specific needs and circumstances of the SME. It's essential to thoroughly assess an SME's energy needs and resources before deciding on the best pathway forward. It is also important to note that innovations relating to these solutions continue to happen at an increasing pace.

This section presents key decarbonisation solutions with a description of each option and a discussion on market availability in New Zealand for SMEs.

4.1 Energy efficiency measures

Improving energy efficiency is often the most cost-effective way to reduce carbon emissions and can be applied across almost all types of SMEs. Energy efficiency measures are a broad category of practices and technologies aimed at reducing energy consumption, often without sacrificing the quality or quantity of services provided. They are typically the first step in any energy decarbonisation strategy, as they reduce the overall energy demand, which in turn decreases the need for energy production and the associated carbon emissions.

- **Energy metering:** Implementing an energy metering system allows businesses to accurately measure and monitor their energy consumption in real-time. This is invaluable for identifying areas of inefficiency, understanding peak demand periods, and tracking the impacts of any efficiency measures implemented. With this data, SMEs can make informed decisions about where and how to invest in energy efficiency measures and other decarbonisation solutions, maximising their return on investment and ensuring they're on the most cost-effective path to net-zero-carbon operations. In addition, metering can help businesses to identify maintenance needs early, potentially prolonging the life of their equipment and avoiding costly downtime.

- **Insulation:** Proper insulation of buildings, steam and hot water pipes, and refrigeration units and lines is a simple yet effective energy efficiency measure. It reduces the need for heating and cooling by preventing undesirable heat loss from process and utility fluids and from rooms, thereby reducing the energy consumption of boilers and HVAC (Heating, Ventilation, and Air Conditioning) systems. Materials like wool, fibreglass, or cellulose can be used to insulate walls, roofs, and floors. Insulation standards are often part of building codes and regulations, reflecting their importance in energy efficiency.

- **Efficient lighting:** Lighting can represent a significant portion of an SME's electricity consumption. Transitioning to energy-efficient lighting, such as LEDs (Light Emitting Diodes), can significantly reduce this. LEDs use a fraction of the energy of traditional incandescent bulbs and have a much longer lifespan, leading to both energy and cost savings.

- **Energy-efficient assets and technology:** Innovation in appliances, machinery and manufacturing equipment often result in lower energy consumption for a given production task and rate. Depending on the specific business, they can be large energy-consumers and incur significant cost. Some equipment are marked with energy performance labels against a set standard, while large manufacturing equipment will have detailed performance datasheets and information. This includes everything from office equipment like computers and printers to industrial machinery. For SMEs, upgrading to energy-efficient technology can lead to significant energy and cost savings over the lifespan of the equipment.

- **Energy management systems:** These systems can be a key energy efficiency measure that build on appropriate energy metering and recording. These systems monitor, control, and optimise the energy usage of a building or industrial process. They can identify energy waste, facilitate energy-efficient practices, and reduce peak demand charges. Common examples include Building Management Systems for optimal control of HVAC systems for the given season and application. Control of industrial processing unit operations and machines is significantly more challenging due to the nature of the materials that they handle and the types of operations (e.g., chemical reactions, separation that are done. Specialist process automation and control engineers are required. They can apply advanced methods, such as model predictive control, to ensure equipment runs at its best efficiency points as regularly as possible.

- **Heat recovery and waste heat:** Processing and manufacturing plants often require process and product flows to be heated and cooled. Operations that transform (chemically), separate, and refine are essential to producing high quality products and usually require particular processing temperatures. Heat recovery seeks to exchange heat from hot fluid that requires cooling to colder fluids that need heating. Ultimately, it reduces demand for both heating and cooling by utility. Additional low-grade and waste heat that cannot be reused with the site could be exported to a neighbouring industrial site or community (e.g., district heating, which is common in Europe).

While energy efficiency measures require upfront investment, they often pay for themselves over time through reduced energy costs. Simple payback periods of less than one year are common. Furthermore, improved energy efficiency can also improve productivity, increase asset value, and compliance with environmental regulations or standards.

As SME vary significantly, energy audits, including those under the ETA scheme, is an essential step to understand how these solutions apply to an individual site. EECA maintains an approved list[12] of engineering consultancies who are certified to carry out ETA reports. The present list is:

- Arup New Zealand Limited: www.arup.com
- Aurecon New Zealand Ltd: www.aurecongroup.com
- Beca Limited: www.beca.com
- DETA Consulting: www.deta.global
- Elemental Group Limited: www.elementalgroup.com
- Energy NZ Limited: www.energynz.com
- Ernst & Young Limited: www.ey.com/en/nz
- Lumen Limited: www.lumen.net
- Worley NZ Limited: www.worleyparsons.com

[12] https://www.eeca.govt.nz/co-funding/energy-transition-accelerator/

4.2 Heat pumps

Heat pumps (and refrigeration) are a highly efficient technology that can provide heating (and cooling, chilling or freezing) by extracting and transferring heat from one fluid to another. Heat pumps work on the same principle of the refrigeration cycle, where a refrigerant absorbs heat at a low temperature and releases it at a higher temperature. The efficiency, or performance, of heat pumps is often three to four times higher than conventional boilers, but they consume electricity, which is more expensive than fuels. Often the higher efficiency despite the higher priced energy source (electricity) results in operating cost reductions when transitioning from natural gas or coal. As the New Zealand electricity grid continues to increase the share of renewable energy, heat pumps are an essential decarbonisation technology. Finally, because they produce zero on-site emissions, they can play an important role in reducing the Scope 1 carbon footprint of SMEs.

4.2.1 Types of heat pumps

Heat pumps represent a versatile and efficient technology for decarbonising heat in SMEs. Their application spans from space heating (and cooling) to process heat and hot water generation. However, as discussed further in Section 5, their installation and operation require technical knowledge and expertise, and the initial investment and retrofit costs can be high.

- **HVAC units for direct space heating:** Heat pumps are widely used in Heating, Ventilation, and Air Conditioning (HVAC) units to provide space heating and cooling for buildings. These units can provide comfortable indoor temperatures year-round with high energy efficiency with coefficients of performance (COP) of up to 6. They are suitable for a wide range of SMEs, from offices and retail outlets to hospitality venues and light industrial buildings.
- **Commercial hot water heat pumps (40-60°C):** These heat pumps typically supply hot water in the 40-60°C range, which is typical for commercial applications like hospitality (hotels, restaurants), healthcare facilities (hospitals, nursing homes), swimming pools, and centralised space heating through radiators. They are usually air-sourced, meaning they extract heat from ambient air or from warm air from building exhaust vents to generate the hot water.

