CASTLES & CARS

SAVINGS IN THE SUBURBS THROUGH ELECTRIFYING EVERYTHING

TECHNICAL STUDY

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Household Electrification: Savings in the Suburbs

Saul Griffith, PhD, Josh Ellison, Sam Calisch, PhD, Dan Cass

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Chapter 1

Australia - the luckiest country

1.1 Summary

Australia has some of the best renewable energy resources in the world. These include enormous solar and wind generation capacity beyond our domestic needs. Australia has low population density, which means we also have a largely suburban development pattern with large rooftops. The low population density means that our energy distribution networks — the gas pipelines and the electricity transmission and distribution networks — have higher per–capita costs than countries with higher population densities. This is part of the reason Australians pay more for their gas and grid than a country like America. We produce very little of the oil we use that is processed into petrol and diesel, and consequently have high per-liter costs relative to the US. Electrifying our end-uses — our driving, heating, cooling and living — and powering it with renewables is the universal recipe for emissions reduction.

Because Australian solar is already cheap, our climate is mild, and we have the structural conditions mentioned above, Australians can be saving money (and making money) sooner in this energy transition relative to other economies that either have lower-cost incumbents (like the US), higher-population densities (like Asia), or less optimal renewables (like western and northern Europe). This is what makes Australia truly the luckiest country in the global race to transition to zero–carbon economies. In regard to our domestic economy, we can win first, win most, and pave the way for other countries to follow.

What makes us even luckier are our extraordinary natural resources. We have phenomenal supplies of not only commodity metal ores like iron ore and bauxite, but significant portions of the world's productive output of uranium, lithium, copper, and other elements in high demand in the race to globally decarbonize.

Australia can win in three ways: in the short–term with domestic savings; in the mid–term exporting the know–how of building and integrating the infrastructure to be the first deeply electrified and decarbonized economy in the world; and in the long–term by being the world's renewably powered smelter and foundry. In future papers we will address transitioning Australia's industries away from fossil fuels through electrification and analyse this in the context of our energy imports and exports.

1.2 Guide to this document

Aggressive emissions reductions are required if we are to successfully prevent more than 1.5 degrees of global warming. Emission trajectories ambitious enough to hit this target are described in Figure 5.1. At this point it will take an extraordinary effort to stay below 1.5 degrees without negative emissions. The problems inherent to net-zero targets, and the enormous but probably very expensive and definitely not guaranteed negative emissions modelled into IPCC AR6, are discussed. The reality is now such that we need to replace any machine that burns fossil fuels in use today with an equivalent piece of electric machinery at the next time it fails or needs to be retired. This is true whether the fossil–burning machine is an appliance, like a stove, a vehicle, like your car, or a manufacturing process. The electricity to power all of these machines needs to come from clean (zero-carbon) sources such as solar, wind, hydroelectricity, or nuclear. As recommended by climate scientists, our climate outcomes are better if we retire our heaviest–emitting power generation sources — coal–fired power plants, but also natural gas plants — as soon as possible,before the end of their service life. We can afford no new built fossil generation capacity.

In Chapter 4 we break down Australian GHG emissions into 3 different components, to enable more clarity around the conversation of what we need to do to hit those aggressive targets. These 3 buckets of emissions are: (1) Our domestic economy emissions — the things we do within the domestic economy; (2) Export services — the emissions within Australia that enable us to export fossil fuels, metals, agriculture and our other exports that are used in other countries; and (3) Exported fossil fuels emissions, the emissions created when our exported fossil fuels (principally coal) are burned in other countries. These exported fossil fuel emissions do not count against Australia in global emissions accounting, but they are significant globally since we export so much coal.

In Chapter 2 we look explicitly at the domestic economy only, and within that the 42% of emissions that are associated with Australia's 10 million homes. These are the emissions largely associated with how we heat our water, heat our homes, and fuel our vehicles. The analysis includes how we power our cars, space heating, water heating, kitchens, laundries, and swimming pools. We analyze the economics of electrifying and eliminating all of the energy emissions from our households relative to today, and into the future. We see that Australian households are positioned to do extremely well economically in the clean energy transition.

In Chapter 6 we describe the methodology, the data sources, and the cost and efficiency models used in determining the household economics of the transition from 2021-2035.

In Chapter 3 we break down the analysis state–by–state and nationally to give regional relevance to the analysis.

Chapter 2

Savings in the Suburbs

2.1 The question...

Will aggressive decarbonization, as necessary to hit a global climate target between 1.5° C and 2° C, hurt or help the typical Australian household?

This question is even more important after the financial disruptions of COVID-19.

2.2 The answer...

We find that by the end of this decade, 2030, the average Australian household stands to benefit to the tune of $5-6,000 per year in savings for their energy and vehicle costs relative to their expenditures in 2021. For the next few years whether it is a slight economic win or loss depends on the details of the individual household and their purchasing preferences. By 2025 the savings are universal across the board. We need to be designing the policy environment that enables this future outcome immediately. It is vital that this electrification revolution is equitable. Governments must ensure that all households, regardless of their socioeconomic status, can reap the economic benefits that electrification can deliver households by mid-decade.

2.3 What is this study?

In this study we specifically sought to answer the following question:

What is the combination of technological solutions, appliance and vehicle costs, regulatory conditions, and, critically access to financing, that can make hitting global climate objectives a win–win for the Australian public?

Our 10 million Australian households, including all of their appliances, vehicles, and cooking, heating and cooling loads, are responsible for approximately 42% of the emissions of our domestic economy (excluding export emissions), as can be seen in Figure 4.2. Household energy emissions account for 33.5% of domestic emissions. These are all emissions that are not ultimately in the service of our exports. This part of our economy is ripe for electrification and decarbonization. If we extend the analysis to our commercial sector — our small businesses, offices, and workplaces — this grows to close to 70% of domestic emissions[1].

We model an ambitious but realistic pathway to decarbonization of Australian households by 2030. We use historical energy use and pricing data to build a model of current households, then we model the electrification of those households by replacing all fossil fuel burning machines with clean or renewable electricity powered electrical machines. We use this model to investigate combinations of finance, regulatory policy, and incremental technology scaling that would save households and the entire economy money. With small and predictable improvements in technology costs over the next fifteen years, and with realistic finance and interest rates, the average Australian household could be saving over $5000 per year by the end of this decade, and upwards of $6000 per year by 2035.

Collectively, the nation would be saving around $40bN per year by 2030. This could have a substantial impact on the shape of the economy. In future research we will seek to quantify the employment benefits. In addition to the many hundreds of thousands of jobs involved in the energy system and household infrastructure retrofit, millions more new jobs will be created in addressing aggressive climate commitments, as other organizations including Beyond Zero Emissions found in their "Million Jobs Plan"[2].

In Figure 2.1 we can see the enormous efficiency win in total primary energy required to operate a household by converting from our current fossil–fuelled lives to all–electric living powered by renewables (and perhaps nuclear). Today the average household uses just over 100kWh of all forms of energy per day for all of

[1] https://ageis.climatechange.gov.au/

[2] https://bze.org.au/research_release/million-jobs-plan/

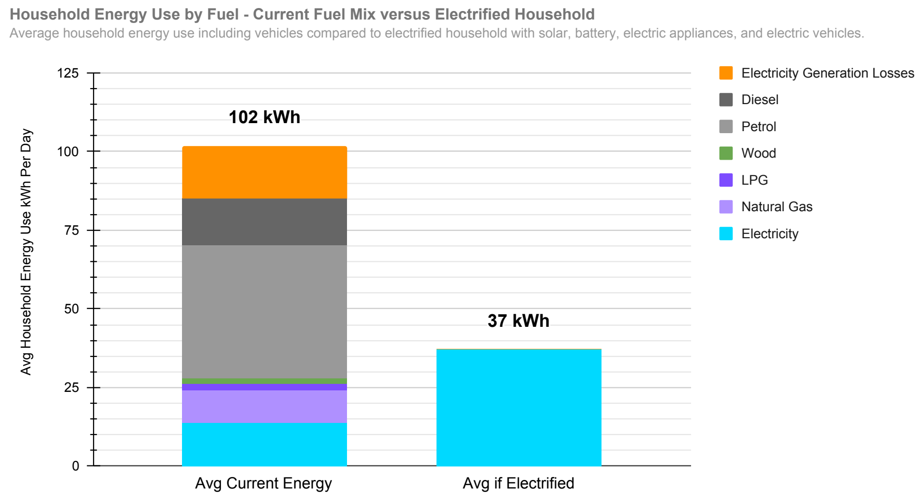


Figure 2.1: *Current "Average" household energy consumption including all household vehicles, and an "average" all–electrified household, both in kWh per day.*

their heating, cooling, electricity, and transportation needs. When electrified with typical electric vehicles and heat pumps, the energy requirement is only 37kWh per day, a reduction of almost two thirds.

Figure 2.2 shows the breakdown of energy, by end-use, today, and what it would be if we electrified all of those end uses and powered it with zero-emissions clean renewables. Australian households average 14kWh of electricity use today, 31kWh when the average thermoelectric losses (from burning fossil fuels in the generation process) of the Australian electricity sector are accounted for. Because of our vast continent and patterns of urban development it is household petrol and diesel use that dominate household energy use, which brings the daily total to 102kWh. The fully electrified conversion of the household is shown in the last column, requiring only 37kWh of electricity.

The capital costs of upgrading a home in 2021 — by replacing fossil–fuelled machines with electric machinery — is high enough that an individual household, if electrified, would be paying more (about $8,000 a year more) for their energy and their vehicles today than in the near future. As we can see by Figure 2.3 falling costs of electric vehicles, electric appliances, rooftop solar, and battery storage systems can be used to predict that the total financed cost of running a fully electrified household will become cheaper for most Australians by 2025. We are that close! And for some Australian households, the economics already work today. Now is the time to invest in the workforce training and infrastructure development that

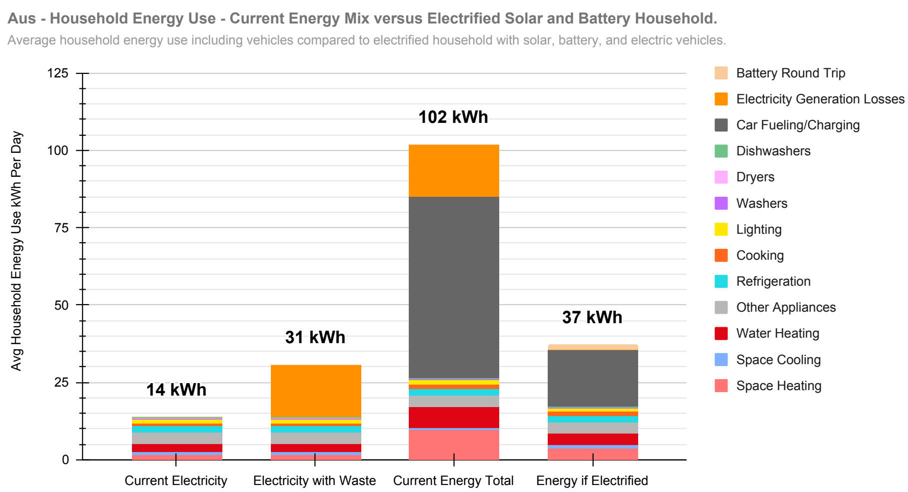


Figure 2.2: *Breakdown of current energy consumption in the "average" Australian household. Showing current electricity consumption and total energy consumption, compared with an electrified household electricity consumption.*

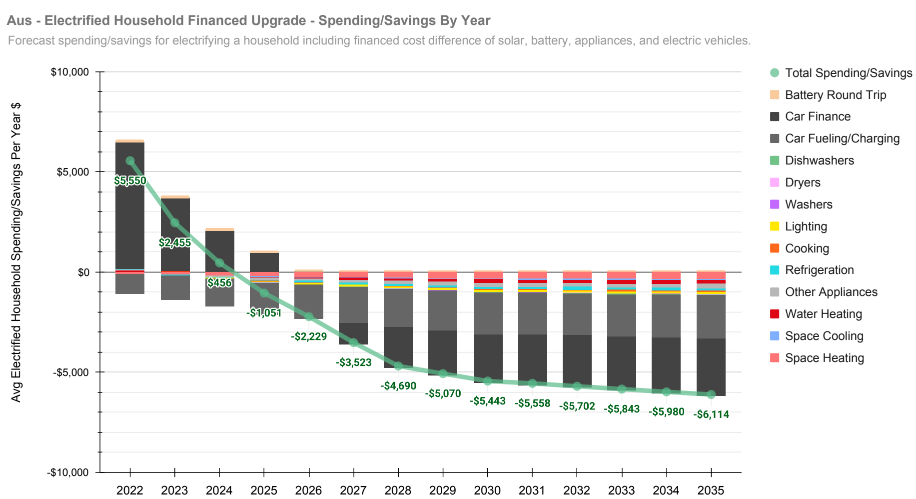


Figure 2.3: *Falling costs of electric vehicles, batteries, rooftop solar, and electric appliances versus year and the effect on total household vehicle and energy expenditures.*

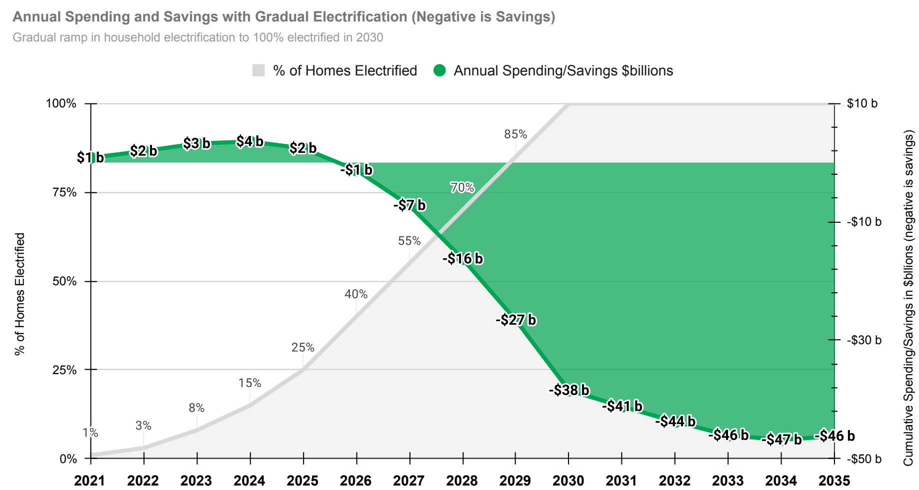


Figure 2.4: *Annual savings in the Australian economy assuming the adoption rate slowly ramps up between 2021 and 2024 and we achieve 100% household electrification by 2030 — commensurate with a 1.5-2 degree target.*

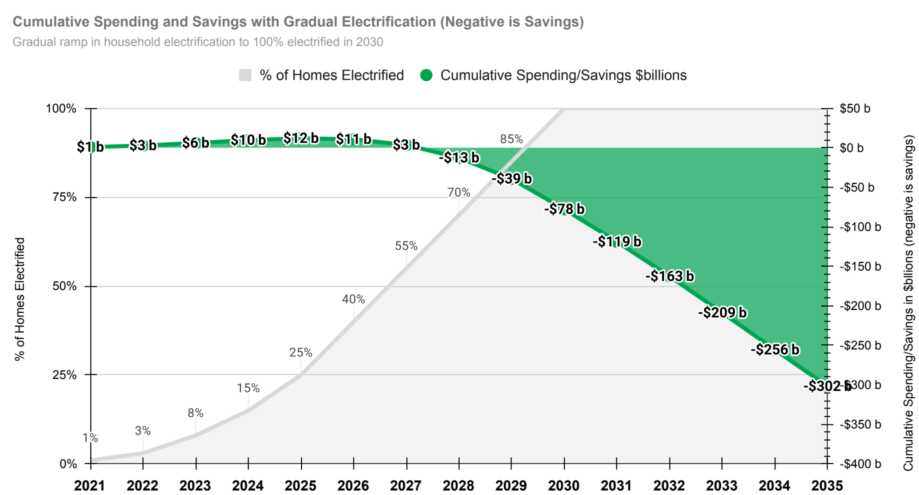


Figure 2.5: *Year-over-year expenditures and savings realized by an aggressive commitment to electrification.*

enables this positive economic energy transition.

In Figure 6.16 we can see that by investing today in electrifying homes, and driving down the costs while training our workforce, is an incredible investment in Australia and its infrastructure. Looking at the cumulative investment and then savings in Figure 6.17 we see that a steadily growing investment in electrified households requires an estimated $12bN investment over the next 5 years and leads to cumulative household savings of around $78bN by the latter half of this decade, and cumulative savings for the Australian economy of over $300bN by 2035.

This study offers the opportunity for a new dialogue about solving climate change that is optimistic, based on abundance and the real possibility that we can aggressively address climate while improving our castles (homes). This analysis also leads to many conclusions and recommendations about policy mixes that can accomplish decarbonization at the fastest possible rate of infrastructure changeover.

Chapter 3

National and State-by-State results

3.1 Results — Australia–wide and state–by–state

3.1.1 Australia

According to the Australian Bureau of Statistics (ABS) there were 9,955,106 households in Australia in 2021, projected to be 11,358,657 by 2030. The average household has 2.6 people and 1.8 cars. The average Australian household spends $5,248 on energy for the household including $1,481 for electricity, $567 for natural gas, $103 for LPG, $3,056 for petrol and diesel, and $41 for wood.

Electricity generation in Australia is currently 56.4% coal, 20.5% natural gas, 2.2% oil, and 20.9% renewables.

The results for the average Australian household and combined state and country results are shown below.

3.1.1.1 Annual country savings

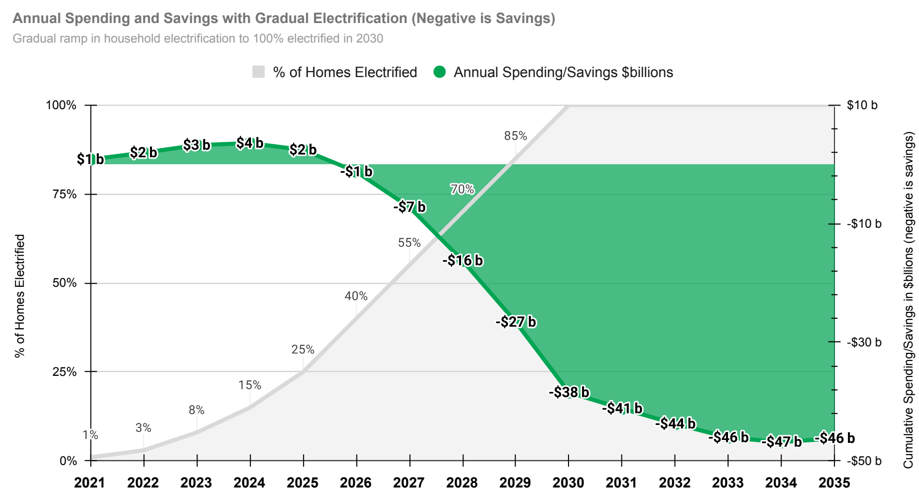


Figure 3.1: *Annual savings in the Australian economy assuming the adoption rate slowly ramps up between 2021 and 2024 and we achieve 100% household electrification by 2030 — commensurate with a 1.5-2 degree target.*

3.1.1.2 Cumulative country savings

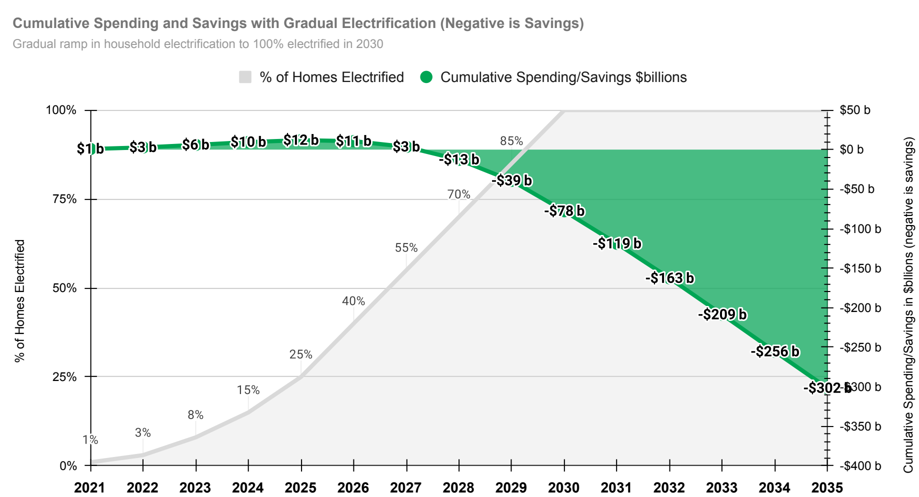


Figure 3.2: *Year-over-year expenditures and savings realized by an aggressive commitment to electrification.*

3.1.1.3 State household energy

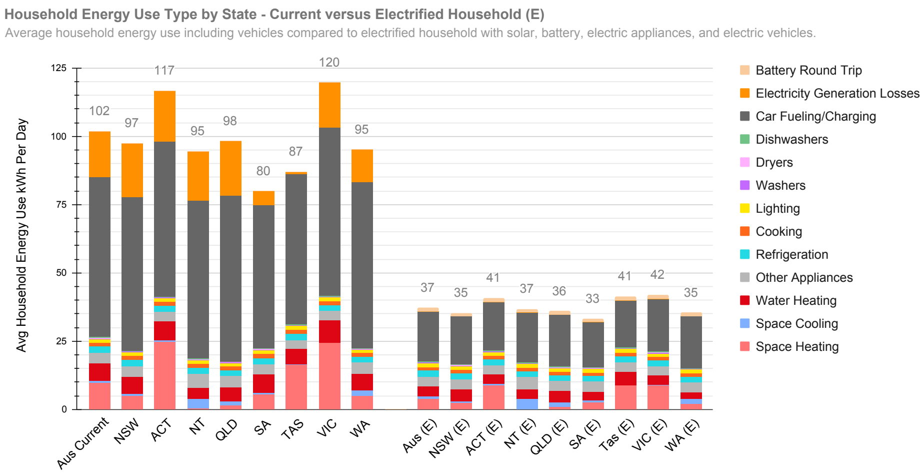


Figure 3.3: *State–by–state energy use mix, current versus future electrified households.*

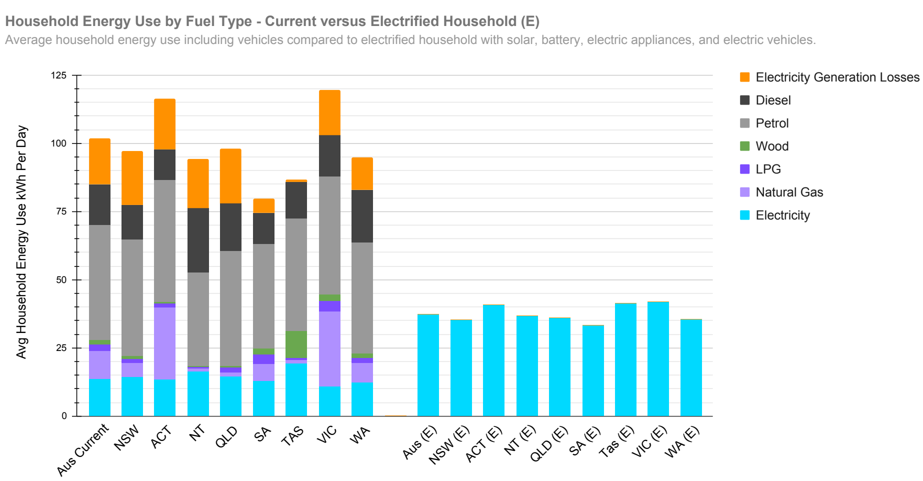


Figure 3.4: *State–by–state energy fuel mix, current versus future electrified households.*

3.1.1.4 Household energy

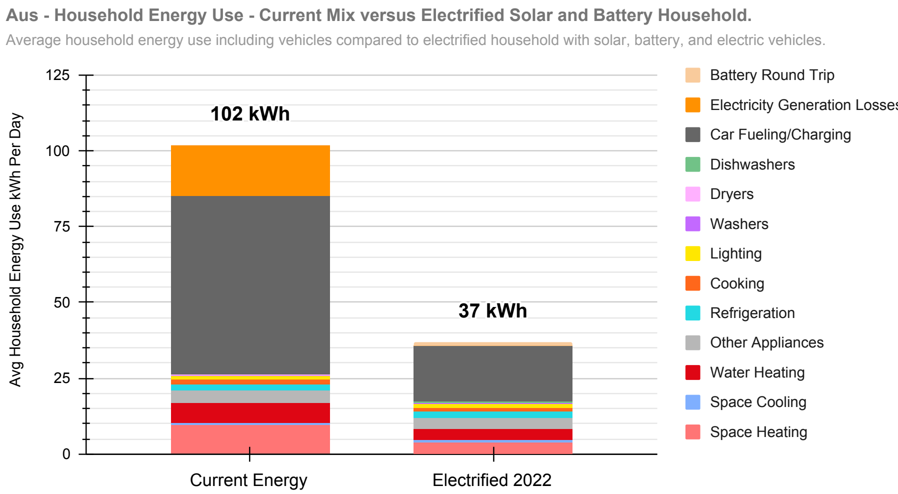


Figure 3.5: *Average household energy use, current versus electrified household with rooftop solar, battery, electrified appliances, and electric vehicles, kWh/Day.*

3.1.1.5 Household Costs

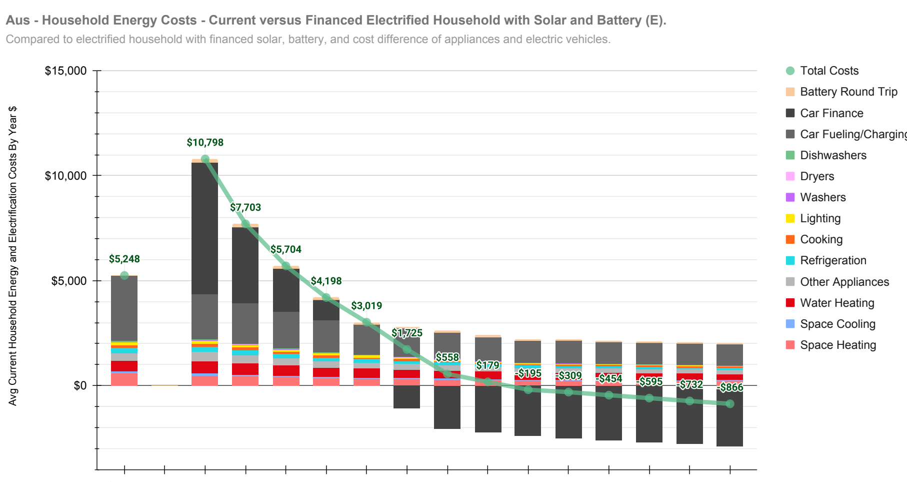


Figure 3.6: *Average household costs, current versus electrified household with rooftop solar, battery, electrified appliances, and electric vehicles. $/Year.*

