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An investigation into the potential of residential solar photovoltaic systems to ameliorate energy poverty in Aotearoa New Zealand

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Abstract
Energy poverty is commonly defined as the inability to affordably maintain healthy temperatures in the home. It affects hundreds of thousands of households in Aotearoa with combined public and private costs measured in the billions of dollars each year. The objective of this paper is to analyse the electricity consumption characteristics of those in energy poverty so that the potential for residential solar photovoltaic systems (solar PV) to ameliorate it can be assessed. Further research in this area is particularly relevant given the historically poor standard of the housing stock, the widespread use of inefficient space and hot water heating technologies, the relatively high cost of grid supplied electricity, and the relatively low uptake of residential solar PV systems. This paper examines the scope and scale of energy poverty in Aotearoa and the history and efficacy of common interventions to date. It examines household characteristics and electricity consumption patterns in households facing energy poverty. Such is the state of Aotearoa's housing stock, particularly that inhabited by those in energy poverty, that there is no significant correlation between electricity consumption, building area or number of bedrooms. However, an analysis of eight properties shows that debt funded solar PV systems can make an immediate, and increasing, contribution to the alleviation of energy poverty in some cases. In others, it may be wiser to undertake alternative energy interventions. It is recommended that programmes be established to undertake house-by-house assessments, to broaden the scope of interventions to include solar PV, hot water heat pumps and hot water timers alongside concessionary loans, such as through Local Government New Zealand's proposed Ratepayer Assistance Scheme, to enable their accelerated deployment. It is also recommended that social housing and energy services providers explore the opportunity to maximise the benefit of solar PV across their portfolios.

Keywords: Energy poverty; Residential solar photovoltaics, Energy cost reductions, Concessionary lending.

1. Introduction
Over the ten years to 2024, the residential sector accounted for 32.5% of national electricity demand. In 2024, this rose to 35.03% (MBIE, 2025b). The affordability of electricity is a major factor in energy poverty and costs have been rising significantly in recent years. This is why it's important to examine electricity consumption characteristics and to determine how the installation of solar PV systems might help reduce costs.

Household electricity expenditure has gone up significantly since 2022. The price index recorded by Stats NZ in its Household Economic Survey (Stats NZ, 2026) records an average increase in index of 22.8% across a range of household types including low income, Māori and beneficiary, between September 2022 and September 2025. Looking at the annual increase in prices for the September quarter, these rose by 5.9% to September 2024, and 11.3% to September 2025.

Energy poverty is a pernicious and persistent problem in Aotearoa New Zealand affecting hundreds of thousands of households (O'Sullivan, 2024; MBIE, 2023; Duffy, 2025; EECA, 2025). It gives rise to public and private costs measured in the billions of dollars each year, as discussed in section 2.3.

Key contributory factors include the poor thermal performance of housing, an inability to adequately heat them, especially beyond the main living area, and the affordability of energy.

Despite interventions focused on improving the fabric of the buildings, such as the Warmer Kiwi Homes insulation and heating retrofit programme (EECA, 2023) and the Healthy Homes Standards (Tenancy Services, 2025 a, b, c and d.), its ill effects continue.

1.2 Objective of the paper

There is a two-part objective to this paper. The first is to examine electricity consumption patterns for those experiencing energy poverty and to compare those to consumers not identified as being in energy poverty. Following on from this, the second part is to examine the potential for residential solar PV systems to lower household energy costs.

2. Literature review

An initial systematic literature review was undertaken to establish definitions around energy poverty in Aotearoa. This was followed by quantitative analyses of the incidence of energy poverty in Aotearoa to establish existing assessments of the number of households or individuals either experiencing, or at risk of, it, and the scope and costs of energy poverty related impacts.

A deeper, semi-systematic, thematic review was then undertaken to establish:

- Contributing factors to energy poverty through a thematic analysis of contributing factors. These are likely to range in terms of specificity under a smaller number of more general themes such as affordability, energy demand and building characteristics.
- What interventions have been tried to date and to attempt to understand their efficacy.
- Research into the cost effectiveness of residential solar in Aotearoa New Zealand.

2.1 Definitions of energy poverty

There are many definitions of energy poverty (O'Sullivan et al., 2024), energy hardship, (MBIE, 2025) and other terms such as fuel poverty. They commonly include measures of the ability to afford to maintain health indoor temperatures within a home as captured by research collective He Kāinga Oranga (2024), which states:

> *"Fuel poverty has been defined overseas as the inability to acquire adequate household energy services for 10% of household income. This includes everything energy is used for within the home setting, including heating to WHO recommended safe indoor temperatures for health. The World Health Organization has recommended maintaining indoor air temperatures of 18-24°C to protect health for the past 30 years, based on evidence that indoor temperature levels outside this range have negative physiological effects."*

2.2 Incidence of energy poverty in Aotearoa

Researchers have worked over many years to quantify the incidence of energy poverty in Aotearoa. They have done so by studying different qualitative and quantitative aspects of it such as: household electricity spend (O'Sullivan et al., 2024), using quantitative tests against defined criteria (MBIE, 2025), and by survey (Duffy, 2025; EECA, 2023).

From this work, estimates of the incidence of fuel poverty can be obtained, as summarised in Table 1.

Table 1. Summary estimates of the incidence of energy poverty in Aotearoa

Measure	Incidence	Notes
Twice median energy spend on energy	360,000/16.37% of households	Not including housing costs
Twice median energy spend on energy	595,000/30.54% of households	When housing costs included
Five measures of energy hardship in Stats NZ Household Economic Survey.	~110,000/4-6% of households by each measure	Data from Stats NZ Household Economic Survey Higher incidence for Māori and Pacific households
Struggle to pay energy bills	20% of households	Press release on unpublished survey
Living in cold homes	11% of households	Press release on unpublished survey
Home is cold and draughty.	All – 17% Renters – 22% Aucklanders – 26%	Self-reported
Worry about increasing home energy prices	Agree – 47% Strongly agree – 36%	Self-reported

2.3 Externality costs of energy poverty

Many studies have been completed over more than two decades on the financial costs felt beyond the household, particularly within the health systems for hospital treatment and stays, Doctors visits and prescriptions, missed school and workdays, as well as related excess mortality being calculated against the Value of a Statistical Life measure.

A quantitative understanding of the private and public costs arising from energy poverty is important when considering the value of responses to it. While this is typically expressed in financial terms, efforts have been made by the likes of Smith and Davies (2020) to assess general wellbeing and social costs as a consequence of a number of energy poverty-related impacts, such as living in a cold home or one with mould. These are included in the Treasury's Cost Benefit Analysis data, shown in Table 2 (Treasury, 2023).

