Our Household Energy Transition

Becoming a Fossil Fuel Free Family

2017 ANNUAL REPORT

UPDATED

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Dave Southgate

Foreword

This is my second annual report tracking the progress we are making toward my family's goal to become a *Fossil Fuel Free Family*. As far as possible I have kept this document in the same format as the 2016 Annual Report to allow easy comparison between 2016 and 2017.

We are continuing to make significant advances towards our goal. Our household energy use and carbon footprint continue to shrink. Over the past five years our annual imported energy use (including petrol) has dropped from approximately 26,500 kWh/yr to around 7,700 kWh/yr. In the same time period our annual solar PV production has increased from around 2,800 kWh/yr to about 14,100 kWh/yr. At the moment I think we are about two years ahead of where I expected we would be at this time – the leap forward has come mainly because of the big advances in home batteries (both capacity and price) that have occurred over the past year.

As we get closer to our fossil fuel free goal the annual improvements in our carbon performance will inevitably become more subtle. Major investments may only bring marginal gains (eg installing extra solar PV to cope with winter energy demands). Nevertheless, I remain keen to continue upgrading our household energy systems until we reach effective grid independence – I believe it is important to practically demonstrate how household fossil fuel freedom can be reached.

For me this annual report acts as my end of year stocktake. After examining the progress we have made each year I work out my broad action plan for the coming year. I spell this out in the final Chapter.

Dave Southgate

Canberra

February 2018

Background

Over the past five 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. 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 2016[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. Early in 2017 I produced my first annual report on the project's progress.[2] That report essentially updated the earlier information to include data on 2016 and also included some commentary on the actions that we took in that year to help us toward our FFF goal.

In this 2017 annual report I have deliberately kept the format as close as possible to the one I used in last year's annual report – I have done this not only to make my writing task easier but also to facilitate easy comparison between successive annual reports. However, I have included two new substantive topics in this year's report – 'Limits to Growth' and 'The Battery'. Both of these topics relate to game changing events that occurred in 2017.

In 2017 the major changes we made to our household energy system were the installation of an additional 2kW solar PV system and the installation of a Tesla Powerwall 2 battery. Aside from that I undertook quite a number of special projects – in particular, I spent a lot of effort optimising our winter heating regime. I discuss all these activities in the text.

Limits to Growth

When I first learnt about rooftop solar PV - a long time ago now - I wondered how a distribution system designed solely to deliver electricity would be able to cope with houses both consuming and generating electricity. I soon forgot about this potential constraint as rooftop solar mushroomed and life seemed to go on as normal. However, in 2017 I ran into the limits to the growth of domestic solar PV systems.

Electricity Retailer Rules

In the early part of the year I decided I would like to add another 4kW solar PV system to our house to get us closer to our FFF goal. At that point I was not aware that my electricity retailer, ActewAGL, had imposed an installation limit of 10kW per phase for solar PV. My proposal would have taken us to 12kW on our single-phase supply so I faced a decision – I either had to cut back my proposed expansion to a 2kW system or opt to go three-phase. In the end I opted to simply max out our single-phase supply to 10kW because I was not sure how going three-phase would affect the

[1] *Our Household Energy Transition.* Dave Southgate. Feb 2016: https://www.slideshare.net/davesouthgate/becoming-a-fossil-fuel-free-family

[2] *Household Energy Transition - 2016 Annual Report*. Dave Southgate. Feb 2017: https://www.slideshare.net/davesouthgate/2016-annual-report-household-energy-transition

performance of my energy diverter (an Immersun) which I was using to both solar heat our hot water and solar charge our electric car.[3]

As things turned out, we were lucky because on 1 July 2017 ActewAGL reduced the allowable solar PV output for new installs to 5kW per phase.

Overvoltage

Our new additional 2kW solar PV system (Solax inverter) was installed in mid-April 2017. For the most part this system performed beautifully over the winter but in late September, when our solar PV output started to rapidly increase, the inverter began to drop out on most days around lunchtime, particularly on sunny days. I discuss this in more detail in **Chapter 3**, but in simple terms these system dropouts were caused by the voltage in the system rising and exceeding the overvoltage limit of 255V for our Solax inverter. I had not come across this as an issue before, but in 2017 not only did it restrict my family's solar PV output, overvoltage also became an issue for two other households that I am friendly with in two quite separate suburbs of Canberra. However, it turned out to be only a temporary issue as our electricity provider reduced the voltage within the distribution system at all three locations and the problem has gone away, at least for now. I imagine that this is likely to be an ongoing issue as more solar PV systems are installed across the ACT.

Roof Space

The third constraint I came across, although somewhat minor compared to the two other issues, related to the availability of good quality roof space for solar PV. I guess this is an issue that all potential solar PV owners have to address in one form or another. We have a large house with plenty of roof space but we hit three issues:

Orientation

In 2017 we were installing our fourth solar PV system. Our original three systems more or less took up all the available space on the north and west facing areas of our roof. This left the east facing roof as the next obvious area for our new system. While this is not an ideal orientation for total solar production (say 20% less production than north facing) it in fact met our immediate requirements very nicely as I was looking to get some 'early start' solar production that would allow us to have a fully charged EV as early as possible in the day. In the end I did not see having to place the new system on the east facing roof as a constraint – it is very useful to have PV panels on east, west and north facing areas of the roof to facilitate PV production throughout the day. The output from our 2kW system on our east facing roof is, in fact, superior to that of our 2kW systems on our west facing roof.

Shading

We have no shading issues with the panels installed on the north and west facing areas of our roof. However, we did have a small amount of shading on the east roof, from a few trees immediately to the north east of the house, very early in the morning when the sun was low. I arranged for some of the offending trees (all exotic plants) to be lopped and we now only get a very minimal amount of shading – importantly this only occurs at times when solar production would be insignificant anyway due to the low angle of the sun. Again, this was not a real issue because I already wanted to lop the trees, irrespective of the solar PV shading, because I thought they were growing too tall.

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[3] *Using an Immersun to Automatically Solar Charge an EV.* Dave Southgate. Jun 2016: https://www.slideshare.net/davesouthgate/using-an-immersun-to-automatically-solar-charge-an-ev-cpawpjyhrnudmrag

Access to roof cavity

It seems to be a regular occurrence for tradesmen to want to have access to our roof space to carry out some task or other. I certainly don't blame them for wanting to go in through the tiles rather than via the ceiling hatches inside the house – I don't like working in an enclosed roof cavity (dark; cramped; and often hot and dusty). As we slowly cover our roof with solar PV panels the options for lifting tiles to gain access to the roof cavity are disappearing. It's not an issue at the moment but it is something I'll need to keep in mind if/when we add more solar panels.

Summary of Energy Outcomes

Overview

Figure 1 shows the energy type split for our energy use during 2017. In very broad terms, about 40% of our household energy use was from petrol; 40% from our solar PV system; and 20% from grid electricity.

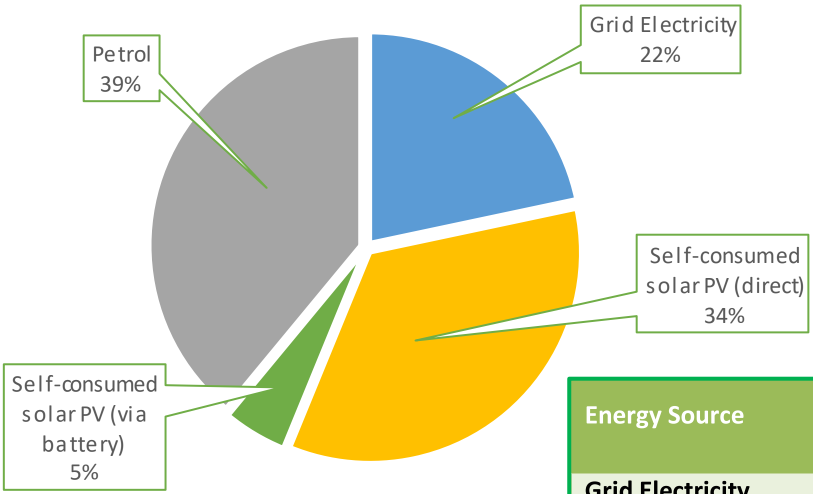

Figure 1: Breakdown of our household energy use for 2017

Energy Source	Energy Use (kWh)
Grid Electricity	2,757
Self-consumed direct solar PV	4,392
Self-consumed (via battery)	611
Petrol	4,964
Total Energy Use	**12,724**

When compiling the data I was surprised that our total energy use for 2017 was almost identical to that for 2016 (only 10 kWh different). I was not expecting such a steady result and suspect this is just a statistical quirk. While the total energy usage was the same, we had quite a significant drop in our usage of grid electricity and a corresponding increase in self consumption of our solar PV. Installing our house battery seems to have had a very marked effect.

As I have mentioned many times before in my other publications, it is important not to neglect the very significant amount of energy we use in the form of petrol even though our main family car is an EV. For some reason most people seem to forget about their family cars when computing their household energy use.

