Electric vehicles and the energy transition - an Australian case study

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Abstract

Electric vehicles (EVs) are rapidly gaining a share of global car sales and offer benefits in both operating costs and avoidance of greenhouse gas emissions. In tandem with household rooftop solar PV in so-called vehicle-to-home (V2H) mode, EVs can operate as home batteries and store excess solar generation instead of exporting that energy to the electricity network. This modelling study seeks to identify the financial and emissions benefits arising from V2H configurations for typical households in Australian cities to explore the economic and emissions reduction potential.

With typical private vehicle use in Australian cities, EVs coupled with solar PV in V2H mode can provide similar savings in cost and emissions avoidance to homes with batteries but without their additional capital cost and environmental life cycle impact. The 15 year Net Present Cost of household energy and vehicle use in Melbourne, Australia is already similar to an existing household with ICE vehicles and natural gas. The financial benefits noted here will only increase in future as the cost of EVs fall as expected. The study illustrates that V2H is similarly beneficial in all Australian capital cities.

Government incentives should target the integration of home solar and EVs, while EV marketing should better identify the combined benefits. Policy and regulation of bi-directional EV chargers is critical to meeting the objectives of widespread V2H operation in Australian homes.

1. Introduction

Electric vehicles (EVs) are rapidly gaining a share of global car sales with a noticeable pickup in the years following the COVID pandemic. Sales in 2024 increased by 25% over the preceding year. Battery electric vehicles (BEVs) are an increasing proportion of new sales, although plug-in hybrid (PHEV) retain a significant share.

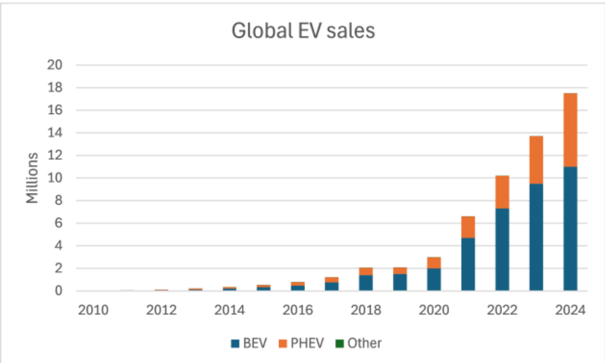

Figure 1 Global EV sales
Source: (International Energy Agency, 2025)

The benefits of EVs are usually cited as financial savings from fuel and maintenance costs. Greenhouse gas emissions are lower than for internal combustion engine vehicles (ICEVs) with the magnitude of the benefits depending on the electricity used for charging.

Many countries have policy and regulation in place to promote the take-up of EVs. In Australia support is presently limited to tax exemption for company owned vehicles provided to employees[1]. Nevertheless sales are also increasing at a similar rate to that globally although still only represent 12% of new car sales and 2% of all cars (Electric Vehicle Council, 2025).

Australia leads the world in the adoption of private rooftop solar PV installations with nearly 40% of houses having systems installed with a total capacity of 26.8 gigawatts (Clean Energy Council, 2025). To date the installation of companion battery storage has been negligible. The Australian Government has recently introduced a grant scheme for home batteries[2] which covers around 30% of installed costs but will diminish to around 10% by 2030. The Australian Government is also incentivising household energy upgrades[3], which include support for electrification of homes and EV chargers.

Although the vast majority of EV owners charge their vehicles at home with the benefit of rooftop solar, there remains a distinct separation in the public discourse between the benefits of home electrification (related to household energy use) and EVs (related to transport) (Haghani et al., 2023). The so-called vehicle-to-grid (V2G) technologies focus on the potential benefits of connection of EVs to the electricity network with literature on that subject even back in 1995 (Kempton and Letendre, 1997) and also much more recently (Tirunagari et al., 2022, Hossain et al., 2023). However there has been less focus on vehicle-to-home (V2H) technology until more recently (Saidi et al., 2025, Liu et al., 2013). V2H benefits are projected by Chen et al (2025) for the United States but with grid energy rather than self-supply. Wu et al (2024) have modelled V2H benefits for solar homes in Australia but include home batteries in tandem with EVs. Geach et al (2026) consider V2H in Australia from the perspective of operational energy costs but not whole of life costs of vehicle ownership and energy supply.

In reality an EV is essentially a mobile electrical appliance with inbuilt energy storage. In this study the financial and emissions benefits arising from the combined deployment of solar PV, storage and EVs are modelled for typical households in Australian cities to explore the lifecycle economic and emissions reduction potential of V2H.

2. Methods

2.1. Data sources

2.1.1. Household electricity demand

Residential household demand varies significantly between Australian cities due to the wide range of climatic conditions. Cities in the south tend to use more energy for space heating (e.g. Melbourne) while those in northern tropical areas (e.g. Darwin) have high cooling demand. However the diurnal pattern of use is relatively similar. This study uses a combination of information from the “2021 Residential Energy Baseline Study: Australia and

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[1] https://electricvehiclecouncil.com.au/electric-car-discount/

[2] https://www.dcceew.gov.au/energy/programs/cheaper-home-batteries#_1-may-2026-changes-to-the-program

[3] https://www.dcceew.gov.au/energy/energy-efficiency/buildings/residential-buildings

New Zealand"[4] (REBS) and previous research on projections for the Western Australian electricity network (Grace, 2023) to establish an approximate annual hourly electricity demand profile for each city.