Table 2. Extract from Treasury's CBAx model detailing the private cost of living in a home that is cold or has mould present. Final, cost per 100,000 homes added by author

Description	2025 value, per year, per incidence	Per 100,000 homes
House mould: some (general population)	-$3,004	-$300 m
House mould: very bad (general population)	-$4,655	-$466m
House cold: sometimes (general population)	-$4,985	-$499m
House cold: sometimes (Kainga Ora tenant)	-$10,580	-$1.06 bn
House cold: often/always (general population)	-$7,537	-$754 m
House cold: often/always (Kainga Ora tenant)	-$11,052	-$1.1 bn

Source: (Treasury, 2023)

The impacts of not being able to maintain a healthy indoor environment relating to temperature and moisture, with a warm, dry home, have been researched extensively. This research is often conducted through a healthcare lens and focusses on specific impacts such a hospital stays (Chapman et al., 2009; Riggs et. al., 2021) or excess mortality (Howden-Chapman et al., 2012). The latter reported the following findings:

> *…vulnerable populations, particularly those on low incomes, the old and the young are more likely to be hospitalised in winter for respiratory and cardiovascular conditions. They are also more likely to die prematurely in winter than those who live in more modern housing, which has been built to higher building standards. Low housing and heating standards are having serious effects on New Zealand's population health.*
>
> *Fuel poverty is thought to be a factor in NZ's high rate of excess winter mortality (16%, about 1,600 deaths a year) and excess winter hospitalisations (8%).*

A 2022 report for the Ministry of Health (Hogan and Song, 2022) includes information on the incidence of disease by income, a key indicator of the risk of energy poverty, and ethnic group. The study found that: hospitalisation rates increased over the study period for bronchiectasis, childhood bronchiolitis, and total respiratory disease, while rates remained constant for asthma and COPD (Chronic Obstructive Pulmonary Disease) and that:

> *Asthma prevalence, hospitalisation and mortality were significantly higher in Māori, and in more socioeconomically deprived areas, with asthma hospitalisation rates over three times higher in NZDep2006 quintiles 9 and 10, and twice as high in NZDep2006 quintiles 7 and 8, compared with NZDep2006 quintiles 1 and 2.*

Studies, such as Elers et al. (2021) have specifically linked those on low incomes to an increased incidence of living in poor quality housing. Poor quality housing and low incomes are coincident risk factors for facing energy poverty.

2.4 Contributing factors

Researchers have identified many causal factors for energy poverty. In broad terms, these can be included in the following simple thematic taxonomy:

- Financial factors – such as household income and the price of energy.
- Property factors – the size and thermal efficiency of the building envelope and the efficiency of energy consuming machines as well as the local climate.
- Occupant factors – number and characteristics of occupants, their energy use behaviours and demands and perceptions of comfort.

MBIE (2023) developed its own Conceptual Framework of Energy Wellbeing. Howden-Chapman et al. (2021) identified three main contributing factors to energy poverty and Brado-Catala et al. (2023) identified three main contributing factors of their own to energy poverty, as summarised in Table 3.

Table 3. Identified contributing factors to energy poverty by researcher against a simplified thematic taxonomy

Study	Financial	Property	Occupant
MBIE Factors			
Household resources	X		X
Dwelling appliances		X	
Energy supply		X	
Environment		X	
Service literacy			X
Dwelling characteristics		X	
Household circumstances and practices			X
Energy prices	X		
Howden-Chapman factors			
Poor quality housing		X	
Income inequality	X		
Increased power prices	X		
Brado-Catala factors			
Food expenses	X		
Energy prices	X		
Housing quality		X	

2.4.1 Financial factors

It is axiomatic that households on the lowest incomes are more likely than households on higher incomes to be dependent on benefits, including Super, for a higher proportion of their total incomes; especially for those in receipt of means tested benefits. This is also reflected in the socioeconomic deprivation decile rating system.

It follows from this that being on a low income makes energy relatively less affordable and, therefore, that the incidence of fuel poverty is likely to be higher. This hypothesis is supported by the data of MBIE (2023) on the incidence of energy hardship in Table 1.

It is also reasonable to assume that if wages and benefits fail to keep pace with rising housing and energy costs then the pressure households face regarding energy poverty will increase against the definitions related to proportion of household spend.

Household energy costs have risen 9.1% in the year to June 2025 (Stats NZ, 2025). MBIE domestic electricity price survey data (MBIE, 2026) shows Wellington City prices rose at an annual average of 3.32% for the ten years to February 2026, and 7.63% for the five years to February 2026. Given this widespread, a mid-point of 5.48% is used in the modelling of the base case.

Ability to pay energy bills has been identified as a factor affecting the use of heaters by both BRANZ (Anderson et al., 2024), with 31% stating trying to keep costs down as a reason for their home being cold in winter, and Motu for EECA (2023).

2.4.2 Property factors

The overall standard of the building in terms of thermal performance and the efficiency of energy conversion devices within, such as space and water heating devices, are perhaps the largest determinant of the ability to affordably maintain healthy temperatures. In the HEEP2 study of BRANZ (2024) 31% gave "*heat just disappears*" as a reason for the home being cold in winter. This study also found internal temperatures were related to prevailing insulation standards.

It should be noted that since 2009, EECA programmes have supported over 385,000 insulations (EECA, 2023), and 75,000 heating retrofits and the deadline for the implementation of the Healthy Homes Standard for rental accommodation has now passed.

A study conducted by Motu and published by EECA (2023) evaluated the outcomes of heat pump retrofits under the Warmer Kiwi Homes programme. It found that recipient households had average measured winter evening temperature rise of 1.1^{0}C, and up to 1.9^{0}C when outdoor temperatures are low but that gains were lost in draughty homes. On inspection, rented homes in the study were found to be in worse condition than average owner-occupied dwelling. This is a differentiating factor compared to the HEEP2 study.

The conclusion in considering the research focused on house condition is that those homes that are draughty, poorly insulated, absent efficient water and space heating devices and are more likely to be colder and more expensive to heat.

2.4.3 Occupant factors

There is evidence to support Pacific and Māori households having more people in them and earning less than their European counterparts (Stats NZ, 2023).

MBIE (2023) found that around 12.2% of Māori, and 14.4% of Pacific households experienced its qualifying criteria for energy hardship. Also, that around 12.2% of renters experience energy hardship compared to 2.5% of owner-occupiers.

Another factor worth considering is the underlying behaviour of householders when it comes to perceptions of comfort and habits around energy use that can entrench fuel poverty (Chard and Walker, 2016). The BRANZ study corroborates this with 18% stating preference or habit to not heat.

Motu's study for EECA (2023) found that around 10% of households did not heat their main living space over winter stating reasons of cost and lack of effective heating devices.

In conclusion, there are some households where an active choice is made to not heat because they think its futile, they do not feel they have adequate heaters, that it is unaffordable or out of habit or perceived preference. Tellingly though, people are more likely to make an effort to keep the bedrooms of children, under-fives in particular, warm overnight.

2.5 Barriers to improved energy efficiency and lower energy costs

In a study into the non-adoption of energy efficient hot water systems in Aotearoa New Zealand (Grieve et.al., 2012), high upfront costs were identified as a consistent barrier to uptake of more efficient systems. So too were split incentives between the landlord, who would have to pay for more efficient systems, and the tenant who would accrue the savings on their bills from such systems. A reliance on the status quo and a lack of awareness of available alternatives and their benefits were also cited.

An EECA (2025a) study into the residential solar buying process also found that there are information and financial barriers to going ahead along with finding out that individual roofs are unsuitable for optimal solar PV performance.

2.6 Savings available from residential solar PV systems

A different EECA study into the value of residential solar PV systems and storage (2025b), both in hot water and batteries, found that such systems can produce returns of 8 to 12% when they are fully funded up front, so no loan servicing is required. Higher returns were found to be possible for households with higher electricity demand depending on retail tariffs, system size, azimuth and tilt, and export limits.

There are currently no programmes to directly support the roll out of residential solar PV systems in Aotearoa.

3. Research methods

A mixed methods approach was undertaken to establish the electricity usage patterns and household characteristics of those identified as facing energy poverty against a control group of customers in the same region that have not being identified as facing energy poverty.

