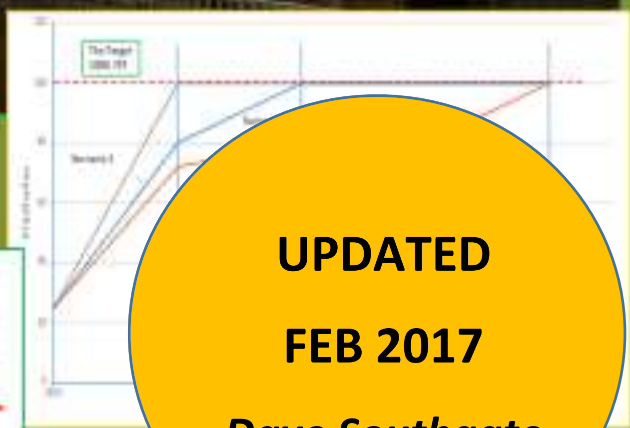
Our Household Energy Transition

Becoming a Fossil Fuel Free Family

2016 ANNUAL REPORT



UPDATED

FEB 2017

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Foreword

This book is intended to simply be an update on my earlier work about my family's goal to become a Fossil Fuel Free Family. As such I have attempted to keep any discussion in this 2016 annual report to a minimum – I want the numbers to do the talking.

We are making progress. Our energy use and carbon footprint continue to shrink. Over the past four years our annual imported energy use (including petrol) has dropped from approximately 26,500kWh/yr to around 8,700kWh/yr. In the same time period our annual solar PV production has increased from around 2,800kWh/yr to about 12,200kWh/yr. I remain confident that we can reach our fossil fuel free goal within the next five years.

I intend that this will be the first in an ongoing series of annual reports on our energy transition.

Dave Southgate

Canberra

February 2017

Highlights for 2016

- ✓ About 50% of our electricity consumption came from our solar PV system
- ✓ About 95% of our hot water came from our solar PV system
- ✓ Established direct solar charging for our electric car (EV) – about 60% of the annual energy use for our EV will come from our solar PV
- ✓ We had no net cash outlay for energy (our income from our excess solar PV balanced our grid electricity + petrol costs)
- ✓ We had an approximate 25% reduction in our total imported energy use compared to 2015
- ✓ We had an approximate 50% reduction in our heating energy use compared to 2015
- ✓ We had an approximate doubling in the amount of solar PV self-consumption compared to 2015

Background

Over the past four years my family has been working toward becoming fossil fuel free (FFF) by transitioning our household energy use. We are aiming to be in a position where we use no fossil fuels, which effectively means no grid electricity, gas or petrol, within our household by 2020. I wrote about the beginning of this journey in my book *Our Household Energy Transition: Becoming a Fossil Fuel Free Family* which I released in February 2015[1]. I refer to this as the 'Transition Book' throughout this short report.

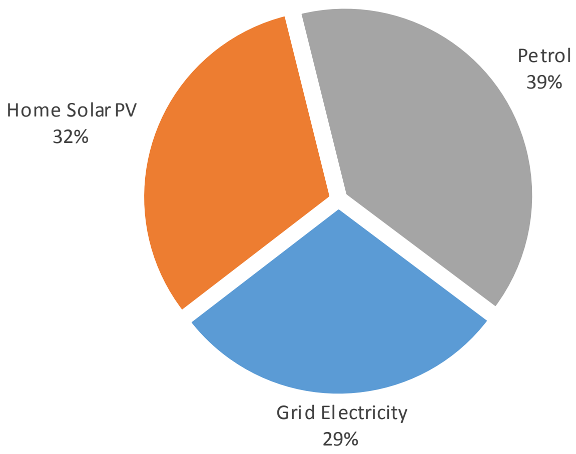
In that project initiation book I provided information relating to our household energy use and carbon footprint for the three years 2013, 2014 & 2015. In this Annual Report, I have essentially updated the earlier information to include data on 2016 and have also included some commentary on the actions we have taken in the past year to help us toward our FFF goal.

While 2014 and 2015 were years of action, 2016 was mainly a year of consolidation. We made some quite dramatic changes to our household energy regime in 2014 and 2015 so in 2016 I mainly wanted to see how these were bedding down by gathering a full year's worth of data under a reasonably stable regime. Having said that, I was able to work on a few niche projects that proved very fruitful – the direct solar charging of our family EV; indoor air quality monitoring; and, in particular, the adoption of Far Infrared (FIR) heating technology. I discuss these in the text.

Summary of Energy Outcomes

Overview

Figure 1 shows the energy type split for our energy use during 2016. In very broad terms, about a third of our household energy use was from petrol; a third from grid electricity; and a third from our solar PV system.



Total Imported Energy Consumption 2016 = 8,699kWh

Energy Source	Energy Use (kWh)
Grid Electricity	3,721
Self-consumed solar PV	4,015
Petrol	4,978
Total Energy Use	**12,714**

Figure 1: Breakdown of our household energy use 2016

If we assume that grid electricity in the ACT is about 20% renewable, in simple terms this means that in 2016 our household energy consumption was about **40% Fossil Fuel Free**.

[1] My 'Transition Book': https://docs.com/dave-southgate/9347/becoming-a-fossil-fuel-free-family

It is interesting to compare the breakdown for 2016 with the energy use breakdown for 2015 shown in **Figure 2**. It can be seen that while the proportion of our 'energy pie' taken up by petrol is very similar over the two years, gas use has been eliminated and the proportion of our energy use derived from our solar PV system has approximately doubled.

While our total energy use in 2016 was only about 7% less than in 2015 (total energy use in 2015 = 13,713kWh), our imported energy use dropped by about 25% due to the big strides we made in improving the direct consumption rate of our solar PV. The gains in solar self-consumption primarily derive from the adoption of automated solar charging of our EV (**see Chapter 3**).

Total Imported Energy Consumption 2015 = 11,369kWh

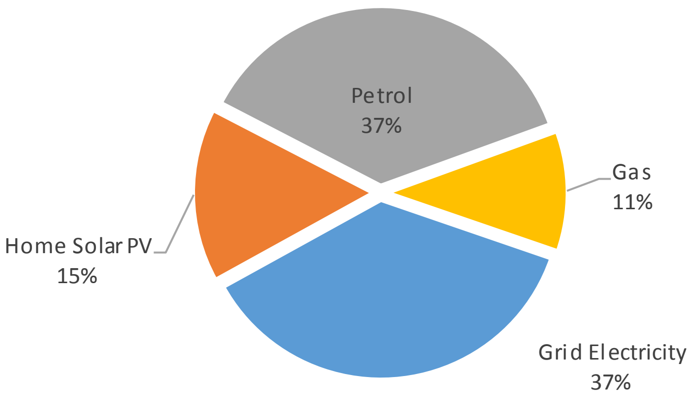


Figure 2: Breakdown of our household energy use 2015

Category Breakdown

In order to place the 2016 data in context, and to allow tracking of changes, the next five Figures are extensions of, and extractions from, Figures that I included in the Transition Book.

While I have very solid data for total electricity use, I have had to make some assumptions in allocating energy use data in other areas. I discuss the key assumptions in **Chapters 3 to 6**. All CO_2 data for electricity for 2016 is based on the 2015 conversion factors published in the Australian Greenhouse Accounts (these are the latest available).[2]

It is important to note that many of the energy and carbon reductions that we made between 2015 and 2016 were made in the context of the quite dramatic changes we made to our household energy set-up in 2015. I would not expect such significant reductions in future years unless we make further major changes to our energy systems. Having said that, I am of course planning such changes! See **Chapter 7.**

Imported Energy (grid electricity, gas, petrol)

It can be seen from **Figure 3** that in 2016 we had an approximate 25% reduction both in the use of grid electricity and in our overall use of imported energy. This translated into an approximate 25% reduction in our household carbon footprint.

[2] Australian Government Greenhouse Accounts Factors 2015: https://www.environment.gov.au/system/files/resources/3ef30d52-d447-4911-b85c-1ad53e55dc39/files/national-greenhouse-accounts-factors-august-2015.pdf

Year	Grid Electricity		Gas		Petrol		Total	
	kWh	CO_2 (kg)	kWh	CO_2 (kg)	kWh	CO_2 (kg)	kWh	CO_2 (kg)
2013	1,790	1,539	8,466	1,559	16,206	3,888	26,462	6,986
2014	4,128	3,550	8,426	1,552	4,964	1,191	17,518	6,293
2015	4,945	4,249	1,460	269	4,964	1,191	11,369	5,709
2016	3,735	3,137	-	-	4,964	1,191	8,699	4,328
% Change 2016/2015	-24	-26	-100	-100	-	-	-23	-24

Figure 3: Household imported energy use for 2016 compared to earlier years

Notes: (1) The grid electricity data in **Figure 3** is extracted from our quarterly electricity bills. The meter readings in the quarterly bills do not precisely coincide with the beginning and end of the calendar year. Therefore there are slight discrepancies between this data and the numbers in some of the other Figures (eg Figure 4) which are based on my daily electricity meter readings throughout the year.

