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Reservoir of hope

Can a positive-net-energy home also be comfortable?

AIRAH

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Reservoir of hope

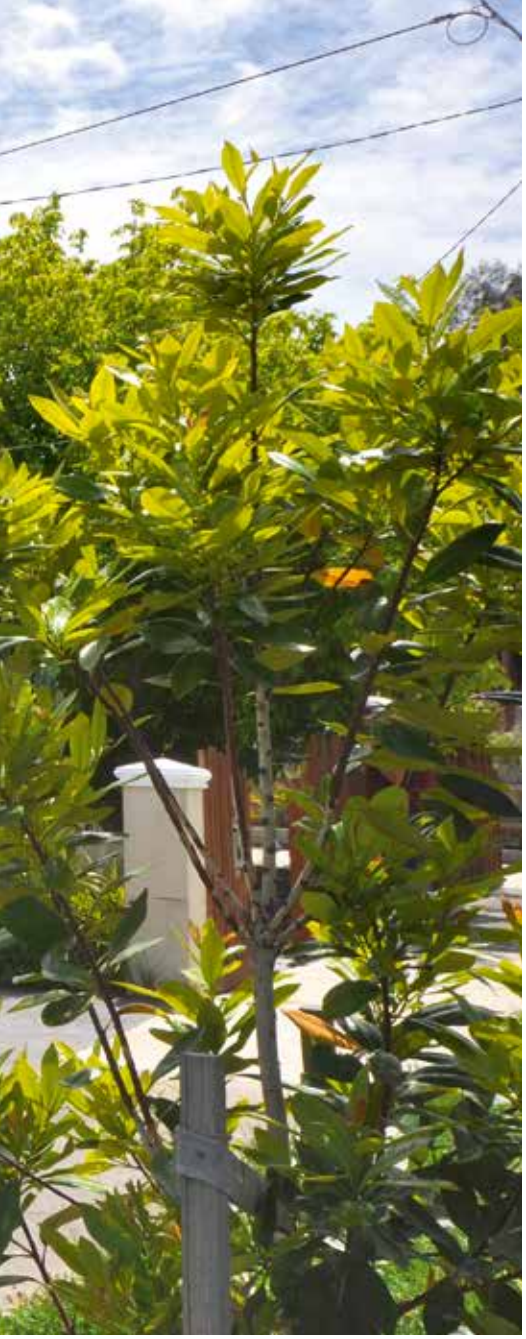
Can a positive-net-energy home also be comfortable? In this case study of a suburban Melbourne home we find out the (possibly) surprising answer. By Bruce Rowse, M.AIRAH, with Kyle O'Farrell and Chris Barnett.

If you are an energy zealot, like I am, your home probably has very low energy use. But there might be times when your inside clothing may well be the same as what you wear outside – even down to the beanie and gloves in winter.

But homeowners Kyle O'Farrell and Nicola Thomson – and modular home designers Habitech Systems – have shown that in Melbourne you can have a home with positive net energy consumption that is also very comfortable. And in June 2016, while I had my beanie on, for Kyle and Nicola their average home temperature was 19°C.

This new 150 m^2 home housing a family of four in Reservoir, Melbourne has been occupied since early 2015. The house has no gas connection, with an all-electric kitchen. It uses electricity to power two reverse-cycle air conditioners, which provide space heating and cooling.

It has a heat pump hot water system, energy-efficient lighting, and energy-efficient passive design. Using modular structural insulated panels and high-performance windows, it's very well insulated and sealed. A heat recovery ventilator provides filtered fresh air and a grid-connected 7.6kW solar PV system is installed on the rooftop.



THE DESIGN BRIEF

"We had a great design brief for the project from Kyle and Nicola, who wanted to build a zero-emission home that could house their family comfortably and maximise the opportunities of their property," says Chris Barnett of Habitech Systems, the house's builder. "Their brief was informed by Kyle's background in sustainable material consulting, and aligned well with our approach to designing and delivering high-performance modular building envelopes.

"The form of the house was driven by the site's orientation. With north being at 45 degrees to the rear of the block the raked parapets of the street façade integrate a PV solar array that is oriented due north for maximum solar generation – we believe batteries and feed-in tariffs will change faster than the path of the sun. The living areas receive full winter sun, with an operable roof rolling between two C-section steel beams provide summer shade. We undertook shading analysis and awning design so that no summer sun hits rear glazing at any time of the day."

