The Machine Count

Building an actionable pathway to an electrified zero-emission energy system for Aotearoa New Zealand

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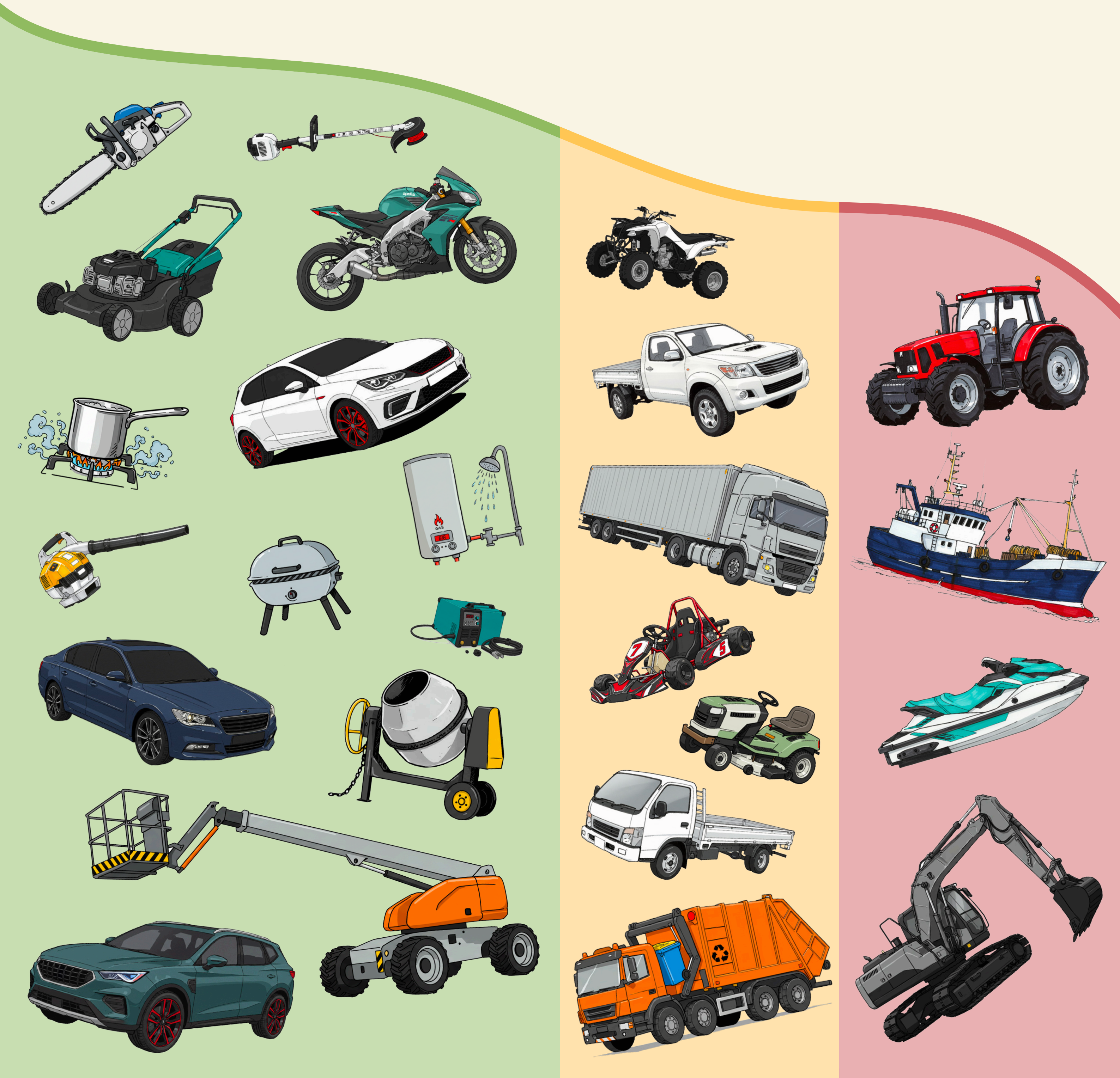
Rewiring Aotearoa

Ara Ake
Future Energy Development



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About Rewiring Aotearoa

Rewiring Aotearoa is an independent non-partisan non-profit. It is a registered charity working on energy, climate, and electrification research; advocacy; and supporting communities through the energy transition. The team consists of energy, climate, policy, data, and community outreach experts.

Acknowledgements

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We also thank all of the homeowners, businesses, farmers, industry professionals, and energy sector experts who took the time to participate in this research and to share their decades of real-world experience with us.

Executive Summary

The Machine Count project is the first known count of fossil fuel machines in New Zealand. It also identifies the technical and economic feasibility of electrifying each type of machine, and the corresponding emissions impact. It aims to be a key building block for an actionable and realistic pathway to decarbonising New Zealand's energy economy. This executive summary provides an overview of the purpose of the project, our findings, and our recommendations.

Why count machines?

The majority of New Zealand's energy emissions and the vast majority of the world's total greenhouse gas emissions come from fossil fuels burned in machines.[1] These range from coal and gas power plants, to diesel buses, petrol cars, and gas water heaters. Replacing most[2] of these machines with electric alternatives and running them on renewable electricity is the most impactful, realistic pathway to achieve a sustainable economy in time to prevent the worst impacts of climate change. Understanding the machines that make up our emissions is foundational to an actionable pathway to zero emissions. It enables us to prioritise action, bridges the gap between emissions reduction targets and on the ground progress, and informs us on what is needed to accelerate progress.

Once purchased, a machine is often in use for 10 to 20 years. This means at purchase, fossil fuel machines "commit" a forward 10 to 20 years of emissions if they are to live out their operational lifetimes. Therefore, these purchase decisions are key to unlocking effective emissions reduction. Shifting purchases from fossil fuel to electric machines is the most viable and realistic way to permanently reduce emissions. Doing this requires us not only to understand emissions and energy flows, but to understand the machines that ultimately underpin them.

By counting machines, this project provides new perspectives on where and what type of energy innovation is needed to accelerate decarbonisation. It shows that we need much more focus on practical deployment innovation to make electric machine purchases easier for homes and businesses. This is because the majority of fossil fuel machines in New Zealand can already be technically and economically replaced with electric zero-emission alternatives while saving money over their lifetime, yet they are not being replaced at sufficient pace and scale today. The deployment innovations needed to unlock rapid decarbonisation through electrification includes accessible finance products that swap fossil fuel bills for finance repayments. This bridges the gap between the large operational savings of electric machines and their often higher upfront costs. It also includes educational innovation, to support the average busy home or business to be aware of the lowest cost and lowest emission options available to them – which are likely to be electric. It also includes measures to make the purchase and installation of electric machines a simple process. Partnered with finance options, this would enable New Zealanders to make electric purchase decisions that can save them money from day one, and cost much less over their operational lifetime than a fossil fuel machine.

How many machines?

Our research estimates that there are approximately 10.2 million fossil fuel machines in New Zealand that make up most of our energy emissions.

- 99.6% or 10.17 million are technically feasible to electrify.
- 94% or 9.6 million are both technically and economically feasible to replace at end of life.[3]
- 84% or 8.5 million are both technically and economically feasible to electrify, and have electric alternatives readily available in New Zealand ("ready to electrify").

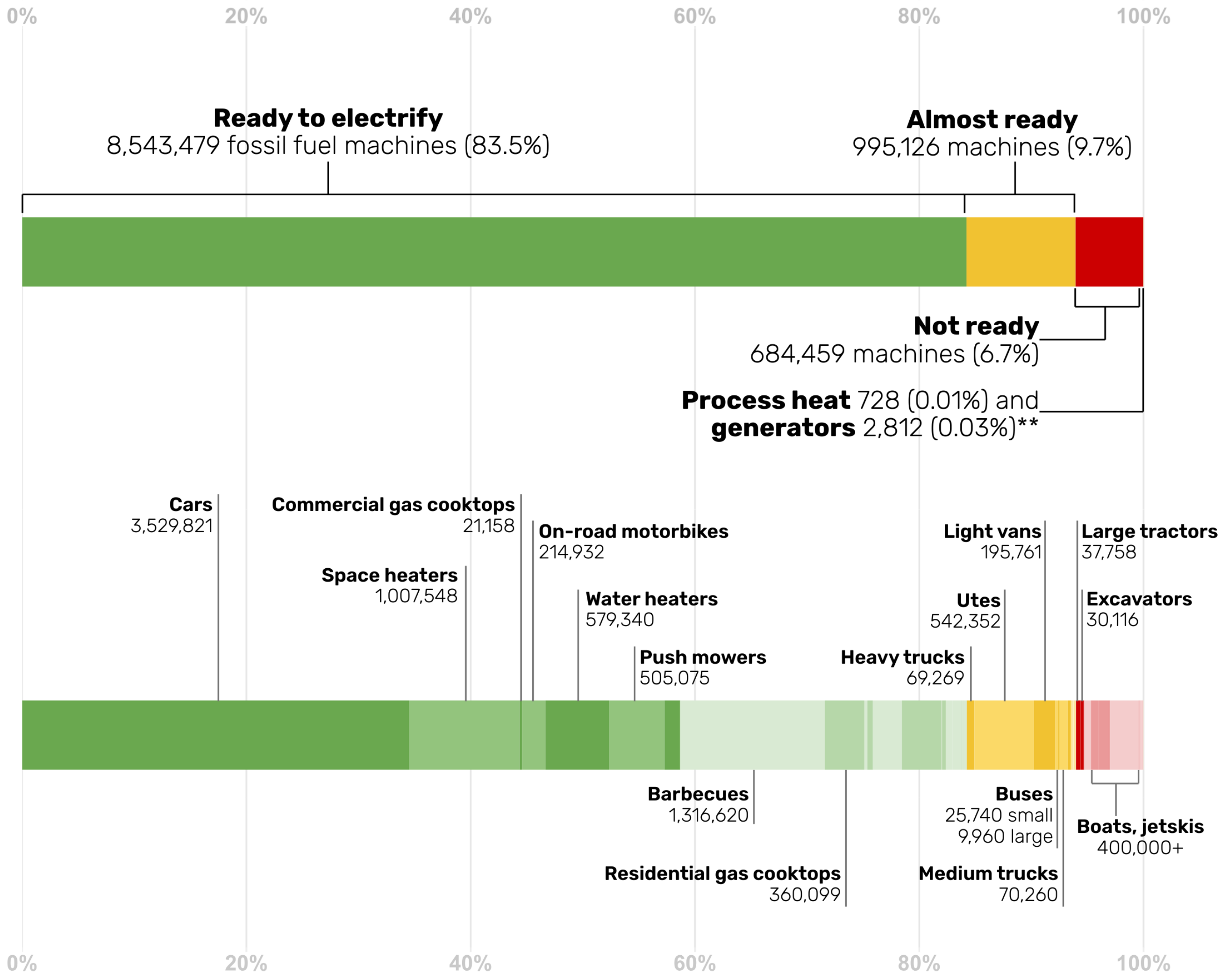
The technical and economic feasibility evaluations for all machine types can be found in the publicly available machine count database,[4] including links to electric alternatives for many of the machines.[5] This feasibility can be summarised into three broad electrifiability categories:[6]

1 https://ourworldindata.org/ghg-emissions-by-sector
2 It should be acknowledged that in some cases there are non-electric, zero emission machine alternatives suitable to niche areas of the economy. However, the vast majority of all fossil fuel machines are likely to be replaced by electric alternatives. As such, we refer to "electrification" throughout most of this report.
3 We have not quantified how many would be economical to replace before their end of life; this is expanded in Section 8 Future work.
4 Click through on the link or see Section 9 Supporting Documents. Full details are on the "Electrifiability" sheet.
5 Go to the "Machine Count" sheet for links to electric alternatives for each machine type, or the "Electric products" sheet for the full list.
6 The full list of the machines and their electrifiability can be found in Summary Table 2 in Section 10.

- **Ready (to electrify) (84%):** Fossil fuel machines where mainstream electric alternatives are cost competitive or cheaper over their lifetime and already available for purchase in New Zealand (e.g. space heaters, water heaters, small and medium cars).
- **Almost ready (10%):** Economically viable electric alternatives are available overseas, but have limited availability in New Zealand which could likely be solved with targeted initiatives (e.g. utes, trucks, vans, buses).
- **Not ready (6%):** Technical or economic barriers exist for these machines. Further research and development may be needed, or the electric alternatives have higher costs than fossil fuel options over their lifetime (e.g. planes, large mining trucks, excavators, cargo ships).

The majority of fossil fuel machines are ready to electrify today

Count of machines sorted by emissions impact*



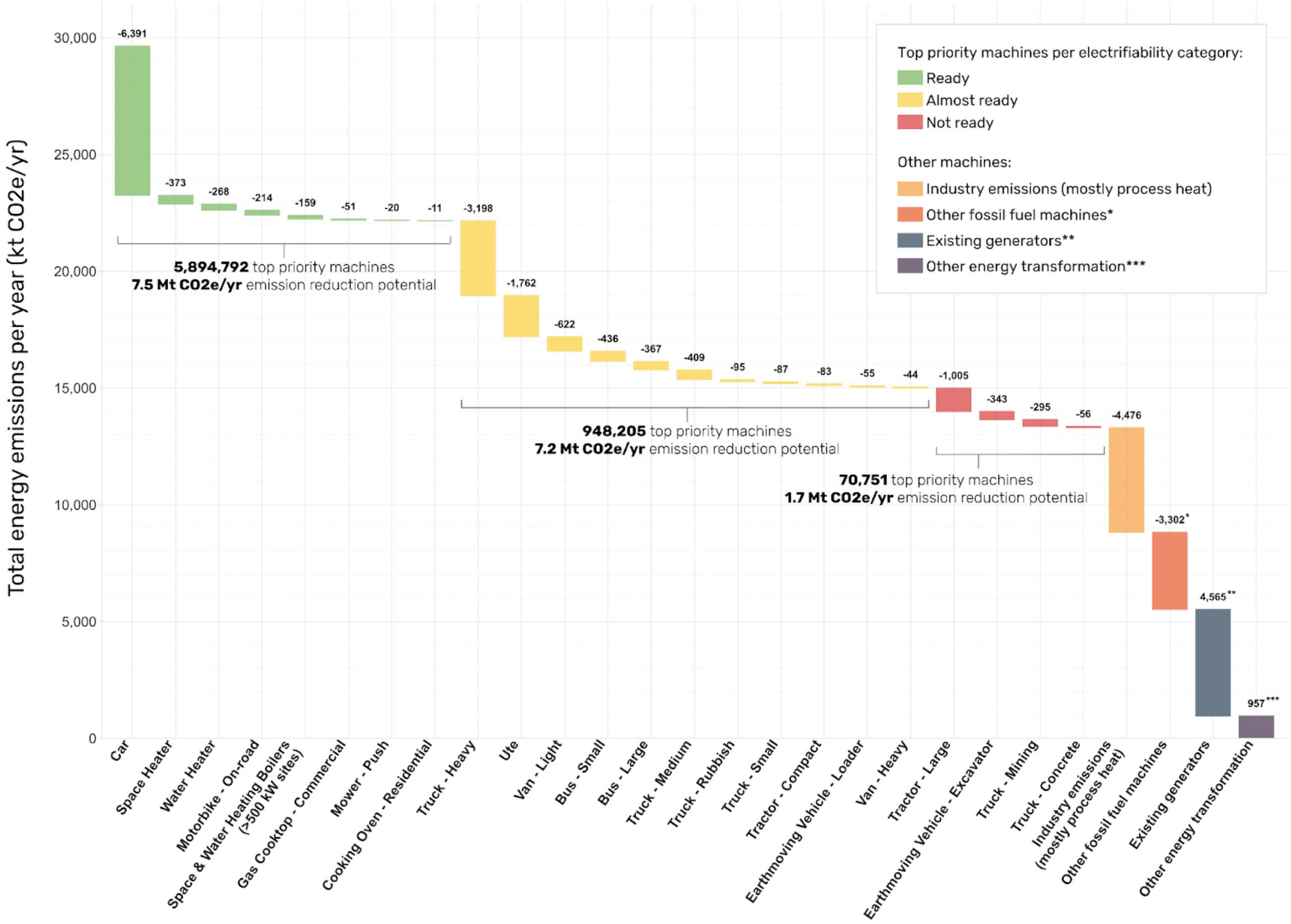
Darker colours indicate priority machines in each electrifiability category based on emissions impact.
*Machines with low counts have been moved to the end of each category for better visibility of alternating larger machine segments.
**While these makes up a small proportion of the total *number* of machines, they are a significant proportion of our total emissions.

What is the emissions impact?

Within each electrifiability category, we ranked the estimated nationwide emissions impact of each machine type and highlighted the top-ranking types. We then calculated the emissions of this subset to create the following emissions reduction pathway chart below. It shows all the energy emissions used across the New Zealand economy, including:

- Top priority machines per electrifiability category: The green, yellow, and red bars show potential emissions reduction from avoided fossil fuel use, through the electrification of the top machine types for each electrifiability category. For example, electrifying all the cars in the country (which are green, as they are part of the "Ready to electrify" category) would reduce emissions by 6.4 Mt per year. Electrifying the top 8 machine types out of 31 in the "Ready" category would reduce emissions by 7.5 Mt per year. Electrifying all of the top 23 machine types out of 95 across all three categories would reduce energy emissions by 16.4 Mt, 55% of New Zealand's estimated energy emissions in 2024.
- Industry emissions due to fossil energy use in industrial sectors.[7] This is mostly fuel use to generate process heat that is used in manufacturing.
- Other fossil fuel machines are emissions from all other machines which are not in industrial use, and did not make the top priority lists of each electrifiability category when ranked by emissions impact.
- Existing generators which are the energy emissions from burning fossil fuels to generate electricity, based on 2024 energy data.
- Other energy transformation includes coal use by NZ Steel; and losses & own use associated with coal and oil provision based on 2024 energy data. Emissions from natural gas transmission and distribution losses, and natural gas production losses and own use, are spread across the emissions reduction associated with the gas use included in the above four categories.

Energy emissions reduction potential from machine electrification



Showing emissions for top priority machines from each category - ready, almost ready, not ready to electrify. Losses from natural gas, own use, distribution, and transmission are included in machine emissions.
*Emissions from remaining fossil fuel machines that are not the top priority subsets from the "ready", "almost ready", and "not ready" categories. Many of these machines are also ready to be electrified, but their potential emissions savings have not been calculated to manage scope.
**Emissions from electricity generation from existing generators. Increasing renewable generation with a combination of hydro, solar, wind, and batteries can help reduce these emissions.
***Emissions from other transformation, including production losses and own use from oil and coal.

7 Excluding agriculture, forestry and fishing, building and construction and mining, which are incorporated into machine categories.

What are the machines?

Ready to electrify (84%, approx. 8.5 million machines)

The majority of fossil fuel machines – around 8.5 million – are ready to be electrified both technically and economically. They are opportunities for rapid emissions reduction at negative abatement cost – they will save New Zealanders money for every tonne of carbon reduced. We estimate that electrifying 6 million priority machines in this category would save approximately $3.7 billion in operating costs and reduce emissions by 7.5 million tonnes of CO_2e every year.[8] These priority machines are:

- Small & medium cars (3.5 million vehicles)
- Space heating systems (999,000 heaters, 455 boilers)
- Water heating systems (566,000 heaters, 64 boilers)
- Push mowers (505,000)
- Motorbikes (215,000)
- Cooking equipment (specifically commercial gas cooktops, and residential and commercial cooking ovens)

Our recommendations for this category is to prioritise a significant programme of deployment innovation to address upfront cost barriers and to make choosing an electric machine easy for all New Zealanders. This will require education to build national awareness that emission reduction is a cost-saving opportunity.

Almost ready (10%, approx. 995,000 machines)

These are still opportunities for rapid emission reduction with no technical barriers. Electrifying 950,000 priority machines out of the 990,000 in this category would save approximately $2.4 billion annually in operational costs and reduce emissions by 7.2 million tonnes of CO_2e per year. These top priority machines are:

- Trucks (69,000 heavy; 68,000 medium; 26,000 small)
- Light commercial vehicles (540,000 utes; 195,000 light vans; 10,500 heavy vans)
- Buses (17,000 small; 9,800 large)
- Small tractors (6,000), loaders (6,800), and rubbish collection trucks (930)

Our recommendations for this category are to:
- Apply similar deployment innovations as for “Ready” machines
- Additionally, accelerate import channels and domestic supply chains for these machine types
- Work on deployment demonstrations to seed the market

Not ready (6%, approx. 684,000 machines)

These machines currently face technical or economic barriers to electrification. However, the market is changing rapidly for many of these, with alternatives already economically viable and near market, or commercially available but not yet cost competitive over their lifetime. They are still important areas for investment, especially to future-proof industries that rely on these machines. Electrifying 71,000 priority machines in this category out of the 684,000 would save approximately $370 million annually and reduce emissions by 1.7 million tonnes of CO_2e per year. Top priority machines are:[9]

- Mining trucks (2,600)
- Large tractors (37,000)
- Excavators (30,000)
- Concrete trucks (990)

8 Prioritised based on their emissions impact ranking as described in the previous section. This was to prioritise the subset of machine types for which we would calculate opex and emissions. Detailed energy use data was not available for all machine types, and some estimates were made. See the “Top Machines Energy Economics” sheet in the Database for full details.

9 We only analysed the machines with the highest emissions rankings, but these were not the most numerous machines in this category. Others include specialised agricultural equipment (e.g. sprayers, harvesters, frost fans, heavy forestry equipment); water transport (ocean-going vessels, jet boats, ferries, larger motorboats); planes and helicopters; and specialised industrial equipment.

Our recommendations for this category are to:

- Expand demonstration pathways for emerging technologies to reduce financial risk of early adoption.
- Prepare infrastructure and policy frameworks in advance of technological advancement, including charging infrastructure and workforce training.
- Fund research and development for electric alternatives, particularly in areas aligned with New Zealand's economic strengths such as specialised agricultural machinery, marine vessels, small planes, and specialised industrial equipment.
- Balance strategic investment in these harder-to-electrify machines with prioritising resources for the 94% of machines in the “Ready” and "Almost ready" categories which already have viable electric alternatives. This approach ensures significant near-term and cumulative emissions reductions.

Process heat & generators

There are approximately 755[10] process heat machines, including boilers and burners, across large manufacturing sites in Aotearoa.[11] This heat used in industrial and manufacturing processes make up the bulk of industrial emissions, approximately 15% - 16% of energy emissions in 2024.[12] The technical and economical feasibility of decarbonising large process heat sites varies by site and temperature requirements. Solutions may include either biomass or electrification.[13] In the case of generators, renewable electricity generation and batteries can replace fossil fuel generators in many situations, with 2,812 generators identified nationwide.[14] [15]

10 This figure is slightly higher than shown elsewhere in the report as it also includes industrial ovens and large grain dryers, which are separated out in other sections.

11 This excludes over 500 space and water heating boilers from large sites with over 500 kW thermal capacity, which we assume are part of the “Ready” category as they can be replaced with heat pumps. This also excludes process heat boilers on sites with less than 500 kW thermal capacity (see Appendix 1, Section 7.3.8).

12 https://www.eeca.govt.nz/insights/eeca-insights/accelerating-the-decarbonisation-of-process-heat. This has decreased from previous years, in part due to declining natural gas supplies limiting industrial gas use.

13 EECA is conducting site-by-site analysis through its Regional Energy Transition Accelerator project to determine optimal decarbonisation pathways for process heat. See Section 6.4 for more information.

14 Excludes backup generators due to lack of comprehensive data.

15 See Summary Table 6 in Section 10 for more information.

Sector Insights

Residential

Households can save money while helping the climate
Electrifying machines is an economic opportunity for most New Zealanders. Households could save thousands annually by switching to electric vehicles, heat pumps, heat pump water heaters, and electric cooktops. Rooftop solar further reduces costs. Higher energy users such as people who drive longer distances or high occupancy households have the most to gain financially from electrification, but even modest energy users can benefit.

The residential sector can be fully electrified now
This is the largest emitting sector after agricultural methane. It is also the cheapest and easiest sector to reach zero emissions, because all household fossil fuel machines are ready to be electrified today. This sector could completely decarbonise in a few short years, if there is the policy ambition to make it happen.

Electric should be the easy default
Households need streamlined processes that make choosing electric alternatives the default when replacing fossil fuel appliances. This should require minimal research or paperwork; the information should be readily available for all demographics. This includes the busy parents, the young renters, and the retirees; not just the early adopters and DIY enthusiasts. For households that can not afford the upfront cost of upgrades, accessible finance is required. All New Zealand households, including renters, should have easy options for electrifying these basic household machines, because this one-time decision permanently secures long-term cost savings, emission reductions, and energy system benefits.

Businesses & Institutions

Learning from real-world electrification journeys
The electrification opportunities and challenges in the business & institutions sector are almost as diverse as the organisations themselves. However, a large proportion of them have similar machines and energy economics to the residential sector, with heaters, cooking appliances, and light vehicles. We provide case studies in Section 6.3 and Appendix 2 as real-world examples of electrification journeys, to help other similar organisations learn from these experiences. For example, one of the main barriers for small businesses appears to be machine and building ownership; many small businesses lease their building, appliances sometimes included. Small businesses therefore have less decision-making power for electrifying machines or installing rooftop solar. Making the case for lifetime costs during procurement or renovation is crucial for an accurate business case on electrification. Businesses may also benefit from electrifying in stages, trialling and leasing one electric machine first before electrifying others.

Be prepared for technology progress
From efficient heat pumps designed for our conditions, to electric trucks with impressive range, to electric loaders that can fully charge in 80 minutes for an 8-hour shift, many zero-emission solutions already exist and are improving rapidly. For the machines that require further development, both history and recent trajectories show that progress happens rapidly – which means our infrastructure, processes, and policies should be prepared to take advantage of these upcoming technologies.

Agricultural

Farm electrification delivers significant cost savings
Electrifying farming operations can replace diesel and petrol costs with electricity from our highly renewable grid or on-site solar generation. This unlocks significant lifetime cost savings, especially when paired with solar.

Mixed bag of easy wins and technology challenges
There are significant opportunities in some areas where suitable electric alternatives to on-farm machines are readily available and worth the cost. In others, appropriate electric machines are not yet available in New Zealand or require further technical development. The "lowest-hanging fruits" include pumps, mowers, tractors, ATVs/UTVs, trucks, forklifts, and handheld tools like chainsaws and line trimmers. Utes are another major opportunity for cost and emission savings, but there are limited fully electric options available so far in New Zealand. High horsepower tractors (120 hp and above) and specialised forestry equipment are awaiting further development of electric alternatives.

Electric machines have added operational benefits
Electric machines tend to have lower maintenance costs, reduced noise and vibrations, and no fumes. They can also achieve better performance than their horsepower ratings due to the instant torque of electric motors.

Industrial

Industrial sector decarbonisation requires focus at an individual site level, especially for high-temperature processes
As Aotearoa New Zealand's largest user of coal and natural gas, the industrial sector presents significant technical challenges. It is also perhaps the most thoroughly investigated area of opportunities for decarbonisation. Solutions exist for process heat below 100°C (heat pumps) and between 100-300°C (electrode boilers), but technologies for higher temperatures are still developing. Large energy users like steel, methanol, fertiliser and cement producers need unique decarbonisation pathways requiring both innovation and supportive policies.

Key recommendation: Refocus innovation on process & finance

While decarbonising large machines like planes, heavy industrial vehicles, and ships remain important challenges for the long term, this project demonstrates that the millions of common household machines that can deliver rapid and significant energy emissions reduction while saving money. This means New Zealand has a competitive advantage: we can develop a world leading deployment innovation program that supports homes and businesses to unlock the benefits of electrifying these "low-hanging fruit". If done well and at scale, this will reduce energy bills and save New Zealand billions in imported fossil fuels while ensuring existing emissions targets are met.

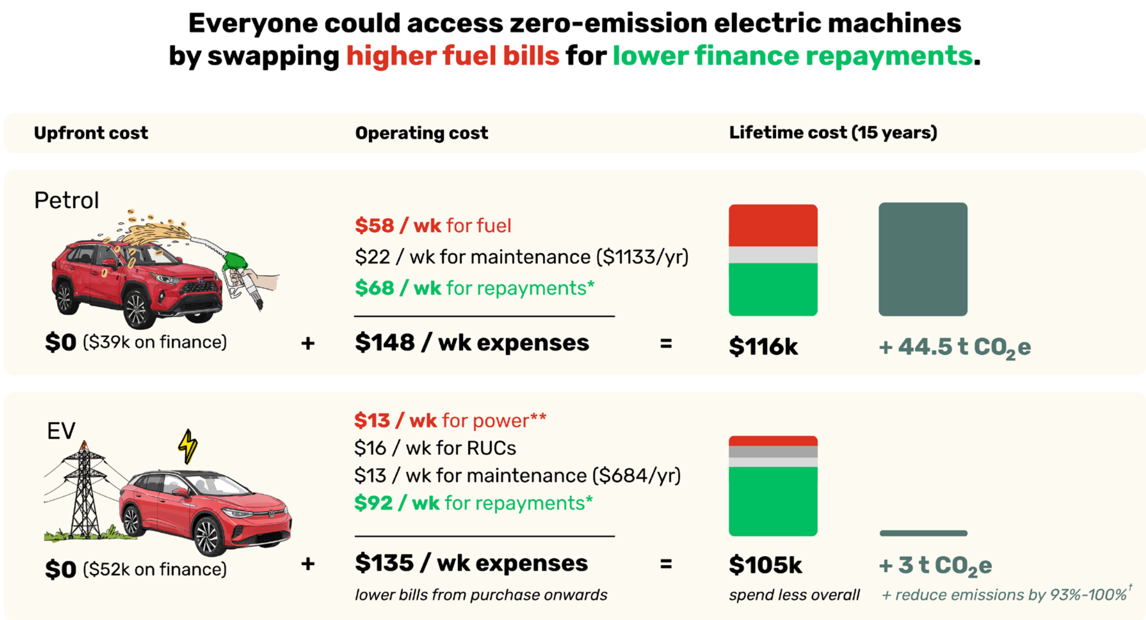
Shifting energy innovation focus to process innovation and electrification finance

We have shown that 84% of fossil fuel machines now have economically feasible electric alternatives (they save money over their lifetime, upfront cost differences included) which are widely available in the country. Rather than additional technological breakthroughs, what's most needed now is investment in deployment innovation. This means simple, affordable finance and better processes to help everyday New Zealanders access these win-win solutions that cut both emissions and costs.

This kind of innovation needs to be scaled and developed well beyond actions happening today. Education on the benefits of choosing electric machines, processes to ensure purchasing electric machines is the easy option (see the "Making electric machines the easy choice" list below), and access to affordable finance need to be widespread and accessible for all New Zealanders. These innovations must also follow through past the time of purchase, through to machine installation.

Rethinking finance for electrification

Our current finance system inadvertently favours fossil fuel machines because of how it structures repayment timelines. Short loan terms disadvantage electric machines. While fossil fuel machines like petrol cars typically have lower upfront costs but higher lifetime expenses (due to constant fuel purchases), electric alternatives have higher upfront costs but much lower running costs. However, the loan terms available today do not account for this reality. Most vehicle loans only cover the initial purchase price over three to five years, not the total lifetime cost of ownership. This means that when financing a fossil fuel vehicle, consumers pay a smaller loan amount upfront, but what is often excluded from the equation are the significant ongoing fuel costs. When financing an electric vehicle, they must finance the entire higher upfront cost and repay this on the short loan term, despite lower lifetime expenses over the vehicle's operational lifetime (approximately 15 years). If financing were restructured so that consumers could make loan payments for electric vehicles in similar amounts to what they currently pay for petrol or diesel each week, the full economic advantage of electric vehicles would become immediately apparent. This is illustrated in the graphic below. There is a need for loans that let consumers choose repayment periods which align with the machine's operational lifetimes.



* This includes principal & interest repayments calculated using 5.5% interest on the upfront cost of the car.
** Charging at night off-peak would result in $8 / wk ($101k over lifetime), and charging with rooftop solar is $7/wk ($100k over lifetime).
† EV emissions are based on the current emissions intensity of the grid. All operating emissions are eliminated if charged from renewable sources, whether grid or self-generated, such as hydro, solar, or wind.

Furthermore, current access to borrowing is unevenly distributed and particularly difficult for low-income households and renters. We need accessible, affordable, flexible, deferrable finance mechanisms that take advantage of the reality that most New Zealanders could save money through electrification if initial costs were distributed over the lifetime of machines. Like our student loan system for education, electrification requires upfront investment but delivers long-term benefits and savings for both individuals and the country.

Loan scheme options

Wide-reaching loan schemes are the best way to provide electrification finance for households and some businesses. This is because the design of these schemes can provide low interest, affordable loans designed to be accessible to renters and property owners, and repayments can be made on timelines that allow them to be covered by fuel savings from electrification. Provisions such as deferred repayments can be made for households to navigate changing financial situations.