3.1.1.6 Household Appliance Costs

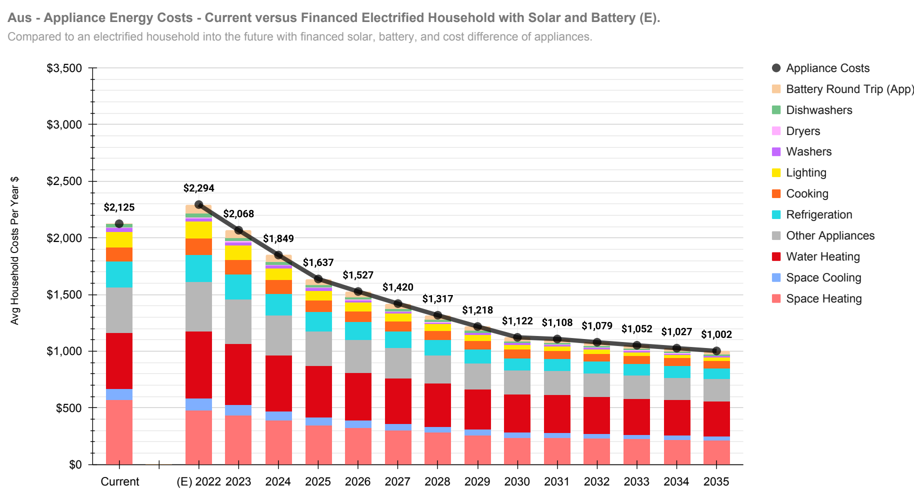


Figure 3.7: *Average household appliance energy costs, current versus electrified household with rooftop solar, battery and electrified appliances. $/Year.*

3.1.1.7 Household savings overview

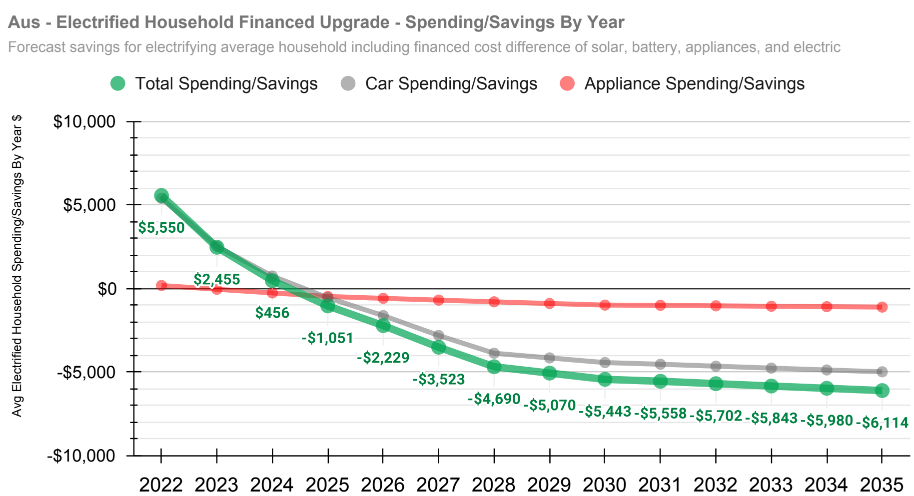


Figure 3.8: *Average household savings forecast by year for an electrified household with rooftop solar, battery, electrified appliances, and electric vehicles. $/Year.*

3.1.1.8 Household savings

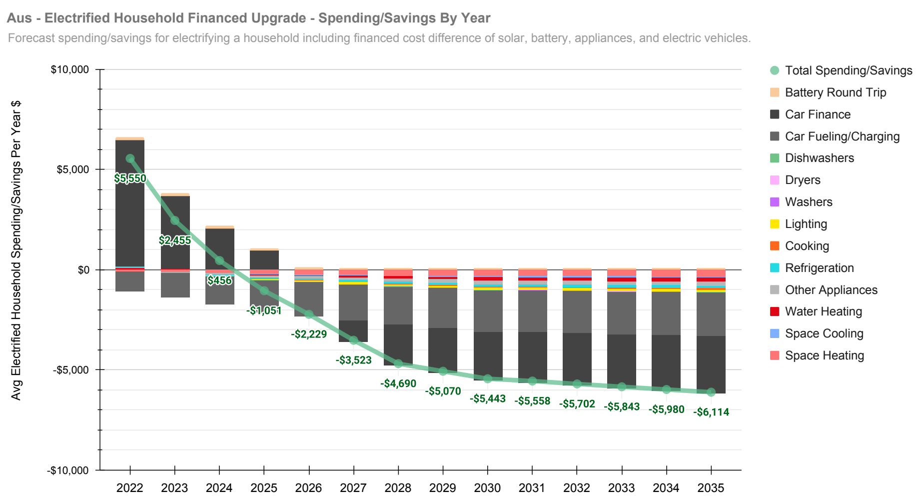


Figure 3.9: *Average household savings forecast by year for an electrified household with rooftop solar, battery, electrified appliances, and electric vehicles. $/Year.*

3.1.1.9 Household appliance savings

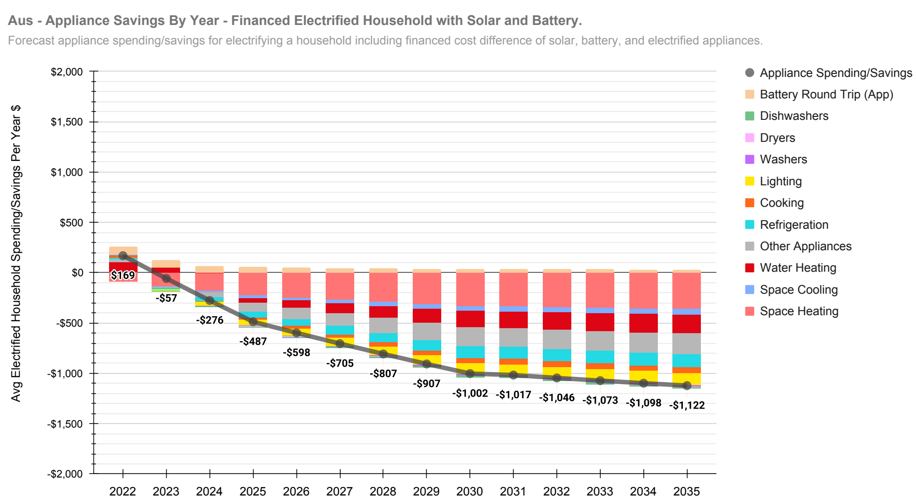


Figure 3.10: *Average household appliance savings forecast by year for an electrified household with rooftop solar, battery, and electrified appliances. $/Year.*

3.1.1.10 Household vehicle savings

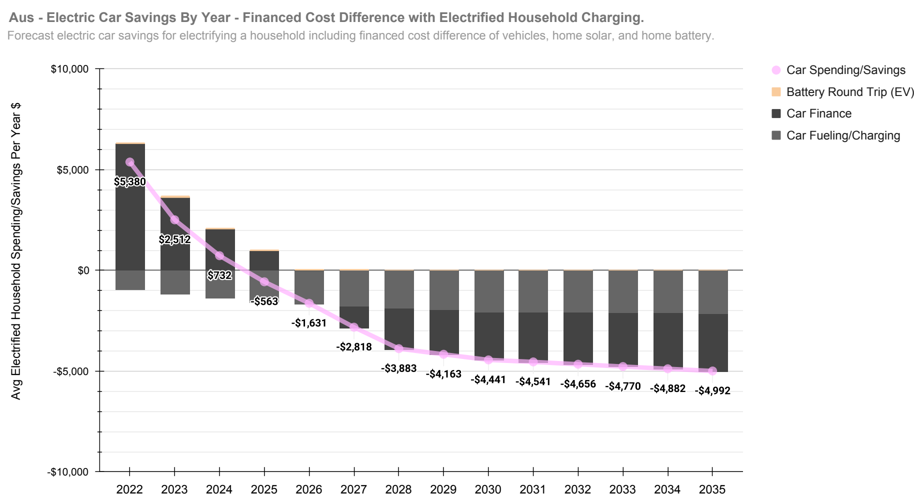
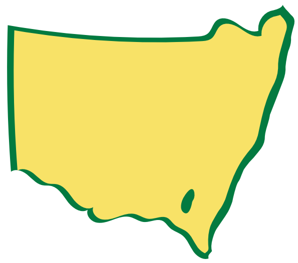


Figure 3.11: *Average household vehicle savings forecast for electric vehicle finance and use. $/Year.*

3.1.2 NSW



According to the Australian Bureau of Statistics (ABS) projections (Series II), there are 3,131,060 households in NSW in 2021, projected to be 3,538,428 by 2030. The average household has 2.6 people, and 1.7 cars. The average household currently spends $4,922 on energy for the household including $1,612 for electricity, $261 for natural gas, $64 for LPG, $2,950 for petrol and diesel, and $37 for wood.

Electricity generation in NSW is currently 76.7% coal, 4.1% natural gas, 0.4% oil, and 18.8% renewables.

The New South Wales grid, like the other heavily populated states of VIC and QLD, is currently largely coal based. The NSW household energy load benefits from not requiring as much heating as the lower, colder states.

The results for the average NSW household are shown below.

Household energy

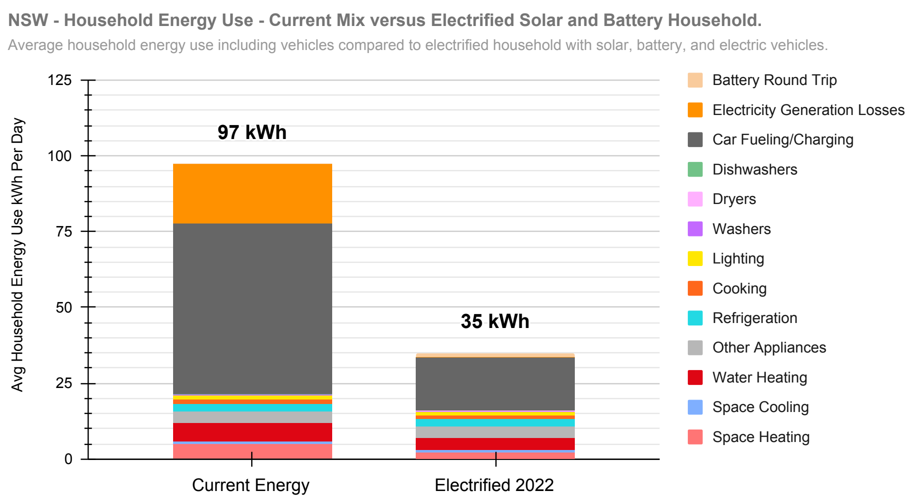


Figure 3.12: *Average household energy use, current versus electrified household with rooftop solar, battery, electrified appliances, and electric vehicles. kWh/Day.*

Household Costs

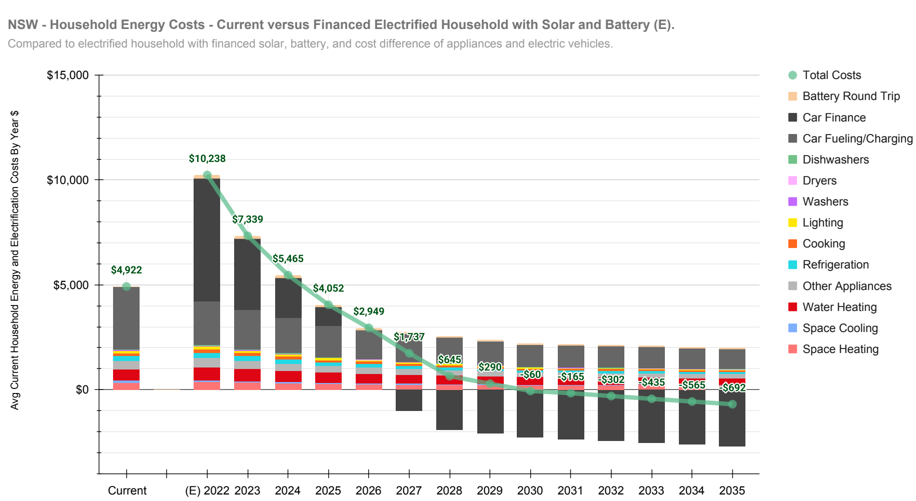


Figure 3.13: *Average household costs, current versus electrified household with rooftop solar, battery, electrified appliances, and electric vehicles. $/Year.*

Household Appliance Costs

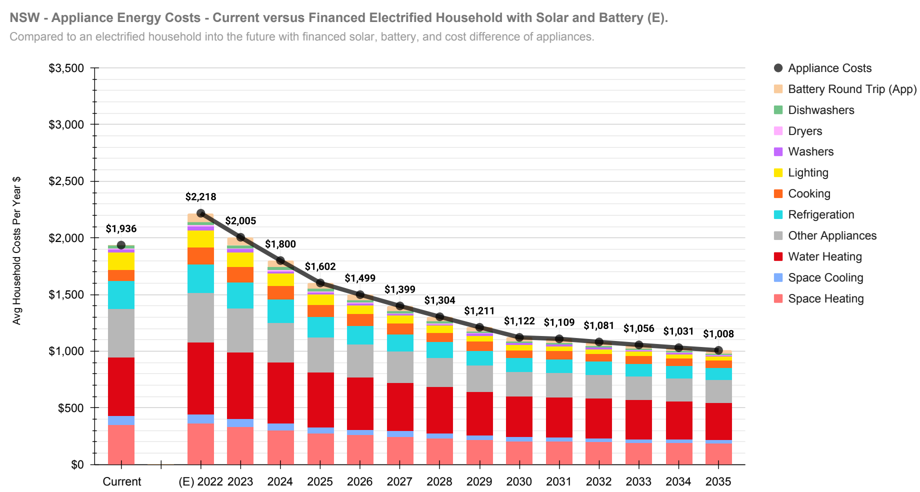


Figure 3.14: *Average household appliance energy costs, current versus electrified household with rooftop solar, battery and electrified appliances. $/Year.*

3.1.2.1 Household savings overview

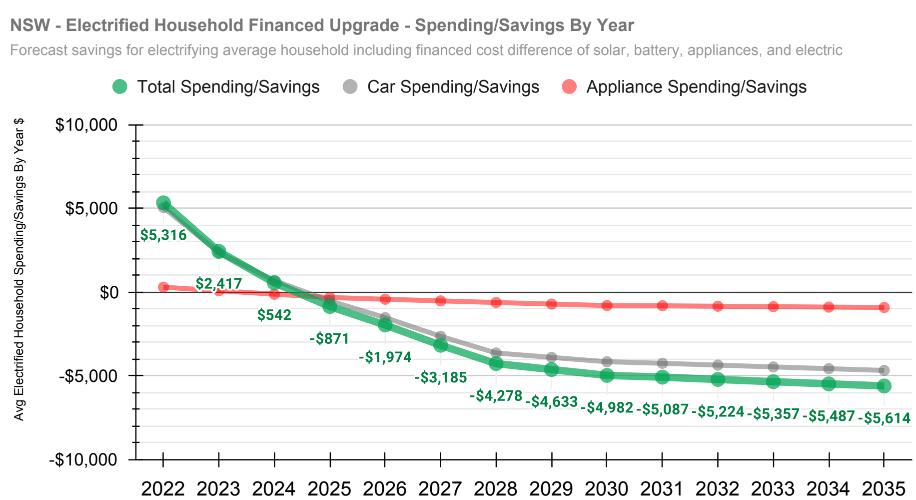


Figure 3.15: *Average household savings forecast by year for an electrified household with rooftop solar, battery, electrified appliances, and electric vehicles. $/Year.*

Household savings

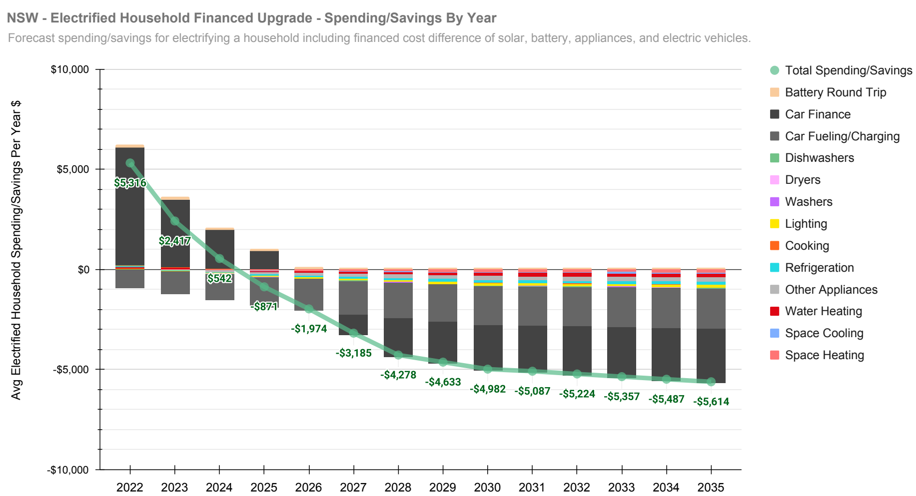


Figure 3.16: *Average household savings forecast by year for an electrified household with rooftop solar, battery, electrified appliances, and electric vehicles. $/Year.*

Household appliance savings

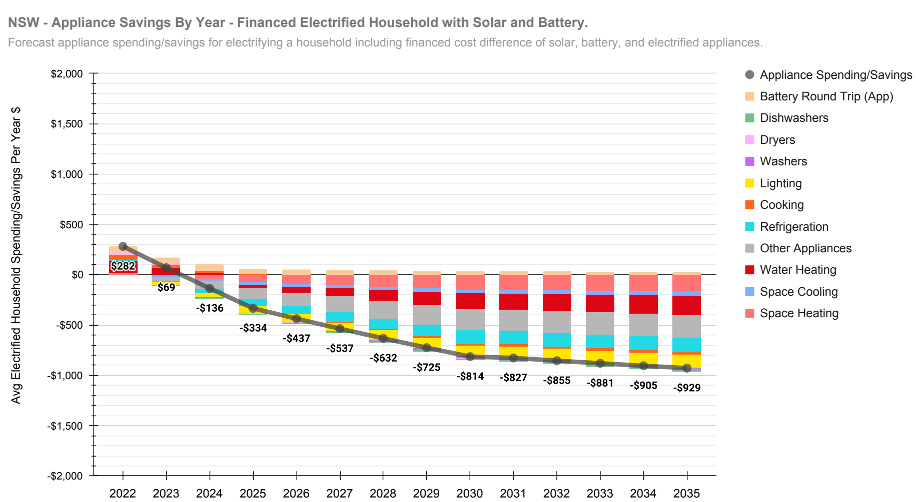


Figure 3.17: *Average household appliance savings forecast by year for an electrified household with rooftop solar, battery, and electrified appliances. $/Year.*

Household vehicle savings

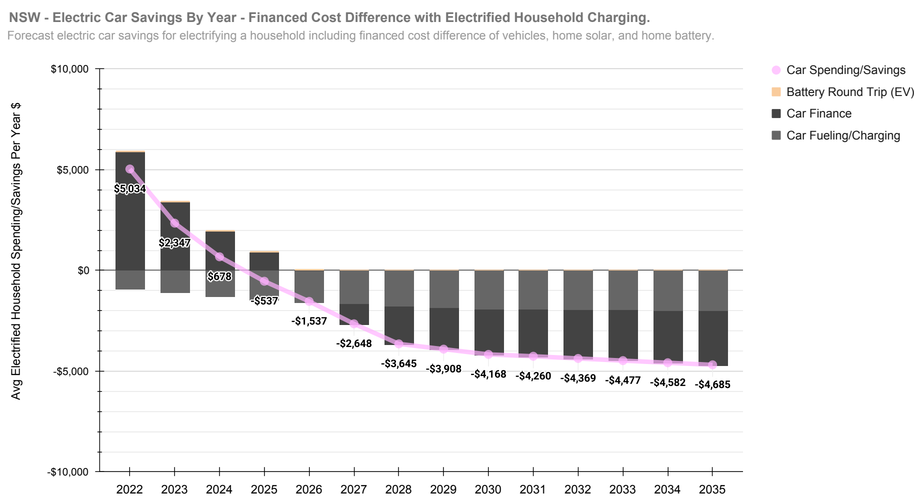
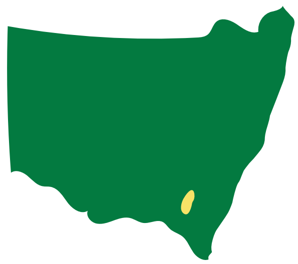


Figure 3.18: *Average household vehicle savings forecast for electric vehicle finance and use. $/Year.*

3.1.3 ACT



According to the Australian Bureau of Statistics (ABS) projections (Series II), there are 173,250 households in ACT in 2021, projected to be 200,569 by 2030. The average household has 2.5 people, and 1.7 cars. The average household currently spends $5,737 on energy for the household including $1,361 for electricity, $1,306 for natural gas, $61 for LPG, $2,986 for petrol and diesel, and $17 for wood.

Average ACT homes have significant energy consumption because of their space heating needs. These needs are currently fulfilled by a large amount of natural gas heating.

The results for the average ACT household are shown below.

Household energy

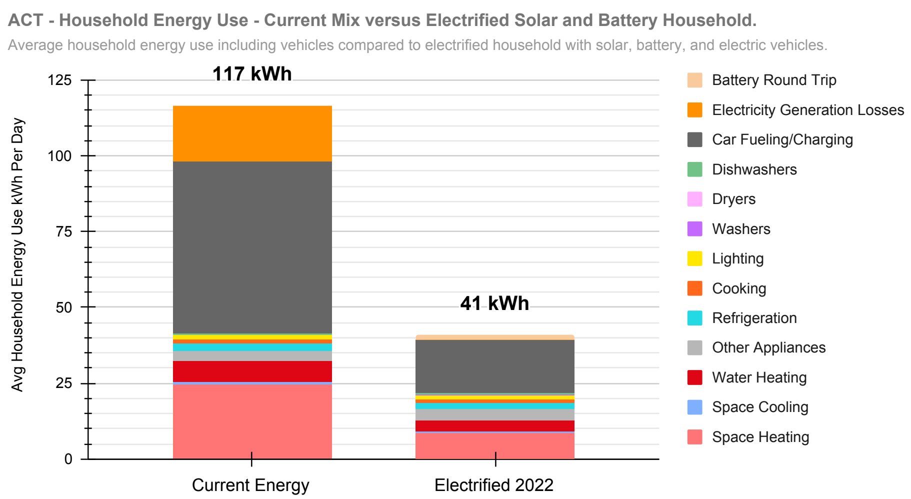


Figure 3.19: *Average household energy use, current versus electrified household with rooftop solar, battery, electrified appliances, and electric vehicles. kWh/Day.*

Household Costs

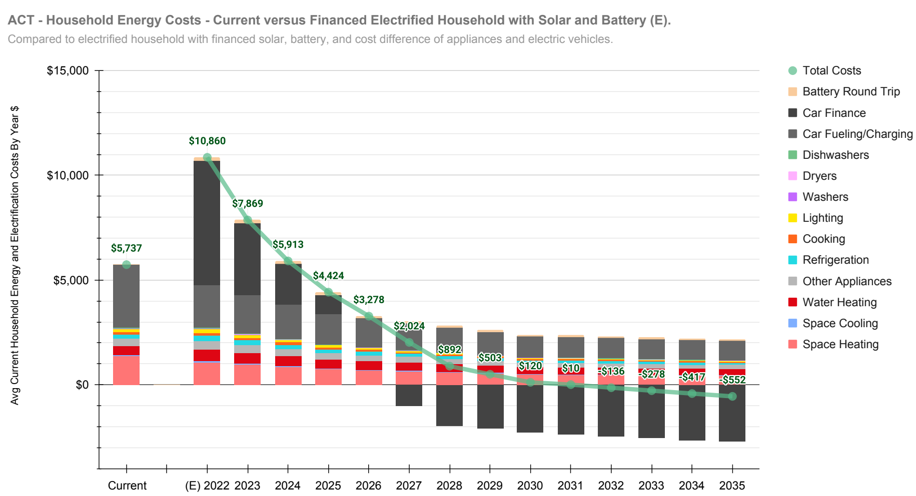


Figure 3.20: *Average household costs, current versus electrified household with rooftop solar, battery, electrified appliances, and electric vehicles. $/Year.*

Household Appliance Costs

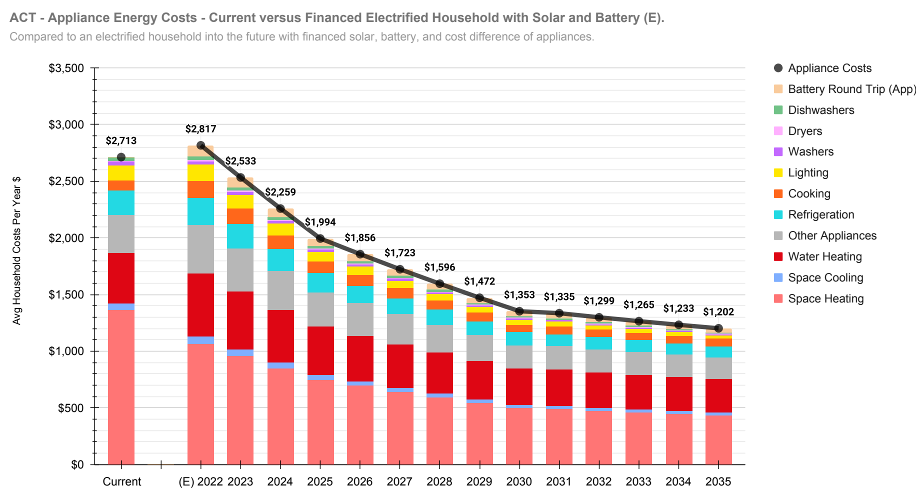


Figure 3.21: *Average household appliance energy costs, current versus electrified household with rooftop solar, battery and electrified appliances. $/Year.*

3.1.3.1 Household savings overview

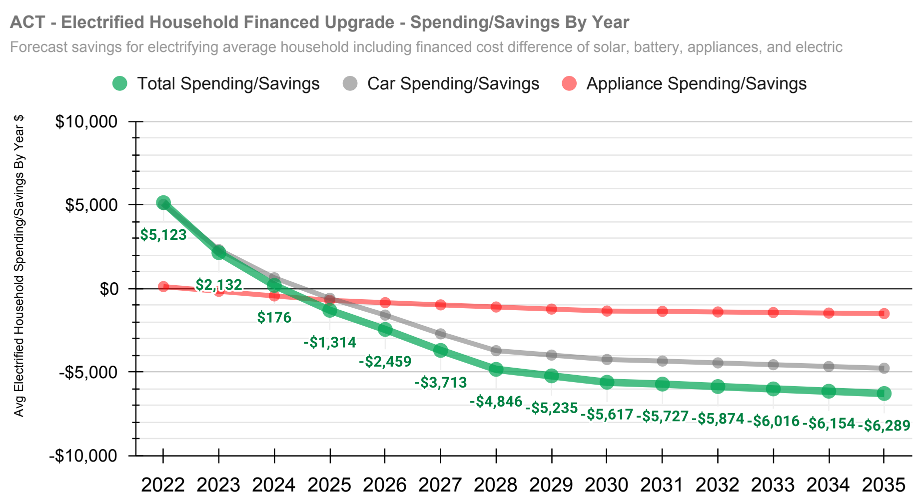


Figure 3.22: *Average household savings forecast by year for an electrified household with rooftop solar, battery, electrified appliances, and electric vehicles. $/Year.*

Household savings

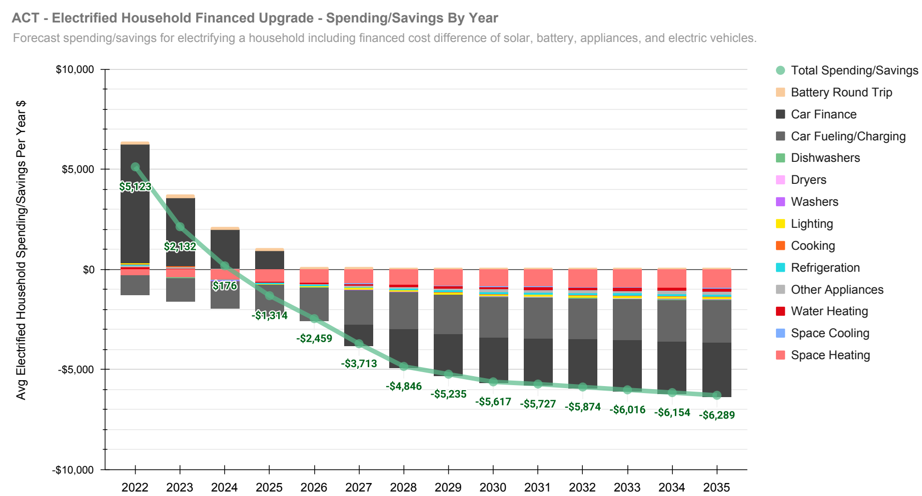


Figure 3.23: *Average household savings forecast by year for an electrified household with rooftop solar, battery, electrified appliances, and electric vehicles. $/Year.*

