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Income inequality and equitable access to energy through the energy transition

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Income inequality and equitable access to energy through the energy transition

Victoria Baikie

Abstract

This paper analyses how income inequality changes through the clean energy transition. Gini Coefficients are used to present overall changes in inequality over the chosen time period. Influences of rooftop solar and electrification are considered in this report as the literature suggests there is unequal access to these technologies. Key findings suggest the energy transition contributes to an overall decline in inequality from 2023 to 2050 and energy prices become cheaper. Larger proportion of households with solar, reduces the burden of high energy prices. However, the fall in inequality is shown to not be equal across all income brackets with the lowest two brackets declining the least. In the data, the gap between the highest and lowest income brackets remains prevalent at the point of Net Zero.

JEL Classifications: P28; Q43; Q58; O15
Keywords: Energy Transition; Income Inequality; Solar: Energy Prices

1. Introduction

In 2022, the Australian Federal Government legislated greenhouse gas emission targets to reach Net Zero in 2050. Reducing greenhouse gas emissions is important in the energy sector, as electricity generation alone accounts for a third of annual emissions (Department of Climate Change, Energy, the Environment and Water, 2023). Energy is the single largest emitting industry in Australia. As such, to reach the Net Zero target, the energy system must go through significant change. The clean energy transition involves moving away from fossil fuels and towards renewable energy sources, such as wind, solar and hydro.

As renewable energy is sourced from natural and recurring resources, energy costs are expected to become cheaper over time. However, the transition requires extensive investment in building new energy sources, linking through networks and upgrades to withstand increases in demand (Energy Networks Australia, 2023). The extensive investment could increase prices for consumers in the short to medium term.

Newly available consumer energy resources (CER) such as electric vehicles and solar panels provide an alternative to the increasing prices of fossil fuels. Although, financial barriers prevent accessibility for all sectors of society. Therefore, while prices of fossil fuel-based energy sources are increasing, those who can afford to are finding ways to significantly reduce energy costs. There is potential for these features of the energy transition to widen the wealth gap between the richest and poorest households in Australia. This project will research the implications of the rapid transition to renewable energy on inequality in Australia.

Utilising the Gini Coefficient method, this project analyses and forecasts how inequality changes over time. Many other studies have utilised this method to outline the changes in overall inequality. However, the Gini Coefficient is constrained in measuring inequality between each sub section of society and can only give an overview of total inequality. The proportion of income spent on energy is also an important metric considered in this report. It can more acutely represent energy affordability than the Gini Coefficient.

One driving factor of the analysis is the rate of growth in rooftop solar Photovoltaic systems (PV) and where this growth can be observed. The households with access to solar can drastically reduce the energy purchased from retailers. Not only are there financial barriers to solar installations, but there are also barriers in control. For example, landlords are less likely to install solar due to no direct financial incentive. Household requirements also act as barriers, as it may be more difficult to access solar in apartment buildings, units, or older homes.

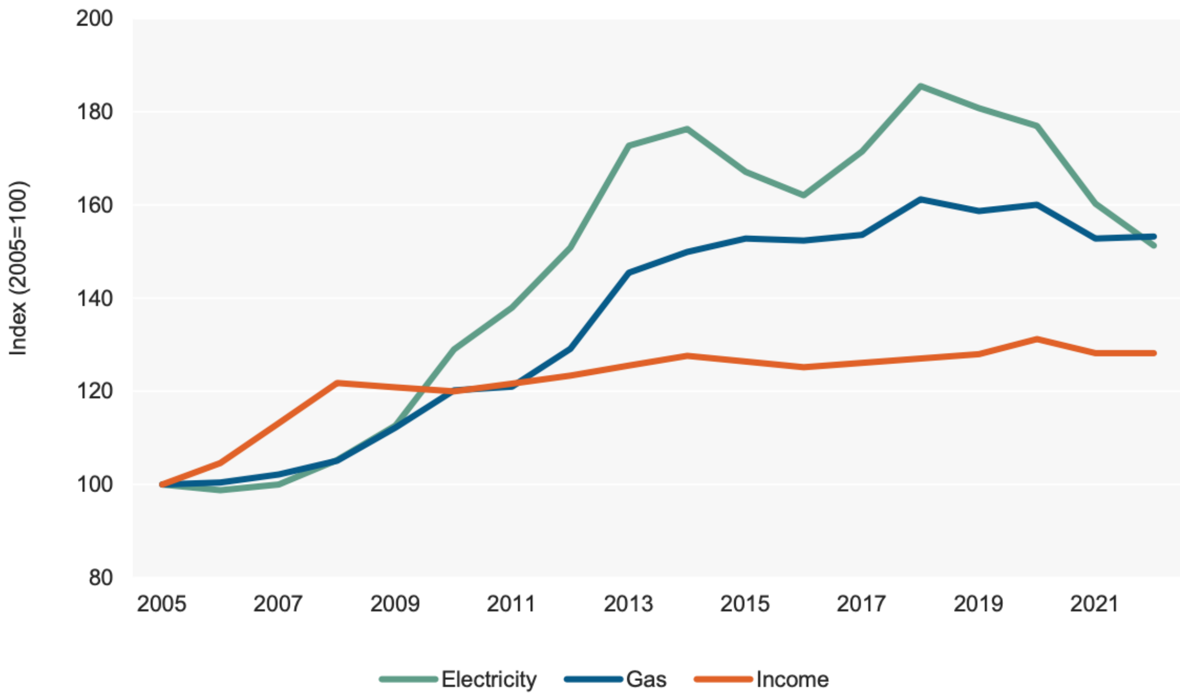
This report is split up into six sections. It will begin with an overview of the available literature. Then the report will move onto an overview of the methodology. The fourth section will present the results from the study. The fifth section is a discussion on the results and some of the limitations of the study that could have influenced the results. Finally, it will conclude the findings and point out areas for future analysis.

2. Literature Review

Energy affordability is a social and environmental issue (Barrella et al., 2023). Equitable access to energy is important for society as energy influences how people can warm or cool their home, cook, and experience leisure. Without reasonable access, energy will flow on to affect one's health and life satisfaction (Bartiaux et al., 2019). Adverse health impacts from inadequate access to energy forces one to be unable to work and cause a loss in income. These same households are less likely to access paid sick leave, further constraining income and increasing the wealth gap.

The Australian Energy Regulator (AER) states energy affordability is emerging as a major challenge. As shown in Figure 1 below, energy prices are continuously increasing, however, income growth has not kept pace. Bartiaux et al. (2019) defines energy poverty as the 'inability to keep [the] home adequately warm and arrears on utility bills in the last 12 months.' AER (2022) consumer research found that 28% of respondents struggled to pay their energy bills, and 37% of respondents anticipate difficulty paying bills in the next few years.

Figure 1: Long-term trends in energy prices and income (inflation adjusted)



Source: AER (2023)

Low incomes are vulnerable to being excluded from the benefits of solar. Venkateswaran et al. (2018) suggests there are financial, social and technical barriers to low income and rural households accessing solar. Households that can afford the upfront cost of installing rooftop solar PV benefit from cheaper electricity bills. These households can generate and use their own energy, purchasing less energy from electricity providers or 'the grid'. Household batteries further support this as it stores energy for when the sun is not shining. In Australia, Zander (2021) found a strong correlation of people's willingness to install solar to the time expected to pay it off. For every additional year it would take to pay off, the likelihood of installing solar reduces by 10%. Similar trends are seen globally with Schlesewsky & Winter (2018) finding a strong correlation between higher income households and installations of solar PV in Germany.