(2) This Figure shows only imported energy data – it does not include the consumption of our own solar PV electricity.

Energy End Use

Figure 4 shows the end use breakdown for our household total energy use in 2016 compared to previous years. It can be seen that the overwhelming energy use in our household is for our two cars (one an EV, the other a small hatch). Energy use in our cars is the only category that did not improve in 2016 compared to 2015.

Year	Hot Water (kWh)	Space Heating (kWh)	Cars (kWh)	Other (kWh)	Total (kWh)
2013	2,920	6,194	16,206	1,142	**26,462**
2014	2,555	6,463	7,581	1,338	**17,937**
2015	2,213	1,995	7,396	2,109	**13,713**
2016	1,733	983	7,482	2,516	**12,714**
% Change 2016/2015	-22	-51	1	-22	-7

Figure 4: End use household total energy consumption for 2016 compared to earlier years

Our major energy improvement in 2016 was in the area of 'space heating'. This was primarily due to the adoption and refinement of the use of Far Infrared (FIR) heating.

I find it useful to look at energy use in terms of daily figures for the major end uses. For 2016 the average daily energy use was:

End Use	Daily Energy Consumption (kWh)
Hot water	**4.7**
Space heating	**6.4** (for the five-month heating season in Canberra)
EV	**6.9**
Petrol car	**13.6**

Energy use in each of the end use areas is discussed in **Chapters 3 to 6**.

Energy Generation (solar PV)

Year	Solar PV Total Production (kWh)	Imported Energy Consumed		Exported Electricity		Net CO_2 Footprint (kg)
		kWh	CO_2 (kg)	kWh	CO_2 (kg)*	
2013	2,772	26,462	6,986	2,772	2,384	**-4,602**
2014	4,906	17,518	6,293	4,476	3,849	**-2,444**
2015	10,980	11,369	5,709	8,863	7,622	**1,913**
2016	12,251	8,699	4,328	8,265	6,942	**2,614**
% Change 2016/2015	**12**	**-24**	**-24**	**-7**	**-9**	**37**

Figure 5: Summary of our solar PV production in 2016 compared to earlier years

Figure 5 provides data for our solar PV generation and export over the period 2013-2016. We had a slight increase in solar PV production in 2016 compared to 2015 due to the fact that our latest solar PV system was installed in late February 2015 and therefore this new system only generated for 10 months in that year.

Our consumption of imported energy dropped by around 25% in 2016 compared to 2015. This was primarily due to the significant improvement in the amount of our solar PV we were able to consume, rather than export. It can be seen that in 2016 we had a reduction in the amount of electricity we exported despite the fact that we generated 10% more solar PV electricity in that year. This was a direct result of our greater level of self-consumption in 2016.

The change in our self-consumption level also led to a significant improvement in our net carbon footprint. We first became carbon neutral in 2015 and last year we moved further into the carbon positive territory (with an approx 40% improvement).

Costs

Year	Electricity ($)	Gas ($)	Petrol ($)	Total Fuel Bill ($)	Credit from Solar ($)	Net Fuel Bill ($)
2013	475	991	2,558	4,024	1,241	**2,783**
2014	766	1,112	780	2,658	902	**1,756**
2015	1,085	488	676	2,249	1,495	**754**
2016	886	-	676	1,562	1,559	**3**
% Change 2016/2015	**-18**	**-100**	**-**	**-31**	**4**	**-100**

Figure 6: Cost breakdown for our household energy use in 2016 (& earlier years)

The data in **Figure 6** is derived from our household electricity bills and includes the electricity and gas supply charges. The petrol costs are estimates (see Appendix A.4 in the Transition Book). We disconnected our house from the reticulated gas supply system in December 2015. We paid $274 for electricity supply charges in 2016 – about 30% of our total electricity bill.

The most interesting thing to jump out of this Figure is that in 2016 we were essentially at the point where we had zero outlays for energy. Our income from our solar PV more or less equalled our bills for electricity and petrol.

Our total fuel bill dropped by around 30% due to us having no gas bill and the reduction in our consumption of grid electricity. While we had an approx. 25% reduction in our grid electricity consumption, the reduction in our bill was less than 20% due to the fact that the supply charges are not related to consumption.

Carbon Footprint of our Energy Use

Year	Hot Water (kg CO_2)	Space Heating (kg CO_2)	Cars (kg CO_2)	Other (kg CO_2)	Total (kg CO_2)
2013	538	1,326	3,888	982	**6,734**
2014	470	1,376	3,442	1,151	**6,439**
2015	435	1,594	3,283	1,814	**7,126**
2016	80	826	3,283	1,390	**5,579**
% Change 2016/2015	**-82**	**-48**	**-**	**-31**	**-22**

Figure 7: End use carbon footprint breakdown for our household in 2016 (& earlier years)

Figure 7 that shows our total carbon footprint is slowly reducing. Petrol of course makes the greatest contribution to our carbon footprint (about 60% of the total). As indicated earlier, we reached a net carbon zero footprint in 2015 (ie the carbon footprint of our consumption = the carbon footprint of the electricity displaced by our solar PV exports). However, the ultimate aim of the transition project is to attain an absolute zero-carbon footprint for our energy usage – that is we want to become 'fossil fuel free'. We are aiming to get to the point where we use no fossil fuel based energy for powering activities within the house (eg heating, etc) or in our cars.

Figure 8 shows how well we went in 2016 as far as electricity is concerned. It can be seen that we used at least some grid based (let's say coal based) electricity in every month. In all months except Jun (we were away on holiday for part of July) our solar PV production exceeded our grid electricity usage. In the heavy usage months we were consuming just under 20kWh/day of electricity from the grid. Clearly we have some way to go until we reach 'fossil fuel freedom' for electricity never mind petrol.

In the immediate term I have plans to tackle the electricity carbon footprint during 2017 and I hope this figure will look somewhat different by the end of the year. I discuss my plans in **Chapter 7**.

Average grid electricity consumption 2016 = 10.2 kWh/day

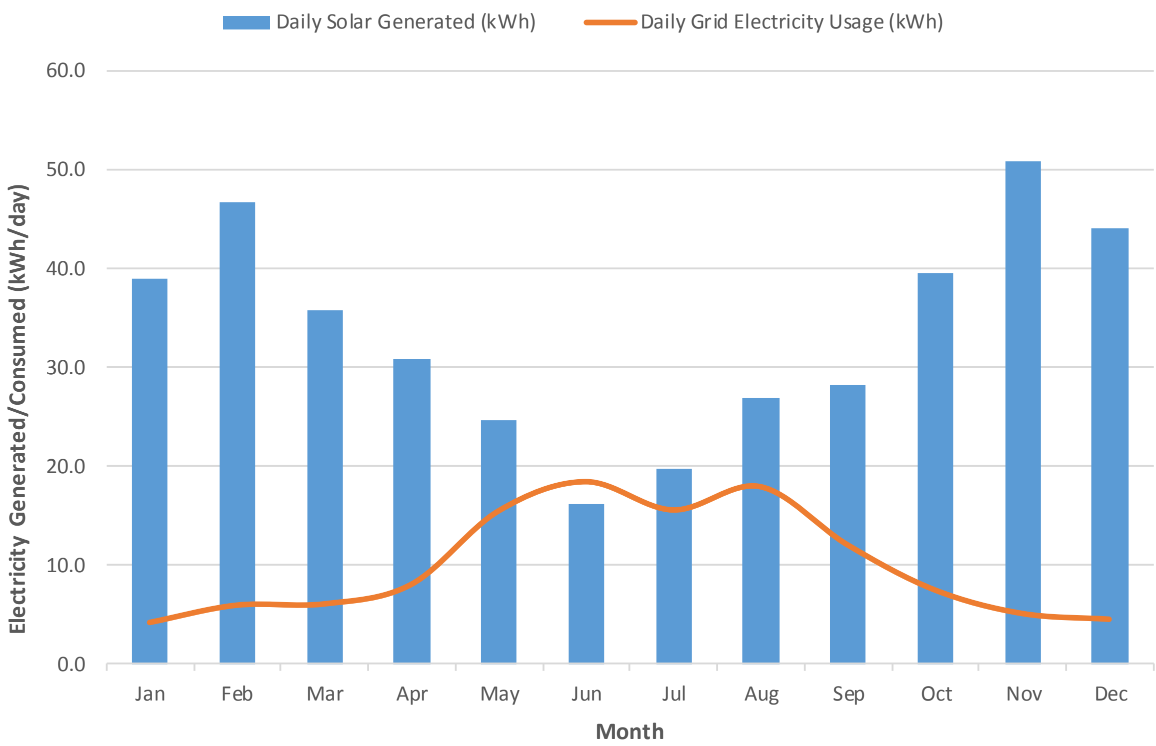


Figure 8: Grid electricity consumption compared with solar PV generation for 2016

Chapter 1

2016 Action

While 2016 was essentially a year of consolidation and monitoring, I was not idle on the energy front. I put in place a number of small, low cost, initiatives which were designed to help us move toward our Fossil Fuel Free goal. These are discussed in a broadly chronological order below:

Direct solar charging of our EV

I have written about this elsewhere.[3,4] In essence, for the first twenty months or so of owning our Nissan Leaf I charged it at night using the off-peak tariff. This was very convenient but I then wanted to see the extent to which I could charge the EV with solar PV electricity from our roof. I did this by opportunistically turning on the EV battery charger during the day whenever our PV system was producing more power than the power demand of the charger (3.6kW). In April 2106 I went the next step by automating my direct solar charging regime by setting up the relay function of our Immersun solar energy diverter. The outcomes are discussed in **Chapter 3**.