NET EXPORTER OF ENERGY

Based on the home's power bills, the home was a net exporter of electricity to the grid, with a net export of 4,156kWh of clean solar power over its first year of occupancy. This means that the home's PV system not only reduces the operational carbon emissions to zero, but it also offsets another five tonnes of carbon dioxide from electricity production annually.(i)

Excluding the solar energy produced, its total annual electricity use averaging 16.9kWh/day, is around 57 per cent of that of a 6 star home in Victoria.(ii)

The total electricity bill cost was $640 (including GST) across the year from October 2015 to September 2016, including the feed-in tariff payments for PV exports. Of this, $420 was the daily service charge, with a net cost of electricity purchases of $220. This compares well to the total electricity cost estimated to be $2,200 for a typical 6 star home.(iii) As the home is not connected to gas there is no gas bill.

Kyle and Nicola installed sub-meters on the electricity supply to various parts of the house, which have been operational since April 2015. This has made it possible to determine where energy is used in the house, and to isolate consumption from solar PV generation (something that a power bill doesn't capture).(iv)

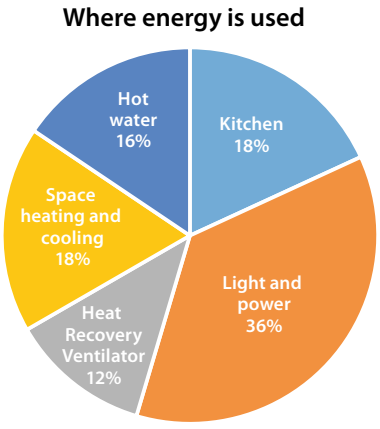


Figure 1: Breakdown of energy consumption.

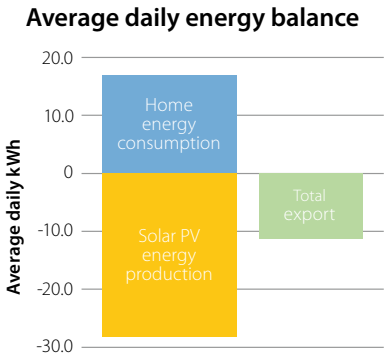


Figure 2: Average Daily Energy Balance.

VERY LOW HVAC ENERGY USE

HVAC energy use is very low, accounts for only 30 per cent of home energy use – or just 1,850kWh over 12 months – and less than is used for light and power. Such low HVAC energy use is due to:

- Good passive design and orientation.
- High levels of wall, roof and floor insulation. Half of the building has a raised timber floor above a garage, with R3.2 spray foam insulation underneath. The other half is an on-ground concrete slab, with under-slab and perimeter insulation. The walls and roof are built from structural insulated panels (SIP), which provide outstanding insulation performance. A typical timber framed house will use bulk insulation in the walls and roofs. It is very hard to install bulk insulation perfectly, with no compression and no gaps, especially around corners and the edges of the ceiling. SIP panels on the other hand provide uniform, gap-less insulation. Habitech's wall panels have an R rating of 4.3, and the roof panels are R5.3.

Figure 3: Construction detail showing the join between wall and roof SIP panels

The back patio features an operable roof.

- High-performance windows: uPVC framed, with argon-filled clear double glazing.
- A highly sealed building fabric. A blower door test showed the air leakage rate was 1.15 air changes per hour at 50Pa (ACH50). This is much lower than the typical range of 10 to 28 ACH50 for 5 star homes as tested by Air Barrier Technologies, who undertook the blower door test.
- High-efficiency reverse-cycle split-system air conditioners.