Household appliance savings

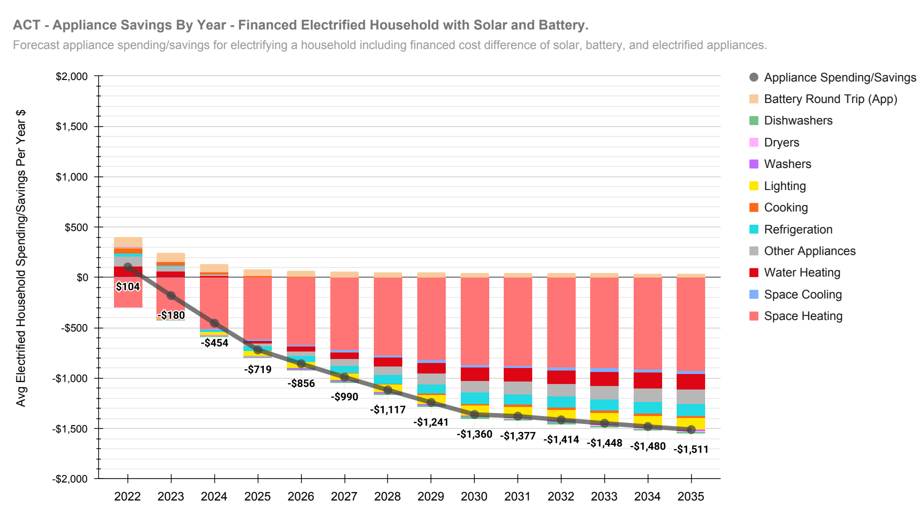


Figure 3.24: *Average household appliance savings forecast by year for an electrified household with rooftop solar, battery, and electrified appliances. $/Year.*

Household vehicle savings

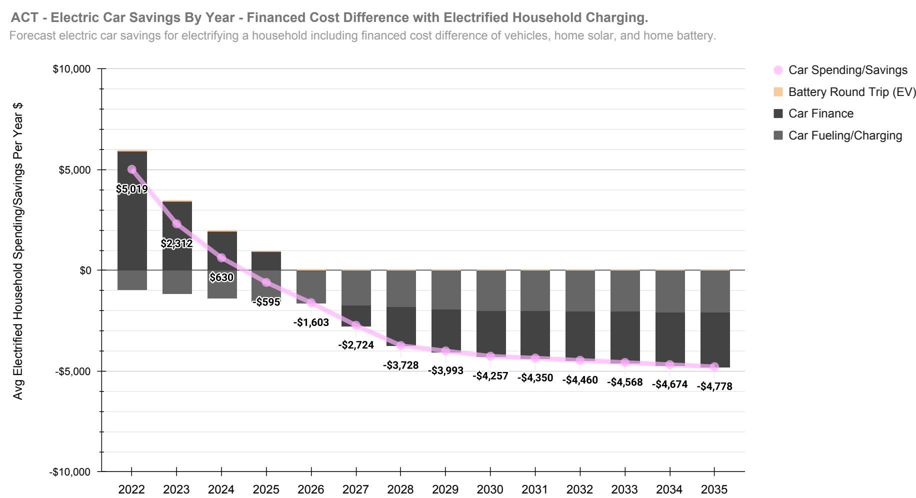
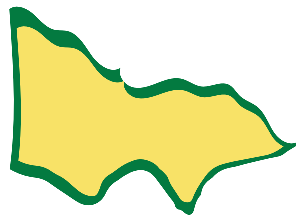


Figure 3.25: *Average household vehicle savings forecast for electric vehicle finance and use. $/Year.*

3.1.4 VIC



According to the Australian Bureau of Statistics (ABS) projections (Series II), there are 2,614,398 households in VIC in 2021, projected to be 3,063,655 by 2030. The average household has 2.6 people, and 1.8 cars. The average household currently spends \$5,407 on energy for the household including \$1,158 for electricity, \$927 for natural gas, \$163 for LPG, \$3,106 for petrol and diesel, and \$62 for wood.

Electricity generation in VIC is currently 70.2% coal, 8.2% natural gas, 0.4% oil, and 21.2% renewables.

The average Victorian home has the largest energy consumption of any Australian state or territory. This energy use is heavily driven by heating needs currently fulfilled largely using natural gas heating appliances in homes. The Victorian grid, like the other heavily populated states of NSW and QLD, is currently largely coal–based.

The results for the average VIC household are shown below.

Household energy

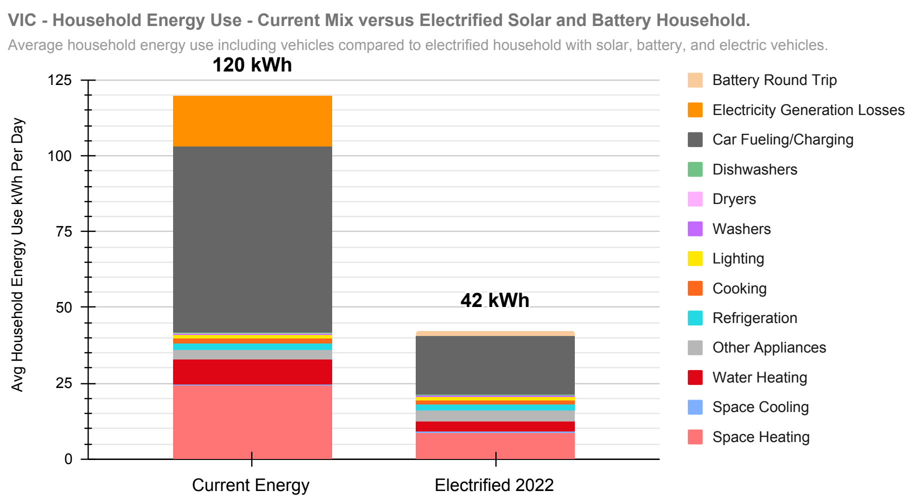


Figure 3.26: *Average household energy use, current versus electrified household with rooftop solar, battery, electrified appliances, and electric vehicles. kWh/Day.*

Household Costs

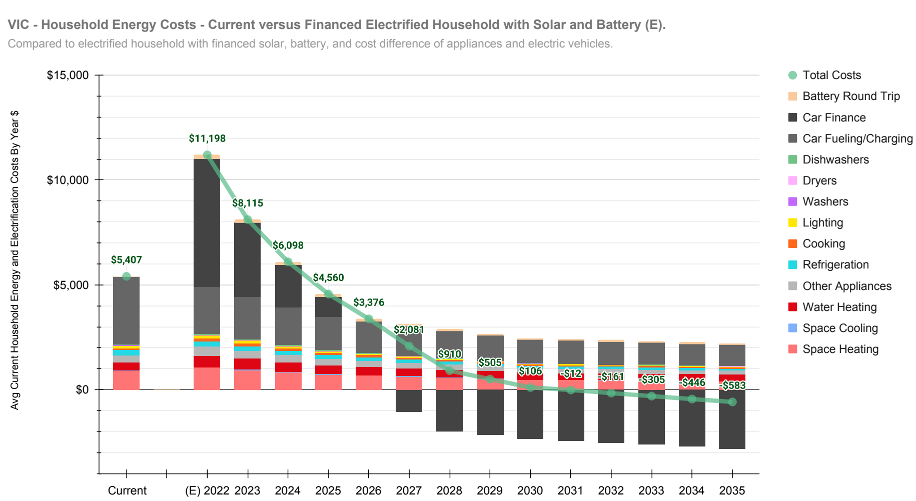


Figure 3.27: *Average household costs, current versus electrified household with rooftop solar, battery, electrified appliances, and electric vehicles. $/Year.*

Household Appliance Costs

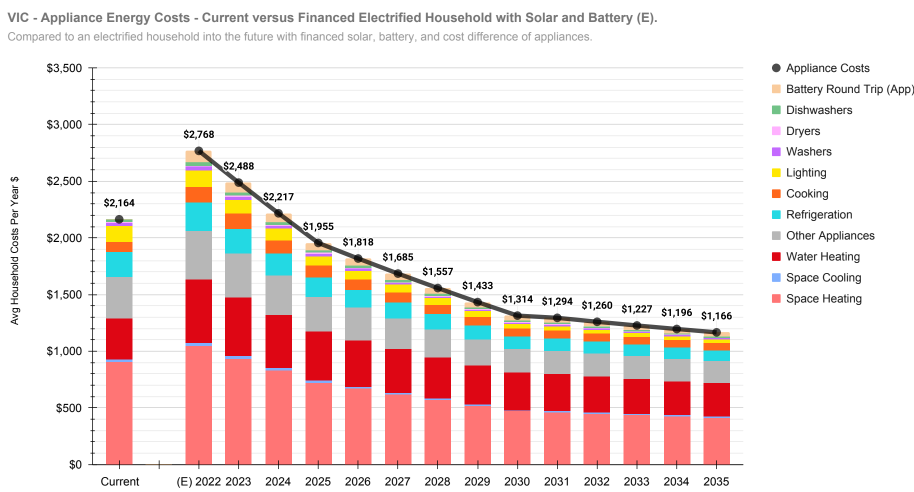


Figure 3.28: *Average household appliance energy costs, current versus electrified household with rooftop solar, battery and electrified appliances. $/Year.*

3.1.4.1 Household savings overview

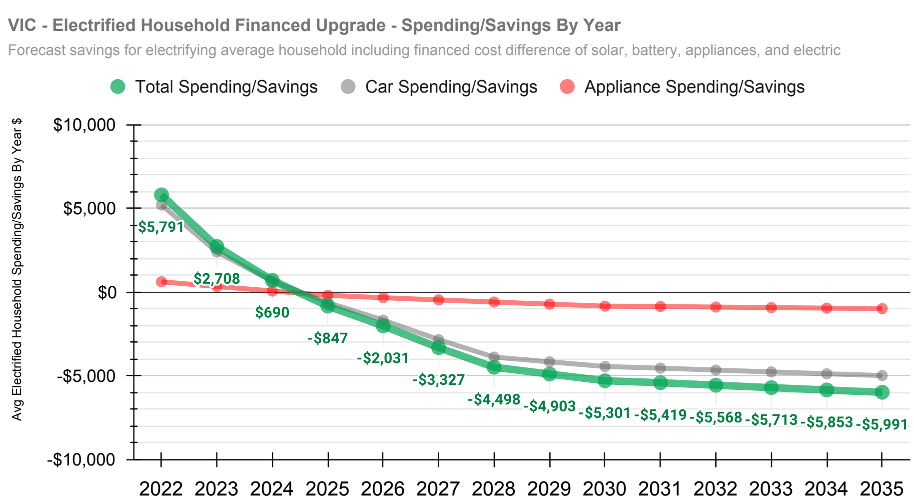


Figure 3.29: *Average household savings forecast by year for an electrified household with rooftop solar, battery, electrified appliances, and electric vehicles. $/Year.*

Household savings

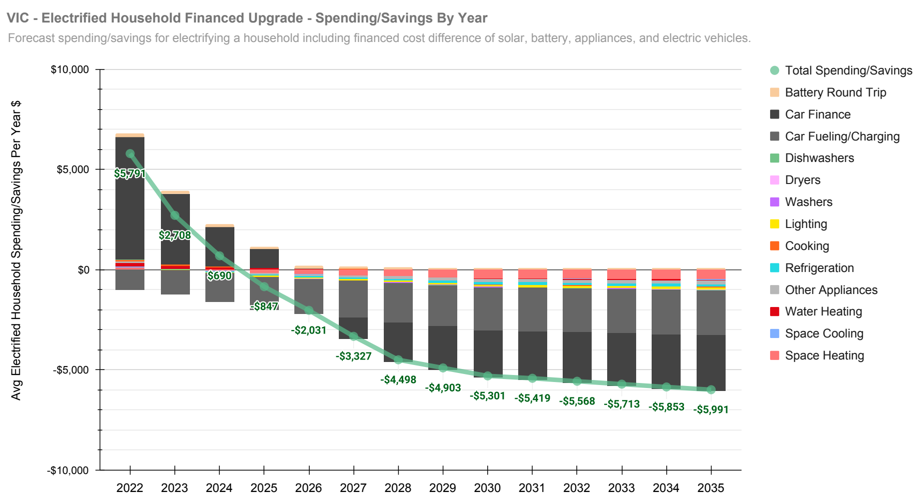


Figure 3.30: *Average household savings forecast by year for an electrified household with rooftop solar, battery, electrified appliances, and electric vehicles. $/Year.*

Household appliance savings

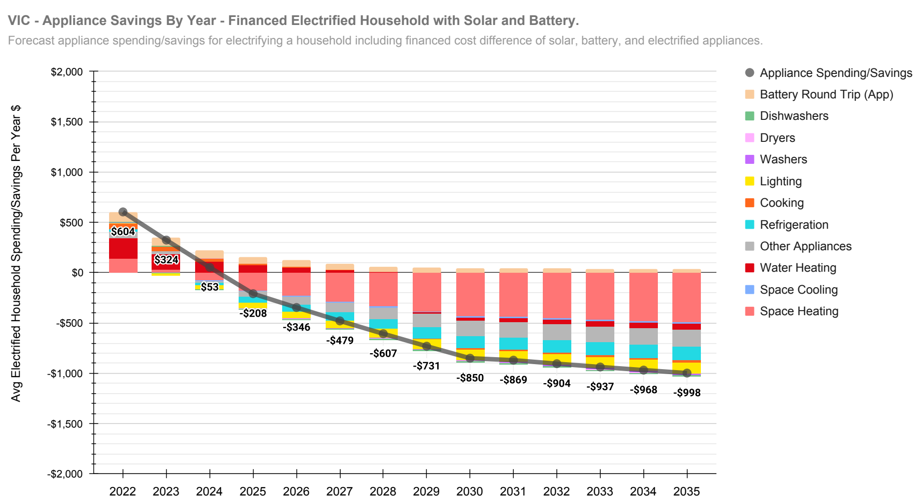


Figure 3.31: *Average household appliance savings forecast by year for an electrified household with rooftop solar, battery, and electrified appliances. $/Year.*

Household vehicle savings

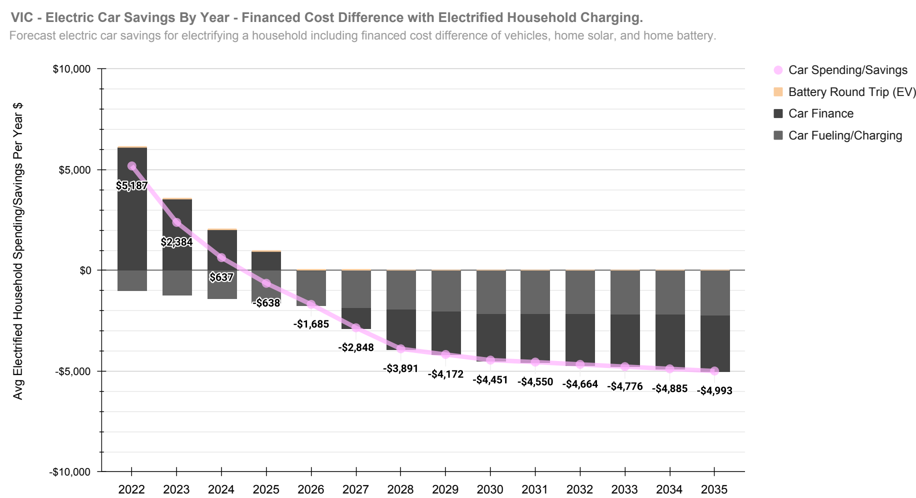
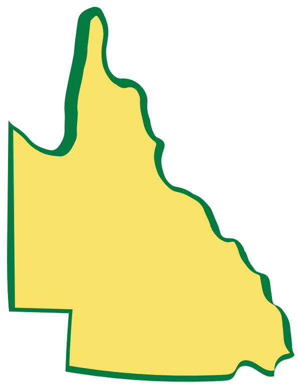


Figure 3.32: *Average household vehicle savings forecast for electric vehicle finance and use. $/Year.*

3.1.5 QLD



According to the Australian Bureau of Statistics (ABS) projections (Series II), there are 1,982,575 households in QLD in 2021, projected to be 2,277,013 by 2030. The average household has 2.6 people, and 2.0 cars. The average household currently spends $4,780 on energy for the household including $1,344 for electricity, $136 for natural gas, $88 for LPG, $3,197 for petrol and diesel, and $7 for wood.

Electricity generation in QLD is currently 70.5% coal, 14.9% natural gas, 1.5% oil, and 13.2% renewables.

The Queensland grid, like the other heavily populated states of NSW and VIC, is currently largely coal based. The average QLD home benefits from not using as much natural gas heating as most other states.

The results for the average QLD household are shown below.

Household energy

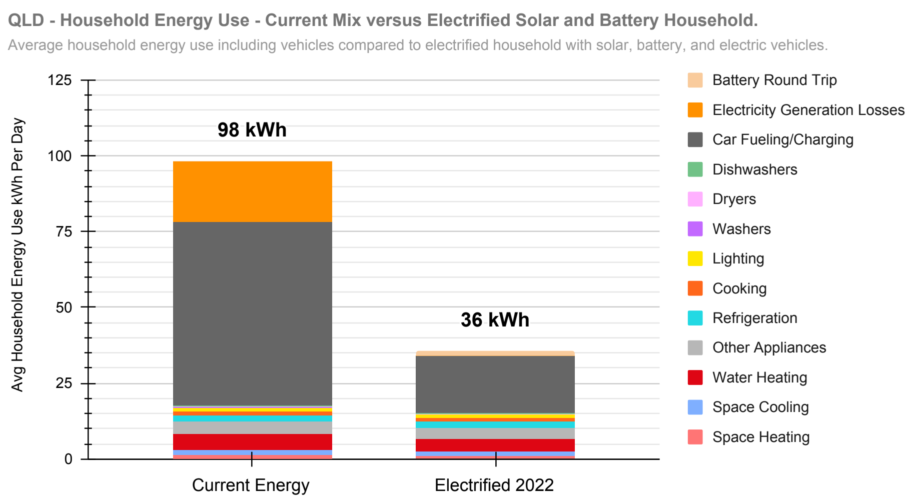


Figure 3.33: *Average household energy use, current versus electrified household with rooftop solar, battery, electrified appliances, and electric vehicles. kWh/Day.*

Household Costs

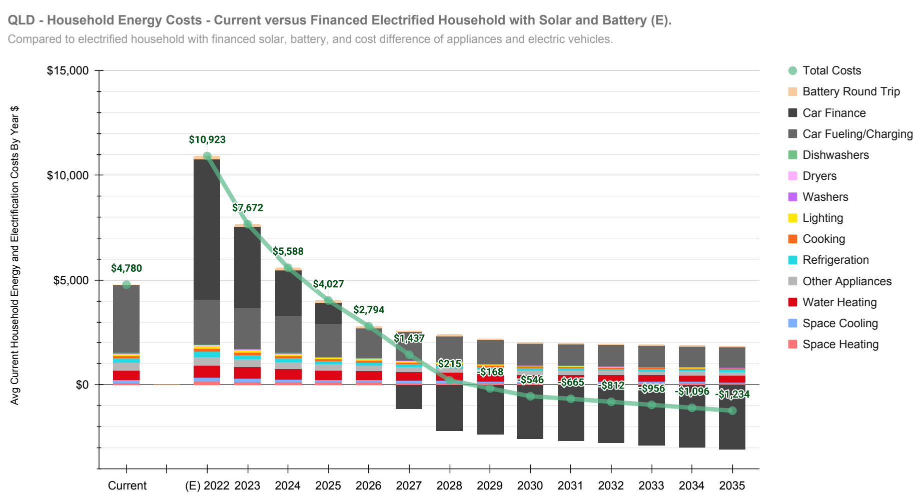


Figure 3.34: *Average household costs, current versus electrified household with rooftop solar, battery, electrified appliances, and electric vehicles. $/Year.*

Household Appliance Costs

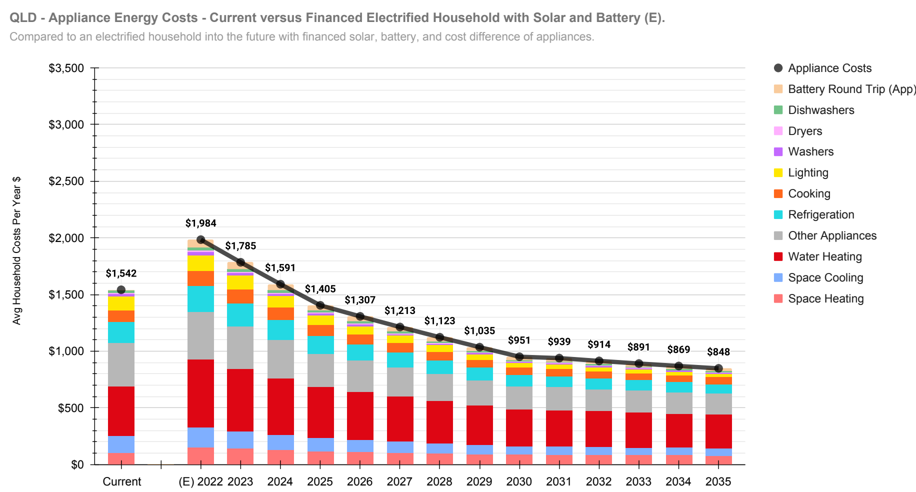


Figure 3.35: *Average household appliance energy costs, current versus electrified household with rooftop solar, battery and electrified appliances. $/Year.*

3.1.5.1 Household savings overview

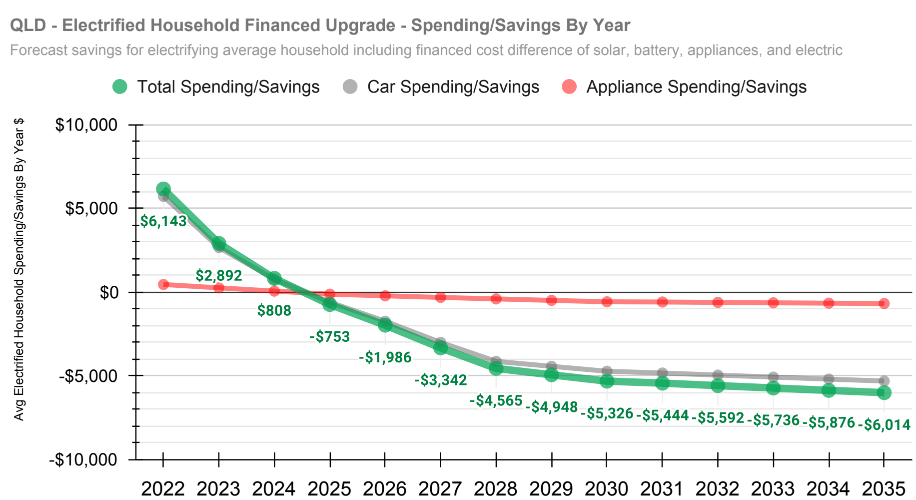


Figure 3.36: *Average household savings forecast by year for an electrified household with rooftop solar, battery, electrified appliances, and electric vehicles. $/Year.*

Household savings

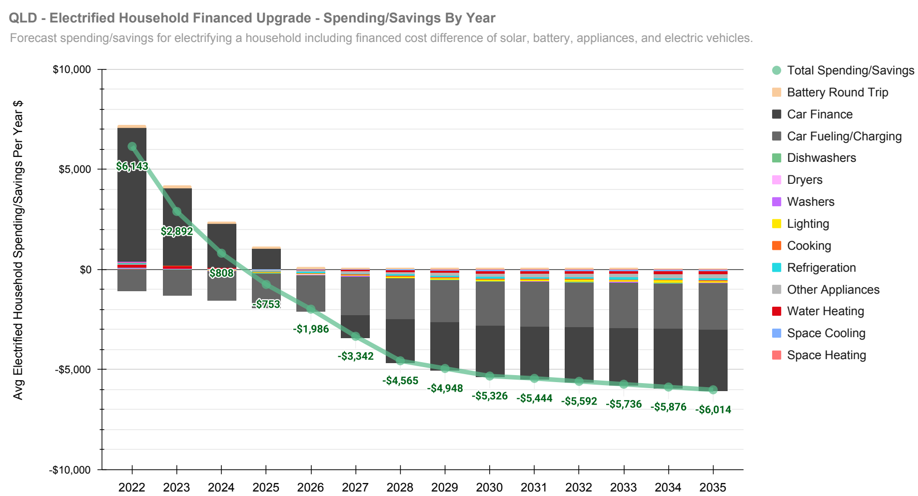


Figure 3.37: *Average household savings forecast by year for an electrified household with rooftop solar, battery, electrified appliances, and electric vehicles. $/Year.*

Household appliance savings

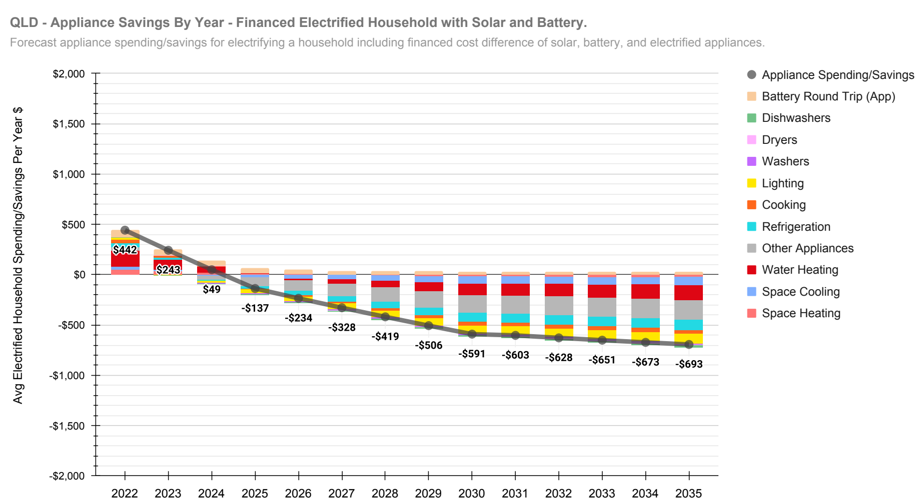


Figure 3.38: *Average household appliance savings forecast by year for an electrified household with rooftop solar, battery, and electrified appliances. $/Year.*

Household vehicle savings

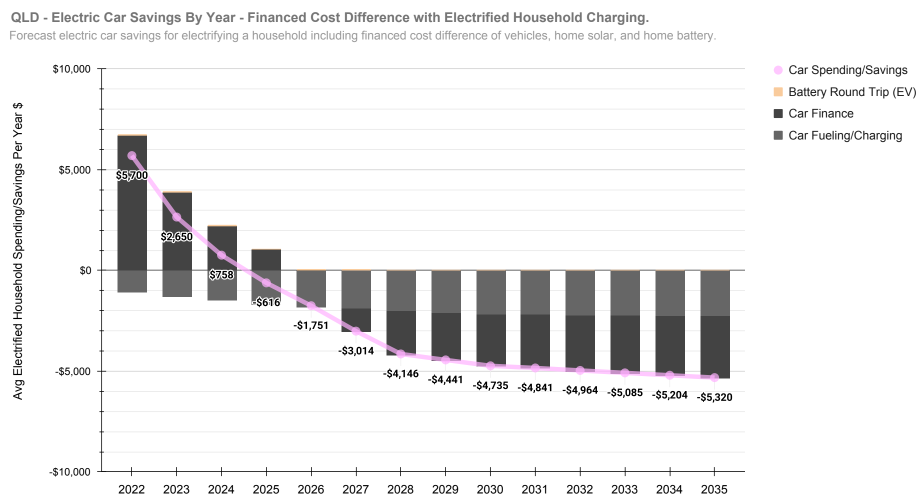
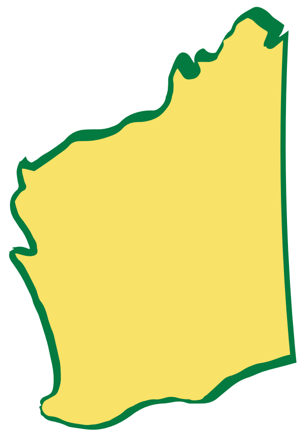


Figure 3.39: *Average household vehicle savings forecast for electric vehicle finance and use. $/Year.*

3.1.6 WA



According to the Australian Bureau of Statistics (ABS) projections (Series II), there are 1,015,729 households in WA in 2021, projected to be 1,165,880 by 2030. The average household has 2.6 people, and 2.1 cars. The average household currently spends $5,003 on energy for the household including $1,323 for electricity, $378 for natural gas, $80 for LPG, $3,188 for petrol and diesel, and $34 for wood.