Changed lighting to LED

In the first quarter of 2016 I systematically went through our house and changed all our CFL globes over to LEDs. I replaced 18 CFL globes with LEDs: the CFL globes were almost all 15W devices which I replaced with 5W or 6W LED globes. I also found two rogue incandescent globes which were lurking in very rarely used lighting spots – I also replaced these with 5W LEDs. I have not carried out any rigorous monitoring of our energy use for lighting but I estimate that, even in the middle of winter, we use well under 0.5kWh/day for lighting.

Retired our storage heater

At the end of June 2015 we installed a storage heater in our main living/kitchen area as a solar driven component of our space heating. The concept was that on any given day, we would inject excess solar energy into the storage heater once the water in our hot water system (powered by solar PV) had reached the thermostat temperature. This worked OK to a point but it had limitations – I have reported on this elsewhere.[5]

At the start of 2016 I had thought that I may need to use the storage heater to supplement our Far Infrared (FIR) heating panels on really cold Canberra winter nights. As things turned out this was not necessary (see next paragraph) and we did not use the storage heater over winter 2016. I now consider this heater to be redundant and don't envisage that we will ever use it again.

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[3] My description of how we are charging our EV with solar: https://docs.com/dave-southgate/8999/using-an-immersun-to-automatically-solar-charge-an

[4] An article I had published on the One Step Off the Grid website about EV solar charging: https://onestepoffthegrid.com.au/lessons-in-automatically-solar-charging-an-electric-car/

[5] Storage heaters are discussed in Chapters 6 & 8 in my Transition Book: https://docs.com/dave-southgate/9347/becoming-a-fossil-fuel-free-family

Assessed performance of FIR heating panels

I have reported on this elsewhere.[6] We installed FIR heating panels in our two main living areas at the end of August 2015 – this gave us about a month to try them out before the end of that year's heating season. While the panels' performance in this initial trial was extremely impressive, I wanted to see how they would perform under really cold conditions so this was a major task for me over the 2016 winter. In summary, the panels were wonderful throughout the winter – they provided a beautiful heat and used very little energy.

Purchased a new fridge

In late 2016 we replaced our 15 year old fridge with a new one. This is a 3.5 star fridge and the predicted energy use on the label (385kWh/year) is about 40% less than the predicted energy use of the one we replaced. I include some energy data for our new fridge in **Chapter 6**.

Purchased a sleeved blanket

As a result of my FIR assessment I began to see home heating in a very different light. I began the winter thinking in conventional terms – my intention was simply to heat the whole space (ie heat the air) in our living areas so that the occupants would become warm; but I quickly came to realise significant weaknesses in this way of thinking. Why was I going to try to heat all the air in a very large room just to keep one or two people warm? Wasn't most of the heat being wasted? I rapidly changed my position and adopted the philosophy of 'heat people, not spaces'.

Putting this philosophy into practice I purchased a sleeved blanket[7] and whenever it was convenient I simply turned the heater off and kept warm by using this blanket. My thermal comfort did not suffer; my CO_2 footprint was reduced!

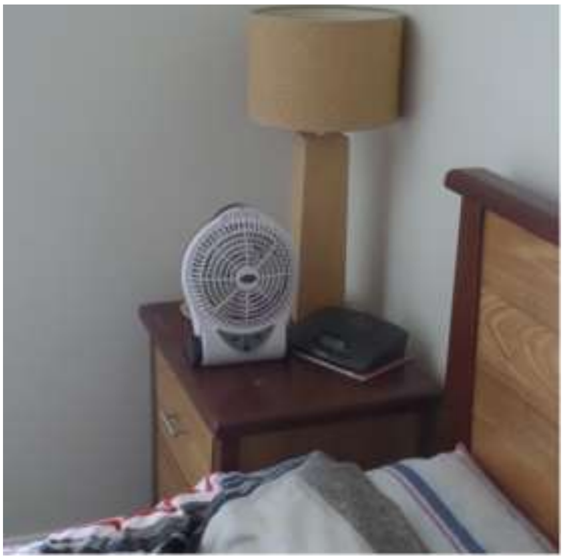

Figure 9: Our 15cm rechargeable fan placed on my bedside cabinet to give head/shoulder cooling

Purchased a Li-ion portable fan

At the end of winter 2016 I began to think about cooling. We have only ever used standalone fans to keep us cool in our home over the four years we have lived here – there is a ducted evaporative cooling system in the house but we have never used it. Domestic cooling is an important energy/carbon footprint issue in Australia since the use of air conditioners is placing significant demands on the national electricity system on very hot days which in turn is imposing costs and the need for network upgrades.[8] I began to turn my mind to the question: Is there a way in which we can re-write the adage 'heat people, not spaces' as 'cool people, not spaces'?

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[6] My assessment report of FIR heating: https://docs.com/dave-southgate/8383/an-assessment-of-far-infrared-fir-heating-panels

[7] The 'sleeved blanket': https://www.kogan.com/au/buy/deluxe-sleeved-blanket/

[8] See the 'Managing air conditioner energy use' tab at: https://www.sa.gov.au/topics/energy-and-environment/using-saving-energy/cooling

My initial response was to buy a portable personal fan based on a Li-ion battery (15cm fan). These are relatively common and are primarily designed for use by campers. The idea is to carry the fan around the house with me to provide personal cooling. At the time of writing we are still at a hot time of the year and so far the concept has worked very well for me. My wife prefers fans that rotate (so she isn't getting a constant stream of air) so the simple fan I have bought doesn't work so well for her. At night for example (except for a very few really hot nights) our 15cm fan has been our only cooling in our bedroom. We place the fan on one of our bedside cabinets, about 1-2m from our heads, and run the fan on 'low' (see **Figure 9**). This pulls about 8W if it is plugged in (we normally charge it up during the day on solar PV and run it on the battery at night for a few hours until the battery runs out). On the very hot nights we have used a larger, mains powered fan (44W).

Established socket level energy monitoring

At the beginning of 2016, when I compiled my book on becoming a fossil fuel free family, I was very aware that I had big gaps in my data. While I had good data on our solar PV production, and on our overall household energy consumption, I had little facility to get time-stamped data on electricity consumption for individual appliances/applications.

I was able to log energy use data on individual hard-wired devices within the house by getting an electrician to place sensors (CT clamps) on designated circuits. However, this was very inflexible because If I wanted to monitor other circuits I had to call out the electrician to change over the sensors since these were positioned 'behind the meter'.

Some key energy uses within the house require socket level monitoring if I'm going to get a clear picture of our energy consumption patterns. During the year I was particularly interested in monitoring portable heaters, which are heavy energy users, as we were moving these around the house. In order to monitor energy use by these portable devices, I initially hooked up some common aggregating energy monitors on the wall power sockets and read them each day but not only was this a bit onerous, the data they provided was too coarse. I was somewhat surprised that I could not find commercially available socket level energy dataloggers. I could find socket level devices which are designed to let the user control the socket remotely (eg so that the user can turn lights on/off), and some of these indicate that they capture energy use data, but as far as I could tell none of these operate in the Windows environment.

In the end I made up my own socket level dataloggers by 'cable splitting' extension cords (care required) to enable me to place a CT on the line wire (see **Figure 10**) and use a wi-fi energy monitoring system that was designed for connecting to circuits at the meter box.[9] I was very pleased with the outcome – this gave me the capability to not only gather some good data but also to monitor energy use patterns of individual devices in real time (the user interface of the monitoring system is very user friendly). I have included some data from this system in **Chapter 6**.

Figure 10: One of the 'cable split' extension cords I have been using for socket level datalogging

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[9] Effergy Engage. Energy monitoring made easy: https://engage.efergy.com/

Purchased a CO_2 Monitor

I have written about this elsewhere.[10,11]

If you are embarking on a journey toward an energy efficient home, one of the most commonly called for actions by the energy pundits is to draft-proof your house. This is fine as it goes, but for some time I have had a growing concern about the way people seem to be radically sealing their homes without paying any attention to indoor air quality. People have to breathe! My response to these concerns was to buy a CO_2 monitor and to begin testing the air quality inside our minimally draft-proofed house.

Given the comparatively 'leaky' nature of our house, before I began monitoring I had imagined that we would have good quality indoor air. I was wrong!! Even with windows open in our bedroom we were exceeding the recommended maximum levels for CO_2 (1,000ppm) – the CO_2 was building up over the night due to our breathing (see **Figure 11**).