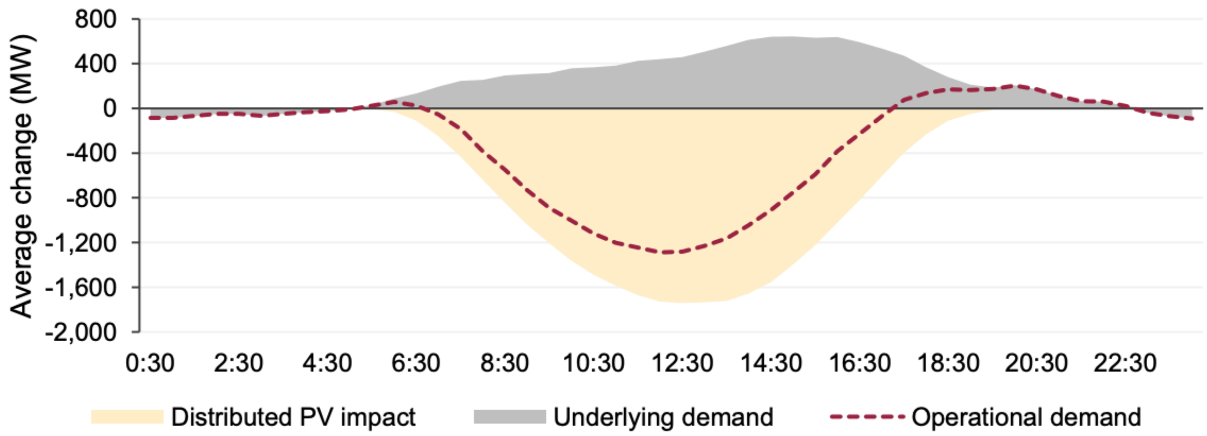
Even when low- or middle-income households can afford the upfront cost of installing solar, maintenance and repair costs may still be a financial barrier

(Venkateswaran et al., 2018). Higher income households are therefore able to make the investment and can benefit over the long-term, potentially increasing the gap between rich and poor.

Observing a gap in uptake by income is not a new phenomenon and is similar to any investment in newer and more expensive technology upgrades. For example, newer cars are more fuel efficient, and fuel would cost less per km. However, solar PV installations require distribution network upgrades, the costs of which are spread across all customers regardless of CER.

Traditionally energy flowed one way, from the generator to transmission networks, then distribution, and finally the household. Now that the households can generate their own electricity, the electricity flow is two ways with electricity flowing back in the other direction from households and into the distribution network. This requires technological upgrades to maintain. Furthermore, distribution networks need technological upgrades to withstand large increases in demand at peak times and large decreases when solar generation is at its peak (Energy Networks Australia, 2023). The sun is shining most usually at the middle of the day, causing a trough in energy demand as shown in Figure 2. When people come home from work or school, turn on all the lights and cook dinner, energy demand begins to peak between 3-9pm. Demand for electricity increases substantially, shown graphically in Figure 2, adding pressure to the distribution network to maintain the changes.

Figure 2: Changes in average NEM demand components by time of day



Source: Australian Energy Market Operator (2023)

Significant investment is required to withstand the two-way system and peak loads, the costs of which are recovered from all distribution customers, not just those with solar. Thus, energy costs are likely to increase for all, but the benefits are only accessible to a select group.

Solar can also be seen as problematic due to discrepancies in logistical access. Buildings requirements to install solar are likely to exclude residents living in multi-occupancy sites, such as apartment buildings, and older housing with poor structural integrity. These kinds of housing are typically occupied by those of lower incomes. Landlords have split incentives to install solar in the properties they own since there is no direct financial benefit for the investment. As of 2018, only 3-4% of rental properties have solar installed, compared to 25% of owner-occupied houses (Hammerle, White & Sturmberg, 2023). Moreover, to increase the proportion of rentals with solar there are difficulties in where the policy should be aimed as the landlord could potentially finance through rent increases instead of government subsidies (Barrella et al., 2023).

There are a limited number of studies that investigate the potential benefit of solar investment for rental properties, however, those that do exist can prove the investment in solar could be worthwhile. Best et al. (2021) studied rental properties in Australia and found properties with rooftop solar charge an average of A$19 more per week. Fuerst et al. (2020) also found the same trend occurring in the UK rental market.

These studies highlight the financial return for landlords in making the investment. They also prove renters are willing to pay extra in rent for the access to rooftop solar. For renters, the higher cost of rent is more likely to be made up in energy bill savings, providing a return on investment for renters as well.

Differences in access to solar is against a backdrop of expected increases in energy costs. The development of new power sources in new locations needs new electricity transmission networks connecting cities and towns to renewable energy sources. This could potentially increase more for regional and rural customers where there is more distance to connect and fewer customers to spread the cost. Schlesewsky & Winter (2018) identify potential locational inequalities in the German energy transition stemming from population density and network costs. Customers in rural areas, where there are fewer people to pay for the upgrades in electricity networks, face higher prices compared to metro customers. The study estimates a 0.67-1.63% increase in income inequality derived from the rising network charges associated with high investment required for the energy transition. In addition, gas prices are also climbing due to trends in electrification. Fewer customers on the gas network means the costs of running the network are spread across fewer customers, increasing the costs for those remaining.

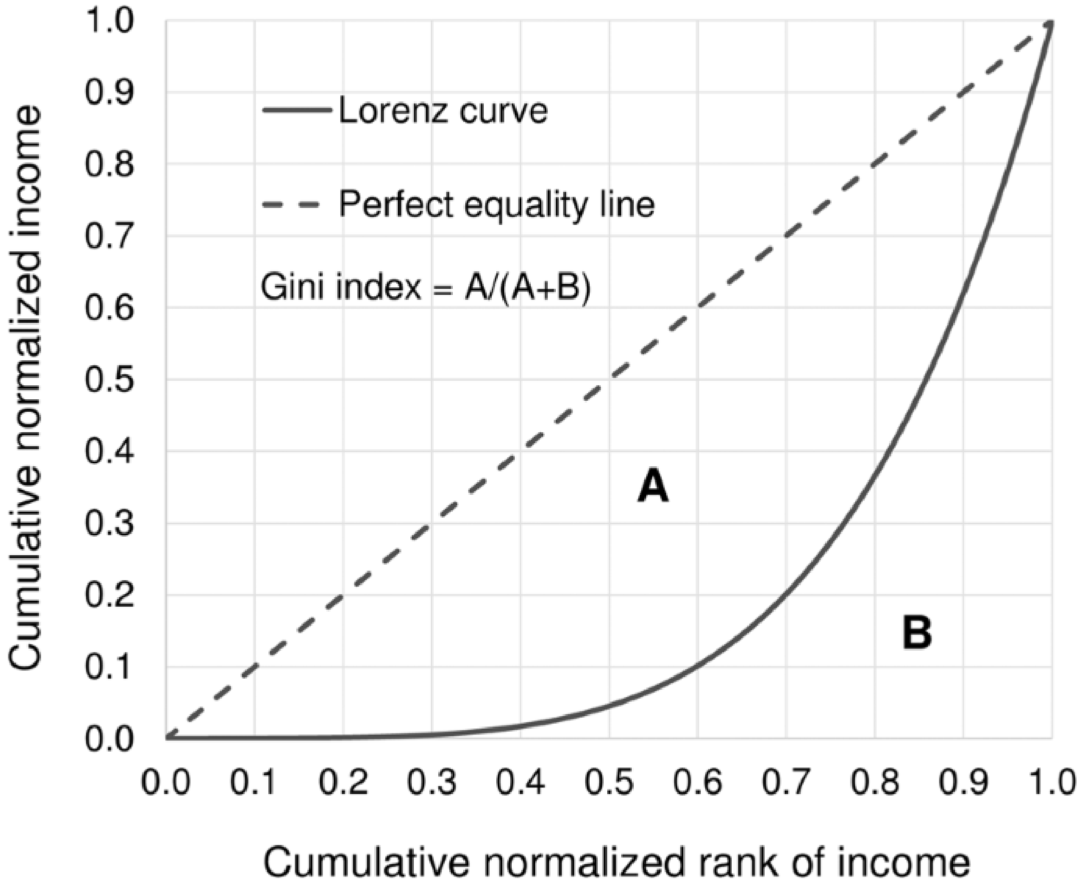
The impact of the divergence in solar ownership is likely seen more acutely where there are external factors increasing energy prices. Those with solar can escape the brunt of the increase, while those who cannot afford the investment go deeper into energy unaffordability. Bouzarovski & Herrero (2017) suggest low-income households bear the brunt of low-carbon policies paid for through energy tariffs. Energy tariffs charge households based on energy consumption. Households that are larger, are more energy inefficient or are in locations more susceptible to extreme heat or cold will disproportionately bear the brunt of the cost of low-carbon policies, which is typically low-income households. Households with solar can avoid the increase from energy tariffs as their consumption is heavily reduced.

