Investing in Tomorrow:
The Electrification Opportunity

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Summary

New Zealand households and businesses spend around $20 billion on fossil fuels every year, most of which are imported. Electrifying New Zealand households by replacing fossil fuel appliances and vehicles with electric alternatives, along with adding rooftop solar and batteries, presents an opportunity to save thousands on cost of living, and could save New Zealand around $10.7 billion per year by 2040.

This opportunity can benefit New Zealand today, as well as serve as an investment with lasting future advantages. By making the switch to low-cost, locally generated electricity and reducing reliance on expensive imported fossil fuels, the nation can improve its balance of trade while enhancing its resilience.

- Electrification is a significant efficiency gain that exceeds conventional efficiency benchmarks (Section 2).
- Energy costs have historically risen faster than inflation, while rooftop solar and battery costs have fallen rapidly, now presenting the opportunity to help flatten and lower rising energy bills for homes (Section 3).
- Electrification efficiency combined with the cost of electricity leads to significant energy productivity gains. Enabling New Zealanders to spend less for every kilometre they drive and every unit of energy they use in their home (Section 4).
- Nationally, this opportunity could save New Zealand households around $10.7 billion a year by 2040, save 10 million tonnes of emissions annually, and 105 million tonnes cumulatively between 2024 and 2040 (Sections 5 and 6).
- Electrification involves swapping fuels for finance, where a higher upfront cost enables significantly lower and more stable operational costs by avoiding fossil fuel bills. Improving the facilitation of this finance to all New Zealanders could help the nation realise this opportunity (Section 7).

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Contents

1. Introduction

In this paper we make the case that electrification of the New Zealand economy, specifically household electrification (meaning homes and their vehicles), is not only a significant energy efficiency gain, but will also create cost savings for the majority of households. In addition, this electrification will likely boost New Zealand's energy productivity, and help flatten rising energy bills.[1] Further, electrification of the economy can reduce our dependence on expensive fossil fuel imports, positively impacting the balance of trade.

1.1 Definitions

Electrification combines a number of sectors from conventional thinking about energy systems (sometimes referred to as sector coupling). In this paper, we use the term *household* energy to describe all of the uses of energy within a household. Households use energy from what are conventionally called the residential, transportation, and electricity sectors. For example, a household will use electricity generated in the *electricity sector* to power an electric vehicle from the *transportation sector* that will be realised in the electricity usage of the house, which sits within the *residential sector.*

1.2 Overview of content and methodology

Our analysis shows that large scale, rapid electrification of the New Zealand economy would have highly positive national financial and emissions benefits. To further understand this opportunity and impact, we undertook the following research:

- We analysed current household energy use and compared it to fully electrified households, and we compared the productivity gain of electrification to conventional energy efficiency measures.
- We compared the costs of energy for households and how they have increased over time compared to general inflation, and what this might imply for future energy prices. We compared this to the history of solar and battery cost decline.
- We utilised Rewiring Aotearoa's existing household energy model to forecast the potential savings of electrification per household.[2]
- We built an aggregated model of the cumulative savings from electrification (using historical energy cost data and national machine numbers) to forecast household energy costs nationwide before and after electrification.
- We explored the rate of replacement of fossil fuel machines and their replacement with like-for-like electric equivalents, to understand how quickly household electrification can proceed in New Zealand given the cost savings on offer and the urgency of climate action.
- We calculated the cumulative savings of electrification for New Zealand households and found that bold climate action can save, as opposed to cost, the economy money.
- We considered the effects of household electrification on the balance of trade by contemplating the impact of more domestically produced energy on New Zealand's existing energy mix.
- We also examined why household electrification is not already happening at pace in New Zealand despite the multiple benefits (reducing cost-of-living and emissions, and improving energy productivity), and proposed measures to address the identified barriers to household electrification.

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1 This is due to the falling costs of solar and batteries as energy sources, and the stabilising influence of finance repayments replacing significant proportions of volatile energy prices.

2 This model was developed by Rewiring Aotearoa for the Energy Efficiency and Conservation Authority (EECA), and has since been updated with more recent energy pricing and data for this paper.

2. How households use energy today

New Zealand households purchase and use energy in a variety of forms. They buy petrol and diesel for vehicles. They buy gas from a network or in bottles (LPG) for heating their homes and water, and doing their cooking. Households also purchase electricity, which can be used for all of these purposes, as well as general appliances, lighting, computing, refrigeration, and entertainment. Additionally, there is some use of wood as fuel for space-heating.

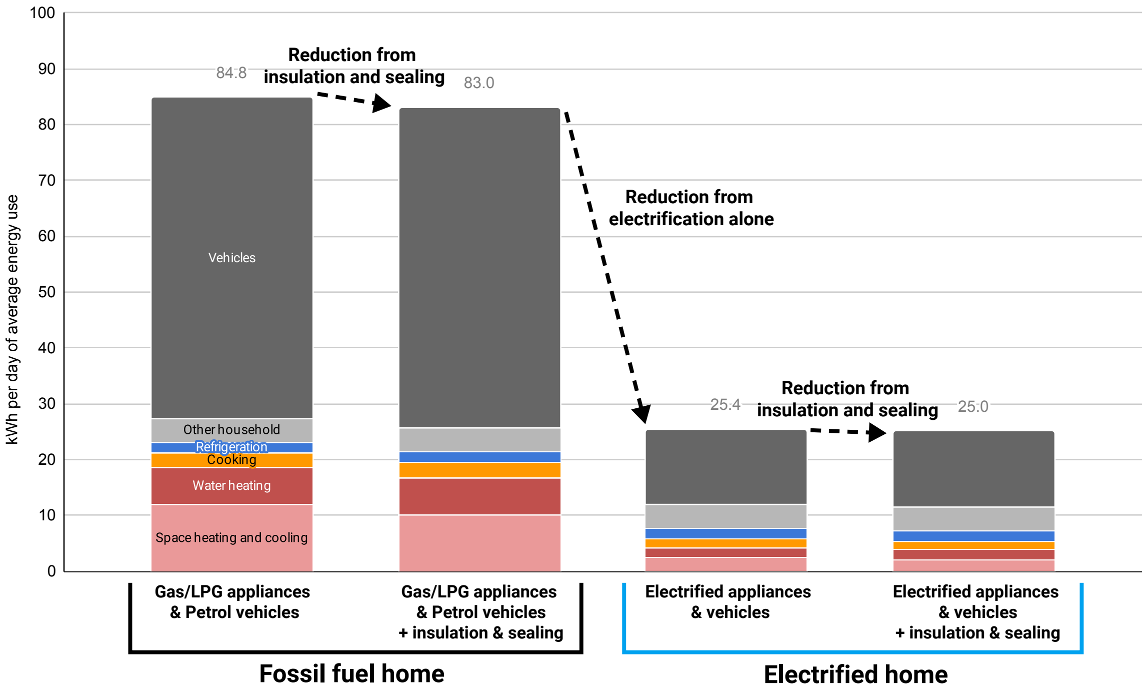
In Figure 1 below we have aggregated data on all household energy uses and graphed them in kilowatt-hour (kWh) equivalents for a fossil fuel home and an electrified home.[3] We have divided the energy these homes use into vehicles (transport), cooking, water heating, space heating, refrigeration, and everything else.

The first column in Figure 1 shows us that vehicle fuels dominate the energy use of a fossil fuel household. When we apply conventional efficiency measures of insulation and sealing to improve thermal efficiency by 15%, we see that the resulting reduction in energy use is limited.[4] This is because the 15% improvement in thermal efficiency only impacts space heating and cooling, which itself only makes up 10-15% of an average household's energy use (including vehicles). As shown in the second column of Figure 1, this only reduces total household energy use by about 2% - from 85kWh per day to 83kWh per day.

The third column in Figure 1 shows the energy use in an electrified household. The significant efficiency gain from vehicle electrification is apparent. Electric water and space heating (by heat pumps[5]) also results in significant gains - three to four times more efficient than fossil fuel heating options.[6] As a result, we see a 70% reduction in total household energy use - from 85kWh per day to 25kWh per day. If we then apply conventional energy efficiency measures to the electrified home, we can further reduce that use to 24kWh per day (as shown in the fourth column in Figure 1).

Figure 1

The efficiency of electrification compared to conventional insulation and sealing efficiency



Source notes: Rewiring Aotearoa analysis. Residential baseline study 2021 appliance energy use. EECA vehicle energy use. 15% improvement average through conventional efficiency measures per U.S. EPA estimates. Note at an individual home level conventional efficiency measures will have varying impacts based on home condition, climate zone and more, though will not exceed the percentage of use that is space heating and cooling, leaving it with limited energy reduction potential. Conventional energy efficiency measures also have other benefits - especially health and wellbeing - which in the case of some homes may exceed the priority of energy or bill savings. This chart is not meant to discourage such measures, but to emphasise the efficiency potential of electrification.

3 See Section 1 of methodology: Household Energy Data.
4 https://www.energystar.gov/saveathome/seal_insulate/methodology
5 Space heating heat pumps are also referred to as reverse cycle air conditioning units.
6 This is due to the Coefficient of Performance (COP) of heat pumps being about 4.0. This means that for every unit of electrical energy used by the heat pump, 4 units of useful space heating energy are provided. This is true even in cooler climates, such as found in much of New Zealand. https://www.eeca.govt.nz/insights/eeca-insights/e3-programme-sales-and-efficiency-data/.

Figure 1(a) Total average energy use of a fossil fuel household in New Zealand, with gas/LPG space heating, gas/LPG water heating, gas/LPG cooktop, petrol cars, and electric everything else. 1(b) Forecast total energy use if a 15% efficiency gain in space heating results from insulation and sealing. 1(c) Energy use of an all-electric New Zealand household with equivalent sized vehicles and equivalent heat to house (a). 1(d) Total energy use of a household if made all-electric and insulation and sealing efficiency measures are applied.

The significant increase in energy efficiency comes from energy productivity. For example, a fossil fuel powered, internal combustion engine converts 16-25% of the energy from the fuel (e.g. petrol) into motion.[7] By contrast, an electric powered vehicle converts 87%–91%[8] from renewable electricity into motion, including charging the car. A typical gas fuelled instant water heater is around 95% efficient, but a heat pump is three to four times more efficient than that.[9] A similar gain can be made for space heating through the use of heat pumps, or even more efficient hydronic heating of a fluid that flows in pipes underneath the floors. Average new heat pump Coefficient of Performance (COP) in New Zealand has been increasing, and is now at over 400%.[10]