My initial response was to start un-doing some of the preliminary draft-proofing measures that I had put in place earlier (eg I opened up certain closed vents). This is a work in progress and a key project for 2017. Ultimately, we may have to install some form of mechanical ventilation if we want to keep our indoor CO_2 below the recommended levels.

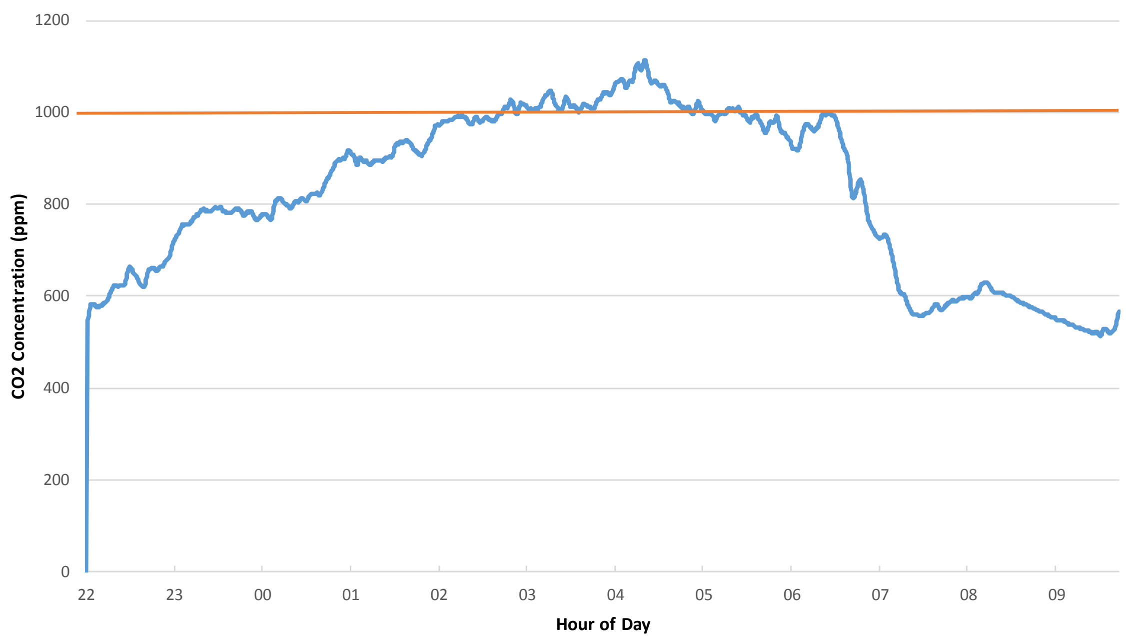


Figure 11: A datalog of one night's CO2 monitoring in our main bedroom

[10] My report on monitoring indoor CO_2 levels: https://docs.com/dave-southgate/8475/monitoring-indoor-co2-levels-enjoying-fresh-air-in

[11] An article I had published on the One Step Off the Grid website about the need for fresh air in homes: https://onestepoffthegrid.com.au/seal-not-seal-dangers-draught-proof-home/

Produced a number of publications

I am a great believer in trying to disseminate information on what we as a household have done in order to get toward our Fossil Fuel Free goal. In 2016 I produced 6 documents and/or published articles about our actions and have referred to five of these earlier in this chapter. I am very keen to not portray what we have done as being the only way to achieve a lower carbon footprint – different options need to be available to suit people in different circumstances and with different values.

While I am highly enthusiastic about some of the things we have done or come across (in particular my finding out about Far Infrared (FIR) heating), and believe it is important to draw attention to new ideas, I always try to avoid becoming captured by any one technology. Unfortunately, in recent times there has been a trend in the energy media to focus almost solely on heat pumps, both for heating and cooling, and to more or less exclude discussion on alternatives. I see this as being to the detriment of the future development of energy efficient domestic heating/cooling – I think we need to expand, not close down, the number of low energy options available for heating/cooling our homes. In April 2016, I published an article on how, and why, we have avoided using heat pumps in our fossil fuel free journey.[12]

My energy epiphany

While not strictly an action, over 2016 I had a major change in my thinking about domestic heating and cooling. This mainly came about from my learning to live with Far Infrared (FIR) heating. This 'conversion' now seems to underpin all my ideas about domestic energy use. In simple terms my thinking has changed from being focused on control of the air temperature in a room or a house to trying to provide specific thermal comfort for each individual in a room or house - 'heat people, not spaces'. [I mentioned this earlier in my discussion on the sleeved blanket.] With this philosophy any variations in the temperature of the air across a room are largely irrelevant from a comfort point of view; the question is are each of the individuals in the room thermally comfortable? If each individual in a room has an acceptable microclimate why waste energy on heating/cooling unoccupied areas of that room? I have written about this in a number of the papers I have referred to earlier. I see this approach as the future: it has the potential to provide much greater thermal comfort with much lower expenditure of energy.

[12] An article I had published on the One Step Off the Grid website about energy efficiency without heat pumps: https://onestepoffthegrid.com.au/a-journey-to-fossil-fuel-freedom-no-heat-pumps-required/

Chapter 2

2016 Generation: Solar PV

Our solar PV production and export for the past four years was summarised in **Figure 5.** The key differences in our solarPV production between 2015 and 2016 were discussed in the text associated with that Figure.

Figure 12 compares our solar production across 2015 and 2016 broken down by month. The diagram clearly shows that we had reduced PV capacity in Jan and Feb of 2015 prior to the installation of our third solar PV system. The chart shows the expected reduction of PV output during the winter months. It is interesting to note the significant year to year differences in solar output for some comparable months (eg April and September).

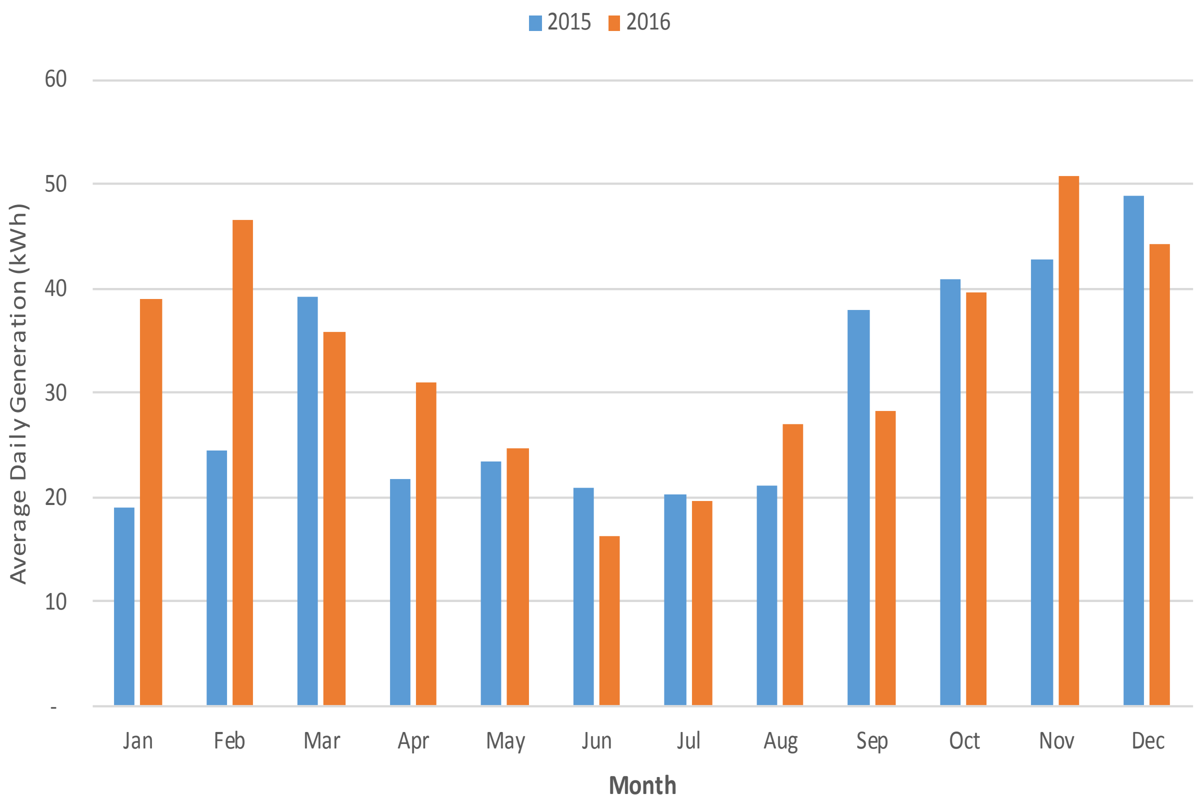


Figure 12: Comparison of our household 2015 & 2016 solar PV production

Self-consumption of solar PV electricity

If we are to reach our goal of 'Fossil Fuel Freedom', all of our electricity consumption will need to originate from our own solar PV system. While this would appear to be a relatively minor challenge in summer, it is going to be a big ask over the winter months.