3. Methodology

The Gini Coefficient is a commonly used method to estimate energy inequality across the literature. Nguyen, et. al (2019) collates nationally representative household survey data and uses the Gini coefficient to measure several inequality factors in Vietnam stemming from the energy transition. Schlesewsky and Winter (2019) use the Gini coefficient, the Theil index, and the Atkinson index, comparing socio-economic household data and panel data regional network charges. The Gini coefficient is a clear way to present the changing nature of equality from the energy transition. The Lorenz curve will also be used to display the Gini coefficient graphically.

This project replicates the method outlined in Nguyen, et. al (2019), with the Gini coefficient measuring the population and the proportion of energy expenditure of their income. Figure 3 shows how the Gini Coefficient is measured. It is calculated as the area between perfect equality and the Lorenz curve. As such, when the Gini Coefficient is equal to 0 it represents perfect equality and when equal to 1 it represents perfect inequality.

Figure 3: Standard Measure of Gini Coefficient



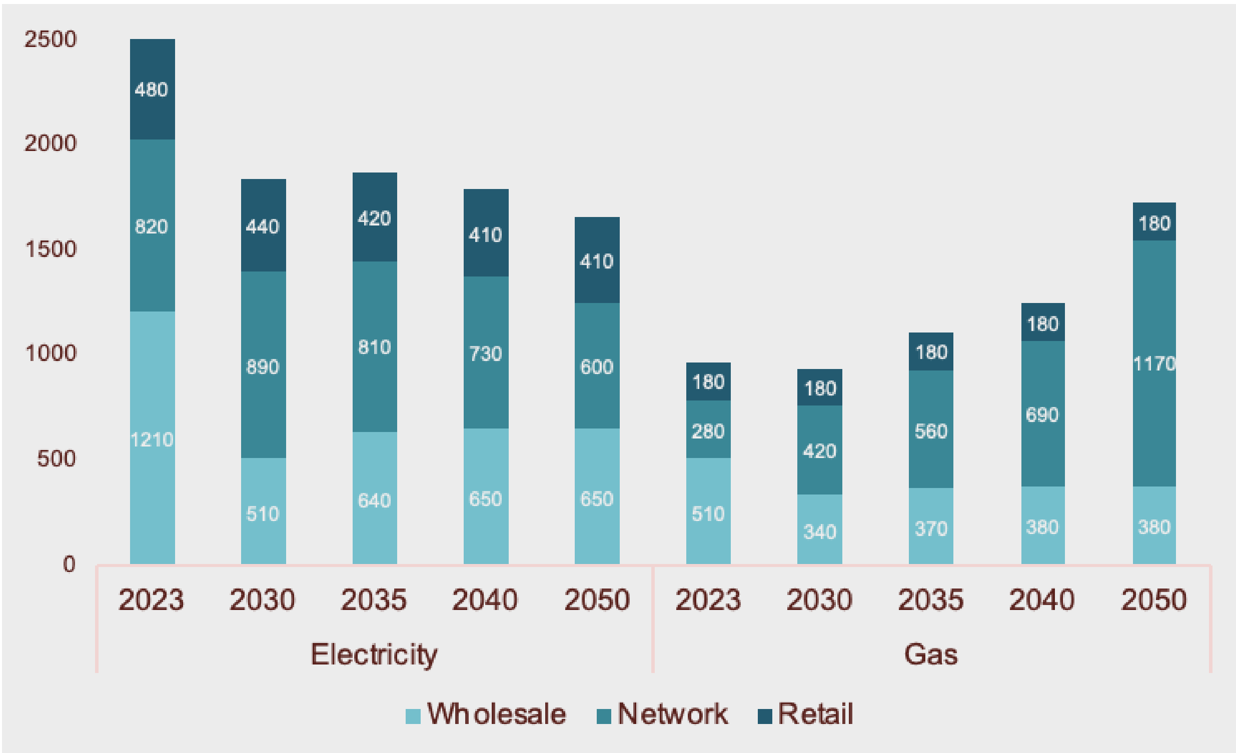
Source: Sitthiyot & Holasut (2020)

Solar owners are more likely to avoid energy debt where energy prices increase. Intuitively, this would be higher income households who can afford the investment. It can then be hypothesised that income after energy costs will be more unequal over time, and the Gini coefficient would increase closer to 1 between 2023 and 2050.

3.1 Energy Prices

Forecasting energy prices is pivotal to the underlying assumptions of this project. This project utilises the CSIRO's energy prices forecast in the Energy Consumers Australia (ECA) Stepping Up report (Graham et al., 2023). Figure 4 presents the forecast for electricity and gas prices.

Figure 4: Electricity and Gas Prices Forecast



Source: Graham et al. (2023)

As shown in Figure 4, electricity prices are expected to decline from the high of 2023, increase slightly in 2035 and reach its lowest point in 2050. The driving factors are changes in network prices. As mentioned earlier, large transmission projects are required to link up new power sources to where power is used. New infrastructure investment largely has not occurred since the transmission system was first built, explaining why there is such an influence on average household prices.

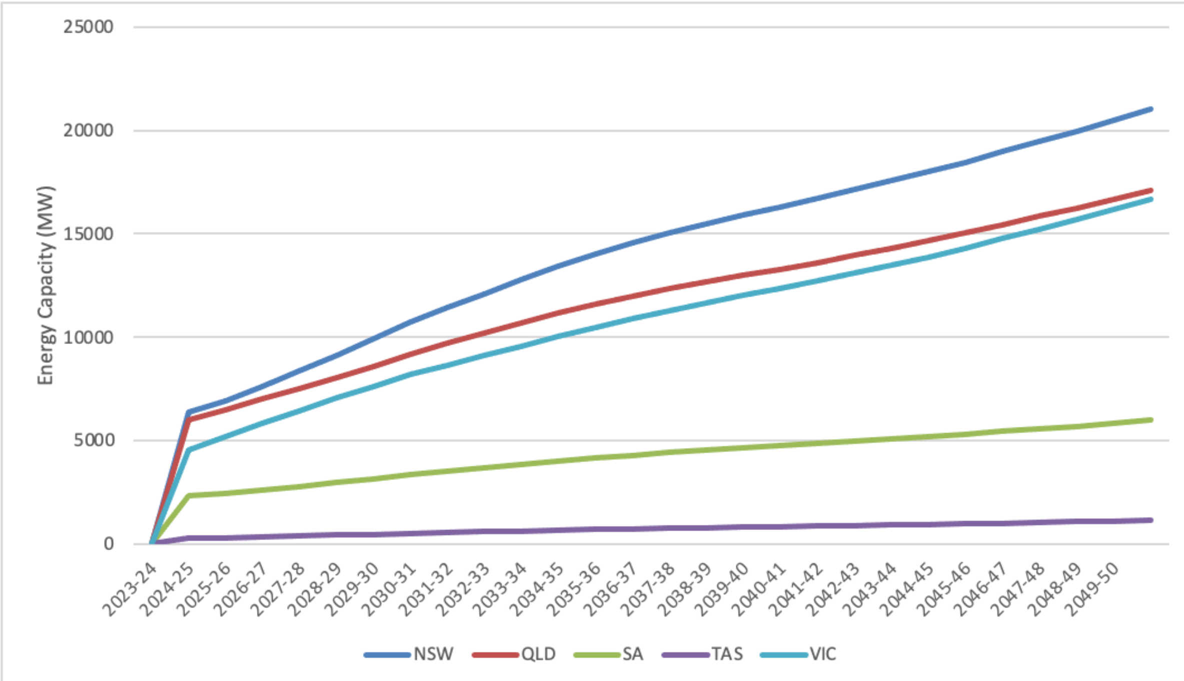
Gas prices present a different story, steadily increasing until 2050. Network costs are the driving factor in price increases, forecast to increase from $280 per person per year in 2023 to $1170 in 2050. This can be linked to electrification. Networks have replacement expenditure to maintain the pipes and infrastructure and replace old assets. Electrification is reducing the number of gas customers there are to spread the cost of replacement expenditure across, increasing gas prices for remaining users.

