Our Household Energy Transition

Becoming a Fossil Fuel Free Family

Project enters Phase 2 in 2020: Net Zero Emissions

2019 ANNUAL REPORT

UPDATED

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Dave Southgate

Foreword

This is my fourth 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 three earlier annual reports to allow easy comparison across the years.

We didn't make any great energy/carbon gains over 2019, but by converting our house to three-phase electricity, and by buying a second-generation electric vehicle, we prepared the ground for the next stages in our decarbonisation. While things felt like they were moving incredibly slowly as the months just disappeared, overall I was satisfied that we had a productive year.

In common with much of the broader energy debate across Australia, my focus is now very much on our transport carbon footprint. It looks like it is going to increasingly dominate our household fossil fuel use for the next year or so.

Given the progress we have made in the last six years in moving away from the direct purchase of fossil based fuels, I have decided to call 2019 the last year in **Phase 1** of our energy transition. While we still have to finish off our work on **Phase 1**, **Phase 2** begins with the new decade. In simple terms in **Phase 2** I plan to work on reducing our indirect carbon footprint: for example, how can we reduce the CO_2 emissions from the food we eat; our use of public transport; the goods we buy; and the services we use?

Australia has received an unprecedented fiery wake-up call over summer 2019/20. If governments don't want to, or are not able to, fight climate change individual households have to take action.

Dave Southgate

Canberra

February 2020

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Background

Over the past six 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, as a family, we make no direct use of fossil fuels, which effectively means not buying any grid electricity, gas or petrol. 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. I treat 2013 as our baseline year – we took our first steps to actively reduce our carbon footprint at the beginning of 2014. Early in 2017 I produced my first annual report on the project's progress (my 2016 Annual Report).[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. I subsequently produced similar project annual reports for 2017 and 2018.[3,4]

As indicated in the Foreword, in this 2019 annual report I have deliberately kept the format as close as possible to the one I used in my previous annual reports – I have done this not only to make my writing task easier but also to facilitate easy comparison between successive annual reports.

When I set up the project I had hoped that we would be more or less fossil fuel free by 2020 if things worked out well. I have been more than happy with our progress on reducing the carbon footprint of our house. However, we are not fossil fuel free primarily due to the much slower development and adoption of electric vehicles than I had hoped for. Having said that, I feel that it is now time to call a close to the first phase of the project and start **Phase 2**. In essence I want us to move beyond simply working on our directly used fossil based energy (the goal of **Phase** 1) and start working on reducing our indirect fossil fuel use.

Against that background I believe it is now worthwhile to look back and see what we achieved in **Phase 1**. I summarise our progress to date in the next three pages.

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[1] *Our Household Energy Transition: Becoming a Fossil Fuel Free Family*. Dave Southgate. Feb 2016: https://southgateaviation.files.wordpress.com/2016/02/transition-final3.pdf

[2] *Household Energy Transition: 2016 Annual Report.* Dave Southgate. Feb 2017: https://southgateaviation.files.wordpress.com/2017/02/annual-report-2016final.pdf

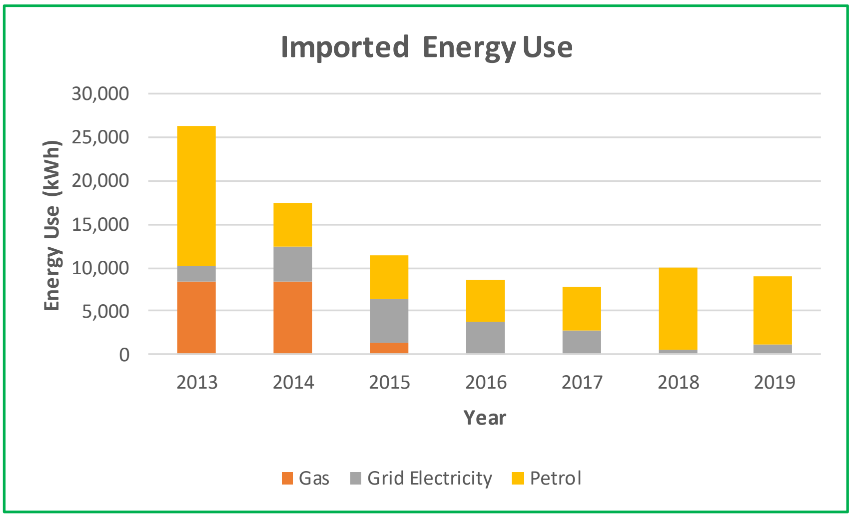
[3] *Household Energy Transition: 2017 Annual Report.* Dave Southgate. Feb 2018: https://southgateaviation.files.wordpress.com/2018/02/2017-annual-report.pdf

[4] *Household Energy Transition: 2018 Annual Report.* Dave Southgate. Jan 2019: https://southgateaviation.files.wordpress.com/2019/01/annual-report-2018-final.pdf

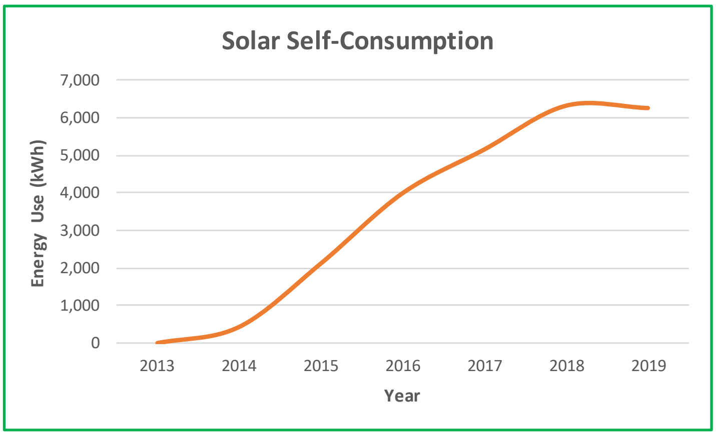
Project Outcomes. Phase 1: 2014-2019

The four following Figures show some key indicators for the outcomes of **Phase 1** of our energy transition. We achieved a lot in **Phase 1** with regard to our house, but petrol remains a challenge which is likely to take some years to resolve.

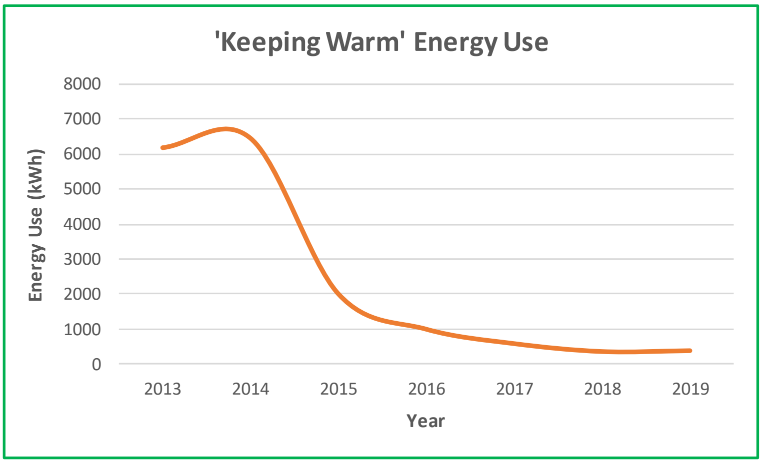
Imported Energy Use: In 2013 (our base year) all of our domestic energy use was fossil fuel based – gas, grid electricity and petrol. By the end of 2019 we had eliminated our gas use and were sourcing about 85% of our electricity consumption from our rooftop solar PV systems.



Solar PV: We installed three solar PV systems between 2014 and 2017. These systems, coupled with the installation of a Tesla Powerwall 2 battery in late 2017, underpinned our transition away from grid electricity.

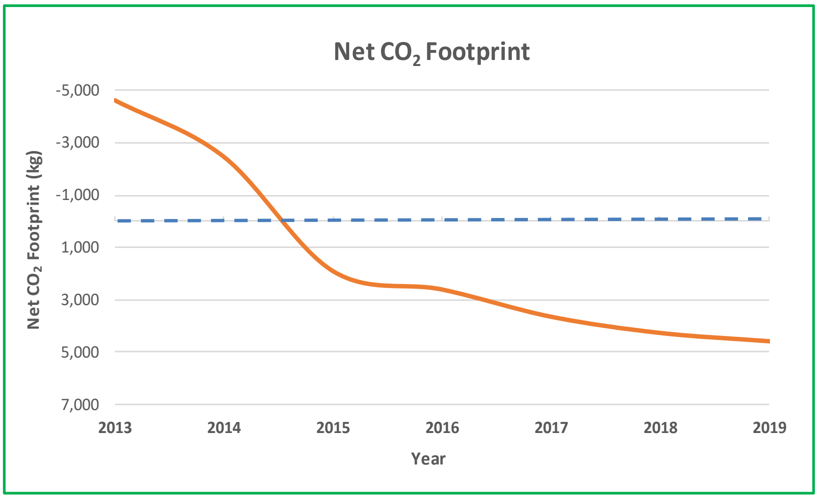


Reduction in Energy Use: While the aim of the project was not to reduce energy use *per se*, we did make some significant energy gains. In particular, by going off gas and adopting a practice of heating ourselves, rather than our house, we were able to cut our 'keeping warm' energy use by around 95%.



Carbon Footprint: Our progressive elimination of the use of fossil based fuels, plus the installation of the solar PV systems and our home battery, resulted in a significant reduction in our household carbon footprint.

We had achieved household carbon neutrality by 2014/15. The downward trend continued to the end of **Phase 1**.



Summary of Key Actions

Year	Key Actions	Key Outcomes
2013	This was our baseline year – we moved into our house in late 2012. In 2013 I simply monitored energy use and did not change any of the energy settings. We were a 100% fossil fuel based family - we used gas for heating, hot water and cooking. We had two petrol engined cars. We had no solar PV self-consumption.	We obtained some good baseline energy consumption data.
2014	We replaced one of our cars with an EV (Nissan Leaf). We installed a 2kW solar PV system. I produced a book on our EV experience.	Reduced our petrol energy use by around 70% and our car energy use by around 50%.
2015	This was the year of the major moves. We progressively weaned ourselves off gas over the year. We installed a 4kW solar PV system; an energy diversion device (Immersun) for our hot water; a storage heater for space heating in our main living area (not a success); and Far Infrared (FIR) panels in a number of rooms (wonderful!).	Eliminated the use of gas. Demonstrated the solar self-consumption abilities of energy diversion devices. Began to understand the energy and comfort benefits of personal (as opposed to space) heating.

2016	I released my ‘Energy Transition’ book. I purchased a CO_2 monitor which led me to eschew rampant draughtproofing. Indoor air quality was a key factor in my beginning down the path to becoming an advocate for the ‘heat yourself: not your house’ philosophy. I cross-linked our EV charging with our energy diversion device. We changed over all lights in the house to LEDs. I evaluated the performance of our FIR panels and produced a report.	Linking our EV with our energy diversion device resulted in about 60% of our EV energy use coming from our solar PV system. Realisation that there is no need (in fact it can be problematic) to seal up a house. Advanced my understanding of the benefits of radiant heating.
2017	We installed a further 2kW of solar PV and a Tesla Powerwall 2 battery (brilliant!). We didn’t heat our house over winter – we heated ourselves. This proved so successful I released a book on personal (as opposed to space) heating. This has been by far the most popular energy report I have produced.	Installing the house battery took the project forward by a great leap – in 2016 we imported about 25% of our electricity; in 2018 (the first full year with the battery) we imported about 10% of our electricity. I discovered the world of low energy, personal, heating.
2018	We installed an enhanced house energy monitoring system (Solar Analytics). I discovered an item of heated clothing which really works indoors. I began exploring personal cooling and purchased/tested a low powered USB evaporative cooler.	Demonstrated that ultra-low energy heating really works – you can keep very warm using clothing with in-built USB thermal patches (pulling 10W or less). Installing the Solar Analytics system significantly improved our energy monitoring/reporting capability.
2019	We converted our house electricity system over from single phase to three-phase. We bought a second-generation EV – the new Nissan Leaf. I bought, and tested, a personal refrigerated air conditioner. I purchased an adjustable heated vest which allows optimised personal heating.	Converting to three-phase set us up for installing additional solar PV. The new Leaf opened up the possibility of relacing many of our petrol based regional trips with EV trips.