Grid electricity in the ACT is about 40% renewable on a net basis,[4] and therefore it could be argued that in 2017 our household energy consumption was about 50% fossil fuel free. However, I am more comfortable to consider that at present we are about **40% fossil fuel free** (the % which derives from our own solar PV) since much of the actual power we draw from the grid is likely to be sourced from coal. If considering electricity on its own, we were approximately 70% fossil fuel free in 2017.

[4] Figure derived from this article in the Canberra Times: http://www.canberratimes.com.au/comment/ct-editorial/williamsdale-solar-plant-a-renewable-energy-milestone-for-act-20171006-gyvz5e.html

I imagine that these figures will change rather dramatically over 2018 as we will (hopefully) have a full year with the Powerwall 2 in operation.

Figure 2 shows a breakdown of our total household energy consumption by use category for 2017.

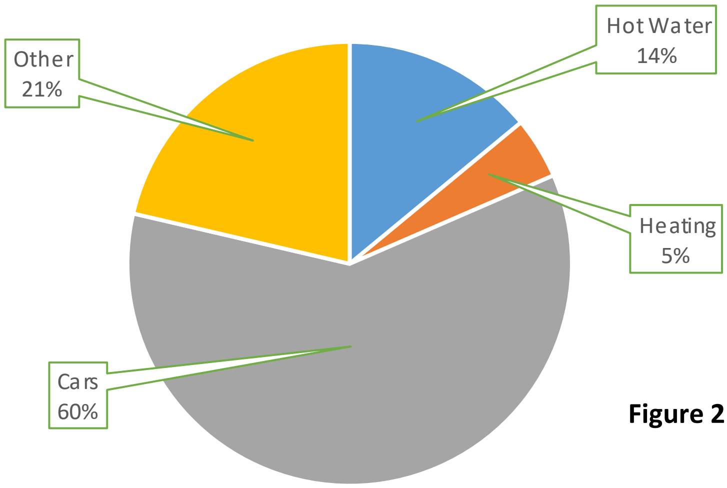

Figure 2: 2017 energy use by use category

This figure emphasises the dominance of motor vehicles in our household energy use. This energy split (ie 60% for cars; 40% for house) is not dissimilar to that for the average household in SE Australia (albeit on a cost basis).[5]

Figure 3 shows the breakdown of our household electricity use over the last three and a half months of 2017 when we had the Powerwall 2 in place. I'm really looking forward to seeing what this Figure will look like at the end of 2018 with a full year of battery use!

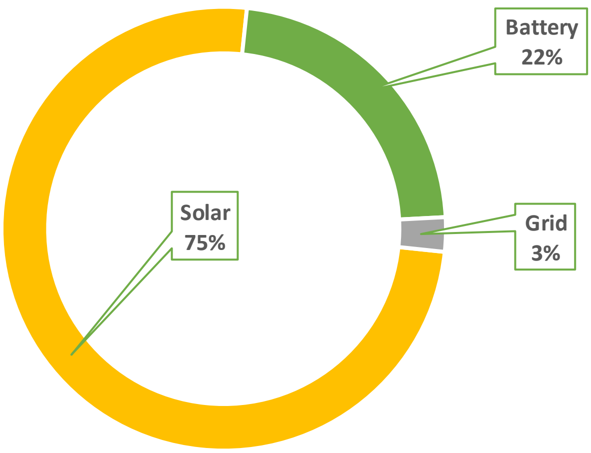

Figure 3: Electricity source over last 3.5 months of 2017

[5] *Household Energy Consumption Survey, Australia: Summary of Results, 2012*. Australian Bureau of Statistics. Sep 2013: http://www.abs.gov.au/ausstats/abs@.nsf/Lookup/4670.0main+features100072012

Disaggregating the data

In order to place the 2017 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 and in the Annual Report for 2017.

While I have very solid data for total electricity use, I have had to make some assumptions in allocating energy use data to disaggregated categories. I discuss the key assumptions in **Chapters 4 to 7**. All CO_2 data for electricity for 2017 is based on the 2017 conversion factor for NSW/ACT electricity published in the 2017 Australian Greenhouse Accounts.[6]

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. However, we are continuing to make step changes in our household energy set up (eg installing the Powerwall 2) and these will result in significant changes in our patterns of energy use in the near term. I discuss my proposed changes for 2018 in **Chapter 8.**

Imported Energy (grid electricity, gas, petrol)

It can be seen from **Figure 4** that in 2017 we had an approximate 25% reduction in the use of grid electricity compared to 2016 - this led to an about 10% reduction in our overall use of imported energy and in our household carbon footprint.

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**
2017	2,757	2,604	-	-	4,964	1,191	**7,721**	**3,795**
% Change 2017/2016	**-26**	**-17**	**-**	**-**	-	-	**-11**	**-12**

Figure 4: Household imported energy use for 2017 compared to earlier years

Notes: (1) The grid electricity data in **Figure 4** 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

[6] *National Greenhouse Accounts Factors*. Department of the Environment and Energy. July 2017: http://www.environment.gov.au/system/files/resources/5a169bfb-f417-4b00-9b70-6ba328ea8671/files/national-greenhouse-accounts-factors-july-2017.pdf

and the numbers in **Figure 7** 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 5 shows the end use breakdown for our household total energy use in 2017 compared to previous years. The most notable change from 2016 is the approximate 40% reduction in the amount of energy we used for heating – this resulted from the major change in heating approach which we adopted over winter 2017. This is discussed in **Chapter 6.**

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**
2017	1,615	569	7,655	2,885	**12,724**
% Change 2017/2016	**-7**	**-42**	**2**	**15**	**-**

Figure 5: End use household total energy consumption for 2017 compared to earlier years

Energy use in each of the end use areas shown in the table is discussed in **Chapters 4 to 7**.

When discussing our energy use I usually like to think in terms of daily use for the separate end uses. I show these in **Figure 6.**

End Use	Daily Energy Consumption (kWh)
Hot water	**4.4**
Space heating	**3.7** (for the five-month heating season in Canberra)
EV	**7.4**
Petrol car	**13.6**

Figure 6: Daily energy consumption for the main end uses in 2017

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**
2017	14,119	7,402	3,215	6,413	5,323	**2,108**
% Change 2017/2016	**15**	**-15**	**-35**	**-22**	**-23**	**-19**

Figure 7: Summary of our solar PV production in 2017 compared to earlier years

***Note:** *It is assumed that each kWh of solar PV (ie carbon zero electricity) which we export displaces one kWh of grid electricity (ie predominantly coal based electricity) somewhere in the generation/transmission system.*

Figure 7 provides data for our solar PV generation and export over the period 2013-2017. We had a 15% increase in solar PV production in 2017 compared to 2016, I think it is safe to assume this increase was primarily due to the fact that we installed an additional 2kW solar PV system in mid-April 2017.

Our consumption of imported energy dropped by around 15% in 2017 compared to 2016. It can be seen that in 2017 we had an approximate 20% reduction in the amount of electricity we exported despite the fact that we generated 15% more solar PV electricity in that year. This was a direct result of our greater level of self-consumption in 2017 – I primarily attribute this turnaround to the installation of our Powerwall 2.

It is interesting to note that the change in the balance of our imported/exported electricity led to an approximate 20% degradation in our net carbon footprint being reported in **Figure 7**. This apparent worsening of our performance is simply an artefact of the way I have ascribed carbon – I have treated the carbon footprint of our self-consumed electricity as having zero carbon but have given a carbon displacement credit to the solar PV output we export. In hindsight it may have been less confusing if I had treated the carbon footprinting of all our solar PV output on the same basis.

Costs

The electricity data in **Figure 8** is derived from our household electricity bills and includes the 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 $310 for electricity supply charges in 2017 – about 40% of the amount we were charged for our electricity consumption.

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
2017	818	-	676	1,494	1,742	-248
% Change 2017/2016	-8	-	-	-4	12	

Figure 8: Cost breakdown for our household energy use for 2017 and earlier years

The approximate 10% increase in our credits for our solar production primarily arises from the fact that our electricity provider increased the value of our feed in tariff from 7.5c/kWh to 11c/kWh in July 2017.

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	397	**5,709**
2016	80	826	3,283	139	**4,328**
2017	62	472	1,784	1,477	**3,795**
% Change 2017/2016	-40	-43	-47	?	-12

Figure 9: End use carbon footprint breakdown for our household in 2017 and earlier years

Figure 9 that shows our total carbon footprint is continuing to slowly reduce.

It is important to read this table in the context of the detailed discussions on our patterns of energy consumption in **Chapters 4 to 7.** While there are large relative reductions in the size of our carbon footprint in the 'hot water', 'space heating' and 'cars' categories the absolute reductions are comparatively small. The 'other' column has been computed by difference and shows a very significant increase. I believe these large swings are simply highlighting the difficulties of accurately computing the disaggregation between the categories rather than identifying major shifts in the composition of our carbon footprint. Clearly as we approach a fossil fuel free status the relative errors in our carbon footprinting are likely to increase.