- **Industrial heat pumps (40-90°C):** Industrial heat pumps often use ammonia (NH_3) as the refrigerant and supply hot water for process heating in industries such as meat, dairy, food and beverage processing, and other sectors. Ammonia has excellent efficiency and heat transfer properties and a low global warming potential (GWP), but it is toxic and requires careful handling and safety measures. Recent technology advances have increased the maximum hot water supply temperature to around 90°C.

- **Transcritical CO_2 heat pumps (40-90°C):** These heat pumps use carbon dioxide (CO_2) as the refrigerant. They are highly efficient, achieve similar COPs as ammonia units, but are environmentally friendly, non-toxic, and have a low global warming potential. These units are particularly well suited to applications where freezing or refrigeration in addition to hot water is required.

4.2.2 Providers of market-available heat pumps

The landscape for commercial and industrial heat pump providers in New Zealand is vast and varied, ranging from local manufacturers to multi-international companies. They offer diverse mass-produced and customised solutions to suit specific needs, which can be particularly beneficial for SMEs seeking to decarbonise their process heat. These providers offer an array of innovative products, ranging from compact and convenient rooftop units to large, high-efficiency water-cooled package units. Many also offer remote monitoring and online diagnostic services, minimising downtime and ensuring optimal system performance. In the list below, several providers are summarised.

- **Temperzone[13]:** This Auckland-based manufacturer offers various air conditioning, hot water heat pump, and ventilation equipment. Rooftop packaged units are compact and convenient, requiring less space while still delivering efficient cooling. Water cooled package units are excellent for large commercial buildings, offering superior efficiency and longevity. They also provide split ducted systems, and variable refrigerant flow systems, which provide superior flexibility and individual room control.

[13] https://www.temperzone.com/

- **Excel Refrigeration[14]:** Specialising in commercial and industrial refrigeration systems, Excel has expertise in serving a variety of industries like dairy, cold storage, food, wine and meat. Their custom-made solutions cater to unique requirements. Maintenance and performance contracts ensure system longevity, while remote monitoring and online diagnosis allow for swift and efficient problem resolution. Express spares delivery helps minimise downtime in the event of a failure.

- **Active Refrigeration[15]:** With a focus on sustainable industrial and commercial refrigeration system solutions, Active Refrigeration also provides air conditioning, comfort cooling and heating services. They are involved in all stages of a project from sales to design and project management. They also offer services and system analysis to ensure the equipment is functioning at peak efficiency. With offices all across New Zealand, they have a wide reach and can service a broad range of clients.

- **Daikin NZ Commercial[16]:** Known globally for their state-of-the-art air conditioning technology, Daikin offers a diverse range of solutions. Their Variable Refrigerant Volume (VRV) systems are efficient and flexible, ideal for large buildings where individual temperature control in different areas is required. They also offer ducted systems, which can heat or cool the entire building through vents installed in the roof or floor. Packaged systems are compact and efficient, best suited to smaller commercial spaces. For more flexibility, split systems allow for control of heating and cooling in individual rooms. Daikin's proprietary and open protocol control systems provide smart control of the HVAC system, while their innovative hydronic systems use water to transport heat, making it an efficient and environmentally friendly option.

- **Fujitsu General[17]:** This company provides a variety of options for both residential and commercial uses. Their Airstage VRF systems are designed for large buildings, offering superior energy efficiency and the ability to control the temperature in individual rooms. Light commercial ducted, split and multi

[14] https://excel.co.nz/
[15] https://www.activerefrigeration.co.nz/
[16] https://commercial.daikin.co.nz/
[17] https://www.fujitsugeneral.co.nz/commercial-products

systems are also available, offering a good range of options depending on the size and requirements of the space.

- **Varcoe[18]:** As a specialist dealer for Panasonic, Varcoe provides commercial heat pumps which are well-known for their lower operational cost and eco-friendly energy efficiency. Their products featuring inverter technology help save energy by varying the compressor speed, while still maintaining desired temperatures. These systems also promote environmental comfort by ensuring consistent temperature control.

- **Mitsubishi Heavy Industries[19]:** The Q-ton heat pump is a product of Mitsubishi Heavy Industries (MHI), a Japanese multinational company. The Q-ton is a highly efficient, air to water heat pump specifically designed for commercial use and can deliver hot water (30kW) up to 90°C. It makes use of CO_2 refrigerant, which has a lower environmental impact than many traditional refrigerants. The Q-ton is particularly suited to businesses with high hot water demand such as hotels, hospitals, apartment buildings, and large commercial kitchens.

- **Aquarian[20]:** This provider designs and makes a range of general purpose hot water heat pumps with cylinders (170 - 275 litres). The heat pump range supplies a maximum of 4 kW of heating with output temperatures of 55-60°C.

- **Hot Water Heat Pumps Ltd[21]:** Provider of a full range of commercial-scale heat pumps (6 - 60 kW) supplying temperatures between -10°C (refrigeration) to 45°C (hot water) for a variety of applications including residential, commercial (e.g., hotels, restaurants, and gyms), swimming pools, aquaculture facilities, underfloor heating, and commercial chilled water.

- **Mitsubishi Electric[22]:** With a range of products with commercial and swimming pool applications, this provider has modular products that can be banked together to deliver higher duties. Three of the main product series are: the QAHV CO_2 air-sourced hot water heat pump (40 kW, up to 90°C hot water from as low as -25°C ambient temperature), CRHV water-sourced hot water heat pump (60 kW, up to 65°C hot water from as low as -25°C ambient

[18] https://varcoe.co.nz/heat-pumps/commercial-heat-pumps/
[19] https://mhiheatpumps.co.nz/q-ton-high-efficiency-hot-water-solution/
[20] www.aquarian.co.nz
[21] www.waterheating.co.nz
[22] www.mitsubishi-electric.co.nz

temperature), and the Zubadan CAHV air-sourced hot water heat pump (45 kW, up to 70°C hot water from as low as -20°C ambient temperature).