The REBS also has information on electricity and natural gas use in Australian homes. Natural gas has traditionally been used for cooking, space and hot water heating but is being overtaken by cheaper electrical appliances such as induction stoves and heat pumps. This study examines both existing electricity use and potential increased demand associated with the complete electrification of homes.

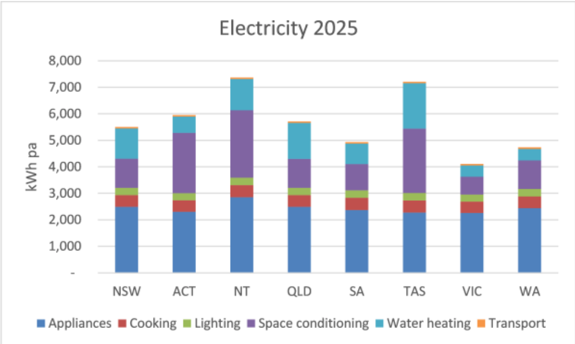

Figure 2 Existing electricity use in Australian capital cities

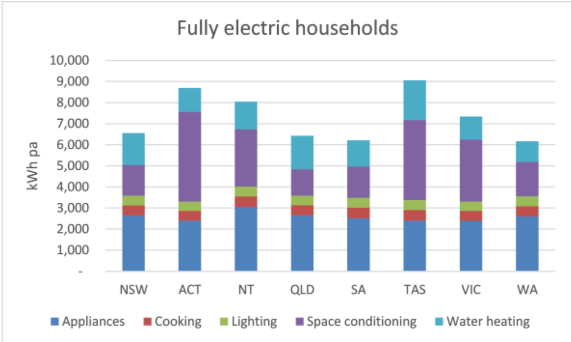

Figure 3 Electricity use in electrified homes in Australian capital cities

The cost of purchasing electricity and natural gas from networks has been sourced from a Victorian Government website[5] that allows consumers to compare retail electricity and gas prices.

2.1.2. Solar PV generation and battery storage

Solar generation has been taken from the National Renewable Energy Laboratory (NREL) "PVWatts" calculator (National Renewable Energy Laboratory, 2025). PVWatts produces an hourly solar generation profile for any worldwide location.

The monthly generation from conventional rooftop solar for each of the Australian cities is illustrated in Figure 4.

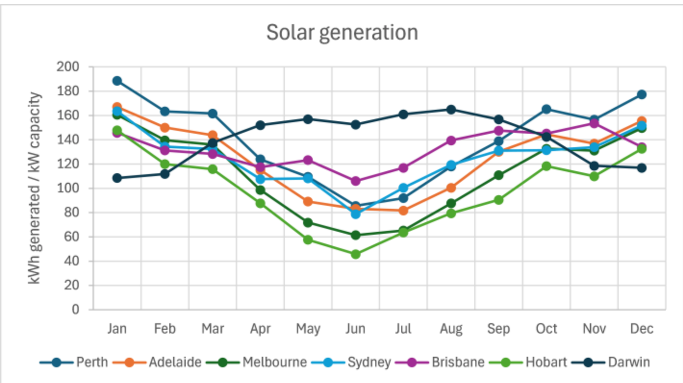

Figure 4 Solar generation from rooftop PV in Australian cities

[4] https://www.energyrating.gov.au/news-and-stories/2021-residential-energy-baseline-study-australia-and-new-zealand
[5] https://compare.energy.vic.gov.au/

Previous studies have been used as the basis for modelling the integration of solar PV and battery storage with the electricity network (Grace, 2018, Grace, 2023).

Data on the historical and contemporary installed costs of solar and batteries has been harvested from a well known and reputable service provider[6].

2.1.3. Urban car use

The Victorian Integrated Survey of Travel and Activity (VISTA) is a major data collection exercise conducted by the Victorian State Government to understand all aspects of day-to-day travel by Victorians. The VISTA dataset is compiled from user surveys which reports on household types, person data and trip data. The 2023-24 data analysed for Greater Melbourne has been used to characterise private car travel to and from houses.

2.1.4. Vehicle cost of ownership

The New South Wales (NSW) Government provides a public information portal that facilitates the calculation of total costs of ownership for ICEV and EVs. This resource has been used for the calculation of capital and ongoing costs for private cars.

2.2. Growth dynamics

The study seeks to quantify the combined benefit of homeowners having rooftop solar PV with EVs, with and without additional home batteries. The financial benefit of the best option will determine likely take-up at the grid scale (see Figure 5).