These data points set the time period to be analysed. This project will forecast the changes in solar and energy prices for 2023, 2030, 2035, 2040 and 2050. The discussion will mainly focus on the differences between 2023 and 2050, representing the changes from now and until Net Zero Targets are supposed to be met.

3.2 Solar Ownership

The energy price forecast in Figure 4 does not consider the energy prices for those with rooftop solar PV. These households would experience vastly cheaper energy prices due to the electricity generated from the solar panels. To estimate this, this project utilises an Australian Energy Market Operate (AEMO) Integrated System Plan (ISP) to estimate the growth expected in order to reach Net Zero. Figure 5 below represents the forecast capacity increase in rooftop solar by State. Naturally, NSW is forecast to have the highest and Tasmania the lowest solar capacity due to their respective populations and weather patterns.

Figure 5: AEMO ISP Rooftop Solar Capacity Forecast by State



Source: Australian Energy Market Commission ISP (2022)

As mentioned previously, solar PV can be expensive to install which is outlined in Figure 6. For the highest incomes it could take four weeks for a 3kW system and nine weeks for a 10kW system to save the funds for solar installation, assuming no current savings are used. For the lowest incomes this increases to 149 and 365 weeks respectfully. Therefore, assuming a straight-line growth in solar across incomes could be misguided. To overcome this, there are two solar growth estimates developed.

Figure 6: Average Solar Installation Cost by State

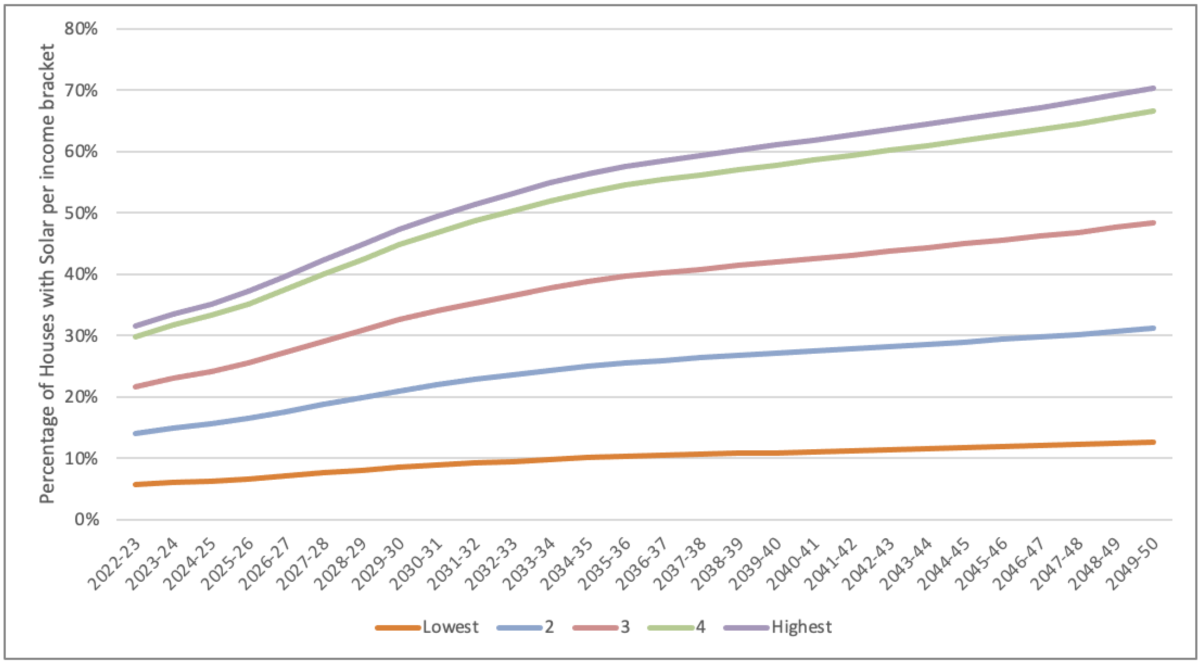
Average cost of solar panels in Australia

Solar panel size	National average price	NSW	VIC	QLD	SA	TAS	WA	ACT	NT
3kW	$4,290	$3,940	$4,200	$4,190	$3,350	$5,020	$3,400	$4,410	$5,800
4kW	$4,940	$4,430	$4,450	$4,790	$3,870	$5,650	$3,730	$4,850	$7,710
5kW	$5,790	$5,050	$5,010	$5,660	$4,540	$6,620	$4,860	$5,650	$8,920
6kW	$6,510	$5,530	$5,510	$6,100	$4,890	$7,560	$5,830	$6,460	$10,170
7kW	$7,490	$6,610	$6,470	$7,390	$5,870	$8,570	$6,240	$7,540	$11,250
10kW	$10,580	$9,050	$8,750	$10,400	$8,990	$12,390	$10,310	$10,340	$14,420

Source: SolarChoice (2023)

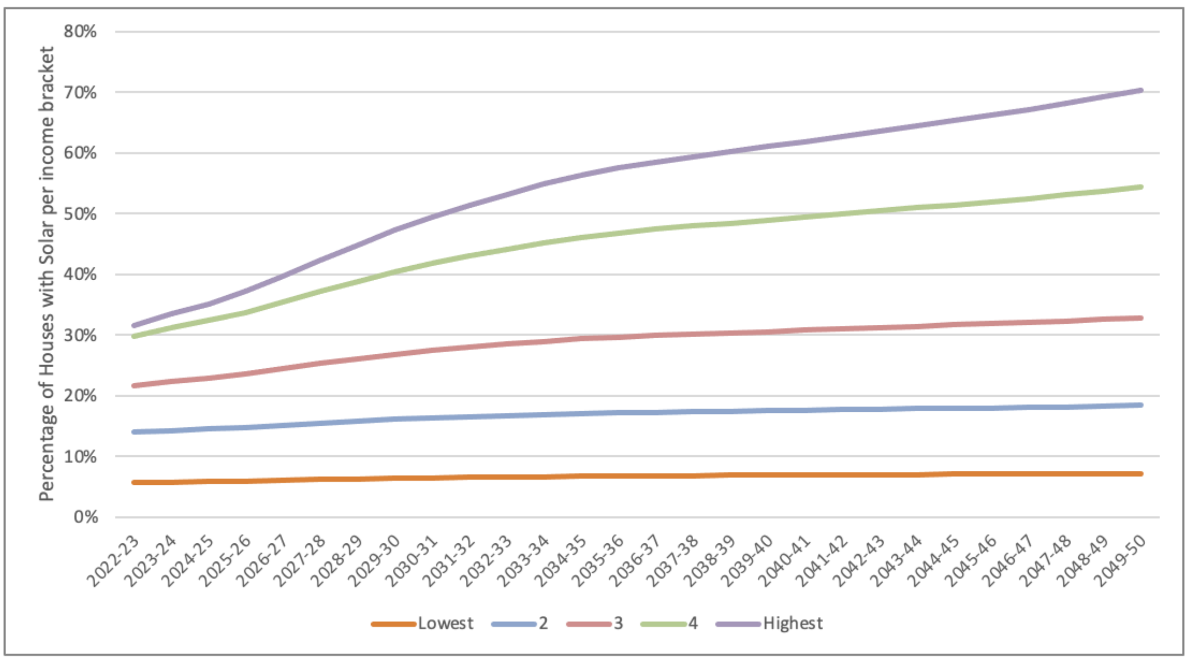
The results will examine the possible effects of different growth rates in solar. One scenario uses a standard growth rate in solar across all income brackets, which is demonstrated in Figure 7. A second scenario will analyse a weighted solar take-up forecast based on savings rates of respective income brackets, making some basic assumptions on general expenses, and is demonstrated in Figure 8. The difference is most pronounced between the top two income brackets when comparing figure 7 and 8. The lowest three income brackets show minimal growth in solar ownership rates, which can be expected to be reflected in levels of inequality.