I am somewhat reluctant to use the term 'self-consumption' as I often find it is used in a somewhat confusing way. In order to clarify the terminology I like to use the term '% grid independence' when I am quantifying the self use of our solar PV output. I explain this in the box on the next page.

Figure 13 shows how the rate of our household grid independence varied across 2016. For the last two months of the year over 70% of our household electricity consumption derived from our solar PV system. In June this figure was only around 30%. Overall for the year our grid independence level exceeded 50%. This compares to a figure of about 30% for 2015.

During 2016 I introduced a way to automatically solar charge our EV and I believe this was the key factor in our greater direct use of our solar PV electricity. I discuss this in **Chapter 3**.

You can see from **Figure 13** that over the mid-winter months in 2016 we were, on average, using just under 20kWh/day of grid electricity. In **Chapter7** I discuss how I propose to improve our self-consumption rate from here.

2016 overall rate of household grid independence = 52%

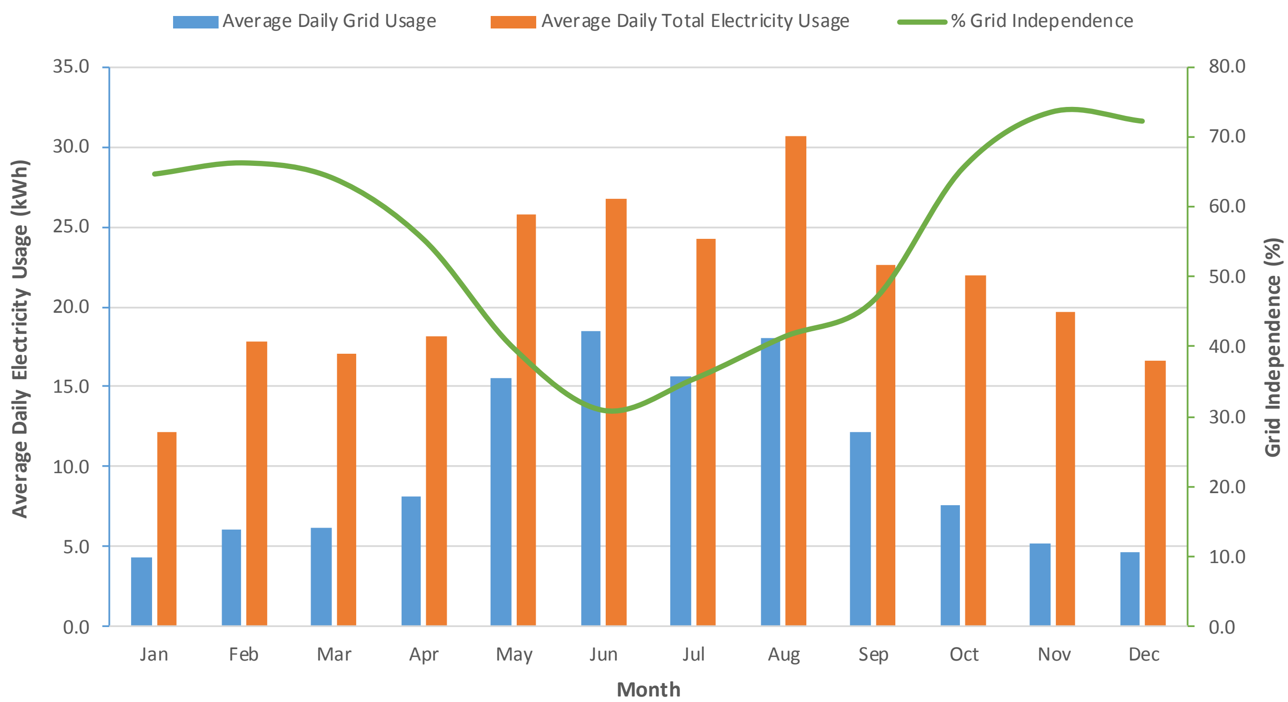


Figure 13: Variation in grid independence over 2016

Optimizing Self-Consumption

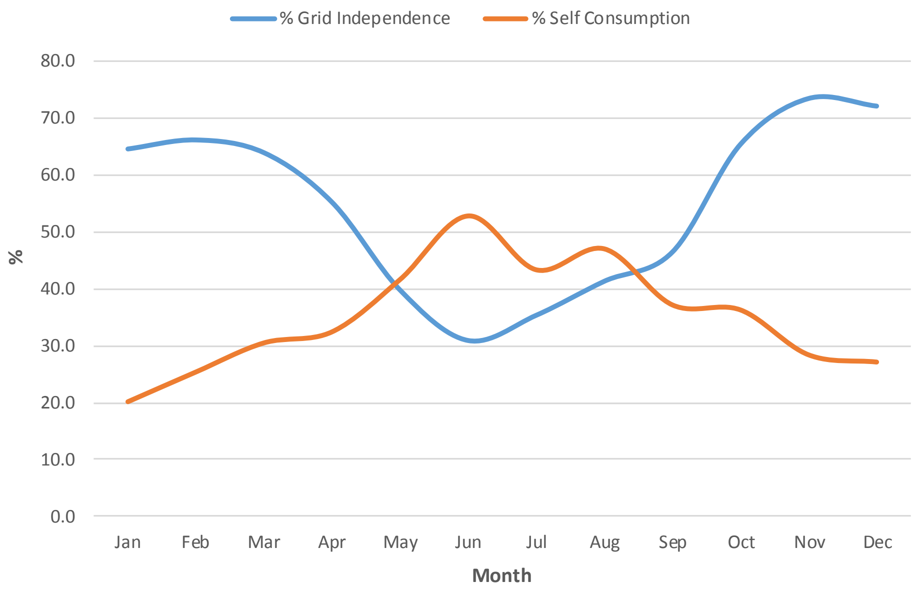
You can look at solar PV 'self-consumption' in two broad ways.

Commonly the owners of solar PV systems are encouraged to maximise their self-consumption – the ideal is seen as 100% self-consumption (ie you consume all the electricity you generate). The reasoning is that this will stop 'wasteful' export of 'cheap' electricity and will lessen the need to buy back 'expensive' electricity from the grid. This is fine as it goes, but in my view this thinking does not get to the heart of the matter. It is very easy to have high rates of self-consumption but to still end up consuming a great deal of grid electricity. This is likely to occur if you are only producing small quantities of solar PV relative to your total electricity consumption.

I believe it is more useful to turn this thinking on its head and to look at the issue in terms of computing the % of a household's electricity consumption that is provided by its solar PV system (or other renewable source). In our household, my aim is to maximise the % of solar PV that is contained in the electricity we consume – eventually I want to be in the position where we no longer need to import any electricity from the grid (ie 100% grid independence). In essence this means that I am developing our solar PV system in a way that can cope with winter demand, but this will inevitably mean that in summer our system will export a great deal of our solar PV (ie we will achieve low levels of self-consumption). As long as this does not adversely affect our local electricity distribution system, I am more than happy to displace coal based electricity on the grid with my beautiful home grown carbon free electricity.

In an effort to avoid presenting a misleading picture, wherever possible in this report rather than talking about rates of 'self-consumption', I use the term '% grid independence'. For example, '60% grid independence' means that 60% of our electricity consumption comes from our solar PV system and 40% from the grid.

The Figure below shows the relationship between '%grid independence' and '% self-consumption' for our household in 2016. There is a clear inverse relationship for our household – this would look very different of course if we had significant energy use during summer (eg air conditioning).



Chapter 3

2016 Consumption: The Cars

We did not change our cars in 2016; we have now had our EV (a Nissan Leaf) for three years and our petrol car (a Hyundai i30) for about five years. We have used the cars in more or less the same patterns for the past three years. Our energy for the cars in our household is summarised in **Figure 14.**

Year	Electricity		Petrol	Total
	Grid (kWh)	Solar (kWh)	kWh	kWh
2013	0	0	16,206	**16,206**
2014	2,617	0	4,964	**7,581**
2015	2,432*	N/A	4,964	**7,396**
2016	1,007	1,511	4,964	**7,482**
% Change 2016/2015	**-59**	**N/A**	-	**1**

Figure 14: Our car energy consumption 2013-2016

***Note:** I did use some solar charging of our EV in 2015 but I did not keep a record of the energy breakdown between grid and solar PV electricity

I do not keep detailed records of our petrol usage and the numbers in the Figure are estimates (see Appendix A.4 in the Transition Book). The petrol energy usage estimates relate only to our normal 'week to week' use of the car – not holiday use. I do this in order to allow a realistic comparison of energy use between years of our 'regular household' energy use. For some of our holidays we fly; for others we drive in our petrol car. Managing the carbon footprint of holidays is an important issue but outside the scope of this study – I want to constrain this analysis to our 'normal' household energy use.