4.3 Electricity to hot water and steam

4.3.1 Electric hot water systems

Electric hot water systems, also known as electric water heaters, are widely used to provide hot water in various applications, ranging from domestic to commercial and industrial settings. These systems use electricity to heat water directly.

The main advantage of electric hot water systems is their simplicity. They are relatively easy to install, operate, and maintain, and they do not require a flue or venting system like combustion-based systems. They also have a smaller footprint than many other systems, making them a good choice for SMEs with limited space. However, because they are less energy-efficient than heat pump systems, the operating costs are significantly higher.

There are several companies in New Zealand that manufacture or provide electric hot water solutions. Here are three common providers:

- **Rheem New Zealand[23]:** A major provider of water heaters in New Zealand, offering a variety of electric water heating systems.
- **Rinnai New Zealand[24]:** They provide a range of electric hot water cylinders and heat pump water heaters.
- **Peter Cocks[25]:** A New Zealand-based manufacturer of hot water cylinders, including electric models.
- **Electro-Steam[26]:** Based in the US, they produce a wide range of commercial-scale electric steam boilers. The maximum pressure is typically 7 bar(g) with heating outputs up to 240 kW for a single unit.

[23] www.rheem.co.nz
[24] www.rinnai.co.nz
[25] www.petercocks.co.nz
[26] www.electrosteam.com

- **Danstoker[27]:** Located in Denmark, they produce a variety of electric boilers, with capacity ranging from 400 to 5,500 kW and up to 13 bar(g).

4.3.2 Electrode boiler systems

Electrode boilers use electricity to heat water and generate steam or hot water for industrial and commercial applications. There are two primary types of electrode boilers: direct and indirect. Direct electrode boilers heat the water directly by passing an electric current through it, while indirect electrode boilers heat a separate water loop using an immersed heating element. Both types offer excellent efficiency, typically greater than 98%, as nearly all of the electrical energy consumed is converted into heat.

Electrode boilers have several notable advantages. They have no direct emissions and can be turned on and off rapidly, providing excellent load-following capabilities. This makes them particularly suitable for applications that require a flexible, responsive heat source. In addition, they are compact, quiet, and require less maintenance than combustion-based boilers. Like electric hot water heaters, their operating costs are much higher than a heat pump if the output temperatures are below 90°C but the investment cost is low compared to a heat pump.

Here are some manufacturers and suppliers of electrode boilers both in New Zealand and internationally:

- **Windsor Energy[28]:** Napier based supplier of Elpanneteknik electric and electrode boilers for producing hot water and steam. Elpanneteknik is a Swedish manufacturer of high and low pressure (up to approx. 100 bar(g) electrode boilers available at low voltages (400 - 690 V) up to 6 MW or high voltage (6 - 14 kV) from 4 to 80 MW. Hot water boilers between 1 to 80 MW. They have supplied several electrode boilers in New Zealand.

- **Energy Plant Solutions[29]**: A Palmerston North based supplier of electrode boilers and electric resistant steam and hot water boilers. Electrode boilers range from 4 - 60 MW up to pressures of 41.5 bar(g). Resistive element boilers

[27] www.danstoker.com
[28] www.windsorenergy.co.nz
[29] www.energyplantsolutions.co.nz

range from 1 - 3 MW. They have supplied several electrode boilers in New Zealand.

- **Advance Boiler Services NZ Ltd[30]:** Based in Hamilton, they offer a range of boiler types, including electric boilers for producing hot water and steam. The boilers originate from Denmark (Fulton), ranging from 12 to 2000 kW with pressures up to 13 bar(g).
- **Precision Boilers[31]:** US-based manufacturer that provides a variety of high-efficiency boilers, including both electric and electrode boilers. Electric boilers come as steam (Model ST - up to 14 bar(g) and 15 to 4,000 kW) and high pressure steam (Model STH - up to 172 bar(g) and 15 to 1,800 kw). Electrode boilers are of the high voltage jet electrode type (Model HVJ) with capacities from 800-50,000 kW and pressures up to 35 bar(g).
- **Parat Halvorsen AS[32]:** This Norwegian company manufactures high voltage electrode boilers for steam and hot water (Model IEH - up to 85 bar(g) and 75,000 kW) and low voltage electric element boilers (Model IEL - up to 18 bar(g) and 5,500 kW). They also make all-in-one hybrid gas-electric boilers that could be an effective transition solution with an appropriate demand-response approach.
- **Vapec AG[33]:** A Swiss company that specialises in the design and manufacturing of high voltage electrode boilers. The output of their units range from 1000 to 90,000 kW and up to 24 bar(g).
- **Acme Engineering Products[34]:** Canadian-based company that offers electric and electrode boilers among its range of products. The electric boilers (Serie C-620) span from 6 to 3,600 kW with steam pressures up to 9 bar(g). The electrode boilers, on the other hand, have ratings from 2,000 to 65,000 kW and steam pressures up to 34 bar(g).

There are no doubt many more manufacturers of electric and electrode boilers for steam and/or hot water production. Additional information is available via each of the manufacturers' websites. As demonstrated in the market analysis, the technology

[30] www.absboiler.co.nz
[31] www.precisionboilers.com
[32] www.parat.no
[33] www.vapec.ch/en/
[34] www.acmeprod.com

is well-established with capacities available across a very wide range of kilowatt values.

4.3.3 Demand-response opportunities

Electric or electrode boilers have the potential to play a significant role in demand response strategies due to their fast response times and controllable operation. In New Zealand, Simply Energy[35] (a subsidiary of Contact Energy) offers a flexible operation contract where they control when the boiler is turned on and off to act as a demand response mechanism for the national grid.

Demand response is a method used by Transpower (and others) to balance energy supply and demand by incentivising consumers to reduce their electricity consumption during peak periods or when the supply of electricity is constrained. This could be due to a high demand for electricity, limitations in the transmission network, or low generation capacity.

Electric or electrode boilers can respond very quickly to signals from the grid operator to either increase or decrease their electricity consumption. When there is excess generation capacity (for example, when there is high wind or solar generation), these boilers can be ramped up quickly to convert this surplus electricity into heat. This heat can then be stored for later use or used immediately, depending on the needs of the facility.

Conversely, during periods of high demand or low generation capacity, the operation of these boilers can be scaled back or temporarily shut down to reduce the load on the electricity grid. This can be done without impacting the operation of the facility if there is sufficient heat stored from previous operations or alternative sources of heat available.

