Appendix 4: Residential Case Study

Outline

This case study outlines the example of a Melbourne home retrofitted according to recommendations in this report. The home is a renovated timber dwelling, home to a family of two adults and two children. Improvements have been made progressively since 2007. 2006 is used as a baseline year for comparison. The occupancy and form of the house has remained consistent over the study period. Floor area is 195m^2 (179m^2 conditioned). The home also hosts a battery electric vehicle but the energy consumption of the EV is analysed separately to that of the home, *ie* consumption figures in this document exclude the EV.

The changes made to the house have led to a reduction in energy consumption of approximately 70%. After taking into account Solar PV generation, a net mains energy reduction of about 100% has been achieved. The use of mains gas has been eliminated (see Part 1 of the main report for a discussion about the role of gas).

Figure A4.1 Case study home

Improvements

The notable energy-related improvements implemented were as follows:

- 2007: Additional ceiling insulation, First PV array
- 2008: Sub-floor insulation, Induction cook top, Replacement refrigerator
- 2009: Draught proofing, Solar/electric hot water service
- 2010: Double glazing
- 2011: Gas heater removed (after heating season), High-efficiency TV, LED lighting, Second and third PV arrays
- 2012: Replacement reverse-cycle air conditioner
- 2013: Wall insulation

Solar PV

Figure A4.2: Solar PV at case study home

Three separate grid-connect photovoltaic (PV) systems have been installed totalling 5.0kW. The first system, 1.3kW in size, was installed in 2007. The balance of PV was installed in late 2011. The system is yielding approximately 6600kWh/annum (18kWh/day) of which about 3/4 is exported. The use of three separate PV arrays was influenced by reducing PV costs over time. If starting again, it would be affordable and practical to install a single 5kW PV array.

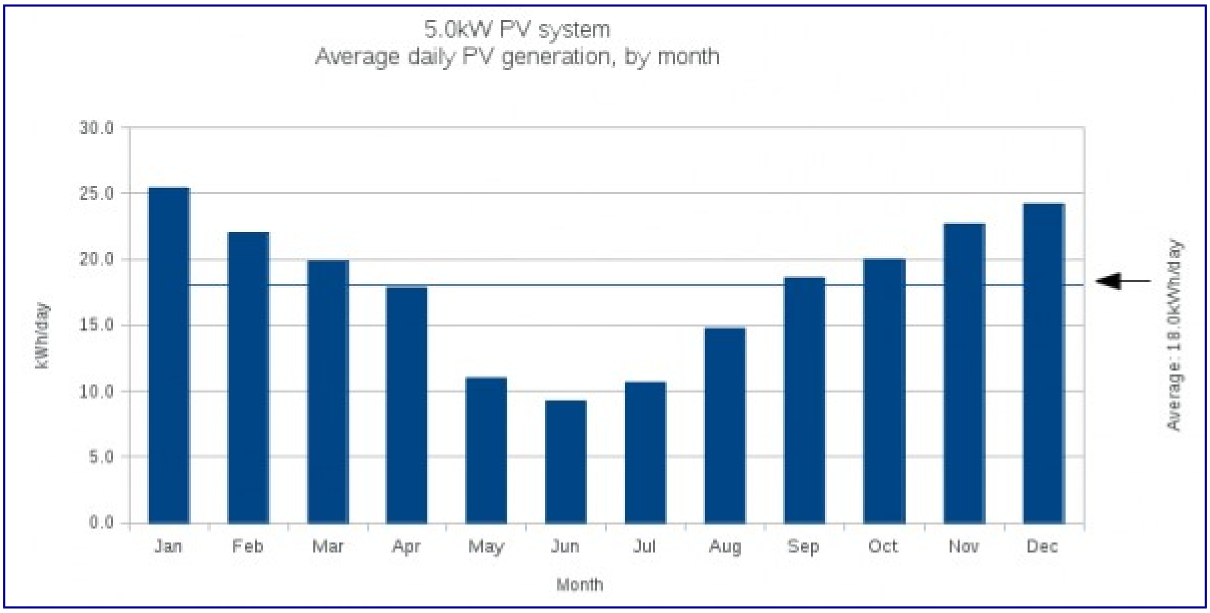

Figure A4.3 PV yield

Insulation

Insulation was improved in 2008, 2009 and 2013. Pre-existing and improved insulation is outlined in the table below:

Table A4.1: Insulation added R values

Section	Baseline	Improved
Main Ceiling	R2.5 bulk batts	Net R6.0 bulk batts, plus Aircell under roof battens
Ceiling of upstairs area	R2.0 bulk batts	no change
Walls	none in old part of house, R1.5 batts in upstairs renovation	Injection foam insulation in all downstairs walls. Added R value estimate to be 2.0 in brick wall and 2.5 elsewhere.
Under Floor	none	R2.5 batts, plus Aircell under floor joists[1]

Glazing

The house was fitted with EcoGlaze on all windows in 2010/2011. This reduced the thermal conductivity of the windows to a level approaching sealed double glazing units at a much lower cost and without the waste associated with discarding old single-glazed windows. EcoGlaze involves adding a perspex glazing element which is held in place with magnetically mouldings, allowing easy removal of the glazing element for cleaning.

Figure A4.4: Secondary glazing

Lighting

In the baseline year, the house already had compact fluorescent lamp (CFL) bulbs in most light fittings. As part of the upgrades, the house was fitted with LED bulbs, mainly from EcoFire, in 2011. In most light fittings CFLs were replaced with LED bulbs requiring about one third to one half the electrical power. 500W of halogen lights in the family room were replaced with new fittings and LED bulbs drawing a total of 54W. This reduced the lighting power density of the entire home to 1.8 W/m^2, which significantly exceeds the performance standard defined under the Building Code of Australia.

1 Note that fitting Aircell (or any foil insulation) between floor joists is no longer an approved method under Australian standards because of the potential for electrical hazard.

The LED bulbs have performed very well giving a satisfactory warm white output. In the short time since installation, the performance and cost of available LED bulbs has further improved.

Draught proofing

Energy lost through uncontrolled air flow has been significantly reduced by fitting of readily available seals around windows and doors. In addition, professional draught proofing was performed which:

- replaced normal exhaust fans with models which are sealed when stopped;
- sealed unused fireplaces;
- sealed redundant wall vents;
- added quad timber mouldings around skirting boards where appropriate;
- added high-grade door seals;
- sealed off ceiling vents leaving the register in place following the removal of ducted central heating.

The house did not have any down lights to be sealed.

Figure A4.5: Air-tight exhaust fan

Hot water

The original hot water service was a five-star gas storage system. This was replaced in late 2009[1] by a hybrid system combining an evacuated-tube solar collector with a Quantum 340L heat pump storage hot water system. The result was a system which is estimated to use about 90% less energy than the system it replaced. The system has the solar collector mounted with a slope of about 64degrees to optimise for winter operation. This has the added advantage of minimizing overheating in summer.

Other measures which improve efficiency are:

a. *Smart setpoint control*. In Australia, hot water services are normally controlled with a fixed set point of 60C. The control of this hybrid heat-pump/solar system is done by a controller which boosts to 60C only as often as required to keep the water free of legionella. This control regime follows the standard AS/NZS 3498-2009;

b. *Valve Cosy*. The pressure temperature relief (PTR) valve is insulated with an insulating shroud called a Valve Cosy. This substantially reduces the loss of heat by conduction through the PTR valve;

c. *Extra pipe lagging*. Pipes (solar and service) have been insulated to a higher standard than normal to minimise losses.