The total energy used by our electric car in 2016 was more or less the same as in 2015. We travelled further in our EV in 2016 compared to 2015 but we achieved a better rate of efficiency. This is summarised in **Figure 15.**

Year	Energy Used (kWh)	Distance Travelled (km)	EV Efficiency (kWh/100 km)
2015	**2,432**	**13,381**	**18.2**
2016	**2,518**	**14,292**	**17.6**

Figure 15: Comparison of 2015 & 2016 EV energy use

Note: The energy efficiency has been computed using data on energy input into the car not energy consumed by the car (about 20% of the energy input is lost in the charging process).

While I would not place too much significance on the apparent improvement in efficiency shown by **Figure 15**, the data in the Figure appears to show that there has been no degradation in the EV's performance over the last year.

The reader can see from **Figure 14** that we moved a long way toward grid independence for our EV charging in 2016. I achieved this by linking our EV charger with our energy diversion device at the end of April 2016. I documented this direct solar charging system in some detail in mid 2016 in the form of a Microsoft Sway (see **Figure 16**).

Figure 16: The cover of my direct solar charging Sway

Figure 17 shows a representation of the month by month proportion of the energy input into the EV that would have derived directly from our solar PV system over 2016 if our direct solar charging set up had been in place for the whole year.

In summary, in the summer months our current set-up is delivering about 80% grid independence but in winter this drops to around 30%. The line in the Figure was computed from detailed 1 minute datalogging that I carried out from May to December 2016 on our Level 1 battery charging circuit. I have had to make some allocation assumptions between grid and solar electricity, and as noted below I have simulated data for Jan-Apr, but I believe the overall picture presented in the Figure is a reasonably robust representation of what would be achieved if our direct solar charging regime were in place for a whole year.

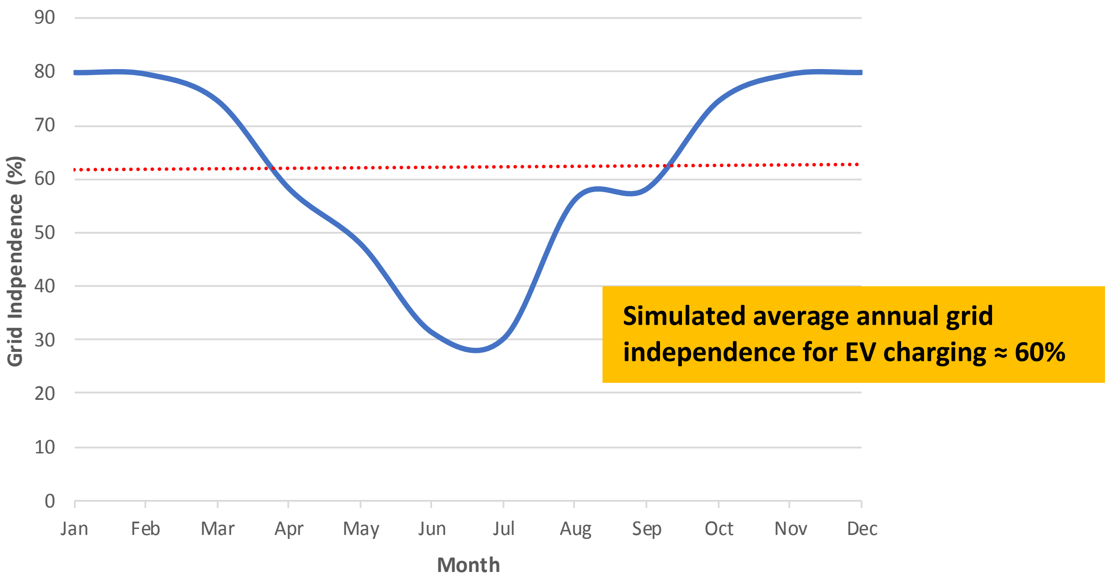


Figure 17: Simulated variation in the grid independence for our EV charging over a full year (actual data for May – Dec 2016)

Note: I only set up the Immersun direct solar charging system in April 2016 and I therefore only have detailed solar charging data for May to Dec 2016. I have simulated the data for the first four months of 2016 based on my readings for the last half of the year. Our grid independence for May to December 2016 (ie ignoring simulated data) was approximately 57%.

While I am unable to present a picture of the actual charging grid independence for Jan to Apr 2016, during that period I was solar charging the EV 'by hand' and would guesstimate that this would have achieved a grid independence rate about 5-10% less than that shown in the Figure.

I hope that the addition of a home battery + additional solar PV in 2017 will have a noticeable effect on our rate of grid independence for our EV charging (see **Chapter 7**).

I have provided a detailed assessment of the energy use of my EV in my companion book referenced earlier and the reader may wish to look at this for additional information. [13]

[13] *Living with a plug-in electric car in Canberra.* Dave Southgate. Aug 2014. http://electricvehicleaustralia.com/electric-vehicles/

Chapter 4

2016 Consumption: Hot Water

I discussed our household water heating in Chapters 5 & 8 of my energy Transition Book.

In essence, we have a resistive hot water system which is controlled by an Immersun proportional energy diverter. The Immersun was operational for the whole of 2016. This was the first time it has been operating for a full year.

I cannot praise the Immersun highly enough. It has enabled our family to enjoy hot water throughout the year using electricity which was almost all (95%) sourced from our home solar PV system. In addition to water heating, as discussed in the previous Chapter the Immersun has also enabled us to make great strides in using our solar PV to charge our EV.

Figure 18 shows the overall picture of our hot water energy use and carbon footprint of our household hot water for the past four years. It can be seen that in 2016 we enjoyed a more than 50% reduction in our hot water grid electricity usage compared to 2015.

Year	Electricity Consumed (kWh)		Gas (kWh)	Total Energy Consumed (kWh)	Carbon Footprint (CO_2 (kg))
	Grid Sourced (kWh)	Solar PV			
2013	0	0	2,920	2,920	538
2014	0	0	2,555	2,555	470
2015	207	544	1,394	2,145	435
2016	95	1,638	-	1,733	80
% Change 2016/2015	**-54**	**201**	**-100**	**-19**	**-82**

Figure 18: Breakdown of hot water energy and carbon footprint

On average we used 4.7 kWh/day to heat our water throughout 2016.

Figure 19 breaks down the 2016 hot water energy use into monthly data. It also shows how the level of grid independence of our hot water electricity varied throughout the year

The data underlying this Figure has been gathered from the data monitoring system integrated into the Immersun unit.

It is interesting to note that at the end of the year our average daily energy use for hot water was somewhat higher than at the beginning of the year. I put this down to my growing children now taking longer showers.