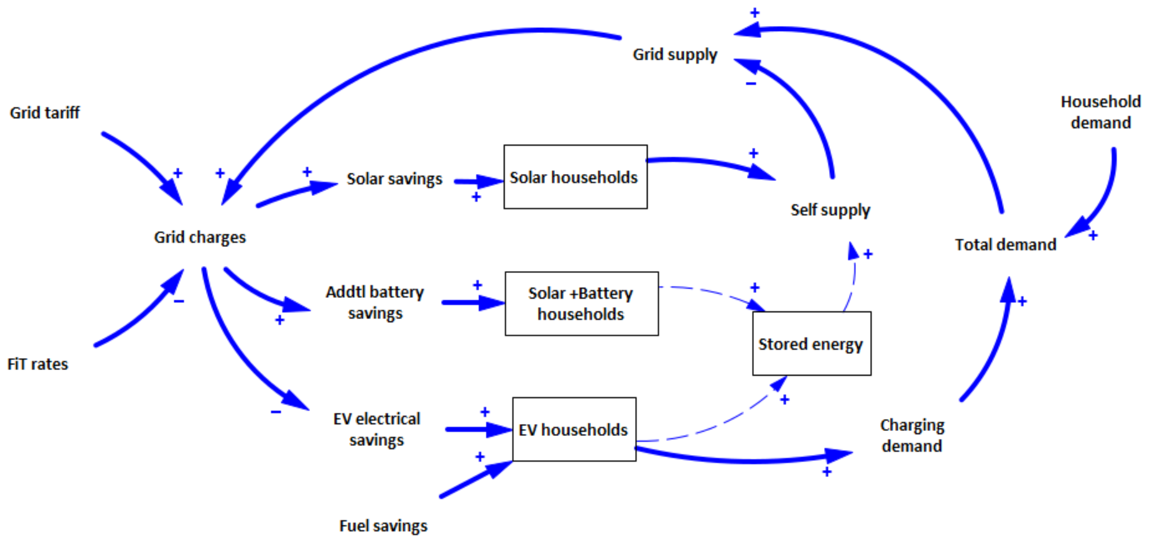

Figure 5 Solar PV and EV growth dynamics

The precursor to simulating these growth dynamics is the establishment of the most optimal combination of solar technology with either stand-alone battery storage or use of an EV in V2H mode for an individual household, which is the focus of the study reported here.

2.3. The Model

The model uses the Vensim software (V10.4.0) to simulate the electricity supply and demand for a typical household over a year in a conventional Australian detached dwelling in V2H mode with the following characteristics:

- 8kW rooftop solar array

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[6] https://www.solarchoice.net.au/

- 2 EVs with bi-directional connection to the house
- Conventional inverter with two way connection to the grid

Figure 6 V2H configuration

The model inputs hourly electricity demand over a year in a conventional Australian detached dwelling using the city of Melbourne as an example in the base case model. The model assumes a fully electric home with an annual demand of 7,355 kWh (see Figure 3).

Data from the VISTA survey was used to characterise private car use, again for a typical household. VISTA identifies car use patterns for each vehicle in a household. The most typical household has 2 cars, used by two persons, denoted here as P01 and P02. Figure 7 and Figure 8 depict the percentage of car trips started at each hour of the day by each person on weekdays and weekends.

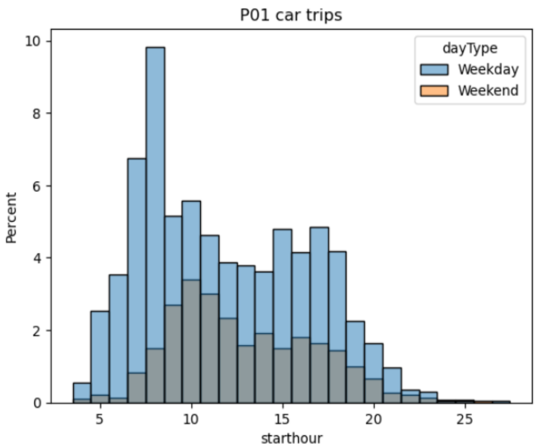

Figure 7 P01 travel patterns

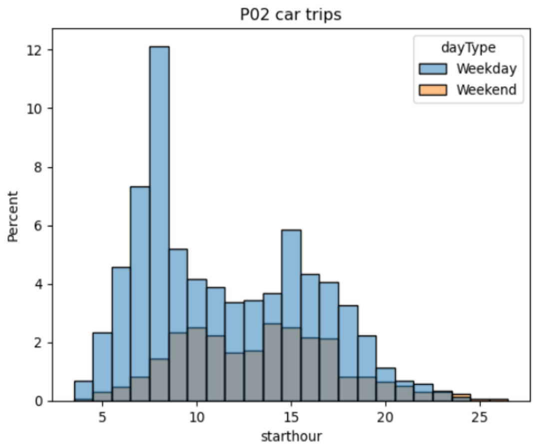

Figure 8 P02 travel patterns

VISTA reports the number of trips for each person and the mean and median travel distance for each trip from home (Table 1).

Table 1 Trip distances

	P01	**P02**	
Weekday	5.10	5.18	median km/trip outward
Weekend	5.14	5.35	
Weekday	9.09	9.24	mean km/trip outward
Weekend	9.33	9.08	

The average annual vehicle kilometres travelled (vkt) for private cars in Melbourne is 10,300km. Combining this with the information in Table 1 allows a calculation of trip distances for each vehicle on weekdays and weekends (Table 2).

Table 2 Average car use

Mean vkt pa	P01	P02
Weekday	8,453	5,992
Weekend	3,411	2,745
	11,864	8,736
Trips per day		
Weekday	1.79	1.25
Weekend	1.76	1.45

The model facilitates any use pattern but the base case assumes that each vehicle has trips with the following pattern of use:

- PO1 is away from home all day on weekdays and the vehicle is only charged during solar hours (9am-5pm) on weekends
    - EV1 is a larger sedan based on a Tesla Y (60 kWh battery / 0.13 kWh/km)
- PO2 is home based and is V2H connected (i.e. operates as a home battery) whenever home
    - EV2 is a medium sedan based on a BYD Dolphin (50 kWh battery / 0.15 kWh/km)

The model operates as follows:

1. Electricity demand from the house is met by the solar PV system whenever generation is available to supply demand.
2. The residual household demand is met by discharging the battery in EV2 whenever the vehicle is at home and has available capacity. Otherwise demand is met by the grid.
3. The EVs are discharged at their designated rate while travelling and are only charged at home.
4. The residual solar generation is used to charge the EVs whenever they are at home and solar power is available. Otherwise they are charged by the grid.