Figure 7: Solar Ownership using Standardised Growth Rates



Source: Australian Energy Market Commission ISP (2022)

Figure 8: Solar Ownership using Weighted Growth Rates



Source: Australian Energy Market Commission ISP (2022)

Through using average energy consumption from the AER RIN analysis, it was estimated that installing solar reduces demand for electricity from the grid by approximately 60.4%, meaning households with solar purchase 60.4% less energy than those without. Table 1 outlines this estimation and was used alongside ECA energy bill forecasts to estimate how much energy bills would be for those with solar, outlined in Table 2. Using the results in Tables 1 and 2 in Appendix 1, estimates were formed for the average energy bills and income after energy for each income bracket to develop the Gini Coefficients for each time bracket. These results are outlined in Section 4.

3.4 Income Forecasts

Income forecasts have been estimated using a linear regression using an Exponential Smoothing (ETS) method with a 95% confidence level. The income forecasts are intended to be simple, as the study focuses on the effect of energy prices on inequality. This income forecast uses historical income data sourced from the ABS's Household Income and Wealth, with the most recent data being 2019-20. Scenario 1 is the income forecast, with Scenarios 2 and 3 being the lower and upper bounds respectively. The lower bound forecasts are conservative and the upper bound is progressive. Forecasts have been developed for each income bracket as wage growth can differ between brackets. Table 3 in Appendix 1 outlines these income forecasts. For simplicity, the order of income brackets will be referred to as lowest, 2nd, 3rd, 4th, and highest.

3.5 Electrification

Energy bills include both gas and electricity costs. The energy bills for solar owners includes the price of gas. This could be somewhat unrealistic as more and more houses go fully electric. Furthermore, due to the savings of solar only applying to reducing electricity costs, there is a financial incentive for disconnecting gas when installing solar. Table 4 outlines the energy bill savings for a transition from a house with electricity and gas to a fully electric house with solar.

ECA's forecast of gas prices includes assumptions of electrification, explaining why gas network prices increase by so much in the later time periods. It is then important to make some consideration on how electrification would affect inequality. The most important consideration is who would be left to bear the high costs. In most cases, fully electrifying is estimated to cost between $2,500 and $12,000 (Frontier Economics, 2022). For the highest incomes, it would take approximately 2-10 weeks to save enough money to pay the upfront costs of electrification taking into consideration energy prices and general expenses. For the lowest incomes, it would take between 87 and 414 weeks to save the same amount.

This report takes a simplistic approach to estimating electrification. The general assumption is every house with solar, has fully electrified and disconnected gas appliances. The rationale behind this is that where houses have made the investment to fully electrify and install solar, household batteries would have also been considered. By assuming this, it overcomes the issue in available data on prices and savings, with ECA providing analysis on the potential savings from solar and battery together. This assumption may also be able to show a clear divide in high and low energy prices and show the maximum amount of inequality under each scenario.

4. Results

This section will analyse the results from the research. First analysing how energy prices affect inequality in 2023.

4.1 Current State

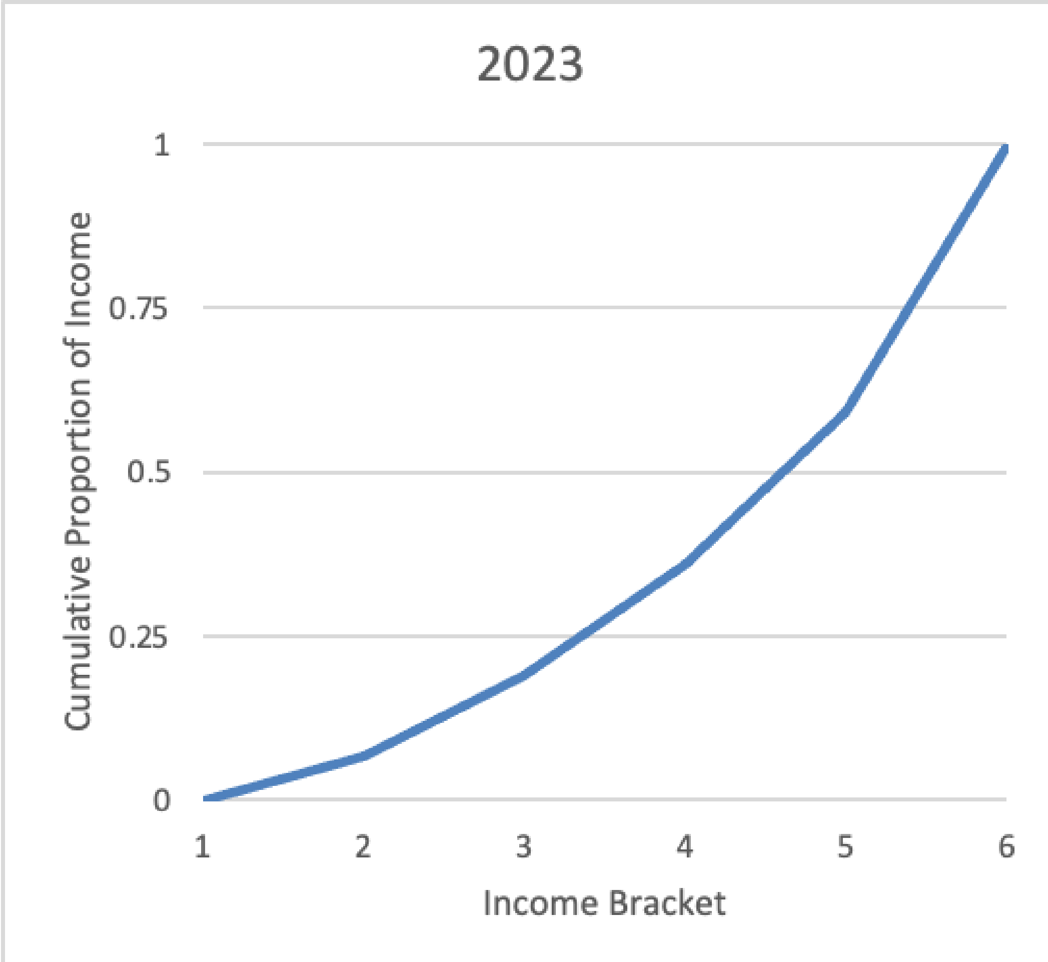
This section will evaluate the current state of inequality taking into consideration energy costs. Table 5 provides an overview of the income, solar ownership rates and estimated average energy prices for 2022 across Australia.

Average annual Income is split into five income percentile brackets with each bracket representing one fifth of the population. It is important to note that annual income is standardised for the year, meaning it is the same average weekly earnings every week. Lower incomes can typically show more volatility throughout the year, due to factors such as seasonal or unstable work patterns. For the purposes of this analysis, income has been assumed to be consistent throughout the year. Table 5 outlines the proportion of income spent on energy as it is important to consider the proportionate effects of energy costs and investment. As shown, the lowest incomes spend approximately 15.1% of their income on energy. This is a stark difference to the highest incomes who spend approximately 2.4%.

Average energy prices are estimated taking into account solar ownership. Households with solar, pay less in energy bills. To determine the reduced quantity, the calculation used average annual solar panel production from each state across Australia. This is important to consider as solar panels in Tasmania are going to produce less electricity than Queensland due to the differences in weather patterns. Therefore, the investment will provide a smaller return in terms of energy savings. A production average across the National Energy Market (NEM), which includes Tasmania, Victoria, New South Wales, Queensland, South Australia and the ACT, to calculate the average energy prices for those with solar. These data points were merged with solar ownership to calculate an average energy price for each income bracket.

From this data, the Gini Coefficient for 2023 is calculated to be 0.3585 represented in the Lorenz Curve in Figure 9 below. The ABS estimates the purely income-based Gini Coefficient as 0.324. These data points suggest there is more inequality across Australia after considering energy prices.