Reflections on Phase 1

Given that I have now decided that **Phase 1** of the project has come to an end, I think it is important that I give at least an informal assessment of how it has gone. I have provided information in the preceding pages on how things have worked out on an energy and carbon basis, but I think it is worthwhile noting down some more subjective thoughts.

Am I happy with the energy/carbon outcomes? I'm very satisfied with the outcomes on gas and electricity. Not so petrol. I always knew that reducing our petrol use was going to be the hardest nut to crack but I guess we haven't got as far as I originally thought we might. Quite simply the EV market in Australia has been slow to evolve – at last things now seem to be happening and I can see a way ahead.

Would I have done anything differently? I don't think so. I'm comfortable with the decisions I've made over the past six years given the options that have been open to me.

Did some things not work out well? My wife sometimes looks at the unused storage heater fixed to the wall in our main living area and reminds me that it was an 'expensive mistake'. The storage heater did indeed not work out for us – some may see this as a mistake; I see it as an important experiment that gave a negative, but very useful, result! I learnt a lot from testing those waters. Another area which required a lot of trial and error was energy monitoring. Clearly having accurate and comprehensive monitoring data underpins our project. Despite having trialled quite a few monitoring systems, we still have gaps in our data – this search will go on into **Phase 2**.

Did we have any big wins? Absolutely!! I guess I am most pleased with how our winter heating regime worked out. Before we started on the project, I could not have imagined the outcome – heating ourselves; not our house. It sounds quite alien, but it certainly provides excellent thermal comfort and huge energy gains. This form of keeping warm inside our home also had positive spin-offs: it minimised the need to insulate and draughtproof our house; and most likely gave us much better internal air quality than we would otherwise have had. I have also been extremely happy with using an energy diverter to both heat our water, and charge our EV, with direct solar PV.

2019 Overview

When I look back on my report for 2018 I think I largely followed the path I had envisaged. Unfortunately, everything happened much more slowly than I rather naively thought it would, and it looks like some of my 2019 goals have turned into 2020 goals. I discuss these under the *'Key events'* heading below.

As always, preparing the annual report forces me to think about where we need to head to next in order to get closer to our FFF goal. This year, as we head into **Phase 2** of the project, I have taken a bit more of a fundamental review of where we are heading and arrived at a revised project goal: ***'net zero emissions family'***. I discuss this in the last part of **Chapter 8**.

Key events

Transition to three-phase

At the beginning of the year one of my main goals was to add additional solar PV capacity on our roof since with our current setup we were not able to meet our electricity demand over winter without using grid electricity. I was aware that, given the rules of our energy distributor (Evoenergy), we would need to go from a single phase to a three-phase electricity system.

I began the process of going three-phase in early March. This was completed at the beginning of September. It took six months! I was amazed how long everything took – at the beginning I was fully expecting to have our new solar PV system in place for winter 2019. Now my aim is winter 2020. Without going into details, getting all the ducks to line up [my electrician, my distributor (Evoenergy) and my retailer (ActewAGL)] for the sequential tasks involved in going over to three-phase was very challenging – it just seems that the electrical installation sector in the ACT is totally overloaded.

Not surprisingly before our going over to three-phase we had a house full of single-phase devices. Going three-phase required taking action for three of our devices/systems – the energy diverter; the Tesla Powerwall 2 battery; and our Solar Analytics monitoring system.

Clearly for us to get effective energy diversion for our hot water and car charging regimes we need to monitor the energy being produced and consumed on all three phases. To achieve this I replaced our Immersun unit with an Eddi (effectively an upgraded Immersun) – I discuss this in **Chapter 3**.

In a similar manner, for our battery to work to its full potential it needs to be able to monitor and react to the energy generation and use across all three phases. Setting up the Powerwall (a single phase device) for three-phase operation was not a simple task**.** Our battery was out of operation for over three months as a result of the switch to three-phase.

Our Solar Analytics energy monitoring system is set up to monitor real time energy flows across nine circuits in our house and, at the time of writing has yet to be re-configured. I discuss this briefly in **Chapter 7**.

The change to three-phase also led to our nice new empty meter box filling up very rapidly (see photos below).

Spot the difference!! Our meter box with three-phase installed (on the left): single phase on the right

Personal heating/cooling

Given my fascination with personal heating, over winter I naturally kept looking for new ideas. I bought two new heated vests: while one of these didn't really work out; one of them was a big success and I used it for my personal heating over almost all of the winter. My new favourite heater is an adjustable size, quite thin, vest which was relatively inexpensive. I also discovered kits for converting clothes into heated garments – I made some heated pants for fun but I never needed to wear these in anger. I report on this topic in **Chapter 4**.

When summer arrived in November, I turned my attention to personal cooling. I was very disappointed to discover that one of my key personal cooling devices (a cube USB evaporative cooler) no longer worked when I took it out of its winter mothballs. However, this was a blessing in disguise as I had no hesitation in buying a similar (but much cheaper) device. This worked fine given its limitations. I also report on this topic in **Chapter 4**.

New electric car

Not surprisingly, one of the highlights of the year for me was getting our new electric car. We bought our first EV at the very start of 2014 (a Nissan Leaf) and for about the last two years I've been hanging out to get a next generation EV. They have been painfully slow in arriving on the Australian market!! All of a sudden in 2019 we had a surge of new 'reasonably priced' EVs – the Hyundai Ioniq and Kona; the Tesla Model 3; the Nissan Leaf; and, to a limited extent, the Renault Zoe. We opted to buy the new generation Leaf and it turned out to be a great decision – extremely happy!! I discuss this in **Chapter 2.**

In 2019 we also started to see a very significant increase in the number of public rapid chargers being installed within the broad Canberra region. These installations, coupled with the much extended range of our EV, enabled us to take our first long-weekend EV road trip (around southern NSW) in October.

Our transport electrification extended beyond our car. In February I bought a 'lightweight' e-bike. This is a very different type of machine to the heavy standard city EV bikes that one generally sees (and my wife uses). I used this to replace my road bike on my longstanding group rides (I've been a lifelong cyclist) - I think this type of e-bike can play an important role in a future low carbon transport system. I also discuss this topic in **Chapter 2**.

Phase 2: Re-thinking some computations

When we began our energy transition the goals were somewhat simple – we set ourselves on a course to be a 'fossil fuel free family' by aiming to no longer directly buy any gas, grid electricity or petrol. Implicit in this was the assumption that we would effectively be carbon free in actuality, not just on a carbon accounting basis, with respect to our primary energy purchasing once we stop buying petrol. However, this is not as straightforward as it may appear.

This is a complex issue because while at the household level we have a strong positive carbon footprint (ie we generate much more carbon free energy than the total amount of energy we use) the actual electrons we import from the grid are from NSW, and these are predominantly coal based. In a similar vein, while the ACT now has 100% renewable electricity on a carbon accounting basis (ie the ACT generates more carbon free electricity (via its renewable energy contracts) than the total amount of electricity it uses) it cannot claim to be fossil fuel free since the electricity being imported into the ACT comes from the predominantly coal based NSW system.

I have therefore decided that for the next phase of the project I have to drop my energy purity to some extent and recognise that we will not have fossil fuel free electricity until the NSW electricity system is totally decarbonised. While we will be carbon neutral, we will not be fossil fuel free. I believe a number of issues need further explanation:

Going three-phase – increasing our actual use of coal-based electricity

When we were a single-phase household monitoring/computing our electricity carbon footprint was relatively simple: if we were exporting electricity all the electricity use in the house was from our solar PV systems; if we were importing electricity at least some of our consumption was coming from the NSW grid.

The situation can be quite different with three-phase. At any given point in time with three-phase, while we may be exporting electricity overall (electricity flows are netted at the meter) we may, in fact, be exporting on one or two phases but importing grid electricity (ie coal-based electricity) on the other phase(s). On a carbon accounting basis the situation is not changed from our single-phase days, but we lose our 'fossil fuel free' purity. We now use grid electricity when we wouldn't otherwise have done so. I see this as unfortunate, but it seems to be the inevitable price of adding more solar PV capacity to our house.

Computing our carbon footprint – not as clear cut as before

So far through the project, when I have been computing our carbon footprint, I have assumed that each kWh of solar PV electricity (carbon free electricity) we produce displaces a kWh of coal-based electricity somewhere in the system. I'm now not sure this is the case. As the National Electricity Market (NEM) has evolved it is now common in the middle of the day for prices to go very low or negative (principally in Queensland and South Australia) as demand drops and solar production reaches its daily peak. Given the inability of coal-based power stations to respond rapidly to changes in demand, solar and wind generators are either curtailing output or even shutting down completely for a short time. I therefore assume that if my household pumps electricity into the system at the middle of the day its net effect may well be to curtail the generation of 'carbon free' electricity rather than coal-based electricity.

Again, this is unfortunate but I can see no practical alternative but to carry on computing our carbon footprint using the same assumptions as before, but recognising that this involves some potential errors. I assume that this 'duck curve' effect will only be temporary as more storage is built into the NEM in response to the low/negative prices and the grid's decarbonisation.

ACT achieves 100% renewable electricity – I don't want to hide

Another important development happened over 2019 as the ACT reached its goal of having 100% of its electricity coming from renewables. As noted earlier, this means it is 100% renewable on a carbon accounting basis, but the grid electricity we import, and actually consume, almost exclusively comes from NSW (the ACT Government has set up three small solar farms around Canberra).

At one level, any ACT household can now claim to be carbon neutral with respect to its electricity consumption and, in effect, any solar PV that they may produce can now be claimed to go toward pushing them into carbon positive territory. However, I would not be comfortable computing our household carbon footprint on this 'offset' basis and will continue to use the factors published in the National Greenhouse Accounts to compute the actual carbon content of our imported electricity (noting the difficulties I've been discussing in the earlier paragraphs).

Change in terminology

From the beginning of the project I have used the term 'space heating' in many of my tables and graphs to describe the energy we use to keep warm. For the first 2/3 years this term accurately described what we were doing, but when we transitioned across to personal heating it no longer accurately described our energy use patterns. I retained the term 'space heating' because it is a very widely recognised term and it allowed my tables/graphs to have continuity across the years.

In **Phase 2** of the project [and in this 2019 Annual Report] I am going to replace the term 'space heating' with the term 'thermal comfort'. This new terminology will not only more accurately capture how we are keeping ourselves warm over winter – using personal heating – it will also nicely capture discussion on personal cooling. It would appear that energy use for cooling will becoming a more important topic as time progresses. I discuss 'thermal comfort' in **Chapter 4.**

Little things

Throughout this, and my other, annual reports I have focussed on the big steps we have taken to reduce our CO_2 emissions. However, I have also been continually looking to make small adjustments to our energy consumption patterns. Individually these 'little things' make extremely small contributions to climate change action, but they could make a significant contribution if they were taken up widely across the population.

The three steps which I discuss below are examples of 'little things' that I/we've done over the past year. These are commonplace and in no way remarkable, but I do believe they are positive environmental steps:

Canberra Times Digital

I retired in 2012 and one of my daily rituals since then has been to walk round to the nearest coffee shop (15 minute walk) first thing in the morning; buy the *Canberra Times*; and catch up on the news/do the Sudoku over my coffee. One of the joys of being retired!

I always felt guilty about buying the newspaper in paper form, but it was part of a ritual. Anyway in 2019 I changed over to a digital form of the paper (apart from my own guilt, my teenage daughter put on some pressure). I've survived the change; discovered some advantages of digital newspapers; and hopefully saved some trees.

New TV

We've had a plasma TV for some years now, and I've always been concerned about its inefficiency (it pulls over 400W). Gladly we've now replaced it with an LED TV (bigger and much higher resolution) which has a power rating of 198W. As I observe later in the text, the energy savings by taking this simple step are likely to equal the total amount of energy we use as a family each year in keeping ourselves warm/cool in our home.