This process requires the model to monitor:

- The times and distances on weekdays and weekends when each vehicle is travelling; and
- The times they are at home and can be charged (both vehicles) and discharged to supply the home demand (in the case of EV2).

The model assumptions are set out graphically in Figure 9 to Figure 14.

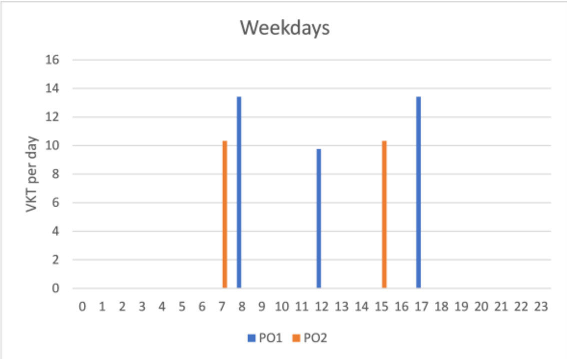

Figure 9 Weekday trips (vkt)

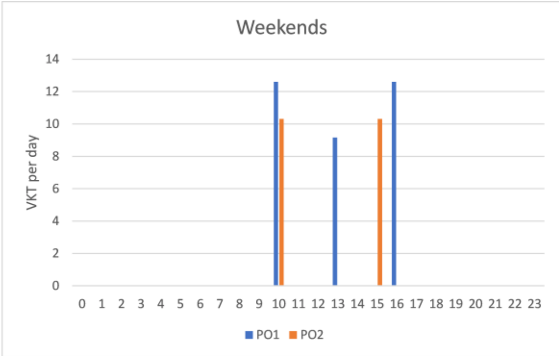

Figure 10 Weekend trips (vkt)

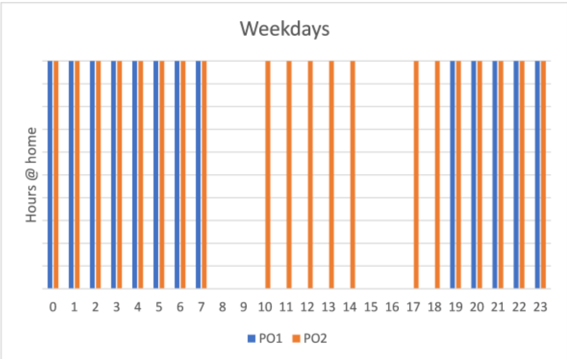

Figure 11 Weekday at home hours

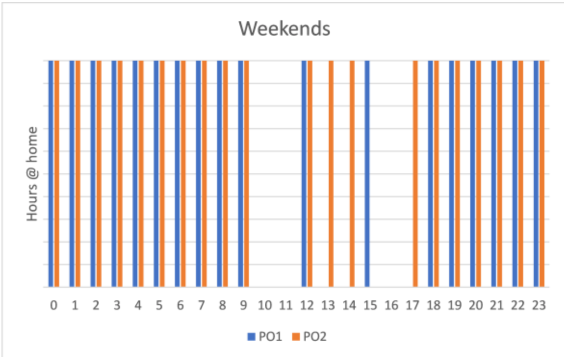

Figure 12 Weekend at home hours

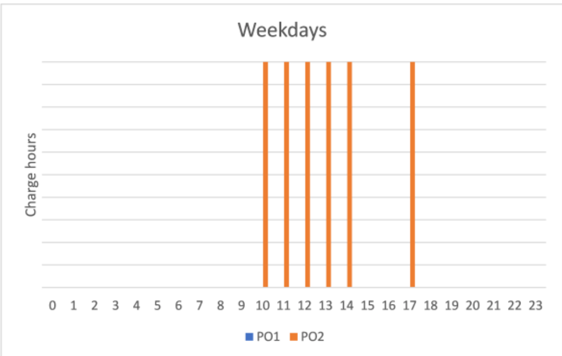

Figure 13 Weekday charging hours

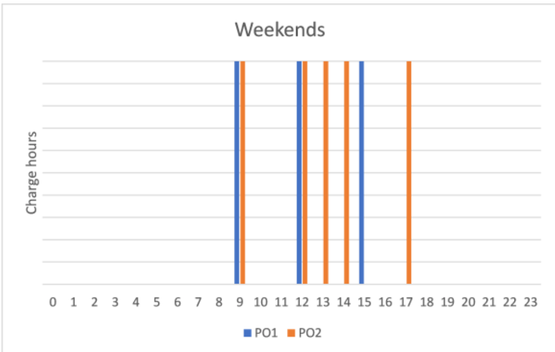

Figure 14 Weekend charging hours

3. Results

3.1. Energy supply / demand

3.1.1. Summer conditions

The peak solar generation occurs mid-summer (see Figure 4) so this period represents the best case scenario during the year.