Figure 9: 2023 Lorenz Curve, energy prices adjusted

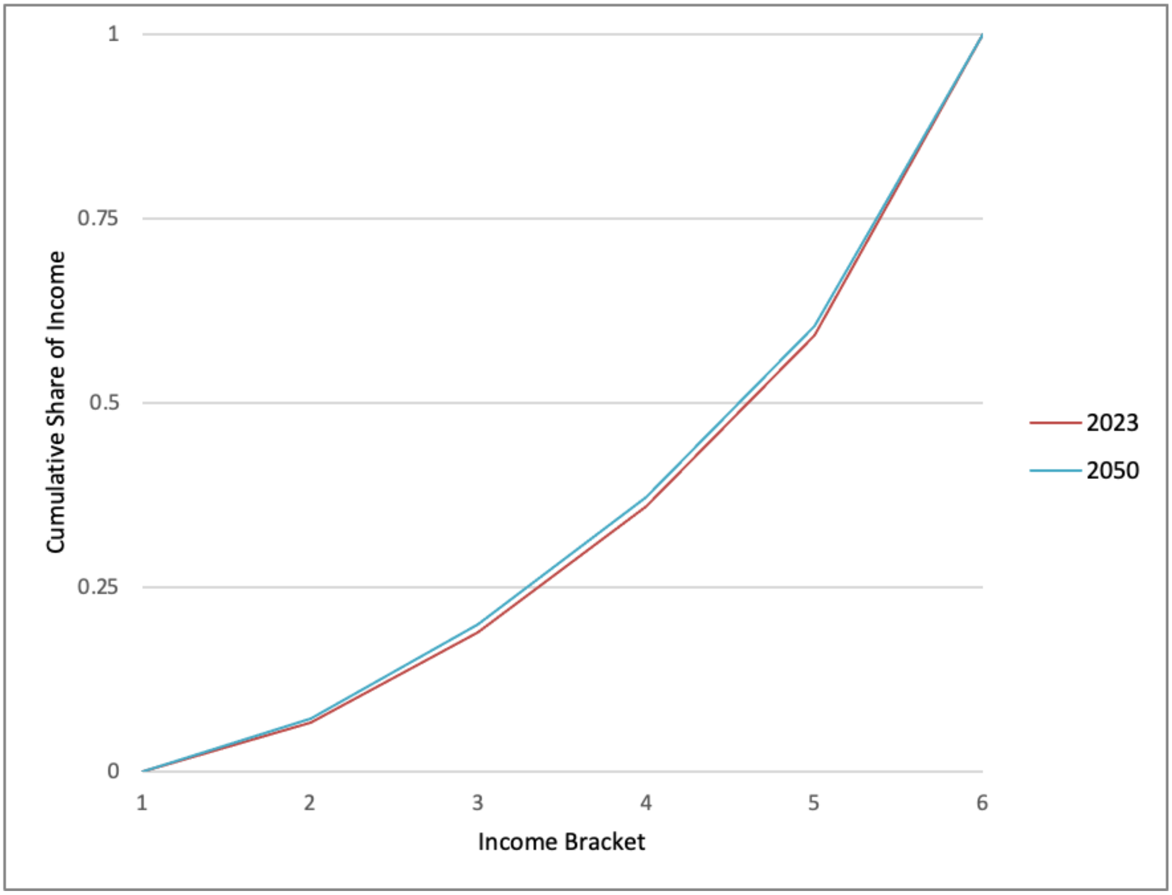


4.2 Future Analysis

Table 6 to 9 in Appendix 1 outlines the average energy costs for each income bracket for all other time periods. These tables represent income scenario 1. As expected, energy prices for households with solar were lower which is skewed upwards from lowest to highest income brackets. Utilising this data and the data outlined in Table 4, the Gini Coefficient can be calculated, outlined in Table 10 and 11 in Appendix 1.

From 2023 to 2050, the Gini Coefficient declines between 0.0117 and 0.0043 across all income and solar scenarios. This shows a trend of total inequality falling over time. The data has been unable to prove the energy transition causes an increase in inequality, instead the data shows an increase in overall equality over this time period. Figure 10 below illustrates the change in Lorenz Curve from 2023 to 2050 from income scenario 1 under solar scenario 2.

Figure 10: Lorenz Curve for between 2023 and 2050



The 2050 line in Figure 10 is straighter than the 2023 line, meaning there is more equality in 2050. Energy bills are becoming cheaper, equalising the proportional income after energy bills. Visually, Figure 10 shows the largest gap at points 3, 4 and 5 which are the middle-income brackets. This means the middle-income brackets have experienced the most improvement over this time period.

It is important to note in tables 6-9, all scenarios show trends of energy bills becoming more expensive for all income brackets over time. This is likely due to the high increases in gas prices.

These differences highlight the importance in considering recent trends in electrification. For simplicity, the electrification scenario assumes every household with solar has fully electrified its appliances. By excluding gas from these prices, the data could give a clear indication of the divide in household energy prices. For the purposes of this analysis, households with solar will also be assumed to have installed a household battery. The results are outlined in Table 12. The difference in Gini Coefficients between table 12 and 11 is very slight, nonetheless there is a trend of higher inequality under electrification than not. The trend is more noticeable comparing income scenarios 2 and 3.

Following on from the results in Figure 10, it is important to outline and consider the changes in each income bracket. Table 13 outlines the share of total income after energy prices for each income bracket to show the income distribution more clearly. Table 13 considers income scenario 1 under solar scenario 1 and Table 14 considers income scenario 1 under solar scenario 2.

Table 13 data shows the share of income earned by the top bracket declining from 40.895% to 39.480% over 2023 to 2050. This represents a 1.415 percentage point decline over this period. It is the only income bracket to decline between 2023 and 2050, reflecting a more even distribution among all income brackets. The largest increase in proportion of total income is in the second lowest income bracket, with an increase of 0.57 percentage points. Following this is the lowest and middle-income brackets with an increase in proportion of 0.4 and 0.24 percentage points respectively. There is also a slight decrease in the share for the lowest and second lowest brackets between 2035 and 2050, while the 3rd and 4th brackets increase in the same period.

Table 15 represents the respective share of total income after energy bills under electrification. The data shows the two lowest income brackets have an income share of 0.008 and 0.005 percentage points less respectively under the electrification scenario compared to Table 14. All other income brackets have slightly larger proportions of income compared to table 13. In dollar terms, the difference of 0.008 percentage points is approximately $27 less for the lowest income households per year. While the difference is minimal, the trend is still observed having an effect on the lowest incomes.

Tables 16 and 17 present the estimated energy bills as a proportion of income. This is the share of income spent on energy bills for each income bracket. For the lowest incomes, energy bills are the highest share of income.

5. Discussion

The analysis in section 4 shows overall inequality is forecast to decline over time as the energy transition progresses. This section will discuss these results in more detail.

5.1 Rooftop Solar Uptake

Table 5 shows solar ownership to be highest in the top percentile and only slightly smaller in the second highest. It can be expected that the highest income brackets would have the highest ownership of solar since this bracket would be the most likely to afford it. As the analysis shows, the top percentile bracket has only 1.2 per cent higher solar ownership. There could be various reasons why solar ownership is so similar between these two income brackets. Households with an average annual income of $68,987 may be more conscious of their energy bills compared to the highest incomes. At the same time, these households would be more able to make the investment in solar PV compared to the lowest incomes. Government subsidies for solar could act as an incentive to make the investment with the investment becoming more affordable. Income earned from feed-in tariffs may also support the financial motives. Furthermore, households within these brackets are more likely to own newly built homes where the cost of solar PV could be placed on a mortgage. The highest incomes may also be in heritage homes where solar PV is not compatible.

The results of the second solar growth scenario, where growth is dependent on savings rates, suggest trends of slightly higher inequality. Comparing Tables 10 and 11 for each time period and income scenario, the difference in Gini Coefficients ranges from 0.0001 to 0.0003. In 2050, average energy bills are between $53 and $160 higher under solar scenario 2.

An uneven distribution of solar uptake is a potential drag on the speed of the energy transition as well as putting upwards pressure on energy prices. A significant hurdle to achieving an even uptake is overcoming split incentives of landlords. Lower income households are typically in rental properties, meaning there are additional social and environmental barriers in accessing solar. There are several government-led initiatives to target split incentives. For example, Solar for Renters is a program offering rental providers a rebate up to $1,400 and interest-free loans for installing solar at their rental properties (Solar Victoria, 2023). The purpose is to incentivise landlords to install solar, providing accessibility to solar for lower income households and equalising the gap in energy prices.