Electricity generation in WA is currently 23.2% coal, 61.3% natural gas, 5.5% oil, and 9.9% renewables.

The Western Australian electricity grid is unique in having the largest proportion of natural gas use in the country, and still a significant amount of coal use. The results for the average WA household are shown below.

Household energy

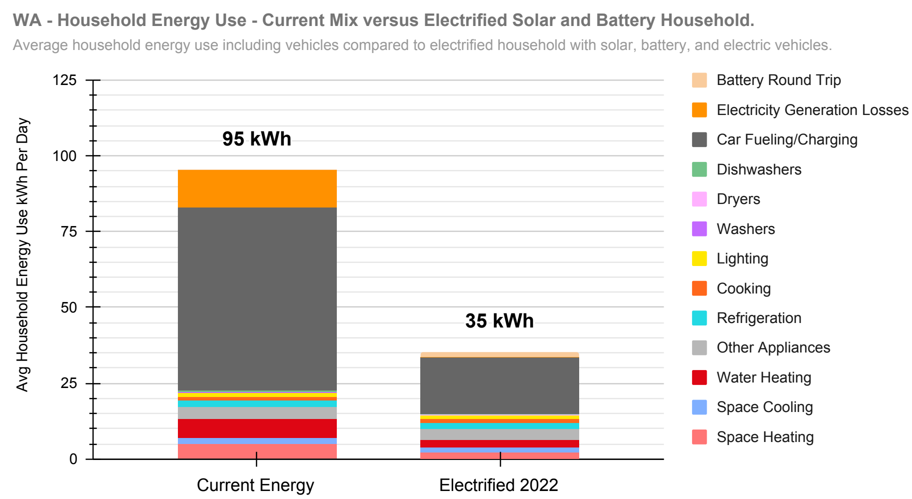


Figure 3.40: *Average household energy use, current versus electrified household with rooftop solar, battery, electrified appliances, and electric vehicles. kWh/Day.*

Household Costs

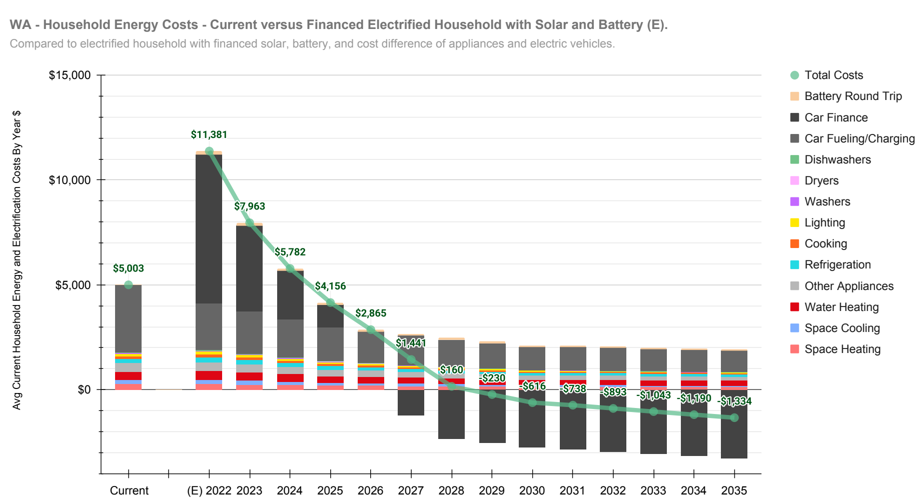


Figure 3.41: *Average household costs, current versus electrified household with rooftop solar, battery, electrified appliances, and electric vehicles. $/Year.*

Household Appliance Costs

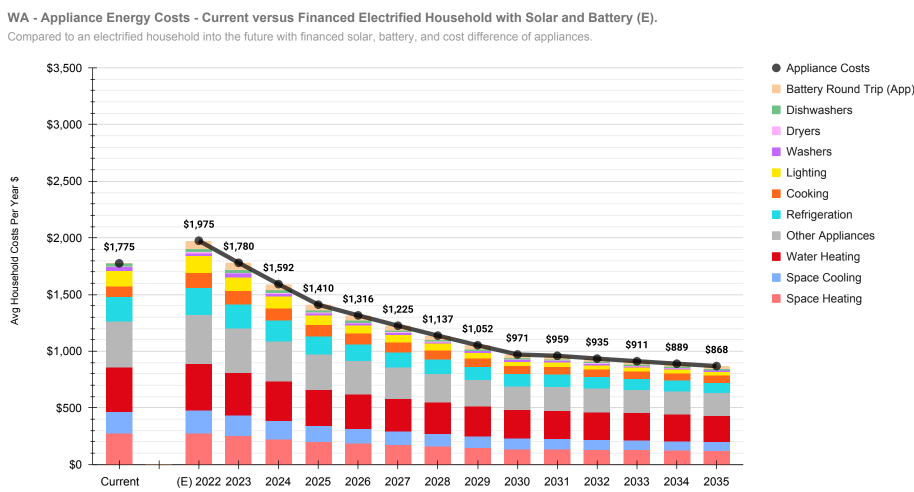


Figure 3.42: *Average household appliance energy costs, current versus electrified household with rooftop solar, battery and electrified appliances. $/Year.*

3.1.6.1 Household savings overview

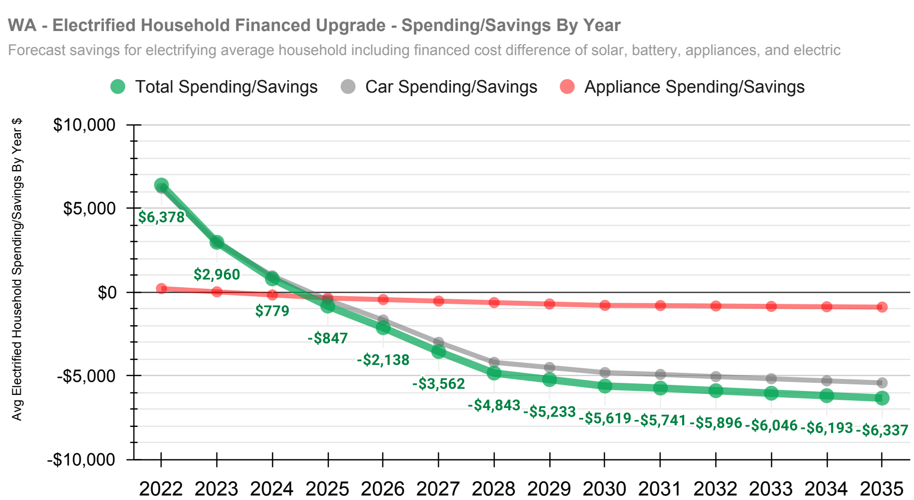


Figure 3.43: *Average household savings forecast by year for an electrified household with rooftop solar, battery, electrified appliances, and electric vehicles. $/Year.*

Household savings

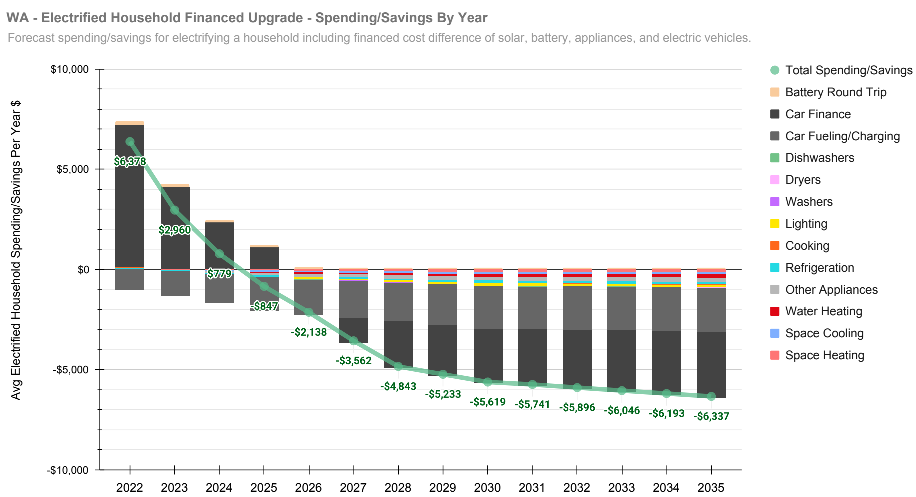


Figure 3.44: *Average household savings forecast by year for an electrified household with rooftop solar, battery, electrified appliances, and electric vehicles. $/Year.*

Household appliance savings

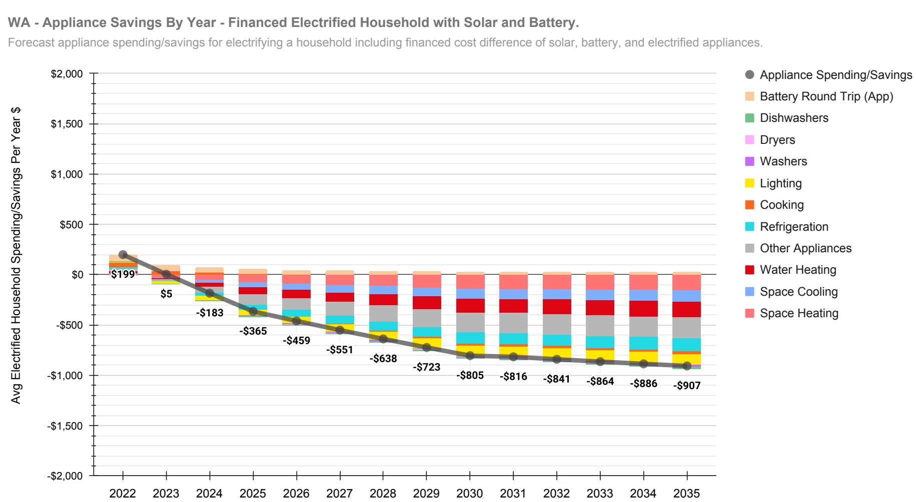


Figure 3.45: *Average household appliance savings forecast by year for an electrified household with rooftop solar, battery, and electrified appliances. $/Year.*

Household vehicle savings

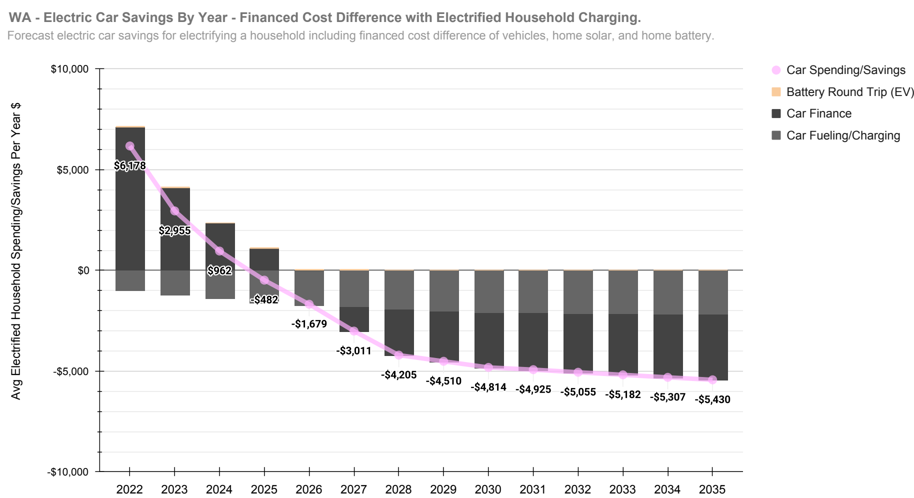
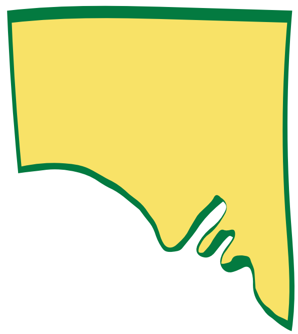


Figure 3.46: *Average household vehicle savings forecast for electric vehicle finance and use. $/Year.*

3.1.7 SA



According to the Australian Bureau of Statistics (ABS) projections (Series II), there are 725,115 households in SA in 2021, projected to be 777,471 by 2030. The average household has 2.4 people, and 1.9 cars. The average household currently spends $5,033 on energy for the household including $1,755 for electricity, $415 for natural gas, $159 for LPG, $2,685 for petrol and diesel, and $43 for wood.

Electricity generation in SA is currently 0.0% coal, 48.9% natural gas, 0.9% oil, and 50.2% renewables.

South Australia has the lowest average household energy consumption in the country, largely because of low grid generation waste from the natural gas and renewables driven grid. The average SA home also benefits from lower heating requirements because of a slightly higher average temperature than nearby Melbourne.

The results for the average SA household are shown below.

Household energy

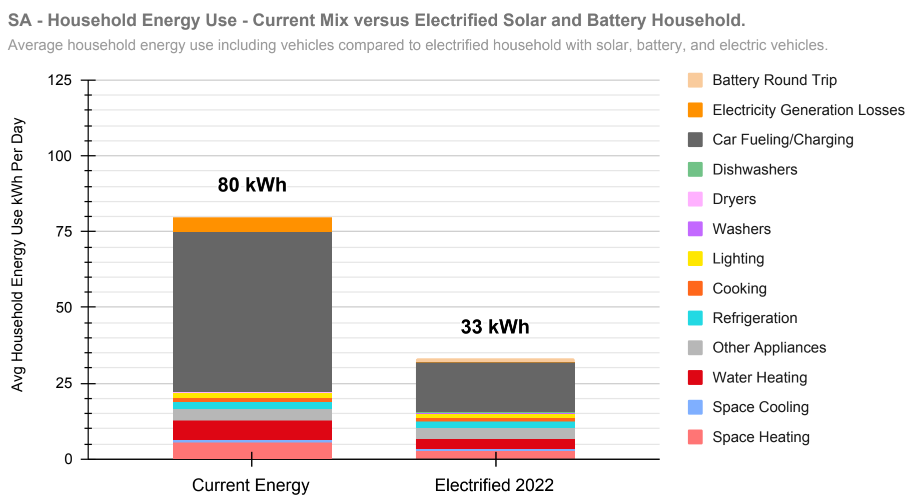


Figure 3.47: *Average household energy use, current versus electrified household with rooftop solar, battery, electrified appliances, and electric vehicles. kWh/Day.*

Household Costs

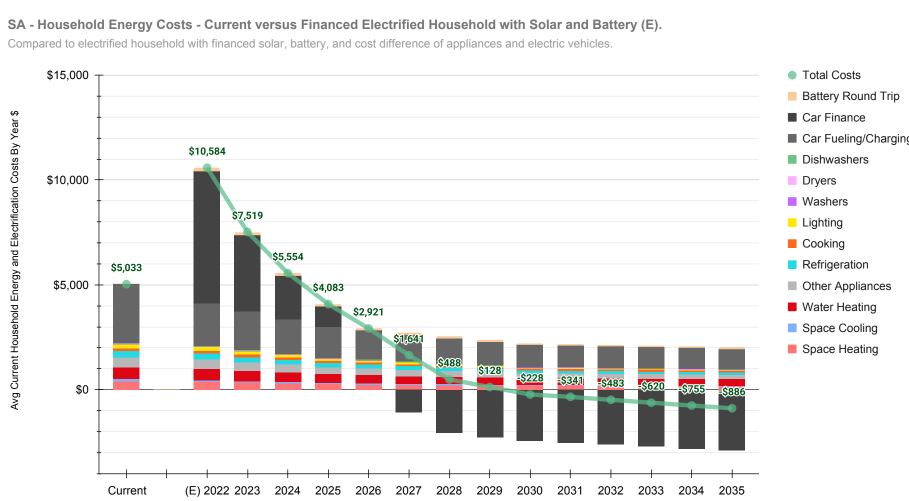


Figure 3.48: *Average household costs, current versus electrified household with rooftop solar, battery, electrified appliances, and electric vehicles. $/Year.*

Household Appliance Costs

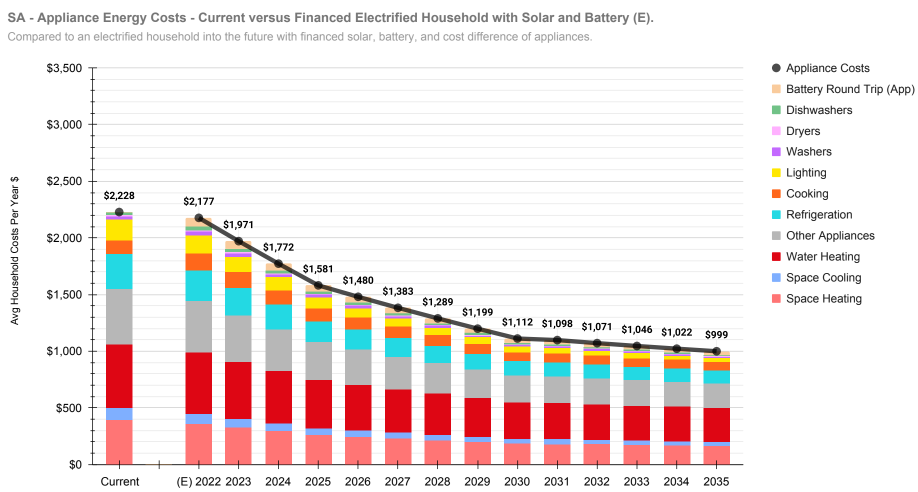


Figure 3.49: *Average household appliance energy costs, current versus electrified household with rooftop solar, battery and electrified appliances. $/Year.*

3.1.7.1 Household savings overview

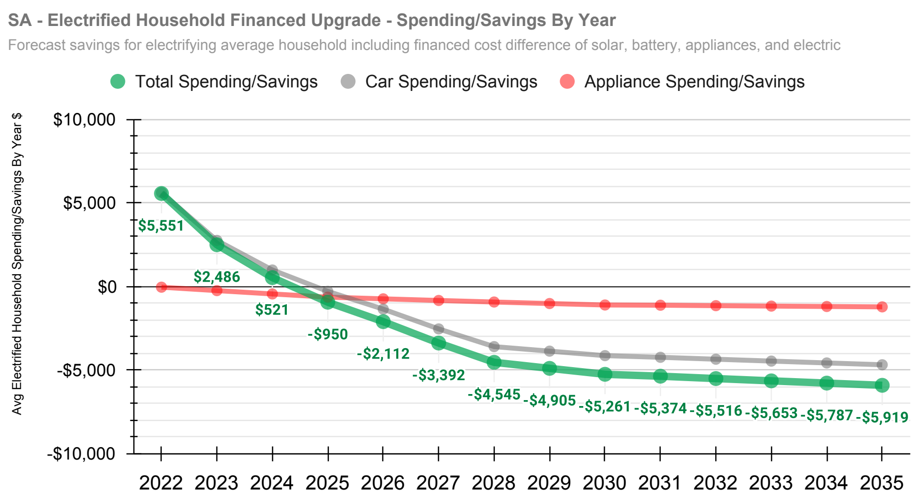


Figure 3.50: *Average household savings forecast by year for an electrified household with rooftop solar, battery, electrified appliances, and electric vehicles. $/Year.*

Household savings

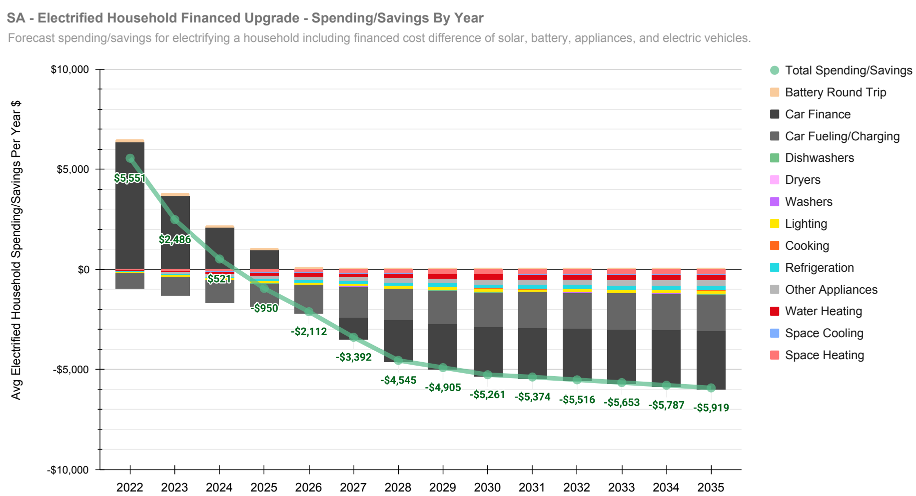


Figure 3.51: *Average household savings forecast by year for an electrified household with rooftop solar, battery, electrified appliances, and electric vehicles. $/Year.*

Household appliance savings

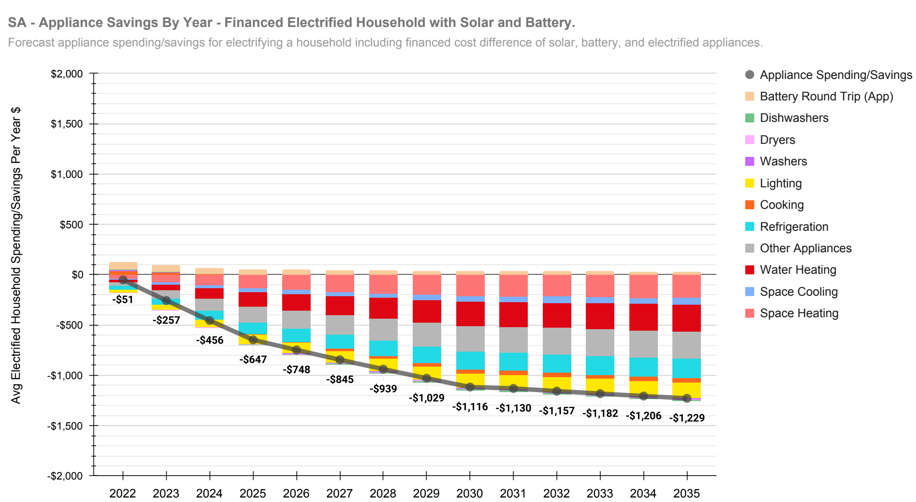


Figure 3.52: *Average household appliance savings forecast by year for an electrified household with rooftop solar, battery, and electrified appliances. $/Year.*

Household vehicle savings

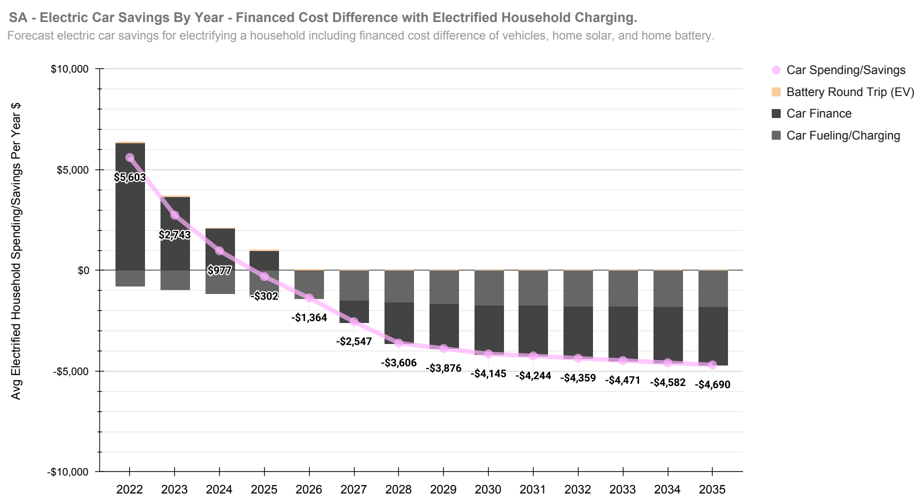
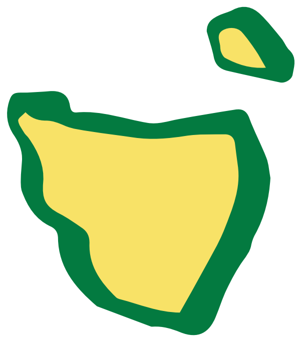


Figure 3.53: *Average household vehicle savings forecast for electric vehicle finance and use. $/Year.*

3.1.8 TAS



According to the Australian Bureau of Statistics (ABS) projections (Series II), there are 231,275 households in TAS in 2021, projected to be 244,698 by 2030. The average household has 2.3 people, and 2.0 cars. The average household currently spends \$5,112 on energy for the household including \$1,733 for electricity, \$72 for natural gas, \$39 for LPG, \$3,111 for petrol and diesel, and \$131 for wood.

Electricity generation in TAS is currently 0.0% coal, 5.6% natural gas, 0.2% oil, and 94.2% renewables.

The Tasmanian electricity grid is the greenest in the country with over 94% renewables (81% of which Hydro). With the coldest average temperatures in the country, Tasmanian heating needs are significant and currently partially fulfilled by the largest proportion of wood heating used in the country.

The results for the average TAS household are shown below.