2016 rate of grid independence for hot water = 95%

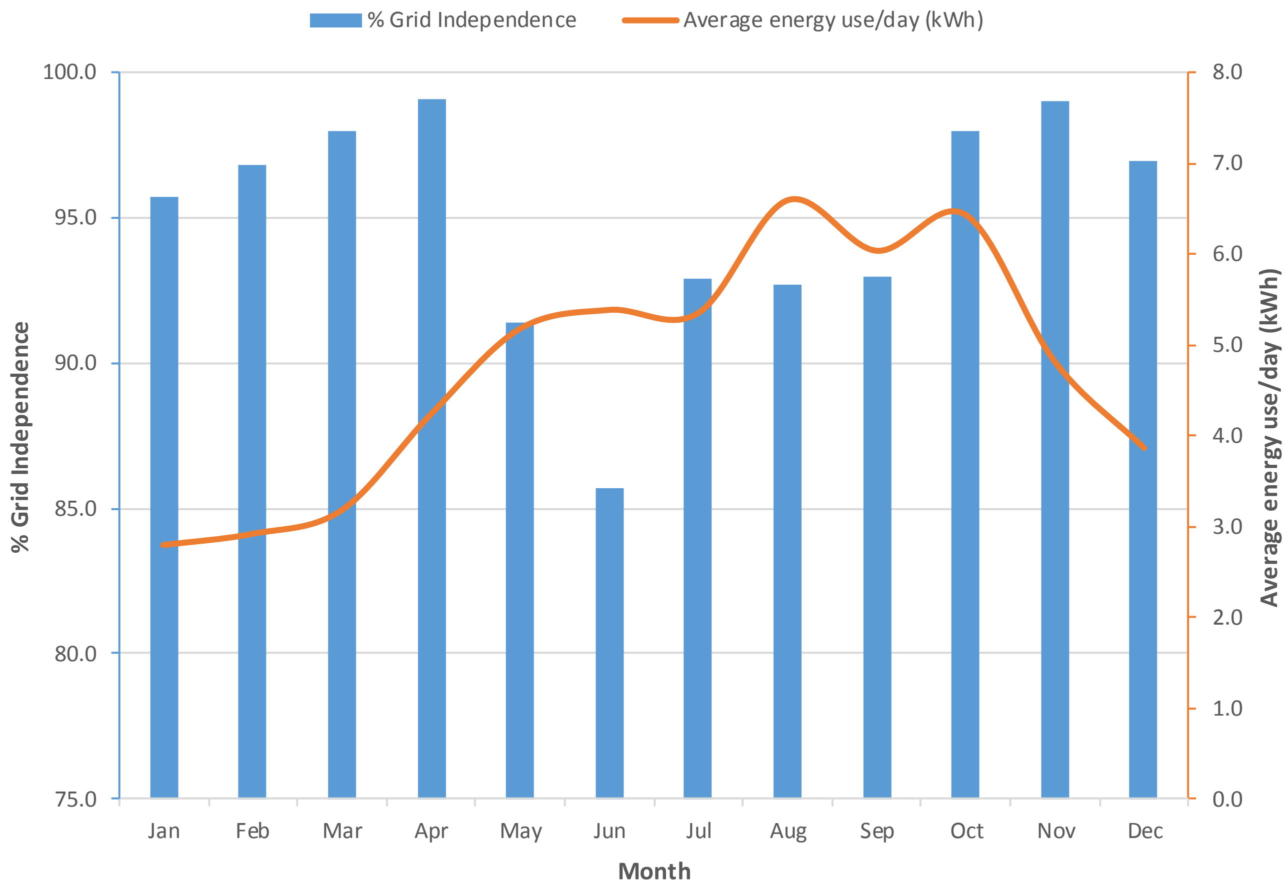


Figure 19: % Grid independence and daily energy use for hot water 2016

Given the reliance of both our hot water and EV charging regimes on the Immersun I was somewhat dismayed when the UK company that manufactured the Immersun went into liquidation in mid-2016. However, the Immersun brand has now been acquired by another UK company and, as far as I can tell, the units are still for sale. The Immersun data monitoring system is being maintained by the new company and I visit this system every day to get an energy update from the internet. However, the marketing of the Immersun is now very low key and I don't think the units can any longer be sourced in Australia. The official Immersun website is apparently not being updated on a regular basis. There is a quite active Immersun users Facebook Group which is a good source of information on the latest developments: https://www.facebook.com/groups/1281444415228864/.

If my unit fails (it is showing no signs of doing this) I will certainly try to replace it with another Immersun. If this is not possible I will aim to replace it with another product which performs a similar proportional solar energy diversion function. I believe automated solar energy diversion is a vital component of a fully functioning domestic solar PV system.

Chapter 5

2016 Consumption: Heating

You can find details of the space heating arrangements in our household, and the reasoning behind our choice of heating method, in Chapter 6 in my energy Transition Book.

In summary, during the Transition we retired our ducted gas heating system and essentially replaced it with far infrared (FIR) heating panels. In 2015 we trialled using a storage heater but this did not prove viable and we did not use it in 2016.

The FIR panels were installed at the end of the 2015 winter and therefore winter 2016 was the first real trial of our far infrared heating in prolonged cold weather. I documented an assessment of our FIR heating experience over the 2016 winter in a Microsoft Sway which I mentioned earlier (see **Figure 20**).

As indicated earlier, if you read the Sway you'll see that over winter 2016 I had an energy epiphany and changed my heating focus from 'space heating' to 'person heating'. I'm now very much in the 'heating people, not spaces' camp – which is aimed at giving individuals thermal comfort while minimizing thermal waste.

Figure 20: The cover of my FIR assessment Sway

Year	Electricity Consumed (kWh)		Gas (kWh)	Carbon Footprint (CO_2 (kg))
	Grid Sourced (kWh)	Solar PV		
2013	274	0	5,920	1,326
2014	274	0	6,189	1,376
2015	1,853	142	0	1,594
2016	983	0	0	826
% Change 2016/2015	**-54**	**-100**	**-**	**-48**

Figure 21: Comparison in our heating energy use/carbon footprint 2013-2016

In common with the other Chapters, I have built on the relevant table in the energy Transition Book to allow a comparison in heating energy use/carbon footprint between the years. This is shown in **Figure 21.**

The most notable feature in the Figure is the more than 50% drop between 2015 and 2016 in energy use for heating. This is largely due to us being able to optimise the use of the FIR heating. However, I did not have a rigorous dedicated monitoring regime in place for our heating over the winter and therefore, while I am confident the data I am presenting is a good representation of the outcomes, the breakdown between the numbers should be treated with caution. I am planning on setting up some dedicated monitoring on the heating circuits in 2017 to improve the reliability of my data.

The heating energy data for 2016 was derived by examining the total house electricity use between the hours of 5pm and midnight for the five month Canberra heating season from May to September inclusive. To all intents and purposes the use of our house heating was confined to this time window. I computed the total energy use in this time window over the five-month period using data from my Immersun monitoring system and subtracted from this the ‘background’ electricity use. The ‘background’ electricity use was the electricity used for all uses other than heating in this time period (eg lights, cooking, TV, computers, etc). I computed this background electricity by looking at the hourly total household electricity load over the 5pm to midnight period for the last two weeks of October 2016 – I took this to be a time when heating had stopped but all the other uses were broadly continuing at the same level as through winter. While this is clearly an approximation, I don’t believe it is inducing gross errors. **Figure 22** shows the breakdown between the energy used for heating over the winter 2016 (May-September inclusive) compared to that used for the background tasks.

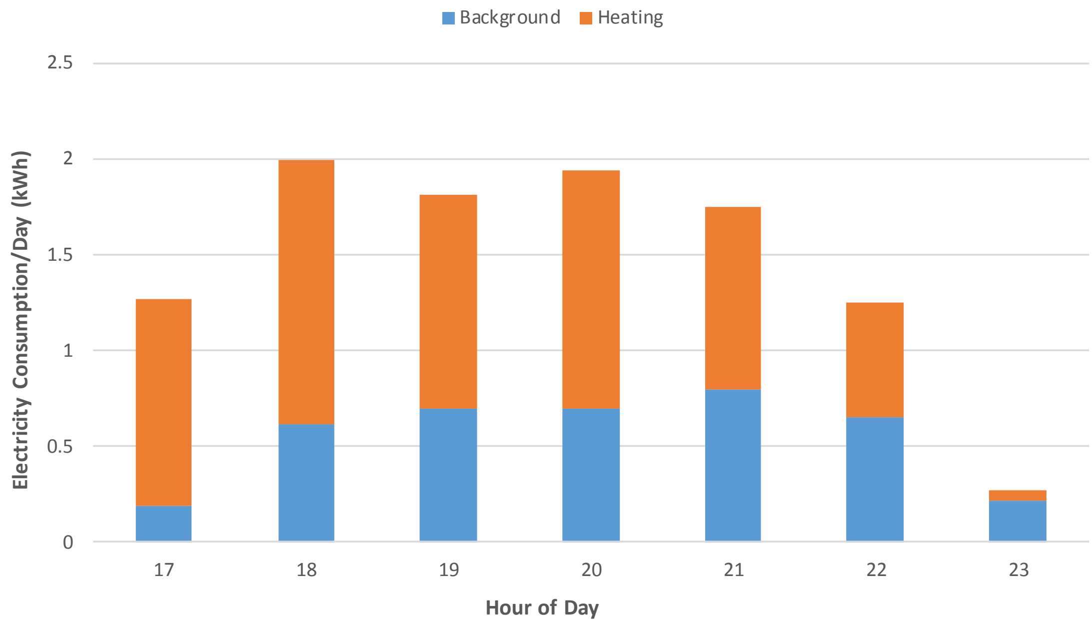


Figure 22: Heating energy over winter in the evening hours compared to ‘background’ energy use

This Figure shows an interesting pattern. The background energy use is reasonably constant through the five main evening hours while the heating energy use reduces as the evening progresses. If we had been space heating our rooms, it would be expected that the hourly heating energy use would increase over the evening as the outside temperature dropped. However, as I explain in the FIR assessment Sway we moved to a ‘person heating’ mode over winter 2016 which resulted in the heating energy use dropping off in the late evening.

Over the winter I became particularly interested in FIR heating and could see from our experience that it holds the promise of being the domestic heating method of the future. As it is essentially a simple form of resistive heating it should be possible to incorporate sophisticated electronic controls into FIR in a way which opens up the possibility of a highly personalised individual, low energy, digital form of heating. In my view, it is important that we move on from using hot air as the medium to keep us warm in our homes.

Thinking about the future, toward the end of the year I came across a range of very basic, low cost, FIR heaters being sold on Ebay and AliExpress. These appear to mainly originate from Eastern Europe (particularly Ukraine and Russia). I could not resist buying one ($50 USD including freight cost)[14] – in essence it appears to be akin to a laminated poster and was sent through the post rolled up in a small package which weighed about 700g. I have attached this 'poster' to a child's drawing easel as a demonstration of how it can be used – this is shown in **Figure 23**.

I have only informally tested the heater but it draws about 450W and has a surface temperature of about 70^{o}C. Subjectively, it throws out much more heat than you would expect for a heater of that power rating.

I am planning on more thoroughly testing this heater in the first part of 2017 and propose to write a short assessment report in the style of my other reports.

