# Smart Home update

## Energy analysis

January 2012

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# Introduction

The Ausgrid Smart Home was created by Ausgrid and Sydney Water to trial the next generation of energy and water efficient technologies and distributed generation. Wherever possible it was fitted out with recycled or sustainable materials with low embodied energy.

More than 20 of the latest energy efficient appliances were installed in the home including LED lights, a 6-star LED backlit television, Eco-kettle, energy efficient microwave and toaster, and dryer using heat pump technology. A Mitsubishi electric vehicle (the 'iMiEV') was also used and charged from the home.

Water efficient appliances and fixtures installed included the dishwasher, washing machine, hot water circulator, taps, showerheads and toilets.

The Smart Home also generates and stores its electricity via a specially-built solar pergola, rooftop solar panels, a gas fuel cell that converts gas into electricity and battery storage technology.

The Smart Home is located in Newington and has been occupied by Michael, Clare and their daughter Ava from July 2010 to January 2012. The family has been trialing the technologies and sharing their experiences with the community through their online blog.

This report provides an overview of the Smart Home's energy performance over approximately a 12 month period.

There were two main objectives during the tenancy of the home:

**OBJECTIVE 1** **For the home to meet its own electricity requirements.**

**OBJECTIVE 2** **Demonstrate efficient use of electricity and water without compromising modern lifestyle.**

The main findings from the report are:

- Distributed generation in the home produced an average 32 kilowatt hours a day – about twice the amount of average daily electricity consumption inside a typical home. Across different months, the home was generally able to generate more power than it needed, except at peak energy usage times in summer and winter
- The home used about 14% less water than a comparable home and about the same amount of electricity compared to the average household in the Auburn LGA, once the home monitoring system and electric vehicle charging systems were excluded.
- Water and energy efficient appliances generally performed well for the family. However, some appliances such as the cooling system and the home monitoring system used more power than expected.
- Electricity consumption was also higher than expected because the family was working from home for a large part of the time. Although a number of appliances were energy efficient, they consumed a higher proportion of power because they were used more often.

## Generation and storage system

The first objective of the trial was for the Smart Home to meet its own electricity requirements.

The home's distributed energy system incorporates the following components:

- 1.5kW BlueGen fuel cell (waste heat used for hot water)
- 1kW conventional solar panels on the roof (also called photovoltaics or PV)
- 0.5kW thin film solar (PV) as pergola roofing
- 5kW/10kWh zinc-bromine flow battery by Redflow, which is used to meet any loads that the onsite generation is unable.

## Results

For the most part, the BlueGen fuel cell and solar PV generated much more electricity than the home consumed. The exception to this was in July when the fuel cell was out of service for three weeks and in the summer months when the home's load was larger than normal (due to the Climate Wizard cooling system). The carbon emission savings over the year November 2010 to October 2011 from the solar PV was 1470kg $CO^2$-e and BlueGen Fuel cell was 6950kg $CO^2$-e, when compared to greenhouse emissions from electricity from the NSW grid.

Although the home exported much more electricity than it imported from the grid, the home's generation and storage system was not able to meet all the demands of the house load all the time. This was due to a number of reasons, including limitations in the technologies to dynamically respond to the home's load. The Smart Home was getting closer to achieving the goal of self-sufficiency in the last 6 months of the year when very little electricity was imported from the grid (this does not include July when the fuel cell was out of service).

The following graph shows the onsite generation from November 2010 to November 2011:

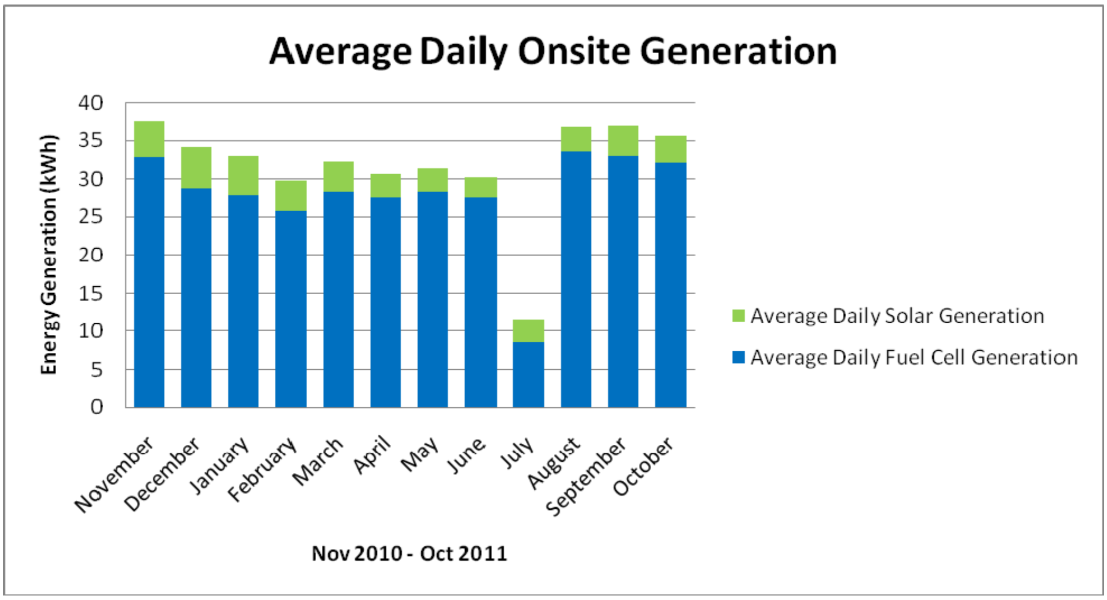



**Figure 1: Average daily generation from the BlueGen fuel cell and solar panels**

The average fuel cell output across the period shown in Figure 1 was 28 kWh/day whilst the average solar output was 4kWh/day. The fuel cell's output varies from month to month, depending on its pre-set program. The fuel cell is not able to dynamically respond to load and instead a number of profiles were trialled. For example, profiles included constant output mode (1.5kW) and a load profile that approximated an average residential profile (i.e. the fuel cell was set to produce the maximum output in mornings and evenings during peak times and drop back in-between).

### BlueGen fuel cell – out of service in July 2011

The BlueGen fuel cell stack failed and was out of service from 7 July 2011 till the end of the month. This explains why the generation was so low in July compared to other months.

### Redflow system – battery upgrade in October 2011

The original battery system installed in the Smart Home was actually a hybrid system consisting of a lead acid battery in combination with a zinc bromine flow battery. The original zinc bromine battery had limited capability to follow load dynamically and was pre-set with a discharge profile. On 30 April the zinc bromine battery was taken out of service due to a fault and from then to October the lead acid battery provided the home's storage.

This hybrid battery system was replaced on 6 October 2011 by the new Redflow R510 battery unit, which consists of a single zinc bromine flow battery. The new battery system is expected to improve performance as it has the ability to match the home's load dynamically. One limitation of the new battery is that it needs to be discharged fully once every 24 hours. It is necessary to 'strip' the battery (that is, taken down to 0Volts) due to its chemistry.

### Carbon emission offset by the onsite generation

The carbon emission savings over the year November 2010 to October 2011 from the solar PV was 1470kg $CO^2$-e and BlueGen Fuel cell was 6950kg $CO^2$-e. This was calculated based on the emission savings when offsetting electricity from the NSW grid. Whilst the fuel cell has some emissions associated with the natural gas consumption, it is able to achieve approximately a 65% reduction in greenhouse gases compared to electricity from the NSW grid. As the fuel cell can generate 24 hours a day, it is able to offset more carbon emissions than the 1.5kW of solar PV.

# Home energy use

The second objective of the Smart Home trial was to test efficient use of electricity and water without compromising modern lifestyle

This analysis found that electricity consumption in the Smart Home was higher than expected, especially in the summer months when the Climate Wizard cooling system was being trialed. Additionally, the Smart Home had a lot of communication and monitoring equipment, which contributed to a higher than expected amount of standby load of the home. It is estimated that the monitoring equipment (Home Area Network) used about 2kWh/day of electricity.

The biggest electrical users in the Smart Home, besides the Climate Wizard and the Electric Vehicle (EV), were the lights, fridge and clothes dryer. The electricity consumed by the gas heaters (by the fans) was also higher than expected, making up 9% of appliance consumption (excluding Climate Wizard and the EV).

The EV was charged on average eight times per month with an average energy demand of 10kWh each charge. This varies according to the vehicle usage.

The following graph shows the average daily energy consumption of the Smart Home from November 2010 to October 2011. The electric vehicle and household usage wasn't logged separately until March 2011, as shown in the graph.