Household energy

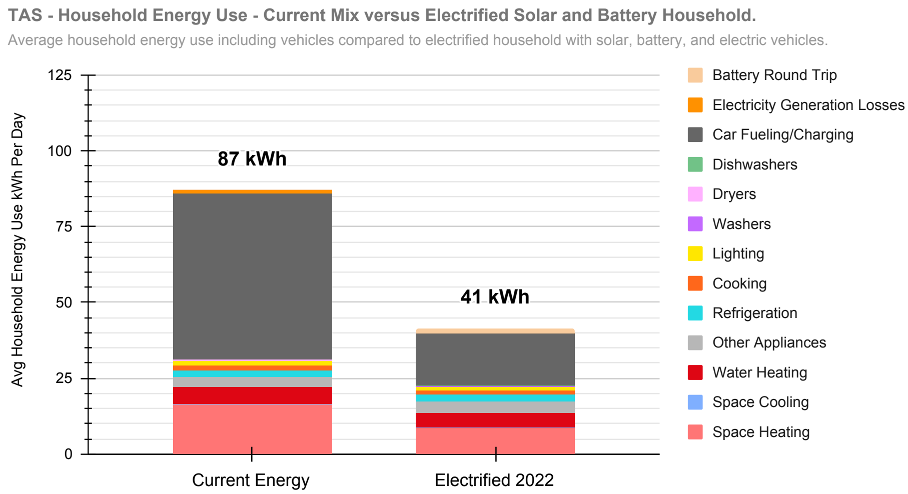


Figure 3.54: *Average household energy use, current versus electrified household with rooftop solar, battery, electrified appliances, and electric vehicles. kWh/Day.*

Household Costs

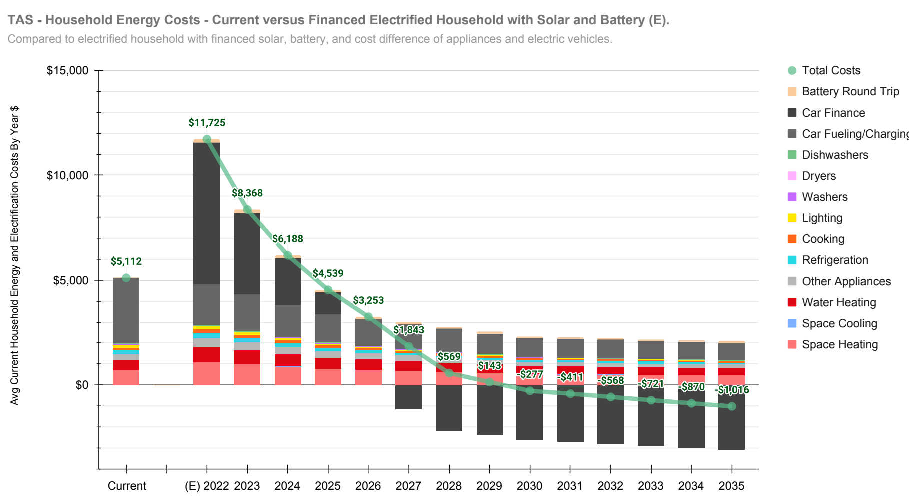


Figure 3.55: *Average household costs, current versus electrified household with rooftop solar, battery, electrified appliances, and electric vehicles. $/Year.*

Household Appliance Costs

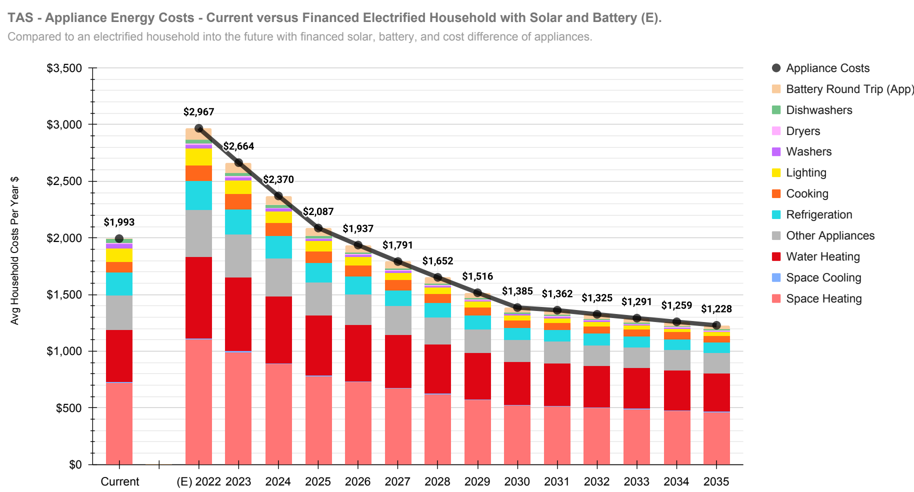


Figure 3.56: *Average household appliance energy costs, current versus electrified household with rooftop solar, battery and electrified appliances. $/Year.*

3.1.8.1 Household savings overview

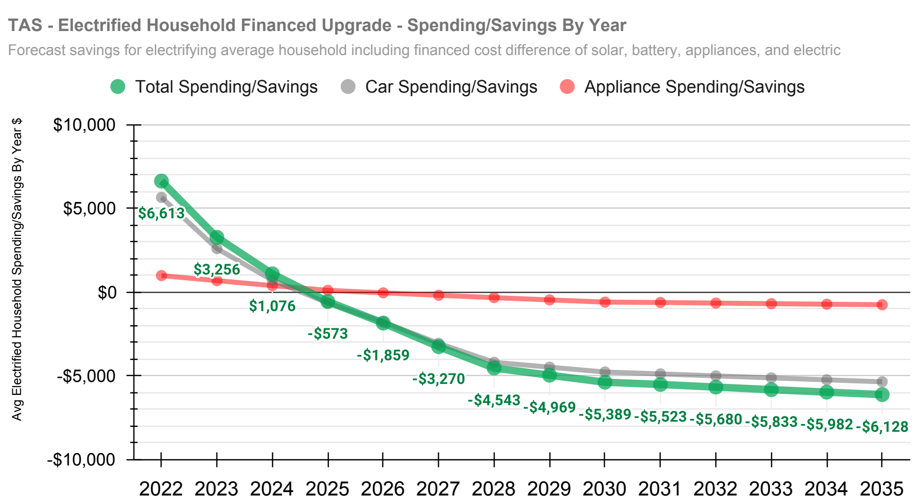


Figure 3.57: *Average household savings forecast by year for an electrified household with rooftop solar, battery, electrified appliances, and electric vehicles. $/Year.*

Household savings

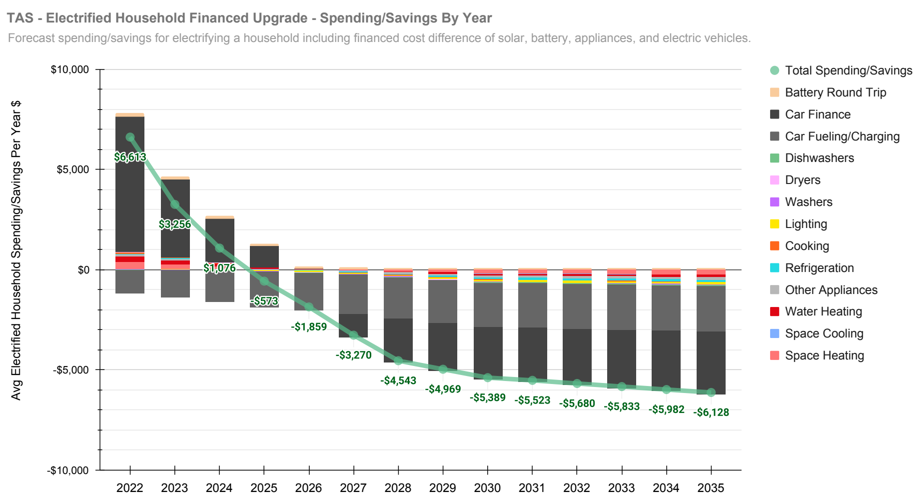


Figure 3.58: *Average household savings forecast by year for an electrified household with rooftop solar, battery, electrified appliances, and electric vehicles. $/Year.*

Household appliance savings

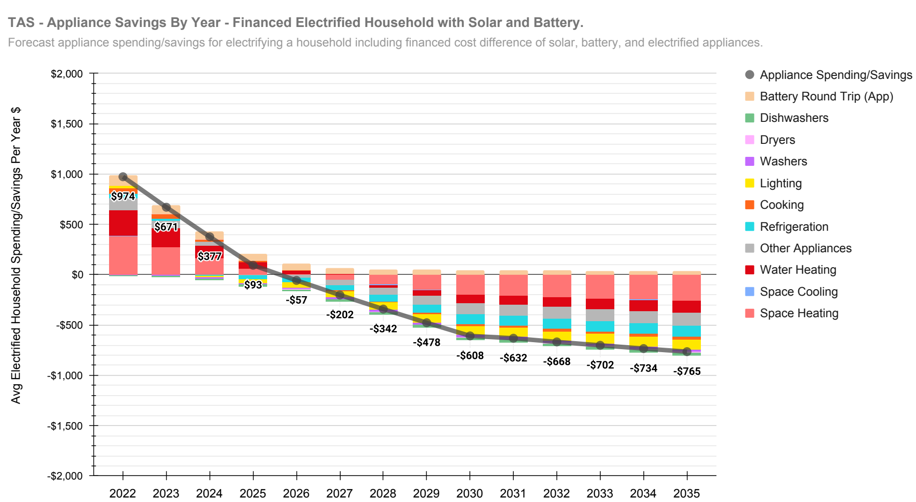


Figure 3.59: *Average household appliance savings forecast by year for an electrified household with rooftop solar, battery, and electrified appliances. $/Year.*

Household vehicle savings

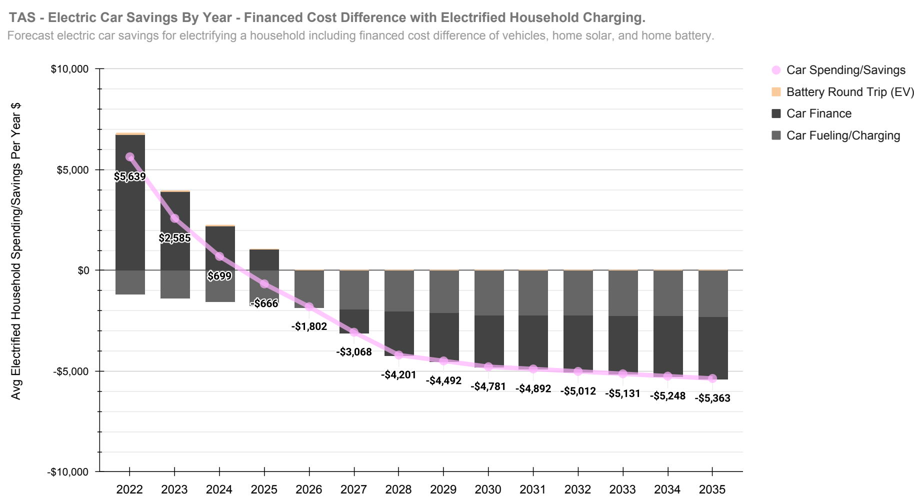
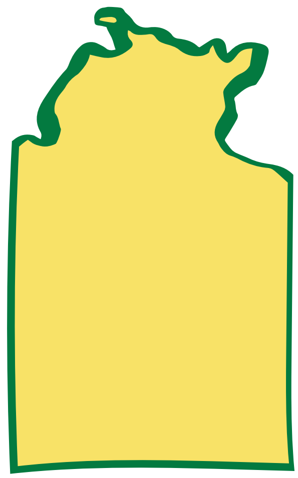


Figure 3.60: *Average household vehicle savings forecast for electric vehicle finance and use. $/Year.*

3.1.9 NT



According to the Australian Bureau of Statistics (ABS) projections (Series II), there are 80,228 households in NT in 2021, projected to be 89,436 by 2030. The average household has 2.9 people, and 1.9 cars. The average household currently spends $5,149 on energy for the household including $1,734 for electricity, $82 for natural gas, $34 for LPG, $3,299 for petrol and diesel, and $2 for wood.

Electricity generation in NT is currently 0.0% coal, 57.6% natural gas, 38.4% oil, and 4.1% renewables.

The Northern Territory grid is unique in using practically no coal, a large amount of natural gas, and the largest amount of oil electricity generation in the country. NT households benefit from lower energy consumption than the average in most other states, because they require significantly less energy–intense heating. The results for the average NT household are shown below.

Household energy

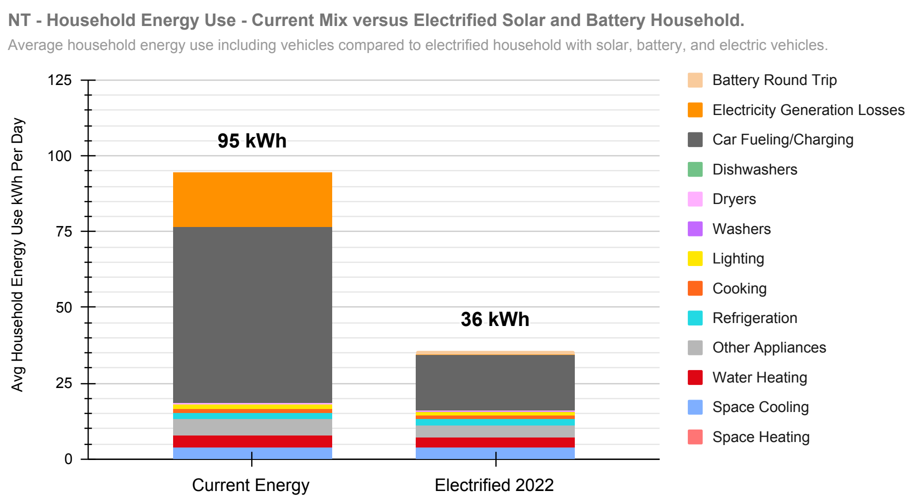


Figure 3.61: *Average household energy use, current versus electrified household with rooftop solar, battery, electrified appliances, and electric vehicles. kWh/Day.*

Household Costs

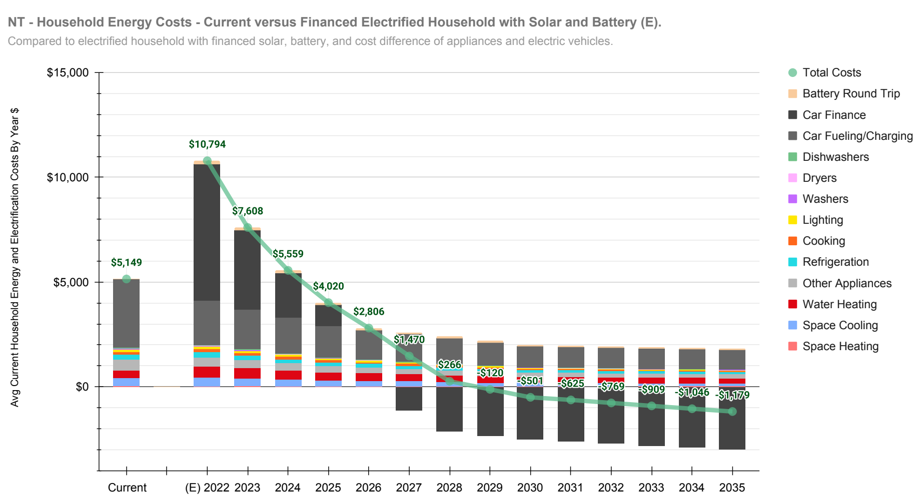


Figure 3.62: *Average household costs, current versus electrified household with rooftop solar, battery, electrified appliances, and electric vehicles. $/Year.*

Household Appliance Costs

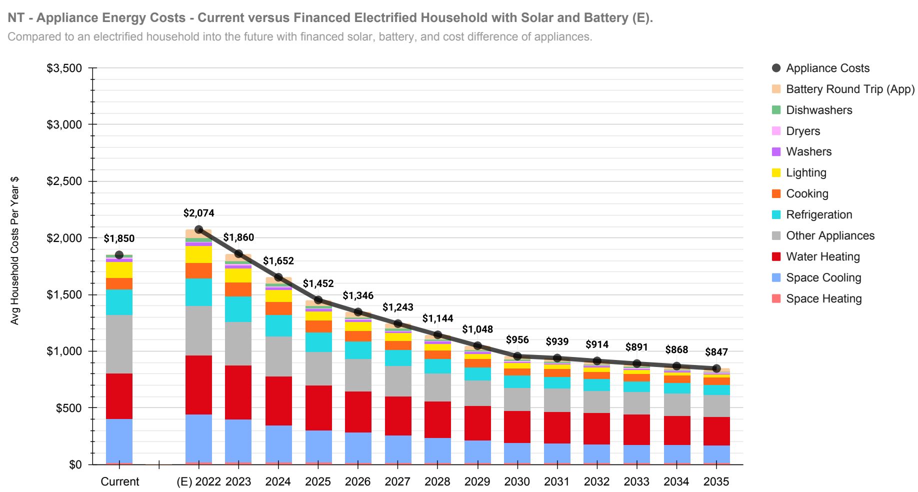


Figure 3.63: *Average household appliance energy costs, current versus electrified household with rooftop solar, battery and electrified appliances. $/Year.*

3.1.9.1 Household savings overview

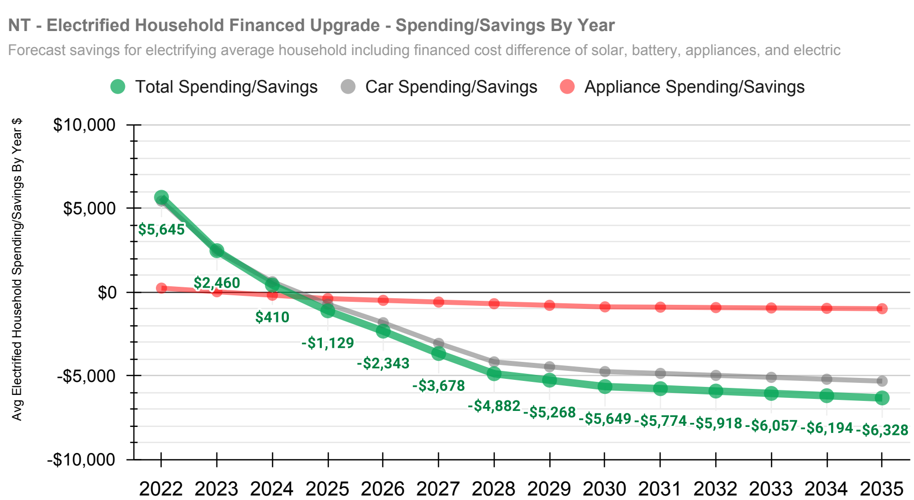


Figure 3.64: *Average household savings forecast by year for an electrified household with rooftop solar, battery, electrified appliances, and electric vehicles. $/Year.*

Household savings

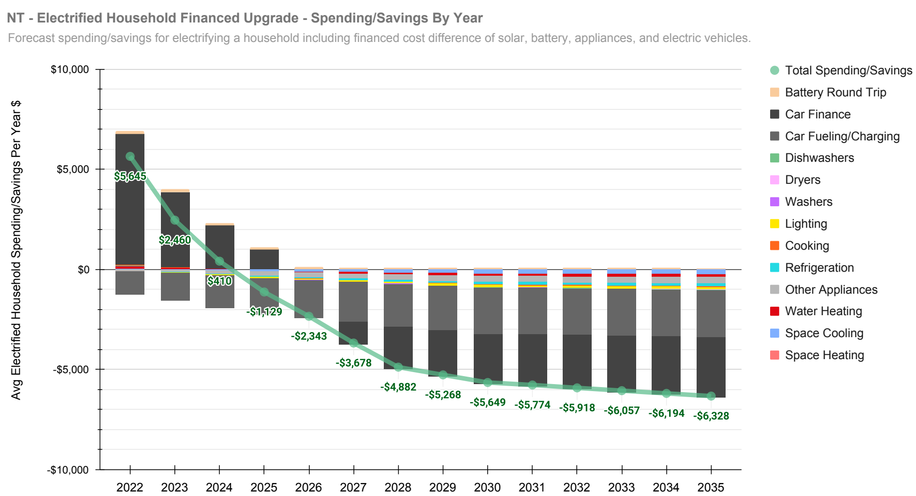


Figure 3.65: *Average household savings forecast by year for an electrified household with rooftop solar, battery, electrified appliances, and electric vehicles. $/Year.*

Household appliance savings

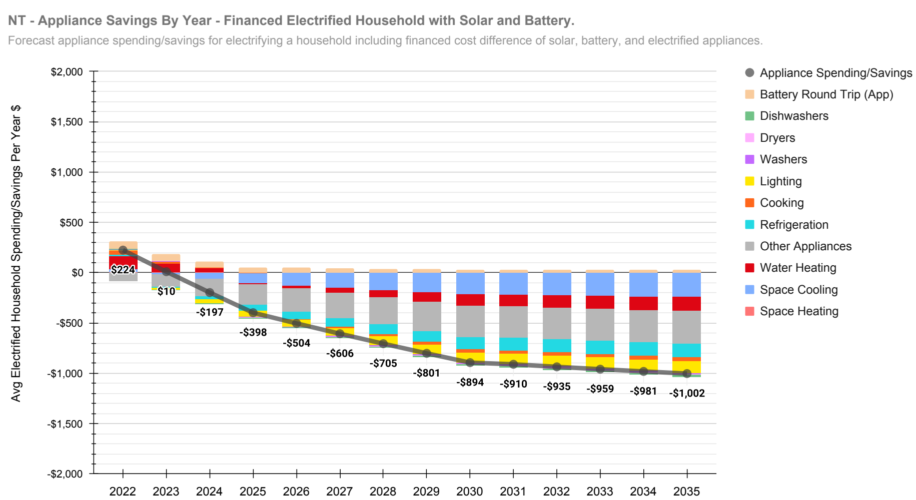


Figure 3.66: *Average household appliance savings forecast by year for an electrified household with rooftop solar, battery, and electrified appliances. $/Year.*

Household vehicle savings

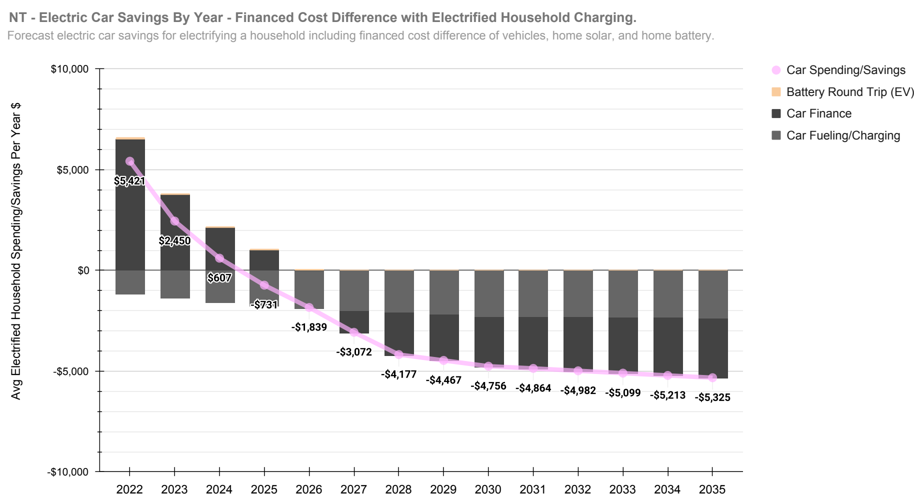


Figure 3.67: *Average household vehicle savings forecast for electric vehicle finance and use. $/Year.*

Chapter 4

Emissions

4.1 Australian emissions: Domestic, Exports, and Exported

We categorise Australia's emissions in a way that enables us to think about domestic economy decarbonization separately from export economy decarbonization in Figure 4.1. We separate out 3 categories: (1) the domestic emissions that support our domestic economy; (2) the emissions that count on Australia's emissions budget but are in fact emissions that are associated with creating our exports; and (3) the emissions associated with our fossil fuels being burned in other countries that do not count as Australian emissions under agreed international carbon accounting rules. This categorization is useful for a few reasons, principally that the stakeholders and decision makers are very different, also that the solution set and technological readiness are quite different. The majority of emissions in our domestic economy are a result of decisions and purchases made by our individual households and small businesses. It is a huge number of stakeholders and physically represents a very large number of small machines that are significant capital expenditures to the individual households. The emissions associated with creating our export economy have a smaller number of larger stakeholders, namely the government and corporations. These emissions come from a small number of high capital, large "machines" — things like smelters, freight rail systems, mining equipment, and export terminals.

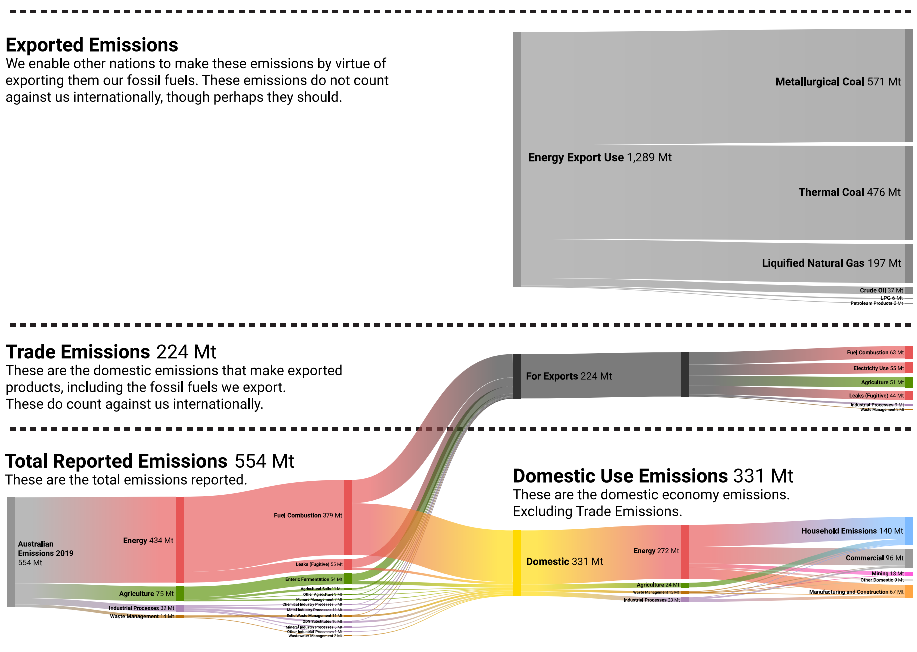


Figure 4.1: *Breakdown of all Australian emissions into 3 categories: (1) Exported emissions that do not count on Australia's emissions but in the country where they are burned; (2) Domestic emissions that support exports, the emissions associated with mining, processing, and transporting our exports that are used in other countries, which do count as Australian emissions; and (3) Domestic emissions that are emissions from the use of fuels in our domestic economy.*

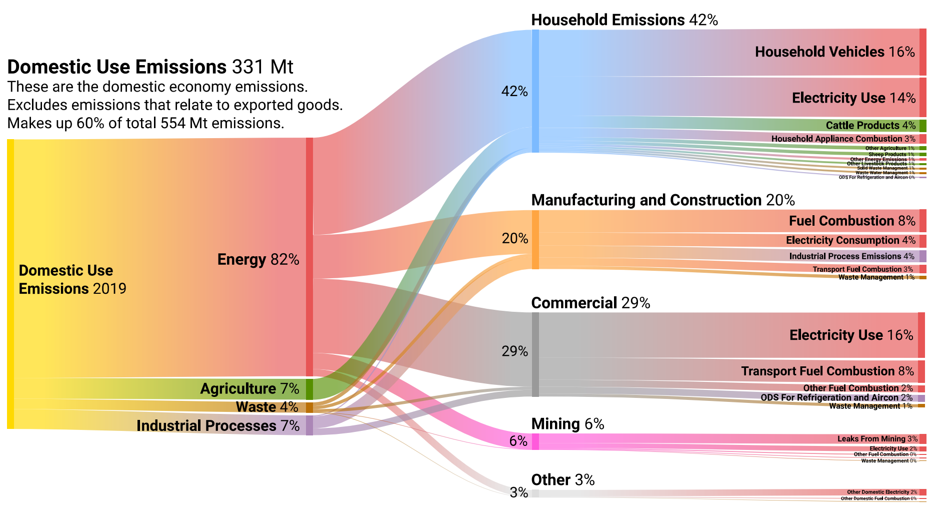


Figure 4.2: *A detailed breakdown of emissions in Australia's domestic economy.*

Chapter 5

Climate Urgency

5.1 We must act now

We must start dramatically increasing decarbonisation now — not ten years from now, or even a month from now. We have arrived at the last moment where we can shift global energy infrastructure without passing a 1.5° C/2.7° F – 2° C/3.6° F temperature rise. We still have the opportunity to address climate change in a way that will make the future better. In the household sector, there's no need to wait for new technologies - solar, batteries, electric vehicles, and efficient appliances can begin an accelerated roll out today at scale.