Figure 15 and Figure 16 illustrate the simulation results for a typical summer weekday and weekend and depict loads from the house and vehicle charging and the source of supply. The state-of-charge (SOC) of the EV batteries is also shown.

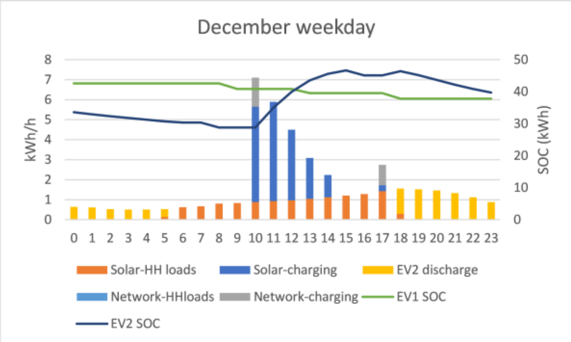

Figure 15 Summer weekday supply / demand

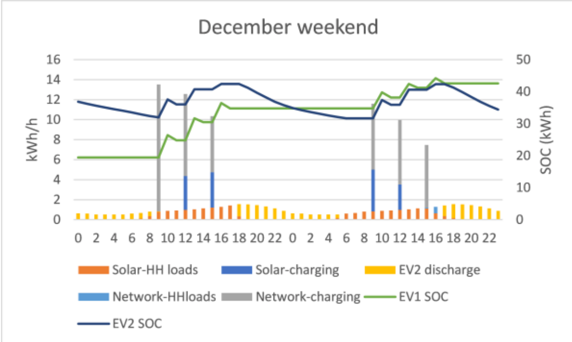

Figure 16 Summer weekend supply / demand

During the week the house's electrical demand is fully met from a combination of direct solar generation and discharges from EV2. EV2 is constantly discharged through travel and household electricity demand but substantially recharged from the excess solar generation available. EV1 is discharged by travel and not recharged and so the battery is continually discharged. By the end of the week EV1 SOC is around 20 kWh (30% of capacity). A small amount of power from the grid is required to charge EV2 in the mornings and evenings, however the SOC is never lower than around 30 kWh (60% capacity).

On weekends the house's electrical demand remains met mainly from a combination of direct solar generation and discharges from EV2, with a minor top-up from the grid late on Sunday afternoon. Both vehicles are charged from a combination of solar generation and the grid.

3.1.2. Winter conditions

The weakest solar generation occurs mid-winter (see Figure 4) so this period represents the worst case scenario during the year.

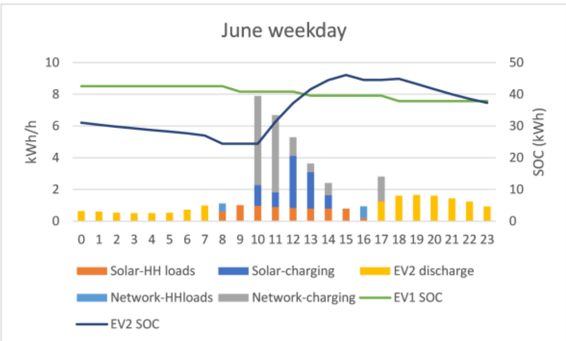

Figure 17 June weekday supply / demand

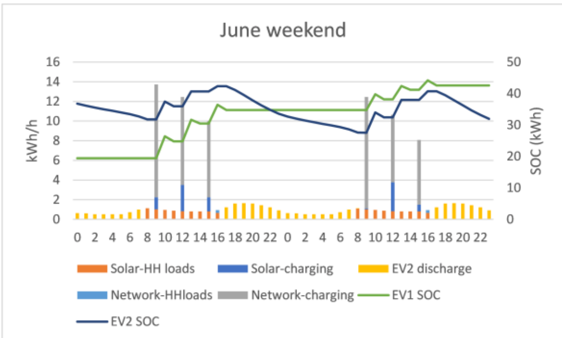

Figure 18 June weekend supply / demand

During the week the household electricity demand is met mainly from solar generation with some top-up from the grid required in the early morning and late afternoon. Solar generation charges EV2 partially but grid energy is also required.

On weekends when both vehicles require charging, most energy is supplied by the grid.

3.1.3. Annual supply / demand

The electrical demand is divided approximately equally between the house and vehicle charging (see Figure 19). A substantial component of this is supplied by solar either directly (44%) or indirectly through the discharge of EV2 (29%). The balance is required from the grid (27%).

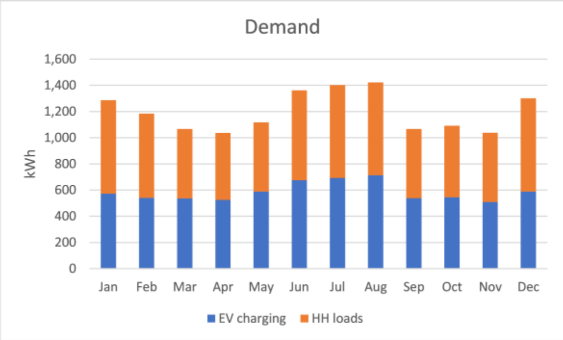

Figure 19 Electricity demand

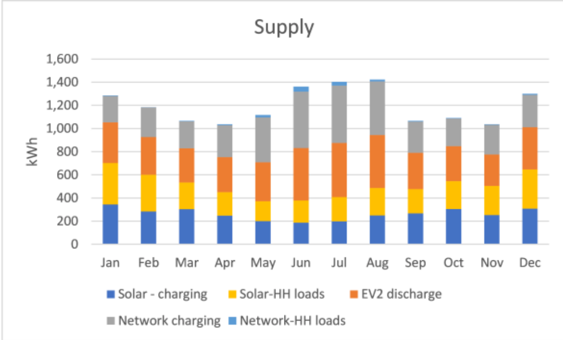

Figure 20 Electricity supply

Even with this substantial contribution to meeting demand the solar system will still export 43% of total annual generation to the grid, predominantly in the summer and shoulder months.