Actual energy space heating and cooling energy consumption corresponds to a home energy rating of 8.5 stars.[v]

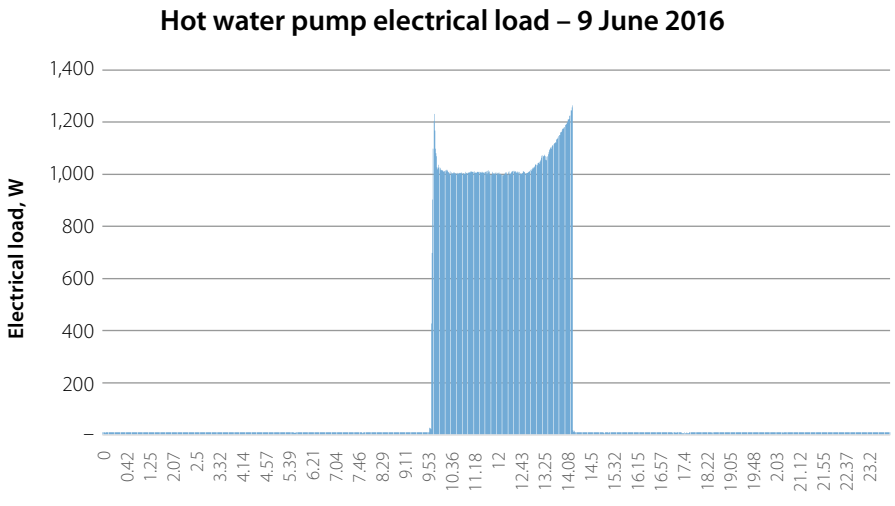


Figure 4: Hot water heat pump electrical load, minute by minute, over one day.

"The Habitech design team did some great work and was well-priced," says Kyle, "and produced an excellent custom design for us."

THE HOT WATER HEAT PUMP

The hot water heat pump with CO_2 as a refrigerant uses one-fifth the energy of a gas hot water service.

Hot water energy use is also low, averaging just 2.6kWh/day.

This is just 19 per cent of the expected energy consumption of a 6 star gas hot water heater.[vi]

The hot water heat pump uses CO_2 as a refrigerant. It is set to operate from 10am each day so as to use solar power that would otherwise be exported. One-minute interval power logging clearly shows refrigerant head pressure building as the water in the tank approaches the 60°C set-point, prior to it shutting off, see figure 4.

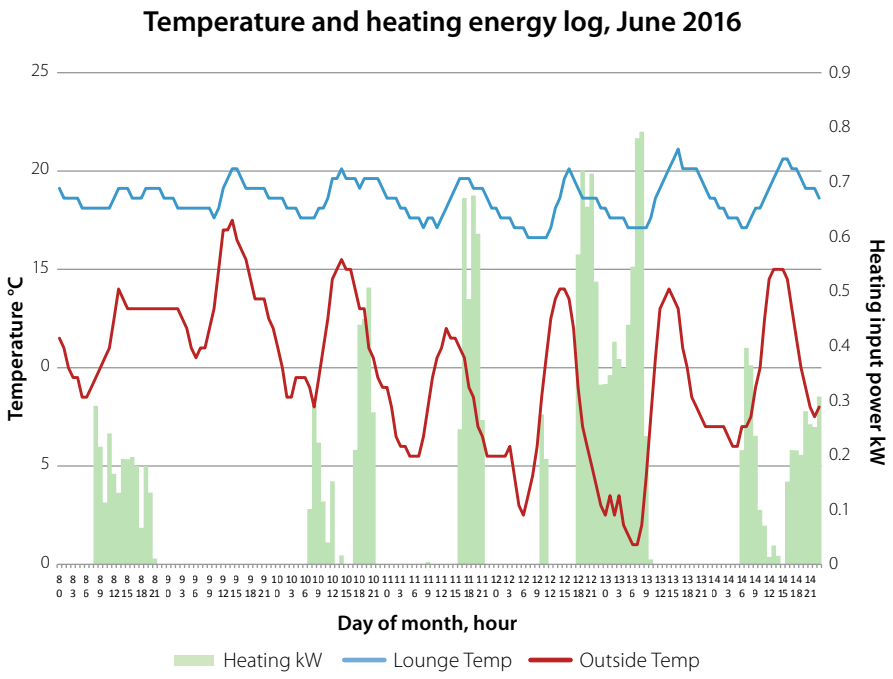


Figure 5: Temperature and heating energy log over one week in June.

A COMFORTABLE, HEALTHY HOME

In comparison with Melbourne homes of 5 stars or more, which have an average winter-time temperature of 17.9°C, this home is even warmer, with an average winter temperature (June 2016) of 18.6°C.[vii]

Over the month of June temperature was logged in the house and outside,

Habitech Systems' managing director Chris Barnett on site with senior architect Jon Pye.