The 2016 Paris Agreement[1] commited signatories to avert climate crisis by keeping global temperature rise this century to 2° C/3.6° F above pre–industrial levels while pursuing efforts to limit the temperature increase even further, to 1.5° C/2.7° F . The targets 1.5° and 2° were political as much as they were technical, and in some respects chosen because they are round numbers. The choice to express climate change in Celsius has been a challenge — a narrative problem that persists in the U.S. where a few degrees Fahrenheit doesn't sound too bad.

Even with the emissions targets championed in these agreements, we have significant chances of not hitting the climate stabilization we would like. In 2018, the Intergovernmental Panel on Climate Change (IPCC), a United Nations group of scientists who summarized the worldwide findings on climate change, concluded that meeting the Paris target of 1.5° C/2.7° F would be possible, but would require "rapid, far–reaching and unprecedented changes in all aspects of society."

The report predicted that "we have 12 years." The report was issued in 2018 but we did not really do anything to improve the situation in 2019 and 2020, so now we have 10 years to halve human emissions by 2030 to stay on schedule. The

[1] *7. d Paris Agreement*. United Nations Treaty Collection, 12 December 2015.

IPCC warned that even a warming of 1.5° C/2.7° F — already an ambitious goal — would result in large–scale drought, famine, species die–off, the loss of entire ecosystems and the loss of habitable land, throwing more than 100 million people into poverty, particularly in the Middle East and Africa[2].

That is especially true because the IPCC report relied on humanity developing "negative emissions" technologies, such as carbon sequestration, to reach that goal. But at the moment, while those technologies would be nice, they don't yet exist on a workable scale, and there are strong arguments that they will never be cost effective[3]. We can't rely on fantasy technologies to reach our climate goal (or to argue that we can continue to burn fossil fuels because someday we may be able to suck the CO_2 out of the air). We must aim to hit 2° C/3.6° F with technology that works *today* — which we have, and will do the job, if we employ it right away.

If we exceed our emissions targets, we will face irreversible tipping points in climate change where we won't be able to stabilize the climate at all. As Timothy Lenton and his colleagues highlight in their recent paper, the more we learn, the more that the tipping points look sooner and more drastic.[4] Given what we know about climate feedback and sensitivities, such as more rapidly melting glaciers, the effects of deforestation of the Amazon, methane emissions from Arctic tundra, and carbon releases from fires, we are already precariously close to such a tipping point. Some scientists argue that we've already lost Greenland's ice sheet[5]. Every year we wait — whether hoping for a political revolution or a technological miracle — has dire consequences to the timeline and the health of our planet. This climate response emergency is expressed best in the analysis and charts of Zeke Hausfather[6] and Robbie Andrew[7] which we redraw in Figure 5.1.

Here we present a breakdown of what this chart shows. If we had started this grand project in the year 2000, we could have hit our 1.5° C/2.7° F target by reducing emissions at the rate of 4% per year. If we started in 2020, we have to reduce at a phenomenal rate — something like 10% per year. If we wait four more years, we use up half the remaining carbon budget. Eight years, and it's gone completely. We simply must start yesterday, or as Saul's friend Jonathan Koomey says we should think about it, we must "halve emissions every decade." We think we should do even better[8]).

[2] *Global Warming of 1.5 °C*. Intergovernmental Panel on Climate change. Retrieved 7 October 2018.

[3] https://doi.org/10.1073/pnas.1012253108

[4] https://www.nature.com/articles/d41586-019-03595-0

[5] *Dynamic ice loss from the Greenland Ice Sheet driven by sustained glacier retreat*. King et. al.,

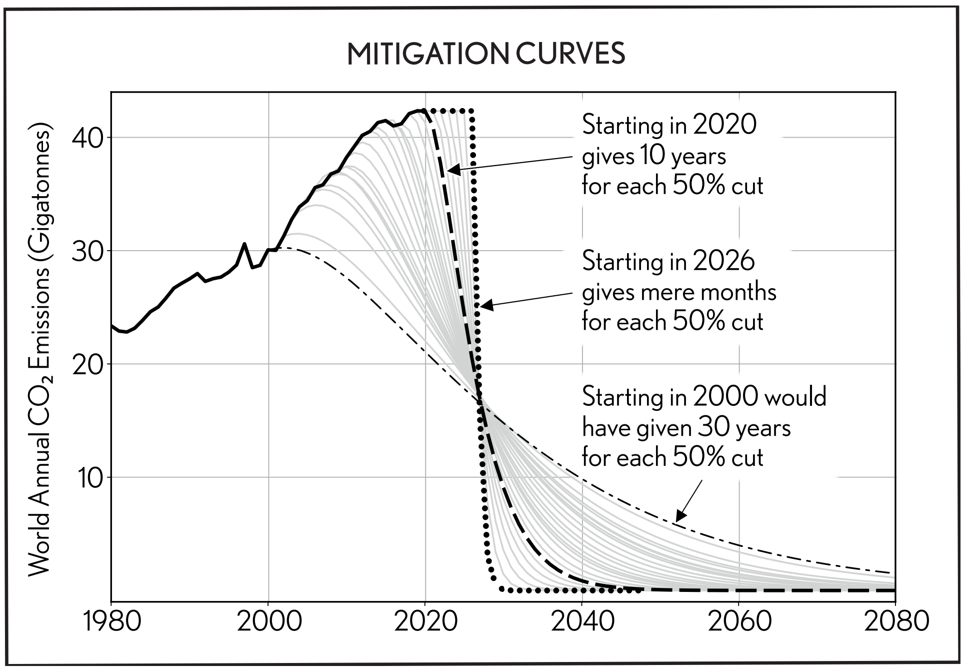


Figure 5.1: *Mitigation curves required to hit a 1.5° C/2.7° F world, redrawn from Robbie Andrew's data. As we can see we have NO time left to begin before any chance of the climate targets we need to hit will slip beyond our reach.*

Committed emissions

The notion that we have ten years also fails to recognize "committed emissions," those that are locked in because we have already invested in a piece of infrastructure that will emit carbon dioxide throughout its useful life. An example is the car sitting in your driveway that burns gasoline but is too new to trade in for an electric vehicle.

Fossil–fueled power plants built today will emit CO_2 for 50 years or more unless we shut them down. A gasoline–powered car or gas furnace purchased yesterday will probably discharge CO_2 for 20 more years. These committed emissions[9] already take us past 1.5° C/2.7° F of warming and closer to the edge of 2° C/3.6° F . That should sober us up, because it means that even if we made perfect climate decisions on every purchase from now on we will shoot past our 1.5° C/2.7° F target.

Let's reflect on what we have just learned for a moment: We have left this fight so late in the game that now every time we retire a fossil fuel–burning machine, it must be replaced with a decarbonized machine. Everything that uses energy, by everyone, everywhere, whether an individual, a power company, or a corporation, must be a decarbonized solution. In theory this calculus would change a little if you retired the heaviest-emitting coal plants before their end of life, but it does not substantively change the fact that we need to eliminate ALL fossil fuel burning machines as soon as possible.

We need a 100% adoption rate

This scenario of replacing everything that uses energy with a zero–carbon solution when it's retired is called a 100% adoption rate. Today when a car reaches retirement age, there is only a small chance the replacement will be electric. If one in ten people buy an EV, then we say the adoption rate is 10%. Because machines like your car have long lifetimes, we can't afford those slow adoption rates anymore. We need everyone buying electrical vehicles. We need everyone purchasing a power plant to choose solar instead of natural gas and wind instead of coal. Fortu-

Commun Earth Environ 1, 1 (2020).

[6] *UNEP: 1.5°C climate target 'slipping out of reach'*. Zeke Hausfather. Carbon Brief. 2019.

[7] *It's getting harder and harder to limit ourselves to 2°C*. Robbie Andrew. 2020

[8] *A roadmap for rapid decarbonization.* Rockström, Johan, Owen Gaffney, Joeri Rogelj, Malte Meinshausen, Nebojsa Nakicenovic, and Hans Joachim Schellnhuber. 2017. Science. vol. 355, no. 6331. pp. 1269.

[9] *Committed emissions from existing energy infrastructure jeopardize 1.5°climate target*. Tong, D., Zhang, Q., Zheng, Y. et al. Nature 572, 373–377 (2019).

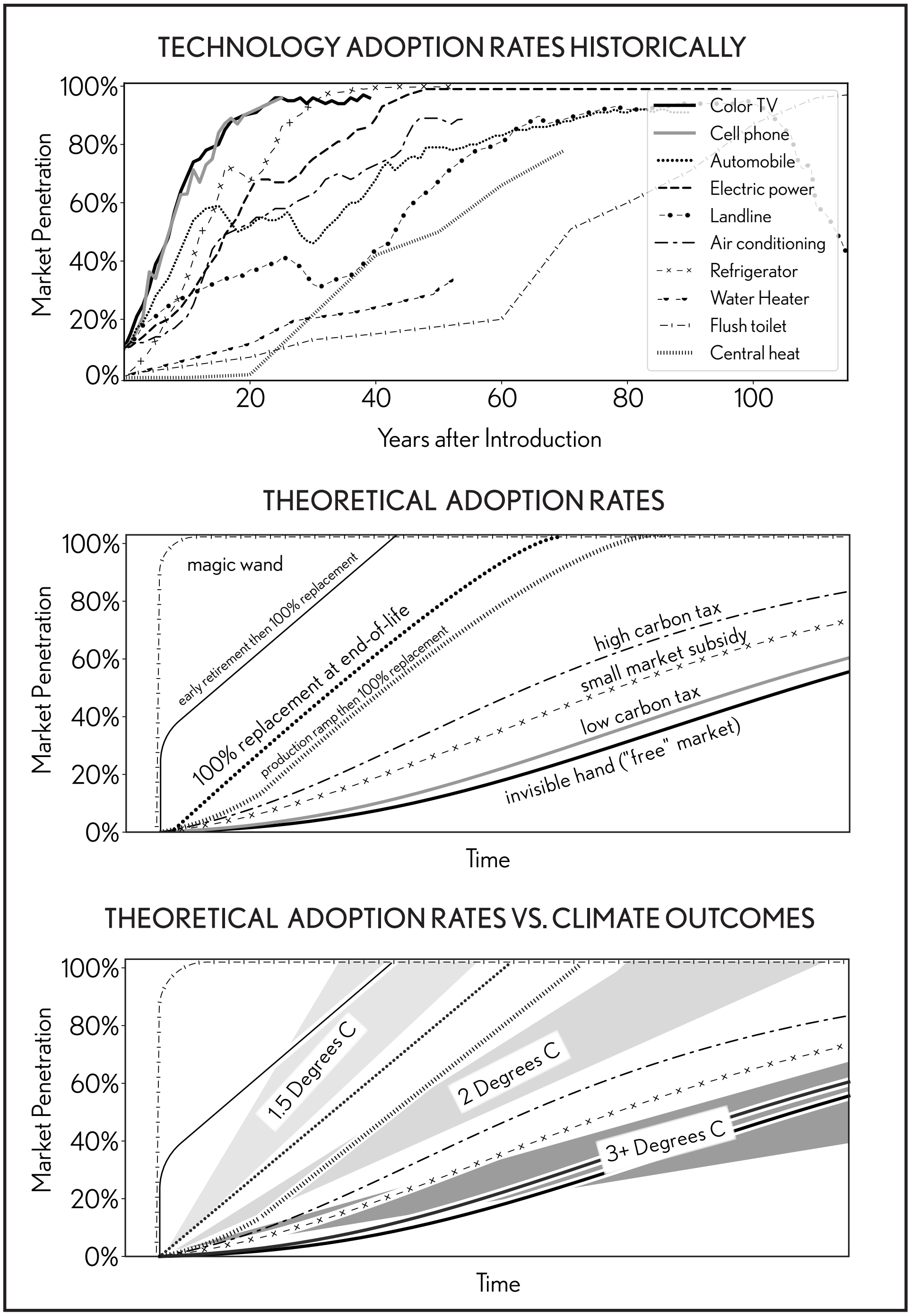


Figure 5.2: *a) Historical adoption curves of ubiquitous technologies, b) Adoption curves of different market mechanisms ranging from the slowest, free market adoption to the fastest, overnight mandated replacement of current infrastructure, c) The adoption rate we achieve will determine out climate fate. To hit a target of 1.5° C/2.7° F to 2° C/3.6° F now requires near perfect execution of the most rapid adoption possible.*

nately, we are further along with this project than you might expect. In 2018, 66% of new power plants globally were renewables or carbon free! [10]. This is good, but not quite enough — across the board we now need adoption rates of 100%. This perfect execution level of adoption rate is what we mean when we say we are now playing end–game decarbonization.

While that sounds dramatic, it doesn't mean you have to run out to buy a new EV today. It means that the next time you need to retire a machine, it should be replaced with a solution that doesn't emit CO_2 . When your car finally dies, you have to replace it with an electric one. *Consumer Reports* says the average life expectancy of a new car is 8 years and 250,000km of travel. The same logic applies to your water heater, your room heaters, your stove, and your roof.

Water heaters last 10 years. Refrigerators, 12; clothes dryers, 13; rooftops, 15; air-conditioning, 18; cars and trucks, 20; thermostats, 35; power plants, 50[11]. No matter how effectively we may sway the market to buy green technology, we are unlikely to decarbonize faster than the curve dictated by the natural replacement lifetime of existing machines. That's why we'll need incentives such as buy–back programs and subsidies to swap out fossil fuel–burning machines for electric ones as soon as possible.

We can buy ourselves a little extra time if we shut down the most polluting infrastructure before it ends its natural life. This is why people advocate for early retirement of fossil fuel power plants, particularly those that burn coal. But consumers, utilities, and other organizations will require extreme motivation to retire their fossil–dependent infrastructure early because of their sunk costs. You aren't going to give up your gasoline–burning car unless there are enough incentives out there to make it easy for you to replace it with a new electric vehicle.

A 100% adoption rate is only achieved by mandate. It more typically takes decades for a new technology to become dominant by market forces alone as it slowly increases its market share each year. Electric cars still only represented 2% of sales of U.S. vehicles in 2018, though 5% in California in 2019 — 15 years after Tesla was founded and 20 years after GM shut down the production of its first electric car, the EV1. We need electric or emissions—free vehicles to be 100% of vehicle sales as soon as is physically, and industrially, possible.

The challenge of 100% adoption presents a giant conflict that we need to address right up front: the "free market" as we know it is not up to the task of keeping us below 2° C/3.6° F and has absolutely no chance of 1.5° C/2.7° F . It may sound like this is a giant screed for government intervention; it is not! This is merely

[10] https://sdg.iisd.org/news/in-2018-66-of-new-electricity-generation-capacity-was-renewab

[11] https://www.interstatebrick.com/sites/default/files/library/nahb20study20of20life20expectancy20of20home20components.pdf

stating what is technically necessary. If your toilet was broken and you called your friend and asked them what to do, they wouldn't tell you "the free market will fix that," they'd tell you to call a plumber. That is where we're at on climate change: no amount of hope in free market solutions can change the fact that it is now too late to rely on the free market to act fast enough. We need to call the plumbers (and electricians, and engineers, and manufacturers) to fix our infrastructure now.

This is not to say that businesses and the market don't have roles; they are critical. But in emergencies, ideologies must be put aside. When Mother Nature arm–wrestles with the invisible hand, she will always win. As Saul's friend and economist Skip Laitner says, the free market needs an invisible foot to give it a swift kick in the ass now and then. The conclusion of this urgency is that we need every player to act and do their bit. Individuals, governments, businesses and the market — we need every tool in the box, and we need them working together.

Chapter 6

Methodology

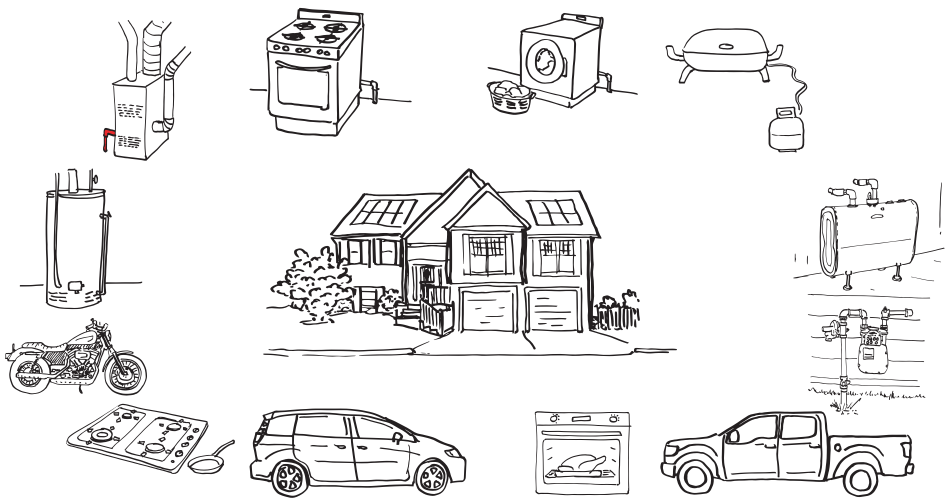
We constrain this study to using technologies that (1) we know can work; (2) already exist at significant scale; (3) are cost–effective somewhere in the world; and (4) can be scaled up to the level required for residential decarbonization. As the final lever to see whether this is possible, we investigate the interest rates and financing methods to make it work economically.[1]

We focus on Australia's households. We do this because it makes climate policy and possibility *personal*, and because the energy (and carbon) expenditures of the household are close to half (42%) of Australia's domestic emissions. We do not calculate the savings for the commercial sector which is our small businesses and commerce sector, which have similar loads (building heating and cooking, vehicles) as our residential sector, but we anticipate similar results. The commercial sector is around 30% of our domestic emissions, so combined these two sectors are approximately 70% of our domestic emissions.

6.1 A note on the average Australian household.

We model the mythical "average" Australian household. Of course every house is different and, as they say "your mileage may vary." This leads to difficulties in the final analysis as the "average" house ends up having a small percentage of a wood fireplace, some electric heating, and some natural gas heaters. The economic outcome collectively is high confidence, but individual households would need to do individual analysis to see where they are on the electrification journey.

[1] This is in the tradition of 1974's *Project Independence*, a collaboration between a nascent DOE and the Federal Reserve to explore whether America could afford to solve the energy crises of that era.



6.2 Summary of methodology, step-by-step

- We use existing data to estimate total current household energy use, by state, in section 6.3.
- We use current energy pricing data by state to estimate household energy costs in section 6.4.
- In section 6.5 we model energy savings through electrification by converting all energy loads (gas, petrol, etc) to electricity using common performance numbers for electrical versus fossil machinery.
- In section 6.6 we look at upgrade capital costs for all associated household machinery.
- We provide forecasts of efficiency in section 6.7.
- We combine the energy savings and efficiency and cost forecasts into a total household cost of energy and vehicles and compare it to existing costs in section 6.8.
- Only the relative difference between today's costs of household items and future costs of household items is accounted for in order to hold all other aspects of household economics constant.
- We localize the forecast analysis state by state and cumulatively for Australia in section 6.9

- We run the model with different input assumptions around our price forecasts to give us a sense of the sensitivity of the model to various inputs.
- We calculate national, and state-level annual and cumulative savings by ALL households.
- In section 6.10 we break down Australia's emissions by domestic use, exports, and sectors.

6.3 Today's household energy use by state and territory.

We begin with estimating current energy use for an "average" household in each state. This uses the Residential Baseline Study[2] (RBS) data for home energy use and Australian Bureau of Statistics (ABS) Survey of Motor Vehicle Use[3] data for vehicle energy use.

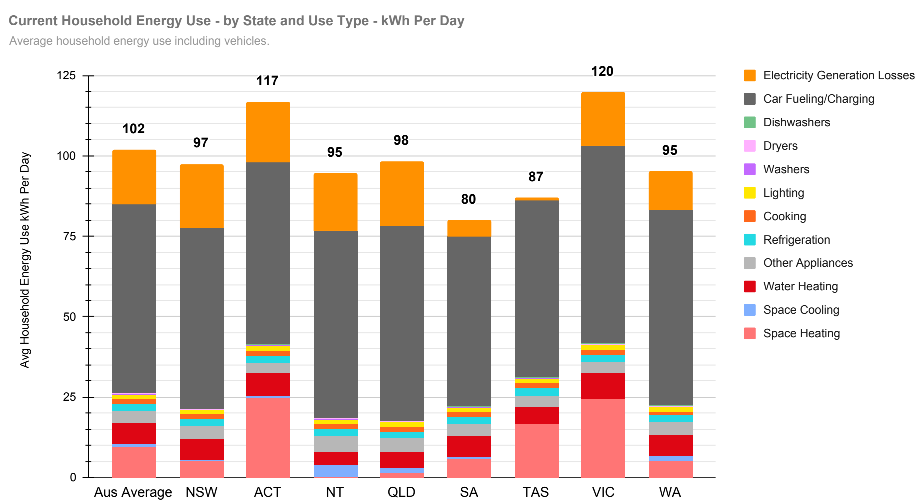


Figure 6.1: *Today's average household energy use for each state, broken down by appliance and vehicles.*

[2] https://www.energyrating.gov.au/document/2015-data-tables-residential-baseline-study-au E2%80%93-2030

[3] https://www.abs.gov.au/statistics/industry/tourism-and-transport/survey-motor-vehicle-use-australia/12-months-ended-30-june-2018#data-download

6.3.1 Average home appliance energy use

We use 2019 data from the RBS for appliance energy consumption. This provides data on many individual appliances, and most appliance data used comes directly from the RBS, however some data is broken down further, specifically, AC Heating and Cooling, and Cooking Devices, as detailed below.

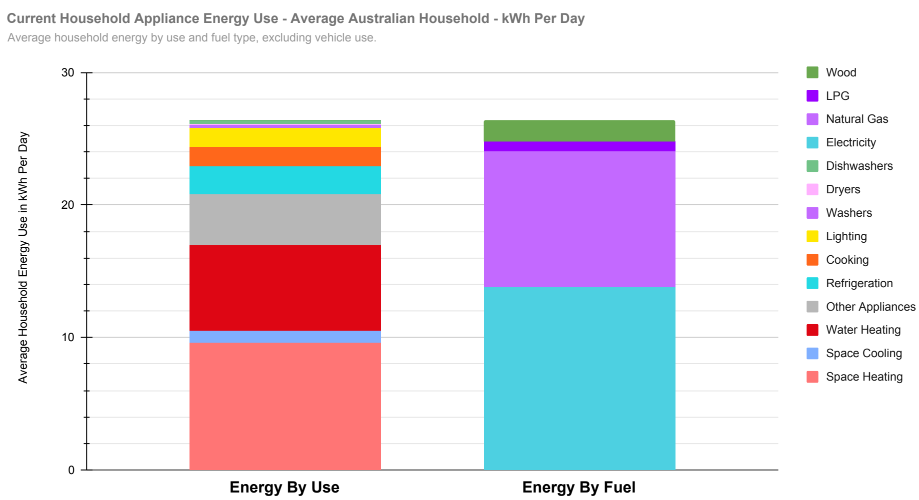


Figure 6.2: *Today's average Australian household appliance energy, broken down by use and fuel type.*

6.3.1.1 AC heating and cooling

While the RBS provides an energy use breakdown for heating-specific and cooling-specific devices, it does not provide a heating/cooling breakdown for Air Conditioning (AC). To get this breakdown we use a ratio derived from the approximate heating and cooling days in each state, based upon various area population densities and how they map onto the heating and cooling days mapped from a Bureau of Meteorology (BOM) 30 year data set[4].

The heating and cooling ratios created from this are used to split the AC energy use into heating and cooling related use. The ratios used for air conditioning are shown in Table 6.1

[4] http://www.bom.gov.au/jsp/ncc/climate_averages/degree-days/index.jsp?maptype=3&period=an&product=cdd18#maps

STATE	Heating (%)	Cooling (%)
NSW	66%	34%
ACT	86%	14%
NT	3%	97%
QLD	38%	62%
SA	77%	23%
TAS	98%	2%
VIC	95%	5%
WA	43%	57%

Table 6.1: *Ratio of heating to cooling energy consumption by state.*

6.3.1.2 Cooking fuel type by device

The RBS data provides the total Electricity, Natural Gas, and LPG used by cooking appliances, and the total energy split between cooktops, ovens, uprights, and microwaves; however it does not provide the ratio of devices by each fuel type. This is necessary for our model to calculate approximately how many devices need to be replaced (e.g. Natural Gas cooktops replaced with electric cooktops). We estimate these devices using the total energy of each fuel, and the average efficiency values for each device type. This enables us to estimate how many of each device there are, and how much of each fuel is used by each cooking category (for example, natural gas ovens compared to electric ovens, alongside natural gas cooktops compared to electric cooktops). To do this estimation, we use the efficiency by device type shown in Table 6.2

The average total cooking efficiency value changes by state, it is a weighted average based on the efficiency values in Table 6.2 and the amount of energy used by each device type in the state (from RBS).

We combine the cooking energy use percentages for each type of fuel (Electricity, Natural Gas, and LPG) from RBS data, with the device efficiencies mentioned to create a percentage of total devices for each fuel type and device type. For example, the % of electric devices is estimated from the equation:

$$(\%ofelectricenergyuse*(\%electriccookingefficiency/\%averagecookingefficiency)). \tag{6.1}$$

In NSW for example, 37.2% of cooking energy use is electric (excluding microwaves), 30.6% is Natural Gas, 14.4% is LPG, and 17.6% is microwave energy use.

If we use NSW electric cooking devices as an example, the percentage of elec-

Cooking Appliance	**Efficiency (%)**
Electric Oven	95.0%
Natural Gas Oven	90.0%
LPG Oven	90.0%
Natural Gas Cooktop	30.4%
LPG Cooktop	30.4%
Electric Resistive Cooktop	71.1%
Electric Induction Cooktop	78.5%
Electric Upright (Uses 50/50)	83.0%
Natural Gas Upright (Uses 50/50)	60.2%
LPG Upright (Uses 50/50)	60.2%
Average Electric Cooking Efficiency (Excl Microwaves)	83.0%
Average NG Cooking Efficiency	60.2%
Average LPG Cooking Efficiency	60.2%
Microwave Cooking Efficiency	65.0%
Average Total Cooking Efficiency (Aus Avg, changes by state)	**69.57%**

Table 6.2: *Efficiency of selected cooking machinery.*

tric cooking appliances is calculated with:

$$(37.6\% * (83.00\%/69.57\%) = 44.45\%) \tag{6.2}$$

We then use the amount of devices provided by RBS data, and multiply it by the percentage of devices in that fuel type. For example in NSW, with 0.5 ovens per household (of all fuel types), we then use the electric cooking devices value above (44.45%) to determine the amount of electric ovens. Because we already have the amount of microwaves, we exclude microwaves from this to create a new % of electric ovens value (in this case 53%). The formula used to determine the number of electric ovens per household).

$$(0.5 * (44.45\%/sum(44.45\%, 26.56\%, 12.50\%))) = 0.27 \tag{6.3}$$

6.3.2 Average home vehicle energy use

For vehicle energy use we use the 2018 ABS Survey of Motor Vehicle Use[5]. We also compare this data to the 2020 survey, but use 2018 data to avoid any vehicle use anomalies created by the COVID-19 pandemic.

As not all passenger and light commercial vehicles (utes, vans etc.) in the country are for personal use, we use a ratio to estimate the amount of cars to be included in households. Because electric vehicles are often charged at home, we cannot use a simple business to personal use ratio. The 2 most popular cars in Australia in 2021 are both utes (Toyota Hilux and Ford Ranger, respectively). These vehicles will often be owned by tradespeople and used for business purposes alongside personal use, and ultimately be parked at home. This is an important consideration for the purpose of home electricity consumption and charging.