Electrification finance is urgently needed and some loan schemes will take longer to develop than others. We see merit in starting now and progressing multiple options, which can compete in the market and increase consumer choice. Such an approach would open access to electric technologies while ensuring economic and environmental benefits for all. Loan scheme options include:

- Council enabled loans: Central government could support local government to establish a scheme that makes affordable[16] finance available to all rateable properties. Such a scheme could build on the success of the Local Government Funding Agency to crowd in private capital through bonds.
- Electrify Everything Loan Scheme: These are loans to finance electrification that is secured on the property title, indexed to inflation, and repaid on sale of the property. This would offer a simple mechanism for everyone, regardless of income, to make the switch, while minimising the cost to taxpayers.
- Finance on-power bill: This is the most "natural" way to pay off electrification upgrades, because the power bill is where money will be saved after electrification. The consumer receives a lower power bill overall; the amount they pay goes towards their finance repayment and paying for electricity.
- Longer-term bank loans secured against the property bank: These are simply longer-term[17] bank loans with simple and streamlined onboarding processes, including preapproval for electric machines that save money over their lifetime. While offering such loans remains a commercial decision for banks, the Government could explore feasibility by working with them to identify and address barriers.

Making electric machines the easy choice

Process innovation is needed to overcome practical barriers, in order to make electrification the obvious choice for busy people. Key initiatives should include:

- Widespread public awareness campaigns on the benefits of electrification, for cost of living, energy independence, health, and the environment.
- Targeted education to influence purchase decisions at critical moments, including breaking the cycle of fossil fuel machines being replaced like-for-like as the default.
- Community-based pilot demonstrations leveraging trusted local voices, which provide real-world data on the economic and emission benefits of electrification.
- Improved energy labeling that clearly communicates lifetime costs and emissions. This includes expanding vehicle emissions and energy efficiency labels for cars to account for operating cost savings from avoided fuel costs.
- Increased transparency of rental property energy costs, such as showing the expected power bills for a rental property. This helps to address the "split incentive" problem in electrifying machines in rental properties.
- Improving access to the 10% of machines that have economically feasible alternatives available overseas, but have limited availability in New Zealand ("almost ready" category). This involves simplifying procurement pathways for commercial vehicles such as trucks, utes, vans, buses, tractors, and earthmoving vehicles.
- Work with industry to develop procurement strategies to seed the market, benefiting from bulk purchase pricing.

16 1% - 1.5% below bank fixed-term mortgage rates
17 Including terms up to the lifetime of the machine being financed

Opportunity to lead on electric agritech innovation

New Zealand has a competitive advantage to invest in technical innovation in electric agritech, because it is one of the first countries where electrification for many agricultural machines provides cost savings over the lifetime of the machine. This provides an opportunity for New Zealand to leverage technological advancement in agritech, working with New Zealand's agricultural sector and dedicated, already-established farm vehicle suppliers. This will not only reduce fuel costs and emissions in the agricultural sector domestically, but also provide scope to export technical advancements internationally. Large batteries in farm vehicles also have the added benefit of providing increased energy resilience as a source of flexible backup electricity supply.

Domestic aviation demonstration

New Zealand could use our advantage as a potentially agile nation to accelerate the necessary regulatory change for global leadership in electric domestic aviation. An electric aviation regulatory sandbox could be implemented, providing a streamlined approval process for regulatory exemptions to develop electric aviation, and converting existing fossil fuel aviation vehicles to electric.

New Zealand's unique opportunity to lead the world

Aoteaora New Zealand stands at a historic crossroad. We are among the first countries on Earth to cross the "electrification tipping point"[18] where replacing fossil fuel machines with electric alternatives will simultaneously save money and reduce emissions. The Machine Count now shows that this economic advantage exists for 84% of all fossil fuel machines across our economy. Climate action is now aligned with economic productivity and energy efficiency.

This project reveals that our barriers are no longer technological or economic – they're practical. New Zealand excels at getting practical. Our small, agile nation needs to focus innovation on finance mechanisms and streamlined processes to make zero-emission machines the default choice in everyday purchase decisions. These decisions collectively determine our emissions trajectory for the critical decades to come.

By embracing this transition, we can redirect billions of dollars spent annually on imported fossil fuels into our domestic economy. We can replace this offshore expense with locally-generated electricity powering more efficient machines, creating substantial savings for households and businesses. These findings provide the foundations for transforming Aotearoa into a world-renowned, highly resilient, highly productive electrified economy. Electric machines and deployment innovations are the practical roadmap for an abundant, sustainable future that other nations will seek to follow.

1.0 Introduction

This report provides the results, insights, and recommendations from the Machine Count project. It is a preliminary estimate of all fossil fuel machines in the country, the first of its kind in Aotearoa New Zealand. It provides insights to create an actionable decarbonisation roadmap that can maximise benefits to New Zealanders. Our research demonstrates that significant emission reduction is achievable this decade, as most of the machines that make up our fossil fuel consumption already have zero-emission electric alternatives available with lower lifetime costs. Therefore, accelerating climate action is largely not a problem of cost or technological advancement, but of deploying existing technologies that already work, using mechanisms like better financing and practical product offerings that make it easier for consumers to make electric machine replacement decisions.

1.1 Definitions

Machine refers to anything that uses energy to perform a task. Machines are defined by their common, easily-understood form, even if they contain multiple components (e.g. one petrol car is considered one machine, even if it also has an air conditioner and heater inside it). The project focusses specifically on fossil fuel machines, because they make up most of our CO2 emissions.

Machine type refers to a particular type of machine. For example, the water transport category might have 11 machine types (cargo ship, diesel launch, small outboard motorboat, etc.), and 450,000 individual machines across those machine types.

Electrification refers to the replacement of machines that are powered by fossil fuels[19] or other emitting fuels[20] with electric alternatives. For example, electrifying a petrol car means replacing it with a battery-electric car.[21] [22]

Electrifiability refers to the readiness of a given machine type for mass replacement with an equivalent[23] electric alternative. This may take into account barriers to electrification such as lack of availability in New Zealand, upfront cost, or lifetime cost.

Emissions refers to operating emissions only, not embodied emissions, unless specified. Although in some cases the embodied emissions of electric machines may be higher than that of fossil fuel machines, the lifetime emissions of electric machines is lower. The operating emissions savings generally far outweigh the difference in embodied emissions.[24]

Opex refers to operating costs of running a machine. Unless otherwise specified, all machine-level opex include volume costs only for the energy used, except vehicles where Road User Charges are included. It does not include maintenance. It does not include fixed connection charges for LPG and natural gas due to the difficulty of attributing proportions of the fixed charge onto particular machines within one ICP connection. In reality, most opex savings from electrification would be higher as electric machines tend to have lower maintenance costs, and fully electrified households and businesses would no longer need to pay the often significant charges for a gas connection or LPG subscription (approximately $0.3778/day for residential LPG, and $1.887/day for residential natural gas).

19 For example, natural gas, LPG, petrol, diesel, coal, jet fuel, and heavy fuel oil.
20 For example, wood and biomass.
21 Replacement with hybrids and plug-in hybrids is not electrification, because they still consume significant amounts of fossil fuel and therefore will still need to be replaced with fully electric alternatives in the near future to reach zero emissions.
22 Installing solar and battery is often included in the definition of electrifying a home or business, as it lowers the cost of electricity and further increases the savings from electrifying machines. However, analysis of the impact of installing solar and batteries has not been included in this report due to the project's focus on machine replacement. For analysis on the impact of solar and batteries on cost savings and energy security, please refer to Rewiring Aotearoa's Investing in Tomorrow and Electric Homes reports.
23 We acknowledge the importance of decarbonisation through the absolute reduction, e.g. mode shift such as replacing a petrol car with a bicycle or e-scooter; right-sizing by replacing a large truck with a smaller, sufficient truck; autonomous machines/drone technology replacing larger existing machines. However, this requires complex socioeconomic analysis outside of the project's scope, including determining the rate and scale of widespread behaviour change. This preliminary machine count is focused on establishing a baseline on achievable emissions reduction through replacement alone, that does not require behavioral change or service reduction. Absolute reduction interventions would complement these findings for even greater impact.
24 Refer to "Why going electric wins on emissions" (Rewiring Aotearoa, Jan 2025) for more information & sources

2.0 Why count machines

This section explains the reasoning behind this project. It illustrates the role of machines in the global emissions context (Section 2.1), its importance for New Zealand's emissions reduction (Section 2.2), and then explains why identifying and counting machines is central to being able to build an actionable pathway to a zero emission economy (Sections 2.3).

2.1 Global context

Our global emissions problem is largely an energy problem, and that energy problem is largely a machine problem. Around 73% of our global emissions profile is energy use.[25]

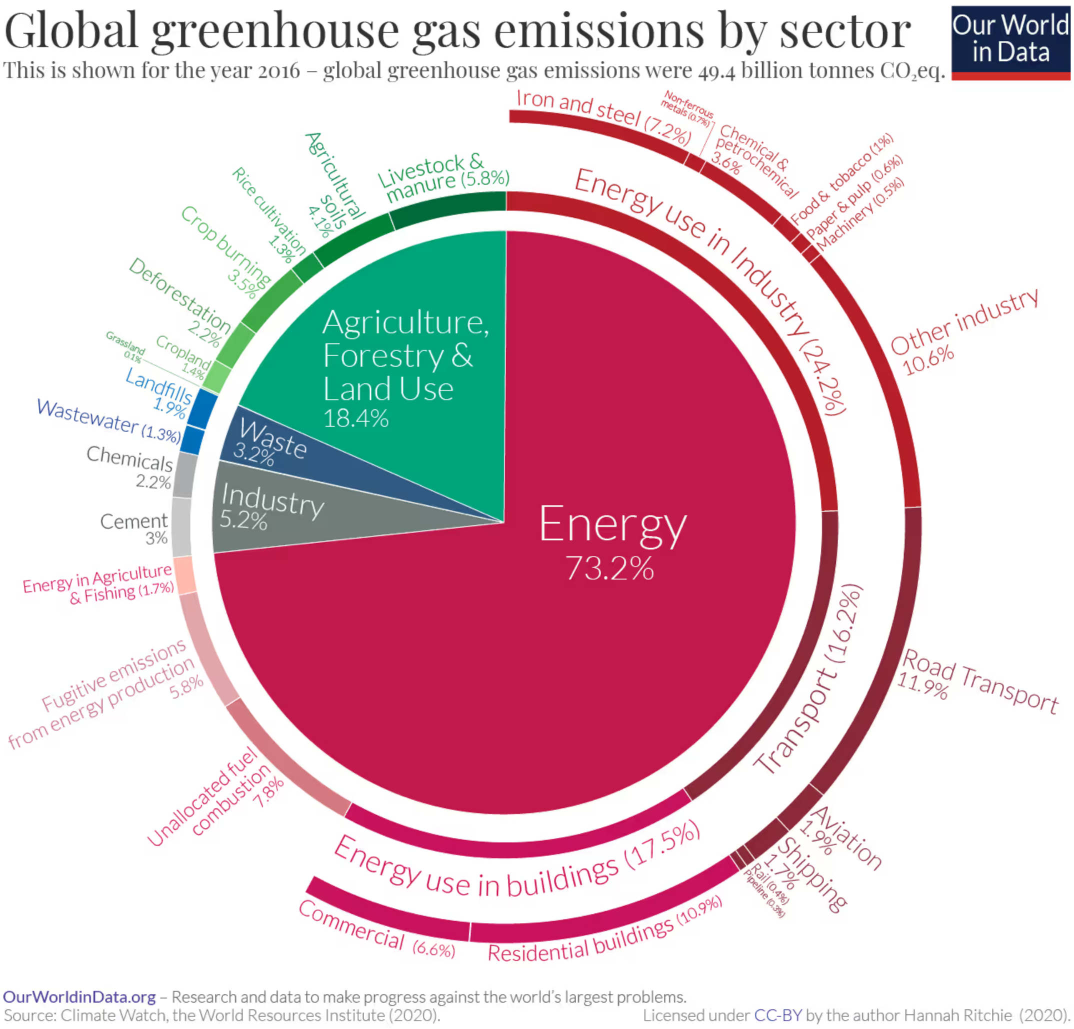


Figure 2.1: Global greenhouse gas emissions by sector (Source: Our World in Data)

Underneath these energy emissions categories sit fossil fuel machines, from coal power plants to petrol vehicles to gas water heaters. These machines burn fossil fuels to create the vast majority of the world's emissions. The most impactful, realistic, affordable pathway to solving our emissions problem is to swap those fossil-fuel-burning machines with non-fossil-fuel alternatives, and running those alternatives on clean zero-emission energy.[26] For the vast majority of machines, the clear option is electrification – swapping a fossil fuel machine for an electric alternative. This is because electric machines are often the only economically and practically feasible zero-emission alternative. In addition, the better thermodynamic efficiency of electric machines results in a much more productive, lower-cost energy economy.

25 Other sources of emissions beyond the scope of this report include agricultural and forestry emissions (18%), industrial process emissions (5%), and waste emissions (3%). This report does not discount that these other emissions need to be addressed too. However, the focus is on the largest portion of global emissions, that is, energy emissions, where they come from, and how to reduce them.

26 Offsets are not considered due to their inability to permanently and reliably reduce emissions at the pace and scale that is needed.

2.2 Aotearoa New Zealand context

New Zealand has a unique emissions profile, yet the solution to rapid emissions reduction is the same: machines. Our national emissions profile includes a lot of agricultural methane emissions, primarily from enteric fermentation.[27] However, it is important to remember that our border-adjusted emissions accounting does not always convey the full picture. Aotearoa produces far more agricultural products than it consumes, resulting in a higher ratio of agricultural emissions than the global average or that of most other nations. This ratio appears in New Zealand's inventory even when agricultural products are consumed elsewhere.

In contrast, while most of New Zealand’s export emissions are included in our inventory[28], much of Australia’s aren’t. This is because emissions are generally counted "where" they occur, i.e. where the cows burp or where the fossil fuels are burnt. Fossil fuels extracted from Australian soil are mostly exported to be burnt overseas, and therefore these do not count on their emissions inventory. Another example is a t-shirt purchased by someone in New Zealand: this may have been made in China with manufacturing emissions that appear on China’s inventory, using Australian coal that appears on China’s inventory, sewn by people consuming New Zealand dairy products which appears on New Zealand’s inventory.

Therefore, it is important to remember that climate change is a global atmospheric problem, not one that is bound by borders. As Carl Sagan observed,

> *“If you burn a lump of coal somewhere, the carbon dioxide goes up in the atmosphere, and you know, carbon dioxide molecules are exceptionally stupid. They don’t know anything about national boundaries. They don’t have passports. They are wholly innocent of the important concept of national sovereignty. They just casually cross over national boundaries one after the other. There is a lesson – the world is a unity – the national boundaries have no bearing on these global environmental issues.”*

This territorial accounting methodology can hinder prioritisation and rapid progress on climate action, because these conventions for emissions accounting only present one perspective of a country’s emissions. The frameworks that categorise national emissions,[29] and the impacts of having trade-heavy emissions profiles like Aotearoa, should not detract from the broader task of reducing emissions worldwide to mitigate climate change.

Technical feasibility of emission reduction is also a crucial consideration when prioritising action, because climate change is a cumulative emissions problem. Carbon emissions can remain in the atmosphere for a thousand years. Therefore, it is important to take every opportunity to reduce emissions *early*, for greater mitigation of long-term warming. Identifying which emissions reductions are *feasible in the short term* is therefore vital to eliminate emissions from entering and staying in the atmosphere. Energy emissions from fossil fuel machines is the major category that fits this criteria. The majority of fossil fuel machines in use around the country today can be decarbonised affordably and *immediately* through electrification, locking in permanent emission savings.

These emissions from fossil fuel machines make up a significant portion of New Zealand’s emissions. The chart in Figure 2.2 below flows from left to right, beginning with conventional emissions categories on the left. Enteric fermentation for products that are exported is the single largest category in the emissions profile (31.2 Mt in green). Towards the right, it splits emissions into “domestic use” and “export/trade emissions” and then splinters further into who makes the decisions on those emissions. When focusing on the “domestic use” emissions, the emissions proportions look strikingly similar to the international emissions breakdown in Figure 2.1, with “Energy” as the largest portion (“Domestic Energy”, 26.2 Mt in red), followed by agriculture products (5.4 Mt in green), industrial processes (3.8 Mt in purple), and then waste (3.1 Mt in brown). It shows that **approximately 70% of our domestic emissions are from domestic energy use** – the fossil fuel machines owned by households, farms, and businesses, where the purchasing decisions are made by everyday New Zealanders.

27 The digestion, breathing and flatulence of cows, sheep, and other ruminants.
28 National Inventory Report submitted to the UNFCCC
29 Under the requirements of the UFCCC

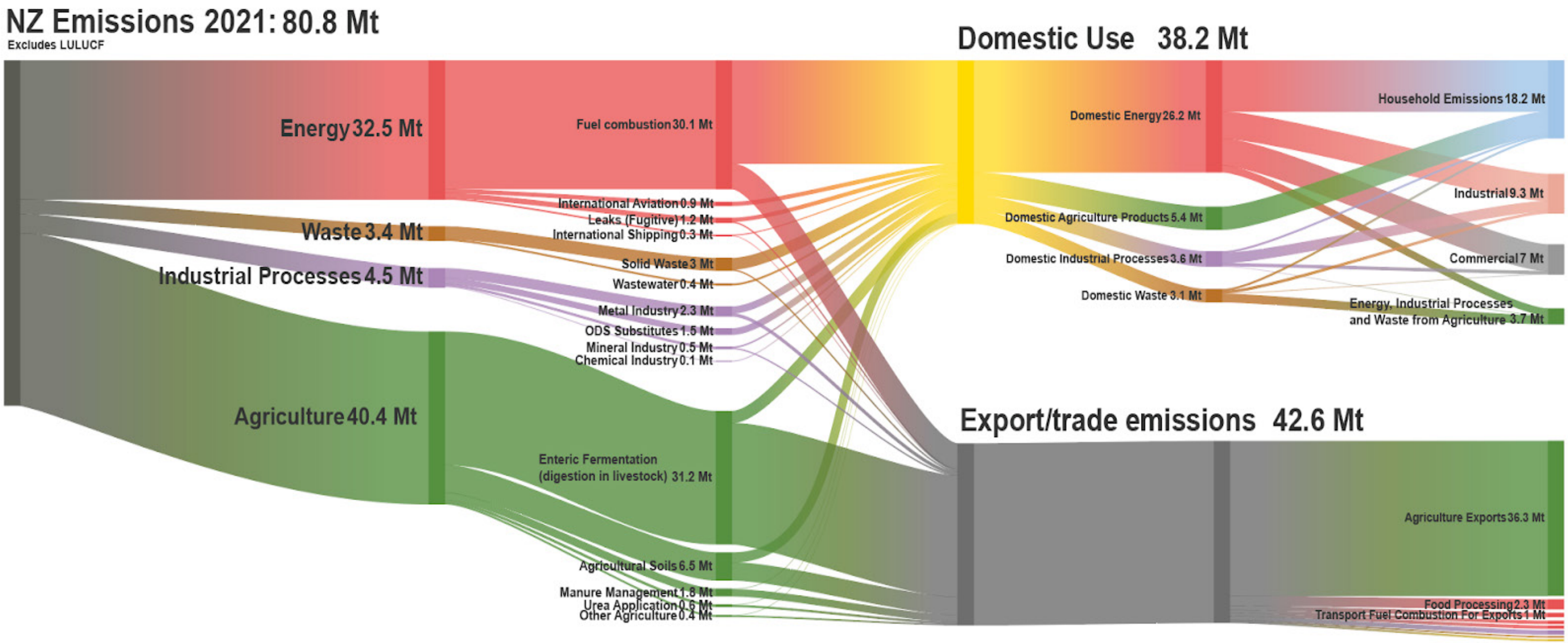


Figure 2.2: Allocation of emissions in Aotearoa New Zealand from sector to end use in the economy[30]

30 From Rewiring Aotearoa Electric Homes (2024) using 2021 data

2.3 An actionable pathway to zero emissions

Given that fossil fuel machines are where we can have the most low cost and long-lasting impact on emissions, the priority then becomes understanding these machines and identifying which ones are both technically and economically feasible to electrify in the short term. This creates an actionable workplan for emissions reduction in Aotearoa, bridging the gap between our emissions profile and practical climate action on the ground. We need data on the energy needs (before and after electrification) of these machines, how they are used, and the capital costs of electrification, to adequately plan the transformation of the energy system for an electrified and decarbonised economy. In this section, we discuss how a machine-level focus supports actionable emission reduction planning.

2.3.1 Maximising our early emission reduction potential

Focussing on machines breaks up the problem of climate change into prioritised pieces. When we catalogue machines, accounting for their emissions impact, and the technical and economic feasibility of zero-emission alternatives, this allows for prioritisation based on what is possible now. This means that we can aggressively focus on the machines that are ready to electrify now and make meaningful rapid progress, locking in permanent emission reductions. This includes machine types which have a negative abatement cost, where electrification doesn't cost people money, but actually saves them money (see Section 4.1).

2.3.2 Emission reduction as individual purchase decisions

Some gradual emissions reduction could be achieved through incrementally reducing our consumption of fossil fuels through efficiency measures. However, there is no way to "efficiency" a fossil fuel machine into a zero-emission machine. Fossil fuel machines need to be upgraded to electric for us to become a zero-emission nation. By counting machines, we put the focus on the individual purchase decisions that make up our emissions reduction trajectory, and how we can reduce the barriers for all New Zealanders to make a zero-emission choice. Each of these decisions, made by a household, business, or institution, creates a step change in their emissions profile as they permanently eliminate the emissions of each fossil fuel machine (Figure 2.3 below).

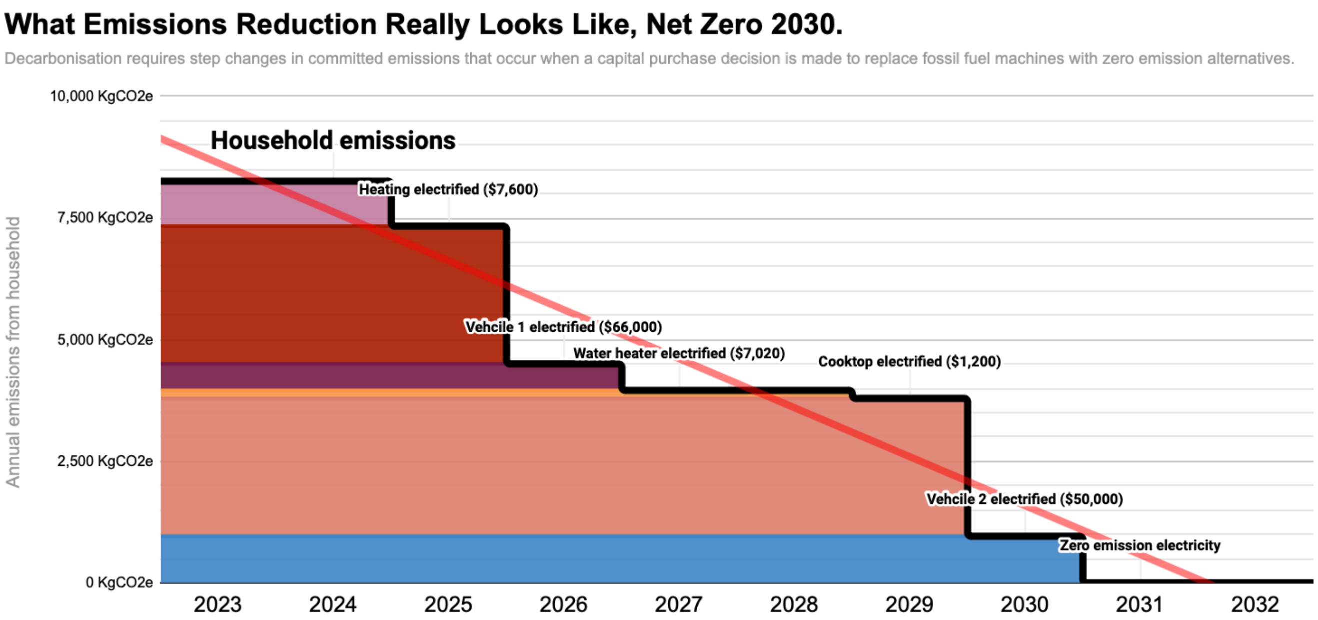


Figure 2.3: Realistic step change emissions reduction projection through electrification of fossil fuel machines in a household

There are millions of fossil fuel machines in Aotearoa, each representing a purchase decision that will need to be made to replace it with a zero-emission, most likely electric, alternative. This approach connects our global climate obligations with tangible purchase decisions for individuals, businesses, and policymakers, and actionable policies to remove specific barriers.

2.3.3 Granular, targeted policies

When we understand the number of machines involved, where and how they are used, the energy needs, the capital costs, the emissions and opex savings, we can:

- Determine the economic implications of increasing or decreasing climate ambition for both individuals and the nation
- Know which sectors can reduce emissions most rapidly and which might need innovation support
- Foresee the specific opportunities and challenges that may arise for certain machine types and their emissions
- Precisely track our progress and trajectory by monitoring the rate of machine turnover, and adjust strategies accordingly
- Plan granular, far-reaching policies that impact on-the-ground decisions, which will drive permanent progress on emissions reduction.

This machine-based perspective helps us understand the practical details along the path to zero.

2.3.4 Economies of scale and learning rates

Technological progress in clean energy and electrification of machines is occurring at unprecedented scale and pace. This is often underestimated when planning for decarbonisation. By focusing on machines in our emission reduction strategy, we can be prepared for the significant opportunities that will come from advances in technology.

Historical lessons in technological adoption

Forecasts from governments and industry have consistently underestimated how quickly new technologies can replace incumbents throughout history.[31] Technological progress is unpredictable, and often surprising. At the turn of the 20th century, experts confidently proclaimed limitations for emerging technologies, such as the car:[32]

The ordinary 'horseless carriage' [car] is at present a luxury for the wealthy; and although its price will probably fall in the future, it will never, of course, come into as common use as the bicycle.

Similarly, in 1903, the president of the Michigan Savings Bank told an original investor in the Ford Motor Company,

"The horse is here to stay, but the automobile is only a novelty – a fad."

Yet by 1908, Ford introduced the Model T. Five years after that, cars outnumbered horses on New York City streets.

Modern parallels in electric vehicles

We are witnessing similar patterns of accelerated adoption with electric vehicles. Electric vehicles have already crossed the economic tipping point where they represent a better financial decision for new car purchases in New Zealand,[33] with forecasts indicating continued price reductions. Yet 15 years ago, mainstream electric cars seemed like a distant possibility rather than an imminent reality.

In 2010, the Nissan Leaf debuted as the first mass-market electric vehicle, priced at roughly $75,000 with a modest 160km range.[34] Today's electric vehicle market offers models starting at around $30,000 and popular models ranging up to around $60,000 new, with some models having over 500 km of range. A robust second-hand market has also developed, with prices ranging from $3,000 for older models (e.g. old Nissan Leafs with a 50 km range) to $30,000 for newer second-hand models (e.g. Hyundai Konas with a higher driving range of 400 km).

High learning rates in solar, batteries, wind, and heat pumps

This pattern of rapid cost reduction is not unique to electric vehicles. Learning rates (the consistent percentage cost reduction that occurs with each doubling of cumulative production) have been observed across numerous technologies over decades. Solar panels (Figure 2.4), batteries, wind turbines, and heat pumps are all following similar cost reduction curves.

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31 https://www.cell.com/joule/fulltext/S2542-4351(22)00410-X
32 *The Literary Digest, 1899.*
33 Page 41, Section 2.1.4 of Electric Homes - Rewiring Aotearoa - March 2024
34 New Zealand Dollar of 2025.

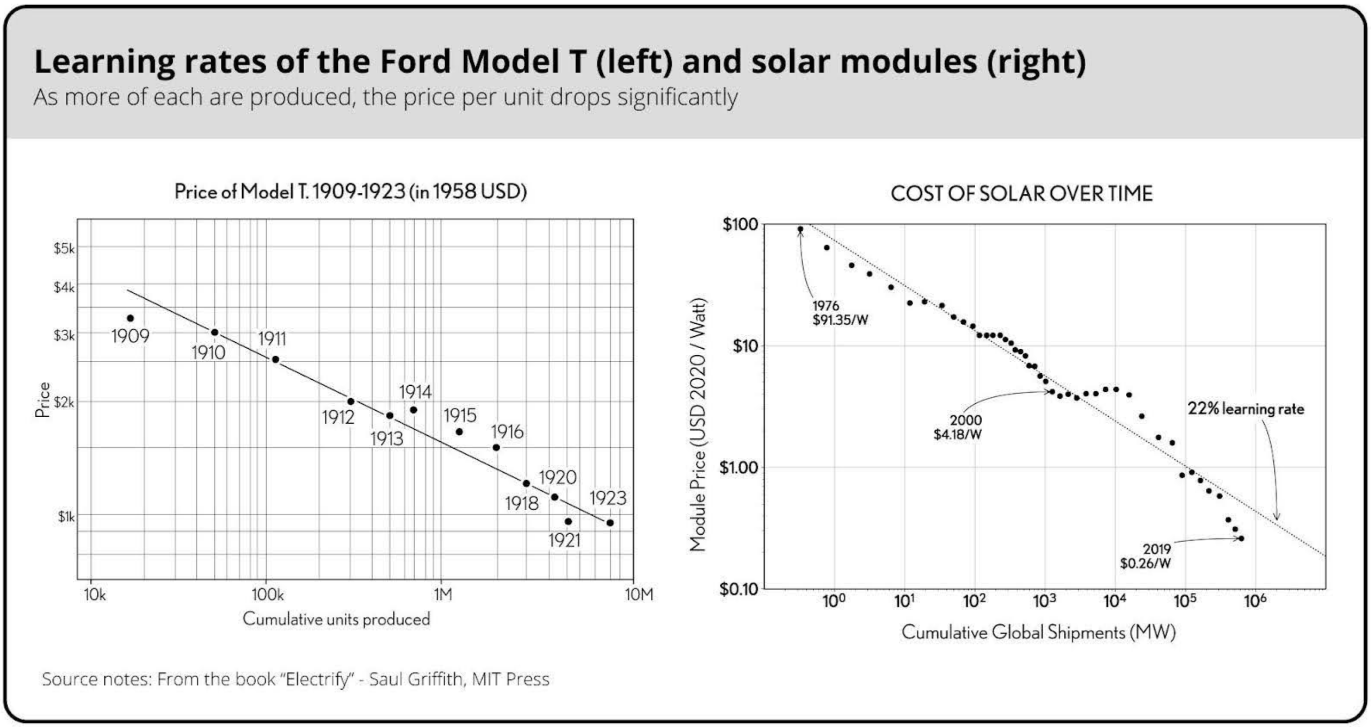


Figure 2.4: Learning rate, or cost curves, of the Ford Model T in the early 20th century compared to solar modules from the 1970s to late 2010s.

The implications for machine electrification are profound. Technologies that today seem prohibitively expensive or technically limited could become viable more quickly than forecasts suggest. By planning our decarbonisation pathway at the machine level, we can account for these accelerating technology learning rates. These can be tracked at the individual machine type level. Learning rates can rapidly transform markets, even for machine types that currently lack viable zero-emission alternatives. Sectors across Aotearoa should have the visibility and machine-level focus to take (or even better, to accelerate) these emission and cost saving opportunities.

2.3.5 Counting machines shows the impact of committed emissions

Annual emission accounts provide an incomplete picture of our climate challenge because they overlook the lifetime emissions of fossil fuel machines. These "committed emissions" represent the total greenhouse gases a machine will produce throughout its operational life.[35] When we purchase a fossil fuel machine, we usually lock in emissions for its entire operational lifespan – typically 10 to 20 years. For example, replacing all vehicles with hybrids today would reduce annual vehicle emissions immediately, appearing beneficial in short-term reporting.[36] However, this approach would still commit approximately 15 years of continued petrol emissions into our economy, a total volume of emissions that is lower than non-hybrid petrol emissions, but still incompatible with our climate targets. New Zealand's emissions profile in 2040 is impacted by machine purchasing decisions made today and in the following years.

A machine-based approach to emission planning provides this crucial foresight. Once a fossil fuel machine is replaced with an electric one, that machine's emissions are eliminated not just for the current year's emissions account, but permanently for every year going forward for the life of the machine. On the other hand, planting trees may show a temporary downward trend in emissions reporting without actually eliminating emission-causing machines. Hybrid vehicles create a modest immediate emission decrease while still committing many years of forward emissions.

While the Ministry for the Environment already uses a vehicle fleet model that incorporates the Ministry for Transport's fleet count to project the long-term impact of today's vehicle purchases, this level of scrutiny doesn't exist for all machine types in our economy. Unless we track the number of fossil fuel versus electric machines that are in use, being purchased, and being retired, we cannot accurately assess our trajectory toward zero emissions. Understanding this machine inventory provides both present and future context on our progress towards a zero emissions economy, and indicates how much we may need to accelerate replacement to meet future targets.