Figure 23: Our simple 'poster' FIR heater

[14] http://www.ebay.ca/itm/Infrared-Heater-Image-Flexible-Wall-Hung-Heating-Panel-220V-Picture/191994501092?_trksid=p2047675.c100005.m1851&_trkparms=aid%3D222007%26algo%3DSIC.MBE%26ao%3D1%26asc%3D39923%26meid%3D0a45c1195ae54748ae3f146745f6eece%26pid%3D100005%26rk%3D6%26rkt%3D6%26sd%3D121932949309

Chapter 6

2016 Consumption: Other

Our house, I guess like the majority of Australian homes, is full of electrical devices. Overall the 'Other' category made up about 15% of our household total energy consumption in 2016.

We simply plug 'in/out' most of the devices in this category on an as needs basis. Some devices are constantly plugged in but use relatively little energy because they are controlled by a thermostat (eg the fridge); others are constantly plugged in but are very low power devices (eg fire alarms, internet router). Given the diversity of these devices and the varying amount of time they are used in a year, I have not datalogged the energy use of most of these appliances. **Figure 24** shows my estimates of the annual energy use of the key individual electricity consuming devices in our house which I have placed under the 'Other' category.

Device	Rated Power (kW)	Variable Power	Typical Use/Week (hours)	Notional Annual Energy Consumption (kWh)	Comments
Induction Top	7.4	Y	5	200	Usually use one/two 'elements'
Electric Oven	3.6	Y	4	200	
Electric Kettle	2.2	N	1	115	
Washing Machine	2.1	Y	6	25	
Iron	1.8	Y	1	15	
Tastics	1.1	N	1	60	
Microwave	0.8	Y	2	85	
Vacuum Cleaner	0.7	N	0.5	20	
TV – Plasma	0.4	N	30	600	
TV - LCD	0.1	N	5	25	
Desk Top Computer	0.1	N	40	200	
Fridge	0.1	Y	168	350	
Lights	0.006	N	40	150	Single globe = 6W

Figure 24: Notional annual energy use by the main 'Other' electrical devices in our house

The Figure only includes what I can identify as the major electricity users in our house. In addition to the items shown in the table we also have numerous low powered, or very occasional use, electrical devices: mobile phones, router, toothbrushes, shavers, radios, laptops/tablets, clocks, cooling fans, etc.

The values shown in column 5 for the annual energy consumption can only be treated as very indicative 'guesstimates'. Having said that, the total annual energy use in the 'Other' category for 2016 shown in **Figure 4** (which I computed by difference based on the energy use of the other end uses) = 2,516kWh. The total of the annual energy use for the individual items shown in column 5 in **Figure 24** = 2,045kWh. Therefore, overall I believe my energy guesstimates appear to be quite reasonable.

The table clearly identifies the main energy hog in our household's 'Other' category – the plasma TV. I hope that we will be sending this to the electronics recyclers in the not too distant future.

Given the 'permanently on' status of our fridge I datalogged its energy over the last two months of 2016 using the socket level monitor shown in **Figure 10**. The results are shown in **Figure 25.** It can be seen that, as expected, the energy use increased toward the end of the year as the temperature rose. I indicated in **Chapter 1** that we installed a new fridge in the later part of 2016 – this has a 3.5 star rating and the label indicates an annual energy consumption of 385kWh. My monitoring to date suggests our annual energy consumption for the fridge should be somewhat lower than the value shown on the label.

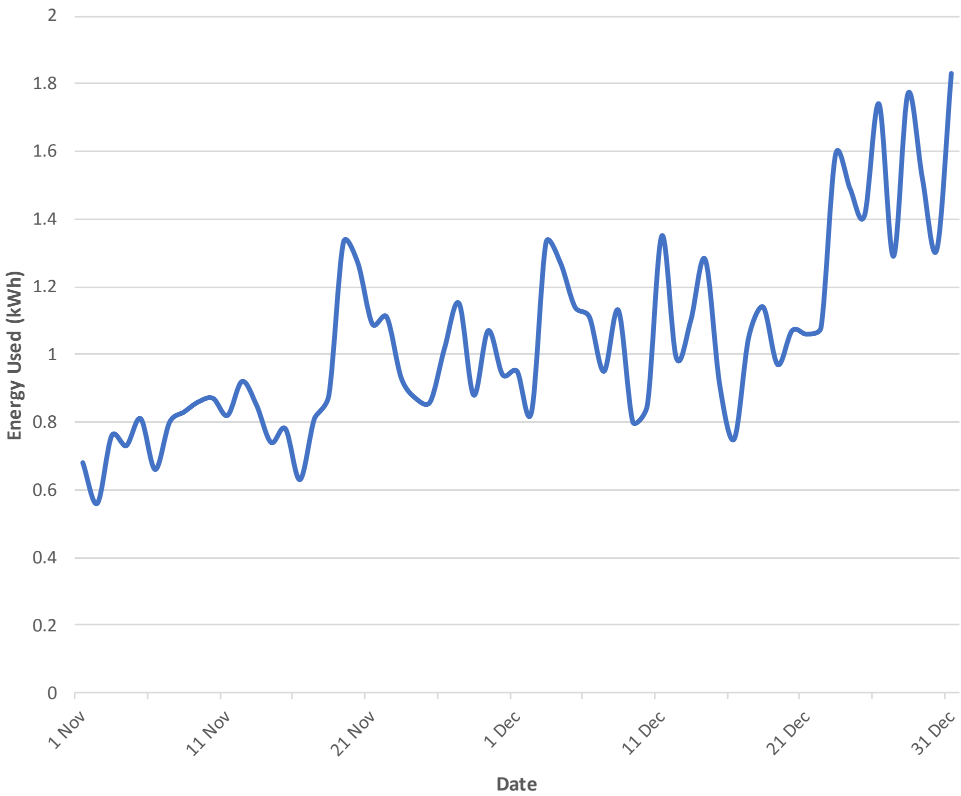


Figure 25: Energy use log for our new fridge: Nov-Dec 2016

Chapter 7

Looking Ahead to 2017

I guess at the start of 2016 I had not really turned my mind to how I expected the energy use patterns for the year to work out. Anyway, now that I have crunched the numbers I am very pleased. We seem to have made a lot of progress by 'tweaking the system': for me the adoption of FIR heating in a 'personal heating' mode was the star of the show – not only for the energy/comfort benefits during last winter but also for the promise this holds for the future. Having said that, using my Immersun to directly solar charge our EV was another big winner. 2016 has now gone; what does 2017 offer us?

I am hoping that 2017 will be the year of the battery. Along with a lot of other people, I was very pleasantly surprised in October last year when Elon Musk made his announcement about the Tesla Powerwall 2 – almost twice the power/energy storage and about half the cost of Powerwall 1 which came out early in 2016! I had been holding out on getting a home battery for a few years – we seemed a long way off my price trigger level of $1,000/kWh – but it now appears that everything has happened in a rush! I'm in the market for a Powerwall 2! Having said that, it has yet to arrive in Australia and we don't yet have all the technical details so maybe I'm getting ahead of myself.

If everything works out OK with Powerwall 2, I propose to install an additional 4kW solar PV system on the east facing part of our roof. I plan to put it on the east facing roof for two reasons: firstly there is no room left on the north and west facing roofs; and secondly I would like to capture some early morning energy since this will help me to more fully solar charge my car before I take it out in the middle of the day.

I have deliberately not worked out in any detail what I expect to achieve if/when I add a Powerwall 2 + 4kw solar PV to our current set up. I would certainly expect that with this installation in place we will need to have very little import of grid electricity over the six/seven warm months in Canberra. Over the winter months I imagine that there will be a significant reduction in the amount of grid electricity we consume, but it will certainly not be enough to meet all our electricity demands. If we install a second Powerwall 2 I guess we may get very close to being fossil fuel free as far as our annual electricity consumption is concerned – but that's for another year!

I am much more confident about predicting our energy use with our cars. I don't anticipate my family's total car energy consumption will change to any significant extent in 2017. However, if we are able to buy the Powerwall 2 + 4kW solar PV combination I would hope that we will be able to make further improvements in our % grid independence for EV charging. Irrespective of that, unfortunately the cars will remain the single biggest contributors to our fossil fuel pie because we are likely to keep our petrol car for a few years yet.

While our family car situation may be relatively static in 2017, this is definitely not going to be the case for the global car industry. General Motors has just released the Chevrolet Bolt in the US – touted as the first long range full EV on the market which sells at a 'reasonable' price.[15] Almost all the major car manufacturers have now announced new plug-in electric cars of some ilk. Some Tesla

[15] http://www.chevrolet.com/bolt-ev-electric-vehicle.html

Mark 3s may appear this year. It seems that battery power advances and price reductions are being announced every week. These are really exciting times for EVs!

Other than the Powerwall 2 + 4kW solar PV package, my main aim for 2017 is to improve our energy monitoring system. I noted earlier in the paper that I believe our current monitoring set-up is inadequate. I have been advised by Efergy that it is going to release an electrical socket level datalogging system this year – if this happens I may well be in the market for a few units. That aside, my main monitoring task for the year is to get a much better handle on our heating energy use. I'm pretty confident that I can make that happen.