This flexible operation makes electric and electrode boilers valuable assets for grid operators looking to maintain the stability of the electricity grid and integrate higher levels of variable renewable energy. It also allows businesses to potentially benefit from lower electricity costs by shifting their electricity consumption to periods of lower demand or lower prices.

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35 www.simplyenergy.co.nz

4.4 Biomass boilers

Biomass boilers use organic material - typically plant or wood waste - to generate heat. This heat can be used to produce steam or hot water for commercial or industrial scale uses. If the forest source is managed sustainably, the process is considered to be carbon-neutral because the CO_2 released during combustion is equivalent to the CO_2 absorbed by the plant during its growth.

Biomass boilers can be an effective solution for decarbonising process heat, particularly in situations where there is a readily available source of biomass. Primary wood processing produces a significant amount of "waste" wood. This waste, e.g. sawdust, chip and hog fuel, can be delivered directly to a consumer to generate process heat or the wood can be dried and processed further into small white pallets, which have a calorific value similar to poor-quality coal.

4.4.1 Sourcing biomass and challenges facing implementation

Biomass boilers are capable of providing a steady, reliable source of heat and can be used in a wide range of applications. However, the price and availability of biomass can also be a limiting factor. Table 2 summarises some of the estimated potential biomass resources for the Auckland region. The values are gross energy (e.g. 100% recovery of the resource) and do not account for the recovery efficiency, which can be less than 50%. For example, the recovery rate of in-forest residues is dependent on the type of residue, terrain and the like. Some of these resources are already utilised. The wood processing industry typically uses their own residues for energy.

There are significant volumes of municipal wood waste in the Auckland region; however, the vast majority of this waste is utilised by Golden Bay Cement in Northland. Furthermore, the make-up municipal waste wood makes it unsuitable for use in typical biomass boilers due to the timber treatments used.

Table 2: Estimated biomass sources for the Auckland region[36].

	Gross Energy [GJ/y]					
	2021 - 2025	2026 - 2030	2031 - 2035	2036 - 2040	2041 - 2045	2046 - 2050
All in-forest residues	1,238,866	1,083,812	700,810	434,023	565,412	753,812
Horticulture & Viticulture residues	60,492	61,702	62,936	64,195	65,478	66,788
Municipal Wood Waste	721,296	816,875	925,119	1,047,706	1,186,538	1,343,767
Port Bark ex Auckland	11,390	12,529	13,099	11,960	11,390	11,390
Port Bark ex Whangarei	283,074	311,381	325,535	297,227	283,074	283,074
Shelter Belts	26,220	26,220	26,220	26,220	26,220	26,220
Softwood Chip Export ex Whangarei	2,139,000	2,139,000	2,139,000	2,139,000	2,139,000	2,139,000
Staw and Stover	151,531	154,561	157,652	160,805	164,021	167,302
Wood processing Residues (After incumbent use)	123,220	123,220	123,220	123,220	123,220	123,220

Additional challenges facing biomass use as a net-zero-carbon fuel for SMEs in Auckland include:

- **Transportation:** Solid fuels like biomass require transportation to the site, typically utilising road networks, in contrast to natural gas which is distributed through pipelines. However, biomass fuels have a significantly lower energy density compared to gas and most coal used for process heat. Consequently, a greater number of truck movements is necessary to deliver an equivalent amount of fuel when compared to coal. The widespread use of biomass as a renewable fuel in the Auckland region, particularly within the city, would have significant impacts on the roading network. Impacts include increased congestion, noise, and dust.
- **Air quality standards:** Similar to the combustion of coal, biomass combustion also generates particulate emissions. To address and minimise these emissions, the implementation of emissions control technologies becomes necessary. Although these are now well-established technologies, it is important to note that integrating such technologies into boilers incurs additional costs. Moreover, these emissions control measures must comply with regulatory requirements, further emphasising the need for careful

[36] Updated data from personal communication from Hall, P. based on Hall, P. (2021) Residual biomass fuel projections for New Zealand 2021, SCION.

adherence to environmental standards and guidelines. By adopting appropriate emissions control technologies and meeting regulatory obligations, the impact of particulate emissions from biomass combustion can be effectively managed.

- **Fuel storage:** The amount of storage depends on the boiler rating, its loading and frequency of use. For continuous operation, substantial storage space is necessary to accommodate the fuel. This need for on-site or near-site storage may pose a hurdle for SMEs, particularly those situated in urban areas where space is at a premium. The issue extends beyond just the physical area needed for storage. It involves considerations regarding fuel accessibility, transportation, and handling, as well as safety and compliance with local building codes and regulations.

4.4.2 Market-available options

Biomass Fuel Suppliers

There are several biomass fuel suppliers operating in New Zealand, although the area of operation and scale varies substantially. Below are a list of major suppliers operating nationally or in regions that could supply Auckland.

- **Azwood Energy[37]:** Nelson headquartered supplier of wood fuels. Azwood supplies nationwide and has a wood pellet manufacturing facility in Nelson. They also source and supply hog fuel and wood chip.
- **Natures Flame[38]:** A Taupo based manufacturing of wood pellets. They supply nationwide and supply to commercial and several large industrial sites.
- **Wood Energy New Zealand[39]:** A partnership between Pioneer Energy Ltd and Niagara Sawmilling Company Ltd. They operate nationwide and supply hog fuel, wood chip, and wood pellets. Pioneer Energy owns and operates the Washdyke Energy Centre that supplies the Timaru Heavy Industrial park with steam using 100% biomass. They also own and operate the Ecogas Reporoa biogas facility that utilises organic waste from Auckland to generate biogas.

[37] www.azwood.co.nz
[38] www.naturesflame.co.nz
[39] www.pioneerenergy.co.nz

Biomass Steam and Hot Water Boilers

- **Windsor Energy[40]:** Napier based boiler manufacturer including a wide range of biomass boiler options. They offer new boilers as well as boiler conversions to biomass fuel. They carried out the boiler conversion for Fonterra Te Awamutu which converted the coal boiler to wood pellets. They have supplied numerous biomass boilers in New Zealand and Australia.
- **Polytechnik Biomass Energy[41]:** An Austrian based company operating in New Zealand for over 10 years. They offer a range of wood/biomass fuelled steam and hot water boilers ranging from 300 kW up to 30,000 kW. They have over 50 years experience in manufacturing biomass boilers and have over 3,000 installations worldwide, including 10 boilers in New Zealand.
- **Energy Plant Solutions[42]**: A Palmerston North based supplier of biomass fired hot water, steam and thermal oil boilers. They have partnered with Polytechnik Biomass Energy but it is unclear if they are the sole supplier of their boilers as Polytechnik has a dedicated representative in New Zealand.
- **Advance Boiler Services NZ Ltd[43]:** Based in Hamilton, they offer a range of boiler types, including biomass boilers fromJustsen Energiteknik (Danish).