3.2. Financial analysis

The results of the simulations were translated into financial cost-benefit analysis for comparison with a number of other energy supply and vehicle scenarios. EV4 is the V2H configuration described above. ICEV1 is the Base Case and represents typical electricity and natural gas demand for households with conventional ICE vehicles in Melbourne. The vehicle travel behaviour is identical in each scenario.

Table 3 Financial analysis scenarios

Scenario	Household energy supply	Vehicles	Solar	Battery
ICEV1	Electricity and natural gas	ICEV		
ICEV2	Fully electric	ICEV	✓	
ICEV3	Fully electric	ICEV	✓	✓
EV1	Fully electric	EV		
EV2	Fully electric	EV	✓	
EV3	Fully electric	EV	✓	✓
EV4	Fully electric	EV	✓	EV2 as battery

In all scenarios except EV4 it is assumed that vehicles are charged overnight between 9pm and 7am at off-peak tariff periods.

Cost assumptions are set out in the Appendix in relation to:

- The applicable tariffs that apply to electricity and natural gas;
- The cost of gasoline; and
- The capital and operating cost of vehicles, EV chargers and solar equipment.

Fifteen year costs are calculated in both raw and net present (i.e. discounted) terms for each of the scenarios. The results are set out in Figure 22, Figure 23 and Table 4. Although a feed-in-tariff of approximately $1.80 is currently in place from most retailers for private solar exported to the network, it has been neglected in this study as it is questionable whether it will be maintained as solar PV penetration rises.

Table 4 Financial analysis results

		ICEV1	ICEV2	ICEV3	EV1	EV2	EV3	EV4
Vehicles	ICEV1	✓	✓	✓				
	ICEV2	✓	✓	✓				
	EV1				✓	✓	✓	✓
	EV2				✓	✓	✓	✓
Nat gas		✓						
Solar			✓	✓		✓	✓	✓
Battery				✓			✓	
EV2 as battery								✓
Vehicle cost V1			$41,318			$70,242		
Vehicle cost V2			$34,050			$42,715		
VKT (V1)					13,126			
VKT (V2)					7,537			
Fuel cost (V1)			$1,457			$0.00		
Fuel cost (V2)			$837			$0.00		
Maintenance cost (V1)			$345			$290		
Maintenance cost (V2)			$315			$277		
Cost of solar (kW)			$7,016	$7,016		$7,016	$7,016	$7,016
Cost of battery (kWh)				$10,271			$10,271	
Electricity (kWh)		4,115	4,399	966	10,155	7,199	3,414	4,032
Charges		$1,044	$1,173	$221	$2,419	$1,726	$706	$925
Saving		$0	-$129	$823	-$1,375	-$682	$338	$119
Nat gas (MJ)		45,514	0	0	0	0	0	0
Usage		$1,391	$0	$0	$0	$0	$0	$0
Saving		$0	$1,391	$1,391	$1,391	$1,391	$1,391	$1,391
Emissions (Electricity		3,210	3,431	753	7,921	5,615	2,663	3,145
Emissions (Nat gas)		2,345						
Emissions (Fuel)		2,875	2,875	2,875				
		8,430	6,306	3,628	7,921	5,615	2,663	3,145
Capital		$75,368	$82,384	$92,655	$112,957	$119,973	$130,244	$119,973
Annual		$5,389	$4,127	$3,175	$2,986	$2,293	$1,273	$1,492
15 year cumulative costs		$156,196	$144,283	$140,274	$157,750	$154,371	$149,342	$142,356
Net Present Cost @ 5%		$131,299	$125,217	$125,607	$143,953	$143,776	$143,460	$135,462

Annual emissions for electricity, natural gas and gasoline are also included in Table 4, and shown graphically in Figure 21.