Using the Canberra Light Rail

This is a bit complex and I'm not sure I'm doing the right thing. [I should say at this stage that I was not a big fan of the light rail when it was being developed – I was an advocate for electric buses. Now that it is here, I freely admit that I was wrong – I now think it is a magnificent addition to Canberra's transport infrastructure.]

For the past six years we've used our EV as our main family car for getting around Canberra but over 2019 I used the Canberra light rail rather than my EV for travelling into the centre of Canberra (Civic) during business hours. I used the light rail primarily because it is so much easier than using the car –

finding a park in Civic during the week can be very difficult these days (and paid parking imposes time constraints that can be difficult). Using the light rail also happens to be much cheaper.

However, there is a catch. When I take my EV I have a carbon free trip. When I take the light rail I have to connect using a diesel bus. Am I doing the right thing? We could have a long debate on this, but in 2020 my plan is to use our EV to get to a nearby light rail station. How well this works out will essentially depend on how easy it is to find a parking spot near to the light rail system.

Smoke – an emerging issue

Throughout December 2019 (and into January 2020) Canberra had long bouts of horrible air quality. On a number of occasions our usually beautiful pristine city was reported to be the most polluted city in the world. The smoke was mainly drifting in from fires to the east and large parts of the community were concerned about both the short and long term health impacts [of course the people directly exposed to the fires had an immeasurably harder time than us simply breathing in the smoke]. Canberrans were advised to stay indoors and not to exercise outside. Was this just a 'once-off' episode or will this become the norm for our Canberra summers as the climate changes?

This situation challenges my thinking and the way we operate our home.

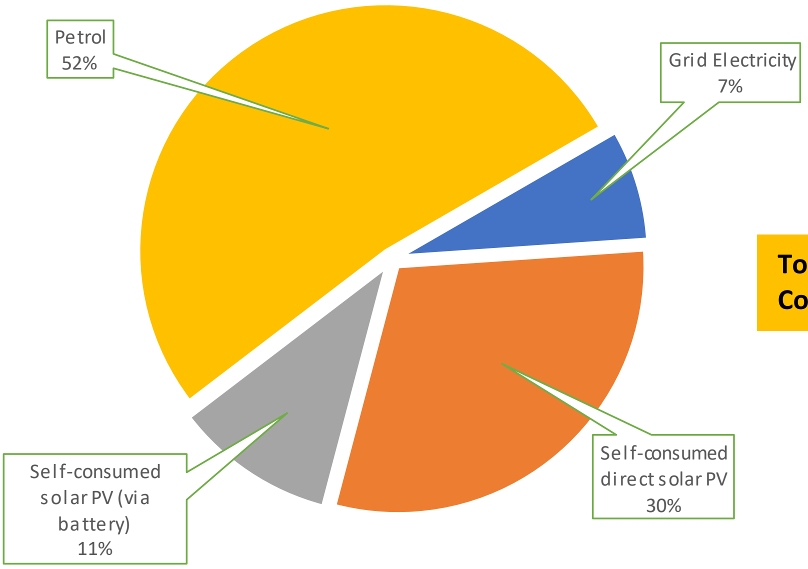
As I have reported for some years, I am very keen on keeping an 'airy' house. We have eschewed sealing up our house, primarily for air quality, but also for thermal comfort, reasons. This approach works extremely well when the outside air quality is good, but how does this work when the outside air quality is bad? I'm finding this is a complex issue which I will need to work through over the coming year.

Summary of 2019 Energy Outcomes

Overview

Figure 1 shows the energy type split for our energy use during 2019. In very broad terms, about 50% of our household energy use was from petrol; 40% from our solar PV system; and 10% from grid electricity.

Figure 1: Breakdown of our household energy use 2019



Total Imported Energy Consumption 2019 = 9,103 kWh

Our energy consumption patterns and level of use did not change greatly between 2018 and 2019. The main difference was that our usage of grid electricity almost doubled – this happened because we were without our house battery for about four months at the end of the year. When we changed over to three-phase at the beginning of September our Tesla Powerwall 2, a single-phase device, no longer worked. It's a long story but we eventually managed to have it re-configured to operate on three-phase in mid-December.

Energy Source	Energy Use (kWh)
Grid Electricity	1,113
Self-consumed direct solar PV	4,634
Self-consumed solar PV (via battery)	1,614
Petrol	7,990
Total Energy Use 2019	15,351

As I have commented many times before, it is important to note 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 family energy use.

Figure 1 shows that in 2019 we were about **40% fossil fuel free** (the % which derives from our own solar PV) which was more or less the same as in 2018. If considering electricity in isolation, we were about 85% fossil fuel free in 2019.

Figure 2 shows a breakdown of our total household energy consumption by use category for 2018.

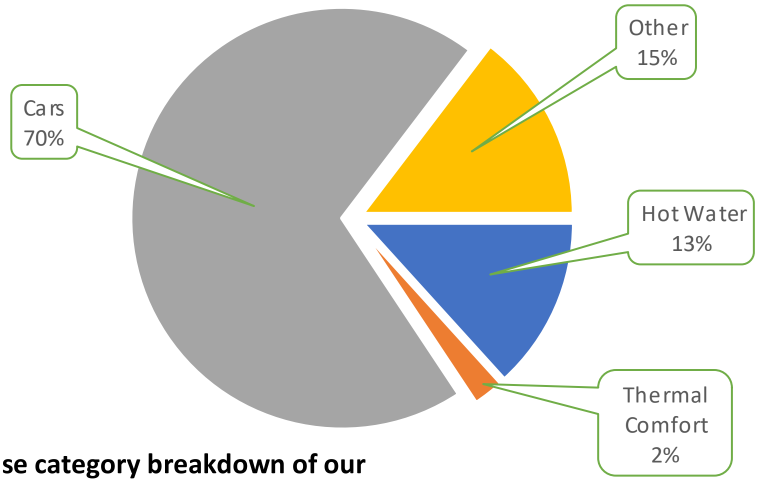


Figure 2: End use category breakdown of our household energy consumption 2019

In a similar manner to **Figure** 1, this distribution has not changed markedly from that for 2018. Two figures really stand out. Firstly, the dominant role that our cars play in our household energy consumption (our main car is an EV). The other is the very small amount of energy that we expend on thermal comfort compared to most Canberra households.

Average daily electricity consumption 2019 = 20kWh/day

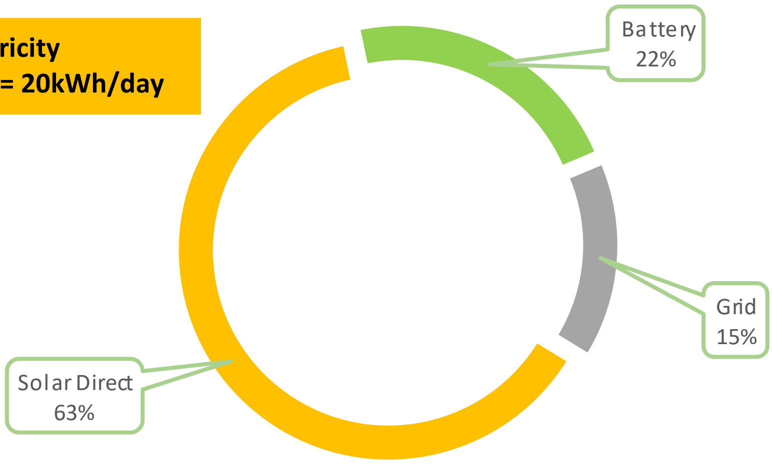


Figure 3: Breakdown of our household electricity use in 2019

Figure 3 shows the breakdown of our household electricity use by source. This figure again shows, when compared to 2018, the impact of the Powerwall being out of use for about four months. Our grid electricity consumption increased from 9% to 15%. Our total daily electricity consumption (solar + grid) was similar to the Australian daily average (20kWh/day). I expect this Figure to look very different in next year's report, particularly if I am able to install a significant amount of new solar PV before winter.

Disaggregating the data

In order to place the 2019 data in context, and to allow tracking of changes, the next six Figures are extensions of, and/or extractions from, Figures that I included in the Transition Book and in the Annual Reports for 2016, 2017 and 2018.

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. The availability and accuracy of data was a particular challenge in 2019 as we transitioned from single to three-phase electricity supply. When we made the changeover my Solar Analytics (SA) system (see **Chapter 7**) no longer provided accurate energy use information since several of the CT clamps were on the wrong circuits. I have alternative monitoring systems in place for my main energy consuming devices (EV, hot water, Powerwall) and I am reasonably confident that the level of accuracy of my main power drawing circuits is solid. I decided not to update the SA system until I have upgraded our solar system – this may not happen to well into 2020. I discuss the key monitoring issues in **Chapters 2 to 5**.

All CO_2 data for electricity use for 2019 is based on the 2019 conversion factors for NSW/ACT published in the 2019 Australian Greenhouse Accounts (the Government updates this publication each year).[5]

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 incremental changes in our household energy set-up which I believe will result in important changes over time. I discuss my proposed energy reduction actions for 2020 in **Chapter 8.**

Imported Energy (grid electricity, gas, petrol)

Figure 4 shows our household consumption of directly purchased energy for 2019.

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
2018	653	535	-	-	9,308	2,258	9,961	2,793
2019	1,113	902	-	-	7,990	1,938	9,103	2,840
% Change 2019/2018	70%	69%	-	-	-14%	-14%	-9%	2%

Figure 4: Household imported energy use for 2019 compared to earlier years

[5] Australian Government Greenhouse Accounts Factors 2019: https://www.environment.gov.au/climate-change/climate-science-data/greenhouse-gas-measurement/publications/national-greenhouse-accounts-factors-august-2019

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 and the numbers in some of the other Figures (eg **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.

Petrol made up about 90% of the energy we directly purchased. The large jump in the relative percentage of grid electricity consumption is primarily due to our battery being out of commission for about four months (the absolute increase is not massive). There was a noticeable reduction in our use of petrol – I discuss this in **Chapter 2.**

Energy End Use

Figure 5 shows the end use breakdown for our household total energy use in 2019 compared to previous years. The most notable change from 2018 is the approximate 20% increase in the amount of energy we used for water heating. I put this increase down to a well-known fact of the universe – growing teenage children take longer showers. I try to impose some control, but I also like to show some flexibility. I think we can wear the extra 350kWh (≈ 1 kWh/day). I also think the reduction in petrol use may indicate the start of a long-term trend. This is discussed in **Chapter 2.**

Year	Hot Water (kWh)	Thermal Comfort (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	1,782	569	7,655	2,718	**12,724**
2018	1,692	342	11,914	2,223	**16,271**
2019	2,040	367	10,695	2,249	**15,351**
% Change 2019/2018	**21%**	**7%**	**-10%**	**1%**	**-6%**

Figure 5: End use household total energy consumption for 2019 compared to earlier years

Energy use in each of the end use areas shown in the Figure is discussed in **Chapters 2 to 5**.

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

End Use	Daily Energy Consumption (kWh)
Hot water	**5.6**
Thermal comfort	**2.4** (for the five-month heating season in Canberra)
EV	**7.4**
Petrol car	**21.9**

Figure 6: End use energy consumption for 2019 broken down to daily figures

Energy Generation (solar PV)

Figure 7 provides data for our solar PV generation and export over the period 2013-2019. Despite my best efforts, we were not able to add any additional PV capacity in 2019. As noted elsewhere, we now have three-phase electricity installed and I hope this means we will be able to add additional solar PV in 2020.

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	3,795	6,413	5,323	**1,528**
2018	15,225	9,961	2,793	8,613	7,063	**4,270**
2019	15,421	9,103	2,840	9,169	7,427	**4,587**
% Change 2019/2018	**1%**	**-9%**	**2%**	**6%**	**5%**	

***Note** *In this table 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 network (see comments in the Overview)*

Figure 7: Summary of our solar PV production in 2019 compared to earlier years

The Figure shows remarkably little change in our solar PV production/consumption between 2018 and 2019.

Costs

The data in **Figure 8** is derived from our household electricity bills and includes the electricity and gas supply charges. We disconnected our house from the reticulated gas supply system in December 2015. We paid approximately $400 for electricity supply charges in 2019 – about 65% of our total electricity bill. The increase in electricity costs were expected given our battery was out of service for approximately four months.