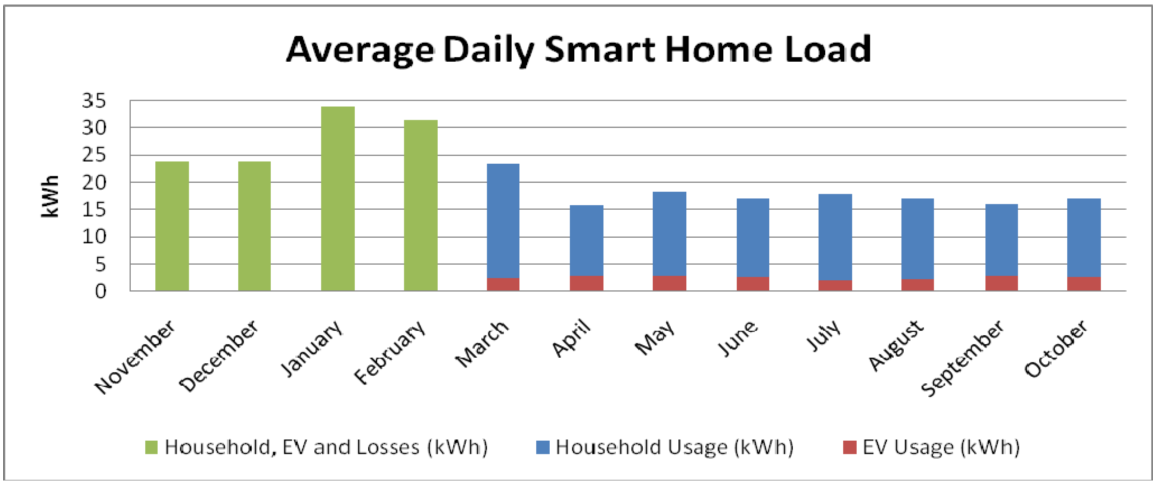



**Figure 2: Average daily house usage across 12 months (house and electric vehicle load distinguished from March onwards)**

The following is thought to have contributed to energy use:

- The Climate Wizard - this is a new 'indirect evaporative' air conditioner. Two units were installed to provide ducted air conditioning to the whole home. Although each unit was able to do a great deal of cooling with only 2.4 kW of power, it still consumed a lot of energy when used for a long time. The Climate Wizard was removed in April 2011.
- There is large standby power from the extensive energy and water sub-metering in the home. The Home control system was calculated to consume about 1.9kWh per day on average, which is significant. This will not be typical of future installations. Firstly, two Home Control Systems were installed in the Smart Home, one to monitor the home's loads and the other to monitor the generators. This can now be done with a single system. It is also expected that the new appliance modules will consume less power (1W rather than 3W). The house also has multiple communication modules (one for better place charger, one for water monitoring system, house ADSL) which contribute to standby power.
- A Smart Home family member generally worked from home during the day.
- The Smart Home family brought additional appliances into the home to use.

## Summary of the home's usage

During cooler weather, the home used about 14.5 kWh/day of electricity (not including the electric vehicle) and 17kWh including the electric vehicle. This is an average over the months from April to October 2011.

Considering that the Home Control System uses about 1.9 kWh/day, 12 to 13 kWh/day is the actual energy consumed by Smart Home appliances. This is slightly less than the average house in the area.

In the summer months from November 2010 to March 2011, on the other hand, the house used on average 27kWh. Whilst this is large, it does include the electric vehicle and Climate Wizard's consumption.

Figure 3 below shows the average Smart Home load profiles for the summer month of February, in the winter month of July and in October.