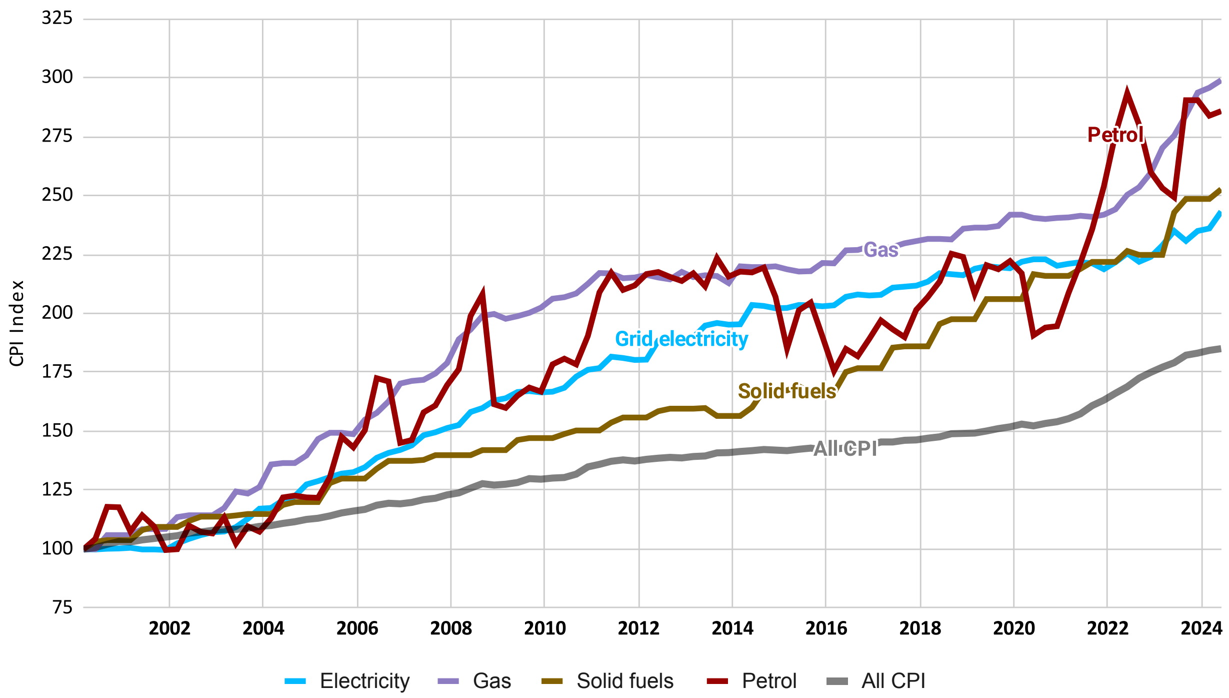
3. Costs of energy for households

3.1 The history of energy prices

Fossil fuels delivered to homes and businesses (as vehicle or heating fuels), and grid electricity have all historically risen at, or above, the rate of inflation. Figure 2 below shows the 20 year history of the price of the main household fuels (grid delivered electricity, petrol, and gas) and compares them to the bundle of goods in the CPI in relative terms to a 2000 baseline. This figure shows that all fuels have risen faster than the CPI.

Figure 2

Cost of energy, consumer price index New Zealand - Indexed to 2000



Source notes: Rewiring Aotearoa analysis. Stats NZ Quarterly Consumer Price Index History 2024. MBIE Energy Prices 2024. ConsumerNZ 2024.

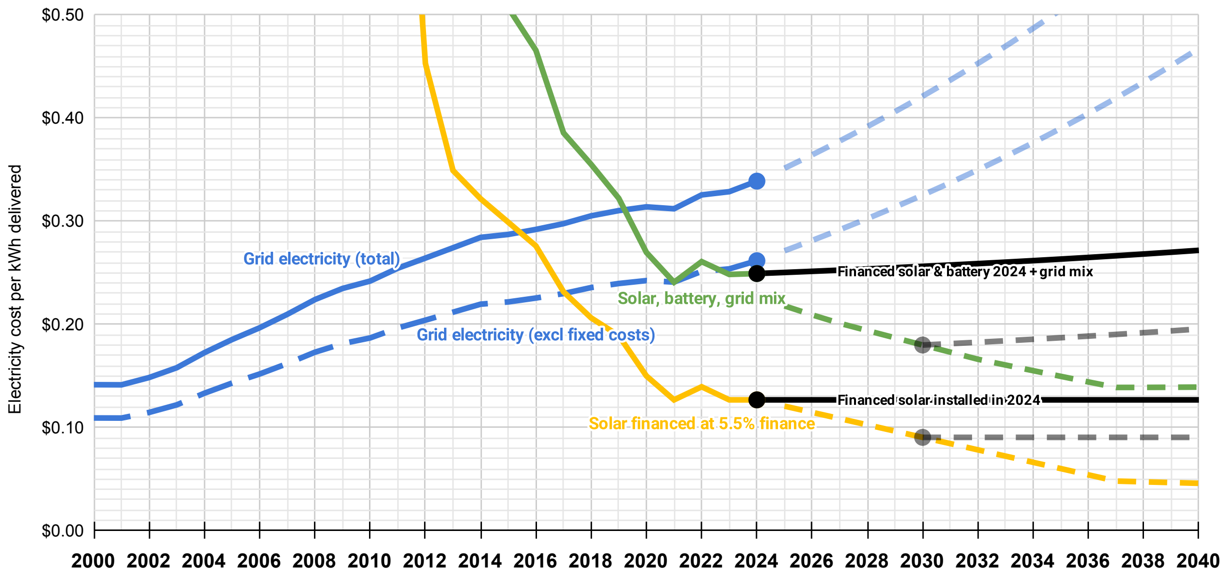
7 This is due to thermodynamic limits, principally the carnot efficiency of combustion. https://www.fueleconomy.gov/feg/atv.shtml
8 https://www.fueleconomy.gov/feg/atv-ev.shtml
9 This is because the heat pump uses a small amount of electricity to gather the heat from a large amount of atmospheric air, the ground, or a water body, and can consequently deliver 350% or more of the heat, for a 100% input. This is known as the Coefficient of Performance, which is dependent on the temperature of the air or input fluid. This means higher performance in summer and lower performance in winter, but even in winter, modern cold temperature heat pumps are often 250% "efficient".
10 https://www.eeca.govt.nz/insights/eeca-insights/e3-programme-sales-and-efficiency-data/

3.2 The future cost of energy prices

In contrast, we can see the fall in the delivered cost of solar from rooftop installations as shown in Figure 3 below. Not only is the price falling - in comparison to rising energy costs shown earlier - installing rooftop solar also helps flatten future energy bills and remove volatility. When a home purchases solar panels, they are effectively buying the 30-year, future energy output of the panels, and fixing the repayment costs. So while the price of other energy rises around it, the price of energy coming from solar panels remains the same as when they were first purchased, that is, a flat line.[11] The same is true of batteries, which store the energy at a flat cost dictated by their utilisation and serviceable lifetime. The green line in Figure 3 below is a realistic household mix of solar, battery, and grid electricity. Because some grid electricity is still being consumed (including fixed costs or daily supply charges), the cost line still increases slightly compared to rooftop solar. However, it inflates significantly less than for the household relying on grid electricity alone.

Figure 3

Electricity cost comparison for New Zealand homes over time ($/kWh)



Source notes: Rewiring Aotearoa analysis. StatsNZ Quarterly CPI History 2024. MBIE Energy Prices 2024. ConsumerNZ PowerSwitch. Micah Ziegler and Jessika Trancik (2021) battery price history. OurWorldInData solar price history adjusted to local NZ pricing. The price history and price forecast in this chart are nominal, based on the 2024 prices of energy as the index.

Australia has seen a large and rapid increase in rooftop solar. Thirty five percent of Australian households now have rooftop solar systems, with an average new system size of over 9kW.[12] The cost of the solar modules has fallen precipitously over the last decade. A reliable estimate of cost is around AUD$1.20c/W installed before the government rebate.[13] The estimated delivered cost of rooftop solar to the appliance or vehicle in the home is (AUD) 4-6c/kWh after financing. This is far ahead of New Zealand, where only around 2.7% of households have rooftop solar, which currently installs for approximately NZD$2.00/W[14] or 12-13c/kWh financed. While this cost is half the cost of grid electricity, there is opportunity to further lower these costs through greater industry scale, and a permitting and regulatory environment optimised for the rollout of rooftop solar.

11 There will be some variation in that line due to changing interest rates, fixed or variable terms chosen by individual homes, and the length they choose to finance the asset.
12 https://cer.gov.au/markets/reports-and-data/small-scale-installation-postcode-data
13 https://www.solarquotes.com.au/panels/cost/
14 Comparison of SEANZ installed medium (7-9kW) solar system costs May 2023.

Consider whole-of-energy-system cost

Tax incentives, concessional government infrastructure financing, and other big policies can enable the household electrification opportunity. It should be emphasised, however, that we can make these policies even more effective by addressing workforce, permitting, public infrastructure investments, and regulatory issues that could further lower the costs of electrification installations and the delivered costs of electricity. Part of the Australian rooftop solar success story was permitting and inspection reforms that made the installations faster, and lower cost, with Australia now leading the world on solar installation costs. It is significantly lower than New Zealand, even though the panel costs for both are approximately the same. Another component of Australia's success was workforce development and certification, which improved the quality of the work and lowered the liability costs.

We also know that the rules of the existing electricity market were designed for one-directional flows from generation source to end use, whereas, this new electricity system will lean heavily on bi-directional flows of energy, and significant local transfers. Rewiring Aotearoa argues elsewhere that a more cost reflective tariff system for consumers would lower the total cost of electricity delivery via lines networks and improve the economics of this opportunity even further.[15] Public infrastructure investments, particularly in public vehicle charging and public property distributed solar generation, also have the capacity to lower the costs to the consumer of delivered electricity and vehicle energy.

The data above shows that electrification provides households with financial savings through flattening bills. In addition, it shows that household electrification helps stabilise energy prices. Less use of fossil fuels means less exposure to volatility in energy prices. When investing in home generation of electricity (rooftop solar), financed at a fixed rate, a household receives a relatively predictable amount of energy for a flat cost. Adding a battery provides a similarly constant cost of storing energy, smoothing the amount of energy available at a fixed cost. This is in contrast to volatile, and relatively rapidly increasing, fossil fuel and grid electricity prices.

Further, New Zealand homes and communities are impacted by and at risk from natural disasters. This was highlighted in 2023 by the severe flooding in the North Island in January, which was noted as a 1-in-200 year event, followed weeks later by Cyclone Gabrielle, reported as the most expensive cyclone in recorded history for the southern hemisphere.[16] Cyclone Gabrielle resulted in widespread power cuts and damages. New Zealand's earthquake risk adds further imperative to the need for a resilient energy system. The 2011 Christchurch earthquake caused significant damage to infrastructure that left thousands of homes without power.[17] There are more reasons than just cost savings for homes to purchase solar and batteries that can provide them with backup power in an emergency.

4. How households save money through electrification

Previous analysis by Rewiring Aotearoa suggests that the average household could save about $1,500 per year through electrification and investment in solar and batteries.[18] (As shown in Figure 4 below). The largest savings are those on petrol and diesel at the pump. This is because the equivalent, comparable price of electricity to power cars in the terms we understand and purchase petrol and diesel in, are $0.31/Litre for rooftop solar and $0.64/Litre for electricity delivered from the grid. The other substantial savings are generated by a combination of the higher efficiency of the heat pump heaters and the more competitive price of electricity compared to natural gas in heating the water and the home. Another, smaller fraction of the savings comes from the lower cost of the portion of electricity use that can be provided by rooftop solar instead of being purchased from the grid. Generally speaking, it is lower than the grid prices because it does not require the network (poles and wires) delivery costs that dominate the retail price of electricity.

15 https://www.rewiring.nz/symetrical-export-tariffs
16 https://en.wikipedia.org/wiki/2023_Auckland_Anniversary_Weekend_floods; https://en.wikipedia.org/wiki/Cyclone_Gabrielle
17 https://www.stuff.co.nz/national/christchurch-earthquake/4734825/Power-restored-to-most-households
18 Rewiring Aotearoa "Electric Homes" March 2024.

Figure 4 - from "Electric Homes" March 2024

New Zealand | Gas/LPG and petrol home versus electrified home, annualised.

