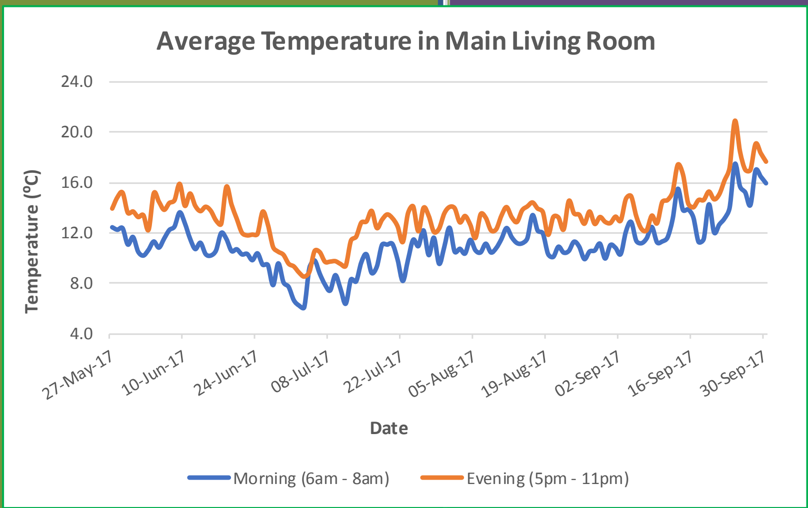
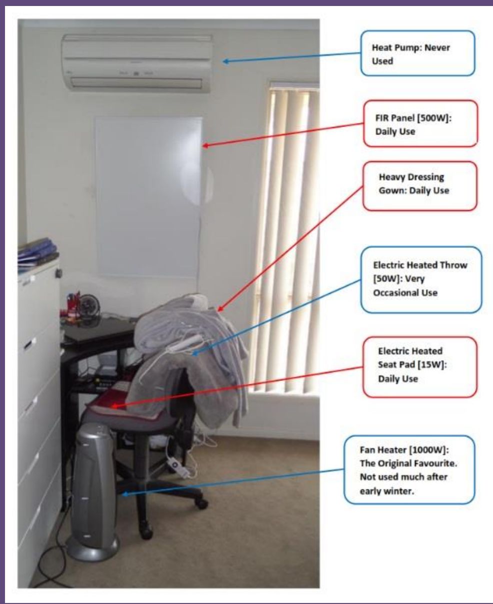
Heat Yourself: Not Your House

The low-cost way to keep warm at home

Over the past five years we have gone through a revolution in the way we keep warm in our Canberra house over winter. We no longer heat our house. We heat ourselves. The result? We're beautifully warm and have reduced our annual heating energy use by around 90%.





It is not hard to conceptualise the perfect residential heating system. In the ideal world, I envisage that each individual will have their own personal heating system attached to themselves as they move around their home. Presumabl[...] will be some form of light, and very compact, battery powered conductive hea[...] allow an individual to choose, and constantly adjust, the amount of [...]e to give them a personalised heating experience. It will [...]eed to heat, insulate or draughtproof houses. Natural ve[...] indoor air quality. The rate of current advance[...] not be too long before we will be able to reac[...]

WINTER HEATING ENERGY GOAL: < 1 kWh/person/day

Dave Southgate

October 2017

Heat Yourself: Not Your House

The low-cost way to keep warm at home

Preface

I have written this document in an effort to generate discussion about finding better ways for people keep warm at home. For me, 'better' means using much less energy while maintaining thermal comfort. I am definitely not interested in reducing energy use at the expense of thermal comfort.

Over the past five years my family has gone through a revolution in the way we keep warm in our Canberra house over winter. We no longer heat our house. We heat ourselves. The result? We are beautifully warm and have reduced our annual heating energy use by around 90%.

While climate change has been the prime motivator behind my search for more efficient residential heating, I am very aware that for many (probably most) families the main interest is in reducing heating costs. It is no doubt very fortunate that the heating solutions we have adopted not only significantly reduce ongoing energy costs, they also do not involve major upfront costs. This contrasts strongly with many other commonly used 'low energy' heating solutions which have low running costs but can have high investment costs.

At one level this book is simply a description of what we did and achieved in keeping ourselves warm in our house over winter 2017. However, the underlying intent is to question why we Australians focus so much of our attention on space heating to keep ourselves warm in our homes. Why do we commonly heat all the air in a room when we are only trying to keep one person, or maybe a few people, warm? On the face of it this approach to residential heating seems very wasteful and clumsy.

Through the example in this book I am trying to build an argument that we will need to re-think our current residential heating practices if we seriously want to reduce the amount of energy we use, and the amount of money we spend, in keeping ourselves warm in our homes.

Dave Southgate

Canberra

October 2017

Disclaimer

The author has no commercial interests in the residential heating industry or in any of the products discussed in this book. He is self-funded and has produced this document as part of his efforts to demonstrate that households can reduce their carbon footprints while, at the same time, saving money and enhancing their lifestyles.

In One Page

Over a cold 2017 Canberra winter we kept ourselves nice and warm in our family home by taking a different path. We heated ourselves, not our house. This not only gave us some very impressive energy savings, it gave us a vision of the future: I can now see that low energy, low cost, comfortable residential heating is entirely feasible.

Key Observations

- ✓ By using personal heating devices we were thermally very comfortable in a 'cool' house – the air temperature in our house over winter was generally around 13^{o}C
- ✓ We kept ourselves warm by using a combination of radiant and conduction heating – this provided a wonderful balance between thermal comfort and energy efficiency
- ✓ Our heating energy savings have been quite dramatic – we have cut our winter heating energy use by around 90% in three years by moving from 'space' heating to 'personal' heating
- ✓ We bought and trialled a number of personal heating devices most of which had power draws between 15W and 100W – they cost significantly less to buy than most commonly used space heaters
- ✓ Our feeling of thermal comfort was more or less independent of room air temperature – this meant that the level of insulation and draughtproofing in our house had little bearing on how warm we felt

Heating Targets

Based on our energy use, and our level of thermal comfort, over winter 2017 I adopted the following heating goals for my family:

Instantaneous Goal

HEATING POWER GOAL: < 100 W/person

Daily Goal

HEATING ENERGY GOAL: < 1 kWh/person/day

1 Background

I retired in 2012 after having worked as an environmental specialist in Australian government agencies for more than 30 years. In the last decade of my life as a bureaucrat I worked on national and international climate change issues. In the end, this experience led me to become very concerned with the lack of Government progress on introducing climate change action – the 'top down' approach simply wasn't working. As soon as I retired I therefore began trying to tackle the problem from 'the bottom up' and started working on ways to radically reduce my family's carbon footprint.

In 2014 I began a project aimed at my family progressively becoming fossil fuel free. In summary, this involved us installing solar PV; buying an electric car; disconnecting our house from the mains gas supply; and using energy efficient ways to live a 'normal' suburban family life. I have closely monitored the energy/carbon impacts of the project and produced a number of reports describing our progress.[1,2,3]

As we live in Canberra, with its frigid winters, it is not surprising that the way we used energy to heat our house came in for some heavy scrutiny. As the first step, we changed from using a gas ducted heating system to installing Far Infrared (FIR) heating panels – I describe the reasoning behind this move in reference 2. This led to us reducing our household heating carbon footprint by about 50% over the period 2013-2016.

As things turned out, the change from heating ourselves with hot air, to heating ourselves with radiation, had a significance far beyond the simple reduction in carbon footprint. It revolutionised the way I think about, and now approach, residential heating.

Winter 2016 – No more space heating

In 2016 as I attempted to monitor and assess our adoption of FIR heating I began to realise (probably more slowly than I should have) that our conventional ways of residential heating are inherently wasteful. Why do we heat all the air within spaces inside buildings (often very large spaces) when all we are trying to do is keep a few people warm? I had begun my journey to becoming a 'personal', as opposed to a 'space', heating advocate – my motto became 'heat people: not spaces'. I describe my initial thinking on 'people heating' in my FIR assessment report which I published after the 2016 winter heating season.[4] I also tried to capture my ideas in an article which appeared in *RenewEconomy*.[5] The box on the next page gives a summary of how my conversion in thinking came about.

---

[1] *Living with a plug-in electric car in Canberra.* Dave Southgate. Aug 2014: https://www.slideshare.net/davesouthgate/living-with-a-plugin-vehicle-in-canberra

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

[3] *2016 Annual Report. Our Household Energy Transition.* Dave Southgate. Feb 2017: https://www.slideshare.net/davesouthgate/2016-annual-report-household-energy-transition

[4] *An Assessment of Far Infrared (FIR) Heating Panels.* Dave Southgate. May 2017: https://sway.com/CjnI8NPUyibAyBHY

[5] *Space heating and cooling our homes – time for a rethink?* Dave Southgate. RenewEconomy. Oct 2016: http://reneweconomy.com.au/space-heating-and-cooling-our-homes-time-for-a-rethink-81185/

Becoming an Advocate for the ‘Heat People: Not Spaces’ Philosophy

In 2014 when we decided to become a fossil fuel free family we committed to disconnecting our house from the mains gas supply. We needed to find an alternative heating system to our ducted gas system. When I began the search for the alternative system I was pretty much locked into conventional low energy thinking – let’s get heat pumps. However, we already had one heat pump in our house and my wife found that the heat it produced didn’t make her feel warm.