Figure A4.5: Evacuated-tube solar collector at 64º slope. Mid-day, mid-winter. Note shadow angle at right angle to face of collector

Figure A4.6: Heat pump hot water unit

The measured average hot water usage is about 140L/day. The electrical energy consumed by the system for 2012 was estimated at 497kWh (1.36kWh/day). During this period the system had two faults which significantly effected performance. These faults have since been rectified. Annual hot water mains energy requirement is now estimated to be 200kWh. By way of comparison, under AS/NZS4334:2008, the annual mains energy requirement of a standard reference electric hot water system (Zone 4, small load) is 10,280MJ (2855kWh). The average Australian house uses about 9.2kWh/day for hot water. The estimated 'normal' usage for the case study system represents a reduction of about 94% from the national average.

Appliances

Refrigerator. In 2008 the 20-year-old fridge was replaced with a new one of the same size. The new fridge has an estimated energy consumption of 544kWh/annum based on 19 days of monitoring.

Television. In 2011, a replacement TV/media centre was installed. This new unit draws 83W and replaced an older system which drew 216W when operating. The standby power of the new TV is only 0.1W. This is a 62% reduction in energy, assuming same utilisation. Based on an estimated average usage of 2h/day, consumption will be 60kWh/annum.

Cooking

Figure A4.6: Induction cooktop

In 2009 the conventional gas cooktop was replaced with an electric induction cooktop. The main motivation for using induction was to eliminate gas in the kitchen. The principles and benefits of induction cooking are fully described in Part 3. The use of induction for cooking has fulfilled expectations, with operation being more favourable than the gas system it replaced.

Standby power

Figure A4.7: Switched powerboard

Figure A4.8: Ecoswitch

Measures to control standby power consumption have been taken, the most simple of which was the use of switched power boards in accessible locations. The powerboard (Figure A4.7) serves the television and media centre. When not in use the units are fully switched off. Likewise, standby power to harder-to-access locations is controlled with products such as the 'Ecoswitch' (Figure A4.8) which allows power to a device to be switched more easily.

Heating/Aircon

The heating and cooling needs of the home were previously met by:

- a four-zone, ducted reverse-cycle aircon system (18kW(e)); and
- a single wall-mounted 5kW(t) gas space heater in the family room.

In 2012 both these systems were replaced by a set of reverse-cycle split system air conditioning systems. These were installed in two 'multi-split' configurations, which involve multiple indoor units for each external unit. In this case there are two 8kW external units, and a total of seven indoor units. The new system has proven very effective, and the winter-time net energy reduction (2011 to 2012), seen in Figure A4.10, can be attributed almost entirely to the new air conditioning system. In addition, two ceiling fans assist in reducing the number of hours per year when active cooling is required.

Figure A4.9: Reverse-cycle air conditioner

Measured electrical energy required in 2012 for heating was 2181kWh, which equates to 44 MJ/m^2. Assuming a heat-pump coefficient of performance (CoP) of 3.5, this is a thermal energy intensity of about 153 MJ/m^2, which is about half that suggested by the NatHERS profile (see Table A4.3). Total estimated electrical energy used for space conditioning for 2012 is 2336kWh (see Table A4.2) which is about 37% of the total electricity consumption of the home.

Table A4.2: Heating/cooling energy 2012

mode	kWh(e)/annum	proportion
Heating	2181	92.5%
Cooling	155	7.5%
Total	*2336*	*100%*

Power monitoring

Energy consumption and generation is tracked by a number of means:

- Solar: Manual inverter readings are taken on the first day of every month;
- Smart meter direct readings: Manual meter readings are taken on the first day of every month;
- Smart meter interval data: Time series data for main power import/export is available from the power distributor;
- Sub meters: Metering modules are installed on circuits as follows: Aircon, Hot water, electric car. These are monitored monthly;
- Baseline monitoring: Energy consumption of key appliances has been sampled, but these are not subject to on-going monitoring;

- Hot Water: Continuous data collection by the hot water controller gives a data point every five minutes.