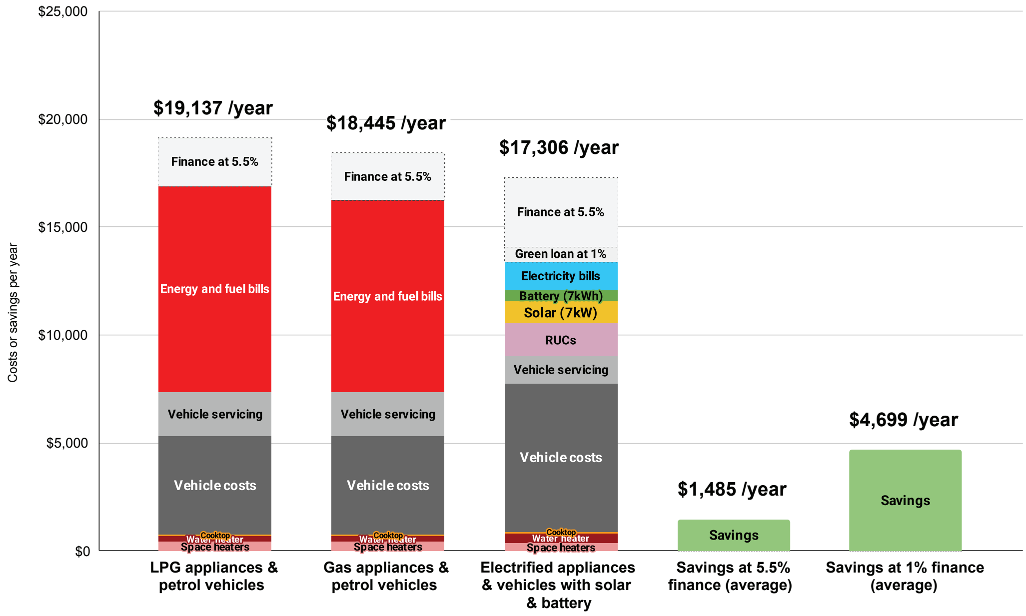


Figure - Average home energy comparison. On the left are the annualised costs of homes with gas/LPG appliances and petrol vehicles (gas is more prevalent on the North Island, LPG on the South Island). In the middle is a home with electric appliances, electric vehicles, and a solar and battery install. This chart shows that while the upfront cost of electric appliances and vehicles is higher, when energy bills are taken into account the all electric zero energy emission home is lower cost. The average New Zealand home could save over $1000 a year electrifying, and over $4,000 a year if they can do so with low interest finance. Every home is different and many factors will affect the amount of savings individual households realise, yet the benefits of widespread household electrification in New Zealand are clear.

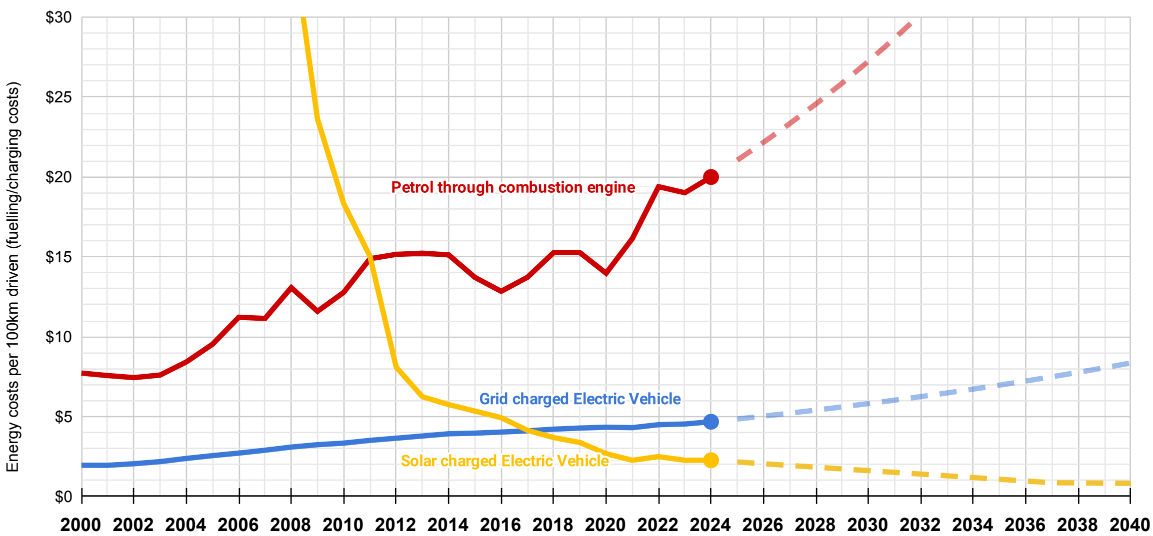
Source notes: From "Electric Homes" Rewiring Aotearoa March 2024.

4.1 The energy productivity of electrification

The fundamental efficiency of electrification, which translates to an operational cost advantage, is demonstrated in Figures 5 and 6 below. Figure 5 compares the cost of driving 100km with a petrol vehicle and an electric vehicle, charged with either grid electricity or rooftop solar. This includes the efficiency increase of electric vehicles (about four times more efficient than petrol vehicles) to show the energy productivity or dollars per 100km travelled with each option.

Figure 5

Energy productivity comparison - $ per 100km of driving - fuelling vs charging costs



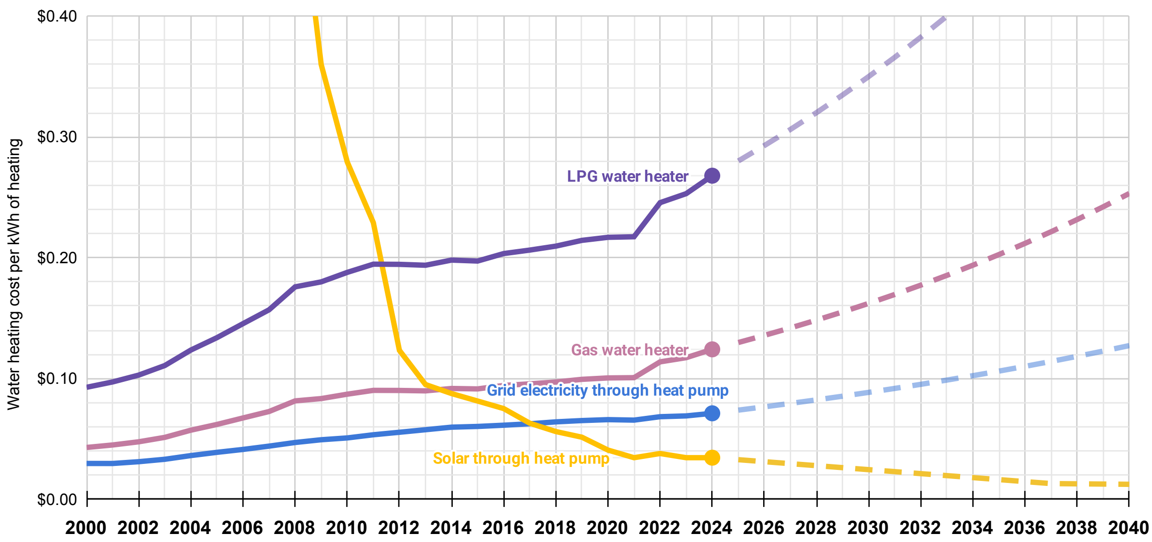
Source notes: Rewiring Aotearoa analysis. StatsNZ Quarterly CPI History 2024. MBIE Energy Prices 2024. ConsumerNZ PowerSwitch. OurWorldInData solar price history adjusted to local NZ pricing. FuelEconomy.Gov vehicle efficiency comparison. Efficiency values: petrol engine 20.5%, electric vehicle 89%. The price history and price forecast in this chart are nominal, based on the 2024 prices of energy as the index.

Similar efficiency gains are seen in heating and water heating. A gas space heater typically operates at about 80% efficiency.[19] By contrast, a heat pump for space heating, outputs about 3 or 4 units (300-400%) of heat for every unit of electricity it uses. Heat pump water heaters have similar efficiency gains.

Figure 6 below demonstrates the cost effectiveness of all-electric heat pump water heating compared to gas, LPG, and grid electricity. Gas, LPG, and electricity "fixed costs" or "supply costs" are excluded from this comparison, and offer further ability to save. Virtually every home is connected to the electricity grid whether they use gas/LPG or not and therefore pay for supply costs (fixed daily charges) for electricity. Removing gas and LPG appliances eliminates the fixed costs for gas connections or LPG subscriptions. Effectively some households are being charged for two subscriptions to energy at the moment which is reduced to one through electrification. By way of example, an average gas connection in May 2024 cost about $689 per year.[20] Electrification removes this additional cost.

Figure 6

Energy productivity comparison - $ per kWh of water heated



Source notes: Rewiring Aotearoa analysis. StatsNZ Quarterly CPI History 2024. MBIE Energy Prices 2024. ConsumerNZ PowerSwitch. OurWorldInData solar price history adjusted to local NZ pricing. Residential Baseline Study 2021. Efficiency values: Gas/LPG 95%, Heat pump 367%. Solar financed at 5.5% over 30 years. The price history and price forecast in this chart are nominal, based on the 2024 prices of energy as the index.

Our analysis shows that across all activities - vehicle transport, water and space heating, and cooking - electrification enables lower operational costs. However, these last two productivity figures only accommodate the operational (fuel/energy) costs of these heating methods. Upfront costs or investment in the machines required is considered in the next section.

4.2 Cost of living savings from electrification

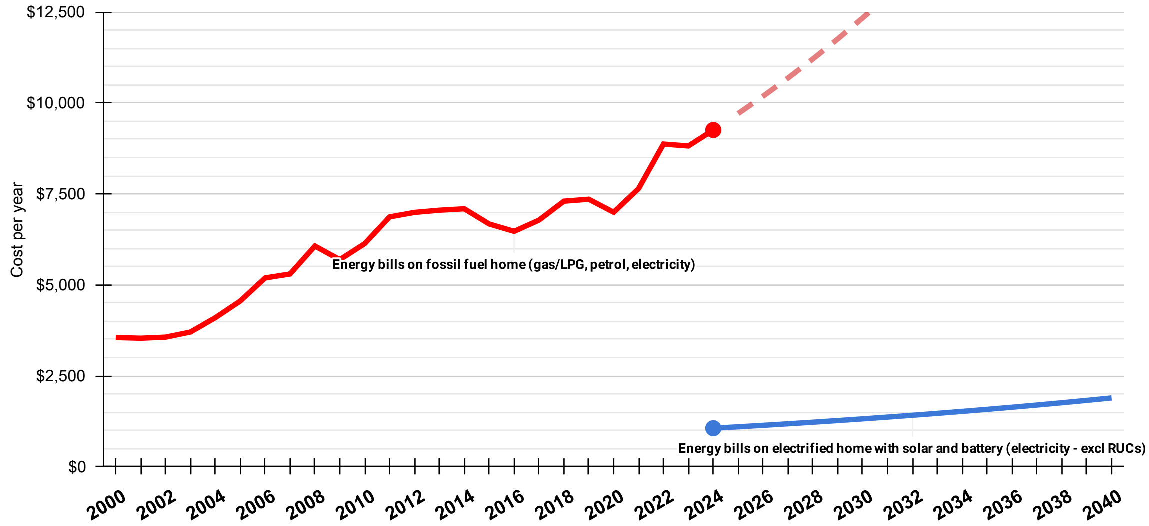
As well as lower delivered energy costs, household electrification reduces the whole of home energy operating costs. Lower costs for solar and battery compared to fossil fuels combine with the added productivity of electric machines to create ongoing lower operating costs, which are not exposed to increasing fossil fuel prices.

Figure 7 below shows an energy bill comparison for homes including vehicles.[21] The red line shows a fossil fuel home with average energy use[22] and the blue line shows an all electric home with solar and battery.[23] This demonstrates the significant difference in operating costs between the two. This Figure shows operating costs alone, it does not include capital costs of appliances or vehicles in either of the homes. These are shown in the next chart, and must be considered to provide the total cost experienced by households for their energy needs.

19 https://environment.govt.nz/assets/Publications/Files/warm-homes-heating-options-phase1.pdf
20 ConsumerNZ PowerSwitch price comparison of gas plans, May 2024.
21 The assumptions for forecast pricing are listed in the methodology appendix.
22 Specifically, a home with average energy use, 1.8 vehicles petrol vehicles (Rewiring Aotearoa "Electric Homes Report", 2024), average of gas/LPG space heating, water heating, cooking, and electric everything else (lighting, refrigeration, other).
23 Specifically, with solar and battery, 1.8 electric vehicle, electric heat pumps for heating and water heating, an electric cooktop and everything else (lighting, refrigeration, other).