4.5 Additional and specialised decarbonisation technologies

This section explores three additional technologies that can support the transition to net-zero-carbon energy. Thermal storage technologies offer a means for SMEs to manage and store excess heat, providing a cost-effective energy optimisation solution. They are commonly integrated with heat pumps, electricity heating and biomass boilers to match energy generation and demand. Electrification technologies in processing and manufacturing plants provide an alternative, more direct pathway to switch to renewable energy. These technologies tend to be highly specific to the application, requiring expert advice to identify, design and implement such solutions. On-site renewable electricity systems, ranging from solar PV to

[40] www.windsorenergy.co.nz
[41] www.biomass.polytechnik.com/en/
[42] www.energyplantsolutions.co.nz
[43] www.absboiler.co.nz

micro-hydro systems, are the final pathway discussed. Once again, these technologies require specific analysis of the resources available. Space is often a significant challenge with significant renewable energy generation, which means at best on-site generation is likely a partial solution.

4.5.1 Thermal storage technologies

Thermal storage technologies complement heat pump, electric heaters, and boiler solutions for the decarbonisation of process heat in SMEs. These systems store heat in a variety of media, such as water for temperatures below 100°C or oil and molten salt for higher temperatures, and release it when needed. This allows for greater flexibility and smaller and cheaper primary heat generation units, enabling businesses to generate heat during off-peak hours when electricity is cheaper, or continuously at a lower flow rate, and store it for use during peak demand periods.

For SMEs, the choice of thermal storage technology will depend on their specific needs and circumstances. Factors to consider include the amount of heat required, the duration of storage, the available space for storage equipment, and the cost of the storage system. Despite their potential benefits, thermal storage technologies also have some challenges. The initial investment can be high, and the system needs to be correctly sized and designed to meet the specific heat demand effectively. These systems typically require regular maintenance to maintain very low heat loss and ensure their longevity.

4.5.2 Process and manufacturing electrification technologies

Replacing gas appliances and systems with electric alternatives can reduce emissions, especially if the electricity is sourced from renewables. The impact will depend on the extent of gas usage within the SME.

Process and manufacturing electrification technologies refer to the use of electricity to power industrial processes, replacing traditional fossil fuel-based systems. These technologies are increasingly considered as crucial components in the effort to achieve net-zero-carbon emissions in the manufacturing sector.

One key area of focus is the electrification of heat. Industrial heat pumps, electric boilers, and electrode boilers can provide high-temperature heat for various industrial processes. These technologies can be powered by renewable electricity, making them a low-carbon solution for process heat. For instance, heat pumps can transfer heat from a low-temperature source to a high-temperature one, providing heat for processes that require temperatures up to 160°C. Electric and electrode boilers can generate steam or hot water for use in a wide range of industrial applications.

In addition to heat, electricity can also power other industrial processes. For example, electric arc furnaces are used in the steel industry to melt scrap steel, reducing the need for coal or gas. Electrically-driven compressors can replace gas-driven ones in industries such as chemical and petrochemical manufacturing.

However, electrification also poses challenges. The high demand for electricity can strain the power grid, especially during peak demand periods. Additionally, the cost of electricity, particularly in regions where it's not predominantly sourced from renewables, can be a deterrent.

Despite these challenges, the benefits of process and manufacturing electrification technologies are significant. They can dramatically reduce greenhouse gas emissions, improve energy efficiency, and reduce dependence on fossil fuels. In addition, as the cost of renewable electricity continues to fall, these technologies will become increasingly cost-competitive.

Government support, in the form of incentives, grants, or low-interest loans, can help SMEs overcome the initial cost barrier associated with these technologies. Furthermore, the use of demand response strategies and energy storage can help manage the increased electricity demand.

4.5.3 On-site renewable electricity systems

On-site renewable energy systems refer to the generation of energy from renewable resources at the location where it will be used, rather than relying on the national grid. Small-scale renewable electricity source in New Zealand include:

- **Solar photovoltaic (PV) systems:** These systems convert sunlight directly into electricity using photovoltaic cells. They can be installed on roofs or ground-mounted and can provide a significant portion of a business's electricity needs, depending on the size of the installation and the availability of sunlight.

- **Wind turbines:** For locations with sufficient wind resources, small wind turbines can be a practical solution for generating electricity on-site. However, factors such as noise, visual impact, and potential interference with bird migration need to be considered.
- **Micro-hydro systems:** For sites with access to flowing water, small-scale hydroelectric systems can provide a consistent source of renewable energy.

On-site renewable energy systems can offer numerous benefits, including reducing energy costs, providing a hedge against future energy price increases, and improving environmental sustainability by reducing greenhouse gas emissions.

However, the feasibility of on-site renewable energy systems can depend on a variety of factors, including the local climate and weather patterns, the availability of space, and local regulations. Upfront costs can also be a barrier, although various financial incentives and schemes can help to offset these costs.

5 Barriers to uptake

The barriers to SMEs in New Zealand converting to net-zero-carbon energy sources and technologies for process heating and cooling can vary depending on the specific industry, location, and other factors. However, there are common barriers that SMEs in NZ face under the two categories of technical and non-technical barriers. Previous work undertaken by EECA[44] and the Climate Change Commission[45] have discussed specific technical and non-technical barriers to process heat decarbonisation.

5.1 Technical barriers

5.1.1 Limited in-house technical expertise

Small and medium-sized enterprises (SMEs) typically face several challenges that contribute to their limited technical expertise in energy decarbonisation. One of the primary factors is resource constraints. Unlike larger corporations, SMEs operate with a smaller workforce and limited financial resources. This situation restricts their ability to employ dedicated full-time technical specialists outside of their core-business.

