Pathways for triple zero housing in Australia

Zhengen Ren

CSIRO Energy, Research WAY, Clayton VIC 3163 Australia

Abstract

In February 2019 the Trajectory for Low Energy Buildings in Australia identified cost effective opportunities for energy efficiency improvements through the building system. One of the key aspects in the Trajectory for residential buildings is to offer nationally accredited Whole-of-Home tool (WoH) for new houses. CSIRO was commissioned to deliver the benchmark WoH tool in the required timeframe. The benchmark tool (named AccuRate Home) for new housing was officially released to the public in June 2023.

With this benchmark tool, this study investigates pathways for triple zero (zero energy, emissions and societal cost) housing in Australia for housing design. Societal cost of energy includes an estimated retail price of energy used by the building and the broader 'cost' or 'impact' to society for the use of that energy. Case study was conducted for a typical detached houses under Typical Meteorological Year (TMY) climate files for major capital cities of Australia. With the National Construction Code (NCC) 2022 minimum thermal rating requirements of 7 stars for new houses, the results show that the largest PV and battery system (6 kW PV and 6 kWh battery) is required for the detached new house to achieve triple zero in Hobart, and the smallest PV and battery systems (4 kW PV and 2.5 kWh battery) required in Brisbane and (4.5 kW PV and 1 kWh battery) in Darwin. PV battery sizes are not larger than 5 kW PV plus 5 kWH battery for the other capital cites.

Methodology

The Whole of Home framework builds on the existing Nationwide House Energy Rating Scheme (NatHERS, https://www.nathers.gov.au) framework and technology by expanding NatHERS energy star rating of building envelop to WoH energy calculations and score rating for new housing design (Ren et al., 2023). The CSIRO Chenath engine (Walsh and Delsante, 1983, Ren and Chen, 2010) is applied to calculate energy requirements for space heating and cooling with hourly data over a period of one year. In collaboration with the NatHERS Technical Advisory Committee (TAC) and other industry experts, Whole of Home National Calculations Method (WHNCM, 2023) were developed for calculating the energy demand of a home, including space heating and cooling appliances, hot water system, lighting, pool and spa pumps, on-site solar PV battery system, plug-in appliances, and energy scale rating.

The societal cost of a fuel source is the sum of the energy tariff and the cost of the carbon emissions associated with the fuel. To calculate societal cost of electricity, different tariffs for peak, off-peak and shoulder will be applied. The costs of electricity, natural gas LPG and wood can be obtained from market survey to identify the average tariff in each state and territory, which are detailed in (WHNCM, 2023), and summarized in Table 1 for electricity.

Table 1 Energy value (societal cost) of electricicty for NatHERS assessments

	States and Territories							
Parameters	**NSW**	**Vic**	**Qld**	**SA**	**WA**	**Tas**	**NT**	**ACT**
Electricity – peak (c/kWh)	39.80	38.41	33.46	51.29	41.24	29.96	37.32	33.88
Electricity – shoulder (c/kWh)	25.97	25.17	21.91	33.20	26.83	19.34	24.30	21.86
Electricity – off peak (c/kWh)	20.44	19.88	17.29	25.97	21.06	15.09	19.09	17.05

Parameters	States and Territories							
	NSW	Vic	Qld	SA	WA	Tas	NT	ACT
Electricity – controlled load (c/kWh)	14.07	20.61	16.74	20.43	12.73	13.50	26.90	14.83
PV Export (c/kWh)	10.08	13.34	11.11	11.64	7.89	9.71	26.85	9.21

The energy value of a home is calculated by multiplying the net hourly fuel consumption by the 'societal cost' of the relevant energy source, and adding them together over a period of one year. Energy rating of the assessed house is calculated using the energy value of the benchmark building as a reference (WHNCM, 2023). The rating scale is defined between 0-150 in (WHNCM, 2023) here:

- 0 - represents the worst performance of the building
- 50 (Benchmark 1) - represents the benchmark building
- 60 (Benchmark 2) - represents 70% of the regulated loads for Benchmark 1 plus the plug and cooking loads
- 100 - represents net zero societal cost (free run)
- 150 - represents the maximum rating awarded under NatHERS

Case study

To investigate potential pathways to achieve thriple zero housing in Australia, a detached single-storey houses were used for simulations for capital cities of Australia states and territories. The house has four bedrooms, a kitchen/family area, a living/dining room, a rumpus, a kids TV room, a laundry, a separate bathroom and toilet, and a double garage. It has a gross floor area of 293 m^2 (air-conditioned floor area of 207 m^2). With combination of insulation to roof space and external wall, air leakage sealing, and timber double air-fill grazing windows, the house achieves 7 stars in all the capital cities. To achieve zero emissions in building section, fossile fuel can not be used for building operation. The case study was conducted for electricity supply only. With high performance electric-boosted solar hot water system with 45 STCs (small-scale technology certificate, https://www.cleanenergyregulator.gov.au), and 4-star non-ducted heat pump for space heating and cooling, the total annual energy consumption is shown in Figure 1 for the capitcal cities.