Chapter 1

2017 Action

We put in place two major system upgrades in 2017 – we added an additional 2kW solar PV system in April and installed a Tesla Powerwall 2 in September. In addition to those steps, my major project during the year was optimising our house heating regime. I believe all these steps were important in helping us make more progress toward our Fossil Fuel Free (FFF) goal. These are briefly discussed below and in more detail in the relevant Chapters.

The House Battery

When release of the Powerwall 2 was announced in October 2016 I immediately realised that this battery met my requirements both for technical specifications and cost. Indeed, I was very surprised that things had moved so quickly – it seemed to be such a great leap forward on the Powerwall 1 (and other batteries on the market) in such a short space of time. Originally I was hoping that my battery would be in place before winter 2017 as that is the time of year when we are under most energy pressure, but as things turned out it was not installed until mid-September.

Given the importance of the battery to the achievement of our FFF goal I have devoted a whole Chapter to discussion on this (**Chapter 2**). As a simple overall comment, I would say that I believe the Powerwall 2 will be a real game changer for us. I am very impressed!

Additional 2kW Solar PV System

As we have progressed toward our FFF goal I have been aware that we will need to progressively upgrade our solar PV systems to meet our electricity demand over winter. As I mentioned in the beginning of the document, I initially wanted to add 4kW of additional solar PV in 2017 but I ran into power output limitations imposed by our electricity retailer. In order to stay under (the then) requirement to not exceed 10kW on any one phase I only installed 2kW of additional solar PV. This system has not been without its own limitations – I discuss this in **Chapter 3**.

I envisage that we will still need to add more solar PV output in the coming years and this will inevitably mean that we have to go three-phase. I imagine that this could take us into some interesting new territory: export limited PV systems (maybe even export limited to zero); and possibly installing panels on the (relatively small) south facing area of our roof.

Winter Heating Regime

While the other two actions were one-off big ticket items, I spent most of my time over winter exploring ways to optimise our winter heating regime. In this context 'optimise' meant trying to reduce our energy use while at the same time maintaining, or ideally improving, our thermal comfort. In addition, as things evolved, and the media and politicians focussed very heavily on electricity costs, I became interested in achieving the gains at a low cost.

I have reported on my winter heating activities in a separate paper which I entitled '*Heat Yourself: Not Your House'.* [7] I give an overview of this work in **Chapter 6**. I also wrote an article on this work which was published on the 'One Step Off the Grid' website in October 2017.[8]

As an overall comment I would say that I was extremely pleased with the outcome of this work. In simple terms, and as the title of my report implies, we moved away from heating our house to heating ourselves. This gave us some rather special reductions in our total winter energy use and introduced us to using a range of low cost personal heating devices that provided beautiful thermal comfort while drawing less than 50W.

In addition to buying and testing a range of personal heating devices I also worked on trying to finesse the performance of our Far Infrared (FIR) heating panels. In last year's annual report I briefly referred to a thin film FIR heater which I had imported from Ukraine at the end of 2016. I used this heater as a test bed for different FIR controllers and released a report on my findings in April 2017.[9] As a result of this work I bought new controllers for both our ceiling mounted FIR panels in our main living area and for a smaller FIR panel in our bedroom. These let us move away from controlling the panels with thermostats, to a regime which gave the user direct control over power use – this move enabled us to make some significant energy savings with our FIR panels.

I consider my winter heating project to be on-going. Indeed, I acquired two new heating devices after the end of our winter heating season and these did not make it into my report: a wonderful fluffy 'Onesie'[10]; and a small area panel heater[11]. The 'Onesie' is simply a passive heater (ie it requires no electricity input) while the small panel heater was part of my quest to find the perfect size for a personal FIR heater. Unfortunately, these arrived too late in the year to be given any real testing but my initial thoughts are that the Onesie will be extremely useful while the panel heater is unlikely to deliver what I am looking for. I discuss FIR heating further in **Chapter 6**.

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[7] *Heat Yourself: Not Your House.* Dave Southgate. Oct 2017: https://www.slideshare.net/davesouthgate/heat-yourself-not-your-house

[8] *How to make serious cuts in home heating costs – and stay warm*. Dave Southgate. Oct 2017. One Step Off the Grid: https://onestepoffthegrid.com.au/make-serious-cuts-home-heating-costs-stay-warm/

[9] *Naked Far Infrared (FIR).* Dave Southgate. Apr 2017: https://www.slideshare.net/davesouthgate/a-thin-film-far-infrared-fir-home-heater

[10] The all-in-one Company. United Kingdom: https://www.the-all-in-one-company.co.uk/

[11] Econo-Heat Wall Panel Heater. TVSN: https://www.itvsn.com.au/include/oecgi2.php/product?product=048823

Chapter 2

The Battery

We had our Tesla Powerwall 2 installed in the second week of September 2017. It is a gamechanger. **Figure 10** shows the Powerwall sitting on the wall in our garage next to our Nissan Leaf and our car chargers.

Our Powerwall seems to have been the missing link in our project to become a fossil fuel free family. In the four months it was in operation at the end of 2017 we used minimal grid electricity (on average 0.6 kWh/day). Based on our energy use/production data for 2017 I estimate that in 2018 we will be in this more or less grid free consumption position for about eight months of the year (if we add no more solar PV).

Figure 10: The Powerwall 2 sitting next to our EV in our garage

The battery has essentially worked flawlessly, without any intervention from me, since we have had it. It did trip out once for no apparent reason (about 9am; fine weather; cool temperature; almost full; charging at a rate of about 3kW). I simply re-set it (there are clear instructions in the manual) and it immediately came back to life – there have been no more problems.

Over the three and half months that the Powerwall 2 was in place at the end of 2017, we sourced about 75% of our electricity directly from our solar PV system; about 22% from the battery and about 3% from the grid (see **Figure 3**).

Storage capacity

The data shown in **Figure 12** suggests that our battery storage capacity is much bigger than we really need for our summer electricity demands – in the four months it was in use in 2017, on average we drew about 5.5 kWh/day from the battery. We ran the battery completely flat once – this happened when we had three consecutive very cloudy/rainy days and we used our EV quite a lot. Even then, we only drew 2kWh from the grid before we were back up to more or less exclusively relying our solar/battery combination.

I hesitate to forecast how well the system will work over winter but, based on our 2017 data, I estimate that if we add no more solar PV, the battery will enable us to operate our house (including our EV) over winter drawing an average of about 5 kWh/day from the grid.

Having said that, I am contemplating adding another 4kW of solar PV to our roof before winter. If I do this, I think it will take us a long way toward being fossil fuel free over the whole year.

Power capacity

While the energy storage capacity in the battery is more than we need for our summer energy needs, the same does not apply to the power capacity. The Powerwall 2 allows a maximum 5kW continuous power draw (7kW max).

This is OK, but not excessive, for summer. For example, if I am charging our car with our Level 2 charger (which pulls 3.6kW) and I put on the electric kettle (pulling 2.2kW) we will be over the 5kW mark. If I do this during the day the output from our solar PV system will generally mean that we will not draw any power from the grid. On the other hand if I do this in the evening we will pull at least 0.8kW from the grid, irrespective of the state of charge of the battery. If you add the electric stove + our induction top + our plasma TV and you can see that we will draw quite a lot of power from the grid even though it may be for a relatively short period of time.

During winter the above scenario of course gets much worse. Add in heaters, lights, etc and the 5kW limit could easily be exceeded for quite long periods. However, in a sense this is not so important because our main constraint in winter will almost certainly be lack of energy storage (ie our solar PV systems will not generate enough electricity to fill the battery) rather than power capacity.

The lack of power capacity was one of the reasons why I held off installing one of the earlier generations of battery. For example, the Tesla Powerwall 1 was only able to deliver 3.3kW which was way under our requirements for any time of the year. At the present time it seems that we will be able to live within the 5kW power constraint for a good part of the year. Ideally I would like to have 10kW available.

Monitoring the Powerwall

For me, an avid data gatherer, a basic requirement for any equipment I install is that I am able to monitor its performance. As far as I am concerned, the monitoring regime that comes with the Powerwall 2 is both good and bad.

Starting with the good. It has a very nice intuitive app (both iOS and Android) which lets the user get a good handle on most of the operating data for the battery and gives an excellent overview of how the battery is fitting into the total energy management regime for the house. **Figure 11** is an example screenshot from the monitoring system.

The downsides? For me the system has two glaring weaknesses. Firstly, it does not work on Windows and, as I do the monitoring for all my other devices using the Windows environment, this is a bit of a nuisance. Much more important, the Tesla system does not let me download data, therefore I cannot do any detailed analysis of how the battery is performing. Each day I do note down the value of three parameters shown by the system – I use this information in the next two sub-sections.