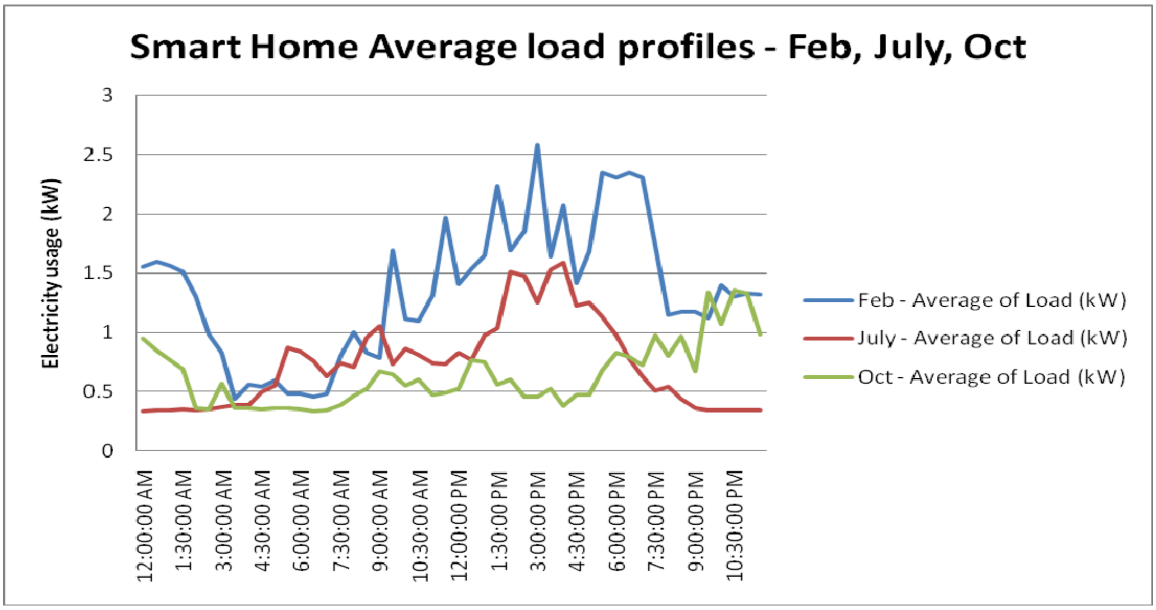



**Figure 3: Smart Home average load profiles for the months of February, July and October**

As expected, the average load in February is greatest, which is most likely due to the Climate Wizard cooling system.

In October the load is greatest after 9pm. The Better Place charger was programmed to only allow the EV to charge after this time.

## Electric Vehicle (EV) usage

The Smart Home was one of the first in Australia to trial the new Mitsubishi i-MiEV electric vehicle. With a range of up to 160km and a regulated top speed of 130km, the car's advanced Lithium-ion batteries can be easily re-charged from empty in just eight hours using a household plug. Charging of the car was initially done at any time of the day. However, later in the trial a Better Place charger was installed and, from September 2011, charging was programmed only to be done over night during off peak times.

Figure 4 below shows the total energy used in charging the EV each month while Table 1 shows the number of times the EV was charged each month and the average energy that was required each time it was charged.

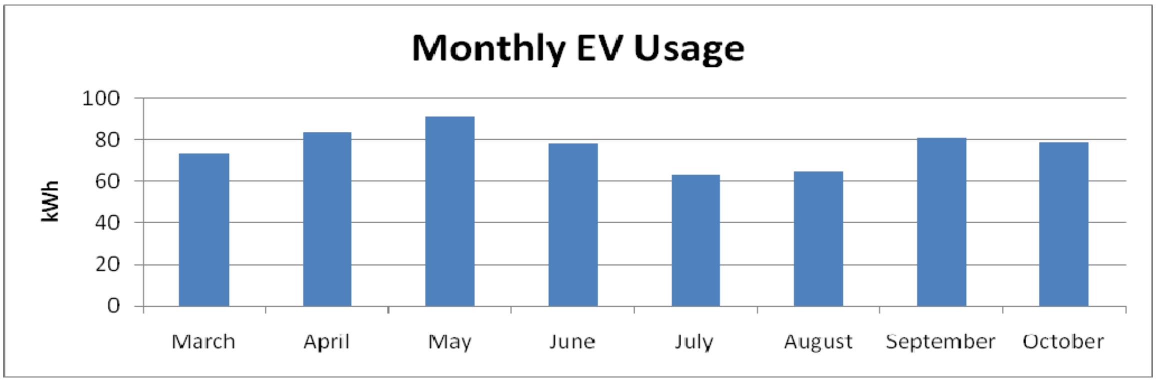



**Figure 4: Total energy required to charge the EV each month**

| | March | April | May | June | July | August | September |
|---|---|---|---|---|---|---|---|
| Number of times EV charged | 6 | 7 | 8 | 9 | 6 | 7 | 11 |
| Average charge (kWh) | 12.2 | 11.9 | 11.4 | 8.7 | 10.5 | 9.3 | 7.4 |

**Table 1: Number of EV charges per month and average energy consumption per charge**

The EV was charged on average eight times per month with an average energy demand of 10kWh each charge. This varies according to the vehicle usage.