The Figure shows that for the fourth year running our energy costs were more or less balanced out by our energy income from our FITs (our feed-in-tariffs for our solar PV exports).

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**
2018	499	-	1,365	1,864	1,811	**53**
2019	617	-	1,153	1,770	1,859	**-89**
% Change 2019/2018	**24%**	**-**	**-16%**	**-5%**	**3%**	

Figure 8: Cost breakdown for our household energy use for 2019 and earlier years

Carbon Footprint of our Energy Use

Figure 9 suggests that, with our current energy use settings, our direct energy consumption carbon footprint has more or less stabilised. It is important to read this table in the context of the detailed discussions on our patterns of energy consumption in **Chapters 2 to 5.** While there are large relative changes in the size of our carbon footprint in some of the categories the absolute changes are comparatively small. The 'other' column has been computed by difference and I don't believe the relative changes are meaningful. I consider 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.

Year	Hot Water (kg CO_2)	Thermal Comfort (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	48	472	1,784	1,491	**3,795**
2018	26	280	2,445	42	**2,793**
2019	21	297	2,059	463	**2,840**
% Change 2019/2018	**-19%**	**6%**	**-16%**	**?**	**2%**

Figure 9: End use carbon footprint breakdown for 2019 compared to earlier years

Chapter 1

2019 Generation: Solar PV

For yet another year my ambition to add more solar PV capacity was thwarted. At least we made some progress in 2019 in that, as reported earlier, we now have three-phase installed and this should, in theory, mean that we can add more solar PV in 2020.

My dream is to more or less use all our remaining available roof space for additional PV panels. My thinking has now evolved to the point where when I see sunshine simply falling ungathered on our roof tiles I get a sense of guilt. This is similar to the feeling I get when I see a tap just left running – reckless waste. I say to myself *'Why are we letting all this solar energy go to waste when it is so simple to gather and either use it ourselves or distribute it to other users?*

I fully recognise that there are constraints on the amount of domestic rooftop solar PV electricity that a local distribution system can accept – this has been the reason for my painful journey to three-phase. I am expecting that whatever size PV system I end up with, my output will be constrained to some extent particularly in summertime when we are generating a significant surplus of electricity. Nevertheless, I'm hoping that we can add enough additional PV capacity that we can more or less meet our winter electricity demand from our own solar PV resources. I estimate that we will need to add another 5-6kW of solar PV capacity to achieve this (see **Figures 12 & 13).**

Generation overview

Our solar PV production and export for the past seven years was summarised in **Figure 7.**

Figure 10 compares our solar production between 2018 and 2019 broken down by month. We installed our last 2kW solar PV system in April 2017, therefore the close correlation between 2018 and 2019 output is not surprising. Hopefully, the comparison between 2020 and 2019 will reveal some significant differences!

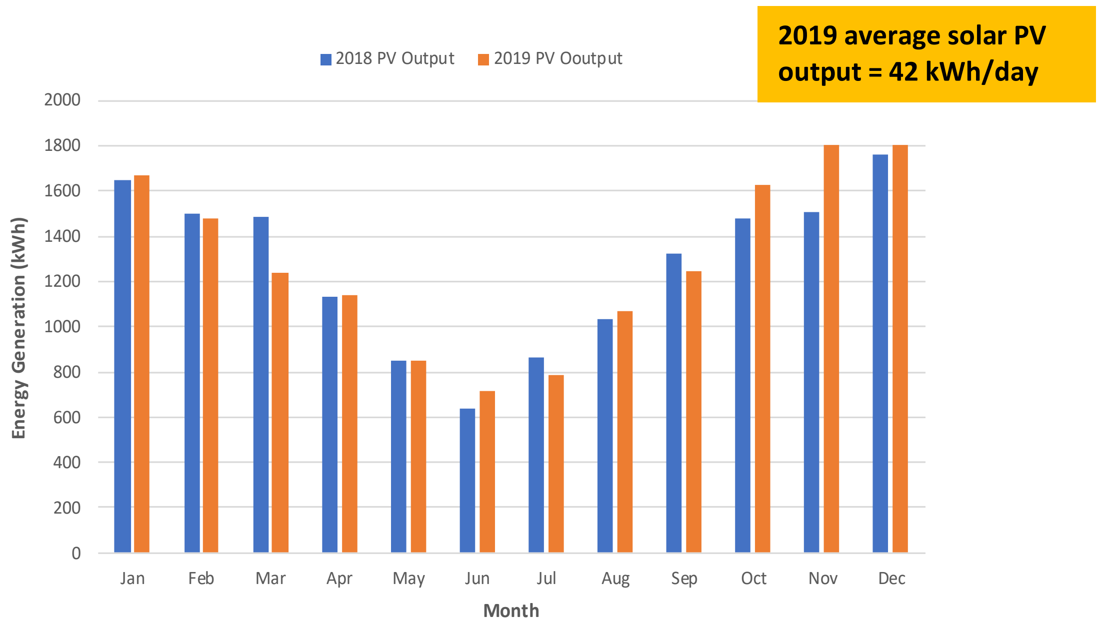


Figure 10: Comparison of our household 2018 and 2019 solar PV production

Self-consumption of solar PV electricity

In my previous reports 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 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).

Figure 11 shows how our level of grid independence varied over 2019. This shows a somewhat different pattern to that shown in the corresponding Figure in last year's report due to the non-availability of our house battery for the last four months of 2019. Not surprisingly, when we lost our battery our grid consumption increased. The grid consumption gradually reduced toward the end of the year as more solar PV electricity became available. Overall for 2019 our level of grid independence for the house was about 86%. This compares with a figure of about 91% for 2018.

2019 overall rate of grid independence = 86%

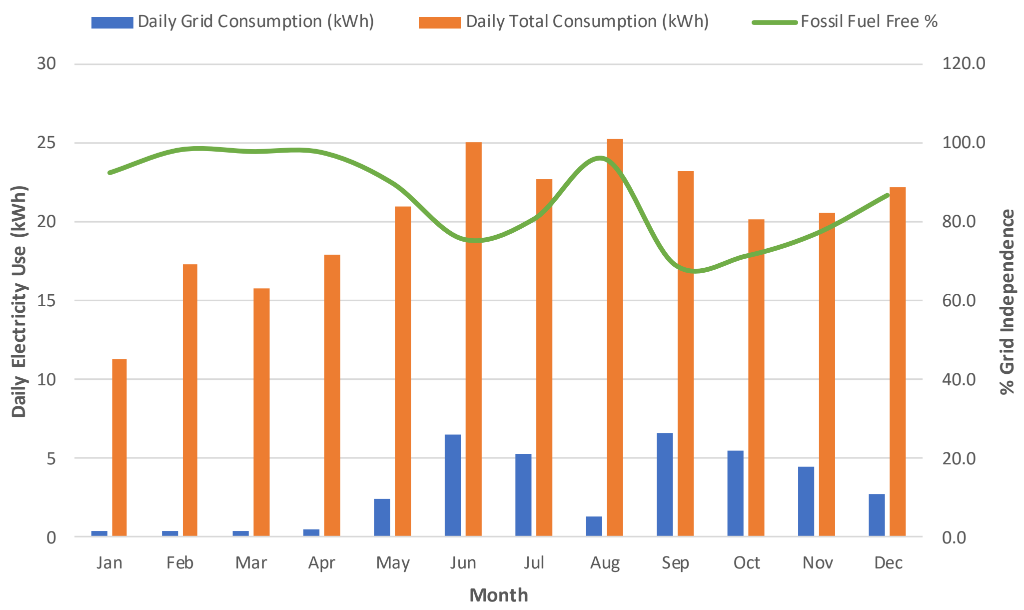


Figure 11: Variation in grid independence over 2019

Adding more solar PV capacity

An important question I hope to face in 2020 is how much grid electricity will we consume if we are able to beef up our solar PV systems by say 5kW? **Figure 12** shows the daily PV production from our net solar PV system vs the 'excess PV' for each day in 2019. In this context 'excess PV' means the amount of solar PV produced over and above the amount of total electricity that we consumed. It can be seen that for most of the year our excess solar was positive, but over winter we struggled to power our house solely from our net solar PV systems (+battery) – we had **67 days** over winter 2019 where we had to draw power from the grid due to a lack of solar PV power/energy. On those days we could not produced enough solar PV to fill our battery to cover evening/night energy consumption.

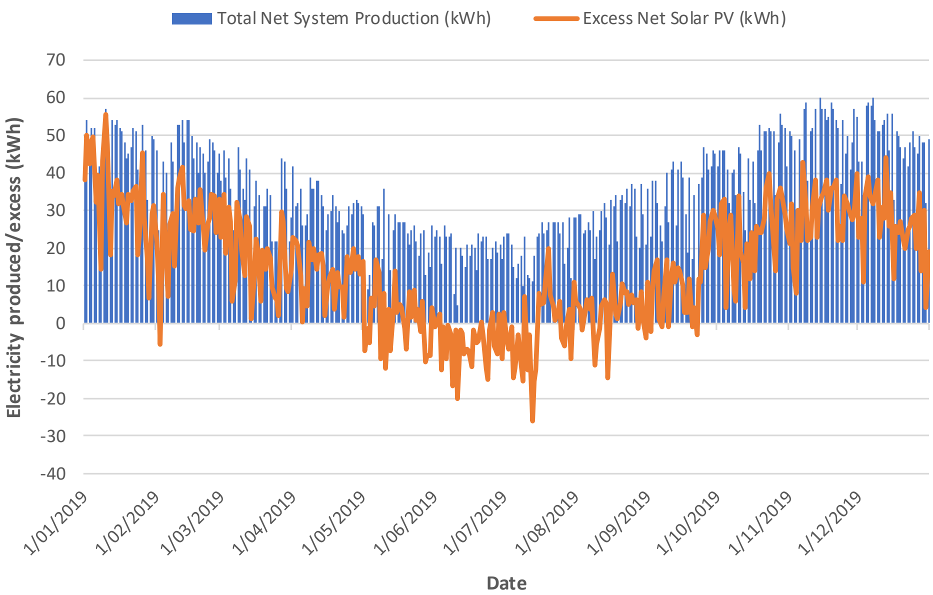


Figure 12: Graph showing the days when we had to draw from the grid in 2019 [the days of negative 'Excess net solar PV']

In order to assess the effect of adding an additional 5kW of solar PV on our eastern roof (the remaining vacant space on our roof is on the east-side roof), I generated a simulated generation/consumption dataset for 2019 by computing the daily PV output from the additional 5kW based on a pro rata computation of the output from the existing 2kW system which is on the east-side roof of our house. The outcome is shown in **Figure 13.** This indicates that if we had had an extra 5kW of solar PV on our eastern roof in 2019 we would have had around **20 days** where the 'Excess net solar PV' would have been negative (ie we would have had to draw electricity from the grid on only 20 days rather than the actual 67 days). By my calculations, the additional solar PV capacity would have given us a figure of around 95% fossil fuel free for the house (assuming we had the Powerwall available for the whole year).

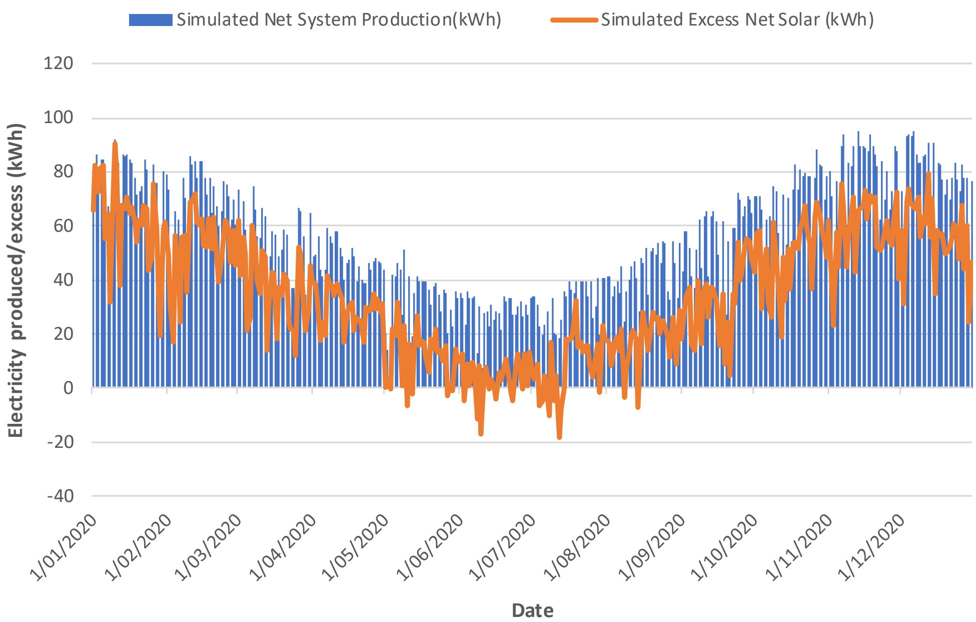


Figure 13: Simulation of the days when we would have drawn from the grid in 2019 if we had had an additional 5kW of installed solar PV

Next Solar PV Steps

If we are able to install an additional 5kW of solar PV in 2020, and we are able to reach around 95% grid independence as far as our house is concerned, then I believe that we will have gone as far as we can go at this time. Having said that, I don't think this is necessarily the end of our solar PV development in the long term.