After some research and tentative trialling, we installed Far Infrared (FIR) heating panels in four rooms in our house. These were a revelation – beautiful heat and low energy use. At the beginning, we were using the FIR panels in the conventional way – we hooked them up to thermostats and used them to control the air temperature within rooms. However, it soon became apparent that the beautiful heat we were receiving was not from the warm air; it was from direct radiation from the panels. In fact, the room air temperature seemed to make absolutely no difference to how warm we felt.

The logical progression then followed; we only turned on a panel when we were sitting under it – it made no sense to leave panels on simply to warm up a room. On many nights we cut our energy use by 50% (ie we only turned on one rather than two panels) and enjoyed an unaffected level of thermal comfort. The ‘penny finally dropped’ – we needed to stop thinking about heating our rooms and to start focussing on keeping ourselves warm. ‘Heat people: not spaces’ or, as I now like to say, ‘heat yourself: not your house.’

Winter 2017 – Ultra-low energy heating

When winter 2016 was over my initial thoughts were mainly focussed on how I could improve our FIR heating regime – better controllers; different types and sizes of FIR panels. While I pursued this work, my thinking opened up and I began to search for ways in which we could take our energy savings even further.

In 2016 I had been primarily thinking in terms of heating the family, as a group, with fixed FIR panels. The next step in reducing energy was clearly to make the heating more personal by bringing the heat source as close as possible to the individual. I went on a mission to buy, and trial, a number of different ultra-low energy personal heating devices (PHDs) – devices typically drawing less than 100W. At one level, I was simply using devices that have been around for a long time. However, new technology is now transforming many of these old ‘clunky’ gadgets. In the end, I was very surprised how far the ‘people heating’ concept could be pursued – we achieved significant energy savings coupled with beautiful thermal comfort.

2 Introduction

In many parts of Australia the energy used for house heating over winter is significant. Clearly, if we are going to make the necessary reductions in our national carbon footprint we will need to find ways to substantially reduce the energy used in residential heating. For many Australians of course, the issue of greatest concern is not minimising their carbon footprint, it is minimising their energy bills. Some politicians have characterised this as a 'life or death' issue: it is claimed people are dying of cold because they can't pay afford to pay their electricity bills.[6] Some academics have adopted a similar position.[7]

Over winter 2017 I made a concerted effort to find better ways to keep warm inside our house during the cold months. I believe I have really good news. Our experience clearly indicated that people can keep nicely warm; use much less energy; and spend much less money, simply by moving their focus from heating their houses to heating themselves.

Commonly in the household energy field it is relatively easy to reduce energy use, and reduce energy bills, by investing money upfront. For example, through: building a passive solar house; installing solar PV; installing double glazing and wall insulation; buying a top of the range heat pump; or replacing the petrol car with an electric vehicle (EV). I have not done all these things but I have been fortunate enough to be able to invest some money in projects that reduce our household carbon footprint. By way of contrast, application of the 'heat people: not spaces' philosophy lets a household enjoy beautiful, low energy, thermal comfort without major upfront costs.

The concepts we applied over winter 2017 are not new. Personal heating devices have been in use for many thousands of years. As a child growing up in post war England in the 1950s all our heating was essentially 'personal heating'. We lived in cold houses and tried to keep warm by clustering around very inefficient open coal fires or we used simple electrical heating devices such as the one bar radiant heater; we were cold for a lot of the time. Today's personal heating devices did not exist at that time.

The widespread adoption of residential 'space heating' about 50 years ago was indeed a boon, but the shortcomings are now apparent. To be effective space heating requires well insulated, draughtproofed, rooms or houses. It requires expensive, and often complex, heating devices. These systems can use a lot of energy and for many households the costs of heating are now becoming prohibitive. I think it is rather unfortunate that by concentrating so hard on developing space heating concepts we have largely overlooked the potential of personal heating.

Many technological advances that have taken place over the past half century have the potential to be applied to personal heating. Synthetic textiles such as thermal and pile materials have made winter clothing much lighter, warmer and more comfortable to wear – it is now no impost to wear many layers of clothing when inside your home. The difference in heating experience between being under a 1,000W FIR panel and sitting in front of its now very aged radiant cousin, the one bar (1,000W) radiator, is nothing short of astounding. I continue to be amazed that these two devices

[6] *'People will die due to renewables': Turnbull government MP Craig Kelly*. Sydney Morning Herald. 13 Jul 2017: http://www.smh.com.au/federal-politics/political-news/people-will-die-due-to-renewables-turnbull-government-mp-craig-kelly-20170712-gxa78z.html

[7] *Forget heatwaves, our cold houses are much more likely to kill us*. The Conversation. August 2017. https://theconversation.com/forget-heatwaves-our-cold-houses-are-much-more-likely-to-kill-us-83030

run on the same amount of power. The electronic controls on simple personal heating devices such as throws and heated seat pads are now very sophisticated and compact compared to electronic devices when I was a child. We only had valves in those days!

Toward the end of the winter I came across a very interesting publication produced by the University of New South Wales entitled *UNSW Personal Heater Guidelines May 2016.*[8] I could have written this document myself! Many of the ideas, and the proposed personal heating solutions, almost exactly mirror my own thinking and are totally consistent with what I write in the following pages.

In the main part of this book I describe the steps my family took over the Canberra 2017 winter to further our move to 'personal heating'.

In Section 4 I provide a brief description of the PHDs I bought and give an informal assessment of their effectiveness.

In Section 5 I describe the changes I made to better control the FIR heating devices we had already installed in our house. I then attempt to address the obvious questions about our personal heating project. Were we warm? Was the heating regime convenient? Probably most important – did we reduce our energy consumption compared to our previous practices?

At a number of points throughout the text I have included a link to additional 'Notes' which I have placed at the back of the book. In the Notes I have attempted to draw out additional information and/or points which I believe are useful for understanding the basis of my thinking on personal heating.

---

[8] *UNSW Personal Heater Guidelines.* UNSW Facilities Management. May 2016: http://fmtoolbox.unsw.edu.au/comms/2016_UNSW_PersonalHeaterGuidelines_May.pdf

OUR HEATING STORY – WINTER 2017

3 Setting Things Up

In Section 1 I referred to my earlier works where I describe how, in 2015 and 2016, we moved from heating our house with a ducted gas heating system (convection heating) to heating ourselves with Far Infrared (FIR) panels (radiant heating). I felt that we had achieved a great deal with this move, but in this transition I had totally overlooked the other, and as it turns out, possibly the most important, means of personal heating - conduction. Conduction heating involves the body being in direct contact with a heating source (eg a heated throw, heated clothing, etc). [See NOTE 2]

Over summer 2016/7, my focus had been on refining our FIR heating set-up in readiness for winter. However, when autumn arrived my thinking changed direction and I began to research ways to more effectively individualise our heating regime for the coming winter. The FIR panels created beautiful 'thermal islands' for groups of people. Could I now somehow improve on this and provide personally tailored heating for each separate member of my family? This search inevitably led me into the world of conduction heating.

All other things being equal, I would expect that the closer a heating source is to an individual the lower the amount of heat that will be required to provide thermal comfort. Conduction is the means of heat transfer involving the closest contact between a person and a heat source, and therefore I came to the conclusion that this is the area I should now concentrate on. It did not take me long to discover that with the right conduction device you can keep a person very nicely warm with an input of only about 50W!!

Against this background, I began my journey of discovery into personal heaters at the start of winter 2017. I rapidly came across a whole world of personal heating devices (PHDs) which I had largely overlooked. I was aware of most, if not all, of these devices but I had simply not appreciated their potential to provide very low energy thermal comfort. I could not resist buying and testing quite a number of these. I describe these efforts in the next Section.

4 Testing Personal Heating Devices

In the following sub-sections I describe in turn the PHDs I bought and tested. In order to try and retain some brevity I have not given detailed descriptions of the devices – if the reader is interested, details can be obtained from the references I have cited.

As best I can, I have listed my purchasing/testing actions in chronological order to give an indication of how my thinking evolved – the reader will see that there was little logic in this: in some instances I was slow to try out cheap, simple, and ultimately very effective devices.

A casual observer may well find the list very unimpressive – after all most of the devices are quite commonplace, simple and relatively cheap. To me this simplicity is the beauty of the listed devices: they all provide effective heat with little, or no, energy input. They are all portable and can quite easily be used in a range of places around a house.

4.1 Heated Vest

Initially I began by researching the most obvious solution - heated clothing. I was very surprised at the range of heated clothing available on the internet – this is essentially clothing with some form of embedded electrical resistive heating pad(s). I eventually bought a sleeveless heated vest from an Australian company.[9] (See **Figure 1**).