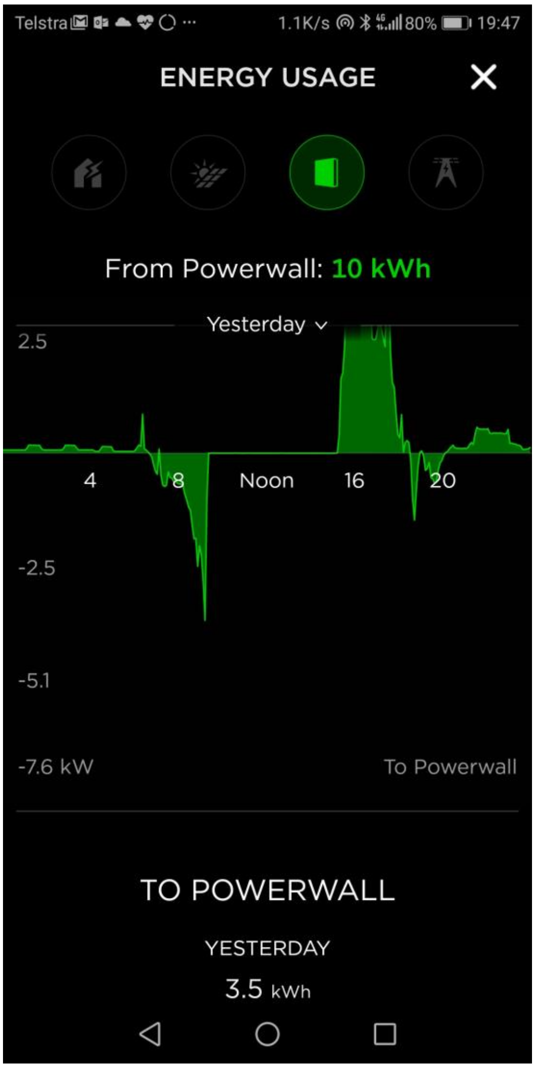

Figure 11: Screenshot from the Powerwall 2 monitoring app

Battery Efficiency

Amongst other things, the monitoring system gives a value each day for the total energy put into, and drawn from, the battery (see **Figure 11**).

Over the period 13 Sept 2017 to 31 Dec 2017 (the time that the Powerwall was in operation) we injected a total of 760 kWh into the battery and we extracted a total of 611 kWh from the battery. This translates to a charging energy efficiency of around 80%. This means that the Powerwall 2 consumed about 1.3 kWh/day over the 3.5 month period.

I am happy with this. This is about the same charging efficiency as that which I have monitored for the charging/discharging of our Nissan Leaf EV. The specification details for the battery shown on the Tesla website says 'Efficiency – 90% round-trip'. I can only assume that the 90% efficiency relates to each separate inversion of AC to DC into the battery and DC to AC out of the battery which gives an overall efficiency of 80%.

Battery Performance

Figure 12 shows the day to day variation in the amount of energy drawn from the battery over the last 3.5 months of the year. It can be seen that this varies quite widely.

For the most part, the days when we drew most energy from the battery were days when we used our EV more than normal. Only a few of the high battery use days were associated with days of poor solar PV production. I assume that when winter comes the days of biggest draw on the battery will mainly be associated with extended periods of gloomy weather.

Average energy drawn from battery = 5.5 kWh/day

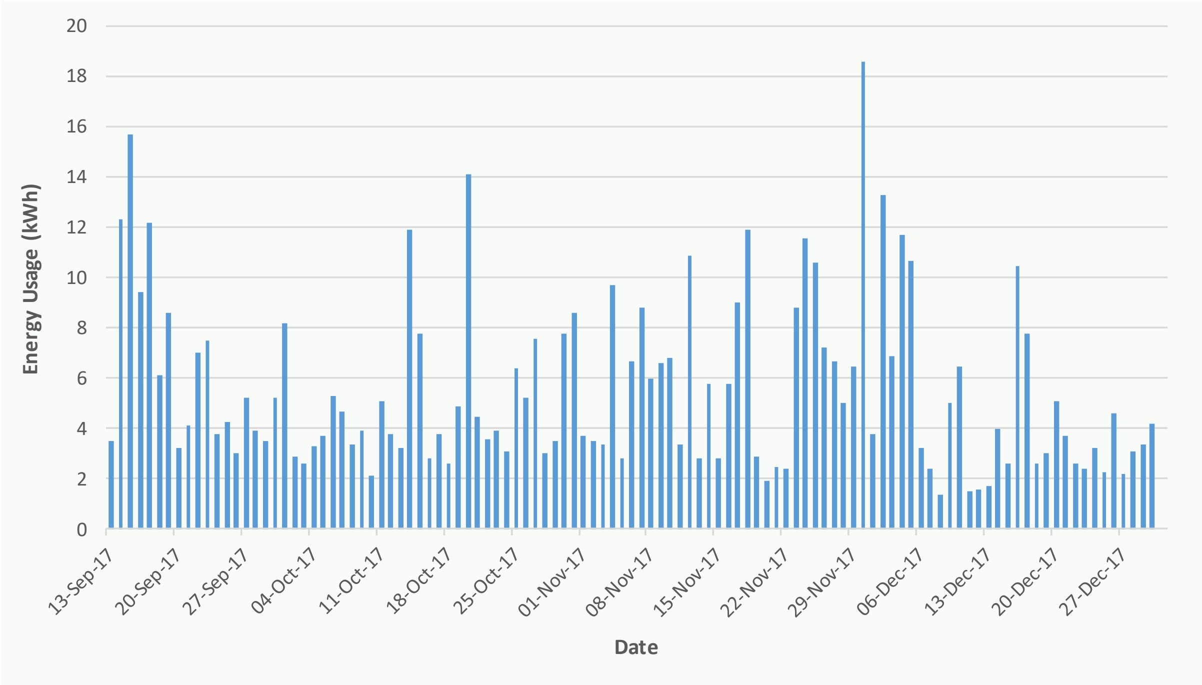

Figure 12: Daily energy drawn from our Powerwall 2

Chapter 3

2017 Generation: Solar PV

Our solar PV production and export for the past five years was summarised in **Figure 7.** The key differences in our solarPV production between 2016 and 2017 were discussed in the text associated with that Figure.

As noted earlier, towards the end of April 2017 we installed an additional 2kW of solar PV (Solax inverter). I had initially wanted to add 4kW but, as I indicated at the start of this report in the 'Limits to Growth' paragraph, I ran into the then limit of 10kW of solar PV/phase rule applied by our retailer.

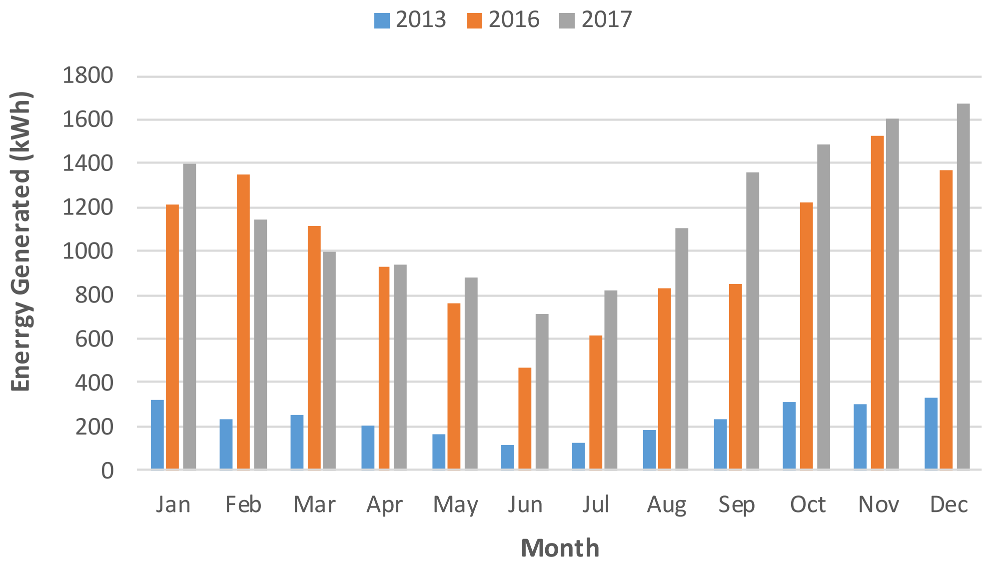

Figure 13: Comparison of our 2013, 2016 & 2017 solar PV production

Figure 13 compares our solar production across 2013, 2016 and 2017 broken down by month. I have included the three years of data to show how our solar PV capacity has increased since we started our FFF project. The impact of installing the additional 2kW of PV in April 2017 can clearly be seen for May 2017 onwards.

Overvoltage drop-outs

I mentioned earlier that in September we ran into overvoltage problems with our latest solar PV system. At the beginning of each day the system worked perfectly as I charged the EV and heated our water – generally about 10kWh/day. However, once this load was removed (typically between 10am and noon most days) the inverter cut out for very long periods. By way of example, **Figure 14** shows the inverter output for a day in late September. On investigating the issue, I found that the inverter was performing as designed – it was cutting out when the voltage in the system reached 255V. At the beginning of each day the system voltage was typically about 249V and without a load it rapidly reached 255V. This issue was solved when our electricity provider dropped the voltage in our local distribution area. After this was done our voltage first thing in the morning was typically around 243V. We had no further problems after this.