Assessed and measured performance

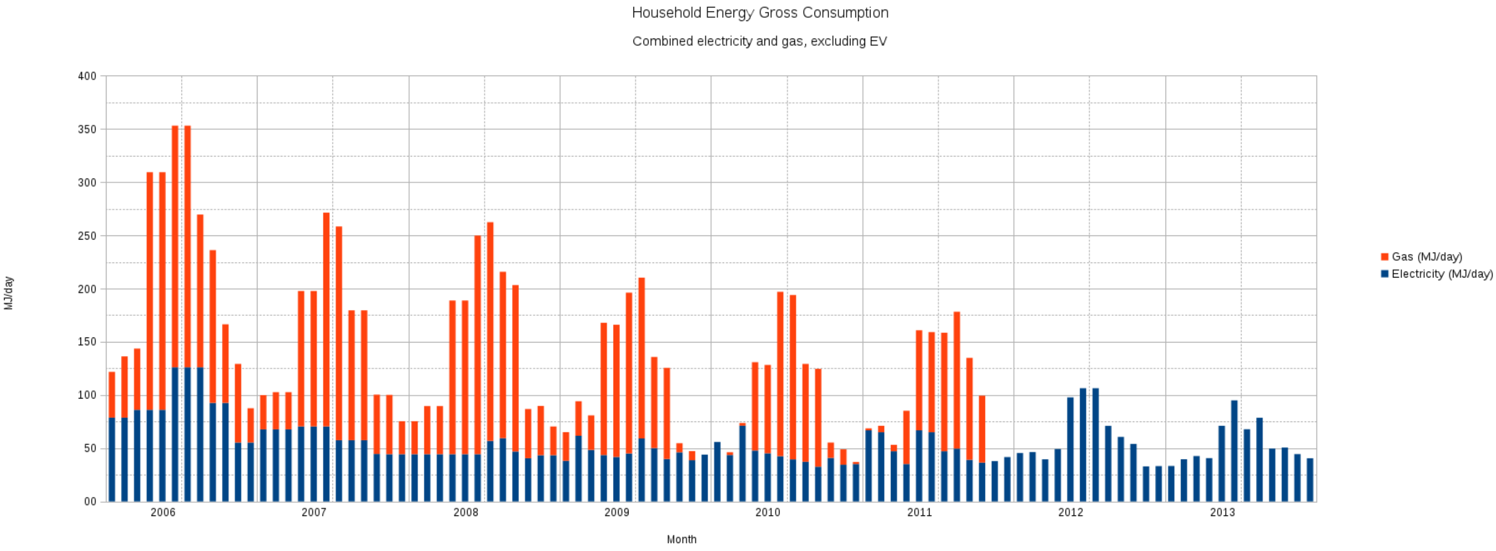

Figure A4.10: Gas end electrical energy

In 2006 the total annual energy requirement was 76GJ, which is slightly more than the average dwelling in the same suburb[2]. By the end of 2012, the energy consumption of the house (excluding solar) was reduced by 71% to 23GJ/annum. In 2006 59% of the energy consumed was provided by gas. Gas use has since been entirely eliminated. The energy consumed by the house has now reduced to the point where it is fully offset by solar generation as shown in the Figure A4.11 below. In other words, net annual household consumption has reduced to below zero.

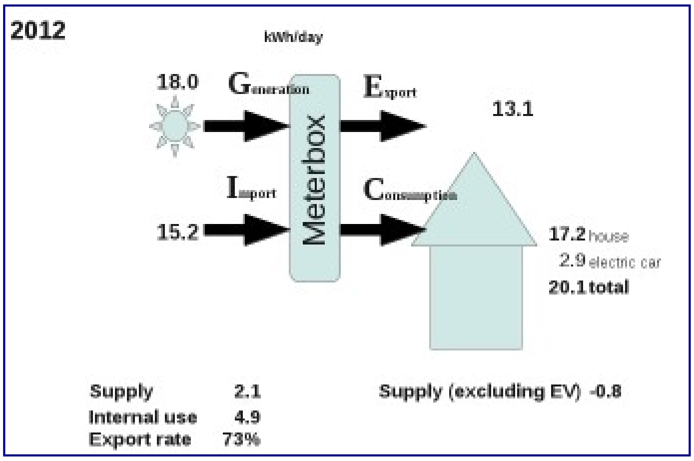

Figure A4.11: 2012 Energy balance

Note: In Figure A4.11, 'Supply' is Import minus Export. The 'Internal use' corresponds to the solar energy used directly on-site and is Generation minus Export. Export rate is the proportion of the generated energy which is exported (Export/Generation).