35 https://www.nature.com/articles/s41586-019-1364-3
36 https://afdc.energy.gov/vehicles/electric-emissions

Electric machine adoption rates

Understanding likely machine adoption rates and comparing this to the rate of adoption needed to reach emissions targets can help inform the urgency and type of emissions reduction measures that are needed. Identifying likely adoption rates for different types of fossil fuel machines will depend on a range of factors, for example:

- The typical machine lifetime
- Whether the machine typically get replaced before end of life (e.g. selling a car to upgrade to a newer one) or only when they stop working (e.g. hot water heater)
- The economic feasibility of upgrading from fossil fuel to electric before the end of life, because the potential opex and emissions savings are high enough
- Falling electric machine prices influencing the cost of electrification

3.0 Project overview

The Machine Count project compiles the information required for an actionable pathway to zero emissions, by quantifying all the fossil fuel machines in the economy and qualifying their electrification feasibility. This section gives a brief overview of the project methodology and its key outputs.

3.1 Methodology

The populated Machine Count database has been made a free, publicly accessible resource with an accompanying public webpage. Development and population of the Machine Count Database involved the following five key steps:

1. An audit of data availability including:
   - Performing an initial audit of the energy and machine data available (Appendix 1, Section 1)
   - Gathering data sources and evaluating their reliability (Appendix 1, Section 2)
2. Energy Surveys involved:
   - Designing and conducting four sector surveys to complement existing data sources (Appendix 1, Section 3) and building a data pipeline to process the responses (Appendix 1, Section 4)
3. Machine Count Database Design and Count which included:
   - Designing a database in Google Sheets to house the insights for our catalogue of machines (Appendix 1, Section 5)
   - Building a machine hierarchy to list and categorise all the machine types in the country (Appendix 1, Section 6)
   - Estimating the count of fossil fuel machines for each machine type, by reconciling data from publicly available data sets, reports, surveys, and interviews from specific sectors (Appendix 1, Section 7)
4. Evaluated the "electrifiability" of each machine type (Appendix 1, Section 8), which involved:
   - Developing a criteria for assessing the technical and economic feasibility of electrifying each machine type, taking into account the availability of electric alternatives in the country, their capital costs, and the opex and emissions savings over their lifetime
   - Quantifying the emissions impact of electrifying
   - Qualifying the barriers to electrification and categorising machines into "electrifiability" categories
   - Modelling emissions and opex savings from electrifying the top machines in each electrifiability category, and reconciling these against nationwide energy use and fossil fuel import values
   - Creating a list of electric products available on the market to demonstrate real-world examples of electric alternatives (Appendix 1, Section 9)
5. Sector modelling, real-world case studies and regional analysis to provide specific insights on key challenges and opportunities to electrification for a range of audiences. This involved the following steps:
   - Speaking to a range of homeowners, farmers, and businesses to complement our modelling findings with real-world case studies (Appendix 2, Section 2)
   - Modelling the electrification pathways of the residential, rural, small business, and large industrial sectors, highlighting specific opportunities and challenges (Appendix 2, Sections 4-7)
   - Investigating the regional factors that may impact electrification (Section 7 of this report)

Results from the research were analysed to identify opportunities and barriers to electrification. This was used to identify the recommended actions for unlocking electrification and maximising benefits to New Zealanders (Section 5 of this report).

3.2 Key outputs

The outputs of this project included the following key resources:

Nationwide checklist of fossil fuel machines

Summary Table 1 in Section 10 (the last section of this report) presents a preliminary count of all the fossil fuel machines in Aotearoa New Zealand. This checklist categorises machines by ease of electrification and ranks them by emissions impact, while identifying barriers to electrification. This data forms the foundation for a practical pathway toward a zero-emissions nation.

Machine Count Database

The Machine Count Database contains the nationwide checklist as one summary sheet, alongside all collected and reconciled data. This resource includes the estimates on the count, feasibility, emissions impact, and barriers to electrification for all machine types. The database also shows examples of real-world electric alternatives, and identifies machines that currently lack reliable data to help target future data collection for further emissions reduction opportunities and comprehensive decarbonisation planning.[37]

Prioritised machines and the impact of their electrification

The Machine Count enables grouping of machines based on electrifiability. It provides a high-level view of potential emissions and operational expenditure savings achievable through electrifying priority machines in each category. Additionally, it maps the necessary actions – including innovation and policy measures – required to advance electrification across all groups. The following section (Section 4) expands on these machine groupings and their recommended actions.

Opportunities and barriers for sector-specific electrification

Through our surveys, case studies, and archetypal modelling, we illustrate typical electrification pathways for a range of scenarios in each sector, including real-world examples. A summary of the insights are available in Section 6 of this report.

Other supporting documents and outputs can be found in Section 9 of this report.

37 For example, <500 kW site boilers are listed as placeholders in the database without counts due to limited data availability, see Appendix 1, Section 7.

4.0 Prioritised machines

Our Machine Count results show that Aotearoa New Zealand has approximately 10.2 million fossil fuel machines.[38] Once we estimated the count, technical and economic feasibility,[39] and emissions impact[40] of each machine type, we divided the full machine list into three "electrifiability" categories shown in Table 4.1 below.

Table 4.1: Electrifiability categories indicating a machine's readiness for mass electrification[41]

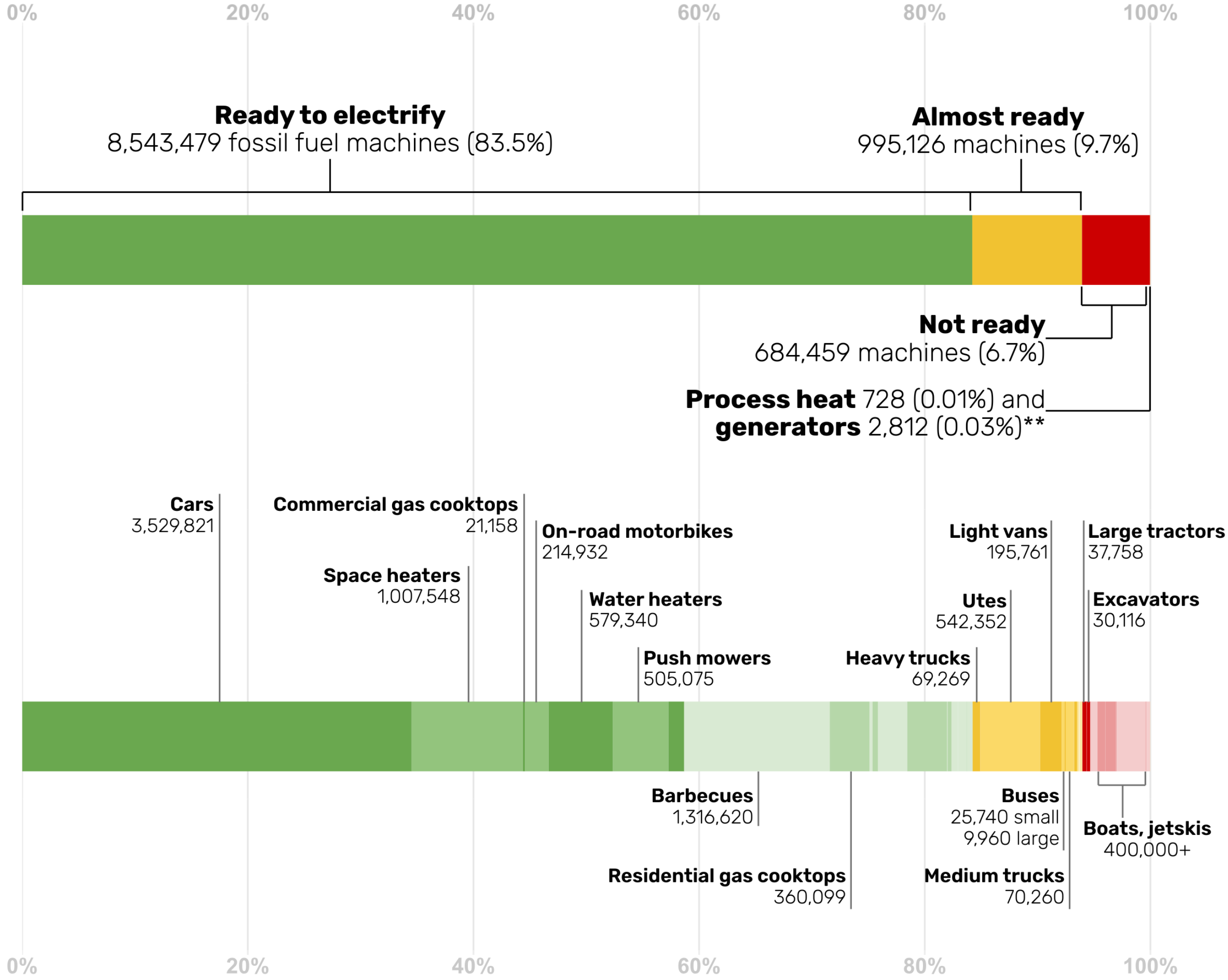
Electrifiability	Description
Ready	technically feasible and mainstream/readily available in NZ AND economically feasible, with equal or cheaper lifetime costs than fossil fuel counterparts
Almost ready	technically feasible with limited availability in NZ (may be commercially available overseas) AND economically feasible, with equal or cheaper lifetime costs than fossil fuel counterparts
Not ready	technically feasible but yet to commercialise, or not technically feasible and needs further development or testing OR not yet economically feasible, with electric alternatives having higher lifetime costs than fossil fuel counterparts
Process Heat & Generators	These machines were treated separately as they have varied or complex barriers to electrification pathways (see Sections 4.3 to 4.4)

The results from this categorisation shows that 99.6% of the 10.2 million machines are technically feasible to electrify, and 94% are both technically and economically feasible. Furthermore, the vast majority of machines (84%) fall into the "Ready"-to-electrify category (Figure 4.1).

38 With an estimated error of 2.4 million, see Appendix 1, Section 7.2 for details on count confidence.
39 Criteria for technical and economic feasibility can be found in Appendix 1, Section 8.
40 Emissions impact takes into account emissions intensity, hours of use per year, and quantity of machines. See Appendix 1, Section 8.3 for detail on how this is calculated.
41 For full evaluation criteria, please see Appendix 1, Section 8.

The majority of fossil fuel machines are ready to electrify today

Count of machines sorted by emissions impact*



Darker colours indicate priority machines in each electrifiability category based on emissions impact.
*Machines with low counts have been moved to the end of each category for better visibility of alternating larger machine segments.
**While these makes up a small proportion of the total *number* of machines, they are a significant proportion of our total emissions.

Figure 4.1: Distribution of fossil fuel machines across electrifiability categories

For each electrifiability category, we ranked machine types by emissions impact to identify the top priority machine types. The total count of these priority machine types summed to approximately 7 million machines. We estimated that electrifying these 7 million machines would save approximately $6.5 billion[42] in operating costs and 16.4 Mt of CO_2e per year. This amounts to a 55% reduction in our total energy emissions. Furthermore, the majority of these savings come from electrifying machines from the "Ready" and "Almost ready" categories (Figure 4.2 below).[43]

42 This is a preliminary estimate which could be improved through further data collection. See Top Machines Energy Economics sheet in the Database for full details.

43 The full breakdown of these calculations can be found in the *Top Machines Energy Economics* sheet of the Database. We choose not to include capex cost comparisons in the analysis, because of how quickly this would be out of date. Section 2.3.4 provides an overview of how quickly the cost of electric vehicles are declining in Aotearoa New Zealand and how fast the driving range on a single charge is improving.

Electrifying 7m top priority machines would save $6.5b and 16.4 Mt CO2e per year

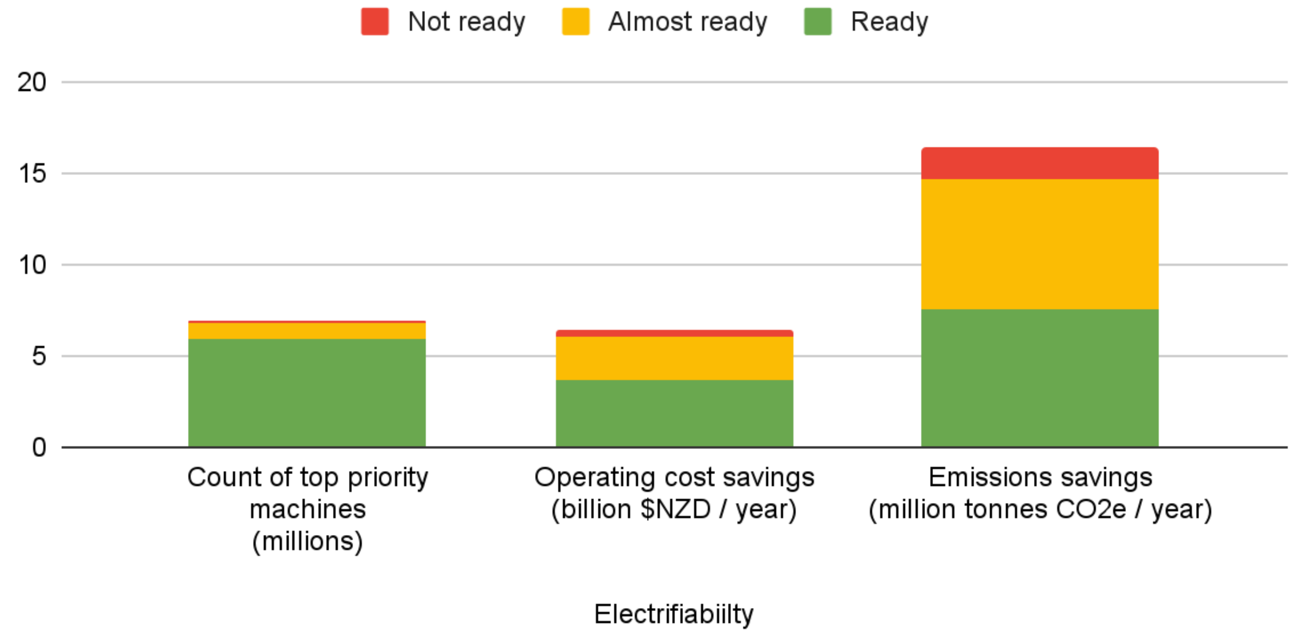


Figure 4.2: Count, operating cost savings, and emissions savings from electrifying the top priority machines across the three electrifiability categories

Figure 4.3 below shows all the energy emissions used across the New Zealand economy. It includes:

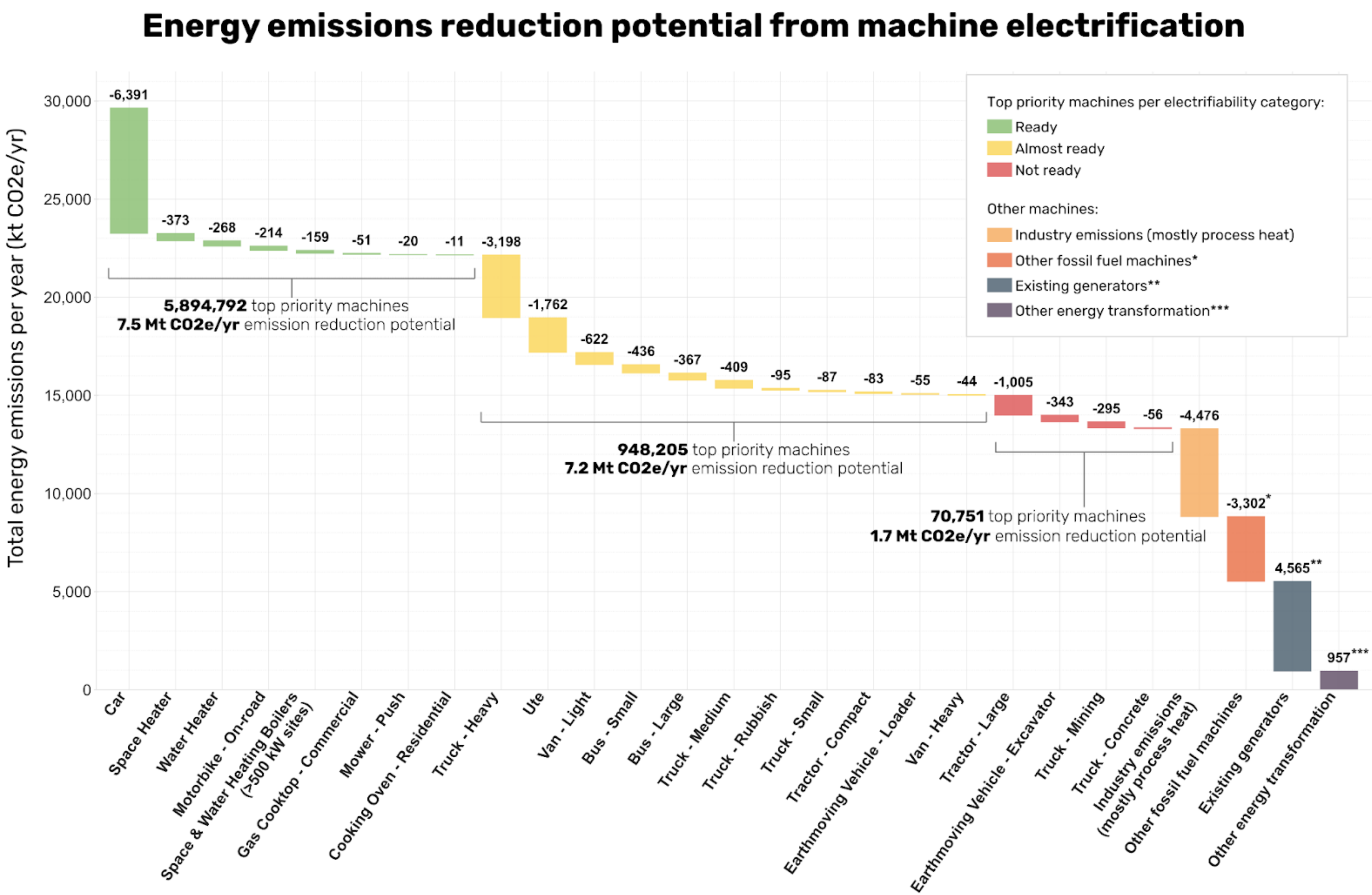
- Top priority machines per electrifiability category: Potential emissions reduction from avoided fossil fuel use due to electrifying each of the top machine types for each electrifiability category. For example, electrifying all the cars in the country (which are green, as they are part of the "Ready to electrify" category) would reduce emissions by 6.4 Mt per year. Electrifying the top 8 machine types out of 31 in the "Ready" category would reduce emissions by 7.5 Mt per year. Electrifying all of the top 23 machine types out of 95 across all three categories would reduce energy emissions by 16.4 Mt, 55% of New Zealand's estimated energy emissions in 2024.
- Industry emissions due to fossil energy use in industrial sectors.[44] This is mostly fuel use to generate process heat that is used in manufacturing.
- Other fossil fuel machines are emissions from all other machines which are not in industrial use, and did not make the top priority lists of each electrifiability category when ranked by emissions impact.
- Existing generators are the energy emissions from burning fossil fuels to generate electricity, based on 2024 energy data.
- Other energy transformation includes coal use by NZ Steel; and losses & own use associated with coal and oil provision based on 2024 energy data. Emissions from natural gas transmission and distribution losses, and natural gas production losses and own use, are spread across the emissions reduction associated with the gas use included in the above four categories.

When the emissions savings from each machine type are shown as a step chart, it illustrates how the largest reductions come from a few target machines – namely, cars and commercial vehicles like trucks, utes, and vans. However, the large cumulative impact of the smaller annual savings from the other machine types must not be overlooked – all of the machines in this priority list represent significant, permanent year-on-year emission reduction opportunities that we can not afford to waste.

Additional electricity is needed to electrify the fossil fuel machines. In the chart above we assumed that additional electricity generation will be from renewable sources and not add additional emissions.

Electrifying all the "Top priority machines" shown in Figure 4.3 would require approximately 17,000 GWh of renewable electricity supply each year. This would increase electricity demand by around 40%.

44 Excluding agriculture, forestry and fishing, building and construction and mining.



Showing emissions for top priority machines from each category - ready, almost ready, not ready to electrify. Losses from natural gas, own use, distribution, and transmission are included in machine emissions.
*Emissions from remaining fossil fuel machines that are not the top priority subsets from the "ready", "almost ready", and "not ready" categories. Many of these machines are also ready to be electrified, but their potential emissions savings have not been calculated to manage scope.
**Emissions from electricity generation from existing generators. Increasing renewable generation with a combination of hydro, solar, wind, and batteries can help reduce these emissions.
***Emissions from other transformation, including production losses and own use from oil and coal.

Figure 4.3: Emissions reduction chart showing the step changes from electrifying each priority machine type across the three electrifiability categories

The following subsections summarise the top priority machines for electrification in each category, their potential emissions and operating cost savings, and recommendations for deployment.

4.1 Ready: Deployable now

The majority of fossil fuel machines are ready to be electrified now. They have mainstream electric alternatives which are cost competitive or in many cases cheaper over their lifetime. Summary Table 2 in Section 10 highlights the top priority machines in this category and their potential savings, while the sections below elaborate on machine types and recommendations for accelerating adoption.

4.1.1 Types of machines

The following is a list of the top-ranking fossil fuel machines based on emissions impact in this category. These have electric alternatives which are immediately deployable with no significant barriers. They are opportunities for rapid emissions reduction at negative abatement cost. That is, it will save money for every ton of carbon reduced, not cost money. In fact, electrifying the following top-ranking six million fossil fuel machines out of the total 8.5 million in this easy-to-deploy category would save approximately $3.7 billion NZD per year in operating costs, and approximately 7.5 million tonnes of CO_2e per year in emissions.[45] This amounts to around 25% of New Zealand's domestic energy emissions.

- **Light passenger vehicles (3.5 million[46]):** Cars of all varieties are the highest-emission machine type nationwide due to widespread usage. As more electric models become available, they offer significant lifetime cost savings for most drivers, especially when purchased second hand. In terms of operating costs, they are cheaper to run from day one. While EV upfront costs are also becoming increasingly competitive with fossil fuel vehicles, it is still a barrier for many New Zealanders.
- **Space heating systems (999,000 space heaters, 455 boilers[47])**: Both commercial and residential heating systems, including fixed heaters (wall-mounted and ducted), portable heaters, and boilers have substantial emissions reductions impact. While heat pumps are more expensive upfront than gas, these costs are typically recouped through operational savings and improved energy efficiency. Electric resistive heaters are less efficient, but also less expensive upfront than gas heaters while being zero-emissions.
- **Commercial LPG cooktops (10,600[48]):** Although relatively low in number, commercial LPG cooktops have higher energy intensity and longer usage periods than residential cooktops. Therefore, replacing these cooktops with induction/resistive alternatives represents an opportunity. Electric alternatives are mainstream, economically viable, face minimal deployment barriers, and have added health and safety benefits especially from the elimination of indoor air pollution.[49] [50]
- **On-road motorbikes (215,000):** Urban electric motorbikes offer significant emissions reduction potential with minimal barriers to adoption. With improving battery technology, models now provide adequate range for most users while delivering substantial operational cost savings through reduced fuel and maintenance expenses.
- **Water heating systems (566,000 water heaters, 64 boilers[51]):** Similar to space heating systems, water heaters are common across residential and commercial settings and are a significant energy user, with mainstream electric alternatives offering comparable or superior performance.

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45 Emissions and opex savings for electrifying space heating boilers and water heating boilers have not yet been included in these numbers. These machines are from large >500 kW sites and would require bespoke solutions to electrify. We did not have sufficient data to estimate their emissions and opex savings from electrification.

46 The quantities shown in this list include only the fossil fuel variants of these machines, i.e. the number of machines that need to be electrified.

47 The number of boilers used for space heating and water heating was estimated separately, however it is likely that some of these boilers will be used for both space and water heating.

48 Natural gas cooktops are not included in this "Ready" category due to natural gas being cheaper than electricity currently. This may change in the future as gas prices change.

49 Gruenwald, T., Seals, B. A., Knibbs, L. D., & Hosgood, H. D. (2023). Population attributable fraction of gas stoves and childhood asthma in the United States. International Journal of Environmental Research and Public Health, 20(1), 75. Accessed from https://www.mdpi.com/1660-4601/20/1/75

50 Kashtan, Y. S., Nicholson, M., Finnegan, C., Ouyang, Z., Lebel, E. D., Michanowicz, D. R., ... & Jackson, R. B. (2023). Gas and propane combustion from stoves emits benzene and increases indoor air pollution. Environmental Science & Technology, 57(26), 9653-9663. Accessed from https://pubs.acs.org/doi/10.1021/acs.est.2c09289

51 Some water heating boilers may be dual purpose and also provide space heating.

- **LPG[52] Cooking ovens (71,000 residential, 1,400 commercial):** Both residential and commercial cooking ovens present straightforward electrification opportunities. Electric alternatives provide precise temperature control, improved energy efficiency, and eliminate indoor air pollutants while reducing operational costs over their lifespan.
- **Push mowers (505,000):** Small to medium sized lawn mowers represent an easy electrification opportunity with immediate benefits. Electric alternatives are widely available, cost-competitive at purchase, more convenient (quieter, lighter, no fuel storage), and eliminate air pollution while reducing operating costs significantly.

4.1.2 Recommendations for this category

Rethink emissions reduction as a cost saving, not a cost burden
Emissions reduction isn't too expensive to pursue; rather, continuing with fossil fuel machines is becoming too expensive to maintain. For the majority of a household or business's decarbonisation journey, emissions reduction is a money saving opportunity. Electric alternatives are typically cheaper to run and far more energy efficient than their fossil fuel counterparts. By clearly communicating the return on investment for different sectors, we can demonstrate the compelling business case for electrification that benefits households, businesses, and farms financially while reducing emissions.

Address short-term purchasing decisions that lock in emissions
Despite the long-term economic advantage of electric alternatives, consumers often make purchasing decisions based on immediate affordability rather than lifetime costs. For example, new gas water heaters continue to be installed because the upfront cost of heat pump alternatives is prohibitive for many households, even though they are cheaper over their lifetime. Similarly, petrol vehicles are purchased when suitable electric options would cost much less to run over their lifespan. These purchases lock in emissions and higher bills for years to come. By addressing upfront cost barriers through innovative financing and removing information gaps, these decisions could rapidly shift to electric alternatives, delivering substantial cumulative emissions reductions.

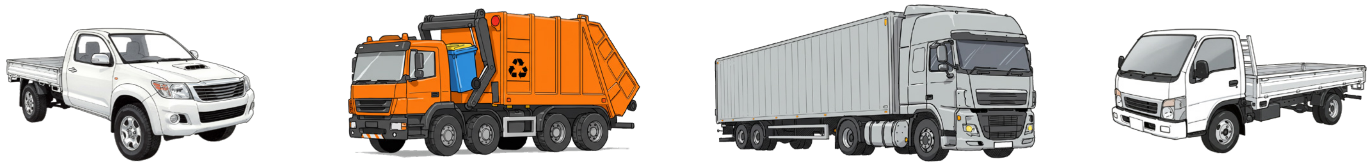
Prioritise process and finance innovation
It is clear that for these "Ready to electrify" category machines, the primary barriers are not technology or lifetime cost, but process and finance (loan product) constraints. Conventional policy focus has emphasised large industrial machines and supply-side economics, overlooking the significant potential of consumer-side machines. Many of the machines are already highly deployable. These machines require practical innovation of process and finance – accessible finance mechanisms, streamlined purchasing pathways, and better consumer information – rather than further conventional technical innovation. See Section 5 for more on process and finance innovation.

Recognise the aggregate and cumulative impact of small changes
Climate change is fundamentally a cumulative emissions problem. Small annual emission reductions turn into large cumulative savings over time. Furthermore, these small machines in aggregate make up more emissions than the big supply side machines. The faster fossil fuel machines are removed from the economy, the greater the avoided cumulative climate emissions. Understanding which machines are both technically and economically feasible to electrify now provides a roadmap for rapid emissions reduction while generating economic benefits.

52 Natural gas ovens are not included in this "Ready" category due to natural gas being cheaper than electricity currently. This may change in the future as gas prices change.

4.2 Almost ready: Limited availability

10% of fossil fuel machines sit in this "Almost ready" electrifiability category. They have electric alternatives which are cost competitive or in many cases cheaper over their lifetime, but have limited availability in Aotearoa New Zealand and therefore require more effort to procure or to install. Summary Table 3 in Section 10 highlights the top priority machines in this category and their potential savings, while the sections below elaborate on the machine types and recommendations for accelerating adoption.



4.2.1 Types of machines

The following is a list of the top-ranking fossil fuel machines based on emissions impact in this category. Their electric alternatives are economically viable (i.e. are similar cost over the machine lifetime) and are commercially available in other countries, but have limited availability in Aotearoa New Zealand. Essentially, they are opportunities for rapid emission reduction with no technical barriers in most cases, that require a little more intervention focus. By electrifying the following 950,000 highest priority fossil fuel machines based on emissions of the total 990,000 in this medium-electrifiability category, we would save approximately $2.4 billion NZD per year in operating costs, and 7.2 million tonnes of CO_2e per year in emissions.

- **Trucks (69,000 heavy; 68,000 medium; 6,000 small):** Smaller trucks have a range of electric alternatives that meet different specification requirements. While heavy trucks present higher upfront costs and less availability, they offer greater operational savings due to their long-haul usage patterns and high fuel consumption. Leasing and distribution businesses are making these increasingly accessible in Aotearoa New Zealand.
- **Light commercial vehicles (540,000 utes; 195,000 light vans; 10,500 heavy vans):** Vans and utes combine high numbers with intensive usage patterns. Electric alternatives are becoming increasingly available, although with limited models available especially in larger sizes.
- **Buses (17,000 small; 10,000 large):** Public and private buses contribute significantly to emissions and running costs due to their high mileage and diesel consumption. With electric buses becoming commonplace in public transit fleets, this represents a mature technology transition opportunity.
- **Small tractors (6,000):** Compact and sub-compact tractors now demonstrate favorable lifetime costs for electric models, with available units in the 40-65 hp range delivering performance comparable to larger conventional tractors due to electric motors' instant torque advantages.
- **Rubbish collection trucks (930):** These specialised vehicles consume substantial diesel while operating on predictable routes with frequent stops – ideal behavioural conditions for electrification. Electric models are already widely deployed in many regions around the country.
- **Loaders (6,800):** Electric loader models are now available for lease, offering substantial operational savings due to their high diesel consumption when compared to conventional alternative

4.2.2 Recommendations for this category

Many of the process and finance innovations detailed for the "Ready" category above (Section 4.1.2) apply for these machines. However, this category also requires an acceleration of our import channels and domestic supply chains for these machine types to enable rapid, large-scale adoption. These machines remain low-hanging fruit for emissions reduction and warrant high priority. See Section 5.2.7 for more on improving procurement of electric machines available overseas.

4.3 Not ready: Technical & economic barriers

6% of our fossil fuel machines have been classified as “not ready” for mass electrification. Their electric alternatives are not yet commercially available anywhere, or their higher upfront costs can not be recouped by their operating cost savings. Summary Table 4 in Section 10 highlights the top priority machines in this category and their potential savings, while the sections below elaborate on the machine types and recommendations for accelerating adoption.





4.3.1 Types of machines

The following is a list of the top-ranking fossil fuel machines based on emissions impact in this category. By electrifying the following 71,000 highest priority fossil fuel machines based on emissions of the total 680,000 in this "Not ready" category, we would save approximately $370 million NZD per year in operating costs, and 1.7 million tons of CO_2e per year in emissions.

- **Mining trucks (2,600):** There is one electric underground mining truck currently available in the USA. Caterpillar has developed a large, battery-powered mining truck that is in the testing/validation stage in the USA.
- **Large tractors (37,000):** Few electric tractor models are available in Aotearoa New Zealand, although more options exist overseas. Current models are limited to lighter agricultural/horticultural applications due to lower horsepower. Higher horsepower models remain in early field testing or prototype development. However, diesel tractors in the 100-120 hp range could potentially be replaced with 50-70 hp electric tractors, as their instant torque delivers performance equivalent to 80-90 hp diesel models.
- **Excavators (30,000):** Limited options are available in Aotearoa New Zealand, with leasing also possible. Hybrid excavators have been successfully deployed by Aotearoa New Zealand companies through leasing arrangements, delivering fuel cost savings, though fully electric options are yet to be seen.
- **Concrete trucks (990):** At least one electric concrete mixer truck is already operating in Aotearoa New Zealand, with additional models available overseas. This technology is near market, but not yet readily available off the shelf, which places it in this category rather than the "Almost ready" category. These vehicles are becoming cost-competitive over their lifetime. They primarily just require import and distribution support to make them commercially available in Aotearoa New Zealand.

Other common machine types on this list include specialised agricultural equipment such as sprayers, harvesters, frost fans, and heavy forestry equipment; water transport such as ocean-going vessels, jet boats, ferries, and larger motorboats; aviation vehicles such as jumbo jet planes and helicopters; snowcats; and specialised industrial equipment like bulldozers, mulchers, and plate compactors.