Figure 7

Historic and ongoing energy bill comparison. Gas/LPG and petrol home with average energy use versus electrified home and vehicles with solar and battery installed.

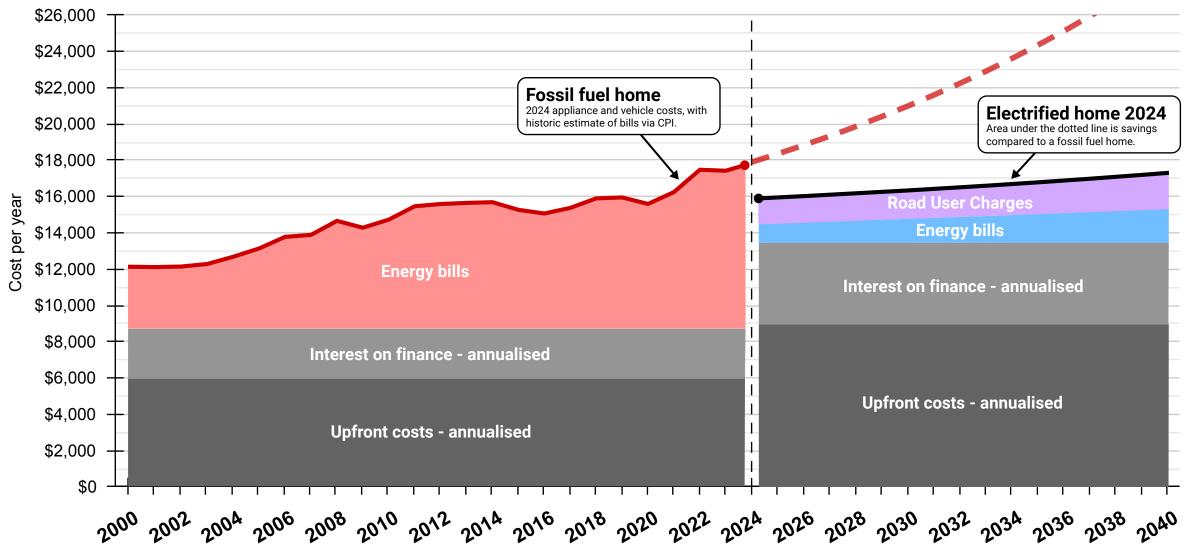


Source notes: Rewiring Aotearoa analysis. StatsNZ CPI History 2024. MBIE Energy Prices 2024 and ConsumerNZ. Residential Baseline Study 2021. EECA Energy End Use Database. The price history and price forecast in this chart are nominal, based on the 2024 prices of energy as the index.

Figure 8 below compares the full home economics of a fossil fuel household compared to an electrified one, including the operational and capital costs. More specifically, capital cost repayments financed at 5.5% on both homes.[24] This demonstrates that even with capital costs included, the electrified home is still an investment that generates cost of living savings. It further demonstrates the opportunity of electrification to flatten energy bills – with savings increasing as fossil fuel prices increase because the home has locked in relatively flat energy costs through their solar and batteries. We note that other costs (such as, Road User Charges and fixed electricity grid supply costs) still cause an electrified home's bills to inflate slightly, though at a slower rate than a fossil fuel home.

Figure 8

Home energy costs comparison. Gas/LPG and petrol home versus electrified home and vehicles. Including operational costs, capital costs, and interest per year for all appliances and vehicles.



Source notes: Rewiring Aotearoa analysis. StatsNZ Quarterly CPI History 2024. MBIE Energy Prices 2024 and ConsumerNZ energy prices. Residential baseline study 2021 appliance energy use. EECA energy end use database vehicle energy. Finance at 5.5% over 15 years for appliances and vehicles, 30 years for solar. Capital costs for both homes set at 2024 prices, with operational costs based on historic CPI trends for each energy type. Shows "full electrification" replacement in year 2024 for demonstration purposes, noting most homes will electrify one machine at a time, for example buying one electric vehicle in 2024, and another in 2026, or replacing a gas water heater in 2024, and then replacing a gas fire in 2025. Does not show forecast price drops in electrification (through learning rates of electric vehicles, solar, and batteries), instead shows electrification at 2024 prices noting that the capital costs (and therefore interest costs) of electrification are expected to continue to decline each year. The price history and price forecast in this chart are nominal, based on the 2024 prices of energy as the index.

24 Financing costs apply to the fossil fuel home due to needing to replace machines and vehicles with fossil fuel versions.

5. National savings from electrification

Our research discussed above demonstrates the economic benefits of electrification for the typical New Zealand household. In this next section, we consider the aggregated cost savings of large scale household electrification across New Zealand.

5.1 What New Zealand spends on fossil fuels today

To assess the national benefits of electrification, we need to understand total energy costs across New Zealand. For that reason, we have calculated the total retail costs paid by New Zealand homes and businesses for fossil fuels. It is important to note the difference between wholesale and retail costs for fossil fuel costs. The latter being what homes and businesses actually pay to use fossil fuels, which includes a mark up on wholesale costs. While the focus of this report is on household electrification, the table below shows total spending on fossil fuels in New Zealand, including business and industry, who typically do not pay the same price for energy as households. However, due to their vehicle use, households still use a very significant portion of the nation's fossil fuels, including most of its petrol.

In the table below we show the retail costs paid by New Zealand homes and businesses in 2023 to purchase fossil fuels.[25] Our figures account for the price difference between the amount industry pays for fuels, and the amount households pay for fuels, and reconciles the two to provide a total figure for New Zealand. For context, 1 petajoule (PJ) of petrol could run approximately 435,000 Corollas for approximately 1,000 km each. In 2023 New Zealand consumed about 101 PJ of petrol and 150 PJ of diesel, most of which was imported.[26] This equates to about 2.9 billion litres of petrol and 3.9 billion litres of diesel costing about $7.7 billion and $7.8 billion respectively.[27]

In total, New Zealand homes and businesses consume about 66.8 PJ of Natural Gas, with another 46.7 PJ used for energy transformation. Approximately $1.5 billion of Natural Gas purchases are made annually by New Zealand homes and businesses. 9.7 PJ of LPG (Liquified Petroleum Gas) is consumed, costing about $567 million. 41.0 PJ of coal is consumed, mostly for industrial heat and electricity generation. Another 57.6 PJ of aviation fuel is imported, with 39 PJ used for international flights and 18 PJ used for domestic flights, totalling around $1.5 billion.

New Zealand retail fossil fuel purchases 2023	Energy (PJ)	Cost
Petrol	100.9	$7,724,047,143
Diesel	149.9	$7,808,602,308
Natural gas	113.6	$1,534,214,167
LPG	9.7	$567,238,703
Coal	41.0	$625,335,556
Aviation fuels - Domestic	18.4	$478,390,752
Aviation fuels - International	39.2	$1,016,223,438
Fuel oil	5.9	$86,625,845
Total		**$19,840,677,911**

Pricing assumptions are listed in Appendix 2: Methodology

25 These are distinct from the wholesale fossil fuel costs.

26 https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-statistics/oil-statistics/

27 https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-statistics/energy-prices/

This shows that when combined, New Zealand spends about $20 billion on fossil fuels per year. Approximately two-thirds of New Zealand's energy needs are met by burning these fossil fuels, most of which are imported. This is despite the fact that the majority of our economy could run on electricity that we could generate domestically using existing technology.

In 2023, 88% of New Zealand's electricity production was renewable.[28] However, as the most recent Energy Update shows, only 30% of New Zealand's final energy consumption is renewable,[29] with fossil fuels largely filling the remaining 70%. With our significant hydroelectric potential, New Zealand has an easier path to 100% renewable electricity than many countries. Wind, geothermal, and solar can easily complement the hydroelectric supply to get New Zealand not just to 100% of existing electrical load, but in a position to accommodate the "load-growth" associated with electrifying our vehicles, the rest of our building heat, and industry. Further, imported fossil fuels create few jobs in our local economy, whereas commissioning, building, maintaining, and operating renewable energy facilities, including the trade-work electrifying the appliances in all our homes, would result in net positive employment growth.

5.2 The rate of household electrification

Even if the international community achieves its existing emissions reduction pledges, the planet is on track for more than 2 degrees of warming by 2100.[30] If all countries achieve emissions reductions to net-zero by 2050, there is still a small chance of 1.5 degrees warming.[31] Electrification with renewable energy is broadly seen as the principle strategy toward these goals. The amount of achievable negative emissions (the "net" in net-zero), is unknown, and there is much reason for caution about the amount of negative emissions already in the Intergovernmental Panel on Climate Change's scenarios.[32]

Because electrification of households is an available technology today (unlike green steel, or zero emission animal agriculture or aviation), we should look at eliminating these emissions "as fast as possible" to do the early work of mitigation while the technologies needed to decarbonise other sectors mature.

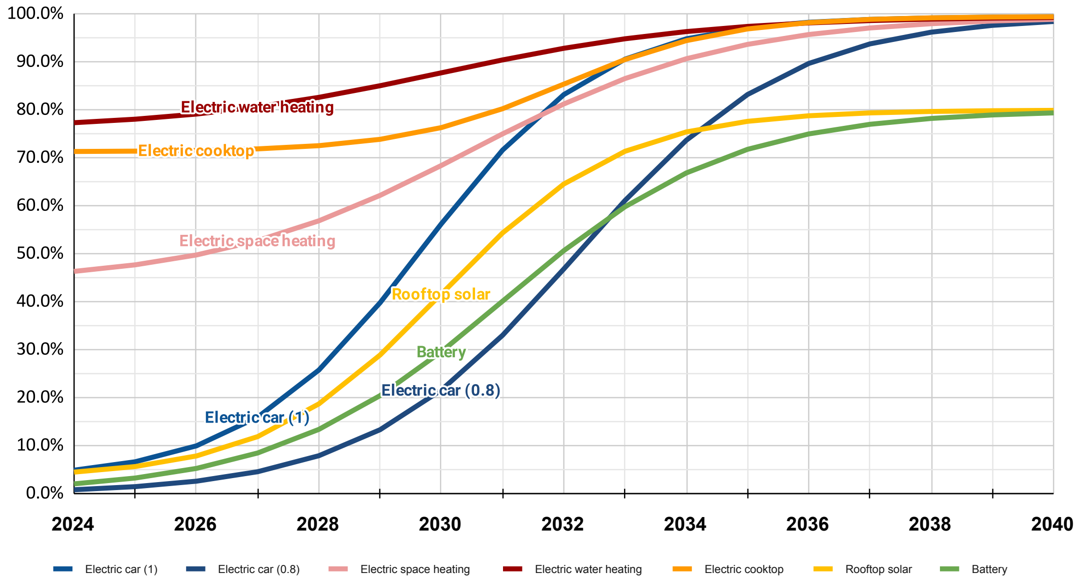
We model "as fast as possible" as replacing any machine that burns fossil fuels at the approximate end of its life cycle with a like-for-like-but-electric replacement. We assume a typical lifespan of a heating appliance or vehicle at 15 years. This would give a linear replacement of fossil fuel machines. However, we model a ramp up of the supply chain, and a rapid decommissioning of remaining fossil fuel machines once the economics make early retirement reasonable. This results in the sigmoidal curve of adoption, which is typical of historical technology adoption curves.

In turn, this results in the adoption or penetration curves we show in Figure 9 below. New Zealand has relatively high penetration of electric water heaters and cooktops already, but just under 50% of space heaters. We have low penetrations (less than 5%) of electric vehicles, rooftop solar and household batteries, the other components of a zero emission electric system. There is an assumed ramp up period of about five years for each technology to allow for the workforce and supply chain capacity to be sufficient for 100% replacement with electric technology at end of life.