Performance rating

Assessing the dwelling using industry-standard tools and methods indicates that it rates as shown below. The baseline year is 2006. The improved year is 2012. Thermal performance of Australian houses is usually defined using the National Home Energy Rating Scheme (NatHERS, see http://www.nathers.gov.au/). This home was rated before and after improvements as shown in the table below. In the table, energy values are in MJ/m^2/annum.

Table A4.3: NatHERS performance rating

Stage	Heating Energy	Cooling Energy	Total conditioning energy	Stars (out of ten)	Percent improvement
Baseline (2006)	645	53	699	0.9	-
Improved (2012)	261	40	301	3.3	57
Improved (2013)	151	27	178	5.1	75

Note. Energy values in this table are:

- for space conditioning (*ie* heating and cooling) only;
- nominal, *ie* they relate to standard modelling occupancy profile and temperature set points;
- area-adjusted, expressed in MJ/m^2/annum;
- thermal energy, *ie* the amount of heat or cooling involved, not the amount of electrical energy.;
- improved (2012) values correspond to the case study period. Wall insulation was added early in 2013;
- percentage improvement based on total conditioning energy.

Actual energy and NABERS rating

Table A4.4: *NABERS Home* Energy performance rating

Stage	Electrical Energy (kWh | GJ)	Gas Energy (GJ)	Total energy (GJ)	NABERS Stars (out of five)	Percent improvement
Baseline (2006)	8844 | 31.8	46.4	78.2	0.5	-
Improved (2012)	6167 | 22.8	0	22.8[*2]	5	71

Note, this is based on energy consumed by the house, independent of solar and excluding energy consumed in charging the electric car. The *NABERS Home* rating is calculated using the online tool at http://www.nabers.com.au/HomeCalculator/YourHome.aspx.
Note 2. The 22.8GJ used in 2012 includes 8.4GJ for heating and cooling.

Energy Costs

A detailed estimate of the dollar benefit associated with the energy savings and solar generation has been produced. Using 2006 energy usage as a baseline, and applying tariff and fixed charges from subsequent years, the red line in the Figure A4.13 below indicates the hypothetical cumulative expenditure corresponding to the no-change scenario. In other words if no energy efficiency measures, and no PV had been deployed, this line represents the estimated amount that would have been spent on energy from January 2006. Conversely, the blue line tracks actual cumulative energy bills during the same time. The difference between the lines represents the net dollar benefit. In this scenario, the blue line actually starts to reduce, which reflects the credit balance on electricity accounts as a result of the exported energy and the solar feed-in tariff. The yellow line corresponds to hypothetical financial position of the improved home assuming the feed-in tariff over the entire period had been 5c/kWh instead of 66c/kWh.

By this analysis, the net financial benefit, arising from reduced consumption and solar generation, from January 2007 to the end of 2012 is $16,030. The benefit for 2012 was $5,065, comprising -$1,138 net electricity account, and estimated avoided charges of $3,927.