4.3.2 Recommendations for this category

Expand demonstration pathways for emerging technologies

Expand funding for sector-specific demonstration programs where businesses can test pre-commercial electric alternatives with reduced financial risk like the EECA Demonstration Fund. These real-world trials build market confidence, and help identify implementation challenges before mass deployment. Early adopters should receive recognition and support to offset the higher costs and risks they assume as technology pioneers. We should recognise that accelerating the adoption of these machines will likely drive millions in savings for the New Zealand economy when they become available to the masses, these calculations (how much accelerating adoption could save) should be taken into account and is likely to justify helping early on to advance progress.

Prepare infrastructure and policy frameworks in advance

Although these technologies aren't commercially viable today, historical innovation curves suggest breakthroughs can happen rapidly. Decision makers should develop forward-looking infrastructure plans and regulatory frameworks that will enable swift adoption once technological and economic tipping points are reached. This preparatory work – including charging infrastructure and workforce training – will significantly reduce deployment lag when zero-emission alternatives arrive.

Target deep tech research and development funding to New Zealand based opportunities

For this category of machines – representing only 6% of our total count[53] – electric alternatives are either still in development or not yet economically viable over their lifetime. Rather than waiting for solutions from overseas, in some cases New Zealand may have an opportunity to become a world leader in developing these technologies ourselves. Our high fossil fuel costs mean we are one of the first nations to reach many electrification tipping points, which encourage this innovation to happen before other nations. An example of this may be our agricultural sector, which could be developing the electric farm equipment and learnings that can be exported to the world. An example of this type of development is seen in the electric sprayer developed for use on Forest Lodge Orchard.[54]

4.4 Process heat

There is significant emissions reduction potential from electrifying process heat boilers, furnaces, kilns, air heaters, other types of burners, and steam methane reformers. These machines use large amounts of fossil fuels to generate heat, which is used in manufacturing processes. There are 1,279 of these machines in larger sites across Aotearoa New Zealand.[55] [56] In 2021, emissions from process heat were estimated to be 28% of energy emissions.[57] However emissions from process heat have dropped in recent years due to decarbonisation efforts and declining natural gas supply. These machines have been treated separately in this research because there is more technical complexity to swapping process heat systems for electric or bioenergy alternatives. The economics and best technical option varies by site and operating temperate range. EECA is undertaking site-by-site analysis of decarbonisation options for large process heat users across each region of the country through its Regional Energy Transition Accelerator project, which provides a comprehensive analysis.[58] Summary Table 5 in Section 10 summarises EECA's findings on the state of technical solutions to electrifying process heat across three different temperature ranges.

For hot water at temperatures less than 100°C, hot water heat pumps are efficient and in many cases can save businesses money over the lifetime of the investment. For steam or direct heat between 100°C to 300°C, electrode boilers or high temperature heat pumps can supply process heating needs. Demonstration of high temperature heat pumps is still in progress in New Zealand.[59] In many cases, the lifetime cost of electrode boilers is a barrier to electrifying medium temperature process heat. This is due to electricity and network charges being higher than current fossil fuel costs. However, for plants using natural gas, expectations of high future gas prices are a key driver for investment in electrification of process heat. For temperatures over 300°C, electric technology is still nascent, but development is underway. The exception is electric arc furnaces, which reach temperatures up to 1500°C and are already used in steel-making to replace coal and natural gas.

4.5 Generators

Summary Table 6 in Section 10 lists the different types of electricity generators in New Zealand. Distributed backup generators excluded from the counts in this table due to lack of comprehensive data. Renewable electricity generation and batteries can provide suitable alternatives to fossil fuel generators in many, but not all, situations. They can provide additional benefits when connected to the local distribution network by exporting electricity when local network demand is high. This reduces network congestion, and can offset the need to invest in network upgrades. In turn, this can reduce costs to consumers who bear the cost of network upgrades.

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53 We do not have the percentage of our total domestic emissions from this category of machines, as it was outside the scope of this project to estimate the emissions for every machine type.
54 https://www.forestlodge.nz/post/the-1500e01-electric-foliage-sprayer-is-now-complete-and-it-works-perfectly
55 This includes large boilers used for space and water heating, which are categorised as "Ready" as it is typically technically and economically feasible to replace these with heat pumps. Excluding these boilers, there remain 755 process heat machines.
56 In this context, larger means over 500kW thermal capacity at each site.
57 https://www.eeca.govt.nz/insights/eeca-insights/accelerating-the-decarbonisation-of-process-heat/
58 https://www.eeca.govt.nz/co-funding-and-support/products/about-reta/
59 There are already very high temperature heat pumps commercially available overseas for temperatures up to 280°C and EECA is in the process of funding demonstration of high temperature heat pumps in Aotearoa New Zealand. https://www.eeca.govt.nz/assets/EECA-Resources/Technology-Demonstration-Projects-Utilising-Very-High-Temperature-Heat-Pumps-Briefing-Slides.pdf

5.0 Recommendations

Aotearoa New Zealand has natural advantages to be a world leader in deployment of electric machines. This is because it is one of the first countries worldwide to pass an "electrification tipping point" for many fossil fuel machines – meaning zero-emission electric alternatives are widely available, and also economically feasible (will save money over the lifetime of the machine). We know from the Machine Count findings that the majority (84%) of machines are already in this category and represent over 25% of energy emissions. Another 24% of emissions are from almost-ready machines, which are economically feasible and available overseas, if not widely available here. Enabling homes and businesses to buy electric will save them money over the lifetime of the machine, reduce our reliance on imported fossil fuel, and reduce emissions – a win-win-win.

The challenge and opportunity for Aotearoa is to deliver these benefits for all New Zealanders, by developing an effective deployment innovation program.This means innovation to support energy emissions reduction does not need to prioritise conventional technical innovation, rather, deployment innovation. This includes:

- Electrification finance: Making zero-emission purchase decisions possible through simple accessible and affordable finance that unlocks benefits for the purchaser.
- Process innovation: Improving import and distribution networks to overcome limitations in supply chains, simplifying installation processes, addressing electrical infrastructure constraints on older sites, and training people to fill workforce skill gaps.
- Building trusted processes for consumers to receive quotes, installation work, and general educational advice on the best energy decisions to make for their interests

Section 5.1 explores electrification finance. For households and some businesses, this could be best provided through wide-reaching loan schemes (Section 5.1.4). This is because the design of these schemes can provide low-interest affordable loans that are accessible to both renters and property owners. Repayments can be made on timelines that allow them to be covered by fuel savings from electrification. For households, repayments can be deferrable to cater for different financial situations.

Alternatives to electrification finance exist, such as energy-as-a-service. This is where electric appliances owned by a third party are put into homes or businesses, and bills for the energy service from the machine (for example, the heat from the heat pump) are paid over time. Rent-to-own schemes are another variation of this. While we think these schemes can add consumer choice, they may not always be the most affordable option for consumers, because a profit margin must be made on this business model. On the other hand, affordable electrification finance can be designed to maximise benefits for the purchaser with low borrowing rates, and provide competition for these alternatives, putting downward pressure on the costs of such services.

Relying on consumer choice as a strategy for electrification means education and process innovation activity need to be wide-reaching, accessible, and prominent for all New Zealanders. Therefore, a step change in these activities is needed to deliver electrification at scale. The first priority in this space is to link the procurement process for electric machines to the process of accessing a council enabled loan (Section 5.1.5). In addition, a range of process and education measures will be required (Section 5.2). These proposed measures are necessary steps to support widespread uptake of electric machines, and could complement any future policy measures such as mandates for electric machines. They provide a flexible future-proof approach that enables consumer choice and maximises benefits to the people using the machines.

As noted in Section 4.3, 6% of our fossil fuel machines have been classified as "not ready" for mass electrification. Their electric alternatives are not yet commercially available anywhere, or their higher upfront costs can not be recouped by their operating cost savings over their lifetime. For many of the machines in this category, significant international effort is underway to develop and commercialise electric alternatives. However, New Zealand has a natural advantage to invest in technical innovation in the agricultural technology sector ("agritech") and demonstration and regulatory development to support electrification of short range domestic aviation, as explored in sections 5.3 and 5.4 respectively.

5.1 Simple, accessible, affordable electrification finance

Most electric machines have higher upfront costs than their fossil fuel counterparts, but lower operating costs. 94% of these also have lower total lifetime costs than the fossil fuel option, meaning they are likely to be better investments overall for a home or business as illustrated in Figure 5.1.[60]

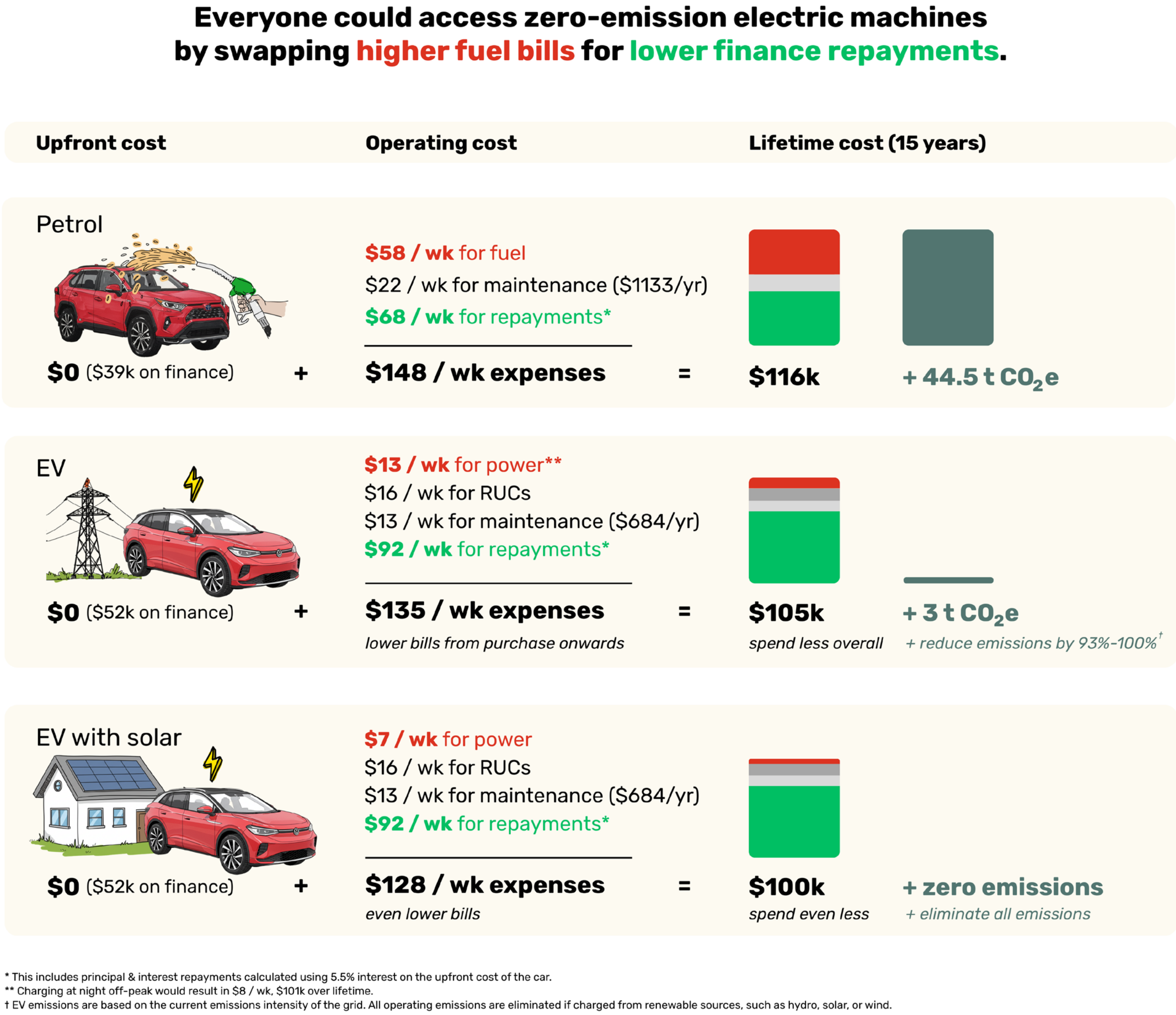


Figure 5.1: Comparison of lifetime cost between petrol and electric cars, taking into account finance repayments.

Addressing the upfront cost barrier through accessible financing options is critical for the widespread electrification. This section highlights the current challenges in finance, and the opportunities for innovation in this space unlock access to zero-emission machines that are already cheaper over their lifetime for all New Zealanders.

5.1.1 Access to capital is unequally distributed

The speed and fairness of the energy transition will be heavily determined by access to finance. Unfortunately, access to capital (including via loans) is currently unevenly distributed. High-income households can get easier access to loans at lower interest rates than low-income households. While mortgage holders can sometimes redraw their loan, they will not always be approved to do so, even for a relatively small investment like a vehicle or solar, which will clearly save them more money over time than it costs to buy. Renters have few options for low-interest loans.

60 94% of fossil fuel machines have commercially available electric alternatives (in NZ and overseas) with lower total lifetime costs. 84% of fossil fuel machines have alternatives available in NZ with lower total lifetime costs

Current loan products designed to finance electrification and home rooftop solar panels are not easily accessible. These "green loans" (e.g. 0% to 1% loans offered on three to five year terms) are onerous to apply for, and have terms that are too short to provide immediate cost savings from purchase onwards (which should be possible given the lifetime cost of electric vehicles, as illustrated in Figure 5.1). This makes them accessible for primarily high-income mortgage holders, which is a very small fraction of New Zealanders.

New Zealand's student loan scheme already makes flexible, deferred finance widely available for students to invest in education regardless of their income - with benefits for them, and for the whole country. Similarly, flexible deferred electrification finance would have large benefits for households, especially those on low incomes, and for the whole country's energy system and emissions reduction. Accessible financing options allow households and businesses to pay for electric machines over time through the operational savings they generate, making it possible to save money on day one, while making better long term economic decisions. Unlocking this finance can be seen as a way to increase national energy productivity.

5.1.2 Lifetime savings are not captured in financing approvals

Fossil fuel machines often have a lower upfront capital cost, but a much higher operational cost. For example, an electric car might be $5,000 to $20,000 more than a similar petrol car, yet if that extra upfront cost is divided over the lifetime of the car, then it will often be lower than the lifetime costs of a petrol vehicle as illustrated in Figure 5.1. Our finance system currently ignores these benefits.

For example if you are approved for $30,000 of vehicle finance, and an electric vehicle will save you $10,000 over the finance period, then it should be clear that you should be approved for a $40,000 electric vehicle or $30,000 petrol vehicle. Yet this isn't the case today, because banks and finance providers often more or less ignore the savings that come from these energy economics. In this way our financing system fundamentally favours fossil fuels, where upfront costs are low and long term costs are high and more volatile.

In the case of households, bank borrowing limits can make it difficult to add cost to a mortgage, or to access a higher value car loan to purchase an electric machine. This is the case even if the purchase would predictably increase the home's disposable income through fuel savings, making the mortgage or loan easier and less risky to repay. It is still not easy to get a long-term loan for solar, which saves money for the home and pays for itself more than once over, even though solar panel warranties can be 30 years long.

5.1.3 Split incentives for renters and landlords

Many rented properties could be saving on their energy bills today with solar on the roof and electrified appliances. However, part of the reason they don't is due to a split incentive between a short-term tenant who pays the energy bills, and a long-term landlord who does not. This is a system inefficiency in the energy market that makes it harder for renters to receive the financial benefits of electrification, and provides the landlord with minimal reason to electrify. This system inefficiency should be corrected to ensure more cost of living savings for New Zealanders, and a lower cost, lower emission, more resilient energy system for New Zealand.

5.1.4 Key criteria for quality electrification finance

Electrification finance should include the following features:

- It should be accessible to all New Zealanders. It should not exclude lower income groups or those with limited access to debt (e.g. pensioners). Borrowing rates should be the same for all New Zealanders. Transaction costs should be low, and the process to access loans should be easy to navigate to avoid creating barriers. For example, energy bill savings should be something that is calculated by the loan provider, not the borrower who does not have energy economics knowledge, potentially via an independent calculator that could also be accessible to the borrower.
- Finance terms need to match or be close to product lifetimes. This is absolutely crucial to remove the bias towards fossil fuels in the financing system. Examples would be approximately 10-15 years for appliances, batteries, and vehicles; and 20-30 years for solar. This enables the savings from the product (compared to fossil fuel alternatives) to go towards paying back the loan, in turn enabling savings from day one. This is more important than the rate of the finance. A loan for solar over 5 years at 1% still requires a home to take a cost of living hit for 5 years to then get savings afterwards. This is not feasible for many New Zealanders, which means the loan only serves wealthier households. In contrast, a loan at 5% over 15 years would enable the home to

save money from day one due to lower weekly repayments that are eclipsed by the savings generated. They would then continue to save money every day over the entire repayment period, making it accessible and beneficial to all homes who can access the loan.

- Finance needs to be affordable. This means the lending rate and the term for repayment must be reasonable, ensuring that New Zealanders can pay back loans using the savings from reduced energy bills. Given that electric products have high repayability (they save more than they cost, and reduce energy bill volatility) and can be highly secured (they are typically appliances that are physically attached to a home, whose asset value far exceeds the product value), the interest rate should be reasonably low, not far above inflation. They could be similar to mortgage rates, not like some of the personal loan products today which can theoretically be used for electrification but may have 10% or higher interest rates.
- Finance should be provided by a trusted party who complies with requirements above. There is a risk of non-trusted parties harming trust in electric technologies. Effort should be made to ensure a high-trust and transparent process for consumers making investments in electrification that will benefit both themselves and the nation.
- Finance should provide safeguards to support changing financial circumstances for households, e.g. loan break periods due to temporary periods of unemployment without removing the electric machines.
- Household electrification finance needs to have safeguards to avoid creating new financial challenges for households. For households that can currently afford to pay energy bills, electrification finance mechanisms need to set borrowers up to benefit from electrification in a way that encourages them to make repayments based on fossil fuel savings and avoids accumulation of debt. It should avoid putting people in positions where they cannot afford their repayments. For example, if households are struggling to pay their current energy bills, swapping fuel bills for finance repayments may lower overall costs, but could add unserviceable debt to a household. This should be avoided. For households in challenging financial situations where paying energy bills can be difficult, alternative options including subsidies and grants for electric machines are required.
- The design should include mechanisms to address the split incentive for investment in electrification between landlord and renters. This could include providing opportunities for landlords to access loans to invest in electrification on rental property, who can pass through a portion of the energy cost savings in rent (at a lower amount than the renters' bill savings), and repay loans using the additional rental revenue.

5.1.5 Loan schemes solution examples

There are a range of loan scheme options that can deliver simple, accessible and affordable electrification finance to New Zealand homes and businesses. Below we set out examples of loan schemes that could be designed to meet the criteria above. It should be noted that electrification finance is an urgent need for rapid emissions reduction and cost of living alleviation, but some loan schemes will take longer to develop than others. Therefore, we recommend starting now and progressing multiple options, which can compete in the market to increase consumer choice.

Council-enabled Loans

The central government has an opportunity to partner with local government to establish a scheme providing affordable financing options for all rateable properties. This initiative would offer interest rates 1%-1.5% below bank fixed-term mortgage rates. Building upon the proven success of the Local Government Funding Agency, this programme could effectively mobilise private capital through bonds. The scheme would leverage council balance sheets and existing council authorities, which would provide robust security for repayments against properties. With minor legislative change, for which precedents already exist, this finance could be structured to avoid impacting council "debt ceilings". Centralised administration and a user-friendly application portal would ensure low transaction costs for both councils and households.

For some households, repayment of loans could be deferred until property sale (similar to the Electrify Everything Loan Scheme described below). This approach ensures that energy savings are available to fully contribute to reducing a household's living costs. Multiple billing options are available for consideration. Integration with a property's quarterly rates bill could include an accurate estimate of what the energy bill would have been without the electric machines installed via this scheme.

Given that the loan is linked to properties, the scheme could be designed to incentivise landlords' investment in electrification by making electric appliances the more financially attractive option when replacements are due. Additional complementary policies and actions would be required to comprehensively resolve the split incentive challenges between tenants and property owners regarding electrification initiatives.

See Rewiring Aotearoa's *Electrification Manifesto* for more information.

Electrify Everything Loan Scheme: Deferred loans secured on property

Past governments have created universal tertiary education through student loans, with repayments linked to earnings. Like education, electrification is an upfront investment in the future with both private and public benefits, and if it can be financed in a way that allows people to repay when they're best able to, it becomes more accessible to everyone.

A loan for electrification that is secured on the property title, indexed to inflation, and repaid on sale would offer a simple mechanism for everyone, regardless of income, to make the switch, while minimising the cost to taxpayers. With clear protections and concessions to protect consumers at the time of repayment for example the ability to add voluntary and/or "income contingent" repayments, this proposition would provide a simple mechanism for New Zealanders to invest.

On-power bill finance: Treating homes as infrastructure

Integrating finance repayments directly into power bills represents the most "natural" approach for funding electrification initiatives, as power bills are where households will realise cost savings. The overall bill decreases, with one portion allocated to finance repayment and the remainder covering actual electricity consumption. To ensure financial viability for consumers, repayment terms should extend over longer terms (minimum ten years), aligning with capital depreciation. This structure ensures bill-payers experience net financial benefits throughout the repayment period. The underlying electricity distribution business (EDB) could potentially hold this loan facility, with repayments seamlessly incorporated into regular billing processes.

Longer term bank loans secured against the property with a caveat

Conventional banking finance for electrification investments (appliances, solar, batteries, and electric vehicles) could significantly expand its usefulness to everyday New Zealanders if extended to 10-15 years, or even 30 years for solar systems which have 30 year warranties. This approach would enable most electrification investments to generate net savings from day one, simplifying purchase decisions for consumers. Anecdotal evidence suggests current bank "green loan" application processes are often cumbersome and time-consuming, frequently leading to abandoned applications. Streamlining this process would substantially increase consumer uptake. Given that technologies like solar panels generate lifetime savings exceeding purchase costs, pre-approval could be a default assuming it is secured against the property. Similar pre-approval calculations could be applied to various electrification products, all of which deliver returns on investment exceeding capital costs. While offering such loans remains a commercial decision for financial institutions, the Government could investigate feasibility by engaging with banks to identify and address barriers to providing these financing options.

5.2 Process innovation

In order to spark mass electrification, we need to make electrification the easy, obvious choice. Innovation is essential to streamline purchase decisions for New Zealanders. This includes eliminating practical barriers by providing clear information on cost savings and benefits of electric alternatives, offering technical advice at point of purchase, and resolving incentive misalignments for equipment in rental properties (such as water heaters and space heating systems). The loan schemes described in the previous section could be designed to link purchasers with trusted advice on electric machines and recommend reliable tradespeople.

5.2.1 Widespread awareness campaign

It is important to build widespread awareness of the benefits from switching to electric machines proactively. Pivotal electrification decisions can be urgent – for example, the house's gas hot water heater breaks, showers are running cold, and the adults in the household are busy. A like-for-like replacement with another gas water heater may seem to be the fastest and easiest option in the absence of better information, but the environmental and economic costs of locking into another fossil fuel appliance will last for a decade or more. Therefore we need education that starts before the breakdown point.

A widespread education campaign can demonstrate the economic, health and environmental benefits of upgrading away from fossil fuelled appliances and other machines to electric alternatives and to avoid lock-in of years of high energy costs and high emissions. Campaigns will need to be targeted to the appropriate audience - for example households and specific sectors, and information can be provided through a range of mediums.

A widespread awareness campaign that includes:

- Education campaign for trades people such as electricians and plumbers to advise on electric options, ensuring that efficient electric options are the default replacement
- Education for sales representatives in key sectors such as car sales and farm machinery sales
- Public funding for widespread roll out of community electrification pilots
- Adaptation and expansion of appliance star-rating stickers and vehicle emissions labels to be more informative
- Regulated requirement for transparency of rental property energy costs

5.2.2 Support for tradespeople as crucial advisors at point of purchase

Hot water systems and air conditioners are frequently purchased through an installer or builder rather than directly by a consumer "off the shelf". These professionals are key influencers in purchase decisions. It is vital that they understand and effectively communicate both the financial benefits and the long-term advantages of electric options to their customers, taking into account the likely future realities of the energy system.

Tradespeople understandably prioritise delivering reliable service based on their past experience, often making them cautious about adopting newer technologies like hot water heat pumps. Customers often expect speedy delivery, and an electric upgrade rather than a like-for-like replacement may introduce additional risks and costs. Installers must also maintain customer trust regarding value. The higher upfront costs of heat pump equipment might appear as unnecessary upselling to customers who are unaware of these options and did not request them.

Clear information, training, and incentives should be provided to help tradespeople advise and support people to make the switch to electric. Specific training should cover key electrification upgrades including hot water systems, cooking appliances, EV charger installation, and gas disconnection. Emerging digital tools such as online quoting systems that compare long-term operational costs across different options can serve as valuable independent resources to support installers' recommendations for electric alternatives.

5.2.3 Education for sales representatives in key sectors

Education should be extended to sales representatives in sectors such as automotive and agricultural machinery sales, equipping them to articulate the advantages of electric alternatives. Independent online comparison tools could effectively reinforce these recommendations and validate the recommendations of sales representatives.

5.2.4 Public funding for widespread roll out of community pilots

Public funding for widespread roll out of community pilots can help rapidly accelerate Aotearoa's energy innovation in a way that could help more homes save money on cost of living sooner, and more businesses lower their operational costs. Pilots can help remove red tape, refine processes, build workforce capacity and knowledge, and test the impacts of better energy education with consumers. They can also help the energy industry rapidly understand what the future energy system can look like, and how best to manage it in a way that will benefit the entire system, i.e. lowering bills for all New Zealanders.

Community electrification pilots should look like pockets of "fast forwarding" the local energy system to 2040. With full electrification, mass solar and battery adoption, and smart demand flexibility that connects between both consumers and networks. New Zealand is well placed - past the electrification tipping point - to run these pilots at minimal cost compared to other nations, and should therefore be taking advantage of this advantageous position in the energy transition.

Pilot projects are the ideal platform for solving the key problem of practical deployment. They allow a sandbox for making mass electrification easy and fast for average New Zealanders. Learnings can then be shared with the rest of New Zealand to help the entire energy transition move faster. Australia, who is at a similar position to New Zealand as one of the first countries to cross the electrification tipping point, is already deploying community electrification pilots,[61] and recently announced an expansion to this.[62]

61 https://theconversation.com/no-home-left-behind-a-postcode-approach-to-electrification-241471
62 https://www.theguardian.com/environment/2025/jan/28/suburb-wide-electrification-trials-to-be-rolled-out-across-australia-in-bid-to-fuel-transition-away-from-gas

For households, mistrust and confusion have been identified as some of the key impediments to electrification. There is a need for trusted, independent voices, especially for household electrification decisions. Community and local voices have an important role to play here, because perhaps the most crucial pathway to awareness and education is "word-of-mouth" – people discussing their choices and options with their friends and family, both generally and at purchase times. This makes community pilots and initiatives a critical part of the electrification picture where trusted conversations can update older social and economic assumptions.

In both Australia and New Zealand, community groups have started tackling this problem. The Electrify Boroondara group in Melbourne has created stickers to go onto existing gas water heaters to provide a prompt when it breaks down with clear information on the benefits and a simple way to find an installer for a heat pump water heater. Rewiring Aotearoa provides community groups with stickers to put on fossil fuel appliances, with a link to information about upgrading to electric appliances (Figure 5.2). There is potential to develop an "electric replacement" campaign utilising these kinds of stickers in New Zealand.

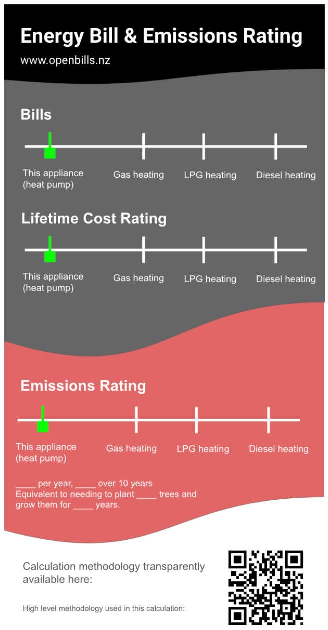


Figure 5.2: Examples of electrification stickers for gas appliances by Electrify Boroondara and Rewiring Aotearoa. (Left)
Figure 5.3: Early prototype of appliance sticker with energy and emissions cost saving information. (Right)

5.2.5 Expanded appliance energy labels

Current government "Energy rating" efficiency star labels on electric appliances help consumers identify more efficient options. However, they lack information on actual operating costs or emissions reductions. Consumers and businesses typically prioritise operational costs over technical energy efficiency metrics. Enhancing these labels to include specific cost and emissions savings information at point of purchase could accelerate electrification adoption while maximising bill savings for New Zealanders (see Figure 5.3 for example).

This initiative could commence immediately through a voluntary programme with interested electric appliance and vehicle manufacturers. It could subsequently be formalised as a mandatory requirement by incorporating it into existing government appliance labelling frameworks. Development as a joint initiative with Australia under the current Australian and New Zealand Equipment Energy Efficiency (E3) Programme would provide consistent standards across both markets.[63]

5.2.6 Expanded Vehicle Emissions and Energy Economy labels

Vehicle Emissions and Energy Economy labels are available and required for new and used vehicles sold in New Zealand.[64] These labels show the fuel cost and emissions from running fossil vehicles, but do not provide information on savings from purchasing an electric alternative. Expanded Vehicle Emissions and Energy Economy labels for cars, could make consumers aware of how much they could save on petrol or diesel costs over a 5 year lease and over a 15 year vehicle lifetime by choosing an electric vehicle.

63 https://www.eeca.govt.nz/regulations/equipment-energy-efficiency/about-the-e3-programme/
64 https://resources.fuelsaver.govt.nz/label-generator

5.2.7 Increase general transparency of rental property energy costs

The lower bills that result from electrification and efficient appliances are also opaque and hidden at another crucial point: when purchasing or leasing a home. People buying or renting a home should know what bills to expect, and making this information clear and required on real estate listings could help drive important improvements in New Zealand's housing. This is particularly important for renters who can't usually make electrification changes themselves. This creates the 'split incentive' problem: the landlord chooses and pays for appliances, but the renter benefits from lower bills. Finance schemes could help remove upfront cost barriers, especially for low income landlords, but other reforms are required to electrify rentals at scale and speed. There could be minimum standards that require landlords to electrify their properties over time. This would include a requirement for landlords to install electrified appliances when any gas appliance is replaced and also provide a clear framework enabling renters to request and access solar and battery upgrades.

Improving disclosure to renters about current energy bills, electrification status and home quality is another key immediate opportunity to drive the longer term improvement of Australia's housing. Openly showing the expected energy bills of rental properties in the advertisement listings could help address the split incentive by rewarding landlords for making bill-reducing investments that make their property more competitive when listed.

5.2.8 Improving access to electric machines

Ten per cent of the machines in our database have economically feasible alternatives available, but have limited availability in Aotearoa New Zealand ("Almost ready", Section 4.2). The highest emissions-ranking machines in this category are mostly heavier commercial vehicles like trucks, utes, vans, buses, tractors, and earthmoving loaders. Demonstration funding has been provided for many of these machines, and will continue to be important in some cases to illustrate the feasibility and benefits to potential buyers. However further steps are required to support the shift to mass adoption of these machines. It is important to make it easier for New Zealanders to procure these machines, without having to seek them out through complex engagements with overseas suppliers.[65]

Measures to facilitate this could include:

- Review machine offerings and prices for machines that don't yet have high availability in New Zealand. Engage with suppliers to understand barriers to expanded imports.
- Develop procurement strategies to seed the market benefiting from bulk purchases pricing.
- Wide-reaching community pilot programmes designed to encourage uptake.
- Engagement with key organisations that own many of these machines to understand machine turnover and barriers to uptake (e.g. rubbish trucks owned by WM New Zealand).

5.3 Agritech innovation

Aotearoa New Zealand possesses a strategic advantage for investment in electric agritech innovation. This advantage stems from our large agricultural sector and comparatively high diesel fuel prices relative to other advanced economies, making electrification economically viable over the lifetime of the machines. This presents an opportunity to leverage technological advancements in agritech that can both reduce domestic fuel costs and emissions while creating exportable technological advancements.

Development of electric task-specific implements such as fruit tree sprayers is already underway. These technologies can interface with electric tractors, drawing power from the tractor battery.[66] A small but growing market exists for purely electric-drive implements that traditionally relied on Power Take Off (PTO) systems.[67] While electric tractors can power existing PTO implements, this is significantly less efficient than powering electric implements directly via the tractor battery. For larger operations, the large power output required from electric tractors to run PTO implements presents challenges to electrification. Greater innovation in electric plug-in implements is crucial to fully leverage the capabilities of electric tractors and to strengthen their business case. The development of compatible implements must advance alongside electric tractors to ensure mutual adoption is not hindered.