Figure 1: My heated vest

Description: This vest was sourced from Austria and it is primarily aimed at the outdoor recreation market. It has a quite large heated panel over the back. It came with a very neat Li-ion battery/heat controller which easily fits in the hand. (See **Figure 2**).

Approximate cost: $200.

Typical power draw: It uses about 10-20W.

Subjective assessment: This proved to be a very interesting purchase. It ticked many of my boxes: extremely low energy use; very comfortable to wear; looks good; not at all evident that it is a heated garment. However, it did not work for me as a substitute for an indoor heater. I found the localised heated patch in the back did not give me a feeling of overall body warmth - I had a hot back and a cold front and legs.

Having said that, I love this vest and I used it almost every day through winter as a casual jacket when I left the house. It can be washed without any problems. Nicely windproof. On very cold mornings when I sat outside at a café the heating worked extremely well.

Figure 2: The Li-on battery and heat controller for my heated vest

[9] APHC – All Purpose Heated Clothing Australia. http://www.allpurposeheatedclothing.com.au/product-list/53

4.2 Heavy Plush Dressing Gown

Having tested out a relatively expensive piece of heated clothing I decided to go back to basics – simply wear warm (unheated) clothes! I started wearing my thermal vests as the base and usually put on another two or three layers. I topped this off with a wonderful heavy plush dressing gown which I bought from a well-known store in my local shopping centre. (See **Figure 3**)

Figure 3: My beautifully warm dressing gown

Approximate cost: $40

Power draw: It uses no external energy – it simply retains my body heat.

Subjective assessment: Amazing! I don't think I have ever owned, or worn, a dressing gown before. I deliberately bought the biggest size I could get so that it almost reaches my ankles and also gives me a very generous overlap of material in the front. When I'm wearing it I look like a total dork but it keeps me beautifully warm even in an unheated room – it is extremely soft and comfortable.

Given the success of my dressing gown I subsequently bought two more similar ones for my wife and my daughter.

4.3 Heat Patches

I can remember as a child my father enthusing about 'Japanese hand warmers'. When I spotted some quite by chance in a chemist in Canberra I could not resist trying them out. [10] These are essentially a hand sized sachet containing some common chemicals which undergo an exothermic reaction when exposed to the air. Once activated they retain their heat for about 10+ hours.

Approximate cost: A few dollars each depending on size.

Power draw: They give out heat.

Subjective assessment: These certainly work as advertised. They get quite hot and can keep your hands and feet nicely warm. Bigger patches can be placed on the torso. While I'm aware of some Canberra cyclists enthusiastically using these during winter, I don't believe these have any great application for keeping people warm within houses. I did not get a sense of feeling warmer when I used them indoors.

[10] *Hot Hands.* Kobayashi. https://www.kobayashihealthcare.com.au/hot-hands

4.4 Heated Seat Pad

Figure 4: The heated seat pad

Heated seats are a common way to provide personal heating. You get a very large number of hits if you search for these on the web. They range widely in complexity from simple heat pads to sophisticated 'smart' armchairs. We opted for something at the bottom of the range and bought the heated seat pad shown in **Figure 4**.[11]

Approximate cost: $55

Typical power draw: It uses about 15W.

Subjective assessment: This was a great success. My wife used this more or less every evening during the winter as she worked on her computer. It seems to deliver a lot of warming effect for very little energy input.

4.5 Heated Car Seat for the EV

Once I realised how effective a simple seat heating pad can be, I bought an equivalent one for our Electric Car (EV).[12] I am including this here because I treat our EV as just another part of our household and monitor and report EV energy use along with all the other energy used in our household on a daily basis.

Approximate cost: $25

Typical power draw: It uses about 30W.

Subjective assessment: Very effective if you are driving alone – it keeps you nicely warm for very little energy use. Electric vehicles use a great deal of energy for internal heating on a cold morning (we have few of these in Canberra!). Our EV reports that the heating system is often using around 2.5kW on a cold morning so the heated seat gives me quite a few extra kms of range.

4.6 Heated Electrical Throw

I have come across many people who use electric throws and speak very enthusiastically about how well they work. They have told me that if they are sitting down for some time they turn off their room heaters and use one of these. I ended up buying two throws.[13]

Approximate cost: $80

Typical power draw: It uses about 50W.

Subjective assessment: These work extremely well. They only require low electrical energy input but provide a great feeling of warmth: the sense of warmth is enhanced by the nice tactile feeling of the blanket. While these were initially very eagerly used by my wife and daughter, in the end they

---

[11] *Sunbeam Feel Perfect Heat Pad.* Reduction Revolution. https://reductionrevolution.com.au/products/sunbeam-heat-pad

[12] *SCA Heating Seat Cushion.* Supercheap Auto. http://search.supercheapauto.com.au/search?w=heated%20seat

[13] *Sunbeam Feel Perfect Heated Throw.* Reduction Revolution. https://reductionrevolution.com.au/products/sunbeam-heated-throw

only got occasional use – I think having a dangling electrical cord from the throw was the main deterrent. I look forward to battery operated versions of these being introduced some time in the future (see Section 7.4).

4.7 Electrical Foot Warmer

My attention was drawn to these by the UNSW publication that I have referred to earlier. This document says '*Heated floor mats …have been successfully trialled at UNSW...they can be used on their own if cold feet are the only problem or in combination with other sources of heating such as compact or micathermic radiant heating panels.'* Many different types of foot warmers are advertised on the internet. In the end I purchased a device from a Melbourne based supplier.[14] (See **Figure 5**)

Approximate cost: $35

Typical power draw: It uses about 20W.

Subjective assessment: I found this device quite surprising. In the past I have had cold feet but it has not been a major issue for me and I have never felt the need, for example, to wear multiple pairs of socks when at home. However, in the end I used this device quite a few times – having toasty feet has a very nice comforting effect for the whole of the body. These work extremely well.

Figure 5: My foot warmer

4.8 Other Devices

I have not included a number of other PHDs which I have bought in the past couple of years (eg a sleeved blanket[15]) or ones that I have been using for decades (eg blankets & hot water bottles). I should also mention that I consider my list to simply be a snapshot - I plan to continue searching for new PHDs. At the moment I am in the process of purchasing a fluffy fleece onesie to see how this performs in a cool house (obviously I won't be able to really test this in anger until next winter).[16]

4.9 Far Infrared (FIR) Heating Panels

While these are somewhat different from the other devices, I have included these in the list of PHDs for completeness. In contrast to the other devices, FIR panels are generally used in a fixed location and use somewhat more energy. [Having said that I note the UNSW is using mobile FIR heaters with a power rating of 160W].[17] We have fixed two large (1,200W) FIR panels to the ceiling in our main

---

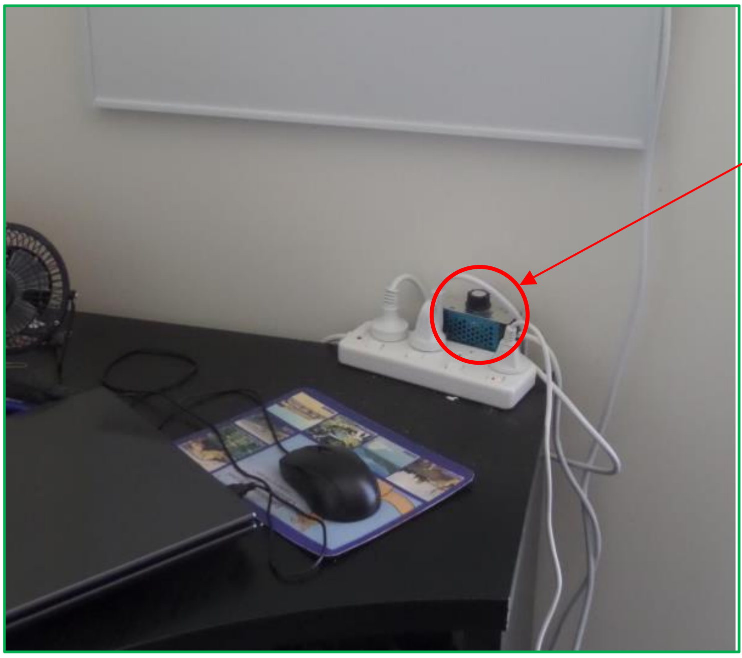
[14] *Electric Foot Warmer.* KG Electronic. https://www.kgelectronic.com.au/p/Heating-Cooling/Electric-Blanket/Micro-Fleece-Heated-Throw-Blanket/FW90

[15] *Deluxe Sleeved Blanket.* Kogan.com. https://www.kogan.com/au/buy/deluxe-sleeved-blanket/?utm_source=google&utm_medium=product_listing_ads&gclid=CjwKCAjw8IXMBRB8EiwAg9fgMHM-Dp3Ej6E_WCVAHwpNCabnZjXuRCdLSCAIj5ANGY8jFOJshfIf7BoCGh8QAvD_BwE&gclsrc=aw.ds

[16] The All-in-One Company. https://www.the-all-in-one-company.co.uk/onesies/allinone/create-your-own

[17] See reference 7. Page 5. The publication does not specifically mention FIR, but quotes a heating energy density of 800W/m^2 for the heaters. This is approximately the heating energy density of the FIR panels in our home.

living area and these effectively function as group heaters rather than PHDs. However, we do have smaller 600W panels in two of our smaller rooms which we essentially use as PHDs.[18] I have installed controllers on the panels in our main living room and in our bedroom which let us reduce the power they draw (and the heat they emit). In **Figure 6** you can see the voltage regulator I have installed to vary the heat output of the 600W panel my wife uses as her main heating source when she sits at her computer.