The rapid innovation, development and inherent complexity of many decarbonisation pathways present another challenge. Without a solid technical foundation or access to technical expertise, these technologies can be perceived as risky. This lack of expertise makes it challenging for these companies to assess the feasibility of different technologies for their specific situation, to understand the potential lifecycle energy and cost savings, and to manage the transition process cost-effectively.

Engineering consultants can compensate for the lack of in-house expertise. However, consultants are also relatively expensive when capital project costs are often much less than $1 million.

[44] https://www.eeca.govt.nz/assets/EECA-Resources/Research-papers-guides/Accelerating-the-decarbonisation-of-Process-Heat.pdf
[45] https://www.climatecommission.govt.nz/public/Advice-to-govt-docs/ERP2/draft-erp2/DETA-Non-cost-decarbonisation-barriers-for-process-heat.pdf

Solution/recommendation: Investigate creating sector-based energy decarbonisation consortiums with shared access to technical expertise to lower the overall cost to individual businesses. SMEs are often willing to collaborate with each other in areas which are viewed as not-core-business. A consortium could facilitate the sharing of case studies and examples. Government agencies, such as EECA, may also be willing to co-fund the shared-expertise through their current mechanisms.

5.1.2 Compatibility with existing infrastructure and space

Buildings and existing infrastructure were often designed to accommodate specific energy supply technologies and distribution networks. Net-zero-carbon energy technologies are often incompatible with existing infrastructure. For instance, a factory set up to run on a natural gas boiler may not have the necessary electrical supply capacity from the local network to support electric heat pumps or electric boilers. Furthermore, an existing steam distribution network supplied by a natural gas boiler would not carry the same heating capacity if supplied by hot water from a heat pump. As a result, many energy-decarbonisation technologies require a complete overhaul of the existing infrastructure, which can be costly and disruptive to business operations.

In addition to the infrastructure challenges, space is another key consideration. For instance, biomass boilers are much bulkier than natural gas boilers. They also require space for fuel storage. Similarly, solar panels need ample space on rooftops or grounds to be effective. Modifying or expanding buildings to increase space for these different technologies involves considerable costs and consents, which can further complicate the transition process.

Electric heating technologies are often a key to decarbonising SMEs with space constraints while biomass boilers tend to be favourable where space is less of an issue.

Solution/recommendation: As a first step, it is essential to understand the capacity of existing grid and distribution infrastructure to deliver electricity to a particular site. SMEs can engage the relevant electricity distribution business, either Vector or Counties Energy in Auckland, or, in the unique case of NZ Steel in Glenbrook, Transpower.

To enable electrification of heat, the Government, Electricity Authority, Transpower and electricity distribution businesses (EDBs) need to co-design strategies to drive modernisation of the electricity grid and distribution networks. Public investment in greater electricity supply capacity would unlock the use of renewable electricity and enable businesses to decarbonise.

5.1.3 Maintenance, reliability and upkeep

Net-zero-carbon energy technologies often require specialised skills and knowledge for routine maintenance and troubleshooting, which can be beyond the in-house technical expertise of SMEs. Although fossil fuel boilers also require regular maintenance, a change in technology may also mean a change in maintenance service provider, which is another uncertainty.

Reliability is another key concern. While net-zero-carbon technologies are rapidly evolving, some of these technologies have not been extensively tested under various real-world conditions. As such, their long-term performance and reliability can be uncertain. SMEs that operate under tight margins cannot afford extended downtime or frequent repairs. The perceived risk of adopting a technology with unproven reliability can deter SMEs from making the transition to net-zero-carbon energy technologies.

Some net-zero-carbon technologies, such as solar panels, are subject to variations in environmental conditions, and their performance can be influenced by factors such as weather patterns and daylight hours. This variability can affect the reliability of the energy supply and require backup systems or supplementary energy sources, further adding to the complexity and cost.

Solution/recommendation: SMEs should consider Energy-as-a-Service (EaaS) providers. The EaaS model is an innovative business approach that offers customers a variety of energy services without the need to make large upfront capital investments. Under this model, customers pay for the service provided (e.g., heating and/or cooling) rather than the equipment itself. The provider handles all aspects of the system, including its installation, operation, maintenance, and upgrades, allowing the business to focus on its core operations. The EaaS model aligns the interests of the service provider and the customer. Because the provider's revenue is often tied to the performance of the energy services, they have a strong incentive to ensure that the systems are as efficient, low-carbon and reliable as possible.

5.1.4 Electrical Infrastructure

The increasing electrification of process heating and transport presents significant challenges and opportunities for electricity transmission and distribution infrastructure. As more industries and transportation sectors shift from fossil fuels to electricity, the existing infrastructure must be adequately upgraded and expanded to meet the growing demand, ensure system reliability, and accommodate the unique requirements of these new loads. There are several key changes and upgrades needed in electricity transmission and distribution infrastructure to support the increased electrification of process heating and transport.

1. **Transmission Infrastructure:**

   a. *Capacity Expansion:* The electrification of process heating and transport will lead to a substantial increase in electricity demand. Upgrading transmission infrastructure capacity is crucial to accommodate the higher load and prevent congestion or overloading. This includes increasing the capacity of transmission lines, transformers, and substations.

   b. *Grid Resilience:* The increased electrification may lead to changes in power flow patterns and load profiles, requiring grid resilience enhancements. Implementing advanced monitoring and control systems, dynamic line rating technologies, and grid energy storage can help manage the fluctuating demand and ensure grid stability and reliability.

   c. *Interconnection:* Strengthening interconnections between different regions and neighbouring countries can support the exchange of surplus electricity, enable access to renewable energy sources, and enhance the overall reliability of the transmission system.

2. **Distribution Infrastructure:**

   a. *Load Management:* The electrification of process heating and transport will introduce significant new loads to the distribution system. Implementing load management techniques such as demand-response programs, time-of-use pricing, and smart grid technologies can help balance the load and optimise the distribution system's performance.

b. *Distribution Automation:* Upgrading distribution infrastructure with automation technologies, such as advanced metering infrastructure, distribution management systems, and self-healing networks, can improve system efficiency, fault detection, and response times.

c. *Distribution Network Reinforcement:* As the electrification of process heating and transport increases, localised distribution networks may require reinforcement to handle the additional load. This could involve upgrading distribution lines, transformers, and equipment to ensure proper voltage regulation and minimise losses.