65 https://www.eeca.govt.nz/insights/case-studies-and-articles/driver-optional-electric-tractor-leads-the-way-for-low-emissions-rural-transport/
66 https://trsequipment.co.nz/electric-cherries-the-journey-to-orchard-electrification/
67 PTO is a mechanism that transfers mechanical power from the tractor engine to an attached implement via a rotating shaft.

Electrification of dedicated application-specific farm vehicles is another opportunity for New Zealand. Innovation support could be provided through collaboration with specific sectors and existing machinery manufacturers. For example, self-propelled, closed-cab sprayers have become a staple for Aotearoa's kiwifruit sector, providing several key benefits for growers. The enclosed cab design eliminates the need for personal protective equipment (PPE) during chemical applications, and features like air conditioning and ergonomic seating enhance operator comfort during long working days. Critically, the low-profile nature of these self-propelled units allows them to easily navigate the confined space under kiwifruit pergola systems. Leading farm machinery providers could be engaged to investigate opportunities for electrifying components. Retrofit feasibility studies could also be explored. For example, assessments could be conducted to determine the technical and economic viability of retrofitting existing dedicated self-propelled farming machinery with electric powertrains, maximising the use of current assets.

5.3.1 Resilience benefits from electric Agritech

Beyond the environmental and operational benefits, electric tractors and self-propelled machinery could also serve as mobile energy storage units. Their large battery capacity could provide backup power or contribute to grid support when the machines are not in use, further enhancing the overall value proposition for investment by the agricultural sector.

5.4 Domestic aviation demonstration and regulatory development

New Zealand could leverage its small and potentially agile qualities as a nation to accelerate the necessary regulatory change that could make it a world leader in the energy transition. One such example is creating an electric aviation sandbox, with a streamlined approval process for building electric aircraft, and converting existing fossil fuel aircraft to electric propulsion. This sector currently faces significant regulatory barriers – some well justified, but others potentially unnecessary. Establishing a sandbox for innovation could attract international investment, talent, and companies, while demonstrating best practice aviation regulation to enable domestic aviation electrification. The Civil Aviation Service has recently developed a policy statement for exemptions from operation policy.[68] A similar approach could be explored for sandboxing to support aviation innovation if it could provide a streamline exemption process.

New Zealand's geography is particularly conducive to electric aviation development, with numerous short-haul routes and tourism flights, such as those connecting Queenstown and Milford Sound. This represents an opportunity for New Zealand to capitalise on its strengths as a premier tourism destination by acting promptly to secure early rewards. Electric aviation technology will initially be best suited to shorter flights – precisely the type common in tourism and sightseeing operations.

68 https://www.aviation.govt.nz/assets/about-us/policies-statements-procedures/Exemptions-Operational-Policy.pdf

6.0 Sector insights

Building upon the recommendations and innovation opportunities discussed above, it is essential to understand how machine electrification will impact different sectors across Aotearoa New Zealand. This section provides targeted insights for various sectors, examining their unique challenges and opportunities in the transition to electrification. This analysis encompasses four key sectors:

- Residential
- Farms
- Business (focussing on small and large offices, restaurants, hotels, earthmoving companies, large institutions)
- Industry (cement, methanol, steel, fertiliser, aluminium)

For the residential and farms sectors, Rewiring Aotearoa has developed models of energy requirements based on archetypal households and farms. These models are used to contextualise our machine-level findings within their real-world contexts, and to reveal sector-specific barriers and opportunities for electrification. These models catalogue the machines used, their annual operating hours, and the types and costs of fuels currently powering them. This data is then used to construct electrification pathways for each archetype (for full context on these sector-based models, see Appendix 2).

Rewiring Aotearoa also conducted a series of case studies across all four sectors, engaging directly with individuals and businesses to understand their machine usage and energy requirements. These case studies include examples of households and businesses that have successfully electrified, as well as those that have not yet begun the transition. This approach allowed exploration of real-world electrification challenges and opportunities using real-world data about energy needs, while also considering additional factors that influence electrification potential, including regional variations and ownership models. The following subsections provide a summary of key insights, as well as more specific survey and modelling insights where applicable, for each of the four sectors.

6.1 Residential

6.1.1 Key Insights

Residentially, electrification economics already work for most homes in most situations across Aotearoa New Zealand. This further emphasises just how fast home electrification can go, and how it can be used to rapidly accelerate Aotearoa New Zealand's emissions reduction while saving money on cost of living for homes.

A key clear insight is that the higher the energy use, the better the economics of home electrification. For example, a vehicle that drives longer commuting distances will save more from going electric compared to a vehicle that drives short distances. This is because the upfront cost remains largely the same, but the fuel savings increase. Prioritising electric vehicle programmes to deliver to longer distance commuters, including rural homes, could provide large emissions savings and larger than average financial savings for those people. With that being said, even homes driving short distances can still save with electric vehicles, and this is shown in the Appendix 2, Section 4. While every home is different, it is clear that for most homes the savings are already there to justify electrifying now.

Water heaters are another example where higher usage (or higher household occupancy) can lead to increased savings. This is because the water heater cost remains largely the same, but the savings from avoiding gas or LPG bills increases with increased water or shower usage. For example, a home with five people will find it easier to financially justify an upgrade to a heat pump hot water heater than a one person home.

It is clear across the residential electrification landscape that more focus should be put on deployment innovation, not technical innovation. The technology already exists to electrify most homes while saving money immediately, but the purchase decisions need to be made simple and easy for households. This includes finance innovation, paying off the upfront cost over the lifetime of the machine upgrade (such as solar or heat pump water heaters), and practical product innovation, such as, enabling renters to invest in solar, which in turn enables lower charging costs to encourage upgrading to an electric vehicle, and so on.

6.1.2 Survey Insights

The [residential & light transport survey] that Rewiring Aotearoa developed gathered data on household machines to complement existing residential data. The online survey collected a total of 1,763 responses during the project period. It gathered information on heating systems, water heating, cooking appliances, other household machines, and attitudes toward electrification. For full details of the survey design and results, see Appendix 1, Section 3.1. The following details some of the key insights.

Demographics

- Regional distribution was generally representative when compared to the Aotearoa New Zealand Census of Population and Dwellings.
- Homeowners were over-represented, and renters under-represented.
- Standalone houses were slightly over-represented, while townhouses and units were under-represented.
- Solar panel owners were over-represented (13.7% for survey compared to 3.0% nationwide).

Machine ownership

- The most common household machines were vehicles (3,432), home heaters (2,578), cooktops (1,791), and water heaters (1,763).
- Other significant machines included lawn mowers (857), line trimmers (433), chainsaws (421), leaf blowers (169), boats (138), motorbikes (138), pool pumps (41), and pool heaters (27).

Machine fuel types

- Only 4.7% of households are fully electric across all appliances and vehicles.
- 31.7% have fully electric home appliances but still use fossil fuel vehicles.
- Home heaters are predominantly electric – 70.5% of homes use electricity such as heat pumps or resistive heaters. The next most common is wood (19.4%), with gas (both LPG and natural gas) making up only 9.1%.
- Gas is more prevalent in water heating and cooking – 32.1% use gas for water heating, and 34.2% use gas cooktops.
- See Figure 6.1 below for further detail.

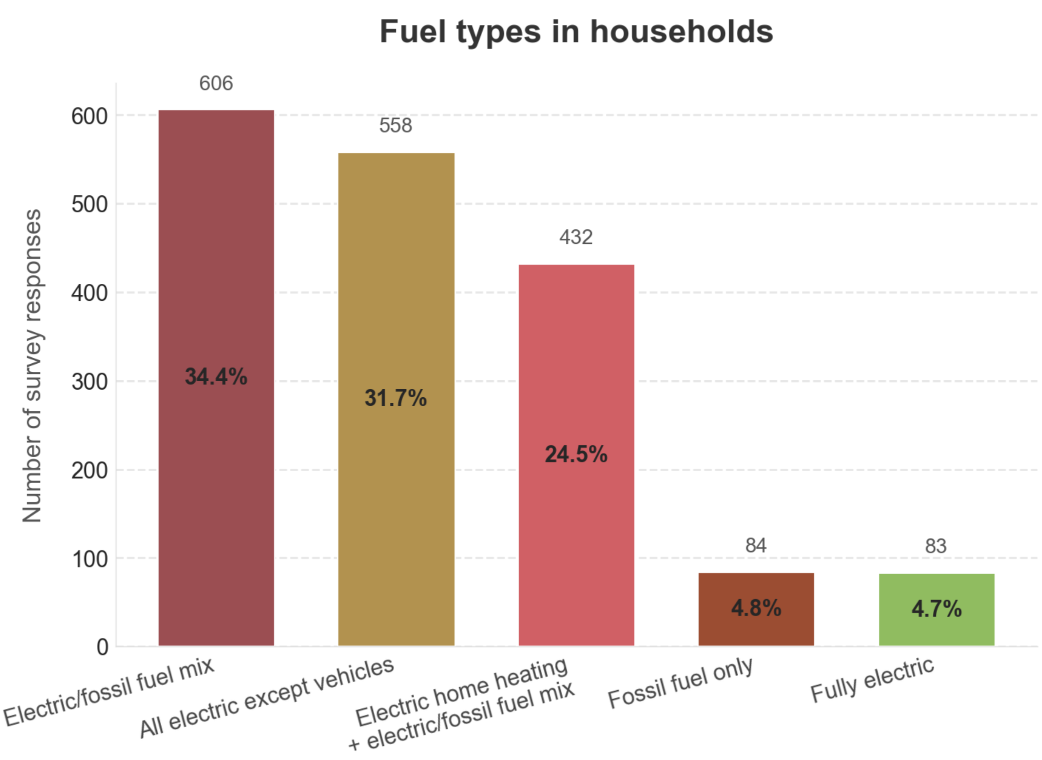


Figure 6.1: Mix of fuel types per household in residential and light survey responses

Vehicles

- Only 4.0% of households have fully electric vehicle fleets.
- Over 40% of petrol cars are driven under 50 km per week.
- See Figure 6.2 below for further detail.

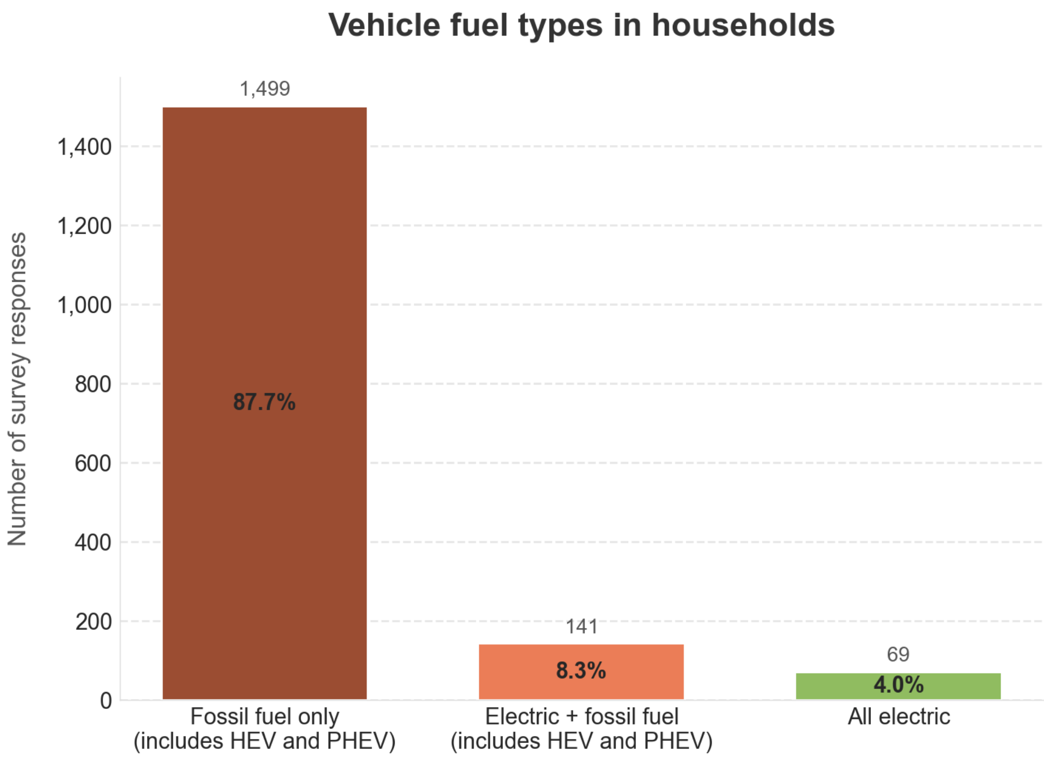


Figure 6.2: Distribution of vehicle fuel type combinations in households from residential and light vehicle survey

6.1.3 Modelling insights

From the residential and light vehicle survey results, we identified five key household archetypes for modeling using K-means clustering, an unsupervised machine learning algorithm for finding groups within data. These archetypes represent diverse household configurations across Aotearoa New Zealand. This included an Auckland apartment, a rural Waikato family home, a Dunedin residence, a Canterbury home with existing electric appliances, and a Wellington family home. Economic analysis demonstrated that electrification (including installing solar, and 5.5% interest on all upfront costs) creates substantial cost savings across nearly all household types at the same time as significantly reducing emissions (between 2,100-12,400 kg CO_2e annually per household). See Figures 6.3–6.7 below.

The most financially advantageous electrification opportunities, or "low-hanging fruit," include: converting LPG water heating (especially in South Island homes); replacing natural gas water heating; and transitioning to electric vehicles (with greater savings for households with higher driving distances). Solar installation further enhances the economics of electrification by reducing electricity costs. The modeling suggests that most household electrification in Aotearoa New Zealand already makes economic sense and could be rapidly accelerated to deliver both financial benefits to homeowners and substantial emissions reductions. For more details, see Appendix 2, Section 4.3.

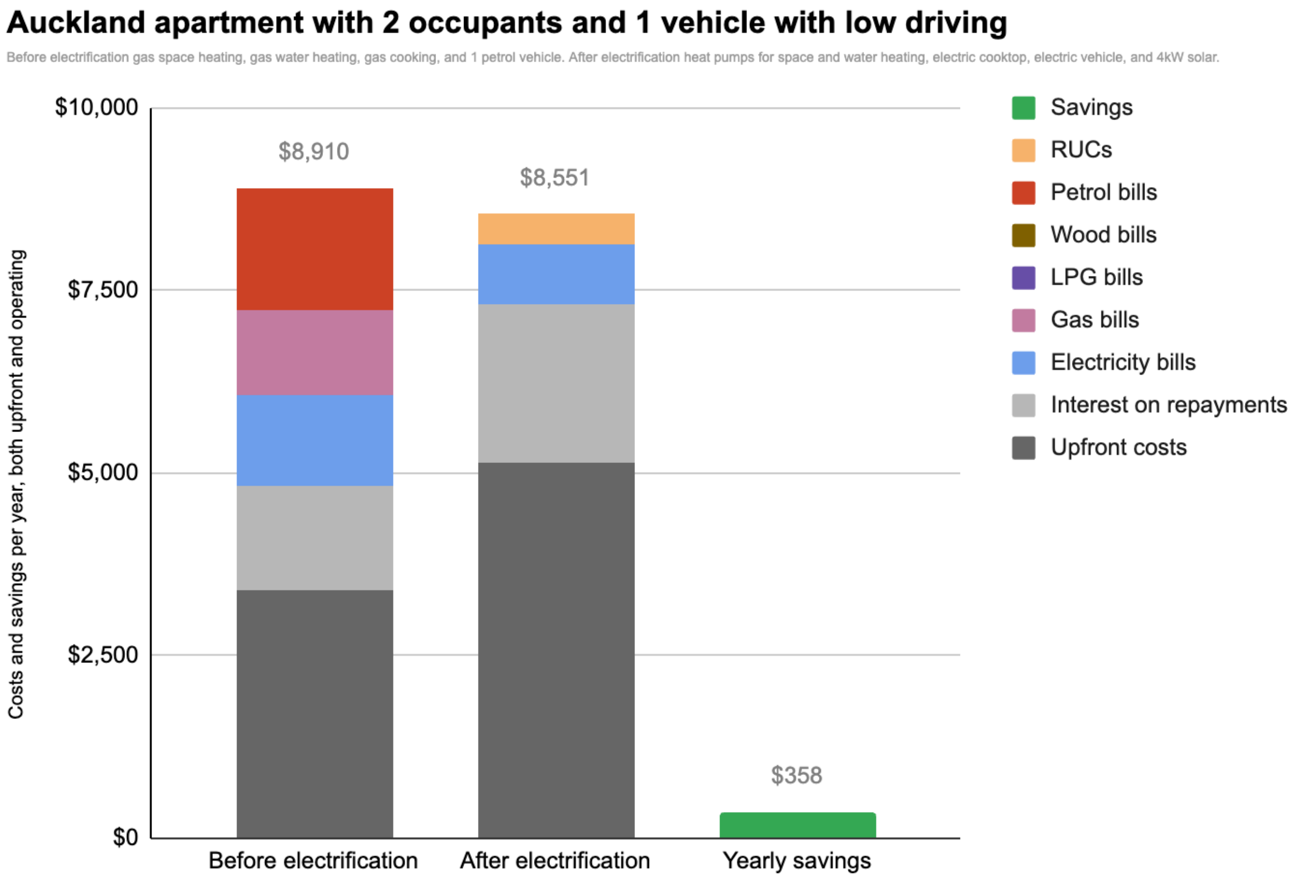


Figure 6.3: Cost savings per year from electrification for Auckland apartment archetype

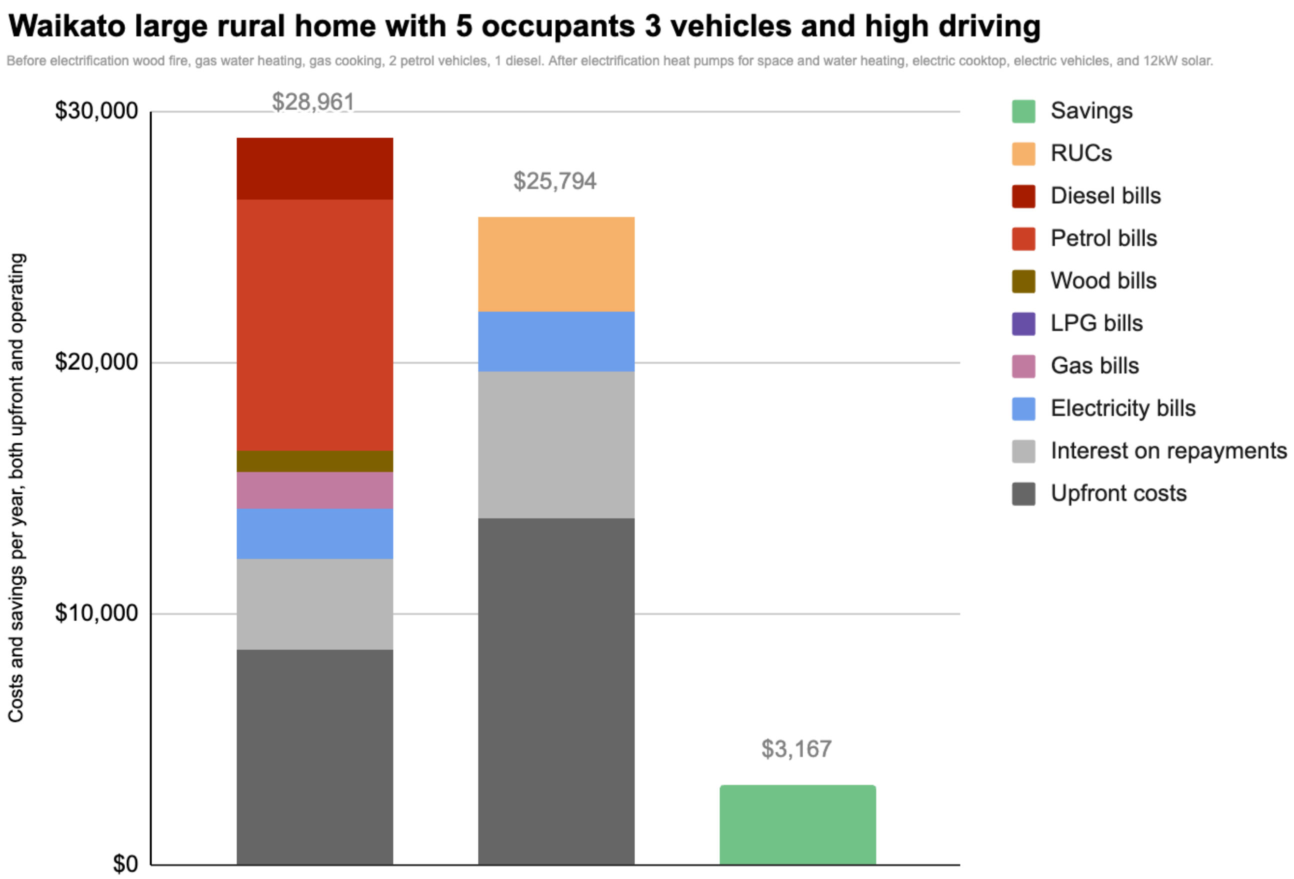


Figure 6.4: Cost savings per year from electrification for Waikato large rural home archetype

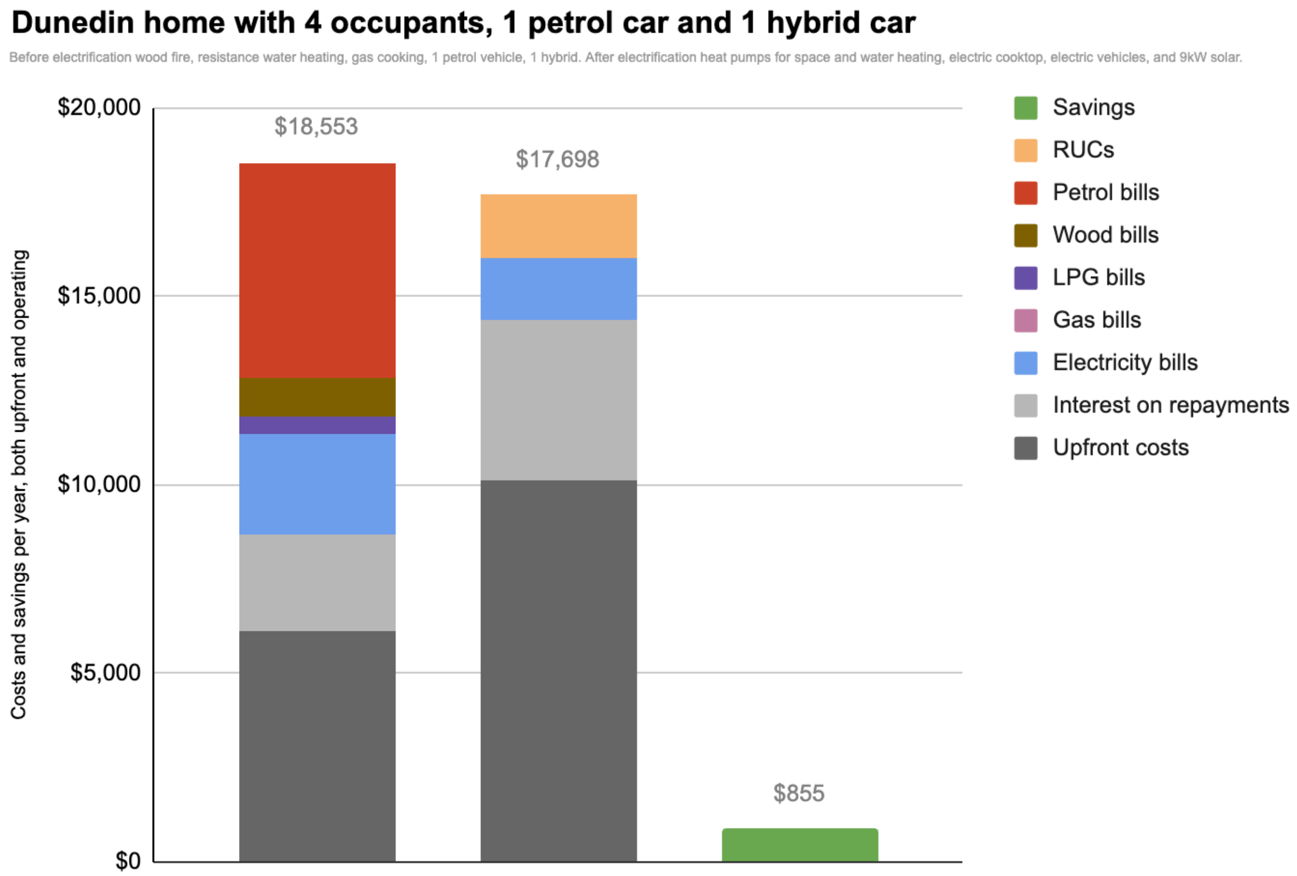


Figure 6.5: Cost savings per year from electrification for Dunedin home archetype

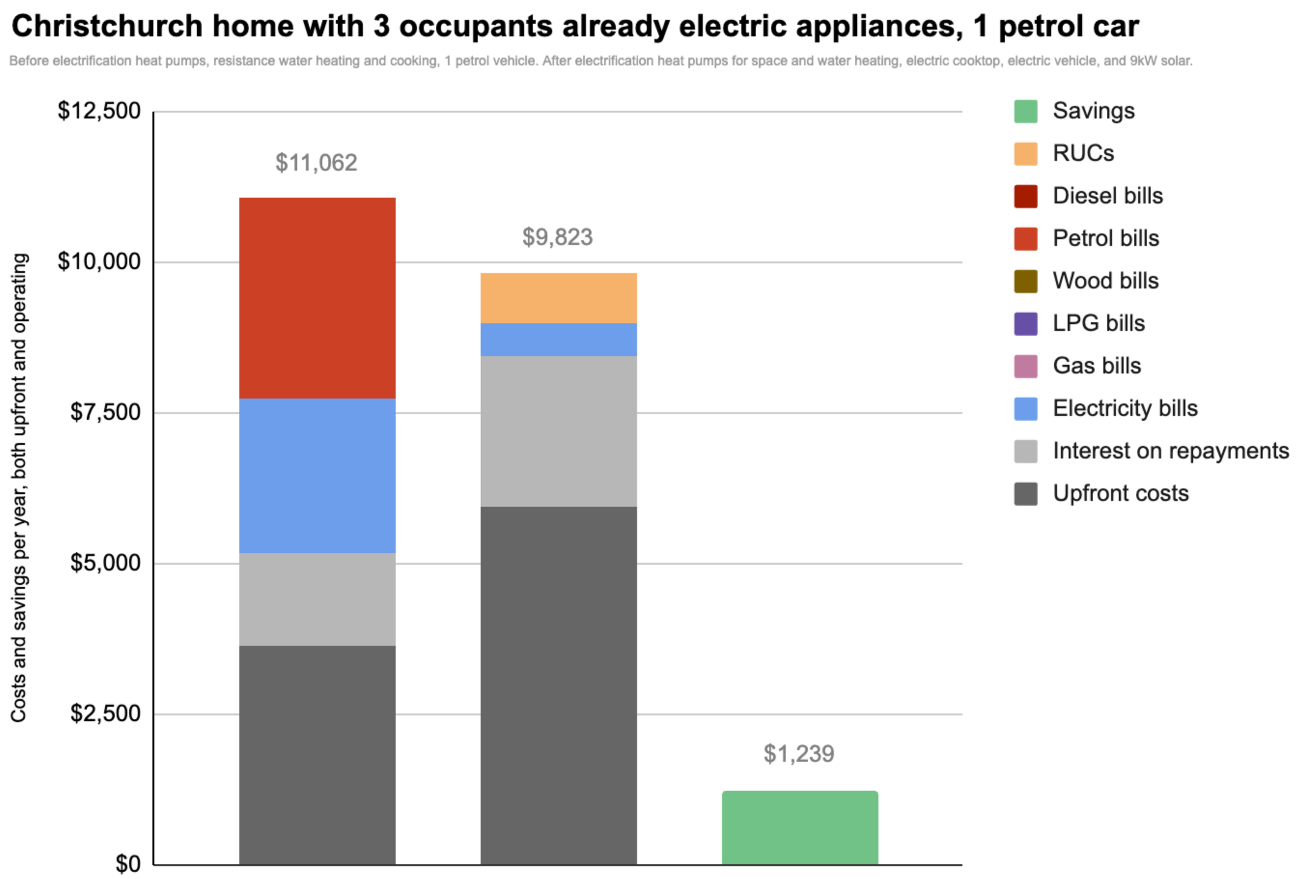


Figure 6.6: Cost savings per year from electrification for Christchurch home archetype

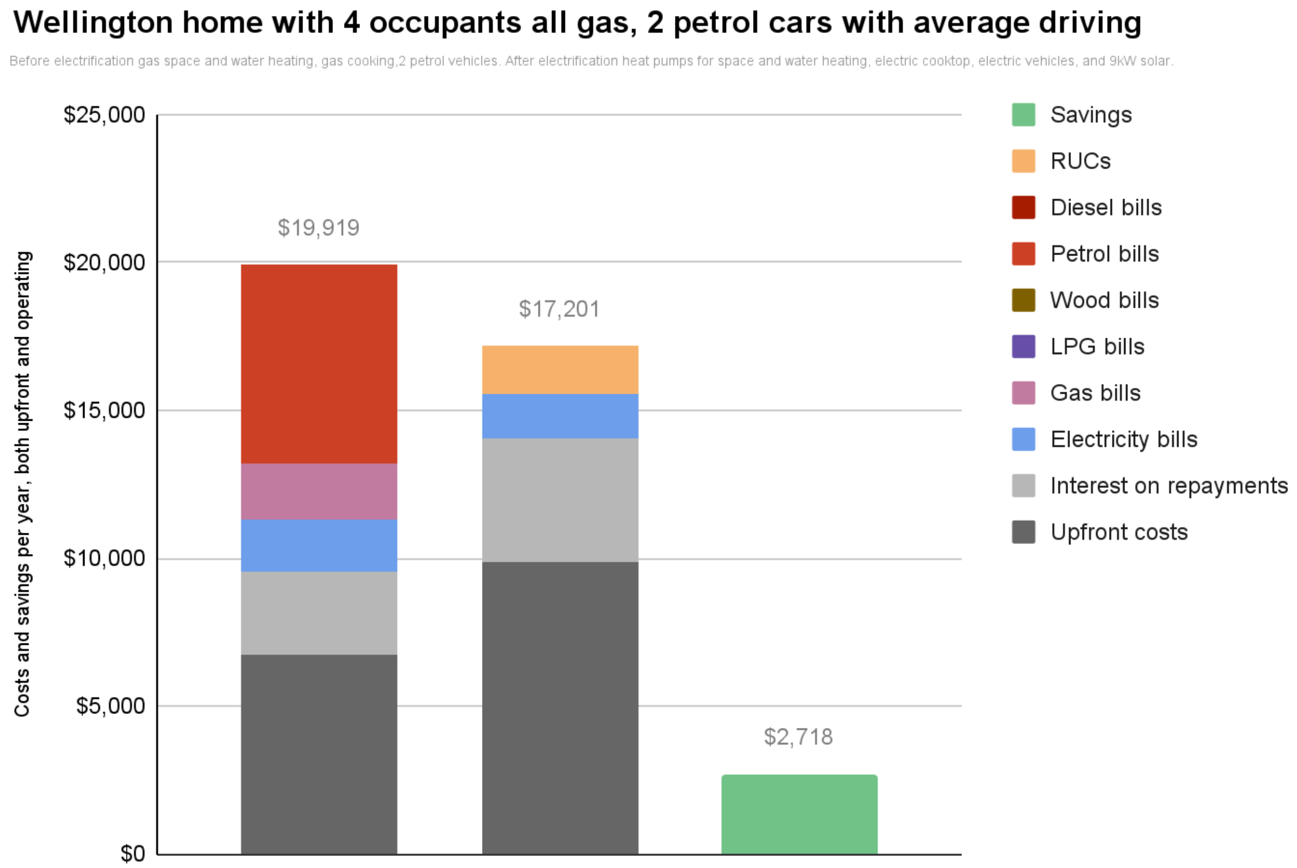


Figure 6.7: Cost savings per year from electrification for Wellington home archetype

6.2 Agricultural

Farming operations rely heavily on diesel and petrol machines, such as tractors, motorbikes, pumps, generators, and harvesters. Electrification offers a pathway to replace these machines with electric alternatives either powered by the country's highly renewable grid, or on-site solar generation. While much on-farm energy machinery, such as milking sheds, shearing equipment, and refrigeration, are already electrified, key farm machines remain dependent on fossil fuels. Given the diversity of farm operations, electrification is best approached at the machine level, allowing farmers to prioritize electrification based on factors such as usage, age, and available alternatives.