For objective 1 regression and comparative analyses were undertaken of anonymised customer data comprising electricity consumption, building area, number of bedrooms and socioeconomic decile for customers facing energy poverty, and regular customers.

For objective 2 a simple 5 kW solar photovoltaic system was then modelled across four homes in a retailer's energy hardship programme, the Wellbeing cohort, against a control group of four similar homes on regular tariffs, the Toast cohort.

The solar model considers baseline half hourly consumption patterns, solar PV production, self-consumption, export and a calculation of annual gross savings. Solar savings were carried over into a separate financial model based on repaying a concessionary loan over 20 years. Variables in the financial model include CPI inflation, electricity price inflation, interest rate and repayment term to allow for sensitivity analysis.

As the roof characteristics were fixed for each home based on real world conditions, Wellbeing and Toast tariff structures remain consistent across the sample for low and regular users. The solar PV systems are uniform.

3.1 Sampling

A sample of residential electricity consumption for 565 residential households was used in the research. Of this, 122 were enrolled in Toast Electric's Energy Wellbeing Programme (Wellbeing). The balance, 443, being regular Toast Electric customers (Toast). All the customers are in the Wellington Electricity distribution area and are therefore subject to the same residential tariffs and the same climatic zone.

Only residential properties with at least 12 months of consumption data were included in the initial sample along with a record of the specific tariff that applied. Half hourly data was used in the solar model.

Wellbeing customers are enrolled in the programme as clients of an approved agency, such as for debt management and that are struggling to pay their power bills. Those in the programme receive a visit from a Healthy Homes Advisor to be given advice on creating a warmer, dryer, healthy home as well as an assessment of eligibility for Government healthy homes programmes, such as Warmer Kiwi Homes and associated programmes, through which grants can be available for heating and insulation.

Wellbeing customers also receive total power bill discounts in the months of June, July and August. In 2025, a 30% discount was applied during these three months. All renters are assumed to be in properties that meet the Healthy Homes standards, noting that measure specific exemptions can apply due to building factors.

For the modelling of solar PV systems, customers were sorted by customer type, Wellbeing and Toast, and by number of bedrooms. One Wellbeing customer was selected for each of one-, two-, three-and four-bedroom properties, starting with the mean customer by consumption for each number of bedrooms group. Control homes from the Toast group were selected based on those with the consumption closest to the selected Wellbeing homes by number of bedrooms. Homes were rejected for solar analysis if they were part of an apartment block, n=4, a flat within a larger home, n=2; issues particularly effecting one bed properties, if the property had excessive shading, n=2, or if solar PV was already present, n=1.

Homes were not selected on the basis of having optimal, north facing, roofs. Rather, the homes reflect real world conditions in terms of roof azimuth and tilt. Table 4 shows summary data for the eight properties selected for solar modelling.

Table 4. Summary area, bedroom, decile and consumption characteristics of homes selected for solar modelling

Home	Area m²	No of bedrooms	Decile	Customer type	Annual consumption kWh
H1 WB1	49	1	4	Wellbeing	3,963.02
H2 T1	35	1	1	Toast	4,017.38
H3 WB2	65	2	8	Wellbeing	6,815.09
H4 T2	92	2	7	Toast	6,730.02
H5 WB3	174	3	4	Wellbeing	9,378.48
H6 T3	129	3	3	Toast	9,348.23
H7 WB4	121	4	10	Wellbeing	11,637.50
H8 T4	139	4	10	Toast	11,603.30

3.1.2 Building the data set for analysis

To compare electricity consumption and costs more equally, the addresses of the whole sample were looked up within Toast Electric to establish:

- Dwelling area in square meters;
- Number of bedrooms; and
- Socioeconomic decile.

The area and bedroom data was taken from QV (2026), Homes.co.nz (2026) council records, and in some cases real estate listing pages. This was cross checked against Google Maps and Street View with some homes having their area calculated using the measure tool in Google Maps. A small number of the sample, n=23, were rejected due to insufficient information. This was a particular issue with large homes divided into flats and apartments within large apartment buildings. Socioeconomic decile by suburb was taken from Stats NZ Census data published by the University of Otago's Public Health Research Group (2024).

Once the data set covering both groups had been completed, the data was anonymised within Toast Electric by the removal of address and ICP information before analysis.

3.1.3 Consumption analysis

Regression analysis was undertaken by dwelling area and consumption and by number of bedrooms and consumption. Each sample was further grouped by number of bedrooms, one to four, to establish average consumption.

Observations were made regarding the spread of consumption by dwelling area and number of bedrooms and between Wellbeing and Toast customers. The average socioeconomic decile rating was also calculated for both the Wellbeing and Toast customer groups.

3.1.4 Solar PV analysis

The OpenSolar design and modelling tool was then used to model solar production, self-consumption, export and costs. A full year's worth of half hourly consumption data was obtained for each of the eight homes modelled as an input along with prevailing Toast day/night tariffs plus the same tariff with a 30% discount applied across June, July and August for the Wellbeing customers for the Wellington Electricity area as per Table 5.

Table5. Toast Electric tariff table, 1 April 2026

	Low User (<8,000 kWh/yr)			Standard user (>8,000 kWh/yr)		
	Night	**Day**	**Export**	**Night**	**Day**	**Export**
Toast	$0.19	$0.38	$0.125	$0.168	$0.336	$0.125
Wellbeing rate (June, July and August)	$0.13	$0.27	$0.125	$0.118	$0.235	$0.125

Notes: Night rate runs from 9pm to 7am.
Day rates apply 7am to 9 pm.
Wellbeing pricing applies only to Wellbeing customers for consumption during June, July and August. Toast pricing applies at all other times.

Financial modelling of payback based on the cost and savings outputs from the OpenSolar model were undertaken in Excel (see the supplementary material). This allows for the following variables to be changed in the spreadsheet so that different financial scenarios can be tested:

- Inflation rate. Base case is the mid-point, 2%, of the Reserve Bank of New Zealand's target range of 1 to 3% (Reserve Bank of New Zealand, 2026).
- Power price inflation. For the base case, an average of 10 and five year retail energy price inflation rates of 5.48% is used. (MBIE, 2026)
- Debt interest rate – Taken from the average of the three-year mortgage rate from the Reserve Bank of New Zealand's Standard Interest Rate data series (2026b), discounted in line with anticipated Ratepayer Assistance Scheme projection of mortgage rate less 1-1.5%. This gives a base case rate of 5.77% less 1.25% to give 4.52%.
- System price. $10,500. Sourced from an anonymous commercial provider for a simple 5kW system with a basic 5kW inverter.
- Loan term. Twenty years.
- Gross system savings in year 1 from OpenSolar model for each dwelling.

For the sensitivity analysis, a long-term view was taken of CPI and power price inflation where they matched each other at 2% and a non-discounted lending rate of 5.17% which is the average two-year rate from the Reserve Bank of New Zealand's hb30 data series since April 2021 (2026). Toast and Wellbeing tariffs remained unchanged as did system price and loan term.

4. Results

4.1 Consumption analysis

The mean annual average for Wellbeing customers is 8,461 kWh, and 7,383 kWh for Toast customers. The mean average dwelling area is 101.5 m^2 for Wellbeing customers, and 127.8 m^2 for Toast customers. On a kWh per meters squared basis, Wellbeing customers use 1.44 times as much electricity. The mean average number of bedrooms is 3 for Toast customers and 2.7 for Wellbeing customers. The mean average socioeconomic decile rating for Wellbeing customers is 6.65 and 4.04 for Toast customers.