While this report only considers households, this is also a barrier for businesses as well. Warehouses are an untapped potential in solar uptake as their roofs are ideal for solar. Businesses mainly use electricity during the day, unlike most households, supporting network loads and getting the most out of peak solar generation times. Most businesses rent warehouse space, are forced to pay the bill but do not have the control to reduce it through solar. Vinnies is an example where the problem can be overcome through commercial agreements. Through a tender process, a retailer is chosen and pays for the solar to be installed, then Vinnies makes monthly repayments on an interest-free loan (Potter, 2023). Data presented in this report, shows a more equal distribution of growth in solar uptake can support reductions in inequality. The processes discussed could potentially be a way to increase solar among low-income and renting households or small businesses that would otherwise be unable to access the benefits of solar.

5.2 Proportionate change in inequality

One way to analyse the effect of energy prices for different incomes is through energy bills as a proportion of income. It can highlight the proportionate impact of energy increases between incomes. As shown in Table 16 and 17, lower incomes spend a higher proportion of their income on energy bills compared to all other income brackets.

These proportions decline across all income brackets between 2023 and 2050 reflecting the decline in overall inequality shown in earlier results.

However, the improvement is less prominent for the lowest two income brackets. While overall inequality is shown to decline, the driving factor is the improving conditions for the 3rd and 4th income brackets. As such, the difference between the top and bottom income brackets remains high. In 2023, energy bills as a proportion of income for the lowest income is 6.22 times that of the highest income. In 2050, this declines only slightly to 6.12, suggesting while overall inequality declines, the inequality between the top and bottom is still prominent.

The trend in the proportion of income spent on energy increases between 2035 and 2050 among the lowest brackets and can suggest that there is a slight increase in inequality between the richest and poorest. 2050 is when gas prices are predicted to surge, possibly having an influence on the shares of income between the top three and bottom two income brackets. Thus, showing that while there is a decline in overall inequality, the lowest two income brackets are proportionately worse off compared to the rest of society. Though the effect on proportion of income is small, there is more inequality shown in the electrification scenario outlined in Table 15.

Recent government decisions have been strict on where gas belongs in the energy market. Since natural gas is a fossil fuel, cutting it out of energy markets has been seen as a way of cutting down emissions and achieving net zero targets. One such policy is the ACT's ban on new gas connections and plans to disconnect the gas network by 2045 (ACT Government, 2023).

The most effective government policies consider accessibility and equality at the forefront. Different income brackets react differently to economic incentives, such as rebates or subsidies. For example, the Sustainable Household Scheme set out in the ACT provides interest free loans between $2,000 and $14,000 to households to invest in solar, energy efficiency, EVs, or other technologies to reduce energy use (ACT Government, 2023). Landlords are eligible for this program, helping to support rentals improve energy efficiency and reduce costs. While the economic incentive may motivate some households and landlords, the loan may be insufficient to make the investment affordable, failing to motivate the lowest incomes from the investment.

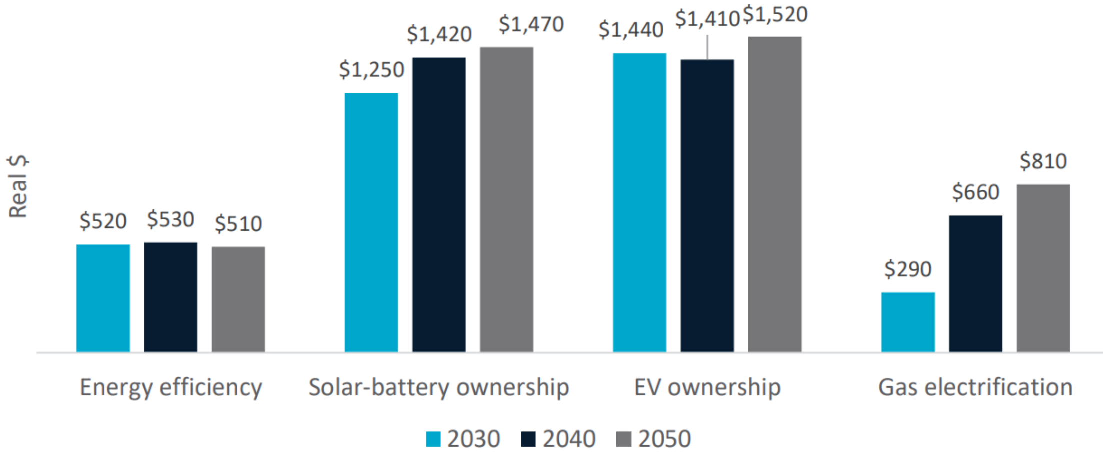
One key difficulty in policy targeted towards vulnerable sectors is the identification and classification on who is vulnerable to the impacts. Again, rental housing causes difficulty in identifying the houses less able to transition, possibly causing an exclusion of renters. These households may be identified as classified in the later stages of the transition where gas prices have already begun to increase significantly. To reduce inequality through transitions like electrification where housing upgrades are required, policies need to focus on targeting vulnerable and low-income households first.

5.3 Limitations

This study focussed on unequal access to renewable energy resources. However, energy inequality also stems from inaccessibility to energy efficient housing. The AER (2022) has identified that customers on energy hardship programs, made up of the most vulnerable groups in society, are consuming 81% more energy than the average. Low energy efficiency in housing is identified as one of the main driving causes of energy unaffordability (Barrella et al., 2023). Factors that influence energy consumption are location, weather, household size and energy efficiency of the house itself.

Graham (2023) found that improving energy efficiency in households leads to significant energy bill savings as outlined in Figure 11. As mentioned previously, energy inefficient housing is typically homed by low-income households and renters. The inaccessibility to upgrade housing, either through insufficient funds or lack of control like in rental situations or multi-occupancy housing where there is a body corporation, restricts the households that need the energy bills savings the most from accessing them. Data limitations were a barrier in the ability to consider energy efficiency in this study. Nonetheless, it can be assumed lower income households would be worse off in the results of this study if energy efficiency of houses could be considered.

Figure 11: Potential Energy Bill Savings by Action



Source: Graham (2023)

Figure 11 also outlines the potential savings from adopting electric vehicles (EVs). While it was considered out of scope for this report, due to the need to consider the whole transport industry, uptake in EVs could have a similar impact on inequality as solar. This is because the benefits could be exclusive to a subset of society while all customers bear the costs of network upgrades. The top income brackets are currently overrepresented in the ownership of EVs due to the high-cost barrier. This factor coupled with higher potential savings compared to solar, could be a significant driver of inequality derived from energy costs.

6. Conclusion

This study seeks to understand how inequality could change through the energy transitions. Gini Coefficients were used to analyse the change in equality. The estimated Gini Coefficients suggest overall inequality is set to decline between 2023 and 2050. This was consistent across all scenarios tested. Though there were smaller declines in inequality seen in the solar weighted growth scenario and the electrification scenario.

Results indicate the benefits from the energy transition would not be distributed equally. The decline in inequality was not analysed as equal across all income brackets.

Energy prices and respective shares of total income for the 3rd and 4th income bracket showed the most improvement, driving the change in overall income. Results for the bottom two income brackets presented little improvement, particularly in its shares of overall income. While energy as a proportion of bills and overall energy bills declined, the share of total income increased until 2035, declining there afterwards. This time period is where gas prices begin to surge, suggesting the gas transition may have an unequal impact on the lowest income brackets. The results presented in this study indicate there is more to do in the policy space to equalise the access to solar for lower income households and renters.