When I first installed panels on my old house around 2008, a standard panel had an output of 250W and the usual system size was around 2kW. We've come a long way since then! Panels of +400kW are now common and typical domestic rooftop solar PV system sizes are around 6kW. At some time in the future if/when I need to replace all or parts of our existing solar PV set-up I will look to increase the output as far as possible. I am hoping that in say 5-10 years' time many of the capacity constraints now imposed on domestic rooftop solar systems will have been lifted and that we'll be able to produce more total annual energy from our house then.

If expansion of our own rooftop solar PV system is not possible, I envisage that I will buy a slice of a community or commercial solar/wind farm so that I can increase the extent of our annual carbon offset assets. At this stage I see this as an important part of **Phase 2** of our energy transition.

Chapter 2

2019 Consumption: The Cars

For us 2019 was a big EV year. After a wait of a few years we were at last able to get our hands on a new generation EV! We bought a new Nissan Leaf and I must say after about five months of use we are very impressed. I discuss this later in the Chapter.

The energy use for the cars in our household over the past seven years is summarised in **Figure 14.** We still have our Hyundai i30 as our petrol car. The data in the table for electricity use covers energy consumption for both the first-generation Leaf (which we used until Aug 2019) and our new Leaf. I provide a breakdown of the data between the two EVs later in the Chapter (the new Leaf is proving about 15% more efficient than the old one).

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**
2018	228	2,378	9,308*	**11,914**
2019	149	2,556	7,990	**10,695**
% Change 2019/2018	**-35%**	**7%**	**-14%**	**-10%**

Figure 14: Energy consumption of our cars 2013-2019

***Note:** I changed the basis for my petrol use calculations for 2018 – hence the sudden jump in energy use for our petrol car in that year.

Breakdown of EV energy use

Figure 14 indicates that our use of electricity for our cars was more or less unchanged from 2018 to 2019. There was a moderate reduction in our petrol use in 2019.

The drop in petrol use could be explained in part by the fact that once we obtained the new Leaf we used that for regional journeys rather than using our petrol i30. All other things being equal, we will probably use the new Leaf for the majority of our trips to Sydney and the coast in the future.

In order to understand the energy consumption patterns a little better, I have split the energy use data for the two Leafs in **Figure 15**.

Year	Energy Used (kWh)	Distance Travelled (km)	EV Efficiency (kWh/100km)
2016	2,518	14,292	17.6
2017	2,691	15,141	17.8
2018	2,606	14,631	17.8
2019 Total	2,705	15,035	18.0
2019 Old Leaf	1,409	7,343	19.2
2019 New Leaf	1,296	7,692	16.8

Figure 15: Comparison of EV energy use 2016-2019

It can be seen from the table that the old Leaf was less efficient than the new Leaf. Having said that, the data needs to be treated with some caution since we used the old Leaf through most of the winter which is the most inefficient time of the year for EV use in Canberra.

About 90% of the energy we used in our original EV during the period Jan-Aug 2019 came from our solar PV system. This level of grid independence is essentially the same as we achieved for this car over the whole of 2018.

Over the period from Aug to Dec 2019, when we had our new generation Leaf, 100% of the energy we put into the car was carbon free. Almost all of this came from our rooftop solar PV system; about 15% of the energy came from public chargers which advertise that they deliver 'green power'. If we had had the new Leaf earlier in the year we would almost certainly have had to use some grid electricity when charging this car at home over winter.

I look forward to being able to present data for a full calendar year's use of the new car in next year's annual report.

Our Solar Analytics energy monitoring system was not operational for the last four months of the year due to our change to three-phase. Therefore the EV energy use data shown above was obtained from energy use information displayed on the dashboards of our two EVs. The reported 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).

In total we travelled **15,035 km** in our EVs over 2019.

Petrol use

In 2019 our petrol engined Hyundai i30 travelled **10,329 km**. Its fuel efficiency was 8.5L/100km. this translates to 77.4kWh/100km. Therefore in crude terms our EVs were just over four times more efficient than our petrol car (a figure which is very much in line with published comparisons).

The new Nissan Leaf

We acquired our new Nissan Leaf in August 2019 (**Figure 16**). It is probably because we'd had the first-generation Leaf for five and a half years that I didn't have massive expectations. I thought it might be just more of the same with a significant boost in range. I was very wrong, and very pleasantly surprised! I have found the new Leaf to be wonderful – it seems to have been significantly upgraded right throughout the car. Putting aside the EV parts of the car it is very much a well-appointed mainstream car with equipment that is far better than anything I've owned before (upgraded lights, sound system, safety features, interior finish, roominess, etc). A very big jump up from our earlier Leaf (which we loved).

Having the extra range meant that instead of our EV being a city car it became a regional car. We were able to take the EV on trips that we would previously have taken in the i30.

On the October long weekend we did a road trip in southern NSW which worked out really well. I published a report on this on The Driven website.

Figure 16: Our new Nissan Leaf

At the end of the year we did a day trip to Sydney. This was very interesting as I knew that doing about 600km in a Leaf in one day would be pushing it towards its limits. The highlight for me was that the overall energy efficiency for the whole trip was 13.6kWh/100km – this was much better than I was expecting (particularly given it was a hot day and we used the A/C a fair bit). Without getting bogged down in details, we did four fast charges in the day and on the last one the battery became hot: the battery management system cut the charging rate back to 18kW. This was not a problem on this particular trip, but I don't like taking batteries into the hot zone.

We didn't really need to do four fast charges on our Sydney trip and next time I do a day trip to Sydney I'll adopt a different charging strategy. Having said that, I'm not a great fan of driving 600km in a day and these days we do that very rarely. I would much rather travel 300km in a day (say to Sydney) and stay overnight at a hotel/motel where I can charge the car.

Charging

One thing I found surprising when I bought the new Leaf was that it didn't come with any form of charger (EVSE). A basic 10 amp charger was provided with the original Leaf and I was expecting a similar story with the new one. Instead the car simply included a Type 2 to Type 2 cable.

We have a hard-wired charger on a 32 amp circuit sitting on the wall in our garage but this is not controllable and I very rarely want to charge at 32 amps (7kW). Given that I have a set-up based on direct solar charging I prefer to charge at no more than 15 amps (3.5kW) – I have described my direct solar charging arrangements in another report. These have been working extremely well for over three years: I upgraded the Immersun unit with an Eddi in early 2019 (I discuss this in the next chapter) but the new system operates in much the same way as described in the abovementioned report. In essence my set-up is a poor man's version of the Zappi which is an EVSE which incorporates energy diversion technology (the Zappi did not exist when I configured the Immersun for direct solar charging).

In order to be able to better control my EV charging I bought an EVSE with switchable charging rates (you can see this on the left in **Figure 17** alongside my hard-wired charger). I've used this device for almost all our charging since I bought the car and it has been faultless. I have always run it at 15 amps. I think I have only used the 7kW charger once (for a very quick charge) since we have had the new Leaf.

Figure 17: Our portable EVSE (on the left) alongside our hard-wired charger

Vehicle to Grid

When marketing the Leaf, Nissan has been quite active in promoting its V2G (vehicle to grid) and V2H (vehicle to home) capabilities. As far as I am aware, these are not yet available in Australia, and I have no idea if/when they will be approved for use in Australia. My initial reaction to these was not particularly enthusiastic; I guess I was concerned at either draining my battery in the short term; or reducing the life of my battery in the long term. However, now that I have had a few months experience with our new Leaf, I have a much more open mind.

Firstly, I have a lot of excess battery capacity with our new Leaf and I believe I could easily use say 15 kWh of the capacity of our battery on an ad hoc basis for either powering our home or exporting to assist the grid. I am now more relaxed about the impact on the life of our EV battery: the car is proving to be very efficient and quite miserly in its energy use; and if the worst comes to the worst the battery warranty is strong (8 years or 160,000 km).

Given that I already have the Tesla Powerwall 2, I'm not sure that we will ever need V2G/V2H capabilities but I can see that it could be very useful for Leaf owners in different situations (eg those who don't own a home battery; or live in a part of the grid with poor reliability; etc). I like the idea that if you run out of electricity at home you can drive your EV round to a nearby charger, 'fill up' and come back with a full battery to power your home.

Probably not for us, nevertheless I will keep an eye on these technologies.

New lightweight e-bike

My interest in electrified transport is not confined to cars.

I've had a long-time interest in e-bikes and think they will have an important role to play in future urban transport systems.

To date, e-bikes have conventionally had big batteries and have been very heavy. The thinking has been that the rider puts in no, or very little, energy. These e-bikes typically weigh around 25kg and are extremely hard work if the battery goes flat. My wife uses one of these to commute to work on occasions – she doesn't want to put in any great effort as she wants to get to work without getting sweaty.

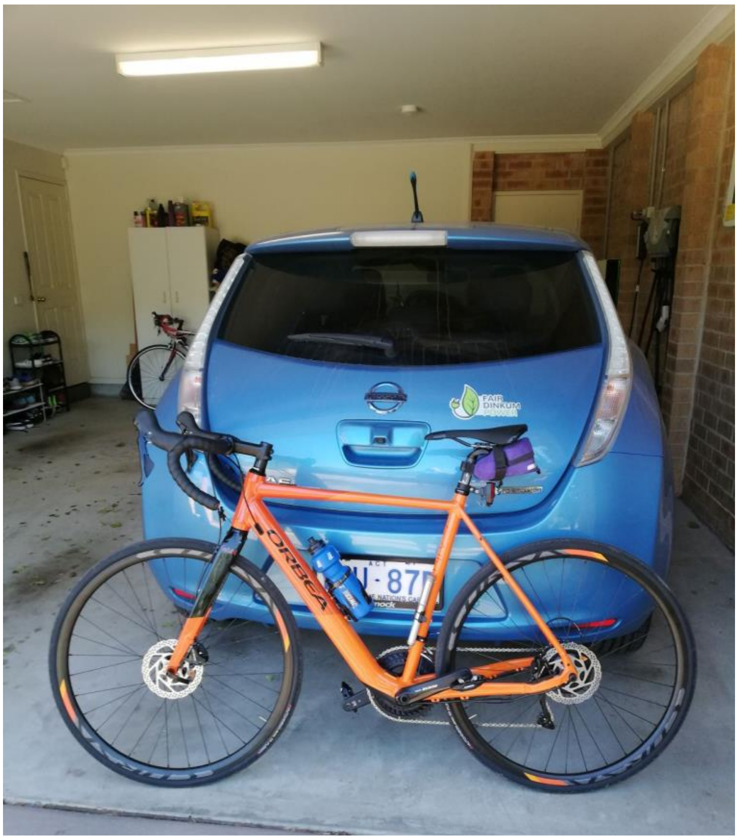


Figure 18: My lightweight e-bike leaning against our old Leaf

In early 2019 I bought a very different type of e-bike: a 'lightweight' e-bike which weighs about 13kg and has the form and equipment of a road bike [if you have deep pockets you can get ones that weigh around 10-11kgs]. One of the reasons these bikes are light is because they have small batteries – most of the effort is put in by the rider. I personally use the battery on my bike very sparingly when I go on a ride with my cycling groups. I normally only turn on the motor when I come to a steep hill or get dropped by the group for some reason.