The mean average cost of power if every Toast customer was paying the composite rate and fixed daily charge for a low or standard user is $2,770 per annum. The mean average cost of power if every Wellbeing customer on the same tariff with the discount applied is $3,004. On average, Wellbeing customers are spending, $234 more, 1.084 times as much, as Toast customers for electricity. The average Wellbeing discount is worth $323.92.

Figure 1 shows average consumption by month for Wellbeing, n=122, and Toast, n=443, customers. Figure 2 shows monthly volumetric consumption variance of Wellbeing customers compared to Toast customers. Figure 3 shows average monthly percentage variance in consumption of Wellbeing customers compared to Toast customers.

Figures 2 and 3 show that the proportional variance between Wellbeing and Toast customers is not uniform across the year. While the difference in kWh is higher in the winter months, the percentage difference is not as high, with a greater proportional difference being recorded across the summer and autumn. The months where the Wellbeing discount is applied is highlighted in both figures.

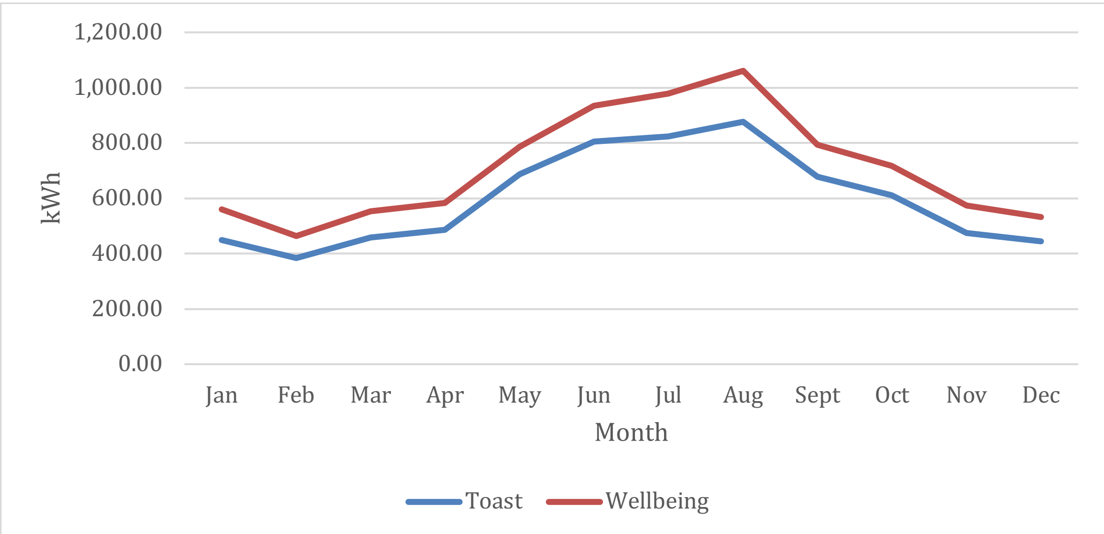

Figure 1. Monthly mean average consumption for Wellbeing and Toast customers

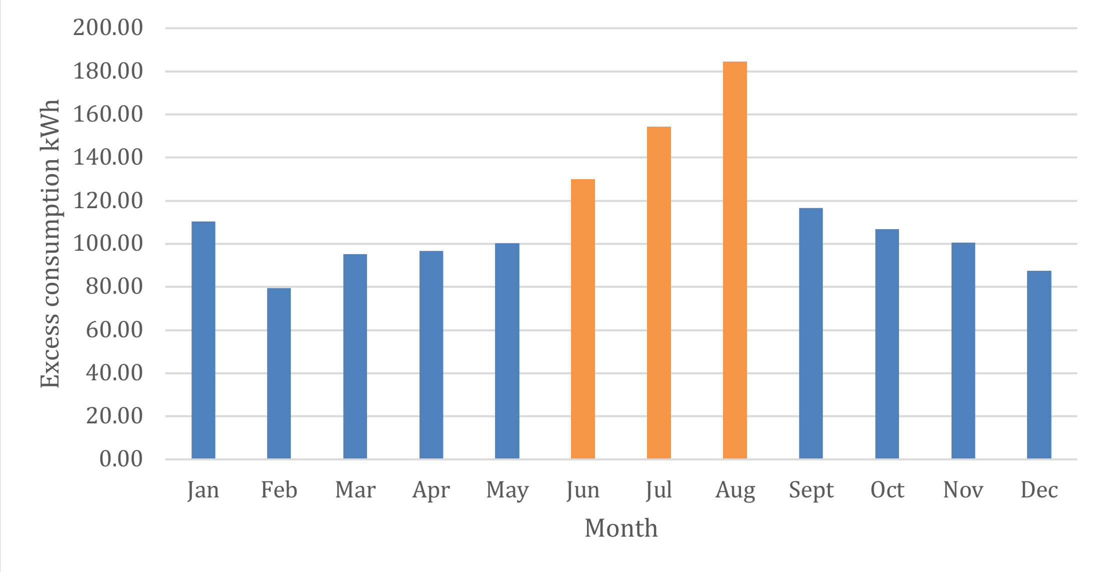

Figure 2. Monthly volumetric consumption variance of Wellbeing customers compared to Toast customers

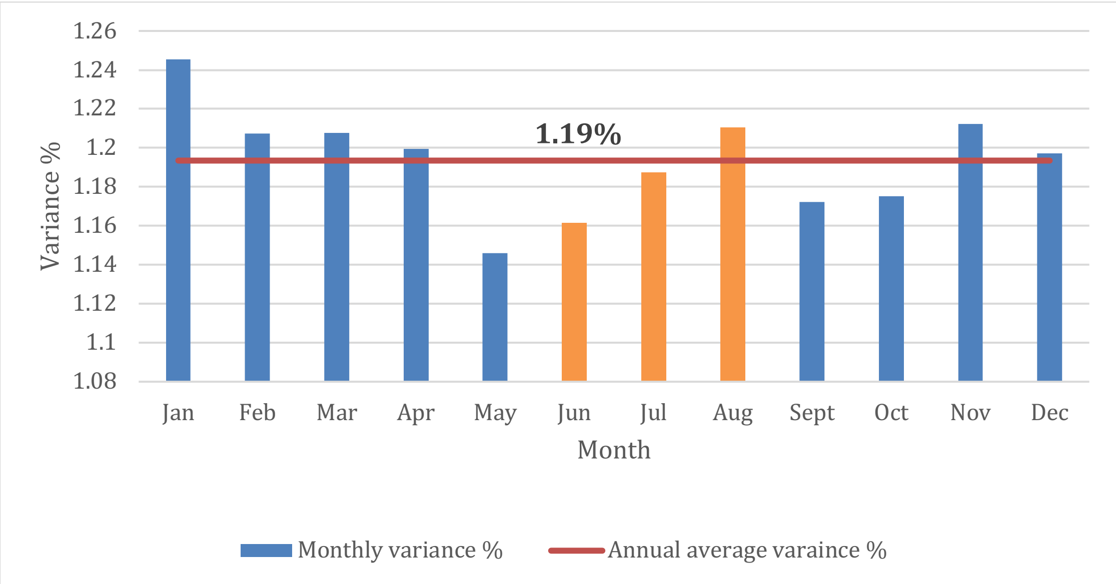

Figure 3. Average monthly variance in consumption of Wellbeing customers compared to Toast customers

Figure 4 shows the percentage of the Toast and Wellbeing customer samples by socioeconomic decile. The mean average decile of Toast customers is 4.04 and for Wellbeing customers, 6.65.