## Homes usage compared to onsite generation

In most months the generators onsite produced more energy than the house consumed. This is illustrated in the graph below.

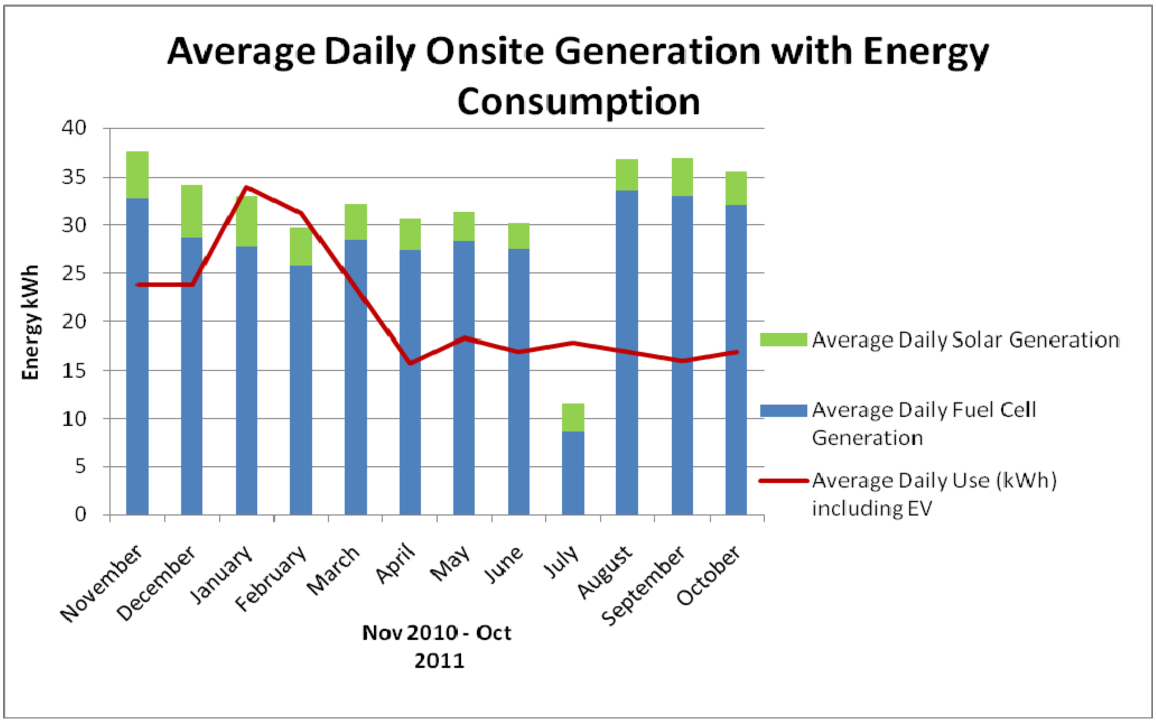



**Figure 5: Average daily Smart Home consumption shown versus onsite generation**

As mentioned previously, in July the BlueGen fuel cell was out of service and thus the generation onsite was significantly less than what the Smart Home consumed for this month. There was also not enough energy generated in a couple of summer months, where the demand was high due to the Climate Wizard.