3. **Grid Integration and Flexibility:**

a. *Renewable Energy Integration:* The increased electrification presents an opportunity to integrate more renewable energy sources into the grid. Upgrading the transmission and distribution infrastructure to accommodate decentralised generation, such as solar PV and wind farms, is necessary to enable the seamless integration of these intermittent energy sources.

b. *Energy Storage:* Deploying energy storage systems, such as batteries and pumped hydro storage, can address the intermittency of renewable energy sources and provide grid stability, demand response capabilities, and peak load management.

c. *Smart Grid Technologies:* Implementing smart grid technologies, including advanced metering, sensors, and communication systems, enables better monitoring and control of the grid. This facilitates real-time data collection, grid optimization, and enables efficient demand-side management.

4. **Planning and Regulatory Framework:**

a. *Long-Term Planning:* Comprehensive long-term planning is essential to identify transmission and distribution infrastructure requirements, forecast load growth, and optimise the network design to support increased electrification.

b. *Grid Codes and Standards:* Developing or updating grid codes and standards to reflect the requirements of electrification, such as load profiles, power quality, and grid integration of renewable energy sources, ensures that the infrastructure is designed, operated, and maintained to meet the evolving needs.

c. *Regulatory Support:* Regulatory frameworks should incentivize investment in infrastructure upgrades, provide appropriate tariff structures, and encourage innovative solutions such as distributed energy resources and demand-side management.

5.2 Non-technical barriers

5.2.1 Financial constraints

The upfront costs associated with the installation of new equipment and technologies and retrofitting existing infrastructure can be substantial, as mentioned. These investments are often additional because the new technology is replacing fossil fuel powered assets that have useful life remaining. Additionally, the costs of identifying and evaluating potential net-zero-carbon technologies can also be significant. SMEs may not have the expertise in-house to conduct this analysis, and hiring external consultants can be expensive.

Compounding this issue is SMEs may struggle to secure good terms for financing these investments due to the project falling outside their core business with no direct return through a traditional bottom-line. Overcoming this barrier will require innovative financial solutions tailored to the needs and circumstances of SMEs.

Solution/recommendation: One concept is green investment funds that could support the decarbonisation efforts of SMEs. These funds could provide low-interest loans or grants for projects that contribute to the transition to net-zero-carbon energy. In 2018, the Government established the New Zealand Green Investment Finance Ltd (NZGIF) with the goal of accelerating and facilitating investment in emissions reductions in New Zealand. This includes leveraging private investment to grow the pool of capital. However, NZGIF is focused on investments of greater than $10 million. This minimum investment figure essentially rules out investment in most SME decarbonisation projects.

Existing schemes administered by EECA, which have been mentioned in Section 2, are also worth reiterating. The GIDI mechanism provides direct support to decarbonisation projects, including the recent funding awarded to NZ Steel for a new electric arc furnace. The ETA mechanism cofunds energy audits with the specific goal of transitioning to low and zero-carbon energy.

5.2.2 Limited access to information

Many SMEs may not have access to information about the available options for net-zero-carbon energy sources, making it difficult for them to make informed decisions. Given the rapid evolution of energy technologies, keeping abreast of the latest developments, understanding the potential benefits, and making informed decisions can be challenging for SMEs.

This challenge is compounded by the lack of technical expertise, time and resources to devote to finding up-to-update information. Without access to comprehensive, accurate, and up-to-date information about available technologies, potential suppliers and existing use cases, SMEs may be reluctant to make the necessary investments in decarbonisation.

Solution/recommendation: One potential solution could be the establishment of a sector-based consortium focused on decarbonisation. This consortium could provide a platform for SMEs to share information and experiences, collaborate on common challenges, and access expert advice and support. It could also develop and disseminate resources on net-zero-carbon energy technologies, suppliers, and financial incentives, helping SMEs to make informed decisions about decarbonisation.

The consortium could also play a role in advocating for the interests of SMEs, for example, by lobbying for favourable policy measures or financial incentives. By working together through a sector-based consortium, SMEs could overcome the information barrier and accelerate their transition to net-zero-carbon energy sources.

5.2.3 People, business-as-usual culture and resistance to change

The cultural fabric of an organisation significantly influences its acceptance of new ideas, and this is particularly true for smaller businesses where decision-making processes are often less formal and more influenced by the owner's or manager's personal attitudes and beliefs.

Traditional energy sources like oil, gas, and coal have been the backbone of many industries for decades. The familiarity and reliability associated with these energy sources, along with a well-established supply chain and their own existing infrastructure, present a significant barrier to change. The switch to net-zero-carbon energy sources, in comparison, can be seen as risky, given the unknown factors related to the technology's reliability, cost-effectiveness, and potential disruption to business operations.

Solution/recommendation: One potential solution could be to implement comprehensive education and awareness programmes. Such programmes could focus on the benefits of transitioning to net-zero-carbon energy sources, including cost savings over the long term, improved resilience, positive environmental impacts and a triple-bottom-line based definition and metric. By highlighting the benefits and addressing the concerns associated with the transition, these programmes could help to shift attitudes and overcome resistance to change.

These programmes could be facilitated through sector based consortiums. For example, workshops, webinars, site visits, and case studies could be shared to showcase successful transitions to net-zero-carbon energy technology by similar businesses. By making the benefits of the transition tangible and relatable, such programmes can play a vital role in overcoming the culture and resistance to change barriers.

6 Policy intervention

The government is using a carrot-and-stick approach to drive the transition to net-zero-carbon and renewable energy. Figure 5 expresses the roles of both government and industry investment to drive innovation in the transition.