Figure 14: Screenshot of the overvoltage drop-out on 25 Sep 2017

Self-consumption of solar PV electricity

In last year's report I discussed my preference not to focus on 'self-consumption' but to think more in terms of achieving '% grid independence'. Ultimately, I am looking at us achieving effective total consumption independence from the grid (say 95% independence) before I will claim we have reached our goal of 'Fossil Fuel Freedom' with respect to our house energy consumption (ie not counting our petrol car).

As discussed in the previous chapter, installing the battery gave us a total step change in our level of grid independence. **Figure 15** shows how our level of grid independence varied over 2017. The impact of installing the Powerwall 2 in mid-September is very evident.

2017 overall rate of household grid independence = 70%

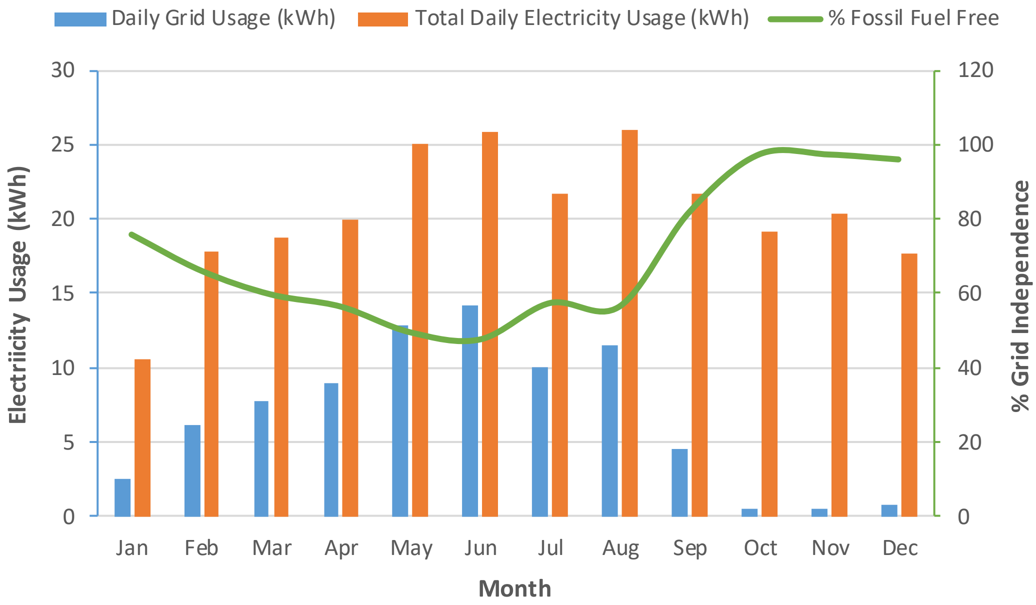

Figure 15: Variation in grid independence over 2017

For comparative purposes I have included the corresponding Figure from last year's annual report as **Figure 16**.

2016 overall rate of household grid independence = 52%

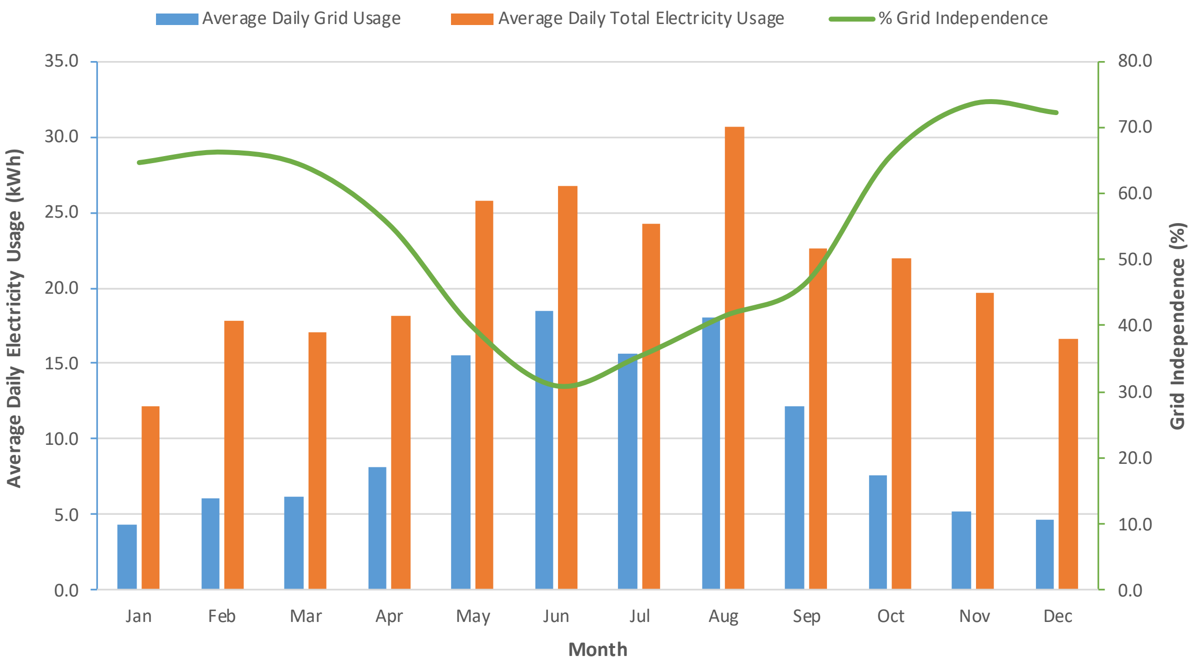

Figure 16: Variation in grid independence over 2016

It is interesting to note the differences between the two charts (keeping in mind that the scale on the axes is different between the two Figures): our monthly electricity consumption rates in winter were up to about 5kWh/day lower in 2017; the lowest monthly % grid independence in 2016 was about 20% lower than in 2017;

I also find it useful to compare how well we are progressing in terms of grid electricity consumption v solar PV production – this is shown in **Figure 17.** This picture is now looking quite healthy but there is still a way for us to go (not all our solar PV generation is available for our consumption as 2KW of our solar capacity is connected to a gross FIT system). Having said that, the impact of the battery + an additional 4kW should change the data in this Figure quite dramatically over 2018.

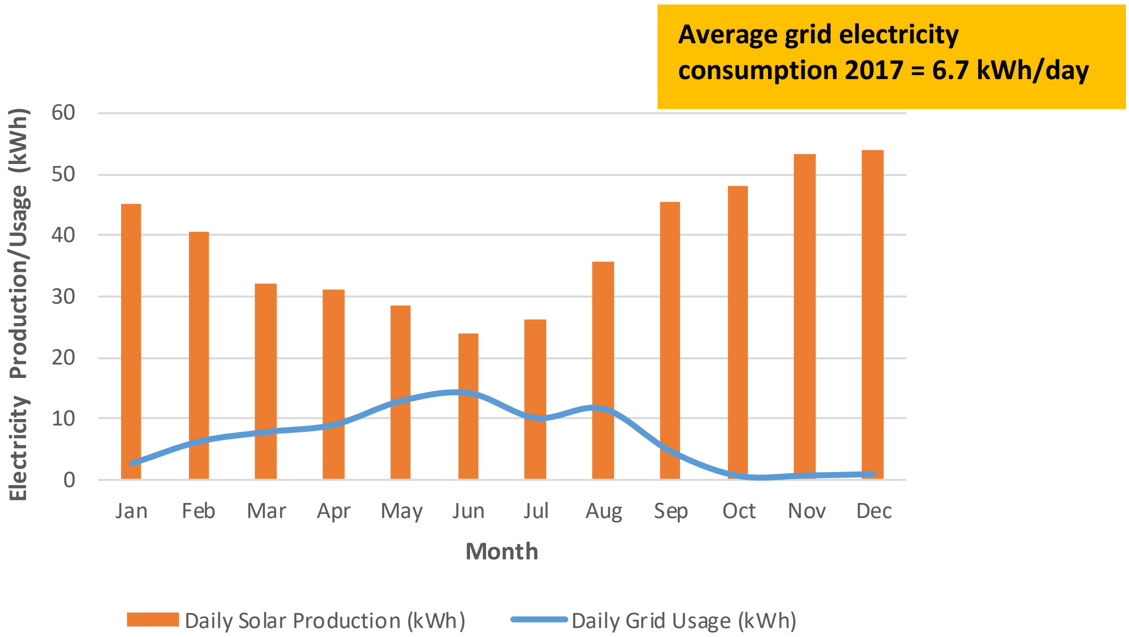

Figure 17: Grid electricity consumption v solar PV production for 2017

Next Solar PV Steps

Looking at the data for 2017 I imagine that we will need to add more solar PV capacity in the future in order to get us through winters in a fossil fuel free state. At this stage it looks like our prime winter constraint will be lack of solar PV capacity rather than lack of battery capacity. At the moment my thinking is to add an additional 4kW of solar PV before winter 2018 – this will take us up to a nominal 15kW of solar PV capacity in total. I have been advised that this is now the export capacity limit in the ACT for domestic solar PV systems. Having said that, it is not hard to find advice which conflicts with this.[12]

As I have discussed earlier, expanding our solar PV capacity is not going to be straightforward. We will have to move to a three-phase electricity system – this means that I will have to review how I use our energy diverter (an Immersun unit – one of my favourite gadgets). While a 15kW system will be fine for now, if we want to install additional PV capacity in the future (eg if/when we get rid of the petrol car and move to two EVs), and the 15kW export limit is correct, I guess we will have to install export limited solar PV systems – ones which are limited to zero export. We may have to install some panels on a south facing part of our roof. An interesting prospect!