## Home Control System data

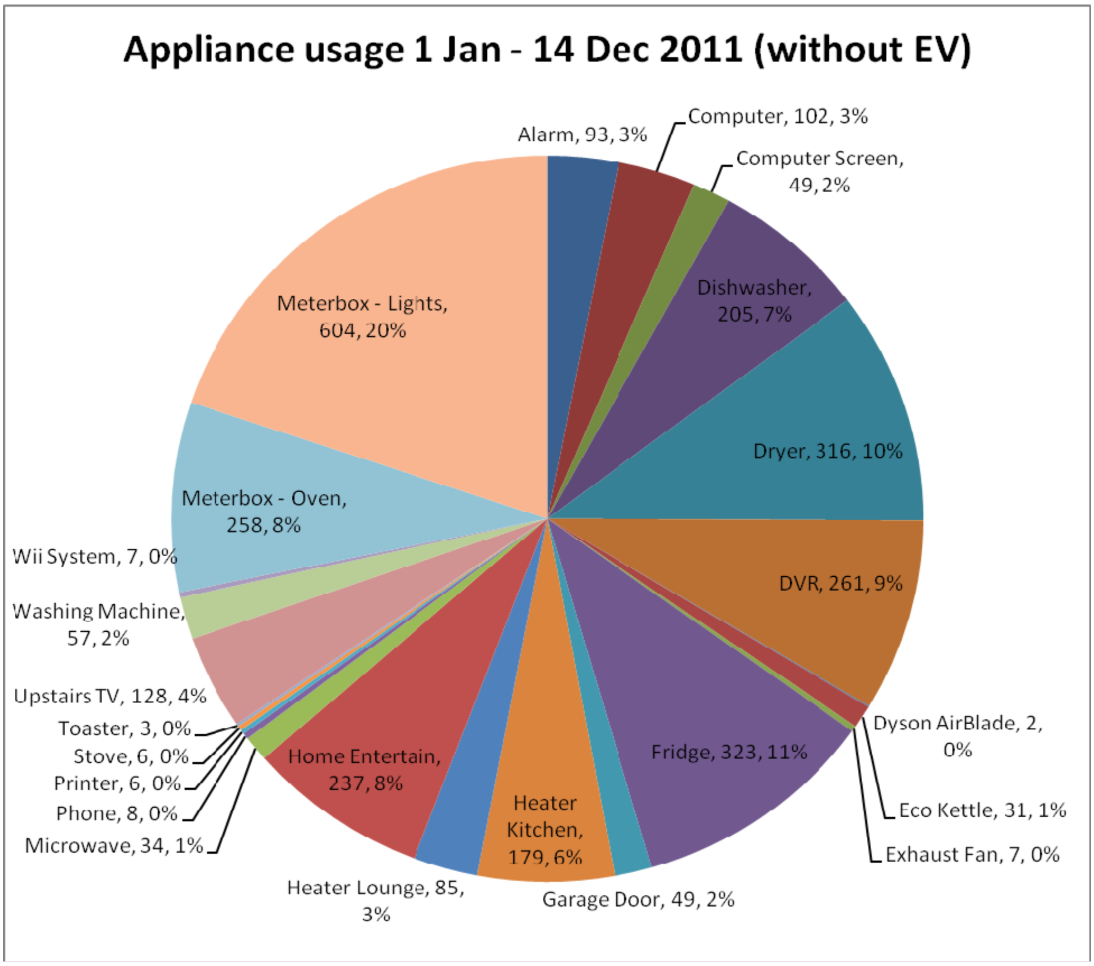
The pie chart in shows the breakdown of appliance electricity consumption during the year and does not include the EV or the Climate Wizard. Figure 6: Appliance energy breakdown – 2011

During 2011, the biggest electricity user was the lights, followed by the fridge and dryer.

Small Appliances such as the phone, printer, toaster, wii system, Dyson AirBlade, gas stove electrical connection and exhaust fan made up just 1% of the total electricity usage.

**Figure 6: Appliance energy breakdown - November 2011**

From this chart, it can be seen that the biggest energy users in November are the Fridge and Lights followed by the Dryer. This pie chart does not include the EV usage.

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## Conclusion

For the vast majority of time, embedded generation at the Smart Home was able to produce much more electricity that needed by the family inside the home. In fact, it was on average producing almost twice the electricity used in a typical home.

The fuel cell was the biggest contributor to on-site generation. However, there were some months when the home was still importing electricity from the grid. Typically, this was during summer and winter peak periods. However, the home was becoming close to attaining the goal of self-sufficiency towards the end of the trial period, after several modifications to battery systems and cooling system.

Electricity use inside the home was higher than expected because of the cooling system, monitoring devices and electric car.

However, the family also used appliances for longer periods than expected manly because a family member was generally at home during the day. The family was also not provided with any energy savings advice during their stay as part of the trial. Lights, clothes dryer and gas heater fans were the among the higher energy consuming appliances.

The electric car performed well. The family charged the car an average of eight times per month and drove it for more than 5,000 kilometers on Sydney's roads.

The electric car added an average 2.5 kilowatt hours a day to the home's electricity use.

Ausgrid found the electric car would have been about 75% per cent cheaper that a comparable petrol car to run. This is because it was only charged after 8pm when times of use electricity rates are cheaper.

The family used 14 per cent less water than a comparable home with water efficient appliances.

Changes to the Smart Home's monitoring systems, cooling devices and home battery storage are expected to make the task of year round self–sufficiency inside the home even more achievable. Regular feedback on their energy use and advice on energy efficiency could also be key to reducing household consumption.