To assign a ratio of vehicles to households, we use the estimated ratios in Table 6.3 for vehicles that will be parked and charged at home.

Vehicle type	(%) Fleet owned by households
Passenger Vehicles	90%
LCV - Utes, Vans etc	75%
Motorcycles	90%

Table 6.3: *Household ownership of Australian vehicle stock.*

6.3.3 Electricity generation losses

Electricity generation losses are derived from the types of electricity generation in each state from Australian Energy Statistics, Table O Electricity generation by fuel type 2018-19 and 2019[6] and by the assumed generation efficiencies in Table 6.4.

[5] https://www.abs.gov.au/statistics/industry/tourism-and-transport/survey-motor-vehicle-use-australia/12-months-ended-30-june-2018#data-download

[6] https://www.energy.gov.au/publications/australian-energy-statistics-table-o-electricity

Generation Fuel Type	Thermoelectric Efficiency (%)
Black Coal	37%
Brown Coal	33%
Gas	56%
Oil	37%
Biofuel	33%
Wind	100%
Solar	100%
Hydro	100%
Geothermal	100%

Table 6.4: *Generation fleet efficiency.*

6.4 Current energy costs

We use current or recent energy prices in each state to calculate the total current household energy costs. Electricity pricing comes from the Australian Energy Market Commission Residential Electricity Price Trends 2019-20[7] for NSW, ACT, VIC, QLD, SA, and TAS. NT electricity pricing comes from Utilities Commission NT[8]. WA electricity pricing comes from WA Gov Household Electricity Pricing[9]. Natural Gas pricing comes from Energy.gov.au Gas Price Trends 2017[10], with an adjustment based on the ABS Consumer Price Index[11] to adjust prices to 2018-19. LPG Pricing comes from Global Petrol Prices Australia LPG Prices[12] and an average of $0.893 is used for all states. Petrol and diesel pricing comes from the Australian Institute of Petroleum Annual Price Data[13]. Wood pricing is an estimate from state based online retail pricing. A summary of energy pricing used for the base year (2021) is shown in Table 6.5.

[7] https://www.aemc.gov.au/news-centre/data-portal/price-trends-2020

[8] https://utilicom.nt.gov.au/electricity/price-regulation/electricity-retail-pricing

[9] https://www.wa.gov.au/organisation/energy-policy-wa/household-electricity-pricing

[10] https://www.energy.gov.au/sites/default/files/gas_price_trends_review_2017.pdf

[11] https://www.abs.gov.au/statistics/economy/price-indexes-and-inflation/consumer-price-index-australia/jun-2021#data-download

[12] https://www.globalpetrolprices.com/Australia/lpg_prices/

[13] https://aip.com.au/index.php/aip-annual-retail-price-data

Energy $/kWh	Australia	NSW	ACT	NT	QLD	SA	TAS	VIC	WA
Electricity	$0.29	$0.31	$0.28	$0.29	$0.25	$0.38	$0.25	$0.29	$0.29
Natural Gas	$0.15	$0.14	$0.14	$0.19	$0.24	$0.18	$0.16	$0.09	$0.15
LPG	$0.13	$0.13	$0.13	$0.13	$0.13	$0.13	$0.13	$0.13	$0.13
Wood	$0.07	$0.09	$0.06	$0.05	$0.06	$0.06	$0.04	$0.07	$0.05
Petrol	$0.15	$0.15	$0.15	$0.16	$0.15	$0.15	$0.16	$0.15	$0.149
Diesel	$0.14	$0.14	$0.14	$0.15	$0.14	$0.14	$0.15	$0.14	$0.14

Table 6.5: *Energy pricing used by state in $/kWh*

The annual household energy spend is compared to the Household Energy Consumption Survey (HECS)[14], to the Household Expenditure Survey (HES)[15], and to annual energy statistics data. We use an average new car price of $40,000AUD[16].

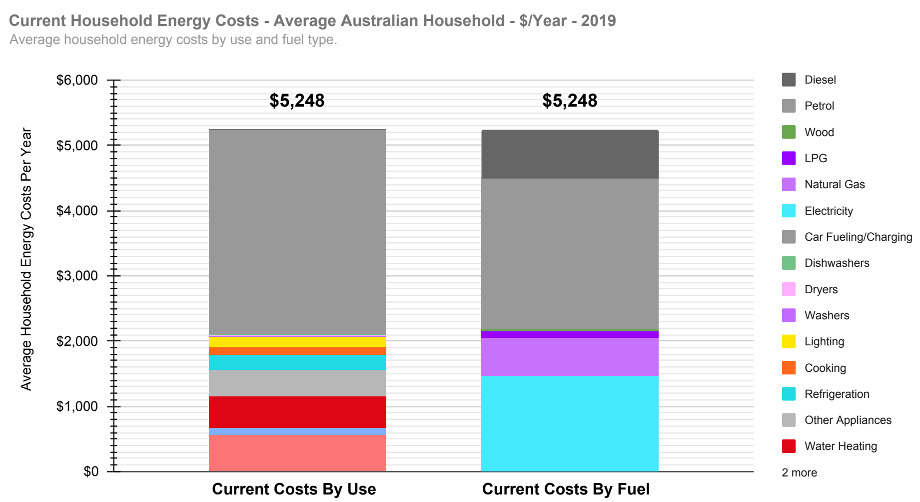


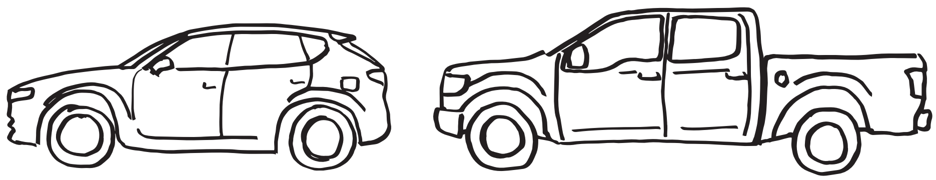
Figure 6.3: *Today's average Australian household energy costs, broken down by use and fuel type.*

6.5 Energy savings through electrification

We determine future electrified energy use by converting the existing loads to wholly electrical loads.

[14] https://www.abs.gov.au/ausstats/abs@.nsf/mf/4670.0
[15] https://www.abs.gov.au/statistics/economy/finance/household-expenditure-survey-australia-summary-results/2015-16
[16] https://www.canstarblue.com.au/vehicles/average-car-price/

6.5.1 Vehicle fuel use



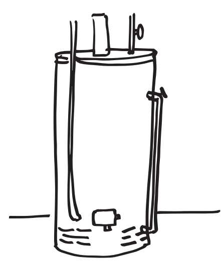
Vehicle fuel use is converted to electricity with the values shown in Table 6.6.

Fuel Type	Energy content (MJ/L)
Petrol	34.2
Diesel	38.6
LPG	25.7

Table 6.6: *Fuel type and energy content in MJ/L.*

We assume a charging efficiency of 90% for electric vehicles.

6.5.2 Water heating



We convert water heating to electricity with an electric heat pump assuming an air source heat pump and a state by state COP determined by climate comparison to an existing US data set. These COP values are listed in Table 6.7.

State	COP
NSW	3.6
ACT	3.6
NT	4.1
QLD	3.9
SA	4.3
TAS	3.2
VIC	3.4
WA	4.7
AUS	3.78 (weighted average by households per state)

Table 6.7: *Air source heat pump COP used by state.*

To convert existing water heating loads (natural gas, LPG, electric resistive, and wood) to electrified heat pump water heating loads, we use the efficiency values shown in Table 6.8.

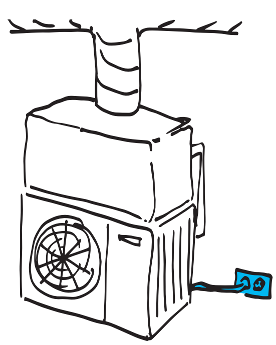
Fuel Type	Efficiency(%)
Electric Water Heating	95%
Natural Gas Water Heating	90%
LPG Water Heating	90%
Wood Water Heating	75%

Table 6.8: *Assumed efficiency of water heaters.*

For example, for Natural Gas water heaters the equation used to convert this to heat pump water heaters is:

$$(NaturalGasWaterHeatingEnergy/0.75)/3.78 \tag{6.4}$$

6.5.3 Space heating



We convert space heating to electricity with the same COP values as water heating because the space heating in the electrified model is heat pump space heating.

We convert current space heating to electricity using the efficiency values in Table 6.9.

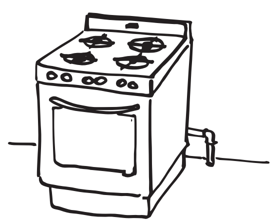
Heating Type	Efficiency(%)
Electric Resistance Heating	95%
Natural Gas Heating	90%
LPG Heating	90%
Wood Fire Heating	75%

Table 6.9: *Assumed efficiency of space heaters.*

For example, we convert electric resistive heating to heat pump heating with this equation:

$$(ElectricResistiveHeatingEnergy/0.95)/3.78 \tag{6.5}$$

6.5.4 Cooking appliances



We convert natural gas and LPG cooking to electricity with the ratios in Table 6.10.

Cooking Type	Efficiency(%)
Cooktops	
Electric Resistive	71.1%
Natural Gas	30.4%
LPG	30.4%
Ovens	
Electric Resistive	95%
Natural Gas	90%
LPG	90%
Uprights	
Electric Resistive	60.2%
Natural Gas	83.0%
LPG	83.0%
Microwaves	65%

Table 6.10: *Assumed efficiency of cooking appliances. Note: uprights use an average of cooktop and oven efficiencies.*

For example, we convert Natural Gas stovetop cooking to electric stovetop cooking with this equation:

$$NaturalGasStovetopEnergy * (30.4\%/71.1\%) \tag{6.6}$$

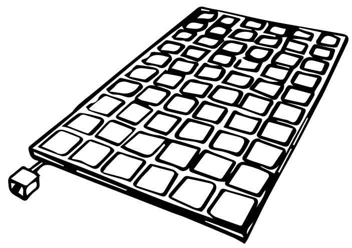
6.5.5 Clothes dryers

We do not convert clothes dryers to heat pump dryers.

6.6 Current cost savings through electrification

As shown above, electrification significantly reduces the amount of energy consumed by the average household. For some appliances, this alone produces a reduction in running costs at existing grid electricity prices. However, some of the largest savings come from switching a significant portion of a households electricity use to rooftop solar and residential battery storage. These items, along with any new appliance replacements, come with a capital cost we must consider in the model.

6.6.1 Rooftop solar costs



We use current (September 2021) retail Australian solar prices provided by Solar Choice[17]. The larger system size prices (6kW, 7kW, 10kW) are then averaged to create a per kW price. Only the larger systems are used because the systems we are modelling will be providing a significant portion of the households energy and therefore be large.

We determine the size of the solar install required by the household energy requirement and the average yearly solar capacity factor in the state that the household is in, and in the case of the average Australian home, we use the weighted average of all states (weighted by household numbers).

The capacity factor is derived from monthly installed solar capacity and output from the Australian PV Institute[18] between April 2015 and March 2021. The average capacity factor for 2021 is estimated by creating an average year–on–year capacity factor increase, which is then applied to the 2020 yearly average from the data. This year–on–year capacity factor increase (3.37%) was derived from a weighted average of all states (weighted by households in each state). This average yearly capacity factor increase was then compared to USA capacity factor increase data which turned out to be close to the average increase derived from the Australian data, as expected.

We then create a financed cost/kWh price for solar electricity in each state. This is based on a 25–year lifetime of the solar install, with 0.5% degradation per year and an inverter efficiency of 85%.

The solar install financing rate is 4% over a term of 25 years (the lifetime of the solar install). Finance rates are further detailed in the Finance Details section.

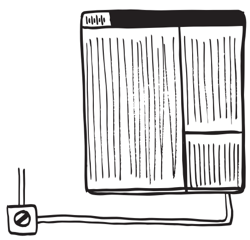
The final base solar price/kWh used for each state is shown in Table 6.11.

[17] https://www.solarchoice.net.au/blog/solar-power-system-prices
[18] https://pv-map.apvi.org.au/postcode

State	Financed Solar Price $/kWh
NSW	$0.06
ACT	$0.06
NT	$0.07
QLD	$0.06
SA	$0.06
TAS	$0.08
VIC	$0.06
WA	$0.06
AUS	000 (weighted average)

Table 6.11: *Solar price per kWh used in the starting year (2021).*

6.6.2 Home battery costs



We use an average of current (August 2021) home battery pricing from Solar Choice[19] to create an average cost/kWh.

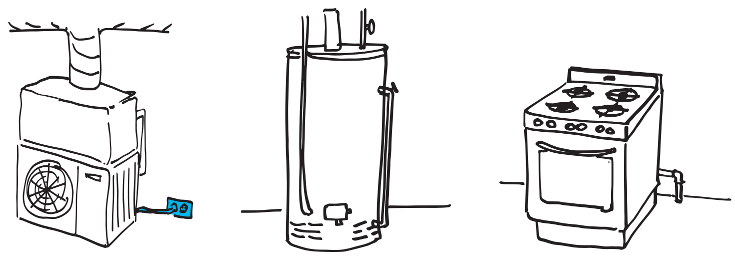
We then create a cost/kWh that includes degradation. We assume 70% battery retention after 10 years (for example, this is what the Tesla Powerwall 2 is warrantied for[20]). The battery price/kWh is multiplied by 1/0.7 to get the battery size required with degradation taken into account. This produces a higher price/kWh with degradation included.

We assume a battery round trip efficiency of 90% which is accounted for in energy use as a separate appliance.

[19]https://www.solarchoice.net.au/blog/battery-storage-price

[20]https://www.tesla.com/sites/default/files/pdfs/powerwall/Powerwall_2_AC_Warranty_AUS-NZ_1-0.pdf

6.6.3 Appliance replacement costs



We use current (August 2021) end-consumer retail appliance pricing and install costs sourced from multiple online retailers. We select a range of appliances and use the average cost of the appliance and install.

The price used for household cost and savings calculations is the difference in cost between replacing an appliance with a similar conventional appliance, and replacing it with an efficient electrified appliance.

The difference in cost is the sum remaining after subtracting the cost of a similar non-electrified replacement from the cost of an electrified replacement. For example, if a home were to replace a natural gas water heater with another similar natural gas water heater, the sum remaining is 0. If a home were to replace a natural gas water heater with a heat pump water heater, the sum remaining would be the price of the heat pump option minus the price of the natural gas option. This is the cost we finance in the model, i.e. the difference in cost of choosing the efficient electrified option. Finance rates used are shown in the Finance details section.

We do not model negative replacement costs for appliances. For example, if the cost to replace a natural gas cooktop with an electric cooktop is less, the price difference we use is 0, not the negative amount.

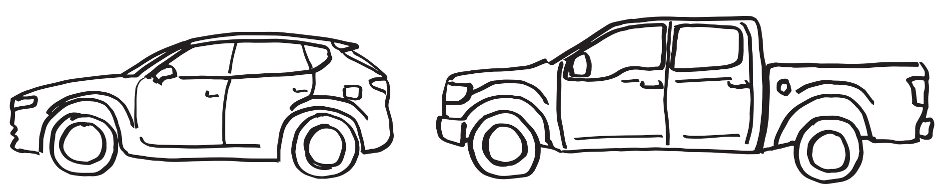
We assume an equal or lower cost of replacement for Natural Gas pool heaters being replaced with electric heat pump pool heaters.

The final average appliance pricing used is shown in Table 6.12.

Appliance	Installed Price $AUD
AC Heat Pumps - Large (7kW/8kW)	$2,274
AC Heat Pumps - Small (2.5kW/3.2kW)	$1,272
Resistive Heaters (2.4kW)	$137.80
Gas Space Heaters	$1,358
LPG Space Heaters	$1,395
Wood Fire Install	$2,827
Water Heater Heat Pumps	$3,333
Electric Water Heater - Med/Large	$1,550
Electric Water Heater - Small	$1,244
Natural Gas Instant Water Heater	$1,303
Natural Gas Storage Water Heater	$1,612
LPG Instant Water Heater	$1,303
LPG Storage Water Heater	$1,612
Electric Resistive Cooktop	$590
Natural Gas Cooktop	$762
LPG Cooktop	$749
Electric Oven	$787
Natural Gas Oven	$1,629
Electric Upright	$882
Natural Gas Upright	$1,272
LPG Upright	$1,075

Table 6.12: *Average appliance pricing used in the model in the base year (2021).*

6.6.4 Electric vehicle costs



For electric vehicle costs we use a multiplier based on the Bloomberg NEF electric vehicle parity estimate for the SUV-C segment (mid-size SUV, e.g. Toyota RAV4) from the report Hitting the EV Inflection Point for Transport & Environment, published May 2021[21].

The electric vehicle cost multiplier is 170% in 2021. Future cost multipliers are shown in subsection 6.8.5.

We use an average new car price of $40,000 for current internal combustion engine (ICE) vehicles. We use the financed difference in price between ICE vehicles and Electric Vehicles (EVs) as the difference cost in the model for vehicles. We then multiply the cost difference per vehicle by the average number of vehicles in each household.

We include an average current cost of one Type 2 home charger for electric vehicles per household, based on multiple current online retail chargers available in Australia. The average price used here is a total of $2,118 with the charger being $1,223 and the install being $895. For future forecasting, the same cost reduction curve is used on these chargers as is used on the electric vehicles.

We do not model the lower ongoing maintenance costs of electric vehicles.

We include the small amount of motorcycles as part of the overall vehicle count for the household.

For example, the average Australian household equation for electric vehicles is shown below:

$$VehiclesPerHousehold * ((\$40,000 * 170\%) - \$40,000) + \$2,118 \quad (6.7)$$

6.6.5 Finance details

For capital costs in the model, we use a financed cost over the approximate warrantied lifetime of the item. For example 25 years for rooftop solar, 10 years for water heaters, and 7 years for electric vehicles.

The financed cost used in the savings and costs calculations is the full cost of rooftop solar and home batteries, and the difference in cost for appliances and electric vehicles. The difference in cost is the sum remaining after subtracting the cost of a similar non-electrified replacement, from the cost of an electrified replacement. For example, if a home were to replace a natural gas water heater with another natural gas water heater, the sum remaining is 0. If a home were to replace a natural gas water heater with a heat pump water heater, the sum remaining would be the price of the heat pump option, minus the price of the natural gas option. This is the cost we finance in the model, i.e. the difference in cost of choosing the efficient electrified option.

Different finance rates and terms are used in the model depending on the items being financed. These different rates are shown in Table 6.13.

[21] https://www.transportenvironment.org/sites/te/files/publications/2021_05_05_Electric_vehicle_price_parity_and_adoption_in_Europe_Final.pdf

Item	Interest Rate %	Term (Years)
Appliances	4%	10
Rooftop Solar	4%	25
Home Battery	4%	10
Electric Vehicles	6%	7

Table 6.13: *Finance rates and terms used in the model.*

We run multiple tests to demonstrate the sensitivity of different interest rates to future household savings. As shown in Figure 6.4, Figure 6.5, and Figure 6.6, different interest rates largely only affect the initial cost and savings for households, and even at high interest rates the savings are still achieved within a short time frame. Figure 6.4 demonstrates that low interest rates would help the average household achieve savings approximately sooner, and would significantly reduce their initial transition costs in 2021.

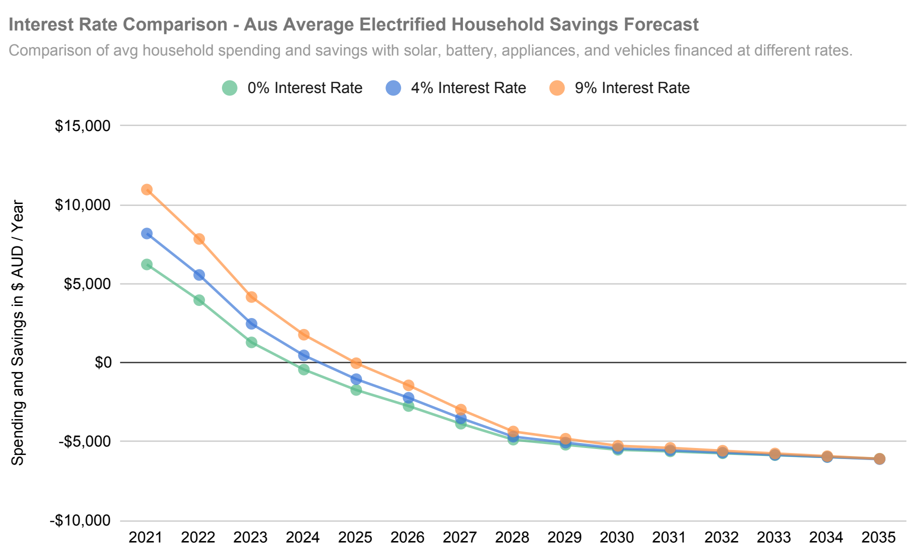


Figure 6.4: *The forecast spending and savings for an "average" Australian home, at different finance interest rates for the financing of solar, battery, appliances, and electric vehicles.*

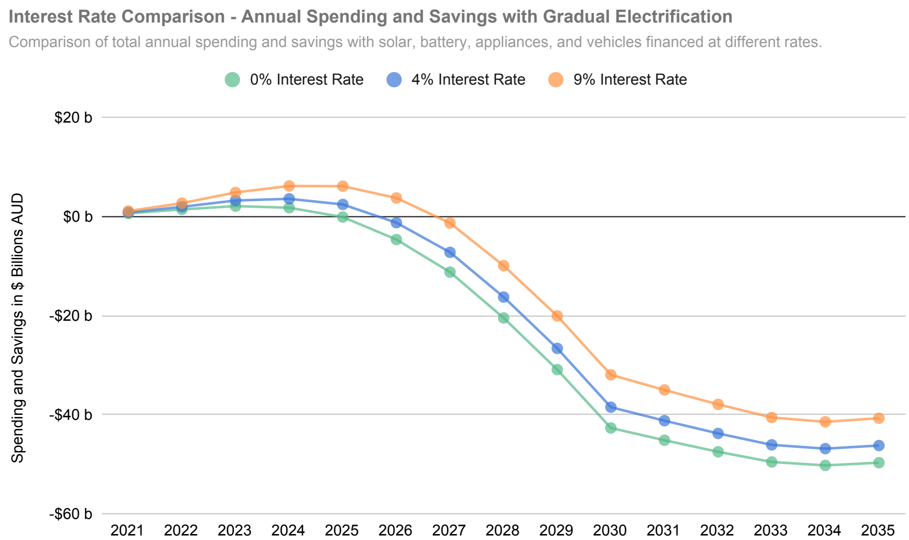


Figure 6.5: *The forecast annual spending and savings for households Australia-wide, at different finance interest rates for the financing of solar, battery, appliances, and electric vehicles.*

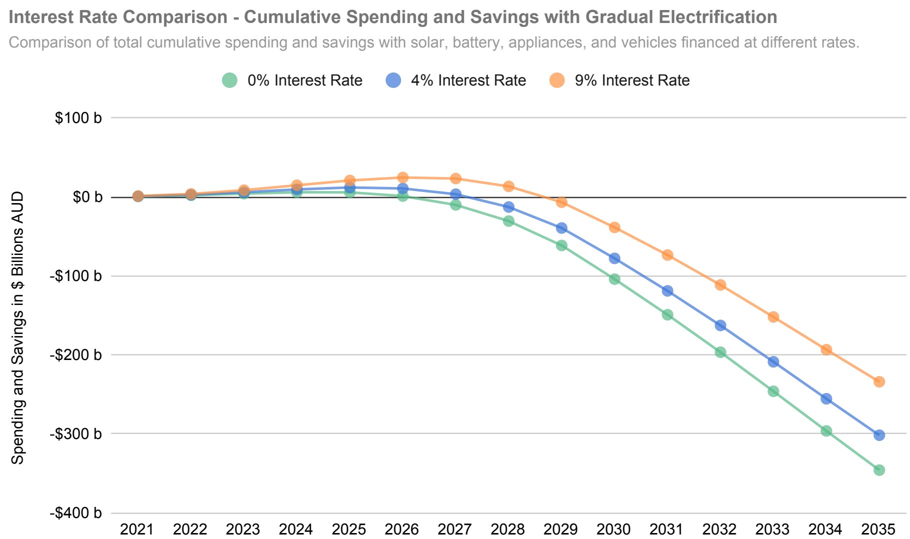


Figure 6.6: *The forecast cumulative spending and savings for households Australia-wide, at different finance interest rates for the financing of solar, battery, appliances, and electric vehicles.*

6.6.6 Solar, battery, and grid ratios.

We built in variable electricity supply and use ratios into the model for self-generated solar electricity, percentage of solar stored in battery, and percentage of grid energy used for the total household supply. For the final model, the ratios used are shown in Table 6.14.

Household Electricity	% of electricity
Solar self-generated	80%
Stored in battery	50%
Total electricity from grid	20%

Table 6.14: *Household electricity generation, storage, and use ratios used in the model. The 20% grid use also accounts for charging electric vehicles away from home and paying standard grid pricing.*

6.7 Future efficiency forecasts

The new electrical load also benefits from ongoing efficiency gains in appliances, heat pumps, rooftop solar, and lighting.

6.7.1 Appliance efficiency gains

The appliance efficiency gains are modelled by a yearly efficiency increase value derived from 10 years (2007 - 2017) of appliance efficiency data from AHAM (Association of Home Appliance Manufacturers). The solar capacity factor increase per year is derived from the past 4 years of Australian solar install and generation data (Australian Government Clean Energy Regulator, Postcode data for small-scale installations).

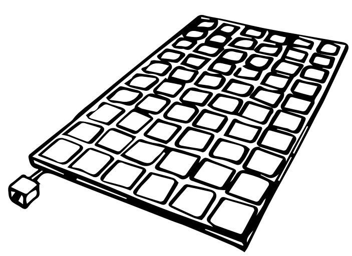
The future efficiency gain values used are shown in Table 6.15.

Appliance	**Annual Efficiency Gain (%)**
Clothes washers	1.18%
Dishwashers	2.62%
Refrigerators	1.13%
Room AC (heat pumps)	1.41%

Table 6.15: *Modelled annual efficiency gains of appliances.*

We do not model cooking appliance efficiency gains.
We do not model "other appliance" efficiency gains.
We do not model battery round trip efficiency gains.

6.7.2 Rooftop solar



Rooftop solar benefits from ongoing capacity factor gains. The yearly capacity factor is derived from monthly installed solar capacity and output from the Australian

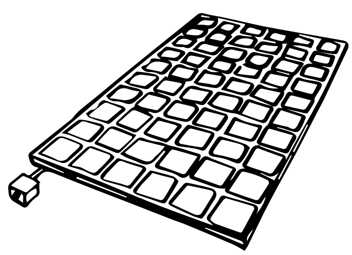
PV Institute[22] between April 2015 and March 2021. The average capacity factor for 2021 is estimated by creating an average year–on–year capacity factor increase, which is then applied to the 2020 yearly average from the data. This year–on–year capacity factor increase (3.37%) was derived from a weighted average of all states (weighted by households in each state). This average yearly capacity factor increase was then compared to USA capacity factor increase data which turned out to be close to the average increase derived from the Australian data, as expected.

6.7.3 Lighting efficiency gains

We do not model the instant replacement of light bulbs; however, we do model the natural continued efficiency gains in lighting from more efficient bulbs being replaced at a natural rate. We derive this rate from the RBS, using the same 10 year period as the appliance efficiency values above (2007 - 2017). We model lighting energy use decreasing at an average of 6.23% per year per household.