28 Ministry of Business, Innovation & Employment *Energy in New Zealand 23* (August 2023).
29 Ministry of Business, Innovation & Employment *Energy in New Zealand 23* (August 2023).
30 https://www.iea.org/reports/net-zero-by-2050
31 https://climateanalytics.org/comment/new-pathways-to-15c-interpreting-the-ipccs-working-group-iii-scenarios-in-the-context-of-the-paris-agreement
32 https://theconversation.com/why-we-cant-reverse-climate-change-with-negative-emissions-technologies-103504

Figure 9

Electrification adoption curves - Rewiring Aotearoa



Source notes: Based on current rates of adoption for each technology in New Zealand. Electric car curves (1 & 0.8) refer to the average home having 1.8 cars, with the first being replaced at a faster rate.

5.3 National savings from household electrification

In the previous sections, we analysed the savings available to households from electrification at an individual level. We now consider the national opportunities for New Zealand generated by the wide scale adoption of household electrification. That is, opportunities that arise from the combined effect of decisions at the individual household level.

Our research shows that while the upfront costs of electrification are higher than their fossil fuel counterparts today, this higher cost is more than offset by lower running costs through time by reducing the use of relatively expensive fossil fuels. As economies of scale continue to drive down the costs of electric vehicles, solar, and batteries, the cost aggregate savings for New Zealand potentially increase as more households electrify.

To demonstrate this, we used the adoption curves of Figure 9 above as the rate of electrification. We then compared the capital costs, financing costs, and operational costs of each machine purchase compared to their alternative in a business as usual scenario where that fossil fuel machine was replaced with another fossil fuel machine. For example, an electric vehicle compared to a petrol vehicle where today the electric car is more expensive upfront (and therefore also in terms of finance interest), but saves on operational cost savings (avoiding high petrol costs).

We then modelled the future capital costs using learning rate predictions. For example, solar, batteries, and electric vehicles are expected to continue to decline rapidly in cost,[33] whereas electric cooktops and heating appliances are not expected to fall in cost as significantly over that time with increased scale. We then assumed typical installation costs, and included switchboard upgrades for a large number of homes. These “soft costs” are one source of uncertainty in the results. Another area of variability is in the learning rate (or economy of scale) predictions for electric vehicles. We used a forecast that predicts parity around 2028 (ie, equal prices for the equivalent EV and ICE vehicle). However, various predictions have been made for parity to be reached before this, which could significantly increase the savings from electrification.

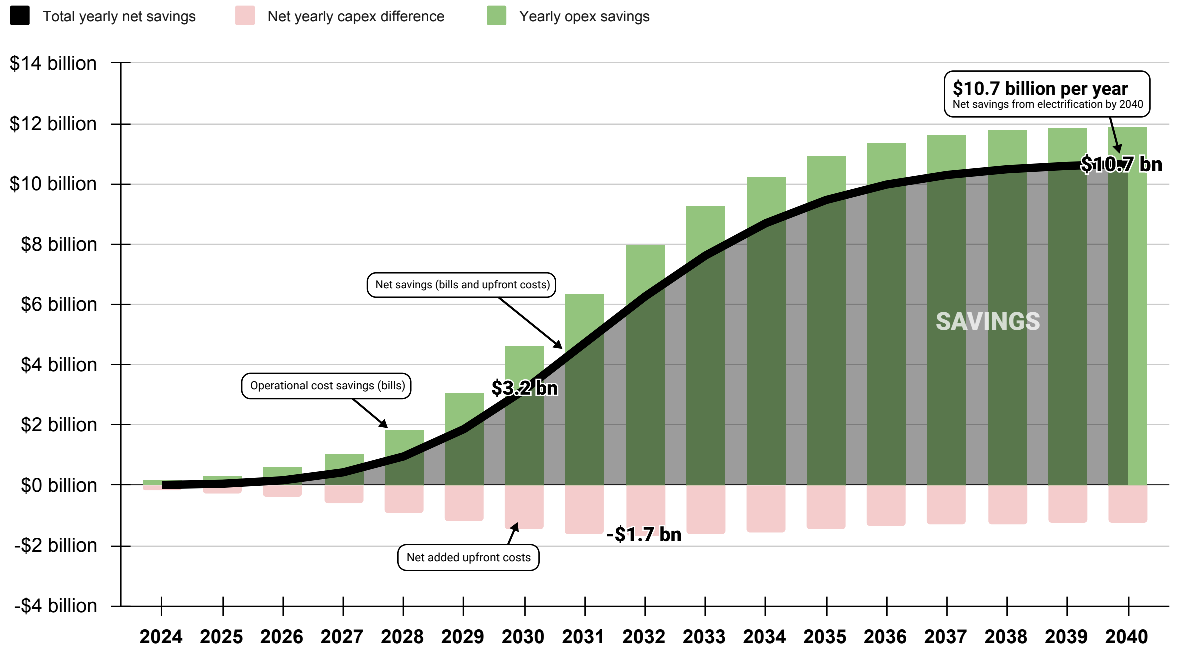
Based on this work, indicative cost savings from the electrification of all households and their vehicles is shown in Figure 10 below. The red columns in that Figure shows the net difference in capital costs required by households to electrify. The lifetime operational cost savings - shown in green columns - already

33 https://atb.nrel.gov/electricity/2023/residential_pv#capital_expenditures_(capex); https://atb.nrel.gov/electricity/2023/residential_battery_storage; Climate Change Commision Electric Vehicle Price Forecast Scenario B; https://www.transportenvironment.org/articles/hitting-the-ev-inflection-point; https://pubs.rsc.org/en/content/articlelanding/2021/ee/d0ee02681f ; https://www.cell.com/joule/fulltext/S2542-4351(22)00410-X

exceed the additional capital costs, as discussed earlier in this report. Around the end of the decade, these capital costs start going in the other direction, largely driven by electric vehicles reaching the cost parity tipping point, and batteries dropping in price. The green line shows the new opex savings as more machines are electrified, and the black line and area shows the combined net yearly cost savings.

Figure 10

Yearly savings from the electrification of New Zealand homes and vehicles - Real $2024



Source notes: Rewiring Aotearoa analysis. MBIE energy pricing and ConsumerNZ energy pricing. Forward pricing forecast at historic CPI Real inflation for each energy type. NREL and CCC forecasts for learning rates. Finance terms 15 years at 5.5%. 30 years for solar. The savings include savings from solar and battery installations. The savings and cost forecast in this chart are Real 2024 dollars.

This Figure demonstrates that by 2030, indicative aggregate savings in the order of $3.2 billion per year are achieved. By 2040, as all homes in the country are electrified, around $10.7 billion per year in savings are achieved. Given that the savings are significant immediately, and the urgency of climate action and near-term emissions reductions, we also looked at the cumulative savings over the same period.

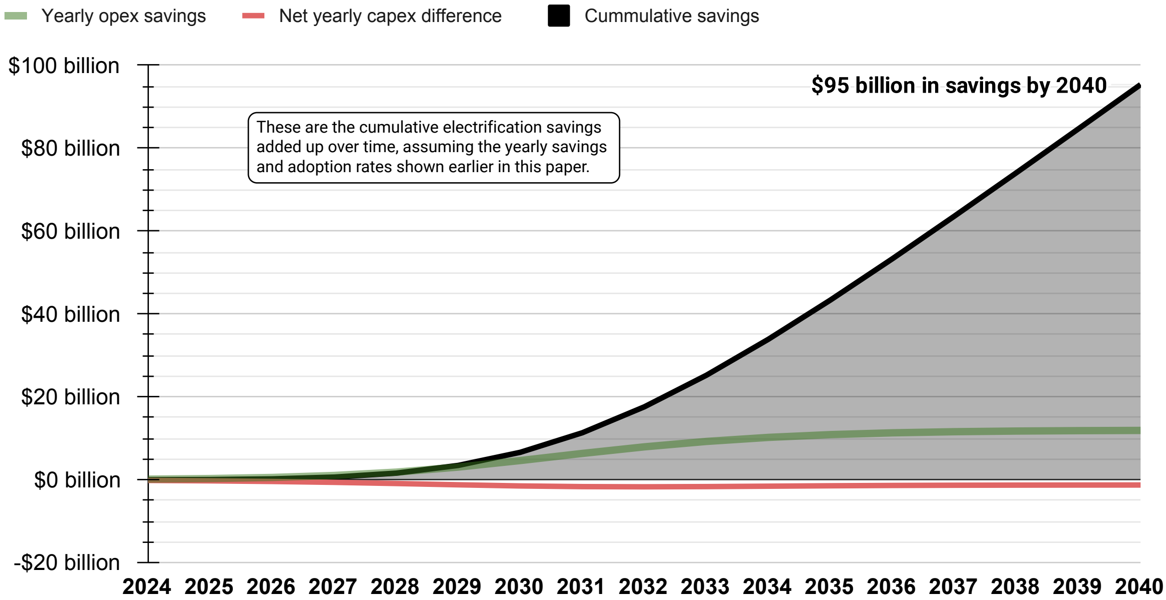
As shown in Figure 11 below, this admittedly aggressive program of electrification could result in New Zealand households saving a cumulative $95 billion by 2040.[34] We could model a delayed or slower pace of electrification but it will merely asymptote in similar annual savings and lower cumulative savings in proportion to the lower ambition. The end state of comparing fully electrified to not electrified would remain largely the same regardless of how fast that point was reached.

While results are indicative, this modelling underscores the scale of the opportunity that home electrification presents in New Zealand. It is an opportunity to lead the world in accessing the savings that electrification can provide, an opportunity to swap expensive imported fossil fuels for renewable electricity generated in New Zealand, to reduce cost of living pressure, and to act on the climate crisis with strategic investment in the future of energy use in New Zealand. This opportunity is not limited to New Zealand, and we speculate that nations with higher costs for imported fuels and good renewable energy resources (like New Zealand) will have similar opportunities for electrification and economy-wide savings.

34 Note that the cumulative savings are somewhat sensitive to the speed of the adoption rates, assuming a natural lifetime machine replacement decision is being made between a fossil fuel versus electrified machine at that point in time. While this number is sensitive to adoption speed, the savings per year number (already discussed above) is largely not sensitive to this, because it compares a fossil fuel machine state of today to an electrified machine state in 2040, which is largely detached from the "time" at which the replacement took place. Note also that these results are sensitive to a number of other assumptions, including future relative price differentials across fossil fuels and electricity.

Figure 11

Cumulative savings from the electrification of New Zealand homes and vehicles - Real $2024



Source notes: Rewiring Aotearoa analysis. MBIE energy pricing and ConsumerNZ energy pricing. Forward pricing forecast at historic CPI Real inflation for each energy type. NREL and CCC forecasts for learning rates. Finance terms 15 years at 5.5%. 30 years for solar. The savings include savings from solar and battery installations. The savings and cost forecast in this chart are Real 2024 dollars.

6. Emissions

Persisting with a predominantly fossil fuel economy has other financial implications. The New Zealand Treasury has estimated that meeting the 2030 Nationally Determined Contribution could cost anywhere between $3 billion to $24 billion worth of international units, depending on the future price and volume.[35] This contingent liability is not yet recognised in the fiscal accounts. Underneath fossil fuel use throughout New Zealand are machines that burn those fuels to operate. These machines are the decision points for effective and rapid emissions reduction. Following the same adoption curves for the savings presented above would result in emissions reductions of 10 million tonnes annually by 2040, and cumulatively of 12 million tonnes by 2030, 105 million tonnes by 2040, and 212 million tonnes by 2050. The reality is that we can buy electric vehicles, heat pumps, solar systems and batteries today, achieving immediate emissions reductions. This is not true of all industries or sectors. Household electrification, along with the electrification of small businesses, is the most significant emissions reduction with cost effective technology available today.