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Appendix 1

Table 1: Rooftop Solar Impacts on Electricity Consumption

	Average Annual Electricity Consumption (kWh)	Average Annual Solar Production (kWh)	Difference (kWh)	Difference (%)
TAS	8,202	2938.3	5,264	-35.8%
VIC	4,527	3022.2	1,504	-66.8%
NSW	5,861	3274.1	2,587	-55.9%
SA	4,606	3525.9	1,080	-76.5%
QLD	5,988	3525.9	2,462	-58.9%
ACT	6,372	3609.9	2,762	-56.7%
Average	5,490	3316.0	2,174	-60.4%

Source: AER RIN Responses (2022), Clean Energy Council (2022)

Table 2: Energy Bill Estimation

	Estimated Energy Bill	Energy Bill for Solar Owners	Savings
2023	$3,480	$1,378	$2,102
2030	$2,780	$1,101	$1,679
2035	$2,980	$1,180	$1,800
2040	$3,040	$1,204	$1,836
2050	$3,390	$1,342	$2,048

Source: ECA (2023)

Table 3: Forecasts of Annual Disposable Income ($) by Percentile Brackets

Scenario 1	**2023**	**2030**	**2035**	**2040**	**2050**
Lowest	22,251	23,365	24,161	24,957	26,548
2nd	37,524	39,431	40,794	42,156	44,881
3rd	50,768	52,959	54,523	56,088	59,218
4th	67,811	70,700	72,763	74,827	78,954
Highest	117,598	121,231	123,826	126,421	131,611

Scenario 2	2023	2030	2035	2040	2050
Lowest	21,578	22,692	23,488	24,283	25,875
2nd	36,634	38,541	39,903	43,990	43,990
3rd	49,449	51,639	53,204	57,897	57,897
4th	66,635	69,524	71,587	73,651	77,777
Highest	111,772	114,804	116,993	119,198	123,644
Scenario 3	**2023**	**2030**	**2035**	**2040**	**2050**
Lowest	22,924	24,038	24,834	25,630	27,222
2nd	38,415	40,322	41,685	43,047	45,772
3rd	52,087	54,278	55,843	57,408	60,538
4th	68,987	71,876	73,940	76,003	80,130
Highest	123,425	127,659	130,659	133,645	139,578

Table 4: Average Energy Bills

	Estimated Energy Bill	Electricity Bill for Solar Owners
2023	$3,480	$1,378
2030	$2,780	$1,101
2035	$2,980	$1,180
2040	$3,040	$1,204
2050	$3,390	$1,342

Table 5: Current State of Income, Solar Ownership and Energy Prices

Income Bracket	Average Annual Income	Solar Ownership	Average Energy Prices	Proportion of income spent on energy
Lowest	22,924	5.6%	3,138	15.1%
2nd	38,415	14.4%	3,016	8.5%
3rd	52,087	22.1%	2,929	6.0%

4th	68,987	30.0%	3,137	4.3%
Highest	123,425	31.2%	3,222	2.4%

Source: ABS (2022), Graham (2023)

Table 6: Solar Ownership and Average Annual Energy Prices in 2030

	Solar Growth Scenario 1		Solar Growth Scenario 2	
Income Bracket	Solar Ownership	Average Energy Prices	Solar Ownership	Average Energy Prices
Lowest	8.5%	$2,685.95	6.4%	$2,708.64
2nd	21.0%	$2,546.52	16.0%	$2,601.95
3rd	32.6%	$2,417.96	26.6%	$2,483.92
4th	44.8%	$2,281.68	40.2%	$2,332.70
Highest	47.4%	$2,253.33	47.4%	$2,253.33

Table 7: Solar Ownership and Average Annual Energy Prices in 2035

	Solar Growth Scenario 1		Solar Growth Scenario 2	
Income Bracket	Solar Ownership	Average Energy Prices	Solar Ownership	Average Energy Prices
Lowest	10.1%	$2,866.16	6.8%	$2,903.33
2nd	25.0%	$2,697.39	17.0%	$2,788.30
3rd	38.8%	$2,541.78	29.1%	$2,651.50
4th	53.4%	$2,376.83	45.7%	$2,463.37
Highest	56.4%	$2,342.51	56.4%	$2,342.51

Table 8: Solar Ownership and Average Annual Energy Prices in 2040

	Solar Growth Scenario 1		Solar Growth Scenario 2	
Income Bracket	Solar Ownership	Average Energy Prices	Solar Ownership	Average Energy Prices
Lowest	10.9%	$2,922.06	7.0%	$2,964.76
2nd	27.1%	$2,747.23	17.4%	$2,851.68

3rd	42.0%	$2,586.03	30.3%	$2,712.90
4th	57.8%	$2,415.15	48.5%	$2,516.10
Highest	61.1%	$2,379.59	61.1%	$2,379.59

Table 9: Solar Ownership and Average Annual Energy Prices in 2050

	Solar Growth Scenario 1		Solar Growth Scenario 2	
Income Bracket	Solar Ownership	Average Energy Prices	Solar Ownership	Average Energy Prices
Lowest	12.6%	$3,264.05	7.3%	$3,317.05
2nd	31.2%	$3,077.35	18.2%	$3,207.09
3rd	48.4%	$2,905.20	32.5%	$3,064.51
4th	66.6%	$2,722.72	53.7%	$2,851.46
Highest	70.3%	$2,684.75	70.3%	$2,684.75

Table 10: Gini Coefficients for Solar Scenario 1 by Income Scenario

	Scenario 1	Scenario 2	Scenario 3
2030	0.35440	0.35181	0.35682
2035	0.35178	0.35055	0.35616
2040	0.35223	0.34903	0.35520
2050	0.35049	0.34678	0.35393

Table 11: Gini Coefficients for Solar Scenario 2 by Income Scenario

	Scenario 1	Scenario 2	Scenario 3
2030	0.35453	0.35194	0.35695
2035	0.35199	0.35076	0.35636
2040	0.35246	0.34926	0.35543

2050	0.35076	0.34706	0.35419

Table 12: Gini Coefficients under Electrification by Income Scenario

	Scenario 1	Scenario 2	Scenario 3
2030	0.35453	0.35847	0.35847
2035	0.35201	0.35453	0.35453
2040	0.35248	0.35201	0.35201
2050	0.35082	0.35248	0.35248

Table 13: Respective Share of Total Income After Energy Prices (Income Scenario 1/Solar Scenario 1)

	2023	2030	2035	2040	2050
Lowest	6.730%	6.998%	7.169%	7.076%	7.130%
2	12.232%	12.482%	12.826%	12.655%	12.801%
3	17.006%	17.103%	16.974%	17.181%	17.244%
4	23.138%	23.153%	23.003%	23.254%	23.344%
Highest	40.895%	40.263%	40.027%	39.834%	39.480%

Table 14: Respective Share of Total Income After Energy Prices (Income Scenario 1/Solar Scenario 2)

	2023	2030	2035	2040	2050
Lowest	6.730%	6.995%	7.164%	7.070%	7.124%
2	12.232%	12.474%	12.813%	12.641%	12.785%
3	17.006%	17.095%	16.959%	17.165%	17.225%
4	23.138%	23.144%	22.987%	23.237%	23.323%
Highest	40.895%	40.293%	40.076%	39.887%	39.543%

Table 15: Electrification Scenario - Respective Share of Total Income After Energy Prices (Income Scenario 1/Solar Scenario 2)

	2023	2035	2050

Lowest	6.730%	7.161%	7.116%
2	12.232%	12.812%	12.780%
3	17.006%	16.962%	17.228%
4	23.138%	22.993%	23.332%
Highest	40.895%	40.072%	39.544%

Table 16: Energy Bills as a Proportion of Income (Income Scenario 1/Solar Scenario 1)

	2023	2030	2035	2040	2050
Lowest	15.144%	11.496%	11.863%	11.709%	12.295%
2nd	8.543%	6.458%	6.612%	6.517%	6.857%
3rd	6.017%	4.566%	4.800%	4.611%	4.906%
4th	4.269%	3.227%	3.362%	3.228%	3.448%
Highest	2.433%	1.859%	1.932%	1.882%	2.040%

Table 17: Energy Bills as a Proportion of Income (Income Scenario 1/Solar Scenario 2)

	2023	2030	2035	2040	2050
Lowest	15.144%	11.604%	12.033%	11.898%	12.514%
2nd	8.543%	6.589%	6.820%	6.749%	7.128%
3rd	6.017%	4.686%	5.000%	4.830%	5.167%
4th	4.269%	3.337%	3.546%	3.429%	3.690%
Highest	2.433%	1.860%	1.934%	1.884%	2.042%