6.8 Future cost forecasts and savings

6.8.1 Rooftop solar



We use current (September 2021) retail Australian solar prices provided by Solar Choice[23]. The larger system size prices (6kW, 7kW, 10kW) are then averaged to create a per kW price. Only the larger systems are used because the systems we are modelling to be installed will be large. We then forecast the future prices with a combination of the STC rebate phase out, yearly capacity factor increases, and historical learning rate price curves. The STC rebate phase out is based on an STC price of $36, and each state is based on the STC zone multiplier[24] that applies to

[22] https://pv-map.apvi.org.au/postcode
[23] https://www.solarchoice.net.au/blog/solar-power-system-prices
[24] http://www.cleanenergyregulator.gov.au/DocumentAssets/Pages/Postcode-zone-ratings-and-postcode-zones-for-solar-panel-systems.

the most populated city of that state. The yearly capacity factor is derived from monthly installed capacity and output from the Australian PV Institute[25] between April 2015 and March 2021. The average capacity factor for 2021 is estimated by creating an average year–on–year capacity factor increase, which is then applied to the 2020 yearly average from the data. This year–on–year capacity factor increase (3.37%) was derived from a weighted average of all states (weighted by households in each state). This average yearly capacity factor increase was then compared to USA capacity factor increase data which turned out to be close to the average increase derived from the Australian data, as expected.

The future solar price decrease is forecast using historical solar trends from IEA PVPS National Survey Data for Australia[26] and the International Technology Roadmap for Photovoltaics (ITRPV)[27]. This data is then forecast forward using a flattening curve into the future.

The IEA PVPS data provides average solar pricing in Australia from 2014 to 2019 with a split of the pricing for Modules, Inverters, Mounting Material, and Soft Costs, and further back for module pricing alone. The ITRPV roadmap provides historic pricing and year on year learning rates for modules. The main data used from this is 2010 to 2020 module prices converted to AUD, and the year on year price drop percentage of modules.

We compare the IEA module only price to the module only price from ITRPV (converted to AUD) in Figure 6.7.

aspx

[25] https://pv-map.apvi.org.au/postcode

[26] https://iea-pvps.org/national-survey-reports/?year_p=&country=&order=DESC&keyword=australia

[27] https://itrpv.vdma.org/documents/27094228/29066965/20210ITRPV/08ccda3a-585e-6a58-6afa-6c20e436cf41

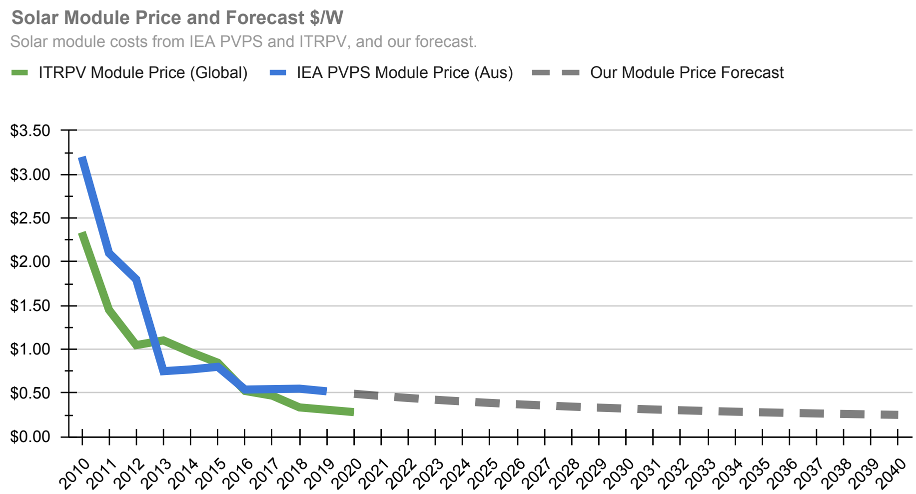


Figure 6.7: *The price curves of solar modules from the IEA Australia data, and the ITRPV international data (converted to AUD).*

To forecast future prices, we then use the average yearly price drop (%) of the last 2 years on each component segment (module, inverter, mounting material, soft costs). For the module price, we use a combination average of the IEA PVPS and ITRPV yearly price drop percentages. For the inverter and soft cost prices, we use the average price drop percentage of the last 2 years from the IEA PVPS data. We then decrease the average drop percentage each year going forward to flatten the price drop curve. Each year, the amount the price drops by gets reduced by multiplying it by 0.95. For the mounting material costs, we continue these forward at the same price because the past 5 years of pricing has been relatively flat. The price history and our forecast is shown in Figure 6.8.

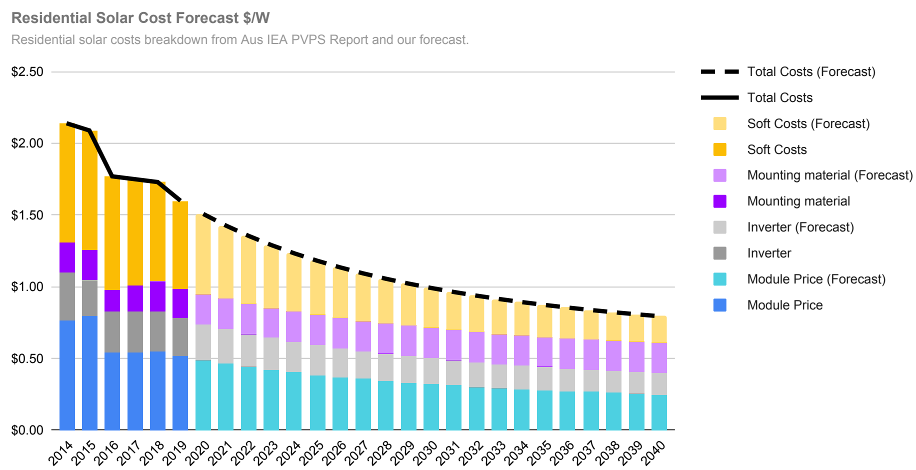


Figure 6.8: *The historical price curve of solar in Australia from IEA PVPS National Reports, and our forecast into the future.*

We then apply the Australian solar incentive phase out to the forecast future price, to derive a forecast Australian solar price per year. The chart below shows the end price in black, alongside the total price without the rebate, and the rebate amount.

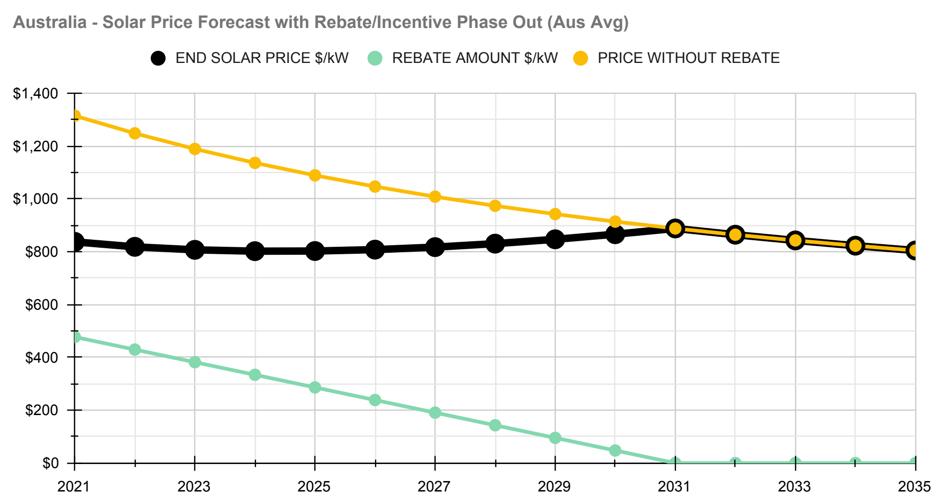
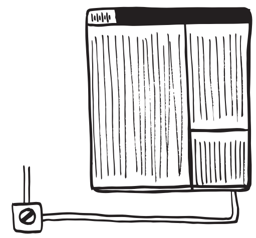


Figure 6.9: *Our solar forecast combined with the planned phase out of Australia's solar incentive, and the total end price.*

6.8.2 Residential battery storage



We use a modified version of the NREL Advanced cost curve for residential home battery pricing forecast. All 3 NREL forecasts appear to be above current retail pricing for residential battery storage in Australia. We apply a multiplication factor to the NREL Advanced cost curve up to 2030, the multiplication factor is 1.5 times the difference in price drop (not the full price). This increases the speed of price drop to more closely align with the prices we see today in the market. After 2030, we apply a price reduction factor of -3.3% per year on the total price up to 2050.

Up to 2030 we use:

$$1.5*(\text{NREL Adv Price Current Year - NREL Adv Price 2019})+\text{ NREL Adv Price 2019} \tag{6.8}$$

For 2031 - 2050 we use:

$$\text{Previous Year Estimated Price} * (1 - 3.3\%) \tag{6.9}$$

We apply this new price forecast curve onwards from today's current costs in Australia, as shown in Figure 6.10.

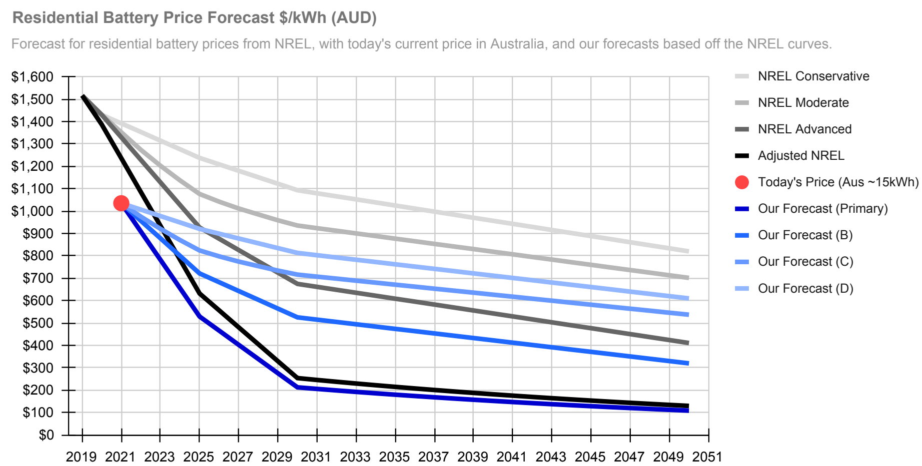


Figure 6.10: *Our battery forecasts using the NREL and Adjusted NREL curves from today's current average price in Australia (from SolarChoice).*

6.8.3 Battery price sensitivity

We test the models sensitivity to the four different battery forecasts as shown in Figure 6.11, Figure 6.12, and Figure 6.13.

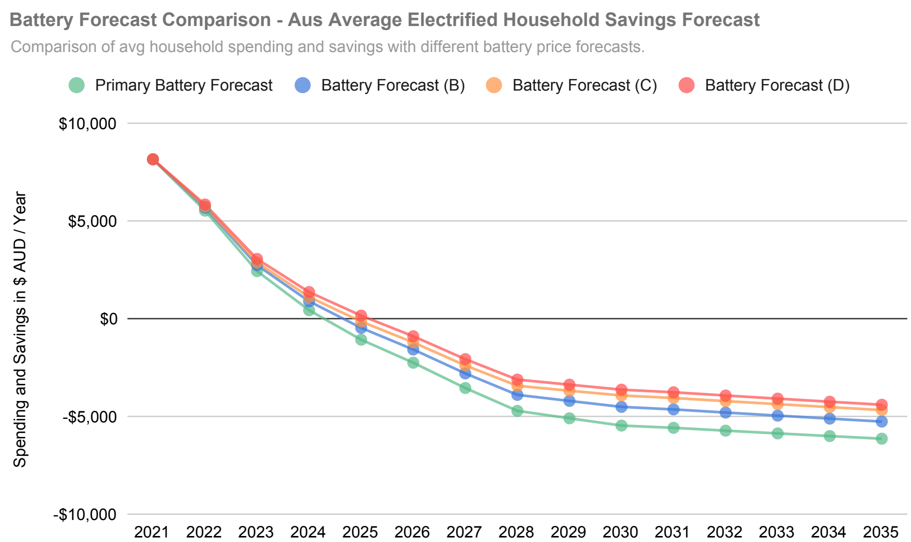


Figure 6.11: *Average household savings forecast with the four different battery price forecasts.*

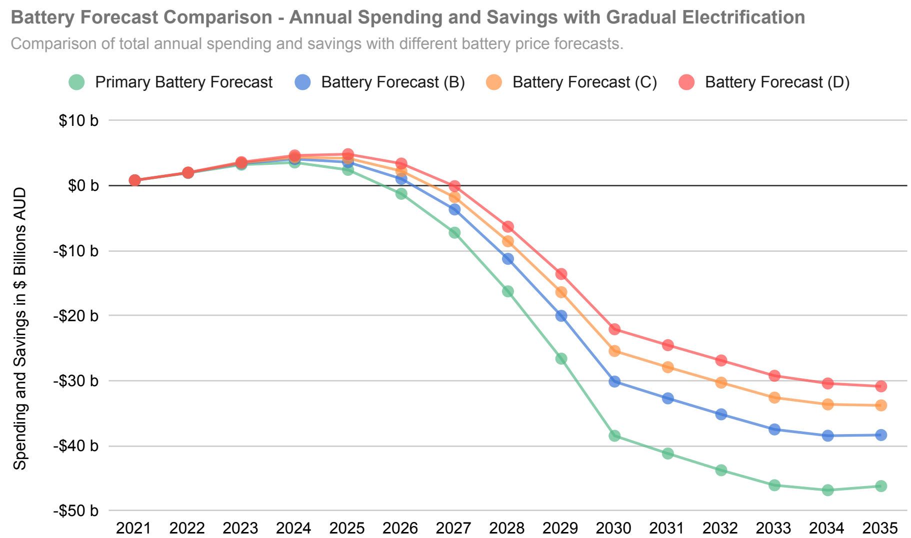


Figure 6.12: *Australian annual savings forecast with the four different battery price forecasts.*

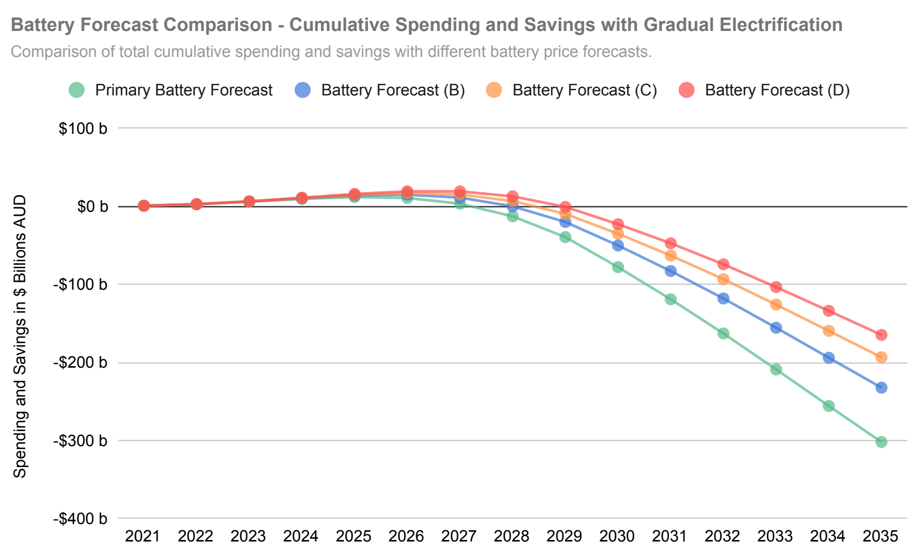
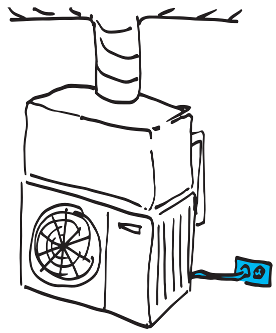


Figure 6.13: *Australian cumulative savings forecast with the four different battery price forecasts.*

6.8.4 Heat pump cost forecast



For future heat pump costs, we derive a yearly multiplier from the IEA Sustainable Development Scenario Heat Pump Price Curve[28]. This cost multiplier is then applied to all appliances that use heat pumps (Space Heating and Water Heating).

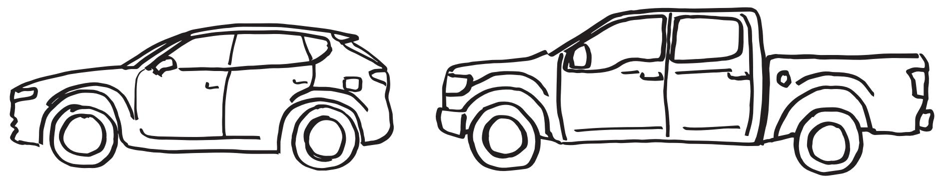
The heat pump price multiplier used is shown in **??**.

Year	Price as % of Current
2021	100%
2022	99%
2023	99%
2024	98%
2025	97%
2026	97%
2027	96%
2028	95%
2029	95%
2030	94%
2031	94%
2032	93%
2033	92%
2034	92%
2035	91%

Table 6.16: *Heat pump future cost forecast used.*

[28] https://www.iea.org/data-and-statistics/charts/cumulative-capacity-and-capital-cost-learning-curve-for-vapour-compression-applications-i

6.8.5 Electric vehicle cost forecast



For electric vehicle costs we use a multiplier based on the Bloomberg NEF electric vehicle parity estimate for the SUV-C segment (mid-size SUV, e.g. Toyota RAV4) from the report Hitting the EV Inflection Point for Transport & Environment, published May 2021[29]. This same cost curve is applied to the price of home chargers for electric vehicles.

When the electric vehicle price forecast goes below price parity, we then use the same finance methodology to calculate the savings from the difference between buying and an ICE vehicle and an EV. This yearly EV cost multiplier is shown in **??**.

[29] https://www.transportenvironment.org/sites/te/files/publications/2021_05_05_Electric_vehicle_price_parity_and_adoption_in_Europe_Final.pdf

Year	EV Price Difference To ICE
2021	170%
2022	152%
2023	130%
2024	117%
2025	108%
2026	100%
2027	91%
2028	83%
2029	82%
2030	80%
2031	79%
2032	78%
2033	78%
2034	77%
2035	76%

Table 6.17: *Electric vehicle (EV) price forecast used in the model.*

6.8.6 Other appliance cost forecast

We do not model in future price forecasts or price reductions for other appliances in the model.

6.9 State and country–level forecasts

For state and territory household numbers, we use the Australian Bureau of Statistics (ABS) Household and Family Projections - Series II[30]. We then derive state and territory savings, and whole country savings based upon the per household savings calculated earlier.

6.9.1 Spending and savings with gradual electrification

We model a gradual electrification ramp with full electrification by 2030, and the associated spending and savings with this electrification.

The spending and saving shown is based upon a fully electrified household, with financed rooftop solar and battery installed, and the financed difference in cost of electrified appliances and electric vehicles. The difference in cost is the

[30] https://www.abs.gov.au/statistics/people/population/household-and-family-projections-australia/2016-2041

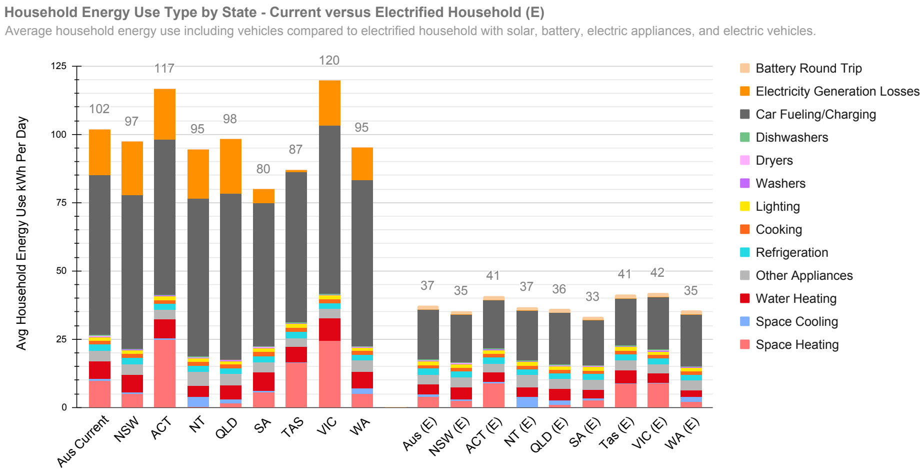


Figure 6.14: *Comparison of household energy use by use. Today's households by state, and future electrified households by state.*

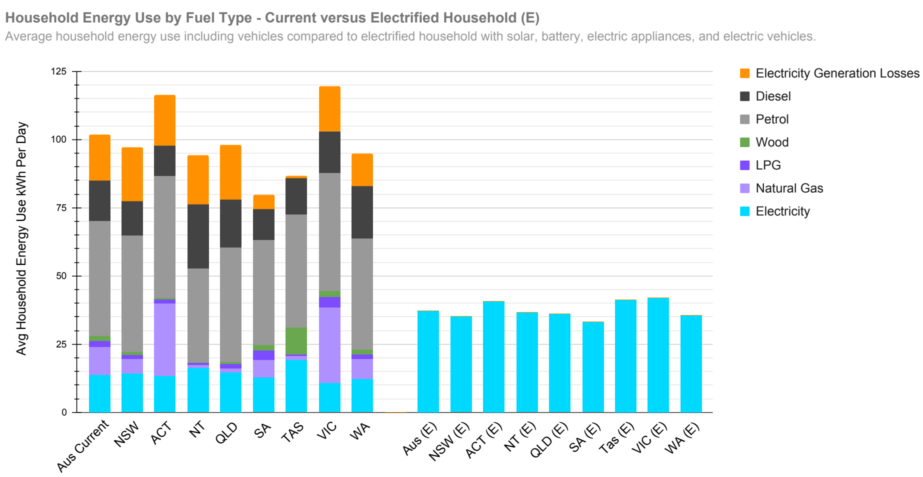


Figure 6.15: *Comparison of household energy use by fuel type. Today's households by state, and future electrified households by state.*

sum remaining after subtracting the cost of a similar non-electrified replacement, from the cost of an electrified replacement. For example, if a home were to replace a natural gas water heater with another natural gas water heater, the sum remaining is 0. If a home were to replace a natural gas water heater with a heat pump water

Year	% of Homes Electrified
2021	1%
2022	3%
2023	8%
2024	15%
2025	25%
2026	40%
2027	55%
2028	70%
2029	85%
2030	100%

Table 6.18: *% of Total Homes Electrified*

heater, the sum remaining would be the price of the heat pump option, minus the price of the natural gas option.

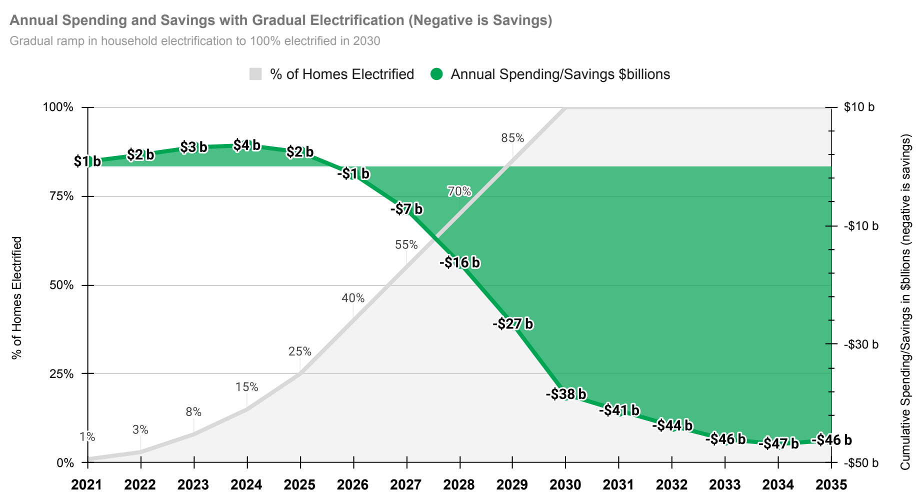


Figure 6.16: *Annual savings in the Australian economy assuming the adoption rate slowly ramps up between 2021 and 2024 and we achieve 100% household electrification by 2030 — commensurate with a 1.5-2 degree target.*

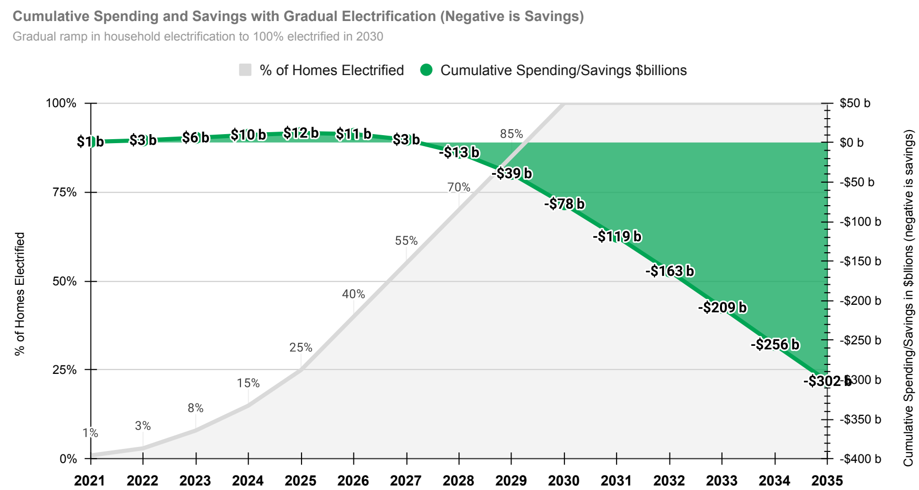


Figure 6.17: *Year-over-year expenditures and savings realized by an aggressive commitment to electrification.*

6.10 Emissions methodology

The base data source is the Australian National Greenhouse Gas Inventory 2019[31]. Estimates are based on the IPCC classification system used to report Australia's greenhouse gas emission inventory to track Australia's progress towards its 2030 Paris target. These estimates are compiled using the global warming potentials from the IPCC 5th Assessment Report.

Multiple other datasets are then used to map this data to a deeper level. For some reported figures, their category is detailed enough already (e.g. Residential Fuel Combustion maps directly to households). For other reported figures (e.g. Electricity and Heat Production), more data sets are used to further break down the data (i.e. who uses the electricity). More data sets are used to find the ratios of exports compared to domestic attribution, and the ratios of manufacturing, commercial, and household emissions. The main other data sets used are outlined below.

For electricity use, the final energy consumption from Energy Flows 2018-19[32] is used, combined with the industry ratios from the 2017-18 release of Energy Use

[31] https://ageis.climatechange.gov.au/

[32] https://www.energy.gov.au/sites/default/files/Australian%20Energy%20Flows%202018-19.pdf

and Electricity Generation, Australia, 2017-18[33], the latest release at the time.

For agriculture, the ratios used come from the Snapshot of Australian Agriculture 2021[34], these are then applied to the agricultural sector, and also the chemical industrial processes that primarily relate to fertiliser products.

For transport, we attribute 90% of passenger vehicle and motorcycle emissions to households, and 75% of Light Commercial Vehicle (LCV) emissions to households. The remaining emissions for those vehicle types and the emissions from trucks are allocated using the ABS Survey of Motor Vehicle Use 2020[35] freight figures by industry.

For Waste, the ABS Waste Account for Australia 2018-19[36] is used to divide waste into industry and household source.

[33] https://www.abs.gov.au/statistics/industry/energy/energy-use-and-electricity-generation-australia/latest-release

[34] https://www.agriculture.gov.au/abares/products/insights/snapshot-of-australian-agriculture-2021#around-70-of-agricultural-output-is-exported

[35] https://www.abs.gov.au/statistics/industry/tourism-and-transport/survey-motor-vehicle-use-australia/latest-release#methodology

[36] https://www.abs.gov.au/statistics/environment/environmental-management/waste-account-australia-experimental-estimates/latest-release#data-download

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