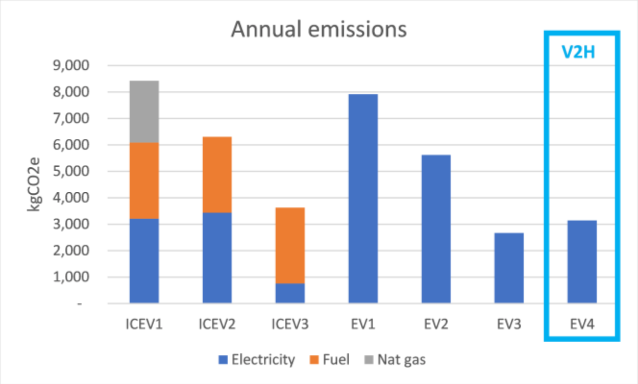

Figure 21 Annual GHG emissions of each scenario

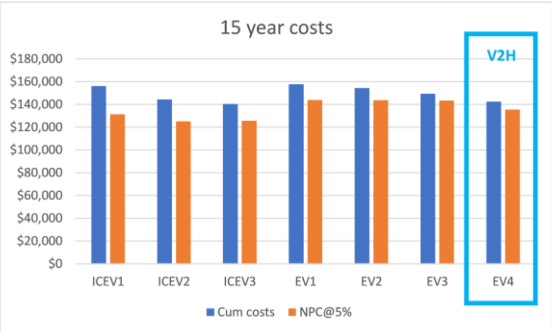

Figure 22 15 year costs of scenarios

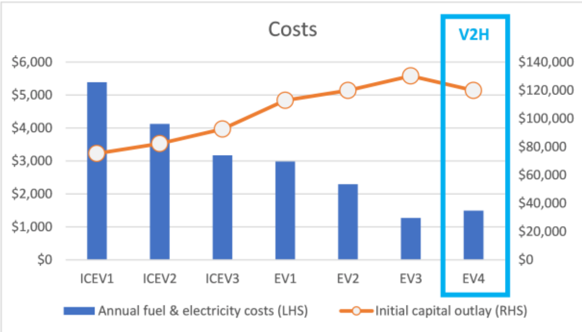

Figure 23 Initial and annual cost of scenarios

The V2H (EV4) scenario has the lowest 15 year undiscounted costs and the Net Present Cost (NPC) is similar to the case that best represents the contemporary situation for households without solar and have ICE vehicles (ICEV1) with 63% lower annual emissions. The V2H (EV4) scenario has similar annual savings (~$4,000) as EV3 (household battery case) with lower upfront capital costs. The V2H (EV4) scenario has slightly higher annual emissions than EV3 but lower than ICE vehicles with household solar and battery (ICEV3).

3.3. Model testing and sensitivity analysis

The model assumptions were varied to evaluate the impact on the findings set out above. A common situation is for both drivers to be working at least part-time.

The first variation assumes the same travel patterns for EV1 but EV2 is away from home during solar hours for 3 days per week and therefore only charges at home on the other weekdays and weekends. The number and length of trips is unchanged from the base case. The second variation assumes the base case vehicle use but has 20% higher household electricity demand. The third variation assumes both the additional household electricity demand plus 20% higher vkt / trip.

The resulting impact on solar and network supply is set out in Table 5.

Table 5 Sensitivity analysis results

	Base case	EV2 3 workdays	Addtl HH load	Addtl HH load & vkt
Network supply	4,032	4,573	4,881	5,235
Solar supply	10,342	9,687	11,870	11,926
Total (kWh)	14,374	14,259	16,751	17,161

Annual electricity costs	$925	$1,034	$1,117	$1,208

As expected, the network supply is higher in all variations resulting in slightly higher annual network costs. However, the worst-case additional cost is only $250 pa which has only a minor impact on the long-term benefits. The solar supply is also higher as more is utilised and less is exported.

3.4. V2H application in other Australian cities

The cost-benefit of V2H was analysed for other Australian cities to establish whether different household demand and solar generation potential has an impact on the findings from the Melbourne case study. The same vehicle use and patterns was applied in the model together with the variations in electricity demand set out in Figure 3 and solar generation in Figure 4. As illustrated in Figure 24 direct and indirect solar generation will supply a similar proportion of household and EV charging demand in most Australian cities. Hobart (with lower solar generation) and Darwin (with higher cooling demand) vary somewhat from other cities.

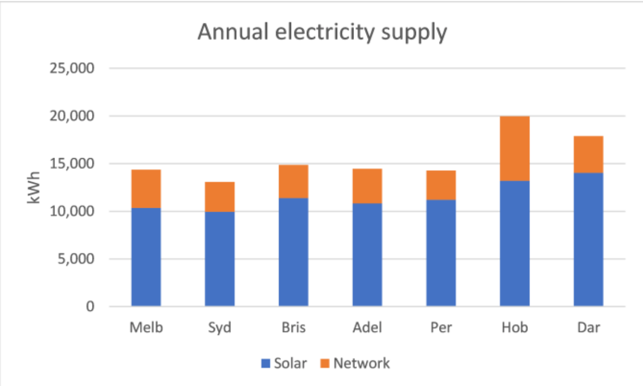

Figure 24 V2H benefits in Australian cities

4. Discussion

The long-anticipated cost-benefit of adding a home battery to residential rooftop solar is coming into view due to the declining cost of battery technology and government incentives. However as shown here, with typical private vehicle use in Australian cities, EVs coupled with solar PV in V2H mode can provide similar savings in cost and emissions but without the additional capital cost and environmental life cycle impact (including embodied emissions) of a separate battery. Households that purchase home batteries now and an EV in the future will have two batteries side by side in their driveway. In fact, the 15 year NPC of household energy and vehicle use in Melbourne is already similar to an existing household with ICE vehicles and natural gas. Accordingly, the promotion of home batteries when EVs (with much larger batteries) can provide a similar service is questionable. The financial benefits noted here will only increase in future as the cost of EVs fall as expected.