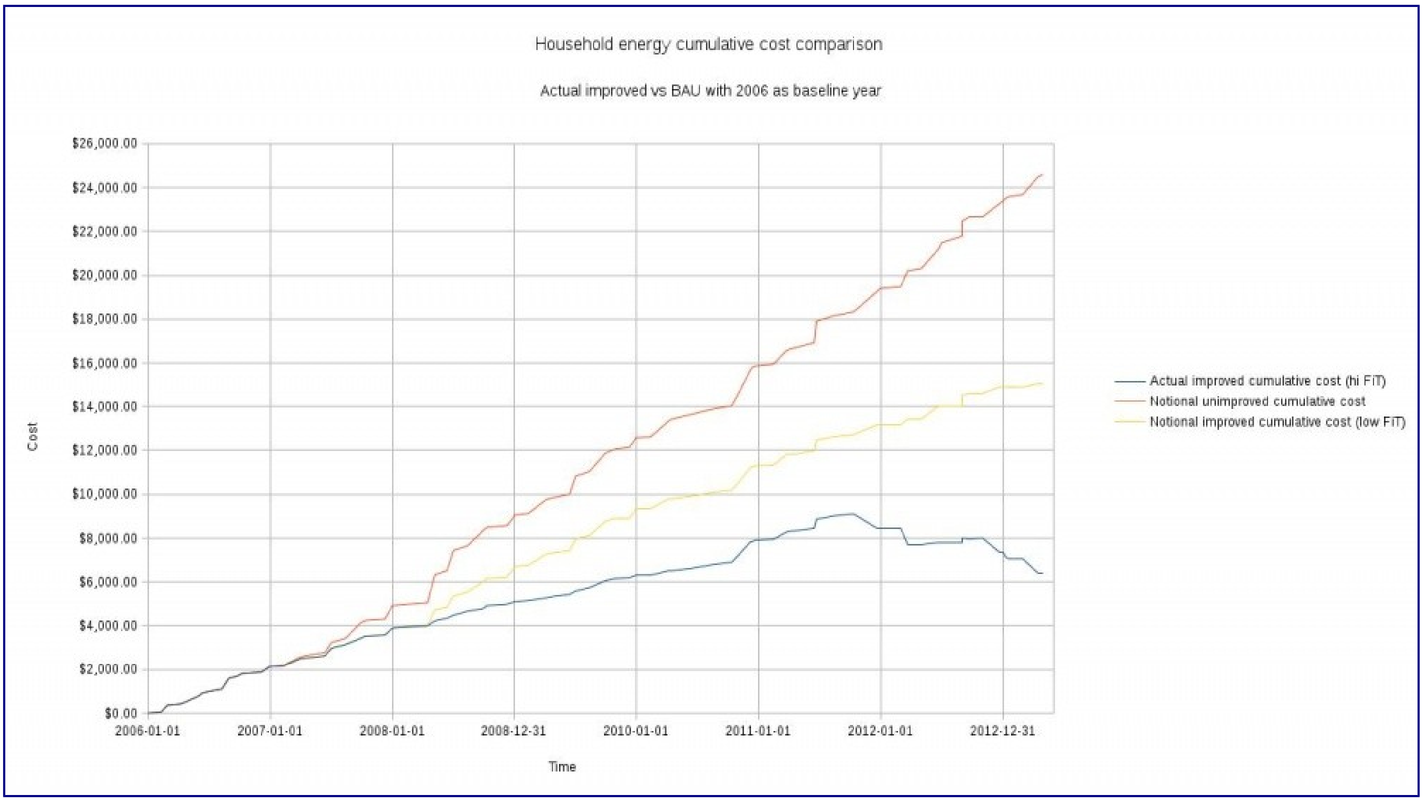

Figure A4.13: Energy cost

Conclusion

The case study home has incorporated measures similar to those proposed by the Zero Carbon Australia (ZCA) Buildings Plan as shown in the table below.

Table A4.6: ZCA *vs* Case-study home

ZCA recommended measure	Case-study home
Wall Insulation improved	yes (but after the case study period)
Underfloor insulation (if applicable)	yes
Ceiling insulation	yes
Heat pump hot water service	yes, plus solar
Improved glazing	yes
Non-ducted heat-pump aircon/heating	yes
LED lighting	yes
Removal of gas service	yes
Induction cook top	yes
In-home display power monitoring	yes

The measured performance of the house, excluding solar PV, is a 71% reduction in energy consumption in 2012 compared to 2006. As expected this is slightly less than the 77% performance improvement in the hypothetical ZCA improved home. Results for 2013, which will include the benefit of wall insulation, are expected to align well with that predicted in the ZCA modelling.