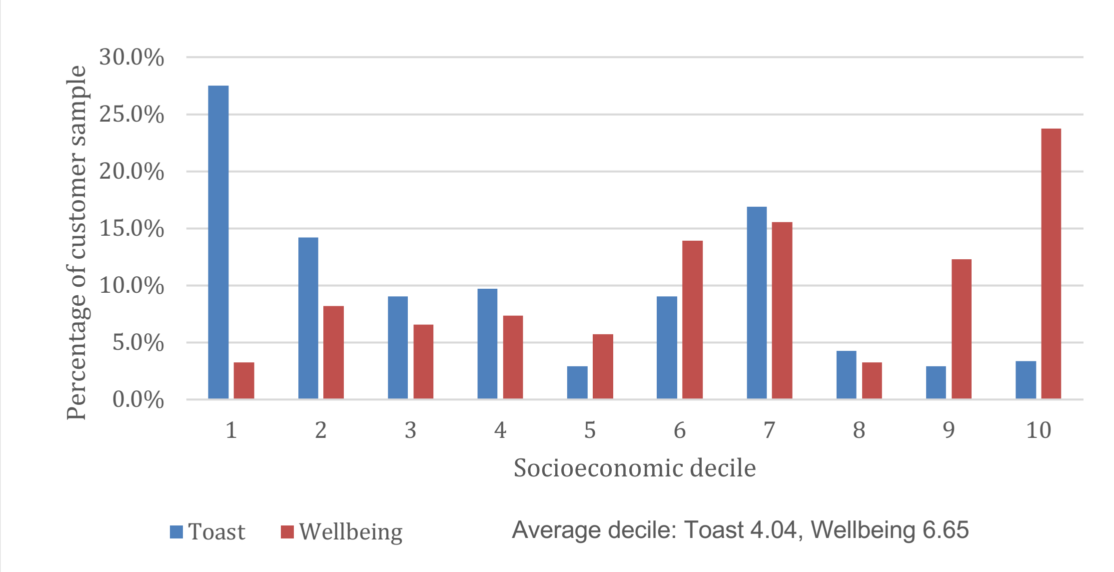

Figure 4. Distribution of customers by socioeconomic decile as a percentage of each sample

4.2 Correlation between consumption, dwelling area and number of bedrooms

Table 6 shows the R^2 regression analysis of consumption against building area and number of bedrooms for the Wellbeing and Toast groups. Figures 5 and 6 plot consumption against dwelling area for Wellbeing and Toast customers respectively.

Table 6. Summary of R^2 regression analysis where Y = consumption and X = dwelling area and, separately, number of bedrooms for Wellbeing and Toast customers

R squared test	Dwelling area	Number of bedrooms
Wellbeing n=123	0.209732535	0.211215
Toast n=361	0.187116547	0.181017

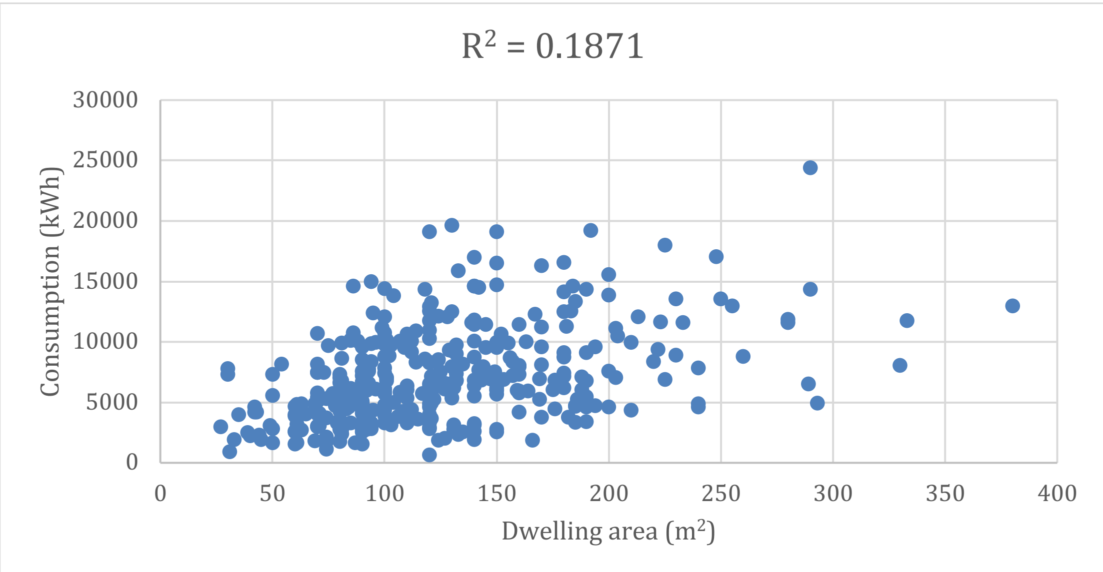

Figure 5. Plot of consumption against dwelling area for Toast customers

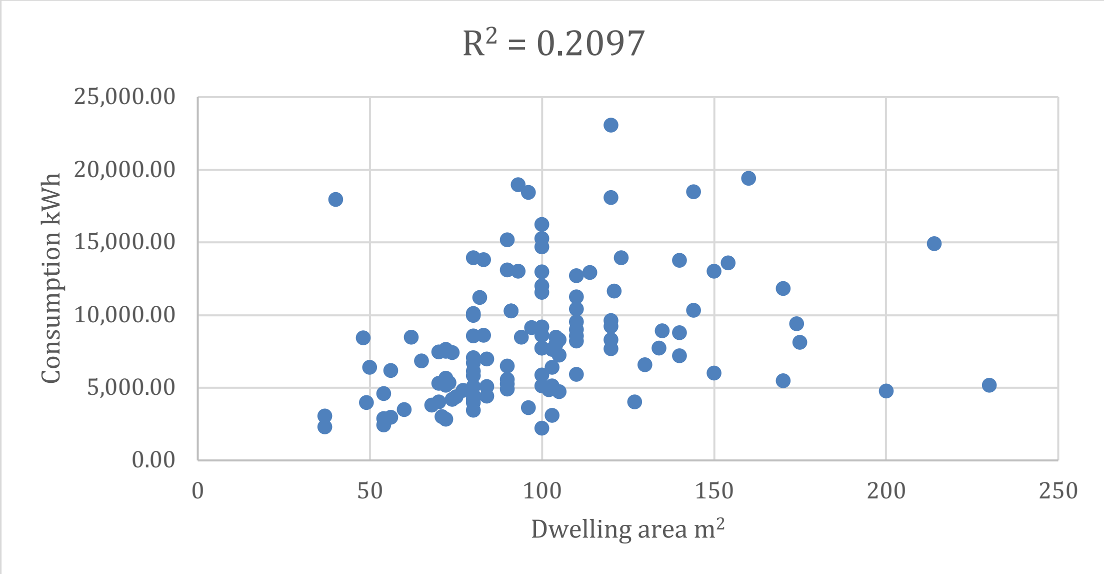

Figure 6. Plot of consumption against dwelling area for Wellbeing customers

Figures 7 and 8 plot consumption against number of bedrooms for Toast and Wellbeing customers respectively.