To unlock the full potential of farm electrification across Aotearoa New Zealand, it is essential to recognise the diversity of farm types, sizes, and operations. Each farm will have a unique electrification journey, shaped by its specific needs and challenges. To better understand these differences, Rewiring Aotearoa engaged directly with farmers to understand their operations, machinery use, electrification potential, sentiments, and barriers. These insights are presented as case studies in this report. Additionally, we analysed responses from the rural survey to map the distribution of farm types in Aotearoa New Zealand, identifying five key rural archetypes. For each archetype, we assessed machine inventories and usage patterns, outlining practical electrification pathways, and highlighting both quick wins and challenges. Our goal is for these case studies and models to serve as templates, guiding farms across Aotearoa New Zealand in their transition to electric alternatives. The following sections summarise key insights, opportunities, and challenges for the sector, as well as insights from modelling and case studies of various farm archetypes.

6.2.1 Key Insights

For each rural business archetype studied and modelled, it was found that, on average, at least 80% of the machine inventory could be electrified. Not only is electrification technically feasible, but it also results in significant cost savings for farmers over the operational lifetime of the machinery. When it comes to machines that are technically feasible to electrify but not yet economically viable, the key factor is machine usage. For equipment with high usage, switching to electric makes financial sense as the savings from reduced diesel consumption accumulate. Although it was initially assumed that larger-scale operations would face more challenges in electrifying their equipment, the higher usage of machinery on such farms actually makes electrification more economically feasible in the long term.

The primary challenge to electrification in the rural sector is the limited availability of electric options for certain machines, particularly those requiring high horsepower, such as large tractors, specialised harvesters, and forestry equipment (e.g., skidders and feller bunchers). The slow pace of technological advancements in these areas has resulted in a lack of electric alternatives.

6.2.2 Opportunities

This is a list of the machine types which are the “lowest-hanging fruit” for electrification due to the availability of electric alternatives and the potential cost and emission savings.

Landscaping Equipment

The easiest machines to electrify on most farms are landscaping and property maintenance tools, such as chainsaws, line trimmers, and push mowers. Electric alternatives to these machines are widely available and already in mainstream use, often with upfront costs equal to or lower than their fossil fuel counterparts. Modeling based on 50 hours of usage per year shows that, on average, these machines can reduce operating emissions by 1 tonne of CO_2e and save $1,000 over a 15-year lifetime. With increased yearly usage, both the emissions reductions and cost savings would be greater.

Electric tractors

Just a few years ago, electric tractors were not available in Aotearoa New Zealand, but today two brands, Monarch and Knegt, are in operation, with more expected in the near future. Utility tractors are used on nearly every farm for tasks such as mowing, cultivating, loading, and fertilising. With moderate usage of 500 hours per year, a single tractor can produce 254 tonnes of CO_2e emissions over its operational lifetime. Despite the higher upfront cost of electric tractors, switching to electric would save farmers $35,000 over the same period. Given the widespread use of fossil fuel tractors in Aotearoa New Zealand and the availability of electric alternatives, this presents a significant opportunity to reduce emissions and achieve long-term cost savings

Side by side UTVs

Side-by-side UTVs are commonly used on farms, with 53% of farms in our survey reporting ownership, and some farms having more than one. On farms with moderate to high usage, UTVs are among the higher emitters due to their high fuel consumption (when compared to smaller farm machines such as motorbikes) and frequent use. While the range of electric alternatives is currently limited, electric side-by-side UTVs are gaining popularity, with more manufacturers offering options in response to growing demand

Medium-sized Trucks

Even for farms with relatively low usage of medium trucks, replacing a diesel truck with an electric alternative can be economically beneficial due to the high hourly fuel consumption. For example, a horticulture farm using a truck for 300 hours per year can reduce emissions from 198 tonnes CO_2e to just 14 tonnes CO_2e over the truck’s lifetime, while saving $72,800 in operating expenses (amounting to overall savings of $54,000). There is a select range of medium trucks now available on the market in Aotearoa New Zealand, offering opportunity for farms to electrify and significantly reduce both emissions and operating costs

Forklifts

Through outreach with forklift vendors, we learned that advances in battery technology are making electric forklifts increasingly comparable in price to their diesel counterparts. For example, a 1.8-tonne diesel forklift is estimated at $25,000, while a similar electric model costs between $27,000 and $28,000. This price parity removes one of the largest barriers to electrifying farm machinery—high upfront costs. Electric forklifts are already in mainstream use and can save $15,000 and reduce emissions by 35 tonnes of CO_2e over 15 years, based on 300 hours of usage per year.

6.2.3 Challenges

Utes

Utes are widely used on farms, with 40% of surveyed farms reporting their use. Due to their high fuel consumption, they contribute significantly to a farm's emissions. Electrifying utes present a significant opportunity for reducing emissions, but currently, Aotearoa New Zealand only has one electric ute option available, the LDV NZ model, which may not meet the needs of farm usage due to limitations in range and towing capacity. However, electric ute alternatives are available in the UK and USA and may soon be accessible in this country. With an estimated yearly usage of 1,000 hours, switching to an electric ute could save $35,500 in operating costs and reduce emissions by 254 tonnes CO_2e over its lifetime.[69] There are also HEV and PHEV utes coming out this year, like the BYD Shark and the Ford Ranger PHEV. However, purchasing a hybrid in 2025 would still lock in emissions from the petrol consumption for the lifetime of the vehicle. Therefore, we do not see these as a true solution to decarbonising utes.

Forestry Equipment

Electrifying forestry equipment presents several challenges due to the limited availability of electric models and the high demands of forestry operations. While electric excavators, such as those from TDX and E-Trucks, are becoming commercially available, models suitable for forestry applications remain scarce. The same is true for skidders, shovel loggers, and feller bunchers, with no electric versions currently on the market. Although there is one electric forwarder developed by Finnish company Ponsse, it is not yet commercially available. The difficulty of establishing charging infrastructure in remote locations is another significant barrier that makes the electrification of forestry equipment challenging at this stage.

6.2.4 Modelling insights

A key finding across all rural businesses is that electrifying small machines, such as chainsaws, weed eaters, and push mowers, is almost always cost-effective. While the emissions reductions are relatively minor, these machines provide a straightforward and practical entry point for electrification. This section includes summary insights from the following model archetypes and case studies:

- Archetype 1: Medium-sized sheep and beef farm
- Archetype 2: Large dairy and dairy support farm
- Archetype 3: Arable crop and vegetable farm
- Archetype 4: Horticulture farm
- Archetype 5: Forestry Business
- Case Study 1: Fully electric cherry orchard
- Case Study 2: Partially electrified chicken farm
- Case Study 3: Solar-powered irrigation system

Archetype 1: Medium-sized sheep and beef farm

This archetype is a 450 ha mixed sheep and beef farm. The farm's machine inventory consists of a mix of vehicles (e.g., ute, side-by-side UTV), motive-powered equipment (e.g., tractor, digger), and diesel-powered pumps used for stock water and effluent management. Every machine on this farm, except for the digger and their high horsepower tractor, can be electrified. The biggest opportunities for cost savings and emissions reductions would be to electrify the 3 diesel fueled irrigation pumps, 2 side by side UTVs, and the utility tractor, due to their high yearly usage, which offsets the upfront investment of going electric. Electrifying these three machines will save the farm $233,700 ($20,700 per year) and 516.5 tonnes of CO_2e (34.4 tonnes per year) over the 15 year lifetime of these machines. See Figures 6.8 – 6.9 below for more detail.

69 For modelling purposes, the converted prices of these international options was considered.

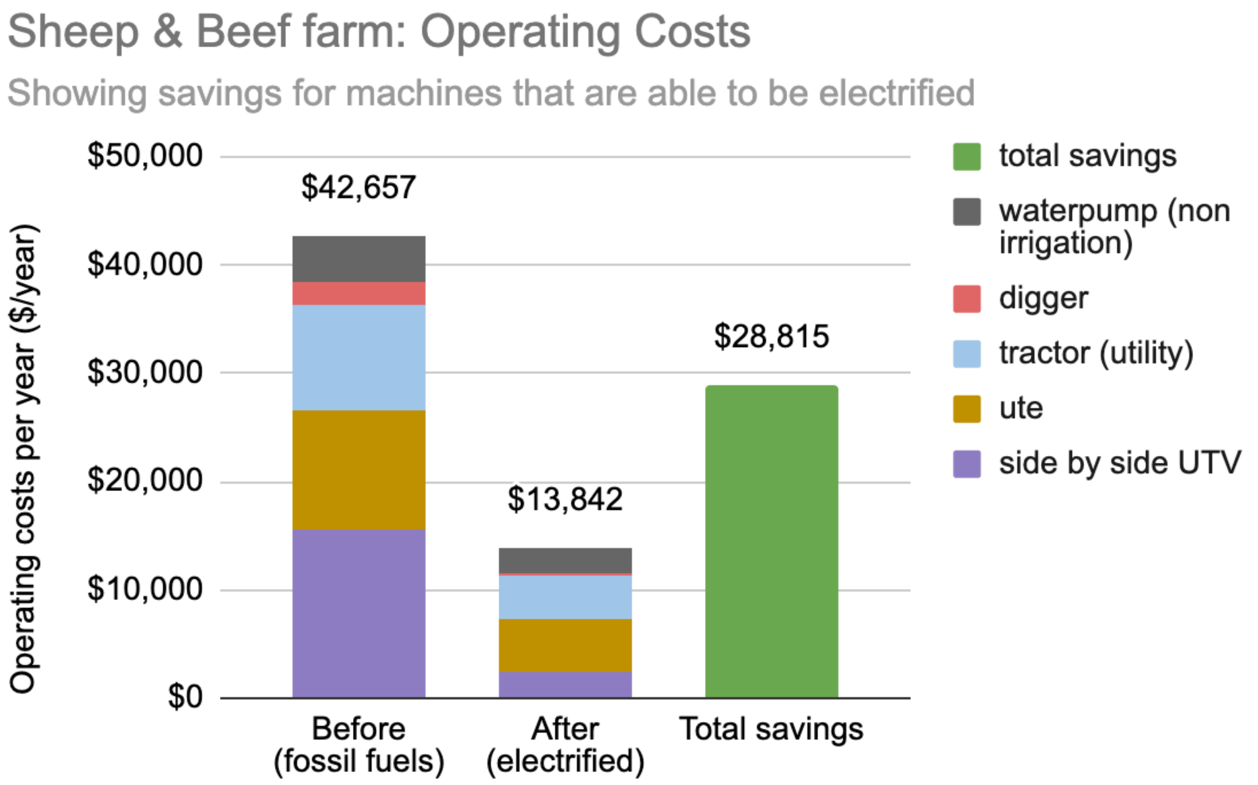


Figure 6.8: Operating cost savings from electrifying select machines on an archetypal sheep & beef farm

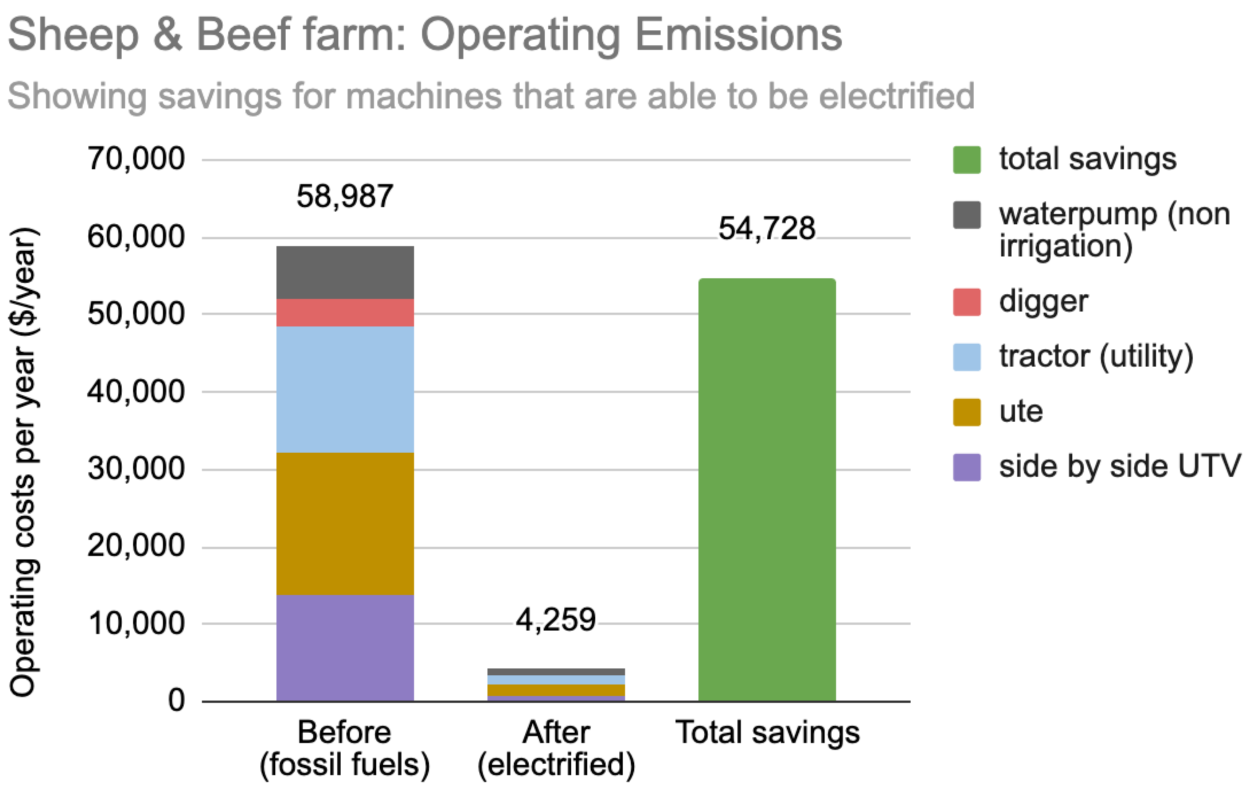


Figure 6.9: Emission savings from electrifying select machines on an archetypal sheep & beef farm

Archetype 2: Large-sized dairy and dairy support farm

This archetype is a 500 ha dairy and dairy support farm. The machine inventory for this farm involves a mix of vehicles (e.g. motorbikes, side by side UTV, ute), motive powered equipment (e.g. tractor, digger) and electric powered water pumps for irrigation and stock. This farm also has 500 m² of roofspace, as well as groundspace available for solar installation. The results from analysing its electrification potential is as follows:

- All machines on this farm can be electrified except for the digger, which is economically unfeasible, and the high-horsepower tractor and specialised harvester, for which electric alternatives are not yet available.
- Electrifying the 3 motorbikes on this farm provides the easiest electrification opportunity, saving $27,000 and reducing 38 tonnes of CO_2e over the 15 year lifetime of the motorbikes.
- Switching both UTVs next can deliver $8,200 in annual savings – totaling $83,700 over the operational lifetime – compared to a diesel model.
- Electrifying the utility tractors is crucial for cost and emissions reduction, saving $7,600 and 20 tonnes CO_2e annually per tractor. Over its lifetime, this amounts to $77,500 and 300 tonnes CO_2e, with double the impact if both are electrified.
- See Figures 6.10 – 6.11 below for more detail.

Solar potential

- Installing 500 m² of solar on the rooftop would generate 130 MWh per year for an upfront cost of $220,000. This could generate up to $1,000,000 ($34,000 per year) of savings over its 30 year lifetime if 50% of energy is exported and 50% is self-consumed.
- Installing 500 m² of ground-mounted solar could generate 130 MWh per year for an upfront cost of $220,000. This could generate up to $1,000,000 ($35,000 per year) of electricity over its 30 year lifetime if 50% of it is exported and 50% is self-consumed.

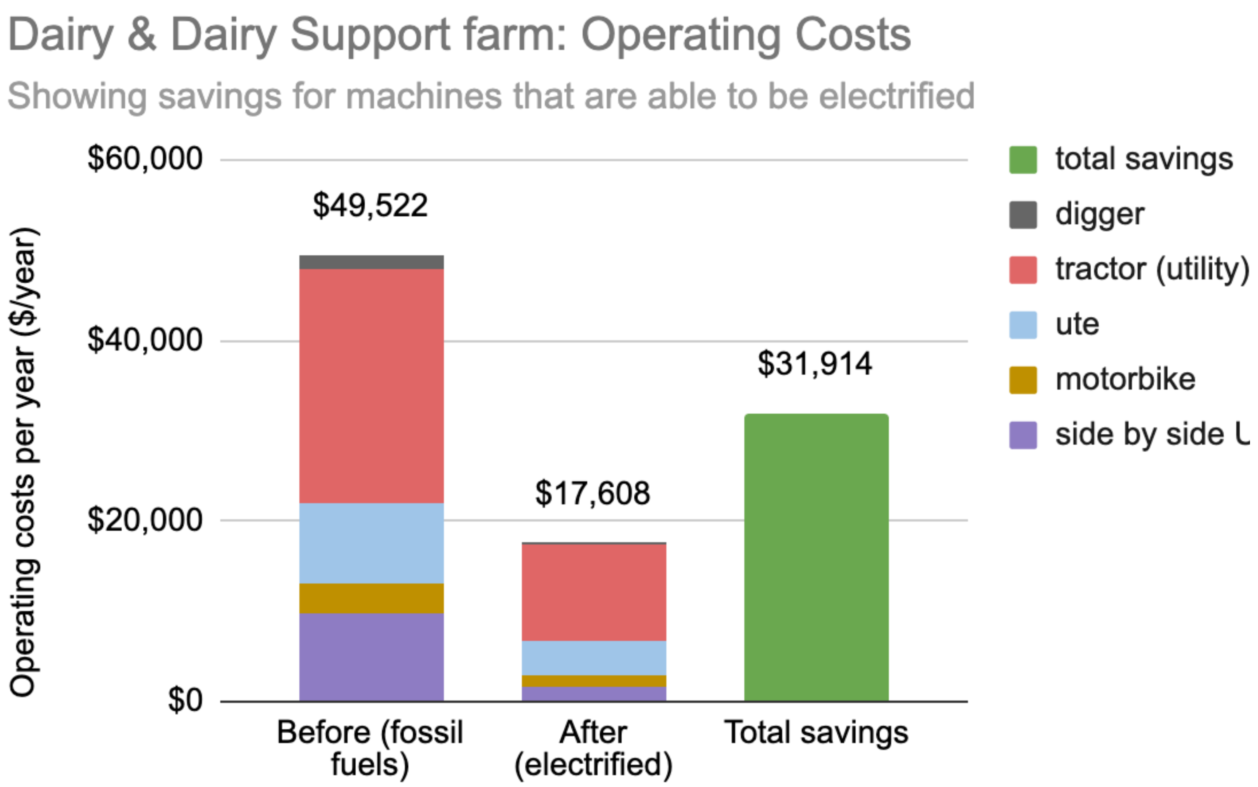


Figure 6.10: Operating cost savings from electrifying select machines on an archetypal dairy farm

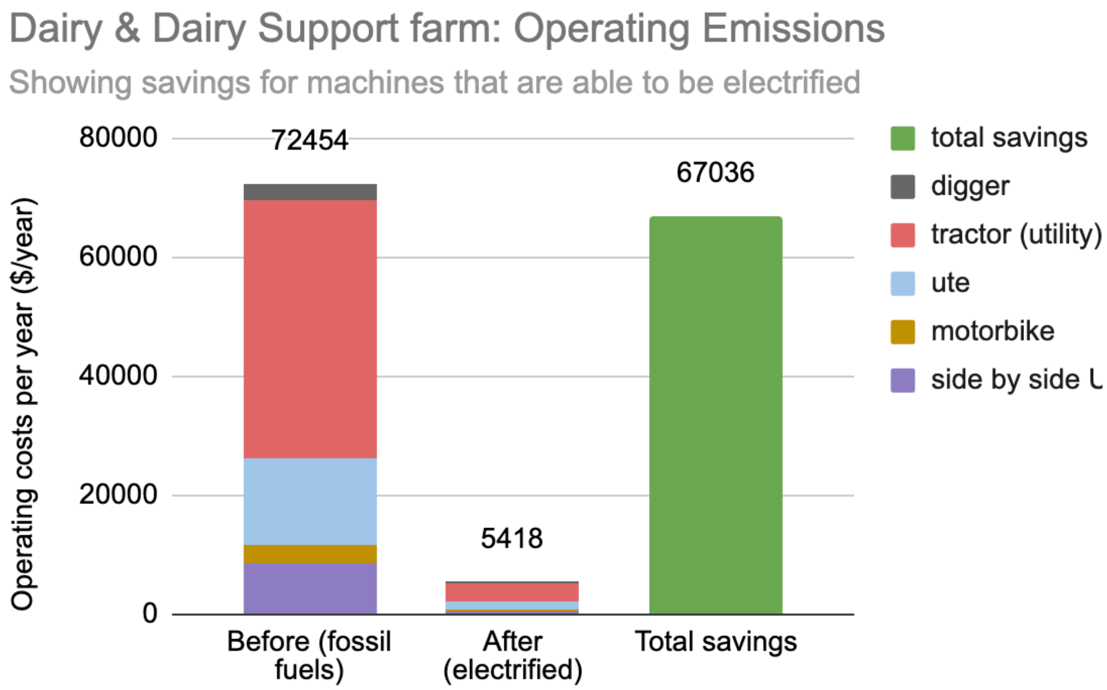


Figure 6.11: Emission savings from electrifying select machines on an archetypal dairy farm

Archetype 3: Arable crop and vegetable farm

This archetype is a 40ha farm that grows wheat, barley, potatoes, and onions with drip irrigation. They own small-to-medium machines such as a petrol ride-on mower, forklift and truck, but contracts infrequently used, larger equipment machines such as specialised harvesters. Due to high upfront cost to electrify, and moderate usage of the current diesel ute, it is not economical for this farm to electrify the ute. Additionally, the high horsepower tractor and the specialised harvesters can not be electrified due to an unavailability of electric alternatives. This farm could relatively easily electrify its ride-on mower and forklift at the time of replacement. For a combined upfront cost of $42,000, electrifying both would give $18,600 in savings and 34 tonnes CO_2e in emissions reduction over a 15 year lifetime. When feasible, the utility tractor and truck can also be electrified for an operational lifetime saving of $64,500 and emissions reduction of 310.3 tonnes CO_2e. This would require a combined upfront cost of $218,400. See Figures 6.12 – 6.13 below for more detail.

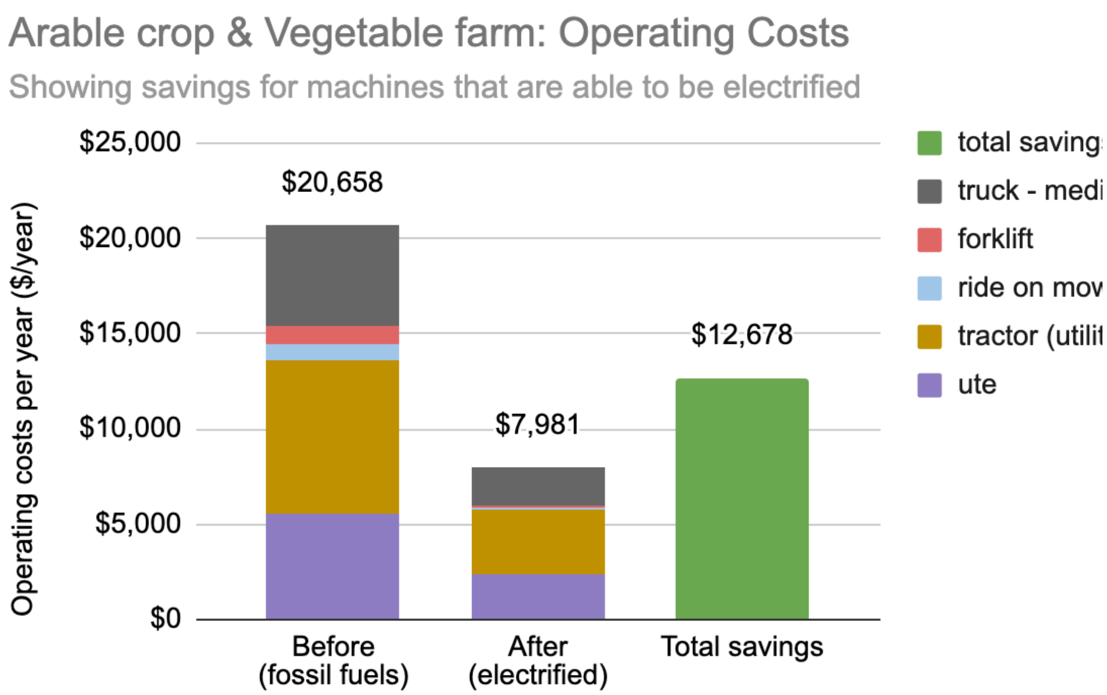


Figure 6.12: Operating cost savings from electrifying select machines on an archetypal arable crop & vegetable farm

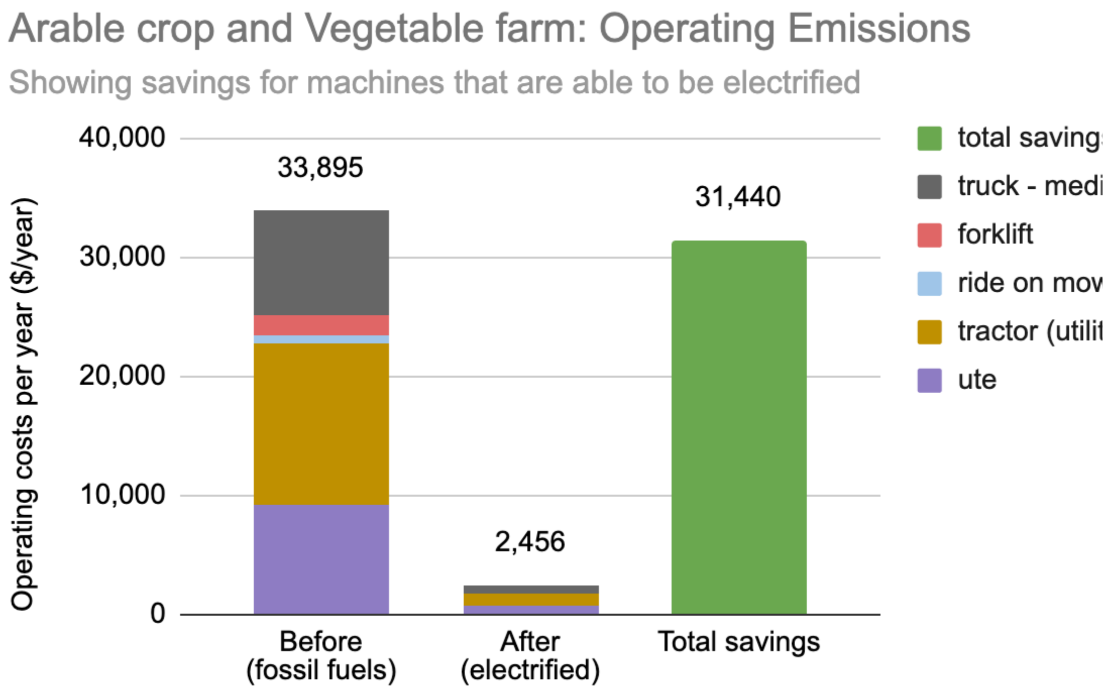


Figure 6.13: Emission savings from electrifying select machines on an archetypal arable crop & vegetable farm

Archetype 4: Horticulture farm

This archetype is a 10 ha farm that models machine usage for a kiwifruit, stone/pipfruit, or viticulture farm. The farm owns frequently used machinery, including a side-by-side UTV for orchard operations, a truck for handling produce, two frost fans for crop protection, and sprinklers for irrigation. The top electrification opportunities on this farm are the diesel truck and forklift. The truck offers the highest impact potential for a reasonable upfront cost, while the forklift has the smallest cost difference between diesel and electric options. Electrifying both could save $70,700 and reduce emissions by 219.5 tonnes CO_2e over a 15-year lifetime. Annually, this results in $6,100 in operating cost savings and a reduction of 14.6 tonnes CO_2e. The utility tractor, side-by-side UTV, and frost fans can be electrified next, recommended in that order based on lifetime cost savings versus upfront costs. While the tractor has a high upfront cost, it remains more affordable than electrifying two frost fans and offers greater savings of $34,700 and 187.9 tonnes CO_2e over its lifetime. If the farm's usage of its side-by-side UTV and frost fans increased, electrification may become more economically viable. As it stands, electrifying these machines could save $31,300 and reduce emissions by 124.1 tonnes CO_2e over 15 years. See Figures 6.14-6.15 for more details.

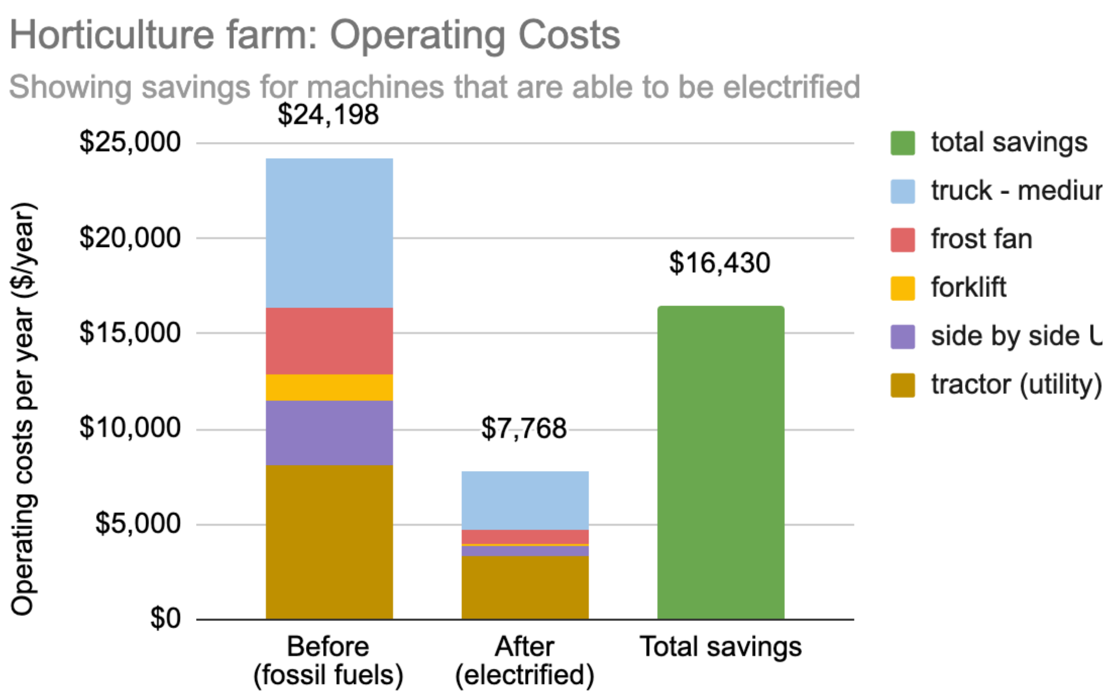


Figure 6.14: Operating cost savings from electrifying select machines on an archetypal horticulture farm

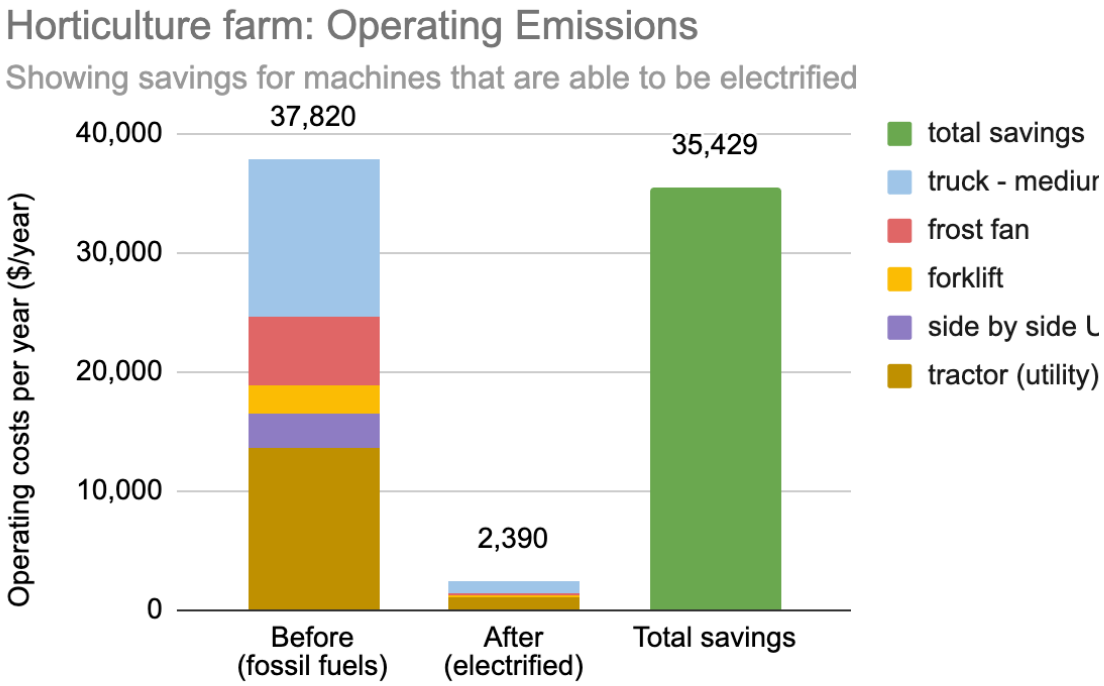
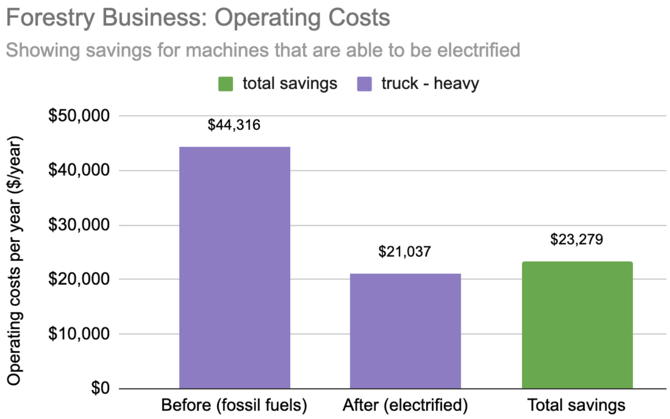


Figure 6.15: Emission savings from electrifying select machines on an archetypal horticulture farm

Archetype 5: Forestry Business

This archetype is a small forestry business that operates in Bay of Plenty plantation forests, typically working with smaller forestry blocks (20–100 hectares). The business relies on contracted machinery for harvesting, but owns a heavy truck for transport. The heavy truck is the only machine this business operates that can be electrified. Switching to an electric truck could reduce operating costs by $23,300 and emissions by 67.6 tonnes CO_2e annually, totalling $215,300 in savings and 1,000 tonnes CO_2e reduced over its lifetime (Figure 6.16). All other machinery, such as the digger, skidder, shovel logger, feller buncher, forwarder, and bulldozer, cannot be electrified at this stage due to the lack of technological advances and the unavailability of suitable models.