In addition to the emissions benefits, the emissions savings would also help to minimise the amount of offshore carbon credits New Zealand purchased, keeping more money in the local economy. One speculative idea is that the government could project these savings on NDC's and use those savings to underwrite the cost of electrification now to keep more of that money in the local economy and create energy productivity and cost of living benefits.

Household electrification represents a significant short term emissions reduction opportunity that will simultaneously save New Zealanders money, build energy resilience, and reduce dependence on imported fossil fuels. It would also have significant health benefits, which are beyond the scope of this piece of research, but which are substantial. Further, investing in electrification today also delivers significant benefits for future generations. By accelerating investment, we reduce the burden of climate change mitigation on future generations, ensuring a more sustainable and resilient future. Delaying these investments only shifts the cost and burden forward, leaving future generations to address these challenges.

35 https://www.treasury.govt.nz/sites/default/files/2023-04/cefa23.pdf

7. Why is it not happening rapidly already?

Having established the considerable economic benefits that could be generated by household electrification, we next turned to consider why this is not already rapidly happening in New Zealand. Rewiring Aotearoa's view is that one of the biggest barriers to electrification of households is limited access to suitable finance. Other barriers include lack of awareness of the benefits of household electrification, misinformation, and workforce constraints to install electrification technology. These are discussed in the following subsections. We also note the need to ensure the policy and regulation environment best enables this electrification opportunity.

7.1 Finance and access to credit is critical

Electrification effectively involves swapping fuels for finance. This helps to add context to what is required to realise this opportunity. When buying a petrol vehicle, a person is effectively locking themselves into paying for expensive fuels to operate the vehicle for as long as a few decades to come. An electric vehicle may cost more upfront, but will have significantly lower operating costs. Finance can bridge this gap, enabling the combined upfront and operating costs to be lower with an electric vehicle than a fossil fuel vehicle.

Rooftop solar in New Zealand provides the opportunity to halve the cost of energy purchased by households during daylight hours. However, if this solar has to be purchased upfront, it is only accessible to those who have thousands of dollars of disposable income readily available, or easy access to finance. Finance enables homes to get rooftop solar and lower their bills from day one. The combined cost of financing the cost of the solar, and continuing to pay electricity bills, will be less than the cost of just continuing to pay more expensive electricity bills without solar. The same is true of other electrification investments, like heat pump water heaters and home batteries. Finance is the key mechanism to unlock large scale household electrification and the cost of living and emissions savings it provides.

How the energy transition plays out, its pace and distributional impacts, will be defined by who has access to, and the cost of, finance. While this paper has outlined the benefits of financing household electrification at a private finance rate of 5.5% interest, this assumes access to that private finance. Not every household has that access. For example, low income households may have to pay a higher finance rate. Some may not receive access to finance at all. This is in spite of the fact that access would save them more money than the repayments, and that their household finances would benefit the most from the cost-of-living savings, as low income households spend a larger portion of their income on energy bills.

Similarly, while solar will save most households money, renters (who make up about one-third of the general population) have little control over whether solar panels are installed on the property they live in, or whether they can charge an electric vehicle at home. Additionally, landlords have little incentive to install these facilities, as the tenant is the main beneficiary. Finance innovation can bridge these gaps, but solving the dual incentive problem of renters and landlords may also require regulation.

One critical idea that emerges from this paper is a resetting of the idea of what energy infrastructure is. Historically in New Zealand, energy infrastructure has been hydroelectricity and geothermal projects, and big transmission lines. Successive governments justified concessional finance because it was "critical infrastructure". Given the technology-enabled capacity of households and small businesses to generate electricity, store electricity, and perform critical electricity demand response, we suggest that these investments should also be considered critical energy infrastructure. They will certainly be critical to balancing a 21st century electricity grid. As such, we also suggest that governments consider concessional finance options for this 21st century critical energy infrastructure.

Example possible financing mechanisms

The 'Electrify Everything Loan Scheme': Deferred loans, secured on property

Everyone who owns a gas hot water system also owns a property, whether as an owner-occupier or landlord. We can take advantage of this fact when we look for ways to fund the switchover to electric appliances. A loan to finance electrification upgrade 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, and the ability to add voluntary and/or "income contingent" repayments similar to Australia's student loan scheme (Higher Education Contribution Scheme or HECS), this proposition would provide a simple and attractive mechanism for households to invest. It would also enable landlords to make the investment, even those on low incomes. Additionally, it could pave the way for rental minimum standards to deliver the cost-of-living benefits to renters.

Past governments have created universal tertiary education through student loans. The Electrify Everything Loan Scheme (EELS)[36] has been a collaboration between Rewiring Australia, Australian National University, and Professor Bruce Chapman, the architect of the original HECS. Like education, electrification is an upfront investment in the future that has both private and public benefits, and if it can be financed in a way that allows people to repay when they are best able to, it becomes more accessible to everyone.

On-bill finance - treating homes as infrastructure

Finance on-bill is the most "natural" way to pay off electrification, because the bill is where it saves money. The bill becomes lower overall, with a portion of it being a finance repayment and the other paying for the remaining electricity. This approach may also help solve electrification barriers (especially solar) for renters, as the finance would be attached to the meter, and paid by each tenant as part of the bill as they move in and out of the property. This loan is best suited to solar and battery upgrades, as it should not fall to the renter to pay for basic replacement appliances. It should also be repaid over a long term (at least ten years) so that the repayments align to the capital depreciation and the bill-payer is still better off overall. This loan could potentially be held by the underlying network providers (EDBs) and passed through to bills, or held directly by retailers. It would be important to make the loan "portable" across retailers to retain choice and competition.

Rebates and tax incentives

The United States' ground-breaking Inflation Reduction Act of 2022 was the largest commitment to climate-solution funding in history. Due to legislative constraints in the United States at the time, it was enacted as a spending bill, and the majority of incentives are recognised as tax rebate incentives. This can be a regressive approach as the rebates are mostly only available to those with high tax burden. The popularity of these consumer incentives has, however, been extremely high and is outpacing the spending assumed by the United States' Congressional Budget Office - making more emissions reductions happen faster. This highlights a policy response to the electrification opportunity that is multi-pronged to target different demographics with appropriate incentives.

Social impact bonds (SIB)

SIB dedicated to electrification offer a pay-for-performance model that reallocates risk to impact-driven investors, ensuring the delivery of measurable outcomes. These bonds serve as a powerful tool to aggregate finance, foster innovation, and incentivise strong performance.[37] By improving access to finance, SIB can empower small-scale investments by households and small businesses in solar energy and battery storage. This approach provides a more stable, resilient, and cost-effective pathway for long-term emissions reduction.

36 https://www.rewiringaustralia.org/eels
37 Government Outcomes Lab "Impact Bonds" (UK) Impact bonds; https://www.beehive.govt.nz/release/first-social-bond-focus-mental-health

7.2 Information, workforce, and supply chain constraints

Many New Zealanders are not aware of the opportunities of household electrification. Many may be receiving misinformation about electrification and decarbonisation. There is a critical role for clear and honest public education highlighting this opportunity and its economic and climate impacts.

There are substantial informational barriers including or perhaps personified in the skepticism of some around electric vehicles and of others around electric cooking - as examples. Once again, public education is key in this regard.

There are workforce and training constraints on having sufficient electricians and technicians to achieve such an audacious national program and additional resources might need to be developed in certification and training.

There are supply chain issues about purchasing the required “kit”. While electric water heating and cooktops are readily available, and the supply chain would only have to increase marginally, the space heating equipment supply chain would have to increase significantly, and the electric vehicle supply chain more than ten fold. We note that New Zealand, as largely an importer of these technologies (vehicles, solar, batteries) is a price taker, and unlikely to face manufacturing supply chain issues or increased prices in response to greater demand.

Geo-political fragmentation and supply chain disruptions for fossil fuels could threaten energy security and resilience. This includes not only the reliance on imported fossil fuels but also the potential challenges in accessing alternative energy sources, such as solar technology and battery storage. Failure to address these risks with proactive investment, and developing a strategic plan to deliver electrification and long term energy independence could leave NZ vulnerable to geopolitical instability and global market fluctuations.[38]

8. Conclusions

Our research so far has highlighted the size of the economic opportunity presented by household electrification. This undermines the idea that we “cannot afford” to address climate change. Indeed, it shows that for households and their vehicles (representing a large portion of New Zealand’s emissions) addressing climate change through electrification could save them money. The cost of not electrifying is likely to be higher bills and higher cost of living for New Zealanders.

This opportunity can benefit New Zealand today and also serve as an investment with lasting advantages into the future. By making the switch to low-cost, locally generated electricity and reducing reliance on expensive imported fossil fuels, the nation can improve its balance of trade while enhancing its resilience.

It is outside of the scope of this paper to provide a detailed blueprint for the policy or financing mechanisms required for household electrification. This is an area of further research that Rewiring Aotearoa is undertaking. Instead, this paper aims to highlight the scope and scale of the electrification opportunity for New Zealand.

38 D Skilling (2022) Supply chains to the last bus stop on the planet: An international perspective on strengthening New Zealand’s supply chain resilience. Prepared for the New Zealand Productivity Commission.

Appendices

Appendix 1: Energy system implications and sensitivity to electricity prices

As homes electrify their appliances and vehicles, more electricity will be needed by those homes. This will likely range from about 150% - 300% of their current supply, depending on how much electricity they already use, and how many electric appliances and vehicles they already have. Much of this new household energy demand is driven by charging electric vehicles,[39] energy they previously purchased from petrol stations for their fossil fuelled cars. Where that new electricity demand is generated, and how it is transported to the home, is a strategically and economically important question for New Zealand's future energy system. It will help to define both how resilient the energy system is to risk, and how high the price of energy paid by homes and businesses is.

The electricity grid in New Zealand is a complex system, serving not only residential customers, who in 2023 consumed around 35% of the nation's electricity,[40] but also businesses ranging in size from small to very large industrial customers such as steel mills and dairy factories. Therefore households' decisions only represent part of what will define the future electricity system, how much investment will be required to build that system, and, ultimately,what price homes, businesses and communities will pay for electricity.

While there is consensus that more electricity will be required,[41] there is not clear consensus on whether the per unit price of electricity will rise, fall, or stay the same. On one hand, the additional infrastructure required to deliver more electricity could send electricity prices upwards for years to come. On the other hand, making the electricity system "smarter" through batteries and demand flexibility could significantly increase the "utilisation rate" of existing infrastructure assets, therefore decreasing the price of electricity per unit.For example, electricity networks typically operate at less than 50% of their maximum capacity. This means that for most of the day they have "room" for significantly more electricity to flow along the same wires, and it is only at peak times that they are closer to 100% capacity or full utilisation, at which point upgrades will be needed to accommodate any increase. These peak times are usually winter mornings and evenings. Household and network batteries, which are now competitive with grid prices, offer the ability to lower usage at peak times, and increase usage off peak. This simultaneously increases room on the network and utilisation. The former enables less infrastructure to be built, and the latter enables a lower per-unit price of electricity. Digitally "smart" devices (smart chargers, water heaters, and heat pumps) present further opportunity for infrastructure utilisation increases, driving the per-unit cost of electricity down. Perhaps most important of all, vehicles that can send electricity back to load, the home, or the grid (variously called V2L, V2H, V2G). The collective size of those vehicle batteries will present the largest opportunity for balancing the load and increasing network utilisation. We note that in this analysis we do not model usage of vehicle-to-grid in any form, and if implemented it is only likely to further increase savings.