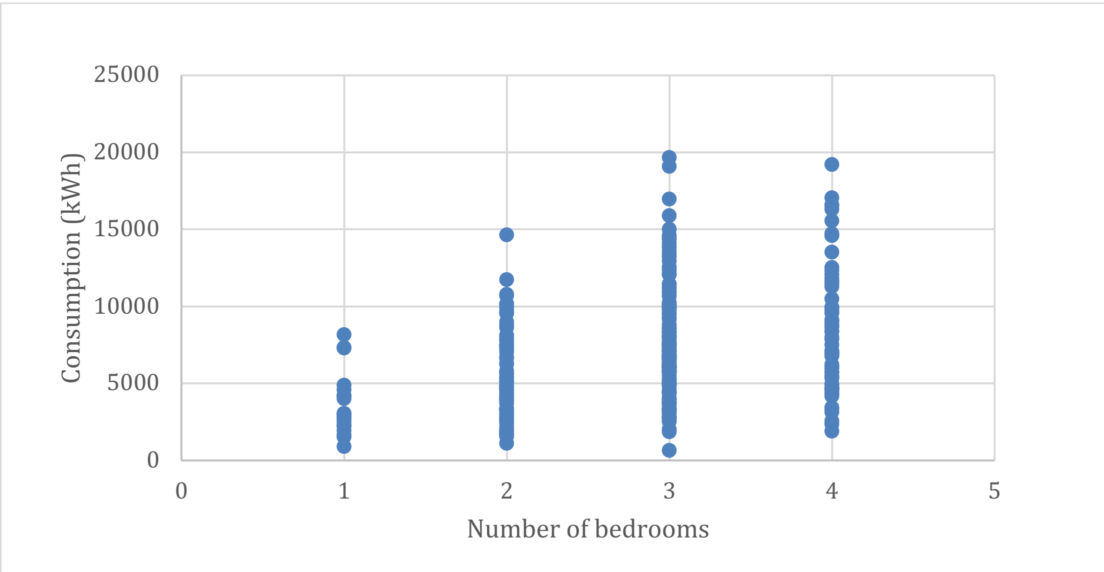

Figure 7. Plot of consumption by number of bedrooms for Toast customers

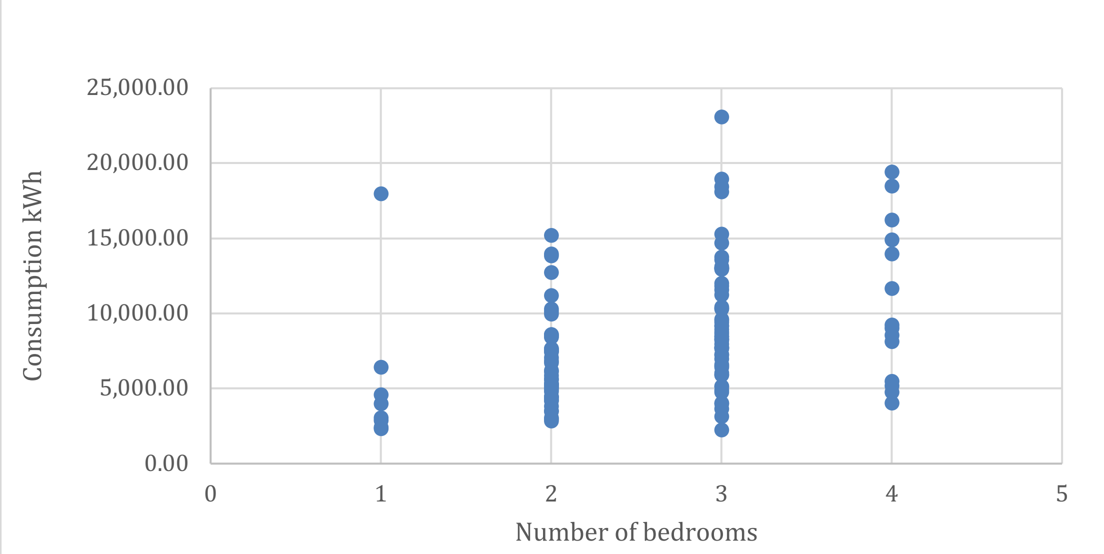

Figure 8. Plot of consumption by number of bedrooms for Wellbeing customers

4.3 Solar analysis

Table 7 summarises the performance of the solar PV systems. Table 8 summarises the base case financial performance of each solar PV system. Table 9 summarises the financial performance of each solar PV system under the sensitivity analysis case.

Table 7. summary of solar PV system performance

Home	Azimuth /pitch degrees	Total production kWh	Self-consumption kWh	Export kWh	Self-consumption	Export %
H1 WB1	329/20	6,550	1,410	5,140	21.5%	78.5%
H2 T1	193/flat	4,766	1,548	3,218	32.5%	67.5%
H3 WB2	235/35 056/35	4,452	1,454	2,998	32.7%	67.3%
H4 T2	023/20 203/20	5,536	1,474	4,065	26.6%	73.4%
H5 WB3	332/20 062/20	6,292	2,455	3,837	39.0%	61.0%
H6 T3	006/20	6,477	2,612	3,865	40.3%	59.7%
H7 WB4	356/20	6,550	2,734	3,816	41.7%	58.3%
H8 T4	283/39	5,767	2,678	3,089	46.4%	53.6%

Table 8. Summary of system financial performance in the base case

Base case settings				
Inflation rate	**Power price inflation**	**Debt interest rate**	**System price**	**Loan term in years**
2%	5.48%	4.52%	$10,500	20

Identifier	Gross savings	Savings after debt repayment
H1 WB1	$1,138	$329.40
H2 T1	$988	$179.40
H3 WB2	$900	$91.40
H4 T2	$1,064	$255.40
H5 WB3	$1,242	$434.80
H6 T3	$1,351	$542.40
H7 WB4	$1,329	$520.40
H8 T4	$1,278	$469.40

Table 9. Summary of contingency analysis of system financial performance

Inflation rate	Power price inflation	Debt interest rate	System price	Loan term in years
2%	2%	5.17%	$10,500	20

Identifier	Gross savings	Savings after debt repayment
H1 WB1	$1,138	$283.27
H2 T1	$988	$133.27
H3 WB2	$900	$45.27
H4 T2	$1,064	$209.27
H5 WB3	$1,242	$387.27
H6 T3	$1,351	$496.27
H7 WB4	$1,329	$474.27
H8 T4	$1,278	$423.27

5 Discussion

5.1 Household characteristics

The average Wellbeing customer lives in a smaller house with fewer bedrooms than the average Toast customer, 101.5 m^2 and 127.8 m^2 and 2.7 and 3 bedrooms respectively. Despite this, the average Wellbeing customer uses more electricity than the average Toast customer, 8,360 kWh versus 7,383 kWh, and correspondingly has higher bills, even after the Wellbeing discount, of $3,004 compared to $2,770; a difference of $234. Without the Wellbeing discount, and if consumption remained unchanged, the difference would be $556.61.

Looking at the average socioeconomic decile measure, the average Wellbeing customer lives is a decile 6 (6.65) neighbourhood, compared to the average Toast customer's decile 4 (4.04) neighbourhood. The socioeconomic decile rating is a composite measure of deprivation that includes measures of household income, the likelihood of being in receipt of a means tested main benefit, failure to meet a minimum income threshold, being unemployed and living in property that is more likely to be a rental, overcrowded and that are homes are always damp or always mouldy.