As something of an aside, I have been very impressed with our Solax inverter. It has worked perfectly and it provides the best monitoring data that I have seen from an inverter – I think our next inverter may also be a Solax.

[12] *Solar system size limits: How much does your local network allow? [UPDATED]. Solar Choice. Nov 2017:* https://www.solarchoice.net.au/blog/solar-system-size-limits-by-network

Chapter 4

2017 Consumption: The Cars

We did not change our cars in 2017; we have now had our EV (a Nissan Leaf) for four years and our petrol car (a Hyundai i30) for about six years. We have used the cars in more or less the same way for the past four years. Our energy use for the cars in our household over the past five years is summarised in **Figure 18.**

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**
2017	714	1,977	4,964	**7,655**
% Change 2016/2015	**-29**	**31**	-	**2**

Figure 18: Our car energy consumption 2013 - 2017

***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 2017 was more or less the same as in 2016. We travelled further in our EV in 2017 compared to 2016 and achieved a slightly worse rate of efficiency. This is summarised in **Figure 19.**

Year	Energy Used (kWh)	Distance Travelled (km)	EV Efficiency (kWh/100 km)
2016	**2,518**	**14,292**	**17.6**
2017	**2,691**	**15,141**	**17.8**

Figure 19: Comparison of 2016 & 2017 EV energy use

Note: The energy efficiency has been computed using data on the car energy efficiency and distance travelled displayed on the EV dashboard; the computed energy use has been multiplied by 1.2 to take account of energy losses in the battery charging process (about 20% of the energy input is lost in the charging process).

I am happy with the data shown in **Figures 18 & 19 -** this seems to indicate that there has been no major degradation in the EV's performance over the last year and that about 75% of the energy consumed by our EV in 2017 was sourced from our solar PV (up from a figure of about 60% in 2016).

I have reported elsewhere about our regime for solar charging our EV (see **ref 3**). In simple terms, we use the relay function of our Immersun energy diverter to carry out this task – as far as I am concerned it has proven surprisingly effective.

In common with the other categories in this report, the battery has been a game changer in improving the extent to which we have been able to reach grid independence for the charging of our EV. **Figure 19** is an indicative picture of the variation in grid independence for charging our Leaf over 2017. I have deliberately used the term 'indicative' because I am not confident about the breakdown between our solar and non-solar charging for the first nine months of the year (I had a number of weaknesses in my monitoring regime). Having said that, I am confident in the total EV energy consumption reported in **Figure 19** and in the data shown in **Figure 20** for the last three months of 2017 (the overshoot for the Oct figure is simply an artefact of the smoothing algorithm).

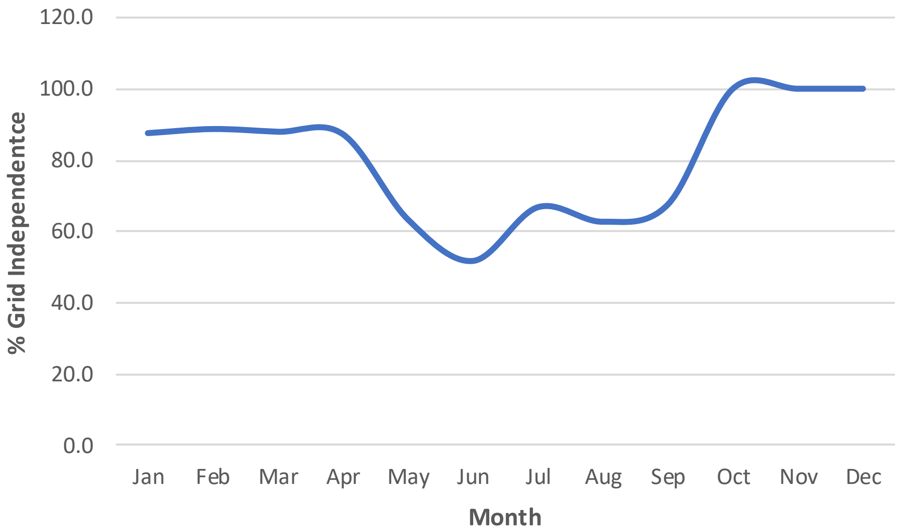

Figure 20: Indicative grid independence for our EV over 2017

In broad terms, until the Powerwall 2 was installed in September 2017 our level of grid independence was similar to 2016. For the last 3.5 months of the year we exclusively charged the car with the output of our solar PV - some of this was direct solar charging: some was from the battery.

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]

Battery Status

When you buy a Nissan Leaf it shows the new battery as having 'twelve bars'. Over time, as the battery slowly degrades, the bars start to disappear. As I understand it, if the battery loses more than three bars before five years, or 100,000km, is reached the company will replace the battery under warranty.

I don't think I noticed when we lost our first battery bar. I think we lost our second bar in mid-2016. We lost our third bar in August 2017. This means that if we lose another bar in 2018 we will be eligible for a replacement battery – it may or may not happen, but I certainly don't intend to deliberately maltreat the battery so that we can get it replaced.

I have found it interesting that, although the disappearance of the bars is indicating the inevitable ageing of the battery, this doesn't seem to be having any great effect on the car's range. When the car was new in 2014 I wrote that I considered it to have a range of about 100km. Today I would describe it as having a 90km range. As far as I can tell, the battery degradation to date has not affected the way I use the car.

Our Next EV

It seems to me that there was much more hype about new EVs being 'just around the corner' in 2017 than in any other year I can recall. Almost all major car manufacturers announced, or firmed up, their electrification plans. Tesla, with its Model 3, probably captured most attention. Being a Leaf owner of course meant that Nissan's September 2017 announcement of the next generation Leaf, the Leaf 2, really caught my attention. Not surprisingly, I found it difficult not to start salivating about my next EV.

When we bought our EV at the start of 2014 I imagined that we might keep it for about five years. This five-year ownership plan was not because I expected the EV to be worn out in that time: I simply expected that the next generation of EVs would be available within five years and I wanted to keep up with the latest EV developments.

There have certainly been quite a few times over the past few years that I have felt things are not moving along as quickly as I'd expected in the EV space – particularly as far as Australia is concerned. However, I have been really heartened by EV developments overseas and in the back of my mind I always had 2020 as the year when things would really change. I am now very optimistic that by the end of 2019 I will be able to buy a new EV in Australia that will be a real step up from my current Leaf at around the same price.

I think it is important to note in passing, that apart from advances in battery technology the new generation of EVs will be marked by the advent of autonomous driving capability. My current Leaf has no driver assist features other than cruise control (not a lot of use in a city car). The new crop of EVs seem to be adorned with all sorts of sensors and driver assistance features. How well these work will be a major determinant in deciding which EV I buy next (assuming I have a choice!).

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

Chapter 5

2017 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 energy diverter. The Immersun was operational for the whole of 2017.

I cannot praise the Immersun highly enough. As in 2016, 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, we use the Immersun to solar charge our EV.

Figure 21 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 2017 we enjoyed an approximate 20% reduction in our hot water grid electricity usage compared to 2016 (however, this represents only a small change in the total amount of grid electricity use). On the face of it the breakdown of our energy use for hot water in 2017 was very little changed from that in 2016.

Year	Electricity		Gas (kWh)	Total Energy Consumed (kWh)	Carbon Footprint (CO_2 (kg))
	Grid	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
2017	75	1,540	-	1,615	62
% Change 2017/2016	-21	-6	-	-7	-23

Figure 21: Breakdown of our hot water energy use and carbon footprint for 2017

On average we used 4.4 kWh/day to heat our water throughout 2017. This was a slight decrease on our energy use for hot water in 2016.

Figure 22 shows how our average daily energy use for hot water for 2017 varied across the year. It also gives data for the monthly level of grid independence of our hot water electricity. This Figure looks remarkably similar to the equivalent Figure for 2016 in last year's Annual Report. With the battery now in place, I envisage that our hot water for 2018 will effectively be 100% fossil fuel free.