Beyond network costs, the price of grid-sourced electricity will reflect the changing costs of generation going into the grid,including households, businesses, and farms exporting solar. While most market commentaries suggest the cost of variable renewables (wind and solar) equipment will decline, the generation output achieved by these grid-scale investments could also decline through time, as the generation companies move from the best solar and wind sites today, to lower yielding sites. There are a number of other factors that play a part in the overall cost of electricity to customers. Including: how close New Zealand can get to 100% renewable electricity; the sources of flexibility (including from demand and supply side) to provide back up in dry years and balance variation in supply and demand during the day; what generation fuels are used to achieve that, and what those fuels cost. It is difficult to estimate what the net effect of these various dynamics will mean for the generation component of grid electricity prices. To acknowledge this clear uncertainty in future electricity prices, we ran three different scenarios on future grid electricity prices to demonstrate the sensitivity of the outcomes. The default scenario was based on

39 Approximately 85% of electric vehicle charging happens at home, according to Tesla APAC.
40 https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-statistics/electricity-statistics
41 https://static.transpower.co.nz/public/uncontrolled_docs/Whakamana%20i%20Te%20Mauri%20Hiko%20Brochure%20V3%20Web%20version%20Sept%202020.pdf?VersionId=pucEWkwT.xFfDESMht0nLqAMqdkxmdLf

historic price rises in delivered electricity costs of 3.6% pa nominal he low scenario assumed an increase in utilisation that results in no increase in electricity price (i.e. 0%pa), and the high scenario with inflation of 7.0% pa that assumes a continuing increase in electricity prices at a higher rate than has been seen historically.[42] The default forward price assumption used in this paper for grid electricity is that it continues to increase faster than inflation at historic rates.

The results of these three scenarios demonstrated that the nationwide economics of electrification were not significantly sensitive to higher or lower prices in the electricity system. This is caused by multiple factors. One being the significant energy efficiency gains seen through electrification compared to fossil fuel usage meaning that moderate fluctuations in electricity prices do not have a significant impact on the overall economics relative to the efficiency gains. Another impactful factor is the costs of solar and batteries now being low enough to compete against grid prices, and expected to continue to fall. This enables households to proportion their grid usage to suit their needs based on the solar and battery economics available to them – a higher grid price justifies a larger solar and battery installation.

An electricity grid with high amounts of distributed resources can be both economically advantageous for New Zealand consumers, and perhaps crucially, provide significantly more resilience. We demonstrate here that this resilience does not necessarily need to come at a cost, but can instead come with significant and lasting cost of living benefits to New Zealanders.

42 As described in the methodology section, because rooftop solar is now the lowest cost source of electricity for New Zealand homes, and financed batteries are falling below the cost of the grid, we model a highly resilient and distributed future residential energy system. A system that uses the grid, solar, and batteries in a way that could significantly lower infrastructure costs and increase New Zealand's resilience.

Appendix 2: Methodology and Assumptions

2.1 Summary of modelling approach

The model used in this paper includes the following analytical steps, which are described in more detail below:

1. We estimate operation and capital costs for all machine types in homes and businesses.
2. These figures are combined with current national residential machine ownership to provide a current snapshot of the operating cost of machines in homes and the capital cost to replace them with the same or an electric alternative.
3. Adoption rates to reach a fully electrified economy are modelled and used to develop an electrification scenario.
   A continued fossil machine use or business as usual scenario is also modelled.
4. National capex and opex curves are created using the adoption rates for each scenario. Net saving from avoiding fossil fuel costs and saving on grid electricity costs both yearly and cumulatively over time are estimated.

Our modelling uses household and vehicle energy use data at a per machine level (e.g. energy use per gas water heater, or per petrol car), combined with up-to-date energy pricing and product pricing, to understand the economics of electrifying each type of individual machine occuring in New Zealand's housing stock. This includes the operating costs (the gas, electricity, or petrol bills paid to operate that machine), the product replacement costs (the costs to replace like for like, or to replace a fossil fuel option with an electrified option including installation costs), and the finance costs associated with paying off the product over its finance term.

Road user charges) are included in the model for electric vehicles and diesel vehicles. Fixed connection costs are included for gas, LPG, and electricity, including a cost to disconnect from gas or LPG and the associated savings each year.

These individual machine operating and capital costs are then combined with an estimate of the current machine adoption rates across the housing stock of New Zealand. For example, how many homes are predicted to currently have gas water heaters, and how many homes have petrol vehicles. This creates a snapshot of current energy economics for New Zealand households, which is reconciled against petrol and diesel imports, and energy flows across the economy.

S-curve adoption rates to reach a fully electrified economy are then modelled, and for each machine two scenarios are compared. A business as usual scenario where the machine is replaced with another one of the same type, for example a petrol car is replaced with another petrol car, and the electrified scenario where the petrol car is replaced with an electric car. Solar and battery installations, though not "machine replacements" also have an adoption curve shown. These curves determine how many of each machine is replaced or installed each year across the economy.

For solar, batteries, electric vehicles and heat pumps, we then model the predicted costs with economies of scale based on international learning rate forecasts adjusted to New Zealand pricing for each item.

The cost differences for each machine decision are then determined for each year going forward, including both opex/operational and upfront cost differences. These then determine a baseline savings per year for each electrification choice, which is applied to the adoption curves.

Combined, these create national capex and opex curves mapped to the adoption rates shown. Showing the net saving from avoiding fossil fuel costs and saving on grid electricity costs both yearly and cumulatively over time. This creates the final national charts shown in this paper.

2.2 Assumptions used in the model

Inflation Rates

We base the rate of inflation of product prices on the New Zealand CPI history from 2000 to 2024 at 2.56%. Energy inflation rates are determined by the respective category rate of inflation in the New Zealand CPI history, with gas at 4.55%, electricity at 3.69%, petrol and diesel at 5.29%, and solid fuels at 3.86%. We set future product price base inflation at 2%.

The real inflation rates used for energy are the nominal value minus the All CPI groups rate over the same period of 2.55% pa (All Groups CPI). Specifically, 1.14% for electricity, 2.00% for gas and LPG, 2.73% for petrol and diesel, and solid fuels at 1.30%. The primary numbers presented are based on 2024 dollars and use these real inflation rates.

Energy Use by Appliance

We derive average household energy use across different appliances through the Australian and New Zealand Residential Baseline Study 2021, published November 2022.[43]

Energy Use by Vehicles

We derive average vehicle energy use through the EECA energy end use database for 2019.[44] We use data from 2019 for vehicles as this is before COVID lockdowns and the database for vehicles had not been updated for 2022 onwards when our analysis was completed. The assumption made here is that New Zealanders drive similar amounts per year today as they did in 2019. The amount of vehicles per home is sourced from the Census 2018. The number of vehicle types (light passenger and light commercial) is sourced from the Motor Vehicle Association historic sales data.[45]

Energy Efficiency of appliances

We use energy factors / coefficient of performance across each appliance type to calculate the base energy requirements needed by a household depending on what appliances it uses. Heat pump space heating Coefficient Of Performance (COP) is sourced from EECA and a COP of 4.08 is used for the average heat pump.[46] Space heating energy factors for other appliances are sourced from the Warm Homes Technical Report published by the Ministry for the Environment in November 2005.[47]

Water heating efficiencies are sourced from the US Department of Energy - Energy Star ratings scheme.[48] Electric Resistive Tank water heating is assumed at 90%, and Heat Pump water heaters are assumed at 367%, which is based upon the 10% tank losses combined with the EECA 408% heat pump efficiency for space heating.

Cooktop efficiency is sourced from the Frontier Energy Residential Cooktop Performance and Energy Comparison Study Report # 501318071-R0, published in July 2019.[49] Electric oven efficiency is assumed at 95%, and gas/LPG oven at 90%.

Energy Efficiency of Vehicles

We use miles per gallon (MPG) vehicle driving data from the US Department of Energy fuel economy database to calculate the different energy requirements across vehicle types popular in New Zealand.[50] For electric vehicles, this includes charging losses. To calculate the average efficiency difference between an electric and internal combustion engine (ICE) vehicle, we use a comparison of popular New Zealand vehicles both ICE and electric and their fueleconomy.gov MPG combined rating from the website administered by Oak Ridge National Laboratory for the U.S. Department of Energy and the U.S. Environmental Protection Agency. Where fueleconomy.gov data is not available for some electric vehicles in New Zealand (e.g. BYD), we use the Electric Vehicle Database real range energy consumption estimate.[51] Where the energy consumption is not available for any remaining vehicles through either of these methods,

43 https://www.energyrating.gov.au/industry-information/publications/report-2021-residential-baseline-studyaustralia-and-new-zealand-2000-2040
44 https://www.eeca.govt.nz/insights/data-tools/energy-end-use-database/
45 https://www.mia.org.nz/Sales-Data/Vehicle-Sales#oss
46 https://www.eeca.govt.nz/insights/eeca-insights/e3-programme-sales-and-efficiency-data/
47 environment.govt.nz/assets/Publications/Files/warm-homes-heating-optionsphase1.pdf
48 https://www.energystar.gov/products/water_heaters/residential_water_heaters_key_ product_criteria
49 https://cao-94612.s3.amazonaws.com/documents/Induction-Range-Final-Report-July-2019.pdf
50 www.fueleconomy.gov
51 https://ev-database.org/ car/1782/BYD-ATTO-3

we use manufacturer estimates provided in technical vehicle documentation or a comparative vehicle model. The average MPG for an ICE vehicle used is 30.24, the average MPG for an electric vehicle used is 117.13.

Energy Prices

Energy prices for petrol, diesel, and natural gas, come from the average of the most recent four quarters of the MBIE Energy Prices data.[52] These prices are reconciled with a comparison of prices available to consumers from PowerSwitch provided by ConsumerNZ for May 2024. Where data is not provided (e.g. wood), an online comparison of prices is used. While MBIE provides combined residential gas fixed and volume costs in a combined rate, this is split into a lower cost volume rate, and a fixed yearly raterom natural gas offers available on PowerSwitch. The following fuel prices are used:

- Gas fixed costs are estimated at $689 (ConsumerNZ). LPG fixed costs are estimated at $69 (Genesis LPG pricing).
- Gas volume cost per kWh is 11.8 cents.
- LPG volume cost per kWh is 25.5 cents.
- Petrol is $2.74 per litre or 28.9 cents per kWh.
- Diesel is $2.11 per litre or 19.7 cents per kWh.
- Wood is 11.3 cents per kWh, or $4.4 per Kg, or $150 per cubic metre.
- Coal price is 7 cents per kWh for consumption and 4.2 cents per kWh for electricity generation. The generation price was taken from MBIE's EDGS 2024 historic coal import price assumptions.[53]

Household electricity price is calculated using data from MBIE Energy Prices and Quarterly Survey of Domestic Electricity Prices (QSDEP) 2024. We split electricity pricing into a volume cost per kWh and a fixed cost per kWh. Electricity fixed costs vary by energy use in the home. We use a ConsumerNZ average estimate for May 2024 of $2.10 per day, or $767.76 per year. Electricity volume cost (excluding fixed costs) per kWh is 26.2 cents. Ripple control off peak is 24.2 cents per kWh. Nightly electricity is 17.3 cents per kWh, and feed in tariff for solar is 13 cents per kWh.

Costs in forward years are calculated using the consumer price index for each fuel, and the national numbers shown in this paper are Real 2024 dollars. Energy costs for product comparisons use the average energy price over 15 years from the date of purchase.

Solar and Battery Cost, Specification, and Utilisation

Solar prices are estimated at $2,000/kW using a combination of 2023 data from the Sustainable Energy Association of New Zealand (SEANZ) and direct surveys from installers. For full household calculations, we use an example 7kW installation. Assuming 0.5% degradation per year over a 30-year lifetime. Inverter replacement costs are assumed at $2,500. The solar capacity factor assumption is 15%.