The voltage regulator I have installed to let us vary the power drawn by our 600W FIR panel

Figure 6: The voltage regulator we use to control the heat output of the FIR panel

I have also acquired a thin film FIR heater which we can use as a mobile heater (see **Figure 7**). I have written about this elsewhere.[19] I briefly used this over the winter to test potential new positions for the 600W FIR panel on the wall in our bedroom.

Figure 7: Our thin film FIR heater

[18] *DIY FIR Heating Panel.* Heat-on heating systems. http://www.heat-on.com.au/DIY.asp
[19] *Naked Far Infrared (FIR).* Dave Southgate. April 2017: https://sway.com/jiGwQDqZDBYBkVq0

5 How we used the PHDs and FIR Panels to heat ourselves and not our house

Having presented the suite of the PHDs we used over the winter, the obvious question is 'How and when did we use these devices?'.

5.1 Maintaining a cool house

It was fundamental to our new household heating regime that we used as little energy as possible in heating the air inside our house – the aim was, as far as possible, to only use energy to heat ourselves. In order to monitor our progress, I set up a commercial grade data logger[20] in our main living area and took one-minute temperature samples over the five months of the Canberra winter 'heating season'. I placed the logger and a temperature sensor on a shelf in the living area just over a metre from our main dining table (red circle in **Figure 8**). This table is directly under one of our 1,200W ceiling mounted FIR panels.

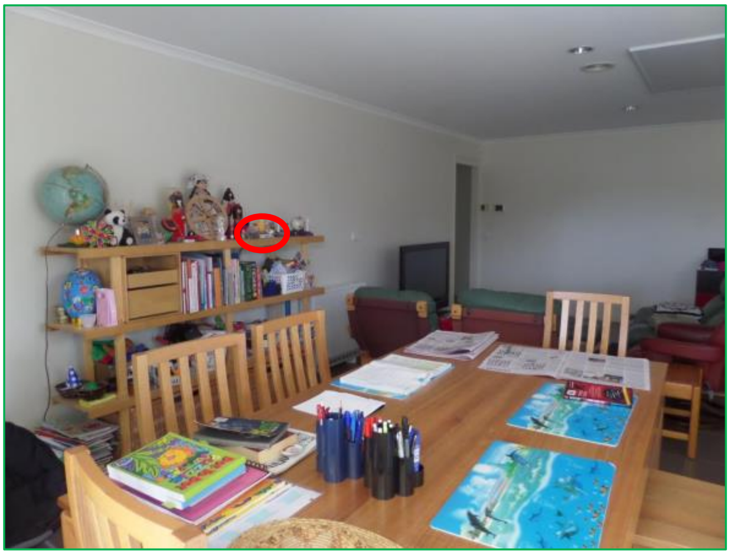


Figure 8: Location of the temperature probe and datalogger in our main living room

The summary results of the data logging are shown in NOTE 4. In **Figure 9** I show temperature readings for breakfast time (6am to 8am) and the evening periods (5pm to 11pm) which were the times that we were most interested in keeping warm and that we almost exclusively used our monitored PHDs.

You can see that over the coldest part of winter the morning temperature in our living room was typically around 10-12^{o}C and the evening temperature was around 12-14^{o}C. (We were away on holiday for the last week of June and the first week of July). There is a very evident rapid rise in both the morning and evening average temperatures from early September (we did not use our FIR panels in our main living area after the first week in September).

The temperatures on the chart indicate that we were largely successful in avoiding significant 'thermal overspill' from our FIR 'thermal islands' around the dining table and around the chairs in front of the television. The temperature in the thermal islands was typically around 18-20^{o}C using the 'medium' heat setting on the controller for our FIR panels. [See reference 4 for discussion on 'thermal islands'.]

When I did spot checks, the temperature at the datalogger was similar to that in other rooms in the house.

[20] *HOBO UX120 4-Channel Analogue Data Logger - UX120-006M.* OneTemp. http://www.onetemp.com.au/hobo-ux120-4-channel-analogue-data-logger-ux120-006m

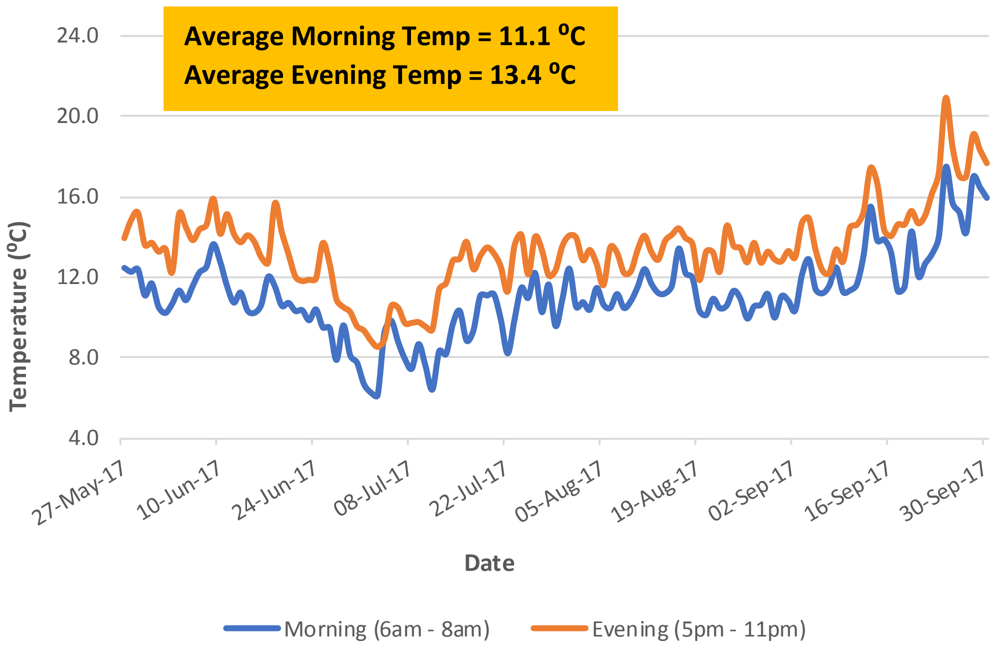


Figure 9: Average temperature in our main living room over winter – breakfast time and in the evening

5.2 Group heating – the large FIR panels

Typically, each day we would all eat together in the evening sitting at the dining table in our main living area enjoying heat from one of our FIR panels. As just mentioned, this table is placed directly under one of our 1,200W FIR panels (see **Figure 10**). I mentioned earlier that I had changed the controller on the panels in this room so that I could reduce the power they consume. This meant that I removed the thermostatic controller – consistent with my comments elsewhere, I was keen to control the heat based on thermal comfort, not on air temperature.

My new controller has three user selected settings – low; medium; and high. In May we almost always selected the low setting for the heater (about 800W); in the coldest three months (June, July and August) we generally used the medium setting (about 950W). We only used the panels on a few occasions in September. We never felt the need to run the panels on the high setting at any time over the winter.

When we finished our evening meal we would often disperse to different parts of the house to do our own things. We would usually leave the FIR panel over the dining table on until everyone had left the table; those of us no longer at the table would normally move into some form of PHD mode at that point in the evening.

5.3 Multiple Choice PHDs

I was keen that all of us in the family had ready access to a choice of PHDs. In our main living room we normally left some form of unheated blanket (eg the sleeved blanket) and an electric throw on the chairs in front of the TV to let everyone have a ready choice of how they wanted to keep warm. This couch is also under one of the large FIR panels so this was always another heating option. **Figure 10** shows a photo of the area where we sit in front of our TV - you can see a heated throw (purple) and our sleeved blanket (red) in the armchair on the right.

My wife has her special little spot in our bedroom where she uses her computer - she usually ends up here later in the evening. This was great from my point of view because I could use her as my heating test dummy. When we were in the trialling stage she had at least six different PHDs she could choose from (see **Figure 11**). My idea was to let her turn on as many of these as she wanted to keep herself warm – I was very keen to learn which devices worked for her and to see whether she would opt for any of the low energy devices. At one stage I was afraid that she would turn on all of the heating devices and become like the frog in the boiling water – just lose any sense of how warm she was!