Being able to accurately establish the reasons for relative excess electricity consumption is beyond the scope of this study and would require house by house analysis. However, several components of the decile rating system may help to explain higher levels of energy consumption. These include overcrowding, the proportional relationship between energy consumption and occupancy, and rental tenure, which have been identified by BRANZ (Anderson et al., 2024) and Energy Efficiency and Conservation Authority (2023) as being associated with lower thermal performance. In addition, measure metrics relating to dampness and mould may indicate increased energy use associated with efforts to mitigate these conditions.

The regression analysis of consumption to building size in area and number of bedrooms shows there is no statistically significant correlation. This finding is in line with smaller homes being occupied by Wellbeing customers using more electricity.

The finding of no correlation is important for policy makers, or energy retailers, if consideration were being given to any size-based benefits or tariffs. While there are clear steps in the mean average consumption by increment of area or number of bedrooms, the reverse, that area or number of bedrooms could be used as an accurate proxy for consumption, is not supported by the data. The spread of energy use by area or number of bedrooms across each cohort is too wide.

There are several factors which may affect this outcome. These include the mix and efficiency of energy consuming devices in the home, and the overall thermal performance of the building relative to insulation levels, draught proofing and window type. There is no evidence in the literature to suggest a difference in the distribution of technologies between the two groups such as heat pumps, resistance, gas or log burners for space heating or between resistance, gas or wet back hot water heating between the two groups that would explain a difference in electricity consumption. These factors are not known across the sample and the depth of analyses required across such a wide sample is beyond the scope of this study.

The BRANZ HEEP2 study (Anderson et al., 2024) do record the incidence of insulation to different levels, by year of construction, as well as the share of some energy using technologies for space and water heating. This may explain some of the differences in consumption between the Wellbeing and Toast groups, especially if it is considered that those in energy poverty are more likely to rent, given their decile, noting the findings in the literature that rental properties are less likely to have adequate thermal performance.

To summarise, assumptions cannot be made about the mix of fuel types in the homes in the sample, so it is not possible to say that Wellbeing customers are more likely to use electricity over gas or solid fuels and so consume more electricity and have higher bills.

Household occupancy data was not available so it is unknown if there is a correlation between that and consumption, which might prove useful for policy makers. However, in general terms, households in higher deciles are more likely to be overcrowded.

5.2 Temporal consumption trends

A monthly analysis of electricity consumption of the two groups shows a clear trend of relatively low consumption across the summer, a ramp upwards over autumn which continues into a winter peak, which declines over spring into the summer. This is entirely expected.

However, an analysis of the monthly difference in consumption between Toast and Wellbeing customers shows the largest percentage variance in the summer, perhaps indicating a difference in baseline demand during a period of low space heating demand. There is a step change in May, a growing level of excess consumption over the discounted months of June, July and August, followed by another relative step down after the discount ends for September and October, before the proportional gap grows again in the relatively low consumption summer period.

In absolute terms, the largest volumetric difference occurs across the discounted winter months of June, July and August. Whereas the variance ranges from 80 to 117 kWh between September and May, it jumps to an average of 130 to 184 kWh per month between June and August. While this trend reflects winter heating load, it is still remarkable given that Wellbeing customers live, on average, in smaller homes with fewer bedrooms.

This jump in the trend suggests that the discount allows Wellbeing households to consume more than they would over the applicable months. It is not possible to say if these households are still under consuming overall across June, July and August compared to the warmer months given the share of total electricity consumption going towards heating.

5.3 Solar PV performance

Solar PV performance is considered across two spheres: electricity production, and financial.

The data shows that the generation and financial output of identical systems installed for the same price can differ greatly. This underlines the importance of modelling real-world situations instead of relying on generalisations.

Whereas EECA's study of residential solar PV focuses on a range of system sizes with a base case of North facing roofs, noting sensitivity analysis for East/West installations, it does not use a sample of real homes as this study does. Likewise, financial analysis does not have a base case of systems being debt funded. Rather, internal rates of return and simple payback are given. Clearly, the EECA study is much more comprehensive in its general scope and scale. As such, the relatively small sample, eight homes for which solar PV systems were modelled, provides a complementary insight into real world conditions as a comparator.

The selection methodology for this study was based on finding suitable one-, two-, three- and four-bedroom homes around the mean average consumption for Wellbeing and Toast customers. As noted earlier, in finding eight homes to model, 17 homes were considered. Given the small sample size, it would be wrong to assume half of the homes are unsuitable for solar.

The sample also returned a range of roof aspects, from 193 to 62 degrees, albeit clustered around 329 to 56 degrees. Three of the eight homes required panels being placed on two roof faces for space reasons. What this suggests, albeit from a small sample, is that that it cannot be assumed that many homes offer predominantly north facing roofs suitable for solar PV systems. Table 10 summarises the solar and financial performance across the eight modelled homes.

Table 10. Summary of solar performance and base case financial modelling

Home	Import before solar PV kWh	Solar PV output kWh	Self-consumption	Export	Gross savings	First year savings after debt repayment at 4.52%
H1 WB1	4,658	6,550	1,410 kWh 21.5%	5,140 kWh 78.5%	$1,138	$329.40
H2 T1	4,301	4,766	1,548 kWh 32.5%	3,218 kWh 67.5%	$988	$179.40
H3 WB2	6,396	4,455	1,454 kWh 32.7%	2,998 kWh 67.3%	$900	$91.40
H4 T2	6,568	6,330	1,511 kWh 23.9%	4,822 kWh 76.2%	$1,172	$363.40
H5 WB3	9,371	6,292	2,455 kWh 39%	3,837 kWh 61%	$1,242	$434.80
H6 T3	9,018	6,477	2,612 kWh 40.3%	3,865 kWh 59.7%	$1,351	$542.40
H7 WB4	11,315	6,550	2,734 kWh 41.7%	3,816 kWh 58.3%	$1,329	$520.40
H8 T4	11,462	5,767	2,678 kWh 46.4%	3,089 kWh 53.6%	$1,278	$469.40

In terms of system performance, and completely as the physics of solar generation predicts, those homes with the most northerly facings systems had the best performance. House 7 has the joint highest performance of 6,550 kWh per annum from an aspect of 356 degrees. The poorest performance, 4,452 kWh per annum, was for House 3 with a system split between 235 and 56 degrees.

Financially, the homes were modelled using half hourly consumption data and the tariffs available to them for both discounted Wellbeing and regular Toast customers split between low and standard users.

The OpenSolar model utilised half hourly consumption data in determining self-consumption and the fiancial performance of the systems. In the base case for the first year, with a 4.5% concessionary loan, retained savings after loan repayments of $806.60, House 3 retained savings valued at just $91. Conversely, House 6 retained savings to the value of $542. The reasons for this variance concern total PV production and the time and rate of self-consumption. As with the EECA Residential PV study, higher rates of self-consumption returned better value for householders as a unit of forgone import is worth more than a credit for an exported unit. For example, for a Wellbeing customer, between September and May, on the standard, >8,000 kWh/yr tariff, a unit of self-consumed solar PV is worth 33.6c in the daytime band compared to 16.8c in the night band. An exported unit is worth 12.5c at all times. See Table 5 for a detailed breakdown of the tariffs.