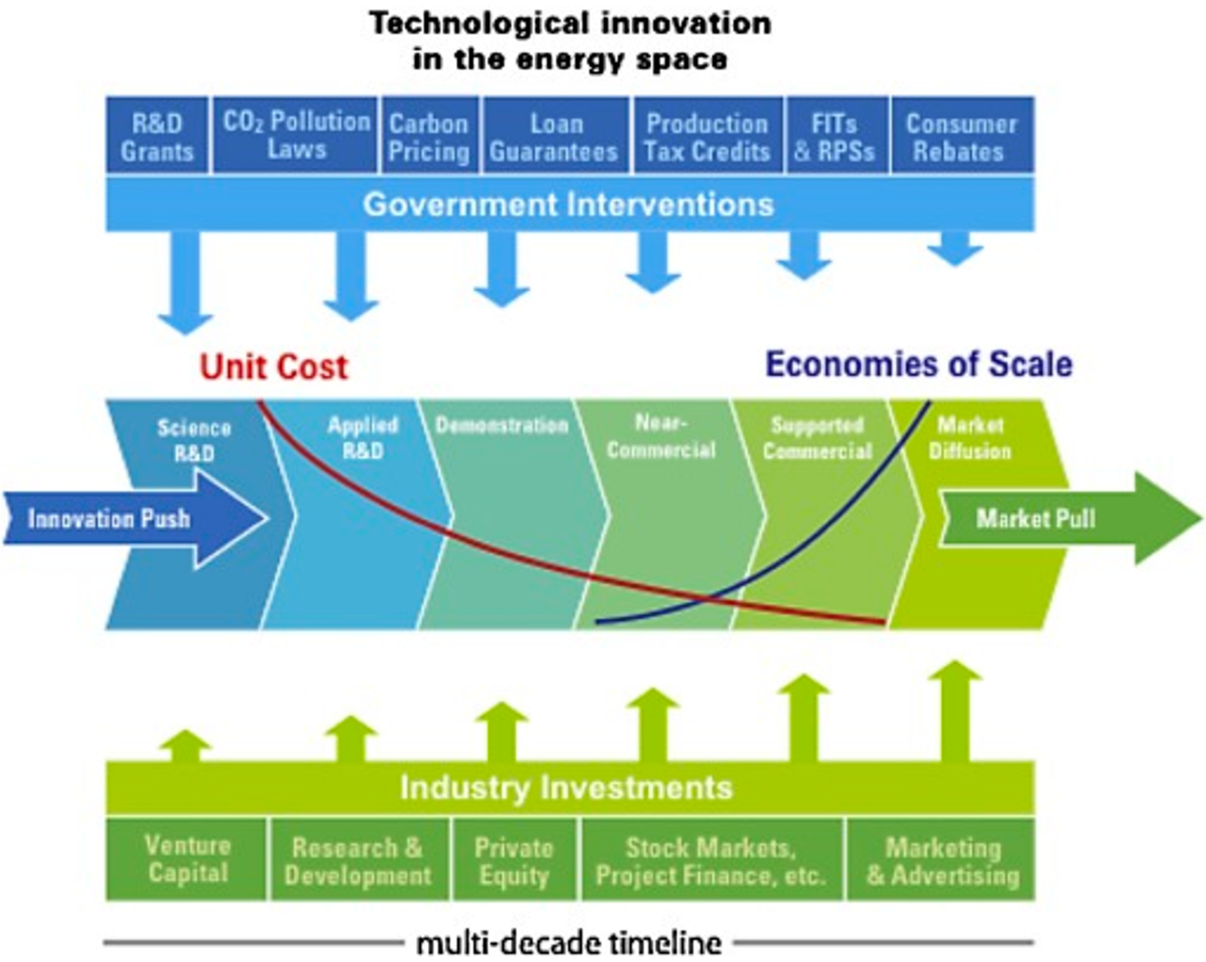

Figure 5. The innovation chain for energy technology and solutions[46].

There are several policy interventions that the government and public entities have already implemented to encourage SMEs to transition to net-zero-carbon energy sources sooner.

[46] Adapted from: Bromley, P.S., 2016. Extraordinary interventions: Toward a framework for rapid transition and deep emission reductions in the energy space. Energy research & social science, 22, pp.165-171. https://doi.org/10.1016/j.erss.2016.08.018

1. **Financial incentives:** Providing financial incentives such as grants, tax credits, or low-interest loans can help SMEs offset the costs of transitioning to net-zero-carbon energy sources. At present, the ETA and GIDI fund (see Section 3) both provide financial co-investment of public funds to support industry's energy transition.

2. **Regulation:** The government has introduced regulations that require SMEs to transition away from coal boilers[47] for low and medium temperature heat applications (<300°C) while new off-shore natural gas exploration permits have ceased being issued[48].

3. **Technical assistance:** Providing technical assistance to SMEs can help them navigate the technical and implementation barriers associated with transitioning to net-zero-carbon energy sources. Indirectly, the ETA programme provides an opportunity for experts to assess and formulate an emission reduction plan.

4. **Capacity building:** Providing education and training to SMEs can help build their capacity to understand and implement net-zero-carbon energy sources.

5. **Standards and certification:** Developing standards and certification schemes for net-zero-carbon energy sources can help SMEs identify quality products and services, and build consumer confidence.

6. **Information and outreach:** Developing targeted information and outreach campaigns can help raise awareness among SMEs about the benefits of transitioning to net-zero-carbon energy sources and the available resources to support them.

7. **Collaborative networks:** Establishing collaborative networks between SMEs, suppliers, and other stakeholders can help promote knowledge sharing and best practices, and create opportunities for joint investments and partnerships.

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

[48] https://www.beehive.govt.nz/release/planning-future-no-new-offshore-oil-and-gas-exploration-permits

These policy interventions can help address the financial, information, technical, and implementation barriers that SMEs face and accelerate the transition to net-zero-carbon energy. The first three interventions have existing programmes that use these avenues. The final four intervention mechanisms are areas where new programmes could be developed.

7 Conclusion

The outlook for decarbonising process heat for Small and Medium Enterprises (SMEs) in Auckland is positive despite the challenges. The government has shown a willingness to provide financial co-investment in emission reduction studies and technology implementations. SMEs are significant contributors to the Auckland economy, and there is a need to keep them in business while transitioning to net-zero-carbon energy. The extraordinary capital investment in new technology brings benefits to SMEs, Auckland and the nation.

The four critical pathways to net-zero-carbon energy are energy efficiency initiatives, heat pumps, electric and electrode boilers, and biomass boilers. Energy efficiency is a critical step that starts with accurate metering and understanding before moving to identify ways to improve the efficiency of buildings, processes and manufacturing plants. Minimising energy demand also means new heat pumps or boilers can have smaller capacities and lower investment costs.

This report has outlined several barriers to decarbonisation, such as initial costs, lack of knowledge, and technology limitations. However, with supportive policy measures, strong government leadership, and collaborative efforts, these challenges can be overcome.