Figure 10: Heating options for sitting in front of our TV

She disliked the heat pump – to her it simply generated draughts – and she would not use it. For some years she has used a very close fan heater blowing hot air directly on her legs as her preferred heating method. However, this year she stopped using this early in the winter – clearly she had other devices that kept her warm. She used the electric throw for a few nights – it certainly made her warm - but she stopped using it because the electrical cord restricted her getting up and down. For most of the winter she ended up just using three core heating devices every night: her fluffy dressing gown; the heated seat pad; and the FIR panel. These three devices seemed to keep her nice and warm. If she got too hot she would turn the FIR panel off for a while.

When I initially installed the 600W FIR panel in this room I hung it like a picture in landscape mode about halfway up the wall. This did not work too well as the radiation was mainly directed over her head when she was sitting down, so I installed two brackets to incline the panel toward her – this improved the situation somewhat but I could see that this needed further work. Ultimately, I turned the panel into portrait mode which had the effect of bringing it closer to her – the position shown in **Figure 11**. At the same time I installed the basic voltage regulator (shown in **Figure 6**) into the FIR circuit which allowed me to de-rate the power draw. I set this at just under 500W: if she wanted to vary the heat output my wife had the option of either turning the knob on the regulator or she could just turn the panel on or off at the switch.

In addition to having access to all the PHDs I've listed above, my kids each had a blow heater in their bedrooms. As far as I can tell they rarely used these heaters, other than when they were getting dressed in the morning, and preferred to use blankets and hot water bottles (in addition to wearing appropriate clothing) to keep warm in the evenings.

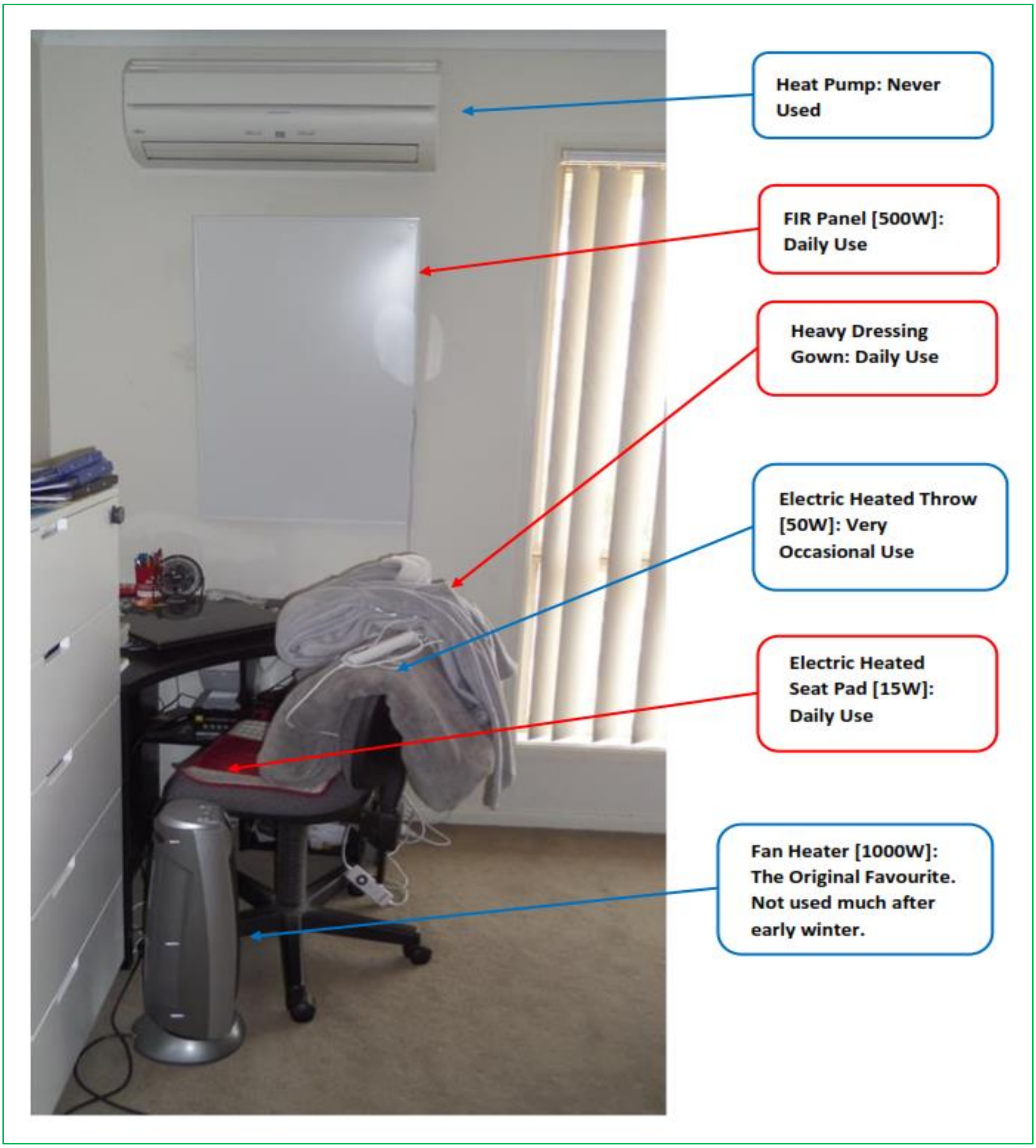


Figure 11: My wife was not short of heating choices!

5.4 Were we warm?

Absolutely!! My fundamental requirement for the personal heating project was that we always kept warm. The idea was that we kept warm while using as little energy as possible: we were not trading off warmth for energy.

Even one or two years ago, if I'd looked at the temperatures shown in **Figure 9** I would have been aghast and would probably have exclaimed 'how could people possibly live in a house that cold?!'. However, that reaction would have been based on my having been habituated to living in rooms at around 18^{o}C-20^{o}C and wearing clothes suited to that temperature.

Rather paradoxically, I found that over this winter, while we were living in a house with much colder air temperatures than we were used to, I tended to pay much more attention to keeping myself and others warm. I wore many more clothes than in previous years and always had immediate access to a PHD to keep me warm. Overall I would say that I felt warmer, and that my body was almost certainly warmer, over the last winter with room temperatures around 13^{o}C than I was when we were using a ducted gas heating system throughout the house with the thermostat set at 19^{o}C. For example, the temperature inside a heated throw was typically around 25-30^{o}C – much snugger than sitting in the heated air from a ducted gas system.

One really surprising outcome of the new heating regime seemed to be the way I, and the rest of the family, habituated to cooler temperatures. Air temperatures which I'm sure would have raised complaints like 'I'm freezing' in earlier years seemed to go without comment. 'Cool' was normal. As the winter progressed this habituation reaction seemed to strengthen. I was certainly mindful of possible adverse health impacts of living in a cool house. I kept asking myself 'Even though we feel warm, is living in a house with air temperatures of 13^{o}C threatening to our health?' [See NOTE 3]

Subjectively I felt terrific all winter: none of us really had the common sniffles/colds we could expect to get in winter.

In summary, by using PHDs we kept ourselves beautifully warm in a house where the room air temperature in the evening was generally around 13^{o}C. I imagine that most home heating experts would find that statement somewhat incredulous. In general, home heating practitioners have been trained to judge 'thermal comfort' by tracking room temperature; they control 'thermal comfort' by using thermostats which respond to room air temperature. Our experience over the winter indicated that the assumed nexus between 'thermal comfort' and room air temperature does not always hold. [See NOTE 1**]**

5.5 Was it Convenient?

In my view 'people heating' is not as convenient as 'space heating.' I imagine that this is one of the main reasons why space heating has become so popular.

Space heating can be almost totally automated through the use of thermostats and/or time-switches. You can set up your heating system at the start of winter and not touch it until spring. Gloriously simple, but this convenience will often come with much greater upfront costs and much greater energy use (and possibly lower thermal comfort).

Personal heating generally involves putting on several layers of clothes – over the winter I normally wore four layers of clothes (the outer layer being my wonderful plush dressing gown) whenever I was in the house. My wife usually only wore three layers of clothes – she preferred to keep warm by using the other forms of heating shown in **Figure 11**. No doubt some people would simply find it too inconvenient to have to make decisions about wearing extra clothes and/or using additional PHDs.

Some PHDs were inconvenient. I mentioned earlier that the heated throws did not get a great deal of use because they were tethered with a power cord and this made them much less flexible than they might otherwise have been. Having said that, some aspects of our new heating regime were very convenient. In particular, as we were running the same temperature throughout the house, and because our thermal comfort was largely independent of room air temperature, we did not need to go round putting draught excluders under doors or keep having to open and close all the interior doors as we moved through the house. [See NOTE 4]

Probably the greatest inconvenience with personal heating is working out how to keep unexpected guests warm. If you are space heating a house there is no problem in this situation – you have a massive amount of 'spare' heat in your house and your guests will no doubt immediately feel warm when they enter your home. On the other hand, with personal heating, if your guests are not going to feel cold, you have to quickly either provide them with some form of PHD or rapidly space heat the room you are occupying.

6 Energy Consumption

6.1 Overall winter heating energy use

To me this is the crux of the issue. How much energy did we use, as individuals, to keep warm? Could we have used less and kept equally as warm?