Given that in recent years retail electricity price rises have outstripped inflation, the base case model settings result in the value of savings increasing in real terms over time, even when system performance degradation is considered. Under the base case settings, where the value of savings increases by 3.48% each year (power price inflation less CPI), the value of retained savings accrued ranges from $10,080 to $21,105 after loan repayments, including interest totalling $16,172 have been made over 20 years.

The conclusion from this is that a house-by-house analysis of the production and financial performance of solar PV systems is required. This can be followed by looking at options to maximise self-consumption and potentially load shift or store production in, for instance, existing resistance hot water systems by way of a timer or diverter or through the addition of a battery.

Sensitivity modelling of solar financial performance was undertaken. In this case, retail electricity price inflation was set at 2% to match the Reserve Bank's medium term CPI target mid-point. As expected, this zeroed out net savings inflation associated with a positive gap between CPI and power price inflation, and so the greater accumulation of real savings over time and total system value over both the period of a loan and its expected physical life, notwithstanding degradation in panel performance.

The other variable changed was to set the interest rate to the average of the Reserve Bank's three-year residential mortgage series of 5.17%. The effect of this was to raise the required debt repayment by $48.13 to $854.73 with a matching reduction in the value of savings. This reduces the range of savings by $45.27 to $496.27.

An interest rate of 5.8% effectively wipes out the savings for House 3, as does a rate of 11.3% for House 6. As expected, what this shows is that for each individually modelled home, there is a debt rate at which it would be very difficult to justify investing in a solar PV system if all other variables remain constant.

The value of total retained savings over 20 years, after debt repayments have been made, falls to a range of $905 to $9,925. By way of comparison, EECA's Home Energy Savings Calculator (2026), projects the following possible annual savings for a three-person household in Porirua with moderate insulation:

- Switch from plug-in electrical heating to heat pump: $440, estimated outlay $2,800.

- Switch from regular electric hot water system to heat pump hot water: $366, estimated outlay $7,000.
- Solar (no EV or load shifting): $1,114, estimated outlay $10,500.

The EECA calculator presents gross savings before meeting the cost of finance and has no home-specific data on roof characteristics.

Another option to cut costs would be to install a timer on an existing standard electric hot water system. Using EECA's estimates that an average household uses around 30% of its electricity on hot water and mean average Wellbeing customer electricity consumption of 8,461 kWh, switching from the controlled to the night rate tariff would save $230 per annum for an estimated intervention cost of $300.

6. Conclusions and recommendations

There are five major conclusions from this research. First, those experiencing energy poverty live in very poorly performing housing, which tends to be smaller and fewer bedrooms and consume around 1.15 times the amount of electricity on an absolute basis, and 1.44 times as much on an area basis, compared to Toast customers. Assuming the same distribution of energy consuming technologies across the study population, and noting the results of the HEEP2 and MOTU study for EECA, those in energy poverty are not only using more electricity, but they are also still more likely to be living in colder, damper homes with a higher incidence of mould.

Second, overall, and for Wellbeing and Toast customers alike, the spread of area-based consumption shows there is no correlation between house area or number of bedrooms and electricity consumption.

Third, those in energy poverty are much more likely to live in neighbourhoods with higher socioeconomic deprivation compared to households not experiencing energy poverty. Given the nature of the basket of metrics that go into the socioeconomic deprivation measure, it suggests that poor quality housing directly influences several other factors that go into the socioeconomic decile metric to result in a high score.

Fourth, residential solar PV systems can deliver immediate savings to householders, even when completely debt funded, and thus help alleviate cost pressure on the fuel poor. However, this is only true for homes with roofs that return high system output and when debt rates are relatively low, such as using concessionary loans under the proposed Ratepayer Assistance Scheme. The ability to self-consume has a secondary influence on the value of a solar PV system but can improve the value proposition.

Finally, solar is not a universally cost-effective tool to address energy poverty. It must be assessed on a case-by-cases basis and used alongside other measures such as further improving insulation, draft proofing, space heating, specifically the switch to heat pumps, switching to hot water heat pumps, especially if that is a switch away from gas, or installing hot water timers on a night rate.

6.1 Recommendations

6.1.1 In depth study of additional fuel poor households

Additional research needs to be conducted on a larger sample of households in energy poverty such as the whole sample, n=122, of Wellbeing customers in this study. The objective of this would be to not only identify the most cost-effective measures to alleviate energy poverty, but to build a body of evidence to better inform the design of intervention programmes. The research should record the main factors affecting energy consumption including level of insulation and draft proofing, types of energy technologies used, especially for space and water heating, cooking, and driving, tariff and consumption analysis, and the modelling of solar performance.

Undertaking this study could be an extension of existing work undertaken by Home Energy Advisors supported by solar and financial modelers utilising tools such as OpenSolar and simple financial payback calculators. Specifically, the outcomes from this research should be used to help design cost effective intervention programmes beyond those covered by the Healthy Homes Standard for rental properties and space heating programmes such as Warm Up New Zealand and associated initiatives.

Tariff and consumption analyses should be undertaken on behalf of householders who might otherwise face information barriers to doing so. So too should electricity and gas use for hot water be analysed so that interventions such as the fitting of timers or switching to hot water heat pumps can be assessed.

Solar potentials should also be assessed on a house-by-house basis for both production and financial performance.

6.1.2 Fund a trial programme for study participants

Research at a household level leading to the identification of cost-effective interventions that could help alleviate fuel poverty and its impact raises ethical questions if suitable measures are not implemented. Funding should be secured to ensure householders benefit from the research.

6.1.3 Set up intervention programmes

The results of the further research should be used to guide policy makers and funders in designing and implementing additional interventions around hot water and solar in particular.

Major barriers to action have already been identified in the literature to investing in such technologies, including access to capital and split incentives. Much of the analysis undertaken, including in EECA's study of residential solar, do not extend to asking questions around how such systems can be financed, especially in rental properties. Work is required to look at mandates and grants for these technologies based on current space heating programmes.

6.1.4 Implement the Ratepayer Assistance Scheme of concessionary lending for homeowners

This study shows that the year-on-year value of solar is a function of the cost of paying off any finance associated with it. Concessionary loans greatly improve this compared to standard lending rates. Heat pump hot water systems should also be able to be installed under the scheme.

6.1.5 Investigate solar for renters schemes

Solar and heat pump hot water modelling can provide clarity around long term financing costs through the Ratepayer Assistance Scheme. Once system costs, interest rates and likely bill savings are understood, rents can be adjusted so that the tenant can benefit from lower overall costs even after their landlord's cost of capital for the installation of a solar PV or heat pump hot water system has been recovered through higher rent. Landlords could of course fund these improvements to make life better for their tenants and to improve the rentability and resale value of their investments.

6.1.6 Investigate shared benefit schemes

Many of those facing energy poverty live in community housing. Having a common owner focused on positive community outcomes gives rise to the opportunity to spread both the costs and benefits of investing in efficient space and water heating technologies and solar PV. This effect can be amplified if housing providers can partner with providers of social energy products, measures, and expert advice. Specifically, research should be undertaken around solar sharing schemes so that systems can be installed on the most productive roofs with the benefits shared among the wider community via metering reconciliation, noting that lines charges would still apply. Another approach would be to investigate schemes where an energy retailer optimises the value of production, including through sharing and arbitrage through storage, to accelerate the payback and maximise the benefits to system owners and the community. A third option could be to set up pay as you go schemes to cover the cost of capital out of consumption savings from heat pump hot water or solar PV systems.

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