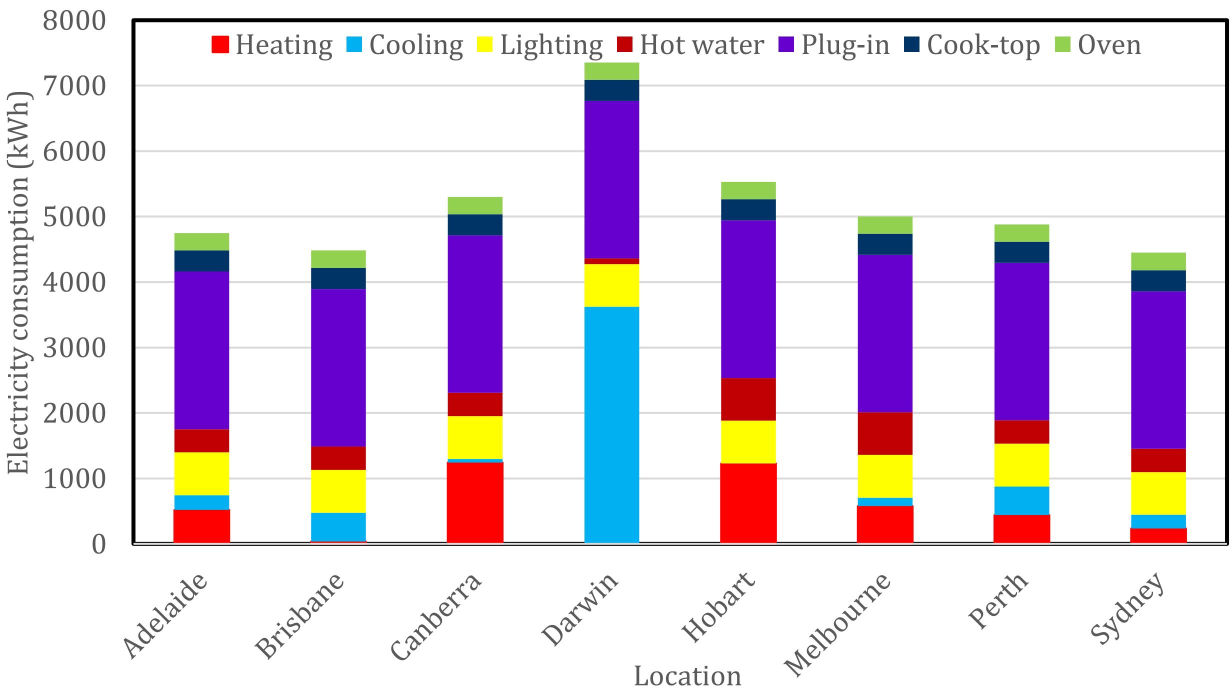

Figure 1. Total annual electricity consumption of the house in the capital cities

As expected, with this 7-star new house, It isn't reauired for space heating in Darwin and space cooling in Hobart. For space cooling, Darwin needs the greatest electricity, and Hobart needs the greatest electricity for space heating. With high performance HVAC (Heating, Ventilation and Air-Conditioning) system and high performance electric-boosted solar hot water system, energy consumption of plug-in appliances and cooking (cook-top and oven) accounts for the greatest part of whole-of-home energy consumption in the captical cities except Darwin.

When the annual electricicty generated by the roof-top solar PV isn't less than the total annual consumption of the house, the house becomes to net zero energy housing (also zero emissions as electricicty supply only). Solar PV sizes for net zero energy (emissions) are summarized in Table 2.

Table 2 PV sizes of net-zero energy (emissions) for the detached house in the capital cities

Location	Total energy demand (kWh)	PV size (kW)
Adelaide	4748.5	3.0
Brisbane	4482.1	2.6
Canberra	5301.6	3.3
Darwin	7354.6	4.4
Hobart	5529.5	4.1
Melbourne	5004.1	3.5
Perth	4881.5	2.9
Sydney	4448.3	2.9

As expected, it needs the largest PV for net-zero energy (emissions) housing in Darwin (4.4 kW) and Hobart (4.1 kW), the smallest PV in Brisbane (2.6 kW), and around 3 kW in Adelaide, Perth and Sydney.

As shown in Table 1, the societial cost of imported electrcicty is different to exported electrcicty by PV, the net energy value of the house can not be zero (i.e., free run) even the house being net-zero energy (i.e., the exported electricity is equal to the imported electricity). To achive zero societal cost housing, two options were conduected for this case study: PV system only and PV plus battery system. The resulst are shown in Tables 3 and 4 respectively.