Figure 12 shows our total heating energy use for winter 2017 (May-Sep inclusive) and compares this with the previous four years. It can be seen that in 2017 we achieved an approximate 90% reduction in our heating energy consumption compared to when we used gas as our primary source of heating. Compared to winter 2016 we used about 40% less energy for heating.

Year	Electricity (kWh)		Gas (kWh)	Total (kWh)
	Grid	Self-consumption		
2013	274	0	5,920	6,194
2014	274	0	6,189	6,463
2015	1,853	142	0	1,995
2016	983	0	0	983
2017	569	0	0	569

Figure 12: Our household heating energy consumption for the past five years

Over winter we carried out almost all our heating in our main living room and my wife's 'study nook'. I consider this to be our primary heating load. Virtually all of the primary heating energy used was by our FIR panels. I datalogged the energy we used for this heating via a widely used home energy monitoring system.[21] We also carried out some supplementary heating in other rooms – in particular the Tastics in our two bathrooms and the occasional use of fan heaters in my children's bedrooms. I estimate that this incidental heating used about 1 kWh/day over winter (153 kWh in total). The heating energy use entries for 2017 in **Figure 12** include both the primary and supplementary heating energy.

6.2 Breakdown of Heater Energy Use

Figure 13 shows a month by month breakdown of the heating energy use between our main living area and the 'study nook' over the five-month winter heating period in 2017.

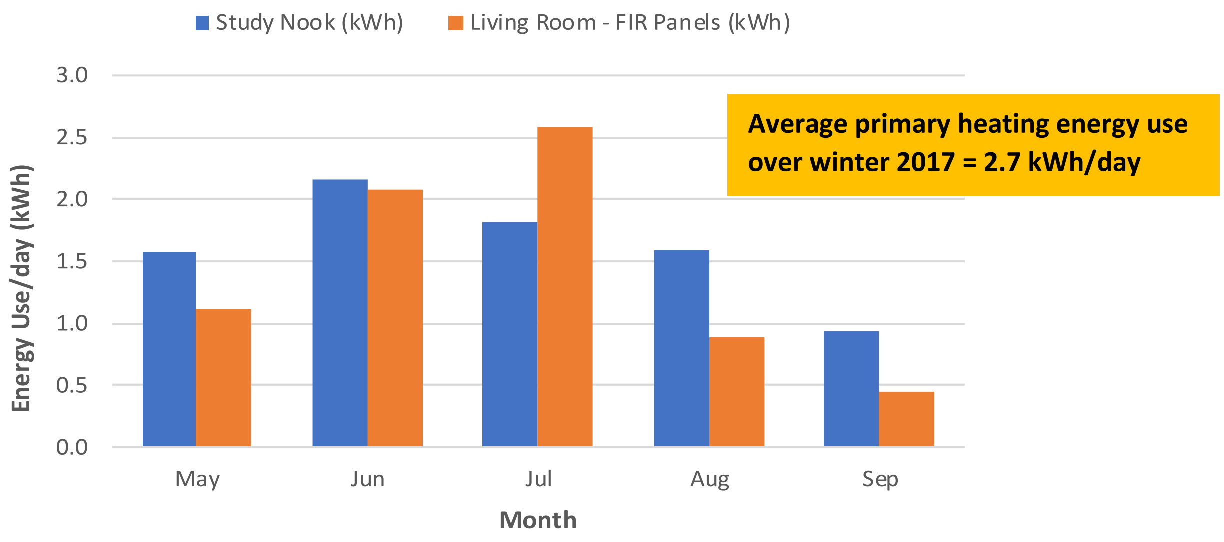


Figure 13: Breakdown of daily primary heating energy use by month over winter 2017

I have reported the energy use on a per day basis because we did not use any heating energy for a two week period in June/July when we were away on holiday – I have excluded this holiday period from the data. In total over the winter we used about 20% more heating energy in my wife's 'study nook' than in our main living area.

Shared Heating

As I noted in Section 5.2, at the beginning of each evening we usually had our evening meal together in our main living area. Very often some of us would stay in that room for about 2 hours doing homework and/or watching the TV. During June/July/August we nearly always had at least one of our 1,200W FIR panels turned on during this early evening period (almost always using the 'medium' setting) – it was somewhat more patchy in the shoulder months of May and September. After about 8.30pm in the evening we generally dispersed to do our own things and we only occasionally used the FIR heating in our main living area – we would all usually be in PHD mode by then. **Figure 14**, which is an hour by hour breakdown of our heating energy use over the winter shows how this pattern of behaviour translated into energy use.

[21] *Engage hub kit.* Efergy. http://efergy.com/au/engage-hub-kit/#.WZvGBT6g9hE

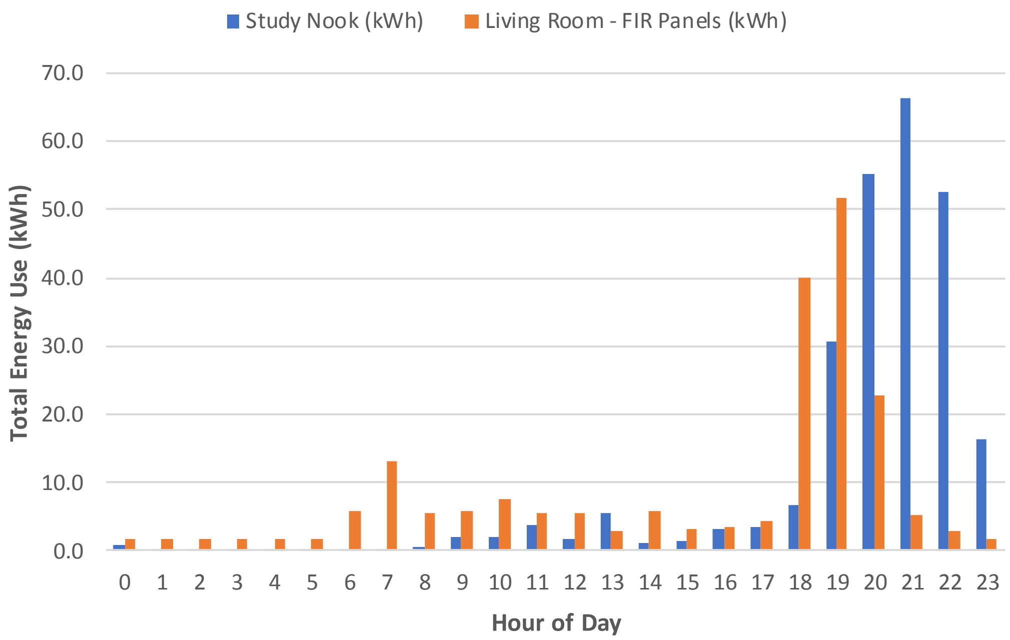


Figure 14: Breakdown of winter 2017 primary heating energy use by hour

It can be seen from the Figure that we used the FIR panels over breakfast on some really cold mornings. The daytime energy use of the panels shown in the Figure almost exclusively relates to heater use at the weekend. Approximately 60% of our FIR energy use in the living room over the winter was in the three-hour period 6pm to 9pm. We very rarely used the FIR panels when there was only one person in the living room. [The FIR system controller used a small amount of background energy all the time - this energy use can be seen in the overnight hours shown in the diagram. The panels were never switched on overnight.]

As I also noted in Section 5.2, in early May 2017, just at the start of the winter heating season, I replaced the original thermostat that had been controlling the FIR panels in our main living area with a more sophisticated controller that let the user select a temperature setting for the panels. The reductions in energy use brought about by the new controller are illustrated in **Figure 15**. This Figure (unfortunately it has a low-quality resolution) is a screenshot from our wi-fi heating monitoring system and shows the power draw across a sample day.

Examining the Figure, when one of the 1200W FIR panels was turned on at around 7am we used the ‘low’ setting on the controller – when a panel is turned on it always uses full power for 15 minutes before it goes into the selected heat mode. It can be seen that the ‘low’ setting gave a power draw of about 800W when it had settled down. This contrasts with the energy draw when the same panel was turned on at around 7pm – this time we used the ‘medium’ setting and the power draw was around 950W.

It is also interesting to note the power draw of the 600W FIR panel in my wife’s study nook. I indicated in Section 4.9 that I had incorporated a voltage regulator into this panel’s circuit – the outcome of my de-rating the panel to 500W can be clearly seen (the level of de-rating can be varied by use of the knob on the regulator).