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

2017 rate of grid independence for hot water = 95%

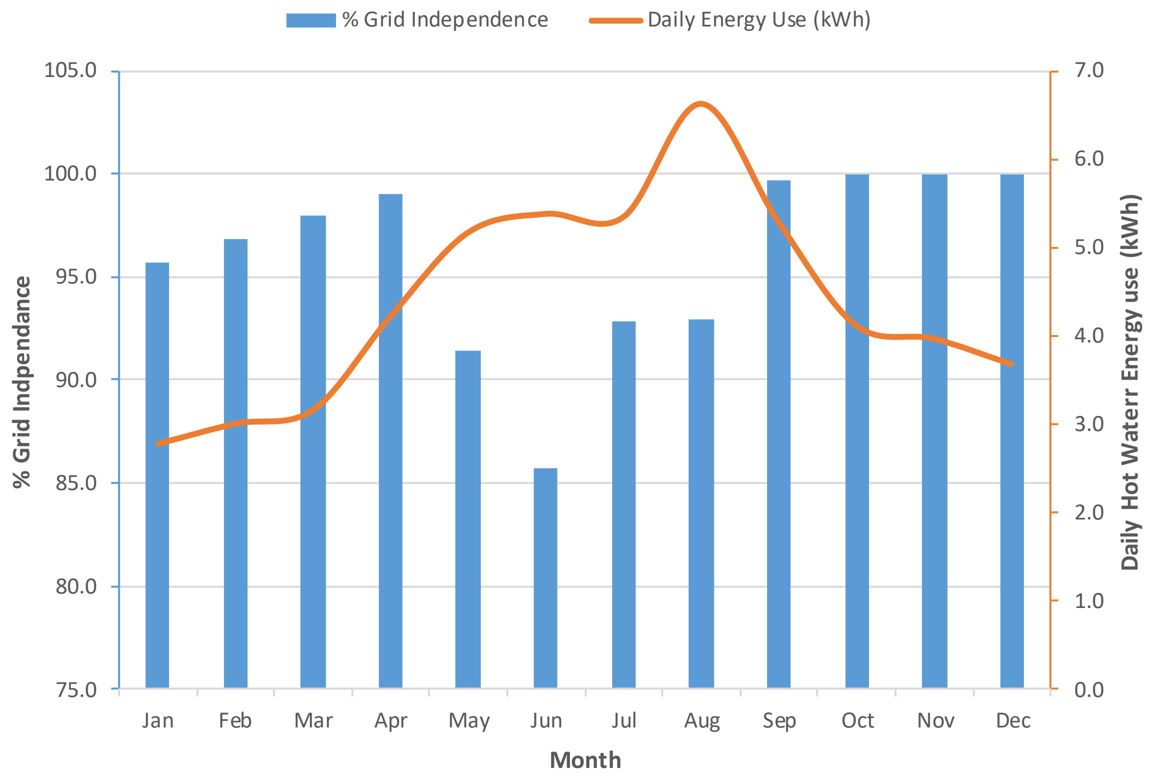

Figure 22: % Grid independence and daily hot water energy use for 2017

I have mentioned earlier that I am contemplating moving to a three-phase electricity supply in 2018 in order to accommodate the installation of additional solar PV. This does raise questions for the operation of my Immersun unit as it is a single-phase device. However, if we go down this path we will have about 5kW of solar PV on each phase and I believe that if I just use one phase for my Immersun/water heating we should manage fine. I will also have the Powerwall 2 as a buffer so I envisage that all our household hot water in 2018 will be produced without any grid electricity (I discuss this further under the '*Going three-phase*' paragraph in **Chapter 8**).

Chapter 6

2017 Consumption: Heating

There is a somewhat long history behind our home heating regime. Over a period of five years we have gone from heating our house with a very conventional gas ducted heating system to a heating regime based on heating ourselves; we no longer heat our house. This transition has given us an approximate 90% reduction in our energy use for winter heating. In October 2017 I released the report shown in **Figure 23.**[14] This gives a detailed description of our family heating regime over winter 2017.

Figure 23: My recent report on our house heating regime in winter 2017

Figure 24 below gives a breakdown of our winter heating energy use and carbon footprint over the five years 2013-2017.

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
2017	569	0	0	472
% Change 2017/2016	**-41**	**-**	**-**	**-43**

Figure 24: Comparison of our heating energy use/carbon footprint 2013-2017

[14] *Heat Yourself: Not Your House.* Dave Southgate. October 2017: https://www.slideshare.net/davesouthgate/heat-yourself-not-your-house

I would recommend that you refer to my report cited on the previous page if you want to learn more details of my heating work over winter 2017. Nevertheless, I think it is worthwhile at this point to bring out the salient points in that report.

Figure 25 is extracted from the report and shows the breakdown of our daily primary heating energy use by month across winter 2017. In the Figure 'Study Nook' is the area where my wife works on her computer in our main bedroom ; 'Living Room' is our main living area where we eat, watch TV, etc. It can be seen that across the heating season we used just under 3kWh/day on our primary heating.

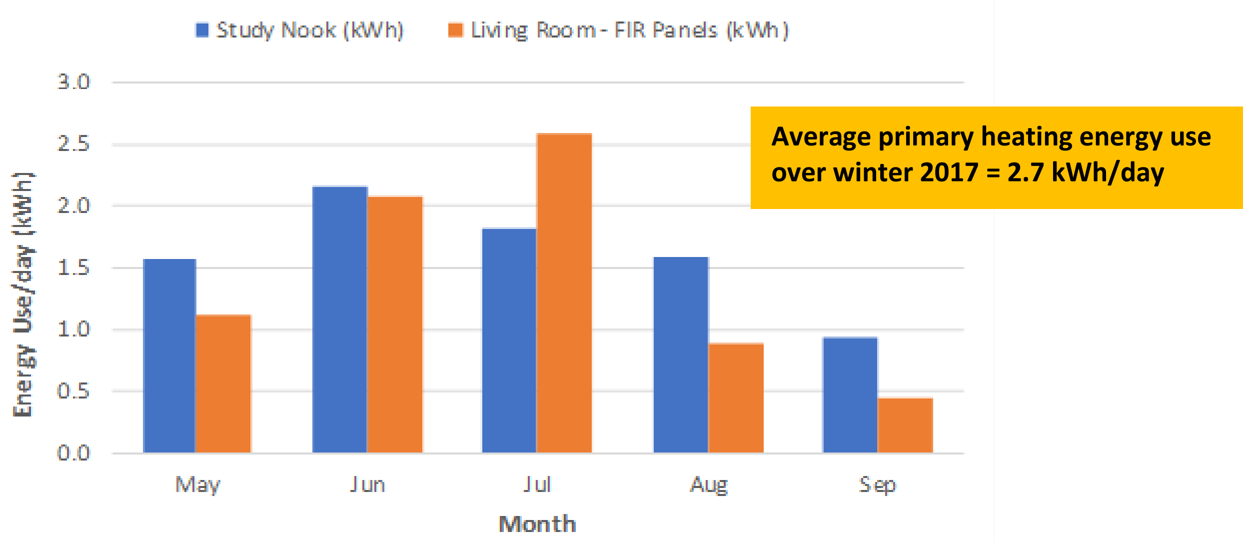

Figure 25: Breakdown of monthly patterns of heating energy use over winter 2017

In broad terms my efforts to manage our heating energy use contained two strands: the purchase and trialling of what I term PHDs – ultra-low powered personal heating devices; and optimising the wonderful heating provided by our Far Infrared (FIR) heating panels.

<u>Trialling the PHDs</u>

Over winter I progessively bought and trialled a number of PHDs. **Figure 26** summarises this work.

Heating Device	Power Use	Comments
Heated Vest	15W	Not suited to indoor use
Heavy Dressing Gown	Passive device	Brilliant
Heat Patches	Exothermic chemical reaction	Not suited to indoor use
Heated Seat Pad	15W	Brilliant
Heated Electrical Throw	50W	Excellent but limited
Electrical Foot Warmer	20W	Surprisingly effective
Fluffy Onesie	Passive device	Yet to be tested in anger – looks very promising

Figure 26: Summary of PHD testing

It can be seen that we identified, and used, a number of very effective, low power, personal heating devices over the winter. These really do work.

Given the success of this part of the project I intend to keep searching for, and trialling, new PHDs. You can see from the last line in **Figure 26** that I did not have the chance to fully test the very nice fluffy Onesie that I bought on the internet. This arrived after the end of the heating season but my first impressions are that it will be a real winner.

Optimising our FIR heating

I am a great supporter of Far Infrared heating panels (FIR). I have now written quite a bit of material on this topic. While I am very much an FIR enthusiast, in this material I have always inserted the caveat that I believe the current crop of FIR heaters on the market could be significantly improved. I spent some time in 2017 trying to develop ways in which I could put my FIR improvement ideas into practice.

