SUSTAINABLE HOUSE DAY - BACKGROUND, EXPLANATIONS to help answer QUESTIONS

Location:




Top left - Front of house, escarpment in background; Top right - escarpment view (Brokers peak) from westerly window; Bottom left - same view in telephoto; Bottom right - Reverse telephoto view of house from Brokers peak; solar panels added later are not visible

We had planned to buy a block of land or a knockdown rebuild in Sydney and put up a fully insulated and sealed house. It would have needed heating/cooling, if at all, only for a short period early morning and/or evening and would have given a constant ~22C irrespective of outside extremes. However, we ended up with an attractive property ~3km from the sea, where the seasonal and daily temperature ranges were moderate. It was feasible to greatly enhance the existing passive design and add many energy efficiency features. The aim was to be energy positive and have zero emissions, without going to extremes of sealing and insulation.


Photos showing near-coast location: Left - sea view (~3km) from easterly window Right - same view in telephoto

Passive Design: The house, facing slightly west of north, had covered decks on all sides which could transmit low-orientation sun while shading high-orientation sun from the downstairs living areas. These areas had numerous windows giving excellent garden, bush and escarpment views while being shielded from neighbours. Therefore reflective roller blinds were chosen to maintain this visual outlook while reducing glare, ultraviolet and infrared (heat).

One of the 12 reflective blinds in the halfway position to show comparative outlooks
UV rejection >99%; Glare reduction 92%; Energy rejection 49%
Bronze/Bronze selected: "Enhances garden/bushland views and goes well with timber window frames"

The upstairs bedroom, bathroom and office areas had no external shading and were less private. Honeycomb blinds were appropriate and were used on all upstairs windows and on downstairs windows facing the street. Some of these blinds could be opened top down or bottom up to provide selective shading and views.

Photos show effect of honeycomb blinds - good protection from UV, Glare and Heat, with some light transmission but (unlike reflective blinds) views are cut off

The remaining, high clerestory windows of unusual shape *(example in photos above)* were coated with metallic films, similar to the reflective blinds. These films gave 99% UV , 82% glare, 70% heat rejection and of course are fixed in position.
Although all blinds represent "passive" design, they were actively managed, together with the windows themselves, for best outcomes according to time of day and seasonal changes. Basically, closed when one wants to keep the sun and/or external hot/cold air out of the house, and open when one wants to let sun and/or external hot/cold air into the house. The numerous blinds were complemented by a few outside awnings *(photo, left)* for supplementary shading; and by inside curtains *(photo, right)* for flexibility or for closing off unused areas to help focus air conditioning needs. Lockable security doors and windows could be left open, overnight if necessary, for maximum cross-ventilation whenever required.

In a 2-storey house warm air rises and cold air falls, allowing the several reverse cycle air conditioners to also be actively managed. For example winter heating in the downstairs living area in the evening can flow up to the bedroom(s), while daytime summer cooling in the upstairs offices can flow down to the kitchen and living areas to help provide evening comfort.

A Velux double-glazed electrically-operated skylight - *photo left* -was installed (replacing a translucent plastic sheet) to minimise heat build up (or cold air entry) at the highest part of the house.

The mix of cathedral and flat ceilings and complex attic space was insulated with Bradford Gold Glasswool Batts (R3.5 and 4.1) to the pitched ceiling and R2.0 batts to the raked walls in the ceiling space.

The colorbond roof required repainting and special reflective paint of the same green colour was used. There have been misleading claims about the effectiveness of such paints, especially as lighter coloured ordinary paints are at least as good (in fact white is best but is almost never allowed/used). Our independent contractors expected a small difference, which we have since observed.
Contractors spraying reflective paint on the less accessible parts of the roof

The overall effect of these combined design features was to delay any need for cooling upstairs even on hot (30C+) days until mid to late afternoon. The heat stored in the attic and roof insulation, potentially released at night into bedrooms, was partially removed via whirlybirds, solar ventilator and ceiling fans. These vents were closed in winter to minimise heat losses.

The insulation aspect of the house is incomplete, notably on the extensive east and west-facing brick walls that are hot in summer and cold in winter. Also while draught-proofing has been improved, it is inadequate particularly on the regular windy days. Therefore cavity wall insulation and professional weather sealing are next on the agenda.