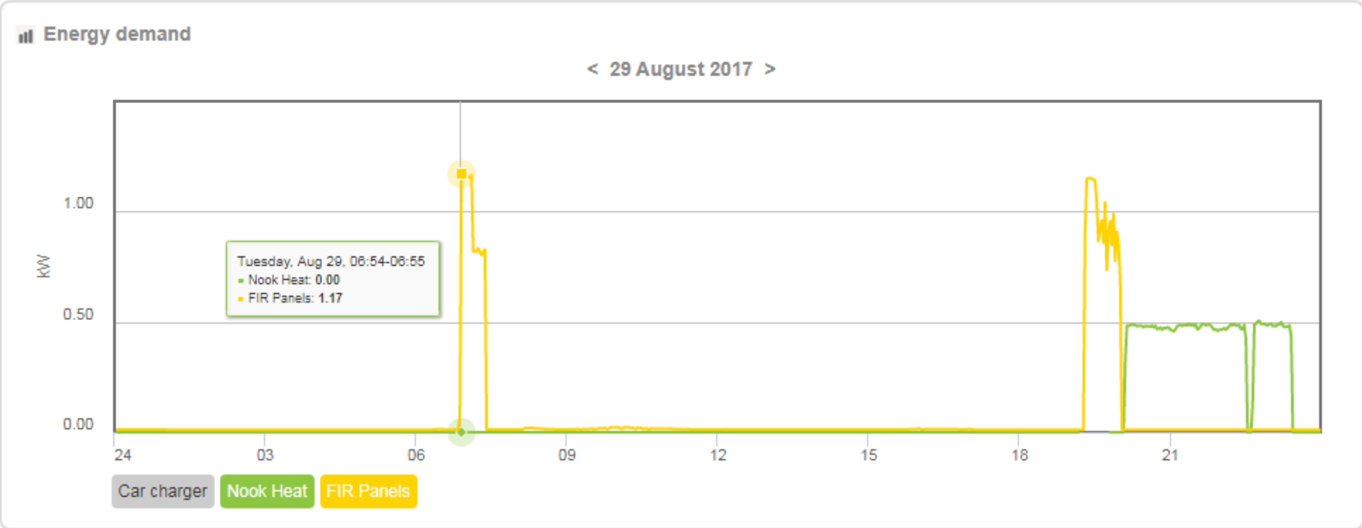


Figure 15: Screenshot of heating power draw for a typical day in winter 2017

Incorporation of the new controllers proved a very successful move – this step was of course a key component of our move from 'space' to 'personal' heating. It gave us back control – we turned the panels on and off when we needed to and no longer relied on thermostats to determine how/when the panels were heating. Being able to select the panel temperature enabled us to always run the panels at a reduced load right throughout winter.

Individual Heating

In Section 4, where I itemise the PHDs, I indicate a typical power draw for each of the electrical devices; this value relates to power drawn by the individual devices when they were being used at the setting we normally used – we rarely used full power. Most the controllers on these devices did not step down the voltage or current but rather turned the devices on or off for varying amounts of time within a minute. You can see that the hungriest of the devices listed (aside from the FIR panel), the electric throw, ran at about 50W.

It is interesting to compare this with the energy that would be used if a room heater were used to keep one person warm. In our main living area, which is a space of about 45m^2, the heating calculators on the web suggest that we would need to inject around 4,000W of heat to maintain the room at 19^{o}C on a cold Canberra evening (this may translate into about 1,000W of electrical energy with a heat pump). Therefore if the space heating device is replaced by a PHD the required heating energy input would only be about 1-5% of that used for space heating. In addition to the energy savings, the person with the PHD would most likely feel much warmer since the temperature close to their body would probably be between 5-10^{o}C higher than if the person were relying solely on hot air to keep warm. My informal monitoring (using an infrared thermometer) suggested that when a person puts on a blanket the temperature close to them typically increases by around 5-10^{o}C; if an electric throw is used instead of a blanket the temperature typically increases by around 10-15^{o}C.

I did not use the FIR panels to heat only myself at any time during the winter. When I was alone in a room I almost always used no electrical energy but simply used four layers of clothing (the outer layer being my dressing gown shown in **Figure 3**), usually with a beanie and slippers. On a small number of occasions I used a heated throw or, more often, the foot warmer (**Figure 5**). I was always very nice and warm.

My wife, who feels the cold much more than me, used a much greater array of ways to keep warm – I have discussed her 'study nook' in Section 5.3.

Initially I was most worried about my kids getting cold. However, they seemed very resilient and very capable of deciding when they needed some extra warmth – without any prompting they seemed to go for one of the many PHDs lying around the house (eg extra layers of clothes or a blanket) rather than turning on one of the main heaters in the living room or the fan heaters in their bedrooms. I was very keen not to try to set rules about which devices they could or couldn't use – I just wanted to observe what they did (but I did prompt them to keep warm if I thought they were not protecting themselves enough).

If the reader is interested in the accuracy of the data I have presented, they may wish to look at NOTE 5 where I have provided some information on my data checking.

7 Discussion and Looking Ahead

7.1 Overview

Having just spent winter 2017 living with a heating regime based on the 'heat people; not spaces' philosophy I'm solidly convinced that this is the future. It works!

While we moved away from space heating over winter 2016, we really only went half the way in that year. Our heating regime at that time was essentially based on establishing a number of 'thermal islands' and we kept warm by moving between those hot spots. The background room air temperature in the house over winter 2016 was probably broadly the same as in 2017 (I did not datalog the room temperature in 2016). In winter 2017 we basically filled in the gaps between the thermal islands by using our PHDs. For much of the time the need for the islands disappeared since each member of the family had a measure of heating independence – as discussed earlier, when we did set up the islands in our main living room in 2017 we ran them at a lower temperature than in 2016 using our new controller.

It should probably go without saying that when comparing 'personal heating' with 'space heating' there is a link between total heating energy used and the number of people being heated. Very broadly, the amount of energy needed to space heat a room is **independent** of the number of people in that room. For example, when space heating a large living room you are likely to use about the same amount of energy whether the room has only one or say 10 occupants. On the other hand, when using personal heating the total amount of energy used to keep people warm is totally **dependent** on the number of people being heated. For example, the amount of energy to keep two persons warm will be double that required to keep one person warm (assuming they are both individually consuming the same amount of electricity). At some point, for any room, when you increase the number of occupants there will be a crossover point where it will be more energy efficient to space heat rather than to use personal heating.

I have no doubt that most people can see the theoretical desirability of using personal, rather than space, heating and can appreciate the logic of only supplying heat where/when it is needed. However, I sense that not many people believe personal heating is a practical form of primary heating. In particular, they imagine that if they use personal heating they will not have the same level of thermal comfort as with their conventional warm air based heating. Unfortunately, personal heating is often portrayed as an inferior option used only by the poor.

My broad conclusion after 5 months of personal experience, and much thinking, is that when comparing personal and space heating:

- personal heating is a big winner when it comes to minimising energy use
- personal heating is a big winner when it comes to minimising costs – there are savings both in using less energy and also in the lower costs of buying and using the heating devices
- personal heating is able to provide glorious thermal comfort – whether this is better or worse than space heating is a matter of subjective judgement
- space heating is much more convenient – it can be largely automated by the use of thermostats and/or time switches.

While I believe society will ultimately need to go down the personal heating route because of climate change imperatives, others will be attracted to any option that promises significantly reduced heating costs. Yet others may be interested in exploring new heating methods for thermal comfort reasons. The beauty of the personal heating route is that options can be trialled on a very simple, and progressive, basis.

7.2 Transitioning from 'space' to 'personal' heating

Any household that uses space heating controlled by thermostats can test the personal heating waters simply by turning down the set temperature on the thermostats by a few degrees. This of course is a recurring piece of advice given by energy experts interested in reducing energy consumption, but it seems that it is very often ignored.

I sense that this call is not heeded because the unspoken message is usually: 'You're too soft; turn the thermostat down and get used to being colder'! I think the message should, in addition to the standard lines about reduced energy consumption and costs, be: 'Turn the thermostat down and use a personal heating device (PHD) – you'll be amazed how much warmer you feel!'. As discussed in Section 4, there are many PHDs available which cost very little, use extremely small amounts of energy and give you beautiful warmth.

If turning the thermostat down, and using some form of PHD, does not work for a household, they can revert to their usual heating regime without any great loss. On the other hand, if a first step thermostat reduction does work, this can then be ramped up so that in the end a household may reach the point where they totally decommission their convection based heating system and move away from space heating entirely (as we have done).

In practice, I imagine that for many households a hybrid heating approach will work best. For example, using convection heating to provide a 'baseload' internal house air temperature of say 15^{o}C and then allowing each member of the household to individually fine-tune their own heat level using PHDs.

7.3 Developing personal heating power/energy goals

Being an ex-public servant I just love setting numerical goals and then using regular monitoring/reporting to track how we are progressing towards those goals. Having goals allows you to not only track your own progress but also to compare your progress against that of others.

In the paragraphs below I put forward two tentative heating goals. Given the thrust of my heating philosophy, I have deliberately framed the goals in terms of heating/person rather than in the form of conventional space heating metrics which are typically expressed in terms of heat/unit of floor area or heat/unit of room volume. The goals below are very much intended for my own family.

However, having said that, I would be very interested in comparing our heat consumption with other households on a heat/person basis.

Heating Power Goal

In Section 4 I itemise my PHDs and give an indication of their typical power use at the settings we usually used over the winter. You can see that most of the devices draw less than 100W.