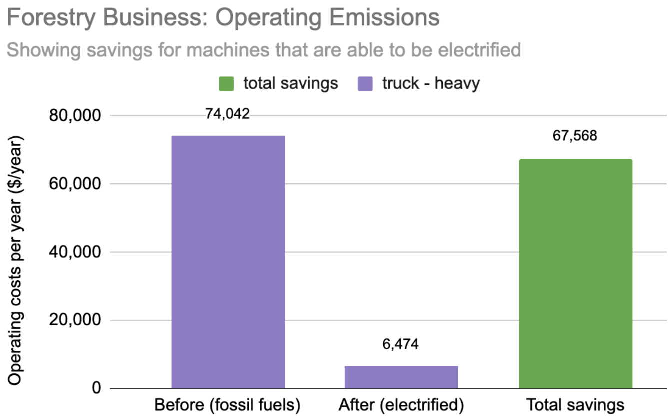


Figure 6.16: Cost and emission savings from electrifying one heavy truck

6.2.5 Case study insights

Modelling electrification for representative rural business archetypes provides valuable insight into what electrification could look like for a wide range of farms. However, every farmer's journey is unique, meaning their electrification pathway, along with the opportunities and challenges they face, may differ from our modeled scenarios. We aim to highlight this variation through three case studies, each showcasing real-world examples of farm electrification at different levels. These stories offer a deeper understanding of how electrification actually unfolds on farms.

The first case study, Forest Lodge Orchard, demonstrated that complete farm electrification can dramatically reduce operational costs while eliminating emissions. By electrifying approximately 20 fossil fuel machines and installing extensive solar generation (160 kWh capacity), the orchard reduced its annual energy expenses from $66,000 to just $5,300. The replacement of diesel frost fans was particularly impactful. These previously used between 20-40 litres of diesel per hour, at $2.70 per litre, with a frost lasting anywhere between 2-12 hours. With electric frost fans, this was brought down to $3 per hour, saving 11.6 tonnes of CO_2e each year.

In total, Forest Lodge Orchard invested $881,590 in electric machinery and $272,604 on the solar and battery system. They aim to recover these costs through operational savings within the next ten years. Full farm electrification eliminated 60 tonnes of annual carbon emissions for this orchard, but also created a new revenue stream through surplus electricity sales to the grid, transforming farm economics while achieving environmental goals.

The next case study highlights a case where full farm electrification may not yet be economically beneficial, but there are still opportunities that create significant cost savings and emissions reduction. A chicken farm consisting of four large sheds on 12 acres of land has electrified almost all of its activities, except for heating. 50kW solar panels have also been installed on the roof of the chicken sheds, saving nearly $10,000 annually on electricity bills. Replacing four fossil fuel vehicles with an all electric fleet charged off rooftop solar has reduced vehicle fuel costs from $9,000 per year to zero. An electric loader imported from China has replaced two fossil fuel tractors, and is capable of doing 70-80% of the work in the sheds.

> *"I just found the loader on the internet, I had no idea what jobs it could do. I had to take quite a risk to import it and see how it could perform. It did more than I expected, to be fair! [..] If I had two of these, I could get rid of the rest of the tractors."*

The main barrier to full electrification is the replacement of diesel heaters. Due to the large space that needs to be heated, at a sustained temperature when the chicks are young, diesel burners are found to be more economical during winter. However, this has not deterred the farm from its electrification goals. It is focused on achieving 90% electrification of its heating needs, reserving the diesel heaters for only the coldest days.

The final case study highlights a sheep, beef, and dairy farmer motivated by the energy independence and resilience achievable through self-generation. This farm operates a 30 kW electric irrigation pump that, prior to solar panel installation, was the largest contributor to high electricity bills, contributing $30,000 each year. With a 55 kW solar panel array, the farm is generating 74 MWh per year and self-consuming more than half the power it generates. There have been some days where the farm has been able to both power the pump and export excess power during the solar window.

> *"At 9:30am on a foggy morning, we're already producing 50% of the power we need for the pump. We're basically running the pump at half price. Even on our greyer days, we're still able to contribute to the pump consumption."*

Having started with solar, the next step for this farm involves machine electrification. Two fossil fuel machines are due for replacement: a Honda ATV, and a Suzuki Escudo SUV. Both machines are used for two hours a day, the ATV in summer, and the SUV in winter, and the farmer assessed that purchasing one electric side-by-side could replace both vehicles while saving money on petrol. We estimate that replacing the Honda ATVs and the Escudo with an electric Hisun Sector E1 side-by-side, a model with good towing capacity and driving range, would save $1,650 per year in petrol costs, and 1.4 tonnes of CO_2e per year.[70] Over the 15 year lifetime of the electric side-by-side, this would accumulate to $24,800 in operating cost savings, 21 tonnes of CO_2e saved, and $34,500 in lifetime cost savings when taking into account the upfront costs of replacing the two vehicles like-for-like compared to one electric side-by-side (Figure 6.17). By recognising that one vehicle could do the job of two, they would save significantly on upfront costs. Like-for-like replacements of other farm vehicles like the ute and the tractor also result in lifetime savings, especially when charged on solar.

70 Based on rural grid electricity pricing; charging on self-generated solar would further increase savings.

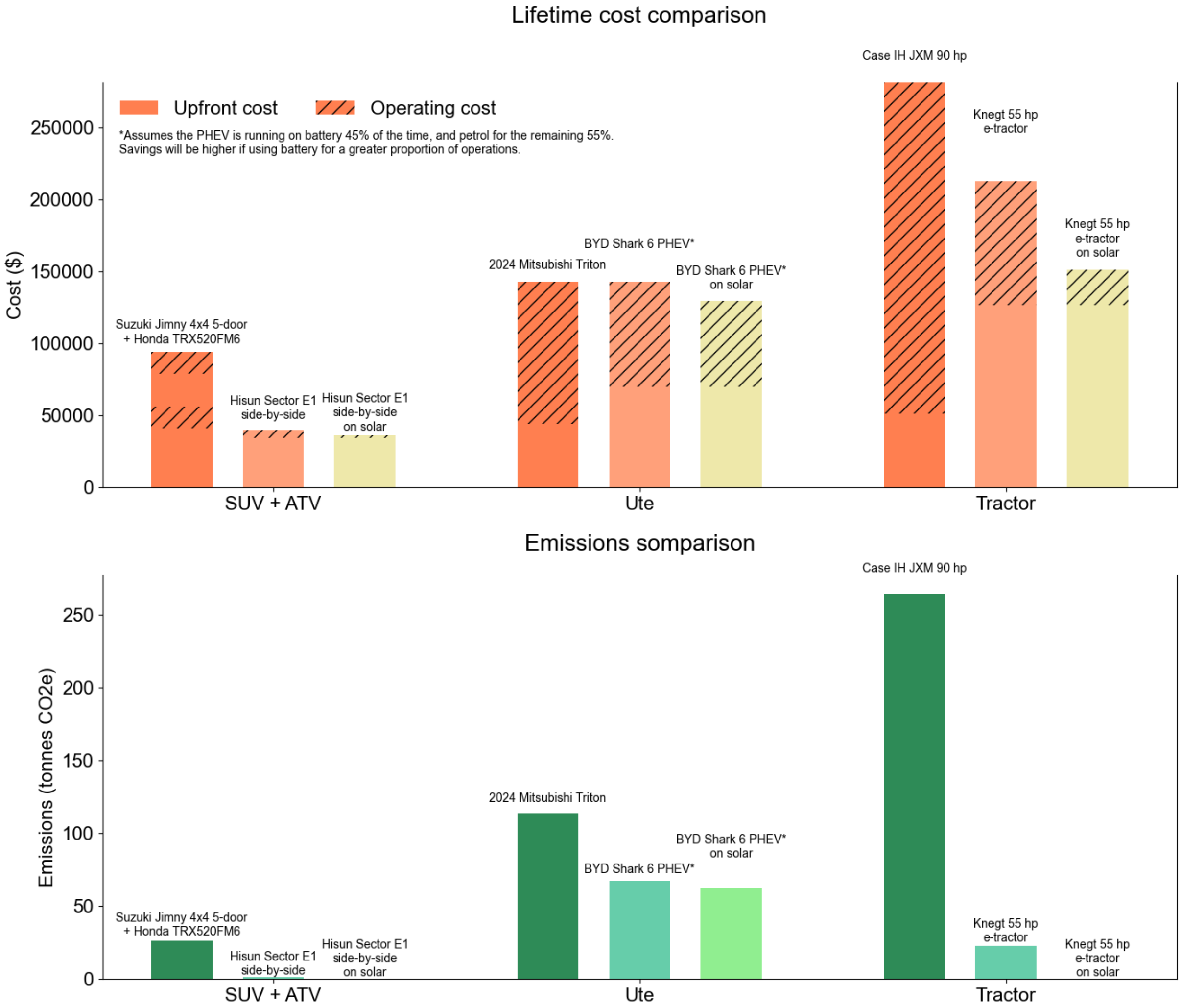


Figure 6.17: Lifetime cost and emission savings from replacing farm vehicles

Major barriers this farmer has faced in their self-generation and machine electrification journey are financial barriers and low incentives for exporting surplus energy. The farmer noted that while electrification offers long-term savings, farm technology must be affordable and fit for purpose. For example, while they would be able to swap their smaller Case 5120 for an electric tractor, for their larger Case Puma 125, there are no electric tractors on the market that achieve the same level of power.

6.3 Business

The business sector represents a diverse landscape for machine electrification, spanning from small enterprises with household-like equipment needs to large operations with industrial-scale machinery. Unlike residential and agricultural sectors, the business sector requires a qualitative approach due to its inherent diversity and the specialised nature of equipment across different business types. To provide meaningful insights into this sector, Rewiring Aotearoa conducted case studies across six representative business categories that collectively cover a substantial portion of Aotearoa New Zealand's commercial landscape, specifically:

- **Small offices:** Professional service firms and non-profits typically relying on electricity for most operational needs including computing equipment, lighting, and HVAC systems
- **Large offices:** Corporate headquarters and substantial commercial operations with more complex building systems and energy requirements
- **Hotels:** Accommodation providers with diverse energy needs spanning guest rooms, food service, laundry, and recreational facilities
- **Restaurants:** Food service establishments with specialised kitchen equipment traditionally powered by gas, including cooktops, ovens, and water heaters

- Large institutions: Universities, healthcare facilities, and government buildings with complex operational needs and diverse building portfolios
- Infrastructure and construction: Companies operating substantial fleets of fossil fuel-powered heavy equipment, with diesel being the predominant fuel source

6.3.1 Energy profile and electrification potential

As expected, the types of machines used and energy needed vary greatly across business types. Our research shows that the larger and more complex the activities of the business, the more challenging electrification becomes. Small offices and restaurants are generally easier to electrify than large offices, institutions, and companies that utilise heavy machinery without readily available electric alternatives. The following sets out the key opportunities and challenges for each business type.

Small offices

Small offices represent a largely homogenous segment of the business sector with relatively lower fossil fuel dependency. These businesses typically rely on electricity for most operational needs, with potential gas usage limited primarily to water heating in some buildings. Key electrification opportunities include:

- Ready pathway to full electrification with relatively few fossil fuel systems to replace
- Operational cost advantages through electric heat pump systems offering 3-4 times greater energy efficiency
- Workplace comfort and productivity benefits, including, more precise temperature control and improved air quality
- Solar generation potential, with consumption patterns closely matching peak solar generation periods
- Electric vehicle charging integration to support employee and client electric vehicle adoption

The primary challenges for small offices are split incentives in leased premises, building-wide system dependencies, and limited capital budgets. The case study of the mSupply Foundation (Appendix 2, Section 6.2.4) demonstrated how commercial office spaces can successfully transition to all-electric operations while incorporating renewable energy, achieving 100% self-consumption of solar generation during weekdays.

Large offices

Large offices typically house hundreds of employees across expansive floor areas, ranging from corporate headquarters to government administration buildings, with centralised HVAC systems and extensive infrastructure. Large offices have all the same opportunities as small offices, at a larger scale with bigger capital investments required, but also bigger operational savings available. They also have additional opportunities around economies of scale for fleet electrification and solar generation.

The primary challenges include split incentives in leased premises (where tenants have limited ability to modify centralised systems), capital budget constraints, and potential grid connection upgrade requirements for full electrification especially when simultaneous charging of a large fleet is involved.

The case studies of WM New Zealand's office, Queenstown Lakes District Council’s building portfolio, and a large telecommunications company office in Auckland (anonymised), demonstrate real-world approaches to large office electrification. These include fully electric office operations, strategic fleet electrification yielding substantial operational savings (QLDC reported that EVs represent only 10% of their fleet energy costs while comprising half of their 62 vehicle fleet), and collaboration with landlords for renewable energy integration.

Successful electrification strategies for large offices typically involve comprehensive energy audits, tenant-landlord collaboration to identify mutual benefits, staged implementation prioritising end-of-life replacements, and employee engagement to build internal support. The economic case is strongest when electrification is integrated with scheduled building renovations, vehicle replacement cycles, and other planned investments.

Restaurants

The restaurant sector faces unique challenges with specialised kitchen equipment that has traditionally relied on gas. Cooking equipment represents the major source of fossil fuel consumption (natural gas and LPG) across establishments of all sizes. Key electrification opportunities include:

- Significant emissions reduction potential through electrifying gas-powered cooktops, ovens, and water heaters
- Operational cost advantages, with induction cooktops converting approximately 85-90% of energy into heat, compared to 40% for gas burners
- Performance and health benefits, including, precise temperature control, faster cooking times, reduced ambient heat, and elimination of indoor air pollution

The case study of Formaggio's, a popular Christchurch Italian restaurant (Appendix 2, Section 6.1.4), exemplifies both the progress and challenges of electrification in the hospitality sector. Having space and water heating that is already electric, their energy profile to two-thirds electricity and one-third LPG, saving costs and emissions. While eager to transition their kitchen from gas to induction cooking – which analysis shows would save $1,550 over 15 years while reducing emissions by 86% – they face challenges including limited commercial equipment availability and electrical capacity constraints. A potential 22kW solar installation on the roof could also generate $6,700 in annual benefits, but landlord reluctance has stalled implementation. Despite these barriers, Formaggio's continues to advance sustainability through holistic approaches, including environmental philanthropy, demonstrating how restaurants can live out their values to successfully balance environmental commitments with business viability.

A second case study at Coco's Cantina in Auckland highlighted challenges for restaurants in leased premises. While their chef acknowledged that "anything we do on flame, we could do on induction" and was open to adapting to new cooking technologies, the restaurant faces barriers related to property ownership structure and capital constraints, where major infrastructure changes require landlord approval and investment. The restaurant emphasised the need for clear information about "the economics of payback periods & financing options." The full case study in Section 6.1.5 of Appendix 2 shows analysis of the potential savings in operating costs, lifetime costs, and emissions through electrification. Coco's Cantina has already established a foundation for further electrification with their electric pizza oven, industrial oven, and an owner and team of staff who are eager for emission reduction. Their experience demonstrates that with supportive financing options, landlord engagement, and a progressive team culture open to adaptation, restaurants can successfully transition from gas to zero-emission electric alternatives.

Hotels

Most emissions from hotels come from natural gas and LPG used for water and space heating. The hospitality sector presents several electrification opportunities:

- Ready pathway to full electrification by replacing gas or LPG boilers with electric heat pumps and transitioning to induction cooktops in kitchens
- Operational cost advantages through more efficient electric heat pumps (3-5 times more efficient than gas boilers)
- Competitive advantage with eco-conscious guests seeking sustainable accommodations, potentially improving reputation and marketability

Key challenges include high upfront costs for equipment replacement, and the need for battery capacity to support full electrification. The hotel case studies (Appendix 2, Section 6.4.4 and Section 6.4.5) highlight opportunities and pathways for successful electrification for two hotel companies in New Zealand.

Large Institutions

Educational institutions, healthcare facilities, and government buildings manage large, and varied building stocks with different ages, designs, and energy needs. Many institutional campuses in Aotearoa New Zealand were established decades ago, with heating and energy systems designed around fossil fuels. Key electrification opportunities include:

- Large cost and emissions savings potential through converting centralised heating systems
- Alignment with scheduled renovations to reduce the marginal cost of electrification efforts
- Load management potential through predictable usage patterns
- Educational value through visible electrification projects

The case study of Otago University demonstrated a comprehensive approach to campus electrification, with a clear plan to reach net zero by 2030. The University faces complex challenges in electrifying diverse systems across heritage buildings, laboratories, and student accommodation. Their experience illustrates that while the upfront capital investment is significant, the long-term operating cost savings make these upgrades worthwhile for institutions with very long building lifespans.

Infrastructure and Construction

The infrastructure and construction sector contains significant energy consumers and emissions contributors, with diverse equipment needs spanning from light vehicles to specialised diesel-intensive heavy machinery. Key electrification opportunities include:

- Significant emissions reduction potential, with some electric alternatives delivering 90% emission reductions compared to diesel counterparts
- Operational cost savings, especially significant given the quantity of fuel used in heavy vehicles
- Performance benefits, including, instant torque delivery, reduced noise levels, and improved operator comfort

The case study of a large infrastructure company demonstrated successful trials with electric loaders saving 65-80% on diesel running costs (approximately $10,000-$15,000 per vehicle annually) and hybrid excavators delivering approximately 20% fuel savings while maintaining operational capability. However, remaining barriers include leasing challenges, regulatory uncertainty, equipment replacement cycles, and availability of appropriately-sized electric alternatives, much of which can be overcome with our recommendations in Section 5 and future work in Section 8.

6.3.2 Key Insights

The case studies and analysis undertaken reveal several key insights that are applicable across the business sector, specifically:

1. **Economic viability varies by business type:** While electric alternatives often have higher upfront costs, operational savings can offset these investments over time. The economic case is strongest for businesses with high utilisation rates of fossil fuel equipment, such as restaurants and construction companies.
2. **Split incentives create significant barriers:** For leased premises, misalignment between building owners (who bear capital costs) and tenants (who receive operational benefits) often delays electrification investments. Novel financing arrangements and building owner engagement are essential to overcome this challenge.
3. **Staged implementation is crucial:** Most businesses benefit from a phased approach to electrification, prioritising equipment replacement at end-of-life and starting with the most cost-effective transitions.
4. **Staff engagement impacts success:** Involving employees in the electrification process, providing training on new equipment, and highlighting performance benefits helps overcome resistance to change, particularly in sectors with established practices, such as, commercial kitchens.
5. **Total cost of ownership analysis reveals true value:** Evaluating equipment based on lifecycle costs, rather than just upfront purchase price, typically demonstrates the economic advantages of electrification, particularly when factoring in rising fossil fuel prices.
6. **Strategic partnerships accelerate electrification:** Working directly with equipment manufacturers and suppliers provides opportunities for early access to new electric models and the ability to influence design specifications for Aotearoa New Zealand conditions.
7. **Co-benefits extend beyond emissions reduction:** Improved air quality, reduced noise, enhanced work environments, and marketing advantages provide additional motivation beyond direct cost considerations.

These insights demonstrate that while the path to electrification varies significantly across business types, strategic approaches tailored to each sector's unique characteristics can unlock substantial emissions reduction potential while delivering operational benefits and cost savings over equipment lifetimes.

6.4 Industry

The industrial sector is the largest user of coal and natural gas in Aotearoa New Zealand (Figure 6.18 below). In 2023, 35% of natural gas was burnt for industrial process heat, 26% of natural gas consumption was used as feedstock for industrial processes, and almost 90% of the coal consumed for energy was used in the industrial sector.[71]

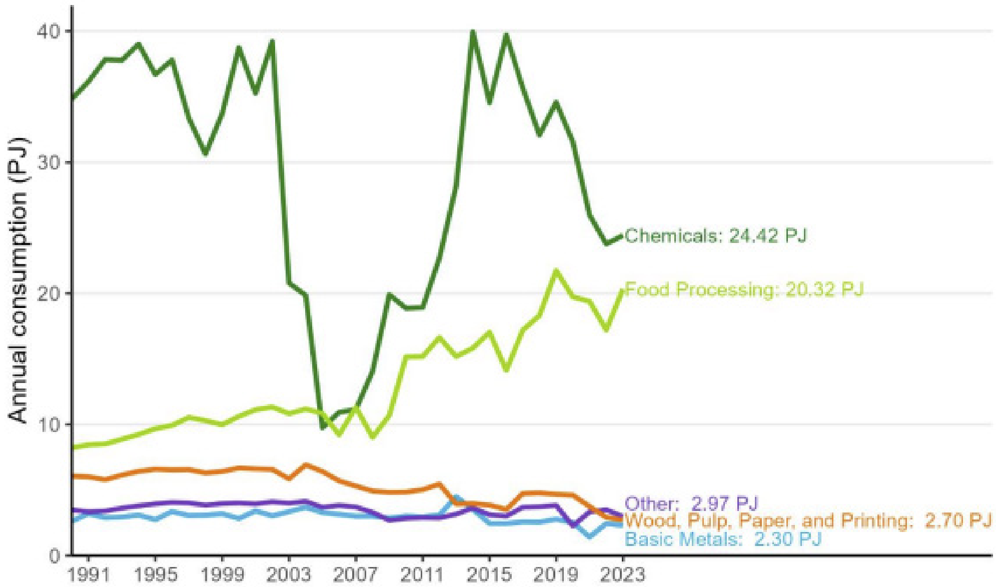


Figure 6.18: Industrial gas consumption by sector, 2023[72]

Energy use in industry is mostly to make heat used in manufacturing, referred to as "process heat". Process heat is provided by boilers, furnaces, kilns, and air heaters. There are 1,279 process heat machines on sites with thermal capacity of over 500kW in New Zealand.[73] These machines are used in dairy product manufacturing, pulp and paper manufacturing, wood processing, food processing, metals and chemicals manufacturing, and other manufacturing sectors. Boilers are also used in commercial and government-owned sites, including education facilities, hospitals and accommodation, primarily for space and water heating.

New Zealand has a small number of businesses that use a large amount of energy. They produce commodities including steel (NZ Steel), methanol (Methanex), Urea fertiliser (Ballance AgriNutrients) and cement (Golden Bay Cement). We have explored the economics of electrifying industrial process heat in more detail in Appendix 2, Section 7, including case studies for large energy users.

The best solution to switch away from fossil fuel use in the industrial sector can vary by site and include both electrification and swapping to bioenergy. For this reason, we talk about *decarbonisation* of fossil fuel use in the industrial sector, which include both these options. The following sections provide a summary of the economical and technical challenges and opportunities to electrify process heat. Appendix 2, Section 7 includes more details and case studies for large industrial energy users.

6.4.1 Key insights

Cost and availability of technical solutions to electrify process heat depend on the required temperature ranges:

- **Process heat below 100°C:** Hot water heat pumps are efficient and sometimes reduce costs over the lifetime using current technology.
- **100°C - 300°C:** Electrode boilers[74] and high temperature heat pumps are existing technology. Very high temperature heat pumps up to 280°C are to be demonstrated in Aotearoa New Zealand by 2027.[75] Electrode boilers typically have a higher lifetime cost at current carbon prices than fossil fuel boilers.

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71 https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-publications-and-technical-papers/energy-in-new-zealand/energy-in-new-zealand-2024/balance-tables
72 Sourced from Energy in Aotearoa New Zealand, 2024 at https://www.mbie.govt.nz/assets/energy-in-nz-2024.pdf
73 https://www.eeca.govt.nz/insights/eeca-insights/regional-heat-demand-database/
74 Biomass boilers are a renewable alternative and can have a lower abatement cost in some situations to decarbonise process heat needs.
75 https://www.eeca.govt.nz/assets/EECA-Resources/Technology-Demonstration-Projects-Utilising-Very-High-Temperature-Heat-Pumps-Briefing-Slides.pdf

- **Above 300°C:** Electrification technologies are still developing, but electric arc furnaces for steel making are already in use.

The costs to electrify process heat machines varies by the temperature of heat required, but also on a site by site basis. We have considered the machines used across these sectors collectively, utilising analysis from EECA's Regional Energy Transition Accelerator (RETA),[76] which includes analysis of the Marginal Abatement Cost of decarbonising (either electrifying, using biomass or geothermal heat) for many process heat users in Aotearoa New Zealand.

Findings of average marginal abatement cost for South Island process heat sites (where fuel use is predominantly coal) include:

- **Efficiency/demand reduction**: -$177/t CO_2e (commercially attractive without carbon pricing)
- **Heat pumps:** $93/t CO_2e
- **Biomass boilers:** $288/t CO_2e
- **Electrode boilers:** $325/t CO_2e

For industrial businesses using natural gas for process heat, the potential escalation in natural gas prices is the dominant factor impacting financial decisions around electrification. EECA's Taranaki RETA[77] included optimal process heat decarbonisation pathways for the region, and analysis demonstrates that higher future gas prices means process heat decarbonisation projects become economical earlier, as shown in Figure 6.19 below.[78]

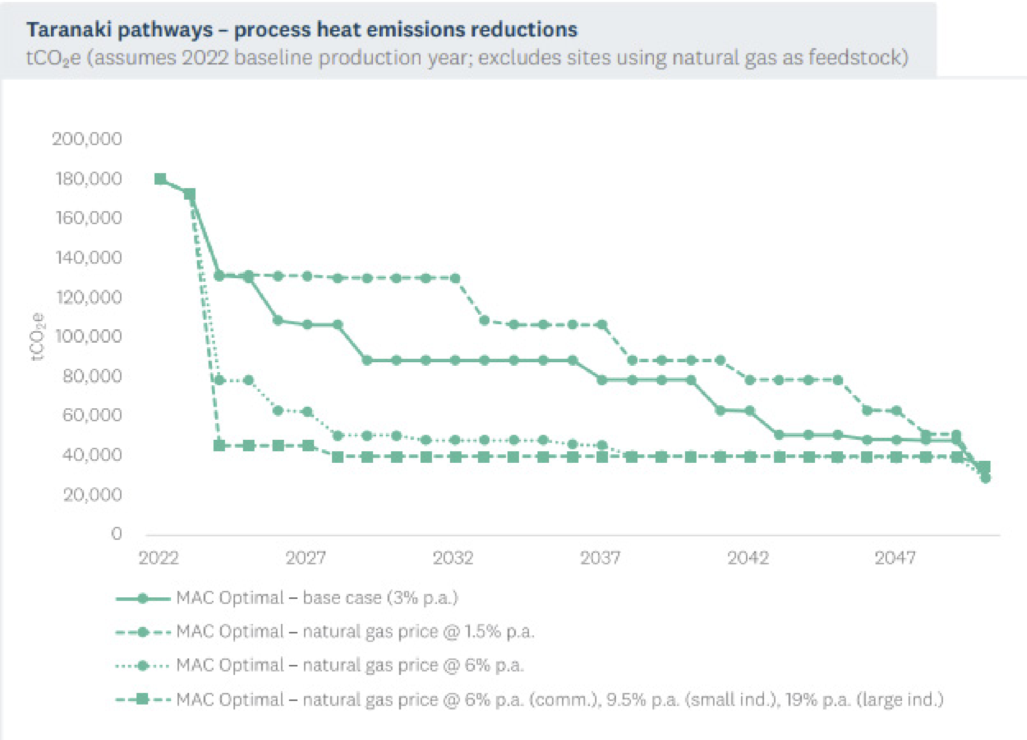

Figure 6.19: EECA's Taranaki Regional Energy Transition Accelerator process heat decarbonisation pathways[79]

6.4.2 Opportunities and Strategic Advantages

- **Cost savings:** Investing in efficiency improvements can save businesses money. In many cases where heat pumps are used to provide lower temperature heat they can save businesses money over the life of the investment.
- **Natural gas price escalation**: Expectation of higher future gas prices could accelerate the economical viability of electrification of gas fired process heat machines.

76 https://www.eeca.govt.nz/assets/EECA-Resources/Co-funding/RETA-South-Island-Phase-One-Report.pdf
77 Taranaki Regional Energy Transition Accelerator | EECA
78 In the pathways each site switches to a heat pump or switches its boiler to the fuel (i.e. biomass or electricity) with the lowest MAC value for that site. Each project is timed to be commissioned in the first year when its optimal MAC value first drops below a ten-year rolling average of Treasury's central estimate of carbon shadow prices.
79 Taranaki Regional Energy Transition Accelerator | EECA

- Competitive advantage: Decarbonisation can enhance export potential, as global markets favor low-emission products.

6.4.3 Challenges to Electrification

- Electricity cost barriers: Electrode boilers have lower capital costs but higher operational costs due to electricity prices.
- Smaller site constraints: Connection upgrade costs can disproportionately affect smaller energy users.
- Technical limitations: High-temperature process heat electrification remains under development, but emerging technologies like induction heating are in development. Electric arc furnaces are already widely deployed to electrify high temperature steel making.

6.4.4 Large energy users

Aotearoa's large fossil fuel energy users, producing steel (NZ Steel), methanol (Methanex), Urea fertiliser (Ballance AgriNutrients) and cement (Golden Bay Cement), have unique technical pathways to decarbonise but common challenges. Large energy users use fossil fuels to make heat used in processes (energy use) and as feedstock to production (non-energy use). There are opportunities to decarbonise both uses, and green hydrogen could be used as an alternative industrial feedstock.

- Key challenges include:
- High capital costs for decarbonisation.
- Need for reliable renewable electricity and hydrogen infrastructure.
- Technological limitations in full-scale zero-emission processes.
- Economic feasibility, requiring subsidies and market incentives.

Each of the New Zealand-based large energy users are exploring partial decarbonisation, but full transformation will require further innovation, investment, and regulatory support. See Appendix 2, Section 7 for detailed case studies.

7.0 Regional factors

While technological progress drives down costs nationally, Aotearoa New Zealand's diverse geography and infrastructure create varying conditions for machine electrification. These regional differences influence both the economic case for switching to electric machines and which machines should be prioritised for replacement. Understanding these regional differences is crucial for developing targeted, effective electrification strategies that account for local circumstances. The following subsections explain these key regional differences.

7.1 Fuel availability: Natural gas in the North Island

All of Aotearoa New Zealand's natural gas is sourced domestically and supplied via a natural gas network to many regions in the North Island. The South Island can only access LPG, rather than piped natural gas, making gas more expensive for South Island households. This means that electrification offers more savings for South Island households using LPG than those using natural gas in the North Island. The outer islands of Aotearoa New Zealand present even more compelling electrification opportunities. Rakiura/Stewart Island, for instance, primarily relies on diesel-generated electricity, which is both extraordinarily expensive and emissions-intensive compared to mainland electricity. Recent natural gas supply constraints have also put upward pressure on North Island gas prices, making future price expectations a key driver for electrification in commercial and industrial sectors throughout the North Island.

7.2 Heating demand

Heating demand impacts both overall electrification economics, and the size of upfront expenditure needed to electrify. Figure 7.1 below shows the median average temperature across Aotearoa New Zealand. While heating needs shift seasonally, this helps to convey areas where more heating is needed across the country for adequate health and comfort.