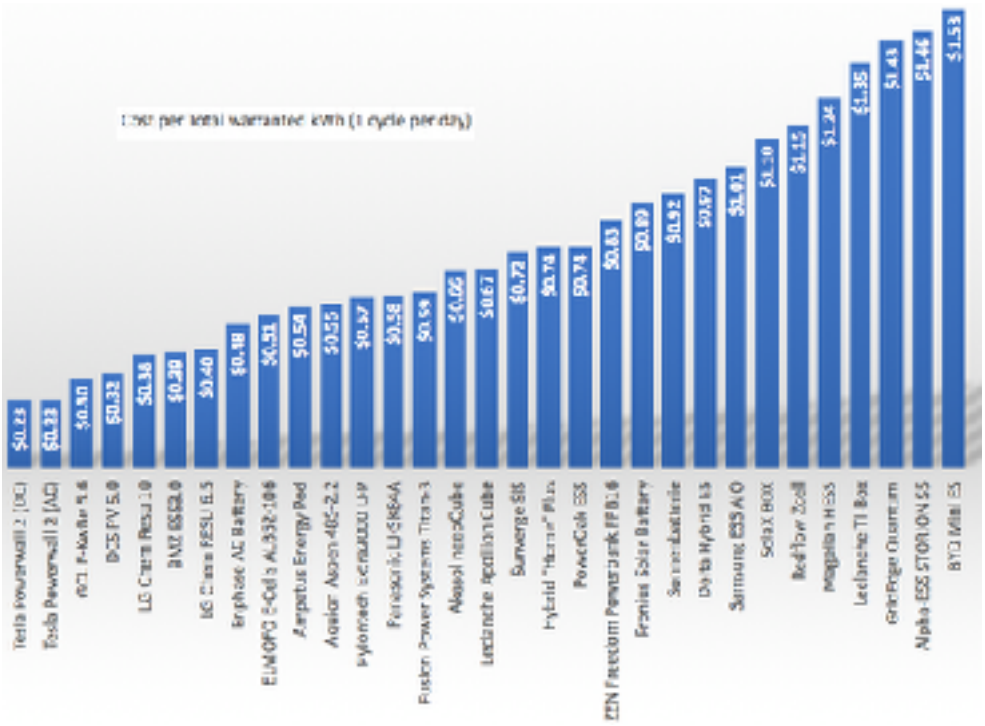
Active Energy Efficiency Measures - Solar and Batteries
Several sets of solar panels were installed from 2013 to 2018, adding up to 9.17kW nominal peak capacity. This is not reached because the different orientations have optimum sun at different times, but the advantage is achieving good generation at all times from sunrise to sunset.

AGL offered a subsidised Power Legato battery (6kWh useable capacity) in 2015 - we were early adopters. In Sept 2016 we added a Tesla Powerwall 2 battery that tripled our kWh storage capacity. Coincidentally, three months later later AGL offered a free upgrade. A second Tesla was the best option and AGL gave a full refund towards that - still awaiting installation at the time of writing. We thus had free use of the Power Legato for over 2 years, plus AGL recently offered its Solar Saver feed-in tariffs of 20c/kWh for the considerable solar we now export!

14kWh capacity, 5kW power, blackout protection

Because of the different orientations of the solar panels and partial shading issues, individual microinverters (below left) are a feature of the newer panels, while the original 12 panels were fitted with Tigo optimisers (below right) to maximise their input to a conventional Solis string inverter. All panels, the Tigo optimisers and the Tesla battery are monitored via the internet and real time displays *(photos underneath).* These also provided for daily, weekly and monthly data collection and performance analysis, including close agreement with the official meter box readings of solar exports and grid consumption. The data also allow for trouble shooting, though this has not been needed to date. Grid regulations limit the export power for single phase systems, in our case to 5kW. The microinverters automatically adjust for this.

An independent analysis in 2016 *(chart below)* of numerous battery systems showed the Tesla to be the most cost-effective. Still not necessarily an economic return proposition relative to investing in (say) a term deposit. The Tesla has effectively halved in price per kWh in about a year, demonstrating how battery costs will continue to fall. So real returns on investment can be expected in the near future, particularly with feed-in tariffs like AGL's 20c/kWh for unused solar.