These bikes are popular with weaker riders who want to keep fit and/or want to go out with groups of stronger riders (eg they are used by riders who are getting older or who have some form of chronic injury).

I believe this type of e-bike has a big potential for being used by commuters. Many potential bike commuters are not attracted to the conventional 'sit-up', heavy, e-bike. Equally they may be put off from using a normal bike for commuting to/from work because of the need to climb one big hill on the ride. The lightweight e-bike allows the commuter to get over that hill using the motor but ride normally for the rest of the distance (to maintain fitness).

Chapter 3

2019 Consumption: Hot Water

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

In essence, we have a resistive hot water system which is controlled by a proportional energy diverter. I used an Immersun unit as our energy diverter between 2015 and early 2019. I replaced this with an Eddi diverter in Feb 2019 - I discuss in the next section.

The Eddi worked brilliantly throughout 2019 and gave us effectively 100% fossil fuel free hot water for the whole year.

Figure 19 shows the overall picture of our hot water energy use and carbon footprint for the past six years. It can be seen that our annual hot water energy use increased somewhat in 2019 (as mentioned earlier, I put this down to growing teenage children taking longer showers) but our hot water carbon footprint has remained minimal for a few years now.

Year	Electricity Consumed (kWh)		Gas (kWh)	Total Energy Consumed (kWh)	Carbon Footprint (CO_2 (kg))
	Grid Sourced	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	58	1,724	-	1,782	48
2018	32	1,660	-	1,692	26
2019	26	2,014	-	2,040	21
% Change 2019/2018	**-19%**	**21%**	**-**	**17%**	**-19%**

Figure 19: Comparison of our hot water energy use 2013 - 2019

On average we used 5.6 kWh/day to heat our water throughout 2019.

Figure 20 breaks down the 2019 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. We used no grid electricity for water heating during nine months of 2019.

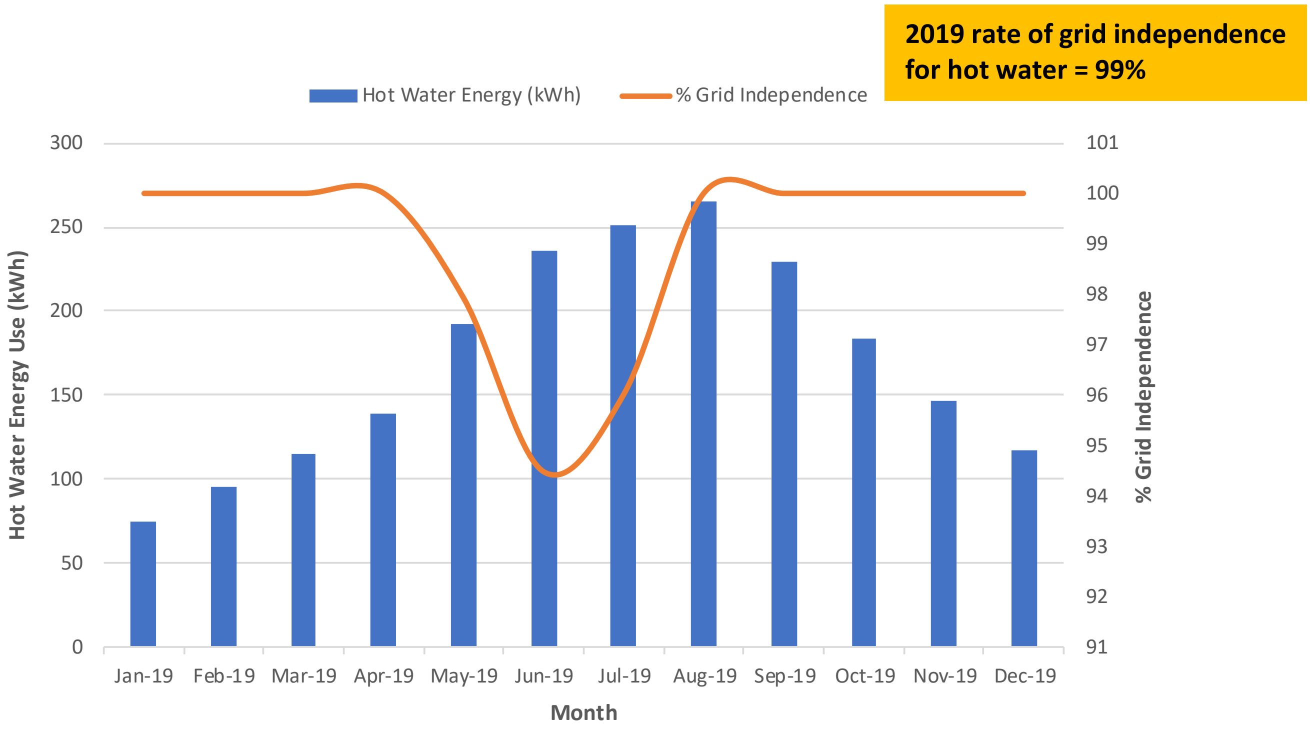


Figure 20: Hot water % grid independence and daily energy use 2019

Eddi – our new energy diverter

When I was setting up the project in 2015, I opted to use an energy diverter to heat our water. In essence this device works with electric resistive heating devices and diverts any excess solar energy away from export in favour of self-consumption. At that time these devices were essentially in a development phase and I elected to install a device called an Immersun (you can find a lot of information on this in my earlier reports). The Immersun worked extremely well for us for about three years but it was a somewhat 'twitchy' device. If it was turned off for any reason, starting it again was a bit 'hit and miss'; but once up and running it worked without problem.

The Immersun unit we had was a single-phase device which could not be configured for three-phase and therefore I could not use this once we upgraded our electricity supply from single-phase. Given the success of the Immersun I was keen to continue using an energy diverter and opted to install a next generation diverter called the Eddi. The Eddi is shown in **Figure 21**.

Figure 21: The Eddi energy diverter

It's a long story, but as I see it the Eddi is, to all intents and purposes, a significantly enhanced and upgraded version of the Immersun. The Eddi is designed by the same engineer who designed the Immersun and it is made at the same location that my Immersun device was made at. [After a company failure, Immersun manufacturing rights were sold off to another company a few years ago and these devices are still being manufactured and sold under the Immersun name from another location].

I have found the Eddi to be a rock-solid device. Over 2019 we were continually turning our power on and off as we went through our power supply transformation. It turned on and started up every time without any hassles and ran flawlessly. Like the Immersun it is very powerful and has a wide range of operating options and parameters which make it a particularly flexible device. As mentioned in **Chapter 2**, we used the Eddi throughout 2019 not only for water heating but also for direct solar charging of our EVs.

Chapter 4

2019 Consumption: Thermal Comfort

As I noted in the report Overview, I have re-titled this Chapter ‘Thermal Comfort’ to more accurately describe our energy use patterns for keeping ourselves warm in winter and cool in summer.

In 2017 we stopped heating our house and transitioned into a ‘Heat Yourself: Not Your House’ mode. We discovered that this person focussed, rather than house focussed, approach to winter heating really works – wonderful comfort; very little energy use. I wrote a report on this towards the end of winter 2017, recognising that I had not yet perfected what we were doing. I continued testing ideas for both winter heating, and summer cooling, over 2018 and 2019.

Figure 22 below shows our energy use/carbon footprint for achieving thermal comfort over winter 2019 compared to the earlier project years (I call the five-month period May – Sep inclusive as our Canberra heating season). I have not included any energy for summer cooling as to date, while I have not monitored it closely, I believe the total is extremely small.

Year	Electricity Consumed (kWh)		Gas (kWh)	Carbon Footprint (CO_2 (kg))
	Grid Sourced	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
2018	342	0*	0	280
2019	367	0*	0	297
% Change 2019/2018	**7%**	-	-	**6%**

Figure 22: Comparison of thermal comfort energy use 2013 - 2019

***Note** I was unable to accurately allocate heating energy use between grid and solar PV electricity.

It can be seen from the Figure that our heating energy use for 2019 was little changed from 2018 (we were away on holiday for a large part of July 2018). I found this unsurprising since we only made what may be termed 'minor tweaks' to our heating arrangements between these two years compared to the significant changes we made in earlier years.

Prior to 2019 we had normally closed all our windows over the winter (at least for three months) but I realised that this made little sense when we were using personal heating to keep warm. I therefore decided that over last winter I would not close off our windows (we usually keep them open a small amount to provide ventilation). I continuously monitored the air temperature in our main living area over the whole of 2019 (ten minute sampling). The monthly average readings are shown in **Figure 23 –** temperatures were typically around 12°C in the evenings during winter. This was fine for me, and no one in my family complained, so we were able to enjoy better indoor air quality over winter than we had in previous years. I found it interesting that over what was a bad winter for flu in Canberra, we all effectively avoided the usual sniffles and colds. Living in an unheated house, with windows open, appeared if anything to help us avoid the nasty lurgies. Maybe it was because we avoided the thermal shocks of moving between a heated house and the cold outside? Maybe it was because we avoided the stuffy air associated with closed down houses?

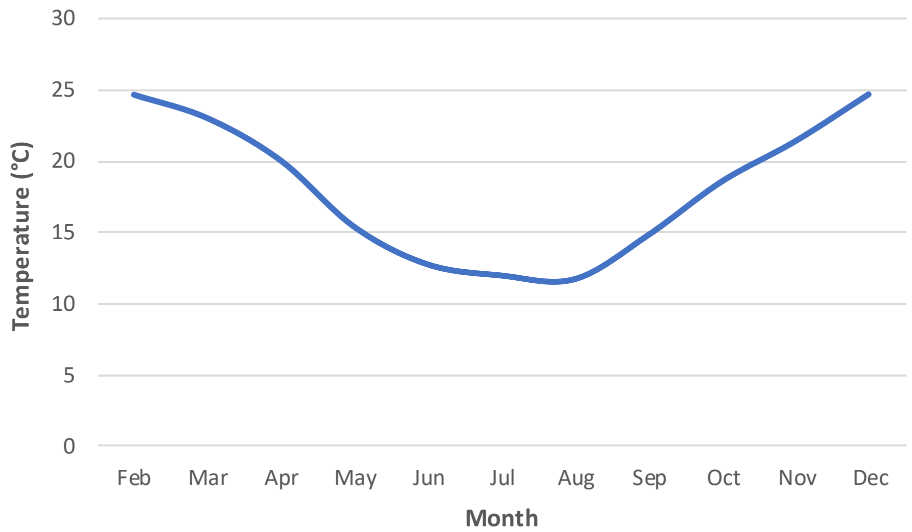


Figure 23: Average monthly temperatures inside our main living area over 2019

As always it is important to point out that my energy use data is subject to error. We lost some data from our Solar Analytics monitoring at the beginning of September when we changed over to three-phase power. However, I don't believe this impacted greatly on our heating data. Similarly, we did have a failure in our socket monitoring in October – this was outside our heating season and therefore did not impact on our heating energy readings. I have been conservative in allocating data to 'personal heaters' – I have assumed that all energy drawn from the power sockets in our three bedrooms was used for heating; in reality the power was also used to run computers and some small electrical devices.

Figure 24 shows the breakdown of our heating energy use by month, and by heating device, over the 2019 heating season on a per day basis.