China is leading the world in terms of production and sales of EVs. According to the IEA report (International Energy Agency, 2025) small BEV cars are already cheaper than the conventional equivalent, while medium size and larger BEVs are at or near parity. Only extended range vehicles remain much more expensive. “Range anxiety” is cited as a constraint to purchasing an EV and this has led to the large battery capacity in modern EVs. However, as noted above the average trip for a typical household in an Australian city is less than 10km, meaning there is more than sufficient battery capacity to support both EV charging and household electrical demands.

While Australia's total greenhouse gas emissions are falling, as are emissions from total energy, transport emissions remain little changed (see Figure 25). According to the Climate Change Authority[7] light vehicles produce around 60% of transport emissions and therefore EVs represent a major opportunity to address this otherwise hard-to-decarbonise sector. According to the most recent EV projections by the Commonwealth Scientific and Industrial Research Organisation (CSIRO)(Graham, 2024) on the basis of current government policy it will take until 2040 for EV sales to reach 100% of new vehicles and 2060 to achieve 100% fleet share. This is some 10 years after the Net Zero emissions target of the government.

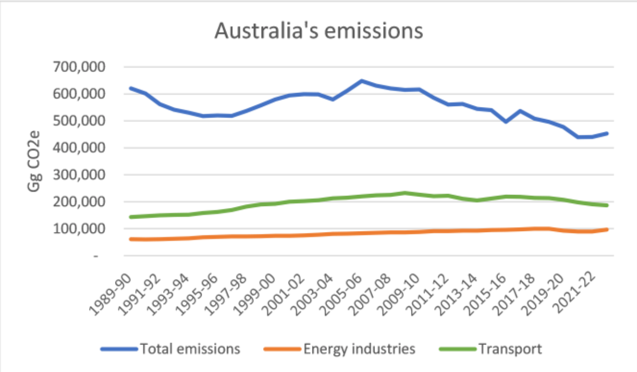

Figure 25 Australian greenhouse gas emissions

5. Conclusions and recommendations

The nexus between household electricity use and electric vehicles is under appreciated in the community. EVs in V2H mode offer a major opportunity to minimise emissions from both electricity and private travel at an affordable and declining cost for typical households in Australian cities.

Given these benefits and the urgency in reducing emissions the government should review incentives for EVs including (as called for by the Electric Vehicle Council):

- the provision of rebates and zero interest loans, or other incentives that effectively reduce the upfront costs associated with purchasing an electric vehicle; and
- retention of the Electric Car Discount.

While government is incentivising energy efficiency of homes, this should be expanded to include to promotion of full electrification including EVs. The incentives for home batteries are questionable considering the growing uptake of EVs and consideration should be given to grants being switched, or at least available, to EV purchases.

EV marketing should be expanded to providing integrated household packages that bundle EVs with solar PV and V2H (i.e. bi-directional charging). Polices and regulation of the electricity sector needs to reflect the opportunity of V2H in respect of both network providers and retailers. While Australian Standards now permit bi-directional charging and more products are becoming available, many EV manufacturers currently exclude V2H/G in their warranties. In the meantime the Australian Renewable Energy Agency (ARENA) has released a roadmap (Australian Renewable Energy Agency, 2025) for widespread use of bi-directional chargers by 2030 "with several products available by 2027".

[7] https://www.climatechangeauthority.gov.au/reviews/light-vehicle-emissions-standards-australia/opportunities-reduce-light-vehicle-emissions

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Appendix

Tariffs

Melbourne electricity		Average
	Supply (c/day)	110.14
	Flat tariff (c/kWh)	24.23
	Feed-in-tariff	1.83
15-21 hours	Peak (c/kWh)	33.26
Other	Off peak (c/kWh)	19.74

Melbourne natural gas		Average
	Supply (c/day)	70.00
	Flat tariff (c/MJ)	3.00

Fuel price

Average $1.85/litre

Vehicle costs

ICEV	RAV4	Corolla	
On road costs	$41,318	$34,050	
l/100km	6	6	
l/year	802	452	1,254
$/year	$1,787	$1,009	$2,796
Maint	$345	$315	$660
Tax (5 years)	$4,647	$4,647	$9,294
	$41,295	$32,681	$73,976

EVs	Tesla Y	BYD Dolphin	
	$67,942	$40,415	
kWh/100km	13	15	
kWh/year	1,737	1,131	2,868
	$330	$215	$545
	$290	$277	$567
	$4,647	$4,647	$9,294
	$50,495	$32,527	$83,022

EV chargers 2,300

Solar PV

Installed prices inclusive of rebate and inverter

Dec-25	3kW	4kW	5kW	6kW	7kW	10kW
Adelaide, SA	$3,680	$4,010	$4,420	$5,000	$5,610	$7,630
Brisbane, QLD	$3,910	$4,420	$4,820	$5,300	$6,220	$8,250
Canberra, ACT	$3,890	$4,250	$4,740	$5,100	$6,140	$7,640
Darwin, NT	$4,530	$6,640	$7,480	$9,320	$10,200	$14,960
Hobart, TAS	$4,600	$5,460	$6,090	$6,910	$7,630	$10,870
Melbourne, VIC	$4,070	$4,530	$5,100	$5,670	$6,370	$8,450
Sydney, NSW	$3,570	$4,000	$4,650	$5,200	$5,900	$7,810
Perth, WA	$3,260	$3,600	$3,980	$4,650	$5,230	$8,430
All	**$3,940**	**$4,610**	**$5,160**	**$5,890**	**$6,660**	**$9,260**