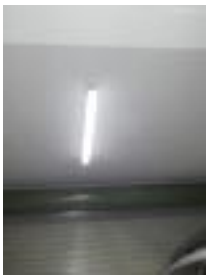
Our Savings: At the time of writing (August 2018) the system is generating close to 40kWh/day on the numerous sunny days when we only use ~10Wh/day, with almost zero from the grid. So the exports are earning up to $6/day. Compare that with the ~$725 debit in the winter quarter before the solar, batteries, insulation and other measures. A large part of that much higher consumption was for air conditioner heating early morning before sunrise and from early evening after sunset, which illustrates the advantages of battery storage. There may be fewer sunny days ahead but the the non-winter seasons provide higher generation (as well as lower consumption) so it is not unrealistic to hope for $2000 credit per annum compared to an annual debit of about that amount in the past. The grid connection charge is not unjustified for the safety it provides when there is little sun for 2 days or more.

Heat Pump Hot Water System:
As part of the plan to make use of the new solar output (and go off gas), a Sanden heat pump hot water system was installed to replace our 8 year old gas hot water system. This heat pump was 1.0kW and high efficiency (COP ~4.5) such that it provided 4.5kW thermal. It required only up to an hour or two each day of ~1kW of solar input to maintain 315 litres of hot water.
It also featured CO2 as the heat transfer medium (refrigerant R744). This means a greenhouse neutral lifecycle.
Conventional refrigerants are now ozone-friendly but very greenhouse-intensive!

Induction cooktop; Gas account closed:

To maximise utilisation of the combined solar output and battery storage, we replaced our gas cooktop with an electric induction cooktop *(photo)*. Then closed our gas account.

Near 100% LED lighting – downlights, screw/bayonet, floods, strips:
We replaced nearly all halogen, incandescent and fluorescent lights with LEDs. As a result we have LED downlights, strip lights, floodlights and bayonet/screw globes *(photos below).* The total wattage is about 20% of the former situation. We also upgraded some older electric appliances to energy-efficient models.



Electric bikes for recreation; Electric car on order - Solar charging:
Lithium batteries drive 24V, 36V and 48V motors. These motors are located on the front wheel, central drive and rear wheel on different bikes. The central drive is most efficient.

Photos L to R show our e-bikes with front wheel, drive chain and rear wheel motors

A Tesla Model 3 was reserved in 2016 and delivery should be 2019. Top up charging from solar and Tesla Powerwall batteries on a daily basis or full charging on a multi-day basis can in principle be done without use of grid electricity.

Gardens: Considerable effort was expended to remove weeds, exotics, tree stumps etc from the gardens and lawns, to revitalise the soil, provide new garden beds, compost bins, worm farm etc. Drainage, termite protection and underfloor ventilation were all improved.

Revitalised garden

Rainwater tanks were installed at the rear of the garden while protecting Illawarra flame trees located there. These tanks connected via a long trench under the lawn to the underfloor of the house and up to three downpipes. Gravity flow fills the tanks and a pump provides good pressure to three taps, including one at the front garden a long way from the tanks. This was a much better approach, based on expert advice, than smaller tanks or bladder tanks under the house and elsewhere. The trench works are now invisible and the tanks themselves will be screened by native shrubs growing in the raised garden bed in front.

This effort extended to the bushland and creek area adjacent to the back fence and accessible from the gate there. Although it belongs to Council or National Parks, who do not have the resources to maintain everything, we felt a responsibility to rehabilitate and look after the area next to and beyond our boundaries. Weeds, exotics, dead trees, fallen branches etc were removed; the stream bed cleared upstream and downstream; paths and steps *(photo)* (re)constructed; soil processed, fertilised and terraced; an old chicken coup repaired and used for a compost heap and storage. Council Bushcare advised on, and provided from the Botanic Gardens, suitable plants and shrubs to help stabilise the stream banks.

Recycling: Logs and branches were recycled for garden borders, pathways etc (photo below left). Many more were used along with other “green litter” to protect the stream banks, both from erosion by floodwaters and to limit the spread of weeds. Council Bushcare had suggested this, while unusable and weeds went to the Council Green Waste Facility. Excess pavers and bricks left under the house were also reused for borders, paths and raised garden beds (photo below right). Wood also left behind replaced rotted fence posts. A long aluminium drain cover from the scrapyard made an excellent bridge over the stream (photo bottom left). A bee “hotel” was made by drilling holes in suitable logs and placing these in a recycled letterbox (photo bottom right).

Waxwood, available locally, was used instead of toxic treated pine for terracing the front garden down from street level - *photo left*

The end result is an attractive and shady rainforest area that attracts birds, frogs and other species. We have contributed to a “citizen scientist” study by academics of the bird species by photographing and identifying the numerous visitors. The creek can now flow freely and more directly - at least in times of rain!