Owner Kyle O'Farrell can relax now that the house is complete.

at one-hour intervals. The graph representing one week, shows temperature inside the lounge room, outside temperature and hourly heating energy supply to the split-system reverse-cycle air conditioners.

Note the stable indoor temperature and the limited use of the home's heating, in comparison to the variation in outside temperature. On cold, but clear sunny days with plenty of sun, little or no additional heating has been required.

Some side benefits of the home are that with no gas connection, there are absolutely no natural gas, nitrogen dioxide, carbon dioxide and carbon monoxide emission risks, or water vapour combustion waste to vent from the home. The timber-panelled walls are treated with a linseed-oil-based sealer with very low VOCs, and the heat-recovery ventilator provides filtered fresh air throughout the house while also extracting stale air. This provides internal air quality that is better than most homes, new or old.

"Thermal performance was always one of our top design/construction criteria, and our new place has definitely met our goals in this regard," Kyle says. "Getting good attention to detail on air sealing during construction was more of a challenge than we were expecting, but we got there in the end."

Relative humidity was also monitored in the lounge room over June 2016. It varied between 49 per cent and 76 per cent. Although the home is tightly sealed, the use of the heat-recovery ventilator has kept internal humidity within a comfortable range. The use of the SIP panels, and the tight sealing of the home, means that there is no pathway for warm humid internal air to condense on, and thus damage cold structural elements of the building framing.[(viii)]

THE HEAT-RECOVERY VENTILATOR

For such a tightly sealed home the heat-recovery ventilator (HRV) is essential. To maintain the high degree of sealing of the home, the kitchen range hood discharges directly into the kitchen, near where the return-air vent to the HRV is located. This has worked well, and provides a clear path to extract water vapour from the kitchen to outside while cooking. The set-up also avoids the need to put another hole in the house or install the kitchen range in a recirculating configuration with the need for carbon filters, which require reasonably regular changeover and additional expense.

Bathroom air is directly vented into the HRV.

The rigid PVC ducting used in the HRV system has led to some noise issues from the unit. Kyle has installed an acoustic damper on the discharge of the HRV to reduce this noise.

The HRV has been located in a cupboard to enable easy access for servicing, which is typically on an annual basis.

GREENHOUSE GAS CONSTRUCTION IMPACTS

The greenhouse gas impacts of the home's construction are dominated by the 130 tonnes of concrete used in the living room and garage slabs, with emissions of around 15–20 tCO_{2e} for the installed concrete alone. Other than the SIPs and structural timbers, the rest of the dwelling relied heavily on recycled bricks and timber. The greenhouse gas impact of the full dwelling has not been calculated but is possibly in the order of 25 tCO_{2e} according to Kyle.

COULD THIS BE THE WAY FORWARD?

As Australia moves towards a low-carbon future this home demonstrates that it is possible to have both a zero-net-energy home, and one that is very comfortable. ▮

The trademarked modular shading system optimises shading to individual windows.

Notes

(i) Based on an end use electricity emissions factor for Victoria of 1.19kg CO_{2e}/kWh. www.environment.gov.au/system/files/resources/e30b1895-4870-4a1f-9b32-3a590de3dddf/files/national-greenhouse-accounts-factors-august-2016.pdf.

(ii) The home used 6,180kWh over the 12 months to April 30 2016. Fourteen Victorian homes ranging from 5 to 6 star were monitored over a year to determine their average annual energy use (by Ambrose MD, James M, Law A, Osman P, White S (2013) *The Evaluation of the 5-Star Energy Efficiency Standard for Residential Buildings.* CSIRO, Australia). Average total annual kWh was 12,401kWh. Since this time the 6 star standard has come into force for all new homes. 6 star homes are estimated to use 24 per cent less cooling and heating energy than 5 star homes (www.vba.vic.gov.au/consumers/6-star-standard). There is no published data, showing how much of a 6 star home's energy use goes into heating and cooling. But this is assumed to be 50 per cent*, which would mean that a 6 star home should use around 12 per cent less than a 5 star home. Assuming that the CSIRO metered homes where all 5 star homes (nine were 5 star homes, two were 5.5 star and three were 6 star), this would mean that the average Victorian 6 star home would use around 10,913kWh a year. The Reservoir home's energy use, at 6,180kWh, is 57 per cent of this.