Colder regions, such as Otago, need significantly more heating than warmer regions like Auckland. As a result, transitioning to electric heating in colder regions can have a higher upfront cost as there are often more heating devices to replace, or they tend to be larger. However, higher heating usage also means higher ongoing costs for fuel. Making the savings from electrification more substantial, when investing in heat pumps, which are three to four times more efficient than fossil fuel or resistive electric heaters. This, in turn, shortens the payback period.

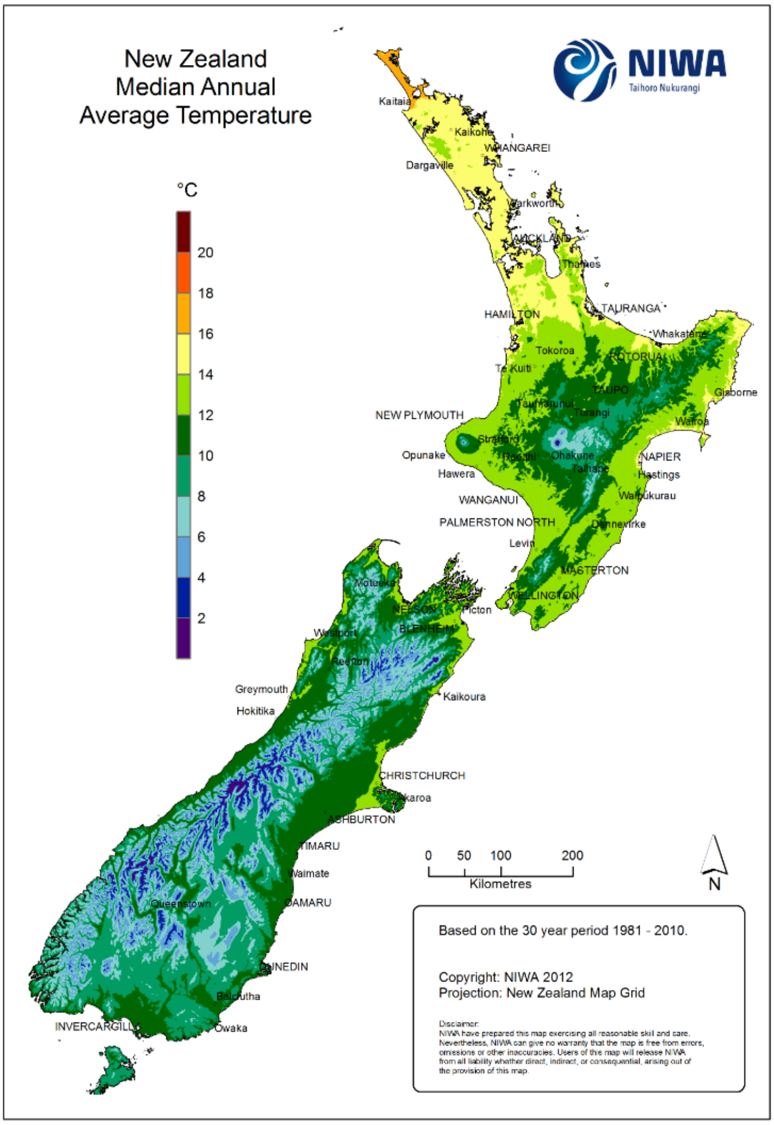

Figure 7.1: Map of median annual average temperature in Aotearoa New Zealand (Source: NIWA)

Heating needs can influence electrification economics both in positive and negative ways depending on the scenario. Here are two examples:

a. In cases where the dwelling is only occasionally heated, for example, a holiday home used only a few times a year, the upfront cost of a heat pump may be harder to justify. However, since the cheapest heating options are typically electric resistive heaters, even with infrequent use, they remain a viable choice, despite being more expensive to operate than gas or a heat pump.
b. If a holiday home is off-grid, electrification can be more challenging. For high-usage properties, a solar and battery system is often the most cost-effective solution. However, for low-usage homes, alternatives like wood-fired heating or occasional bottled gas deliveries may be more practical. In such cases, eliminating the need for small bottled gas presents an interesting challenge.

7.3 Average driving distance

The distance driven per year, whether it be a family car or a freight truck, makes a significant difference to the economic feasibility of electrification. Some regions with more rural communities, where average driving distances are further, will be able to save more money from driving an electric car than in urban regions where the population does not drive as much.

7.4 Solar capacity factor

Given that solar has the cheapest delivered cost of electricity for most places, the amount of sunlight in a region can impact electrification economics, although not by much. More sunlight means more electricity generation, reducing overall energy costs compared to grid electricity. Cloudy and rainy regions, such as Dunedin, experience slightly higher solar energy costs than sunnier locations like New Plymouth.

7.5 Population and economic activity

The population, the number and scale of urban centres, and the make up of the sectors in a region have a big impact on the energy needs and electrification opportunities for each region. For example, Auckland will have a significant opportunity to electrify cars and household appliances given the large population and number of homes and vehicles in the region. Whereas, other regions, such at the West Coast (Aotearoa New Zealand's least populous region), would find greater opportunity to electrify economic activity, especially in the agriculture, tourism and manufacturing sectors.

7.6 Future regional analysis

The nationwide machine count establishes a foundation for developing region-specific electrification roadmaps across Aotearoa. Future work can create localised electrification roadmaps tailored to each area's unique machines, infrastructure, climate, economic activities, and demographics. By translating nationwide data into targeted regional action plans, local governments can prioritise their decarbonisation efforts more effectively and implement policies that address their specific circumstances. While electrification represents a common solution nationwide, this regional approach recognises that optimal implementation pathways will vary. This creates opportunities for communities to develop strategies that reflect their particular needs and advantages.

8.0 Future work

This preliminary machine count is a first attempt at a granular, machine-based understanding of Aotearoa New Zealand's pathway to zero energy emissions. While not exhaustive, it offers a new level of granularity and establishes a valuable platform for climate pathway planning, energy system innovation, and electricity system modelling.

We hope that this research can be continuously improved through open availability. All feedback is welcome, including improvement to methodology at both macro and micro (individual machine-specific) levels, as detailed in the appendices (see Section 9 Supporting Documents). Below are recommendations on building upon this research:

Develop targeted surveys to enhance data quality

We did not find high-confidence data for some machine categories and sectors within the timeframe of this project. Targeted sector surveys, with improved survey and sampling design in collaboration with Stats NZ, could fill these gaps. For example, we do not have full machine counts for boilers used for space and water heating in buildings and process heat boilers and burners that are on sites with a thermal heating capacity of less than 500 kW. Particular sectors to target include indoor cropping, food processing, accommodation and healthcare.

Sector-specific counts, which were not a priority for this preliminary count, may also provide opportunities for businesses to benchmark their progress against sector averages, and to track the sector's decarbonisation progress. Additional targeted surveys could also improve information about temporal energy use to better model demand flexibility, and enhance counts of specific machine types such as residential and commercial LPG heaters (e.g. portable and fixed) and commercial cooking equipment.

Balance further data collection and modelling with immediate action on emissions

The machine count framework enables detailed capex and opex calculations for fossil fuel machines nationwide, as well as scope for region-specific machine opex (based on different energy prices and needs across regions). It may be possible to engage with relevant sectors, teams, and agencies that already have much of the information and knowledge required to populate these values.

While this data would provide valuable insights into the economics of transitioning to zero emissions, we must balance further research with urgent action. We recommend pursuing emissions reduction immediately with existing knowledge, as many electrification opportunities are already cost-effective and technically viable. Simultaneously, we can enhance our dataset through collaboration with sectors, agencies, and businesses that understand their machine economics. This parallel approach enables near-term, measurable progress on emissions reduction while continuously improving our evidence base for future policy and financial innovation.

Model future cost trajectories

Incorporating cost curves or learning rates at machine level would provide insight into how economics will likely change over time. Technologies that appear costly today may become economically advantageous in the near future, as we've already witnessed with electric vehicles transitioning from higher lifetime costs to delivering clear savings compared to fossil fuel alternatives.

Develop strategic replacement timelines

Based on typical replacement cycles and operational lifespans, we can establish realistic phase-out timelines that consider:

- Sector-specific replacement cycles
- Emissions impact prioritisation
- Changing availability and maturity of electric alternatives
- Economic feasibility assessments for early replacement (before the end of a fossil fuel machine's operational life)

This information will enable us to create a national roadmap with sequential targets for different sectors and machine types. By implementing policies to phase out the sale of new fossil fuel equipment where mature electric alternatives exist, and aligning finance options and process innovations with these timeframes, we can achieve the electrification rates required to meet our climate targets.

Include detailed energy requirements and demand flexibility

The Database can be expanded to include detailed energy requirements of machines at an individual level. This could include their average yearly energy consumption, seasonal energy consumption, peak energy consumption, and ability to shift energy consumption to other times of day. Understanding this could provide more granular machine economics, and identify opportunities where load shifting will improve energy economics further than previously thought. For example, when energy use can be moved into the solar energy window or night time energy window, this would significantly lower the operating cost of an electric alternative even further, making it an easier purchase decision to justify. It would also allow us to estimate how electrification of certain machines, sectors, and/or regions would impact electricity demand, during what hours and seasons.

Update the database as a time series

By regularly updating the database and maintaining the changes as a time series,[80] we can accurately track decarbonisation progress over time, identify trends, and measure the effectiveness of various interventions. This continuously updated resource will provide a practical view of Aotearoa New Zealand's decarbonisation journey, leading to a more resilient and efficient energy system with higher utilisation rates and lower costs.

Build a more granular demand-side energy model for Aotearoa New Zealand

With the granularity provided by the machine count, and especially with the energy data expansions mentioned above, a much more granular demand-side electricity system model could be built. This level of granularity could enable more cost-effective transmission and distribution planning, and efficient generation location planning. The model could even account for regional variation in machine types and energy uses, as the machine count database structure is scalable to include region data.

80 Where any changes to machine count numbers or electrifiability criteria values are recorded with a timestamp, to then be converted into a time series.

9.0 Supporting Documents

Machine Count Database - Link

This publicly available Google Sheet spreadsheet contains the preliminary review of all fossil fuel machines in Aotearoa New Zealand, their estimated nationwide quantity, electrification potential ("electrifiability"), and emissions impact. It also includes a list of electric machines in Aotearoa New Zealand and overseas. The Database is intended to be an open-source document. Users are encouraged to download or duplicate the spreadsheet for customised analyses as needed. For details on the contents of each sheet and explanations of columns, please see Appendix 1, Section 5.2.

Appendix 1: Database Methodology - Link

This contains the methodology for how the Machine Count Database was developed.

Appendix 2: Modelling & Case Studies - Link

This contains all information about our sector modelling, including how Rewiring Aotearoa developed modelling archetypes and analyses of case studies from the deep dive interviews conducted.

Information website - Link

Information for the general public about this project, with links to key resources.

Shared data folder - Link

This shared Google Drive folder contains all working reconciliation sheets, source data from public datasets, OIA results, and other material.

Sector surveys

Residential & light transport survey (Appendix 1, Section 3.1) - Link
Agricultural survey (Appendix 1, Section 3.2) - Link
Small business survey (Appendix 1, Section 3.3) - Link
Industry survey (Appendix 1, Section 3.4) - Link

Machine count data pipeline - Link

A Python data pipeline was built to clean and transform the raw data from the residential and agricultural surveys. It is available open-source on GitHub under the GPL-3.0 license. For more details about the tech stack and potential architecture improvements, see Appendix 1, Section 4.

Models

Household spreadsheet model (Appendix 2, Section 4) - Link
Agricultural spreadsheet model (Appendix 2, Section 5) - Link
Energy prices - Link
Solar generation & area requirements calculator - Link

10.0 Summary Tables

Summary Table 1: Nationwide checklist of fossil fuel machines

Summary Table 1 below presents all the fossil fuel machines in Aotearoa New Zealand, ranked by priority based on electrification and savings potential. It includes:

- **Electrifiability:** The ease of mass electrification based on the machines' technical[81] and economic[82] feasibility of electrification (from Table 4.1 in Section 4)
- **Count:** the estimate of how many of each machine there are in the country
- **Barriers to electrification:** The specific barriers to mass electrification (from Table 10.1 below)

Table 10.1: Barriers to deploying electric alternatives to fossil fuel machines and actions required

Status	Barrier	Description	Action required
Non-technical barriers Electric alternatives are available and ready to adopt at scale, with relatively easy process, educational, or financial barriers to overcome, if any.	Upfront cost	The lifetime total savings are worth the upfront cost, but the barrier is accessing appropriate financing mechanisms for the higher upfront cost.	Accessible finance products that allow all New Zealanders to upgrade to electric alternatives, e.g. longer term financing for electric vehicles and heat pump hot water heaters.
	Availability in NZ	Electric alternatives are not readily and openly available in Aotearoa New Zealand.	Support procurement (e.g. demonstration grants, importing programmes).
	Lifetime cost	The lifetime total savings of the electric alternative do not make up for the higher upfront cost compared with the fossil fuel status quo.	Discounts such as the EECA Low Emissions Heavy Vehicle Fund, bulk procurement, emission reduction incentives.
Technical barriers The technology to electrify this machine has not been fully developed yet.	R&D late stage	Electric alternatives are being tested and demonstrated in the field, and are expected to be commercially available within a few years.	Invest in making sure Aotearoa New Zealand is one of the first places where it is trialled and deployed.
	R&D early stage	Electric alternatives are under development, but not yet being demonstrated in the field and could be many years away.	Investment and indicating support for trial and deployment in Aotearoa New Zealander, e.g. with accessible regulatory exemptions for trials.
	Needs new development	Electric alternatives do not currently exist and will need R&D support to be developed.	Invest in R&D, as Aotearoa New Zealand startups could build these solutions.

81 Our definition of "technical feasibility" focuses on practical implementation rather than the physics of electrification. We are asking: "Can we realistically deploy working electric versions of these machines that have the technical specifications to meet real-world Aotearoa New Zealand conditions?". This allows for machines without commercial electric versions to be considered, if they are able to be retrofitted. See Appendix 1, Section 8.1 for more details.

82 See Appendix 1, Section 8.2 for more details.

Summary Table 1: Counts and barriers to electrification of all machines, ranked by electrifiability, emissions ranking (based on emissions intensity, typical hours of use per year, and count; see Appendix 1, Section 8.3), and then by count. Some machine types are in multiple stages of development depending on their sub-type (e.g. smaller mining trucks are in late R&D, while larger trucks need new development) or fuel type (e.g. LPG cooking ovens are economical to electrify today, while natural gas ones are still cheaper over their lifetime at current gas prices). Top priority machines for each category are indicated in bold, with further details in Summary Tables 2-6 and Section 4. View this as a Google Sheet.

Electrifiability	Machine type	Count	Emission Ranking	Non-technical barriers			Technical barriers		
				Upfront cost	Availability in NZ	Lifetime cost	R&D late stage	R&D early stage	Needs new development
Ready	**Car**	**3,529,821**	3.7	Yes					
Ready	**Water Heat**	**579,340**	3.3	Yes					
Ready	**Water Heating Boiler**	**64**	3.3	Yes					
Ready	**Space Heater**	**1,007,548**	3.0	Yes					
Ready	**Cooking Oven - Commercial**	**2,784**	3.0	Yes					
Ready	**Space Heating Boiler**	**460**	3.0	Yes					
Ready	**Mower - Push**	**505,075**	2.7	Yes					
Ready	**Motorbike - On-road**	**214,932**	2.7	Yes					
Ready	**Cooking Overn - Residential - LPG**	**70,970**	2.7	Yes					
Ready	**Gas Cooktop - Commerical**	**21,158**	2.7	Yes					
Ready	Barbeque	1,316,620	2.3	Yes					
Ready	Line Trimmer	362,385	2.3	Yes					
Ready	Gas Cooktop - Residential	360,099	2.3	Yes					
Ready	Chainsaw	263,693	2.3	Yes					
Ready	Air Compressor	50,501	2.3						
Ready	Spa and Pool Heater	27,722	2.3	Yes					
Ready	Water Pump	2,100	2.3	Yes					
Ready	Clothes Dryer - Commercial	1	2.3						
Ready	Industrial Oven - - LPG	1	2.3	Yes					
Ready	Welder	78,912	2.0	Yes					

Electrifiability	Machine type	Count	Emission Ranking	Non-technical barriers			Technical barriers		
				Upfront cost	Availability in NZ	Lifetime cost	R&D late stage	R&D early stage	Needs new development
Ready	Handheld Pruner	59,778	2.0	Yes					
Ready	Concrete Mixer	34,477	2.0	Yes					
Ready	Motorbike - Off-road	1,920	2.0	Yes					
Ready	Forklift	252	2.0	Yes					
Ready	Leaf Blower	29,942	1.7	Yes					
Ready	Concrete Saw	18,066	1.7	Yes					
Ready	Concrete Grinder	2,455	1.7	Yes					
Ready	Grain Auger	1,200	1.7	Yes					
Ready	Post Hole Borer	1,122	1.7	Yes					
Ready	Cherry picker	70	1.7	Yes					
Ready	Sprinkler	11	1.0	Yes					
Almost Ready	Bus - Small	25,740	4.3	Yes					
Almost Ready	Bus - Large	9,960	4.3	Yes	Yes				
Almost Ready	Ute	542,352	4.0	Yes	Yes				
Almost Ready	Van - Light	195,761	4.0	Yes	Yes				
Almost Ready	Truck - Rubbish	930	4.0	Yes	Yes				
Almost Ready	Truck - Heavy	69,269	3.7	Yes	Yes				
Almost Ready	Truck - Small	26,013	3.7	Yes	Yes				
Almost Ready	Van - Heavy	11,912	3.7	Yes	Yes				
Almost Ready	Truck - Medium	70,260	3.3	Yes	Yes				
Almost Ready	Tractor - Small	8,271	3.3	Yes	Yes				
Almost Ready	Earthmoving Vehicle - Loader	6,772	3.3	Yes	Yes				
Almost Ready	Mower - Ride-on	7,999	3.0	Yes	Yes				
Almost Ready	Crusher	387	3.0	Yes	Yes				
Almost Ready	Quad bike	13,404	2.3	Yes	Yes				

Electrifiability	Machine type	Count	Emission Ranking	Non-technical barriers			Technical barriers		
				Upfront cost	Availability in NZ	Lifetime cost	R&D late stage	R&D early stage	Needs new development
Almost Ready	Side-by-side	1,910	2.3	Yes					
Almost Ready	Coffee Roaster	300	2.3	Yes	Yes				
Almost Ready	Go-kart	3,726	1.7	Yes	Yes				
Almost Ready	Snowmobile	117	1.7	Yes	Yes				
Almost Ready	Snow bike	23	1.3	Yes	Yes				
Almost Ready	Rail Grinder - Handheld	20	1.3	Yes	Yes				
Not Ready	**Tractor - Large**	**37,758**	3.7	Yes	Yes	Yes	Yes		
Not Ready	**Earthmoving Vehicle - Excavator**	**30,116**	3.7	Yes	Yes	Yes			
Not Ready	**Truck - Mining**	**2,618**	3.7	Yes	Yes	Yes	Yes		
Not Ready	**Truck - Concrete**	**989**	3.7	Yes	Yes				
Not Ready	Plane - Large/Jet	135	3.7	Yes	Yes	Yes	Yes	Yes	
Not Ready	Cooking Oven - Residential - Natural Gas	70,970	3.7	Yes		Yes			
Not Ready	Truck - Roller	4,208	3.3	Yes	Yes				
Not Ready	Gas Compressor	763	3.3	Yes		Yes			
Not Ready	Commercial Ocean-Going Vessel	79	3.3	Yes	Yes		Yes	Yes	
Not Ready	Jet Boat	50	3.3	Yes	Yes	Yes			
Not Ready	Caravan	53,550	3.0	Yes	Yes				
Not Ready	Grain Drier	2,631	3.0	Yes	Yes	Yes	Yes	Yes	
Not Ready	Truck - Fire	1,250	3.0	Yes	Yes	Yes			
Not Ready	Crane	574	3.0	Yes	Yes	Yes	Yes		
Not Ready	Train	234	3.0	Yes	Yes	Yes			
Not Ready	Commercial Non-Fishing	198	3.0	Yes	Yes	Yes			
Not Ready	Commercial Fishing	40	3.0	Yes	Yes	Yes	Yes	Yes	Yes
Not Ready	Jet Ski	93,000	2.7	Yes	Yes	Yes			
Not Ready	Recreational Motorboat - Inboard - Medium	72,000	2.7	Yes	Yes	Yes			

Electrifiability	Machine type	Count	Emission Ranking	Non-technical barriers			Technical barriers		
				Upfront cost	Availability in NZ	Lifetime cost	R&D late stage	R&D early stage	Needs new development
Not Ready	Helicopter	915	2.7	Yes	Yes	Yes	Yes	Yes	Yes
Not Ready	Bulldozer	441	2.7	Yes	Yes	Yes			
Not Ready	Passenger Ferry	200	2.7	Yes	Yes	Yes			
Not Ready	Frost Fan	174	2.7	Yes	Yes				
Not Ready	Truck - Ground spreading	172	2.7	Yes	Yes	Yes			
Not Ready	Plane - Medium	119	2.7	Yes	Yes	Yes			
Not Ready	Recreational Motorboat - Outboard	260,800	2.3	Yes	Yes	Yes			
Not Ready	Recreational Motorboat - Diesel Launch	8,550	2.3	Yes	Yes				
Not Ready	Heavy Forestry Equipment	218	2.3	Yes	Yes	Yes			
Not Ready	Train - Heritage	148	2.3	Yes	Yes	Yes			
Not Ready	Boat Hoist	100	2.3	Yes	Yes	Yes			
Not Ready	Snow groomer	95	2.3	Yes	Yes	Yes	Yes		
Not Ready	Industrial Oven - Natural Gas	23	2.3	Yes		Yes			
Not Ready	Rocket	10	2.3	Yes	Yes	Yes	Yes	Yes	Yes
Not Ready	Self-propelled Sprayer	3,700	2.0	Yes	Yes				
Not Ready	Plane - Small	3,380	2.0	Yes	Yes	Yes			
Not Ready	Harvester	384	2.0	Yes	Yes	Yes	Yes	Yes	Yes
Not Ready	Rail Grinder - Carriage	1	2.0	Yes	Yes	Yes	Yes	Yes	Yes
Not Ready	Plate Compactor	18,444	1.7	Yes	Yes	Yes			
Not Ready	Pedestrian Roller	12,810	1.7	Yes	Yes				
Not Ready	Mulcher	1,871	1.7	Yes	Yes				
Not Ready	Recreational Motorboat - Inboard - Large	450	1.7	Yes	Yes	Yes			
Not Ready	Gyroplane	80	1.3	Yes	Yes	Yes	Yes	Yes	Yes
Not Ready	Post Driver	146	1.0	Yes	Yes	Yes	Yes	Yes	
Not Ready	Hot Air Balloon	64	1.0	Yes	Yes	Yes	Yes	Yes	Yes

<table>
<tr><th rowspan="2">Electrifiability</th><th rowspan="2">Machine type</th><th rowspan="2">Count</th><th rowspan="2">Emission Ranking</th><th colspan="3">Non-technical barriers</th><th colspan="3">Technical barriers</th></tr>
<tr><th>Upfront cost</th><th>Availability in NZ</th><th>Lifetime cost</th><th>R&D late stage</th><th>R&D early stage</th><th>Needs new development</th></tr>
<tr><td>Process Heat</td><td>Process Boiler</td><td>625</td><td>4.0</td><td colspan="6" rowspan="5">See Section 4.4 and Appendix 2 Section 7.1 for details on opportunities and challenges to decarbonise process heat.</td></tr>
<tr><td>Process Heat</td><td>Reformer</td><td>4</td><td>3.7</td></tr>
<tr><td>Process Heat</td><td>Furnace or Kiln</td><td>68</td><td>3.3</td></tr>
<tr><td>Process Heat</td><td>Process Air Heater</td><td>21</td><td>3.3</td></tr>
<tr><td>Process Heat</td><td>Process Burner</td><td>10</td><td>3.0</td></tr>
<tr><td>Generator</td><td>Generator - Grid-connected - Coal/Gas Baseload</td><td>3</td><td>3.3</td><td colspan="6" rowspan="8">See Section 4.5 for details on opportunities and challenges to replace generators with renewable generation and batteries. These vary based on the size of the generator and, if it is connected to the national grid, the role it plays in the electricity system</td></tr>
<tr><td>Generator</td><td>Generator - Grid-connected - Combined Cycle Gas Turbine</td><td>2</td><td>3.3</td></tr>
<tr><td>Generator</td><td>Generator - Grid-connected - Cogeneration</td><td>14</td><td>3.0</td></tr>
<tr><td>Generator</td><td>Generator - Grid-connected - Gas Peaker</td><td>10</td><td>2.7</td></tr>
<tr><td>Generator</td><td>Generator - Grid-connected - Diesel Peaker</td><td>2</td><td>2.7</td></tr>
<tr><td>Generator</td><td>Generator - Portable</td><td>2,304</td><td>2.0</td></tr>
<tr><td>Generator</td><td>Generator - Distribution-connected</td><td>304</td><td>2.0</td></tr>
<tr><td>Generator</td><td>PTO Generator</td><td>173</td><td>2.0</td></tr>
</table>

Summary Table 2: Ready

Top emissions-ranking machines from the "Ready" electrifiability category with annual emissions and opex savings,[83] sorted by total emissions savings

Machine type	Nationwide Count	Per machine emissions savings per year ($kgCO_2e/yr$)	Per machine opex savings per year ($/yr)	Total emissions savings per year (kt CO_2e/yr)	Total opex savings per year ($M/yr)
Car	3,527,838	1,812	768	6,391	2,711
Space Heater	999,073	378	448	373	442
Water Heater	565,834	591	506	268	230
Motorbike - On-road	214,904	994	972	214	209
Space & Water Heating Boilers (large sites)	50	N/A	N/A	159	N/A
Gas Cooktop - Commercial	10,579	4,783	3,948	51	42
Mower - Push	505,075	39	34	20	17
Cooking Oven - Residential	70,790	149	28	11	2
Space & Water Heating Boilers (small sites)	N/A	N/A	N/A	N/A	N/A
Total	**5,895,261**	**8,746 $kgCO_2e/yr$**	**$6,074 /yr**	**7,486 kt CO_2e/yr**	**$3,653M /yr**

83 All machine-level opex savings, including in this table and following summary tables, include volume costs only, and does not include fixed connection charges for LPG and gas due to the difficulty of attributing proportions of the fixed charge onto particular machines within one ICP connection. In reality, opex savings would be higher because once an ICP eliminates their natural gas connection or LPG subscription, they would no longer need to pay these often significant charges. As an indication, we estimate connection charges to be approximately $0.3778/day for residential LPG, and $1.887/day for residential natural gas.

Summary Table 3: Almost Ready

Top emissions-ranking machines from the "Almost ready" electrifiability category with annual emissions and opex savings, sorted by total emissions savings

Machine type	Nationwide Count	Per machine emissions savings per year ($kgCO_2e/yr$)	Per machine opex savings per year ($/yr)	Total emissions savings per year ($kt\ CO_2e/yr$)	Total opex savings per year ($M/yr)
Truck - Heavy	68,909	46,416	13,373	3,198	921
Ute	539,048	3,269	1,099	1,762	592
Van - Light	194,690	3,197	1,729	622	337
Bus - Small	17,359	25,119	12,318	436	214
Truck - Medium	68,250	5,990	1,910	409	130
Bus - Large	9,817	37,364	7,034	367	69
Truck - Rubbish	930	101,706	34,117	95	32
Truck - Small	25,949	3,347	1,066	87	28
Tractor - Compact	5,960	13,892	6,194	83	37
Earthmoving Vehicle - Loader	6,772	8,136	4,280	55	29
Van - Heavy	10,521	4,175	1,428	44	15
Total	**948,205**	**252,611 $kgCO_2e/yr$**	**$84,547 /yr**	**7,158 $kt\ CO_2e/yr$**	**$2,404M /yr**

Summary Table 4: Not ready

Top emissions-ranking machines from the "Not ready" electrifiability category with annual emissions and opex savings, sorted by total emissions savings

Machine type	Nationwide Count	Per machine emissions savings per year ($kgCO_2e/yr$)	Per machine opex savings per year ($/yr)	Total emissions savings per year (kt CO_2e/yr)	Total opex savings per year ($M/yr)
Tractor - Large	37,052	27,122	1,296	1,005	48
Earthmoving Vehicle - Excavator	30,092	11,391	6,206	343	187
Truck - Mining	2,618	112,555	46,871	295	123
Truck - Concrete	989	56,955	13,003	56	13
Total	**70,751**	**208,023 $kgCO_2e/yr$**	**$67,376 /yr**	**1,699 kt CO_2e/yr**	**$370M /yr**

Summary Table 5: Process Heat

Technical and economical barriers to electrifying process heat machines and their emissions reduction potential

Machine type	Output heat temperature	Nationwide Count	Technical feasibility	Is it economical to electrify without subsidies?	Emissions reduction potential
Process heat boiler	Low 0 to 100°C	186	Y	Y	~4 Mt CO2-e/yr
	Medium 100 to 300°C	423	Y	N	
	High over 300°C	16	N	N/A	
Furnace or Kiln	Low 0 to 100°C	3	Y	Y	
	Medium 100 to 300°C	25	Y	N	
	High over 300°C	40	Limited applications, e.g. steel-making 1500 C electric arch furnace	N	
Process Air Heater/Burner	Low 0 to 100°C	15	Y	Y	
	Medium 100 to 300°C	8	Y	N	
	High over 300°C	23	N	N/A	
Reformer (steam methane reformer)	High over 300°C	4	Y*	Maybe**	~1 Mt CO2-e/yr

*Replace hydrogen made from natural gas with green hydrogen made from hydrolysis of water using renewable electricity
**Green hydrogen being considered for Urea production, but unlikely for Methanol production in the near term in NZ. Emissions shown are the savings from reducing natural gas use for energy, (excludes non-energy emissions savings).

Summary Table 6: Generators

Generator types and technical feasibility of renewable electricity generation and batteries as alternative replacements.

Machine type	Nationwide Count	Technical feasibility of renewables and batteries replacement
Generator - Grid-connected - Coal/Gas Baseload	3	Genesis Energy's three Huntly Rakine coal and gas fired units provide back up energy supply during dry hydro periods when hydro lake levels are low. This often occurs during winter when seasonal electricity energy demand is higher. Investing in additional distributed renewable electricity generation provides additional energy supply, which can reduce use of hydro generation, keeping hydro lake levels higher for longer and reducing the need for thermal back up. However, renewables and batteries do not store energy for a long time i.e. from season to season. Therefore, to fully replace the back up role of Huntly, which can store coal onsite for when it is needed in dry hydro periods, overbuild of renewable generation, or longer term renewable storage such as pumped hydro would be needed.
Generator - Grid-connected - Combined Cycle Gas Turbine	2	
Generator - Grid-connected - Cogeneration	14	Cogeneration plants can be included as part of an industrial process plant to improve efficiency, using waste heat or providing both electricity and process heat. This can offset costs associated with grid electricity supply. Renewables and battery systems cannot provide similar optimisation opportunities or heat supply.
Generator - Grid-connected - Gas Peaker	10	Renewable generation and batteries, or just batteries that charge from the grid in offpeak periods, can provide flexibility supply in the same way grid connected gas and diesel peakers do. Batteries have the added benefit of being able to balance oversupply of intermittent renewables by charging when there is surplus energy due to high wind and sunshine periods. As they are distributed, they also have the opportunity to provide flexibility services to local networks, by exporting electricity at times of high demand on the local network reducing network congestion. This can offset the need to invest in distribution network upgrades reducing costs for consumers, who bear the cost of network upgrades. For some households and businesses, installing rooftop solar and batteries can reduce overall energy bills, before factoring in value from these flexibility services.
Generator - Grid-connected - Diesel Peaker	2	
Generator - Portable	2,304	Distributed renewable generation that is able to charge a portable battery can provide a renewable alternative to a portable fossil fuelled generator. Where portable generators have low kW, portable solar and battery systems are available, meaning the battery can be charged during the day on site. There are some situations where a battery will not have sufficient storage to replace a large portable generator, especially when longer term continuous use is required and taking the battery to be charged regularly is not feasible.
Generator - Distribution-connected (excludes backup generators)	304	Distributed renewable generation and battery systems when properly scaled to meet energy needs can substitute for a distributed generator. Both technologies can provide increased resilience to outages i.e. they will be available if electricity lines are damaged and supply is interrupted.
PTO Generator	173	PTO-powered implements, which rely on tractor power or standalone generators rather than having their own engines, can transition away from fossil fuels by replacing them with unpowered tow-behinds, using electric tractors' PTO systems (which drains battery quickly), or adopting newer electric-drive implements that plug directly into electric power sources like the battery of an electric tractor (much safer and more energy efficient).[84] This would eliminate the need for fossil fuel PTO generators.

84 An example is the Forest Lodge electric foliage sprayer that was built to run off the back of an electric tractor.