Average heating energy use over winter 2019 = 2.4 kWh/day

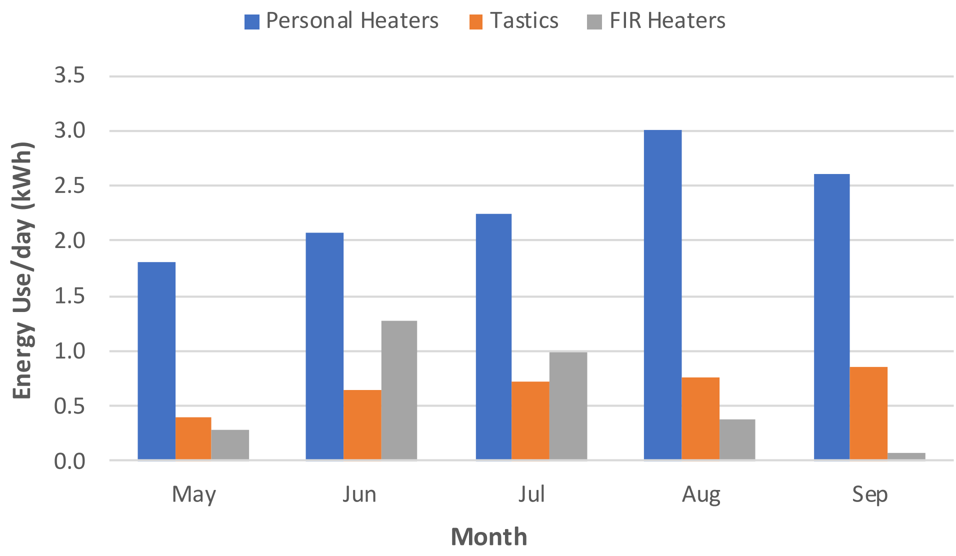


Figure 24: Breakdown of heating device contributions by month

The total amount of energy we used for heating over winter 2019 was not dissimilar to 2018, but there was a discernible increase in the proportion of our heating energy budget that was used by our ‘personal heaters’. I believe that some of this can be accounted for by the new regime I introduced for monitoring our heating (see **Chapter 7**). The category ‘personal heaters’ includes a 400W FIR panel which is used solely by my wife – this is separate from the ‘FIR Heaters’ category shown in the Figure. She did not use the 400W FIR panel in the early part of the winter but when her 50W personal blow heater failed (see discussion a little further on) she reverted to using the FIR panel.

I envisage that from here, unless I’m able to persuade the rest of my family to wear heated clothing, our winter energy use will not change greatly. Overall I’m pretty happy with the current state of affairs – at an average of 2.4kWh/day our heating energy use it is well within our budget of 4kWh/day – but I will of course continue to look for personal heating options that may reduce our energy consumption even further.

Thermal comfort over winter - Personal Heating

In the opening part of the report I have already mentioned my fascination with applying the ‘heat yourself: not your house’ principle to keeping warm inside a house. Keeping warm in this way demonstrably uses much less energy, and subjectively I feel much warmer when heating myself directly with either radiant or conducted heat rather than using warm air to heat us indirectly.

Adjustable Heated Vest

In my 2018 Annual Report I described how I had found a brilliant piece of heated clothing that really worked for me. I am very happy to now report that in 2019 I discovered something that works even better – an adjustable size, USB powered, heated vest.

I was very excited in 2018 when I discovered my beautiful soft warm heated hoodie. It surpassed by a long way all the other heated clothing options I had tried up to that point. In fact, I was so happy with it I didn't really plan to test any other heated jacket for my own use. However, I wanted to keep an eye on the market to see if there were alternative heated garments that might suit the other members of my family. While I was always going on enthusiastically about my heated hoodie I had not been able to sell the idea to my wife or my teenage children – I think they saw the hoodie as an outdoor garment (which I guess was the makers intention) rather than as a cumfy, soft, heated undergarment for wearing indoors.

Figure 25: My adjustable heated vest – the side zips and the stud fasteners on the shoulders allow excellent adjustment

In March/April 2019 I began my renewed hunt for heated clothing that would work indoors. I was quite surprised that my Google searches seemed to throw up many more options than I had found in previous years. I was particularly interested in testing what might be described as heated skins – something very light and thin that could be sandwiched between other more 'normal' winter clothing such as thermal underwear and jumpers. I soon found quite a number of possibilities on the internet and they seemed to be much cheaper than my heated hoodie. My first choice (cost around $40) did not work out too well – bizarrely small and made of a rubbery material that would not have been all that comfortable even if I could have worn it. Then I seemed to hit the jackpot!

Given my failure with sizing, my eye was then caught by an adjustable size heated vest (see **Figure 25)**. This turned out to be a very impressive purchase: nice and soft material; thin; light; and a very clever adjustable sizing system – it fitted both myself and my wife (and I'm somewhat larger than her!). I initially set it up for my wife (I could make it quite a snug fit) and even though she liked it, and found it warm, she stopped wearing it after a few nights* so I thought I would give it a try. It almost immediately replaced my heated hoodie as my preferred heated garment.

Why did I change? First of all, for heated clothing to be effective it needs to be as close as possible to your body (but not touching your skin) – I could adjust the new vest to fit beautifully; snug but not tight. I always wore a base layer of thermal underwear. This made the sizing of the new vest better than my hoodie which had a much looser fit. Given that it was so thin and light I could more easily wear it under my onesie or my dressing gown, or just put on a jumper, and not feel like I was over dressed. In my experience it is very important to have layers of clothes over the heated garment so that the heat is trapped inside. I never felt the need for supplementary heating once I was wearing my heated vest and my other layers of clothing.

Figure 26: The inside of my experimental heated pants – I positioned heating pads on the top of the thighs and the lower abdomen

Another interesting outcome of my search for heated clothing was my discovery of [kits for making your own heated garments](). These USB (powerbank) powered kits are particularly inexpensive (I paid about $20/kit (powerbank not included)). I bought a couple of kits just for fun and made myself some heated pants (see **Figure 26).** I never really tried these out in anger because I was warm enough simply wearing my heated vest and my standard thermal undies and onesie. Nevertheless, it was not too hard for me (a definite non-tailor!) to produce my heated pants – I'm confident that someone with good sewing skills could turn almost any garment into a piece of heated clothing with invisible heating elements.

* *When I asked my wife why she no longer wore the vest she said she didn't need it because her body was already warm from wearing her other clothing. Nevertheless, she needed additional heat (primarily radiant heat) on the exposed parts of her body, mainly her face, because having a warm core did not give her thermal comfort. This is a somewhat different reaction to me – maybe having a stubbly male face means that I am not as sensitive to losing heat through my face. On the other hand, being totally bald, I always wear a beanie throughout winter.*

Given that my heated vest was not the thermal comfort answer for my wife I still needed to find some form of supplementary heating that suited her. Ideally, I would like to have found some form of low energy FIR panel - I wanted to buy a small size panel that would run at about 200W, but I was unable to find anything that fitted the bill. So I widened my search and came across some low energy, personal, blow heaters which my wife was attracted to. [Interestingly, she does not like room fan heaters which cause draughts and make her feel cool, but is quite content to have a blow heater very close to her directly warming a particular part of her body (eg her face and/or her legs)].

Low energy blow heaters

In last year's report I showed a photo of a small 50W blow heater which I bought before winter 2019 (see **Figure 27**). I was surprised that my wife had such a positive reaction to this heater – to me it appeared more like a toy than a real heater. Anyway, she really liked this: when sitting at her desk she sat it close to her and directed its very low volume, but relatively hot, airstream toward her. For the first part of winter she used this heater, along with her beloved heated seat pad, and her warm layers of clothing as her only thermal comfort aids.

Figure 27: The 50W personal blow heater

Given the success of this device I bought a more substantial personal blow heater to replace the 50W heater (see **Figure 28**). This heater, which is nicely designed and well built, is rated at 250W, which I estimate is about the max amount of energy needed for good, non-wearable, personal heating but it did not work out at all well for us. The air volume delivered by the fan was too great and it produced a somewhat diffuse, blowy, heat which my wife found cooling rather than warming (the reason she doesn't like heat pumps). This heater did not get much use.

I wasn't surprised when the 50W heater died in the middle of winter. My wife's response was to revert to using the 400W FIR panel – this kept her nicely warm but it meant that my dream of getting her supplementary heating to below 200W had to be put on hold for the rest of winter.

I intend to keep searching for the next personal heater for her in the first part of 2020.

Figure 28: The Honeywell Heat Bud

Thermal comfort over summer - Personal Cooling

Consistent with my thoughts on 'personal heating' as opposed to 'space heating' I have also developed an interest in 'personal cooling'. I have written *ad nauseam*, that in my view using the air that we breath to heat/cool people in a building via space heating/cooling is bound with problems: it is very wasteful since large volumes of air have to be treated; to be effective gaps need to be sealed and the fabric of the building insulated; and sealing gaps can lead to poor indoor air quality.

Having said that, achieving effective personal cooling is a much greater challenge than personal heating. I have yet to find the equivalent of a heated vest (I am aware of ice vests, but these don't offer anything like the heating control and convenience of the heated vest).

Our normal active devices for keeping us cool are fans. We have quite a number of these around our house and we simply move them around as/when required. The large ones typically draw around 40W; by way of contrast both my wife and son use small USB fans (10W) to good effect when they are sitting at their computers. At the end of 2018, I decided to test out a USB evaporative cooler (10W) that I fell across one day on the internet. I reported on this, very positively, in last year's report.

USB Personal Evaporative Cooler – Take Two

Our USB cooler worked very well over the whole of the 2018/19 summer and when autumn arrived I put it into storage following the published instructions. Unfortunately, when I got it out at the beginning of the hot days in November 2019 it no longer worked properly: when I plugged it in the fan simply started at full speed and it could not be controlled – it seems that the electrical parts worked OK but the electronic controls had died.

Figure 29: Our replacement cube evaporative cooler

Given my very positive reaction to the effectiveness of our USB cooler when it was working my immediate reaction was to order another one. This time I decide to opt for a very basic device (see **Figure 29)** to test out how this would compare. In a few words, it was OK but not brilliant. It had a three-speed fan and it wasn't too noisy but it was a real hassle to get water into the (very small) reservoir. Adding water involved removing the cover. I used this cooler almost every day for a few weeks at the start of summer but I didn't bother with adding water – I therefore got no evaporative cooling from the device.

Initially I found the dry cube provided enough cooling for us to use it most nights on one of our bedside cabinets and during the day as a cooler sitting on the desk in my office. However, one day in mid-January I chanced across a $10 minifan [this link takes you to an Indonesian website: I bought my fan in a shop in Singapore] and discovered that this much smaller and lighter device provided much better airflow, and was much quieter, than the cube cooler. At the time of writing this minifan is my preferred personal 'carry around' cooler.

Having said that, USB evaporative coolers are very comforting and convenient to use (and of course very low energy), but if I were going to get another one I'd buy one where you can simply add water into the reservoir using a jug with a spout (rather than one which you have to take apart to add the water).

Refrigerated Personal Cooler

In last year's report I also indicated that I had a strong interest in testing a particular refrigerated personal cooler – the *Close Comfort*. This device was proving controversial on some of the energy blogs because it went against conventional practice and vented warm air into the same space as that being occupied by the person being cooled. This was never a problem for me since I could see that all the device is aiming to do is generate a small cool zone around an individual (or a small number of individuals close together); it is not designed to cool a room. A device that fits exactly into my philosophy of 'cool yourself: not your house'!

I bought a unit toward the end of summer in early 2019 (see **Figure 30)**. Without going into great detail (the reader can get a fair bit of information on the thinking behind the device from the *Close Comfort* website; I also published an article containing some of my thoughts on the *Close Comfort*), I can categorically say that this device works really well for us. It got a fair bit of use over our hot and very smoky 2019/2020 Canberra Christmas/New Year.

The Close Comfort is an Australian invention/product and in my view demonstrates the sort of lateral thinking that society needs to adopt if we are to progress toward a low carbon future.

Figure 30: Our Close Comfort unit sitting on the floor in my office

In a world that is progressively getting hotter, it would seem inevitable that demand for refrigerated cooling is going to rapidly increase. Personal refrigerated cooling, as opposed to refrigerated space cooling, promises very significant energy gains. You don't have to cool a whole house in order to achieve thermal comfort in summer.

Chapter 5

2019 Consumption: Other

In my first Annual Report (2016) I included the table below in an attempt to capture the main electricity consuming devices in our house that haven't been monitored/reported on elsewhere in the book. I term these devices as being in the 'Other' category.

Over the past few years we have made several purchases of electrical goods of some kind or other and almost all of these have insignificant power and/or energy draws and I haven't changed this table since day one. However, next year I will change one important entry in the table – our plasma TV. Our plasma TV has been a major energy user in our household over the life of the project and I am very pleased to say that right at the beginning of 2020 we bought an LED TV: much larger TV but about half the power rating (the new one has a power rating of 198W). I estimate that this will save us about 300kWh over a year – about the same amount of energy that we use annually for maintaining thermal comfort!