We assume 50% of appliance energy needs and 50% of vehicle energy needs can be met during the solar window. Water heating, which is near a third of average household loads, can be moved almost entirely into the solar window in what is described as a "thermal battery". This is similar to existing "ripple control" used in New Zealand electric water heaters to avoid peak electricity times. Other appliances, such as space heaters, can only be moved a small amount, with significant energy needs being met outside the solar window. We consider this to be a conservative estimate of the load shifting possible by households. For example, with new electric vehicles having more range than a week or even two weeks of driving, households could choose to charge near 100% from solar on weekends or, if they are at home during sunlight hours, any time during the week. The other electricity consumption is assumed at full grid electricity costs, which we also consider to be conservative as households often have access to low cost electric vehicle charging rates during off peak periods.

52 https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energystatistics-and-modelling/energy-statistics/energy-prices/

53 https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-modelling/electricity-demand-and-generation-scenarios

All households remain connected to the grid, consume grid electricity, and pay for grid fixed costs and volume costs for the amount of electricity used. The solar export feed-in-tariff is assumed at 13 cents per kWh based on an online comparison of feed-in tariffs. We note that the primary electrified comparison home in the model also has a battery. However, the battery export feed-in-tariff is assumed to be the same as the solar feed-in-tariff. This is considered conservative, as the battery can feed in at peak times when electricity prices are significantly higher, and where some EDBs and retailers provide higher reward for peak feed-in.

For individual appliance comparisons we calculate a cost/kWh for solar based on the above example installation. This is then applied for the portion of the appliance energy use that could be feasibly powered during the solar window and the rest of the energy comes from the grid.

Battery costs are assumed at $1000/kWh, from multiple surveys of 2023 installation costs in New Zealand direct from battery installers, in addition to comparison of available online prices for batteries in New Zealand. Battery cycle costs are calculated over a 15 year, 5475 cycle life. Degradation is assumed at 60% after the 15th year with an accelerating degradation curve from the first year of use. We assume a round trip efficiency of 95%.

Appliance Prices

Appliance prices come from a comparison of over 100 different quotes for appliance costs, sourced both online and direct from installers. An average capital cost and average install cost is used for each individual appliance. The scope of the appliance cost comparison aims to compare products that are not the cheapest possible product, nor the most expensive, as appliance costs can vary significantly. The aim of the comparison was to create an assumed common cost for each option, in the middle of the cost spectrum.

Appliance installation specific costing is scarce, and we acknowledge the need for detailed work in the area of obtaining these “soft costs” or installation costs of devices. Installation costs also vary significantly between installers, creating further complexity. This paper uses installation costs that are the result of real quotes from both online and direct installer but A detailed analysis of the impact of different household conditions and installation costs across different appliances would be valuable for emissions reduction and energy system planning in New Zealand.

The following appliance price and installation cost are assumed:

- Heat pump costs are $3,800 per device, including $1,050 per device installation.
- Gas flued heater costs are $3,200 per device, including $1,250 per device installation.
- LPG flued heater costs are $3,300 per device, including $1,250 per device installation.
- Resistance bar heater costs are $300 per device and $0 for installation as they plug in at the wall.
- Wood fire costs are $2,900 for the fire, $1,000 for the flue, and $1,000 for installation.
- Gas instant water heaters are $1,400, and $2,180 for installation.
- LPG instant water heaters are $1,400, and $2,180 for installation.
- Heat pump water heaters are $4,700, and $2,320 for installation.
- Resistance water heaters are $2,000, and $2,000 for installation.
- Gas and LPG cooktops are $1,000, and $700 for installation.
- Induction cooktops are $1,400, and $1,300 for installation.
- Resistance cooktops are $900, and $300 for installation.

Vehicle Prices

Vehicle prices are based on a comparison of popular New Zealand petrol vehicles and their prices, compared to a similar EV option and its price, using pricing data from vehicle manufacturer websites accessed in August 2024. Clean car rebate is not included as it was phased out in 2024. The average new price used for ICE vehicles is $41,175 and the average new price used for EV’s is $55,176. One $2,000

EV charger per home is also added onto the costs of a new EV. RUCs are included on electric vehicles at 11,000km per year, $76 per 1000km.

Finance Rates, Terms, and Lifetimes

The primary finance rate used to compare homes is 5.5%. The term used for the finance is 15 years, with acknowledgement that some homes may pay this off faster and reduce total interest spending on finance. The lifetime for appliances, vehicles, and batteries is assumed at 15 years, with solar panels at 30 years with one replacement inverter required. Solar panels often have 25–30-year performance warranties, some up to 40 years, and the assumption is that products will not die the moment the warranty ends. Batteries often have 10-year warranties for capacity, e.g. the Tesla Powerwall 2 has a 70% capacity warranty of 10 years, and some have 15 year warranties. The assumption is that capacity will continue to degrade increasingly, and the battery will still remain functional (at lower capacity) for 15 years. Electric vehicles often come with 8-year warranties (and/or around 160,000km) for the battery and drivetrain, and it is assumed the vehicles will last longer than their warranties as most cars significantly outlast their warranty (e.g. a 15 year old car did not have a 15 year warranty). Heat pumps, water heaters, and stovetops are assumed to last 15 years, noting that the quality of device impacts this lifetime, and this study has purposely avoided choosing only the cheapest options, instead aiming for common expected pricing in the middle of the cost spectrum for appliance choices.

Price History and Forecasts

Historic prices for electricity, gas, LPG, petrol, diesel, and wood are modelled using the quarterly consumer price index for the associated type of fuel for the past 24 years - indexed to 2000 - with today's pricing as the basis.[54] Future prices for each of these energy types is based on the Real price increase seen historically. Calculated as the average nominal price increase minus the average All groups CPI increase.

Solar price history is based on international solar price trends adjusted to current New Zealand solar prices. Nemet (2009); Farmer & Lafond (2016); International Renewable Energy Agency (IRENA).[55] Future solar price forecasts are based on the National Renewable Energy Laboratory Residential PV Advanced cost forecast,[56] adjusted to New Zealand solar prices. With acknowledgement that forecasts have historically underestimated the speed at which renewable energy technology drops in price.[57]

Battery price history is based on the paper by Ziegler from 2021,[58] adjusted to New Zealand battery prices. Forecast battery prices are based on the National Renewable Energy Laboratory Residential Battery Storage Advanced cost forecast,[59] which is adjusted to New Zealand battery prices and has the cost decline offset (delayed) by one year to represent delays in supply chain cost reductions reaching New Zealand consumers.

Electric vehicle price forecasts are based on an index derived from the Climate Change Commission (CCC) EV price parity forecast Scenario B,[60] reconciled with market EV and ICE pricing data comparisons done by Rewiring Aotearoa. We found that both EV and ICE vehicle prices on market were lower than the average price used in the CCC forecast, and that the CCC forecast delayed by 1 year represented a more reflective mix of the higher cost of EVs today (about 130% of ICE vehicle costs).

Machine Counts

For each residential machine, we estimate the number in households across New Zealand. We note that residential specific (or most sector specific) machine level data is not available in granular detail, and therefore estimates are used.

For residential vehicles, we estimate a total of 3,758,846 based on Census 2018 data of vehicles per home, combined with the number of occupied dwellings in New Zealand in June 2024.[61] We estimate 69.72% to

54 https://www.stats.govt.nz/indicators/consumers-price-index-cpi/
55 https://ourworldindata.org/grapher/solar-pv-prices
56 https://atb.nrel.gov/electricity/2023/residential_pv#capital_expenditures_(capex)
57 https://www.cell.com/joule/fulltext/ S2542-4351(22)00410-X
58 Ziegler M. S.; Trancik, J. E. Re-Examining Rates of Lithium-Ion Battery Technology Improvement and Cost Decline. Energy Environ. Sci. 2021, 14, 1635–1651. DOI: 10.1039/D0EE02681F, https://pubs.rsc.org/en/content/articlelanding/2021/ee/d0ee02681f https://doi.org/10.7910/DVN/9FEJ7C
59 https://atb.nrel.gov/electricity/2023/residential_battery_storage
60 https://www.climatecommission.govt.nz/our-work/advice-to-government-topic/preparing-advice-on-emissions-budgets/advice-on-the-fourth-emissions-budget/modelling-and-data-consultation-on-emissions-reduction-target-and-emissions-budgets/
61 https://www.stats.govt.nz/information-releases/dwelling-and-household-estimates-june-2024-quarter

be petrol, 21.44% to be diesel, 7.13% to be hybrid, and 1.71% to be electric residentially. We note that while fleetwide vehicle data is available in various forms, there is minimal disaggregation of this data between residential and business vehicles, with many vehicles that will be parked at home (utes/vans) coming under the light commercial vehicle category even though often being popular home vehicles. Similarly, not all electric light vehicles will be owned by homes, with some clearly owned by businesses. For this reason, we use fleet wide estimates and then adjust them by the number of vehicles per home reported in the census.

For residential heating we estimate there are currently around 1,361,536 heat pumps, based on the Residential Baseline Study 2024 (RBS) estimates.[62] We estimate a total of 220,238 Natural Gas space heaters (21,789 ducted), and 343,628 Natural Gas water heaters based on the RBS 2024 forecasts. We estimate 207,241 LPG space heaters, and 157,878 LPG water heaters based on RBS 2024 forecasts. We assume one 7kW heat pump replaces one individual gas heater, noting this is likely to be conservative as Gas heaters are often rated below 7kW. Three 7kW heat pumps replace one gas ducted heater. We assume one 7kW heat pump replaces two LPG heater individual heaters, as the energy use in LPG heaters (per RBS) is less than a quarter of Gas heaters. We note this may be caused by homes using small LPG heaters that are now being phased out, and that newer LPG flued individual heaters have similar heating capacities to flued natural gas heaters. Based on the RBS, we estimate that there are around 455,279 wood fires in homes and 2,058,068 electric resistance heaters. We assume that one 7kW heat pump replaces three small resistance heaters. We assume that one wood fire requires one and a half 7kW heat pumps to replace it. For energy use of each machine, we divide the number of machines in the RBS by the energy use per home adjusted for occupied dwellings. For the energy use of replacement heat pumps, we take the energy conversion of each machine to be replaced combined with its COP/efficiency, and compare it with the COP of the heat pump and how much energy it would need to perform the same task. We then build a weighted per device heating energy needed by the heat pump replacing other fossil fuel machines.

We note that every home is different, and there are both usage (e.g. occupancy) and climate factors that impact energy use. As this is a national model, we use New Zealand averages of home energy use. The Electric Homes Technical Report (March 2024, Rewiring Aotearoa and EECA) demonstrated the impacts of different energy use scenarios and different climates on electrification economics.

We assume 31.6% of homes need a wiring/switchboard upgrade costing $2,000. We model a $200 gas disconnection cost for Natural Gas homes, noting that data here is not transparent from the industry, though temporary gas disconnection is specified at around that cost. With gas connection fees exceeding $600 a year, this disconnection will likely pay itself back quickly, even if it were a higher price. We estimate 2.64% or 55,098 homes have solar, and 0.23% or 4,819 homes have batteries, based on the Electricity Authority installed distribution trends, accessed August 2024.[63]

62 https://www.energyrating.gov.au/industry-information/publications/report-2021-residential-baseline-studyaustralia-and-new-zealand-2000-2040

63 https://www.emi.ea.govt.nz/Retail/Reports/GUEHMT?DateFrom=20130901&DateTo=20240331&RegionType=NZ&MarketSegment=Res&Capacity=All_Total&FuelType=solar_all&Show=ICP_Count&seriesFilter=NZ&_rsdr=ALL&_si=_db_Capacity|All_Total,_db_MarketSegment|Res,_db_RegionCode|NZ,_db_RegionType|NZ,db|5YPBXT,dri|3745,s|dmt,v|3

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. Learn more at https://www.rewiring.nz

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