Table 3 PV sizes for triple zero housing in the capital cities

Location	PV size (kW)	PV generation (kWh)	Electrcicty imported (kWh)	Electricity exported (kWh)	Net energy value (A$)
Adelaide	7.1	11324.7	2755.8	9331.4	-15.8
Brisbane	4.7	8065.8	2604.9	6188.0	-8.5
Canberra	6.8	11082.3	3169.5	8949.8	-4.0
Darwin	4.5	7577.5	4743.7	4966.7	-25.6
Hobart	7.6	10155.4	3350.9	7977.3	-2.9
Melbourne	6.1	8646.5	2935.8	6578.7	-12.6
Perth	7.9	13203.5	2784.3	11105.9	-0.5
Sydney	6.4	9746.5	2541.6	7839.3	-13.4

For free run housing, societal costs of imported and exported electricity play a key role for determing the PV size. In Darwin the societal cost of exported electricity is up to 26.85 c/kWh (near the averaged societal cost of imported electricity, see Table 1), 4.5 kW PV is required for free run housing (i.e., only additional 0.1 kW PV is required for the housing updated from double zero to triple zero). In Perth the societal cost of exported electricity is only 7.89 c/kWh, 7.9 kW PV is required for the house to be free run (i.e., additional 5 kW PV is needed for the housing updated from double zero to triple zero). For triple zero housing, Hobart and Adelaide also need large PV (7.6 kW and 7.1 kW respectively). With these PV installations the houses in all the captical citiese become carbon positvive housing (i.e, exported electrcicty is larger than the imported electrcicty).

As shown in Table 4, for triple zero housing, Hobart needs the largest PV battery system (6 kW PV + 6 kWh battery), Brisbane and Darwin require the smallest PV battery systems (4 kW PV + 2.5 kWh battery, 4.5 kW PV + 1 kWh battery, respectively) and Canberra and Perth both need large PV battery systems (5 kW PV + 5 kWh battery).

Table 4 PV battery sizes for triple zero housing in the capital cities

Location	PV (kW)	Battery (kWh)	PV generation (kWh)	Electrcicty imported (kWh)	Electricity exported (kWh)	Net energy value (A$)
Adelaide	5	4.5	7975.1	1523.7	4513	-23.36
Brisbane	4	2.5	6864.5	1897	4144.1	-18.44
Canberra	5	5	8148.7	1828.1	4413	4.69
Darwin	4.5	1	7577.5	4437.8	4605.7	-41.4
Hobart	6	6	8010.2	1857.9	4051.4	-2.39
Melbourne	5	4	7087.3	1869.7	3748.7	-12.19
Perth	5	5	8356.6	1426.6	4635	5.35
Sydney	5	3	7614.5	1714.2	4719.9	-25.1

Conclusions

With the AccuRate Home – the benchmark tool for whole-of-home energy calculations and rating, this study investigated potential pathways for triple zero housing in Australia under TMY climate. With the difference of the societal cost between imported electricity and PV exported being larger in Australia (except in NT), without battery storage the extra PV size is greater than 2 kW for most of the capital cities (except Darwin) for the 7-star detached house updated from double zero to triple zero housing. The PV size is up to 7.9 kW in Perth, 7.6 kW Hobart and 7.1 kW in Adelaide. Except in Brisbane and Darwin, the PV is greater than 6 kW in the other capital cities. Considering limited roof space and benefits of battery storage of on-site PV generation, PV battery system is a potential option for triple housing in Australia. Except Hobart, for three zero housing PV battery system is not greater than 5 kW PV plus 5 kWh battery in the capital cities. Darwin and Brisbane need the smallest PV battery systems (4.5 kW PV + 1 kWh battery, 4 kW PV + 2.5 kWh battery respectively). Hobart needs the largest PV battery system (6 kW PV, 6 kWh battery).

References

Ren, Z. and Chen, D, 2010, ‘Enhanced air flow modelling for AccuRate – A nationwide house energy rating tool in Australia’, *Building and Environment*, 45, p1276-1286.
Ren, Z., Jian, A., Law, A., Godhani, A. and Chen, D, 2023, ‘Development of a benchmark tool for whole of home energy rating for Australian new housing’, *Energy & Buildings*, 285, p11292.
Walsh, P. and Delsante, A, ‘Calculation of the thermal behaviour of multi-zone buildings’, *Energy & Buildings*, 5, p231-242.
‘Whole of Home National Calculations Method (WHNCM)’, available from https://www.nathers.gov.au/Whole-of-Home-Calculations-Method/ (assessed on 23 June 2023).