Figure 27: My April 2017 report on FIR heating

In last year's annual report I included a photo of a 'poster' FIR heater I'd imported from Ukraine. In early 2017 I carried out an informal assessment of this heater: in particular I used it as a test bed to try out potential new ways to control FIR heaters. I reported on this work in April 2017 (**Figure 27**).[15] Before winter I applied the outcomes of this work by installing new controllers on the FIR heaters that we use every day during our heating season. In summary these controllers were a big success and enabled us to run our FIR panels at significantly lower power rates than would otherwise have been the case.

The current industry focus on marketing FIR panels as 'space' rather than 'personal' heaters means that the only panels that I can find are somewhat oversized for personal heating. With an oversize panel much of the emitted heat is wasted if you are simply trying to heat one person. I have spent some time trying to identify the best physical dimensions for an FIR panel for personal use. Based on my testing, I believe that this should be around 600mm x 600mm. With the usual FIR panel heat emission intensity of around $1kW/m^2$, this gives a full power rating for my 'ideal' personal FIR panel heater of around 350W.

In an effort to find my ideal panel heater I bought a compromise 600mm x 600mm panel heater on the internet to try out a device that would meet at least some of my requirements (see ref 10). Given that this arrived after the winter heating season, I have yet to test it in anger but my preliminary examinations suggests that while it is the ideal size, it will not give the radiant heating performance I am looking for. This is sold as a convection, rather than a radiant, heater and I therefore have no complaints about my purchase.

Conventional FIR panels are one-sided devices. The panels are designed to emit the heat from one side only. This allows them to be fixed to walls. This also means that (almost) all the energy put into the heater can be received as radiated heat by a person located in front of the panel. The new panel heater I bought is a two-sided heated panel which means that as much heat is radiated from the back, as from the front, of the heater. In essence, this means that it cannot be directly attached to a wall (potential damage + fire hazards) and that a person sitting on one side of the panel will not

[15] *Naked Far Infrared (FIR).* Dave Southgate. Apr 2017: https://www.slideshare.net/davesouthgate/a-thin-film-far-infrared-fir-home-heater

receive as much radiated heat per unit of energy input as they would if they were using a one-sided panel of the same size.

I will continue my search for the perfect personal FIR heating panel. In the meantime, we will continue to use our 600W FIR panels (using a voltage regulator) as a personal heater (recognising that it is a compromise).

Chapter 7

2017 Consumption: Other

I reported in my 2016 Annual Report that the 'Other' category made up about 15% of our household total energy consumption; during 2017 this category made up about 20% of the total. During 2017, while I made several purchases of personal heating devices (see **Chapter 6**), none of these had a significant power draw and I don't feel the need to add them to the list of the 'Other' devices that appeared in that report. Therefore Figure 24 in the 2016 Annual Report is exactly the same as **Figure 28** shown below.

Figure 28 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 28: Notional annual energy use by the main 'Other' electrical devices in our house

The values shown in column 5 for the annual energy consumption can only be treated as very indicative ‘guesstimates’. A gauge of the confidence can be gained by some cross comparison: the total annual energy use in the ‘Other’ category for 2017 shown in **Figure 5** (which I computed by difference based on the energy use of the other end uses) = 2,885 kWh; while the total of the annual energy use for the individual items shown in column 5 in **Figure 28** = 2,045kWh.

Clearly there is a high relative difference between these two values, but the absolute difference (840 kWh) is not great in the context of our total household energy use.

Chapter 8

Looking Ahead to 2018

Overall, I am very pleased with the progress we made in 2017. As I have indicated in the earlier chapters, having the battery has been a game changer; and being able to get on top of our winter heating has also been a very exciting development. However, I do not think I can claim that we have made great strides in the level of our Fossil Fuel Freedom (FFF) overall – we remain about **40% FFF.** In terms of electricity use we are now about 70% FFF and I envisage that this situation will improve significantly in 2018 as the Powerwall 2 will be in place for the full year. Owning a petrol car is now the main constraint to us becoming a fossil fuel free family.

Clearly, from here it is going to be harder to reduce the fossil based part of our household carbon footprint as we approach the asymptote of the fossil fuel freedom line. Having now crunched the numbers for last year and having thought quite a lot about where this is leading, I think I have worked out my plan of action for 2018:

Buying a new EV

As I indicated in Chapter 4, I had always envisaged that I would update our EV at around the five year mark – this point occurs at the end of 2018.

Unfortunately, there does not look like there will be a great deal of choice for new EVs within the next year. The Nissan Leaf 2 appears to be the only likely available EV on the Australian market which meets my technical specifications and sits in my price bracket (hopefully). The data available at the moment seems to be less than conclusive, but it appears the new Leaf will have about twice the range of my current car. This is achieved with a battery that is physically about the same size and weight as my current battery. Having said that, I would imagine that even if we do buy a Leaf 2 it will not make any great inroads into our fossil fuel use.

Having an EV with a larger battery would give us greater opportunity to avoid charging with grid electricity during winter. For example, with the larger battery capacity of a new EV, it is likely that I will not need to charge the car each day and could avoid charging it from the grid if/when we have a run of very cloudy days over winter.

We may also be able to use the EV on trips that we now use our ICE car for. I can see it being quite feasible for us to do day trips to Sydney and to the coast provided there are fast chargers in place at key locations. I think this may happen over the next couple of years. While using public chargers will almost inevitably involve using grid electricity (ie fossil based electricity) it will still be replacing petrol.

Going three-phase

I discussed this briefly in Chapter 3. As I mentioned, I have so far resisted going three-phase because of its possible effect on the operation of our Immersun unit which has worked brilliantly – I have used this to solar charge our hot water and our EV for the past two years**.** However, if we are to go to the next step in our household Fossil Fuel Free project we will need to have a beefed-up household electricity capacity and I will have to make it work. This step has been helped by the arrival on the market of the *Zappi* – a solar car charger which works on the same energy diversion principles as the Immersun. I discuss this in the next but-one sub-section.

I believe it is important to note in passing that going three-phase has made me think about how I define our 'fossil fuel free' goal and what 'grid independence' really means. When operating on a single phase, which we do at present, it is simple to monitor how much electricity we import from the grid and to ascribe a figure to our level of 'grid independence'. However, as I understand it if we go three phase the situation is somewhat different since the three phases can, and do, import and export independently. At any given time we can be exporting on two phases but importing on the other – while this may well mean that overall we are exporting at that time (and our net electricity meter will be showing that we are exporting), we could still be importing 'hidden' coal based electricity in the background. The purity of my 'fossil fuel free' status will be compromised. I'm still trying to get my head around the implications of all of this.

Installing a further 4kW of solar PV

I mentioned earlier that I had limited our solar PV capacity because of the three-phase issue. Going three-phase will enable us to max out our solar PV capacity. At this stage I envisage that we will add an additional 4kW of solar PV – this will take us to a nominal 14kW in total which will mean we will just sit within what I understand to be our provider's current allowable solar PV power export capacity of 5kW per phase.

If we install this before winter, I figure we will be able to get through the coming heating season with minimal use of grid electricity.

Installing a dedicated solar charger for our EV

I first began to directly solar charge our EV in late 2014. At that time I could not find any dedicated EV solar chargers and I initially carried this out manually. In the end I automated this charging using our Immersun.[16] In mid-2017 a small UK energy company (the same group which developed the Immersun) brought out a dedicated EV solar charger called the *Zappi.*[17] This is shown in **Figure 29.** The Zappi works on the same energy diversion principles as the Immersun.

At the time of writing the Zappi has yet to receive approval to Australian electrical standards. I am assured that it already does meet these, but I expect that an Australian electrician will be reluctant to install this device unless all the necessary approvals are finalised.

The Zappi is able to be hooked up to a three-phase system. If I am able to import and install one of these chargers, my plan is to keep my current EV chargers so that I will have a house that is capable of simultaneously charging two plug-in cars. I imagine that this will be the normal state of affairs for Australian homes within a few years.

Figure 29: The Zappi solar charger for EVs

[16] *Using an Immersun to Automatically Solar Charge an EV.* Dave Southgate. Jun 2016: https://www.slideshare.net/davesouthgate/using-an-immersun-to-automatically-solar-charge-an-ev-cpawpjyhrnudmrag

[17] The Zappi. Myenergi. UK: http://myenergi.uk/product/zappi/

Other things

While the above four actions are my proposed big steps for 2018 I will not be idle on other fronts. In particular, I intend to still actively pursue new options for putting in place my '*Heat Yourself: Not Your House*' philosophy. I also intend to closely monitor how our Powerwall 2 performs when winter arrives. Acquiring a second Powerwall 2 in future years is an option that I haven't ruled out.

My monitoring regimes have been a constant source of frustration over the course of our energy transition. I have often been left with gaps in my sub-data and have had to resort to gathering energy breakdown data which I don't have a great deal of confidence in. As always, in 2018 I will keep making efforts to find, and install, monitoring systems which give a more solid disaggregated picture of our household energy use.

Editorial Note

In the final stages of production of this document I encountered a major file corruption. Untangling myself from the mess unfortunately meant that I lost some of the formatting in the tables. I trust this does not detract from the information.