Figure 31 shows my estimates of the 2019 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	
Close Comfort	0.3	Y	10	20	Only used over summer
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 31: Notional 2019 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: a range of PHDs (personal heating devices), mobile phones, router, toothbrushes, shavers, radios, laptops/tablets, clocks, cooling fans, USB cooler, air purifier, 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 2019 shown in **Figure 5** (which I computed by difference based on the energy use of the other end uses) = 2,249kWh. The total of the annual energy use for the individual items shown in column 5 in **Figure 31** = 2,065kWh. Therefore, overall I believe my energy guesstimates for the ‘Other’ category are quite reasonable.

Chapter 6

The Battery

Our Tesla Powerwall 2 battery worked flawlessly for the whole year, but unfortunately, due to no fault of the battery, it was offline for about four months at the end of the year. This was due to our converting our house over to three-phase and the battery needing to be re-configured. This proved to be a long process.

Given the disrupted year for the battery, our electricity supply and our Solar Analytics monitoring system, I've decided not to include any data for the operation of the battery in this year's report. I propose to start reporting again in next year's report.

The only comment that is worth making is that even though the Tesla Powerwall 2 is a single-phase device it can be configured to work successfully in a three-phase environment. I have not been able to detect any problems with its operation since it has come back on-line.

Chapter 7

Energy Monitoring

In last year's report I described my Solar Analytics monitoring system and expressed my excitement at having a robust real-time monitoring system on nine of the circuits inside my house. Unfortunately, like our battery, this system suffered from our change over to three-phase and was not in effective operation for the last four months of 2019. This down period can in no way be blamed on Solar Analytics. Once we changed over to three-phase the whole system naturally needed to be re-configured but I decided that I would hold off on doing this until the battery was up and running again.

At that point I opted to wait until I have my new solar PV system in place (hopefully reasonably early in 2020) so that we can set up a stable monitoring system rather than keep messing around with it every three months.

While I lost my detailed energy monitoring capability for a large part of the year, I had alternative (less accurate, but OK) ways of tracking the energy use of our main devices (the EV, and hot water) so all was not lost. I'm hoping that I will have the Solar Analytics system up and running early in 2020 and envisage that I can report the system's performance in next year's report.

Plug level monitoring

While the Solar Analytics system gives me excellent energy use data at the circuit level this is not sufficiently fine grained to give me the information I need to closely track our heating energy use. The key personal heaters we use over winter are all on the same power circuit, along with a number of non-heating devices, and therefore I need energy use data at the individual plug level to really understand our heating energy use patterns.

In order to obtain the plug level monitoring I bought four smart plugs. These worked extremely well throughout the winter and provided apparently very robust energy use data via a mobile phone app. The app provides instantaneous power level and 24hr energy use data. It also shows aggregated energy use for every month (see **Figure 32**). I used data from these plugs to derive the results shown in **Chapter 5**.

Three of the devices appear to be still working fine but one suffered what appeared to be a catastrophic failure just after the end of the heating season. I did not follow this up because I had stopped monitoring our heating energy use by that time: I may possibly be able to resurrect this unit; I will try this before heating season 2020.

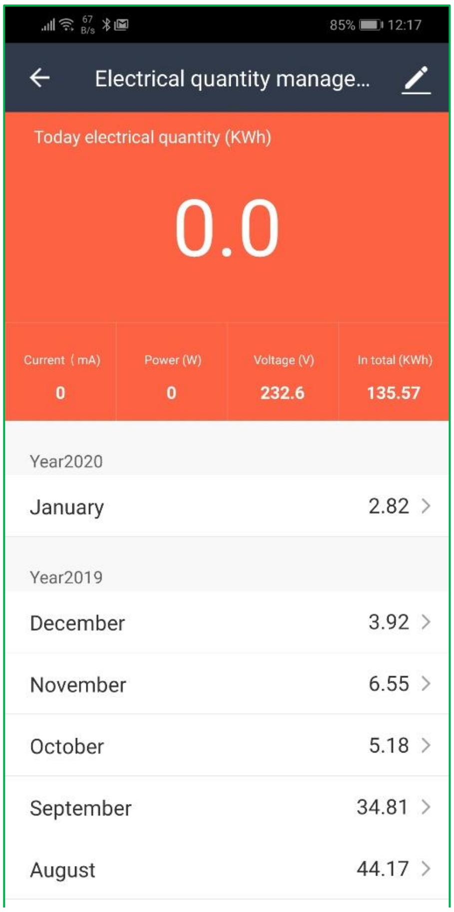


Figure 32: Screenshot of the smart plug energy report

Chapter 8

Phase 2: Where to now?

We started our energy transition at the beginning of 2014. The inspiration to start the project was the war against climate change action that was being waged at that time by conservative forces. The carbon tax was in the process of being axed, and the then new Federal Government was doing everything in its powers to stall the adoption of renewable energy. Investment in wind and solar PV more or less dried up. I felt compelled to do something.

Thankfully a lot of progress has been made since 2014. We are still without a price on carbon, but renewable energy has taken a stranglehold on our electricity system. The system is changing, and it is changing very rapidly. Prices have dropped dramatically and, as I believe I have demonstrated during the first stage of the project, it is now relatively easy for a household to have a low carbon footprint and still enjoy a 'normal' lifestyle.

While this is great, are things happening quickly enough? Unfortunately, the background context has deteriorated markedly since 2014.

In 2014, in my view, we were 'alert, but not alarmed'. I think many of us thought that while things were undergoing a temporary setback we were largely in control. However, at the start of the 2020s I, like huge numbers of people around the world, am 'alarmed'! Australia's, and the world's, carbon footprint is still growing not shrinking. *We are in a climate emergency.*

Figure 33: Franz Josef glacier: New Zealand. Photo taken 3 Jan 2019

At the start of 2019 the urgency of the situation was brought home to me when I saw the extent to which the Franz Josef glacier in New Zealand had receded in the last decade (see **Figure 33**) [I also included this photo in my 2018 Annual Report]**.** This sense of foreboding was only exacerbated throughout 2019 by, for example, the ferocity of the bush fires first in California during their Autumn and then here in our Australian Spring. Sadly, but also more alarmingly, the fires which began in Spring turned into infernos in late December 2019 and early January 2020.

This has made me question how we can extend our project to the next level. We've tackled our direct CO_2 emissions in **Phase 1**. How do we respond to our indirect emissions? I believe we now need to work on extending our target from not directly buying any fossil based energy to having ***'net zero emissions'*** across every aspect of our lives. I suspect this will involve complex computations and much greater expenditure and/or change of lifestyle than was required in **Phase 1** of the project. I very briefly discuss this at the end of the Chapter.

Finalising Phase 1

As reported in the other parts of this document, we still have a fair way to go until we are in a situation where we will no longer need to directly buy fossil fuel based energy. In particular, we need to address our petrol use.

Increasing our Solar PV

In **Chapter 1** I described the point we have reached in the development of our household solar PV potential. I hope to have our roof more or less completely covered with solar PV panels by winter 2020.

As I theorised in **Chapter** 1, this does not necessarily mean the end of our solar PV development, but I imagine it will be our last solar installation for some years.

Petrol – the real challenge

In 2019 we made some progress in reducing our petrol use. In 2020 I see our new Nissan Leaf helping us to build on these gains as we undertake more of our regional trips using our EV rather than our petrol Hyundai i30. I plan on testing the capability of the new Leaf by taking it on progressively longer trips throughout 2020.

The network of rapid chargers in our part of the world now seems to be expanding quite nicely. It seems that before long there will be charging stations about every 150km along the Hume Highway between Sydney and Melbourne. Rapid charging stations are also now being installed in regional centres close to Canberra. I hope it won't be too long before we can retire our i30 to being solely a five days/week commuter car.

Having said that there is one issue: our son!! Our son has just got his P plates and not surprisingly he has dreams of 'borrowing' the i30 'from time to time'. No doubt he will get his own petrol car at some point. I suspect his dream of unconstrained mobility will trump my dream of little/no petrol use!!

At some stage I hope that we can replace the i30 with an electric, or maybe plug-in hybrid, car but I don't think it will be in 2020. Maybe some time during **Phase 2** if this has a life span of about 5 years.

Change of lifestyle

Throughout the project to date, I have deliberately not focussed on reducing our carbon footprint through lifestyle change because I wanted to see what could be achieved by a 'normal' suburban family.

In the Overview at the front of this report, I briefly mention a few 'little things' that I did in 2020 which modified my lifestyle – for example, no longer reading print newspapers; taking the light rail into the centre of Canberra. Essentially trivial, but I suspect we will need to focus on these types of changes as we move into **Phase 2** of the project.

Phase 2: The new target - Net Zero Emissions Family

The world is nominally on a trajectory to have 'net zero [carbon] emissions' by 2050. Unfortunately, at the present time Australia is not on the same page as the world's progressive countries, so once again, as with **Phase 1** of our energy transition, we have to ask the same question. If Australia as a country is not prepared to act, can individual Australian households take meaningful action? How quickly can Australian households meet the 'net zero emissions' goal?

It is self-evident that in order to carry out a controlled change you first need to fully understand the existing situation. In **Phase 1** this was easy – I knew and/or could readily monitor our direct purchase and use of fossil based energy in the baseline year. When I made changes, the energy consumption/CO_2 footprint effects could be tracked and reported with reasonably accuracy. On the other hand, monitoring/measuring indirect fossil fuel based energy use is much more complex.

Almost all aspects of our lives at present involve the indirect consumption of fossil based energy. Most notably: the food we eat; the products we buy (both manufacturing and transport components); the services we use (eg going to a theatre performance) and public transport. Of these, I see public transport as the easiest to carbon footprint. For example, the carbon footprint of air travel can be computed with a good degree of accuracy. However, what about the others? These are usually made up of many components sourced from all over the world. The carbon footprint of these components will involve some form of contribution from transport – how can you possibly compute this without the most detailed information? Even if you had detailed information on where a product, and its constituents, had travelled it would not be a straightforward computation.

At this preliminary stage I can only see being able to compute my family's indirect carbon emissions to a very crude level. Once I obtain an estimate of our indirect carbon footprint, what do we do? I guess we can stop doing/buying some things. We can maybe find substitutes. Do we buy into a major solar or wind farm to compensate for our family carbon emissions? Perhaps we just buy carbon offsets and carry on as before? It will be an interesting exercise.

Post Script

I have been writing and publishing reports relating to climate change for more than seven years since my retirement. To this point I have tried very hard to be non-political in my writing; I have deliberately avoided any criticism of particular political parties. However, the events over the past summer have caused me to crack. Indeed, I feel that it would be irresponsible of me if I did not make at least some comment about the political situation that has arisen over December 2019 and January 2020.

In my view the Australian Government's failure to recognise the climate change imperatives arising out of the fires over the 2019/20 summer is utterly bizarre. The Government's position that it will take no action to address climate change other than to 'allow the market to work' (eg its reliance on technological advances to drive the rate at which renewable energy and EVs are taken up) represents an arrogant disregard for its obligations to protect the Australian public. Malcolm Turnbull seemed to sum things up nicely when he said the Government's stance is based on 'ideology and idiocy'.

What would I like to see the Australian Government do to address climate change? I would like to see our government take similar action to that being undertaken by national governments around the world which are committed to addressing climate change:

1) Adopt a target of ‘net zero emissions’. At the very least this could be based on the Paris Agreement target date of 2050. Ideally the target would have an earlier date.

2) Enact legislation that enshrines the target and establishes some form of Climate Change Commission which is charged with the responsibility for designing a plan to reach the target; implementing that plan once approved by Parliament; and monitoring and reporting on the plan to Parliament at intervals of no less than once a year.

3) As an interim, and emergency, measure impose some form of price on carbon.

4) Once the policy is established, work very hard within the UNFCCC and other United Nations bodies to get all other countries to implement urgent climate change action. [Until Australia has a credible Climate Change policy we will have no influence on the behaviour of other countries.]

You can find consolidated information on our household energy transition project at my website: https://netzeroemissions.net/