* *The Residential Energy Baseline Study for Australia 2000–2030,* published 2015, showed that in 2014 for the average Victorian home heating and cooling comprised 59% of energy use; this was projected to drop to 58 per cent by 2030. This looks at all houses, not just new houses compliant with the 6 star standard. On this basis it's unlikely that a 6 star home would use more than 50 per cent of its energy for space heating and cooling.

(iii) Annual cost at the home based on electricity bills. Note that while the house was a net exporter of electricity, due to the low solar feed-in tariff plus connection and service fees, there is still an energy cost. Annual cost for a 6 star home based on the average of actual bills for 14 Victorian homes ranging from 5 to 6 star. (Ambrose MD, James M, Law A, Osman P, White S (2013) *The Evaluation of the 5-Star Energy Efficiency Standard for Residential Buildings.* CSIRO, Australia), which was $2,306. It's assumed energy tariffs are unchanged, and that energy costs in a 6 star home uses around $100 less (as claimed at www.vba.vic.gov.au/consumers/6-star-standard), or around $2,200 a year.

(iv) Checking the sum of consumption from these meters shows that the total is within 1 per cent of the actual power bill, indicating

The street facade form was generated by the mounting of PV panels.

high accuracy. The hot water was metered on the same circuit as the reverse-cycle air conditioners. However, by undertaking a minute-by-minute analysis of consumption over June it was possible to isolate average daily hot water energy use as 2.64kWh/day. Average monthly hot water energy use is assumed to be 90 per cent of this to account for lower summer hot water demand. Similarly, the heat-recovery ventilator (HRV) was metered on the same circuit of light and power; however, spot measurements showed an average power draw of 85W. The HRV operates all the time, using just over 2kWh/day.

(v) The homes space heating and cooling energy use (ventilation not included) over the 12 months to March 30, 2016 was 30.2MJ/m^2 (m^2 is based on conditioned area). In Melbourne 8.5 stars corresponds to 39MJ/m^2 and 9 stars to 25 MJ/m^2.

www.nathers.gov.au/files/publications/NatHERS%20Star%20bands.pdf

(vi) Based on a 6 star gas hot water heater using 18,785MJ/year.

www.elgas.com.au/blog/450-star-ratings-for-gas-hot-water-heater-systems.

(vii) Winter-time internal temperature of 17.9°C for 5 star or more homes in Melbourne as reported by Ambrose MD, James M, Law A, Osman P, White S (2013) *The Evaluation of the 5-Star Energy Efficiency Standard for Residential Buildings.* CSIRO, Australia. This was based on measurements in the main living area, using data loggers at half hour intervals, in 14 houses of between 5 and 6 stars. The same logger types were used to log the Reservoir house, recording an average lounge room indoor temperature of 18.6 °C at one-hour intervals over the 30 days of June 2016.

(viii) Temperature logging was undertaken using a popular make of data loggers. Logging was undertaken at one-hour intervals. The logger used outside has a manufacturer-stated accuracy of plus or minus 1°C. It was placed in a shaded position on the wooden fence on the east side of the backyard. The logger was position where it would be reasonably well ventilated. However, radiant warming of the fence by the sun may have increased recorded temperatures on sunny, still days.

The logger used to measure lounge room temperature was a combined temperature and humidity logger, with a manufacturer-stated accuracy of plus or minus 0.5°C for temperature readings. It was located on a bookshelf near the brick wall, in a position away from the room air conditioner, away from ventilation registers and away from windows. It was located at roughly head height. There was no or minimal direct line of sight from the logger to the windows. It's likely that it provides a reasonable representation of temperature in the position where it was placed.

PROJECT AT A GLANCE

The personnel

- **Architect:** Habitech Systems
- **Builder:** Henry Netherway, Pty Ltd

The equipment

- **Heat-recovery ventilator:** Atlantic Duolix Max
- **Hot water heatpump:** Sanden Eco HWHP (315 L)
- **SIP panels:** Habitech Systems
- **Split systems:** Mitsubishi Heavy Industries SRC25ZMXA-S/SRK25ZMXA-S
- **Temperature loggers:** Dallas instruments i-button Thermochron loggers
- **Windows:** Windows for Life (Deceuninck uPVC Tilt and Turn Window – double-glazed. Double-gasket seal).