On the basis of my monitoring, and our subjective assessments, I would surmise that, conservatively a person can be kept nicely warm in a typical Australian house using a PHD drawing 100W irrespective of the internal air temperature. I have therefore selected this value as our heating power goal.

Instantaneous Goal

HEATING POWER GOAL: < 100 W/person

Having this goal means that at any given point in time in our home, with my family of four, I am looking to be drawing no more than 400W of electrical power to meet our heating needs.

Based on winter 2017 it will be difficult for us to reach this goal all of the time. When we are collectively heating ourselves in our main living room using our large FIR panels in the early part of the evening we exceed 400W. However, we get close to meeting the goal when we disperse to separate rooms for an hour or so before bedtime.

Having said that, as PHDs evolve in the future I'm confident that this figure can be achieved. In the meantime, the goal gives me something to aim for and allows me to gain an idea of how well we are tracking in our heating energy use.

Heating Energy Goal

I believe setting a heating energy goal is probably more useful than the power goal because this combines our heating power draw with the length of time we are heating ourselves.

Over the whole five-month heating season we used about 600 kWh of electricity on heating. This equates to about 4 kWh/day or 1 kWh/day/person. I have therefore set a heating energy goal of 1 kWh/person/day for the whole heating season recognising that in the three coldest months we are unlikely to achieve it.

Daily Goal

HEATING ENERGY GOAL: < 1 kWh/person/day

At this stage I am not thinking that I will take drastic action if we don't achieve our energy goal. Rather, as with the heating power goal, the energy goal will enable us to get a better sense of how well we are doing in managing our heating.

Over time I hope that we will be able to beat both the goals relatively easily as new, and more sophisticated, PHDs appear on the market.

7.4 Observations on the future of residential heating

It is not hard to conceptualise the perfect residential heating system. In the ideal world, I envisage that each individual will have their own personal heating system attached to themselves as they move around their home. Presumably this will be some form of light, and very compact, battery powered conductive heating. This will allow an individual to choose, and constantly adjust, the amount of heat that they receive to give them a personalised heating experience. It will mean that there will be no need to heat, insulate or draughtproof houses. Natural ventilation will hopefully provide good air quality. The rate of current advances in battery technology suggests it may not be too long before we will be able to reach this goal.

While I imagine that large public buildings such as shopping centres and cinemas will continue to be heated by convection (air-conditioning systems), I cannot see this form of heating being used widely for residential heating in the long term. It is inherently inefficient, imposes significant building overheads (insulation, etc) and engenders poor indoor air quality (through uncontrolled draughtproofing - see NOTE 4).

Radiant and conduction forms of heating address many, if not most, of the weaknesses of convection heating. While I personally am interested in radiant and conduction heating because of their superior energy efficiency, I imagine that ultimately these heating methods will gain popularity primarily because of their lower costs (both upfront and ongoing costs).

Having said that, both radiant and conduction heating devices require further development:

- Most of the Far Infrared (FIR) heating panels currently on the market (FIR is my favoured form of domestic radiant heating) do not incorporate temperature controllers – they are simply on/off devices and normally don't allow the user to select an output temperature. I see this as a major weakness. In addition to the need for much more sophisticated controllers, I would like to see lower power FIR panels, and mobile FIR panels, become more widely available. Essentially, I am looking for FIR panels that are specifically designed to be personal heaters. For example, I am pretty confident that my wife would have felt the same warmth with a correctly located 200W FIR panel as with the 600W panel which we currently use (600W is the lowest power rated rigid FIR panel I have been able to find to date in Australia).
- Many of the personal heating devices which transfer heat by conduction (eg electric throws) operate at 240V and need to be plugged in. In our experience, this 'tethering' is a major constraint and severely limits the usefulness of the devices as PHDs. I am hoping that as battery technology advances, the manufacturers of PHDs will look to un-tether the devices through the use of small/light battery packs. In the end, I imagine that most domestic heating will be provided by battery powered heated clothing of some form (I think having a nice fluffy heated jump suit would be a good start).

NOTES

NOTES

These notes amplify some of the topics raised in the body of the report.   I have tried to restrict the notes to topics that have been important to me as my thinking has evolved over the past two years.

Note 1 Questioning the nexus between indoor air temperature and 'thermal comfort' [Return]

Almost all academic energy articles and government/commercial heating system brochures put forward a heating goal broadly between 18^{o}C and 23^{o}C for the desirable air temperature inside a house. This seems to be commonly taken as the air temperature range that will provide 'thermal comfort' within a house at cold times of the year. Building on this, most heating systems use thermostats to control the room air temperature as a surrogate for maintaining 'thermal comfort'.

While the conventional way to capture indoor 'thermal comfort' is to report air temperature, in my experience thermal comfort only has a weak correlation with air temperature. Other factors can be equally, or more, important:

The Type of Heating

For some people, warm air inside a room does not provide thermal comfort (my wife is very much in this camp!). They are looking for some form of direct heat on their body such as radiant or conducted heat [see NOTE 2]. When exposed to direct heat in a room, the temperature of the air in the room has little, or no, impact on how warm they feel.

Body Temperature; Not Room Air Temperature

It is self-evident that for any given room air temperature a person's body temperature will be heavily influenced by the type and quantity of clothing they are wearing and whether or not they are using any form of personal heating.

Clothing Worn

I can only assume that the 18-23^{o}C comfort range mentioned above is based on people wearing 'average' clothing. If you wear enough of the right type of clothing you can feel nicely warm at 0^{o}C (eg skiers, etc); by the same token, if you wear enough of the wrong type of clothing you can be uncomfortably hot at 20^{o}C.

Additional PHD Use

If layered clothing and personal electrical heating are used as a combination (in my terminology these are both forms of PHDs) there would appear to be no physical constraint on a person feeling, and being, perfectly warm in a room where the air temperature is, say, 13^{o}C. This of course reflects my family's experience over winter 2017 which I discuss in the main part of this book.

Logical Outcome

The above observations of course raise some very fundamental questions. If thermal comfort is only loosely related to air temperature: Why do we use air temperature as our main indicator of warmth within a room? Why do we control almost all our domestic heating using the output of thermostats (measuring air temperature)? Why do most heating/health researchers base their conclusions on room air temperature?

Without getting bogged down in detailed discussion, it seems to me that the answer to all these questions is that we have locked ourselves into a chronic state of groupthink when it comes to residential heating. We now seem to almost exclusively think in terms of 'space heating' (or room heating). At best, 'personal heating' is looked on as a form of supplementary, rather than primary, heating. In these circumstances, it makes perfect sense to control our heating using thermostats.

I would challenge this somewhat myopic view of the residential heating world. Our experience over winter 2017 is that personal heating can be a very effective form of primary heating. The effectiveness of personal heating is largely unaffected by room temperature. Compared to space heating, personal heating is likely to give dramatic reductions in energy use and can provide significantly improved thermal comfort.

Note 2 What are the different ways to keep house occupants warm? [Return]

In simple terms, there are three heat mechanisms which can operate to transfer heat from heat sources to individuals inside a house: conduction; radiation; and convection (natural or forced). Looking at these in turn:

Conduction

This is transfer of heat from a hot object to a person via bodily contact. I would expect as a general proposition you will use less energy to keep a person warm the closer the heat source is to the person. Given this, I would expect heat transfer by conduction to be the most effective form of personal heating.

Examples of conduction heating may be a person holding a hot water bottle or using an electric seat pad or throw.

I also think of passive heating in this section. I would essentially define a passive heating device as anything that traps body heat and requires no external energy inputs - for example, warm clothing, blankets, etc.

Radiation

This form of personal heating is also very efficient since infrared rays directly heat the person, or their clothes. Infrared radiation does not directly heat air. A greater amount of heat will impinge on a person the closer they are to the heater.

Convection

Convection uses air as the medium to transfer heat to the person (eg ducted gas, heat pumps, fan heaters). I would expect this to be a relatively inefficient way to heat a person since you will generally need to bring the temperature of the air in a whole room up to a relatively high level to give thermal comfort. This means of heating can be made more efficient by strict control of air movements and air exchange, however, since the heating medium is also the air we breathe there has to be some exchange of air if adverse health impacts are to be avoided.

I like to think of convection heating as being a form of 'baseload' heating which is akin to the role coalfired power stations play in our electricity system. Convection heating tends to be indiscriminate and unfocussed – we simply fill up our whole room or space with air of the same temperature (putting aside thermal stratification) in the hope that some of it may provide useful warmth. In reality, only a very small proportion of the air in a room is in contact with, and is heating, people.

Overview

While the above would suggest that heating via conduction or radiation are likely to be the most efficient ways to heat an individual, there is a wide range of competing factors in providing warmth to individuals and each heating situation needs to be examined on its own merits. In practice, most households are likely to use a combination of all three categories of heat transfer – however, the balance of energy use between the three categories is likely to vary widely across houses.

For example, a useful heating combination could be to run a convection heater to provide baseload heating to say 15^{o}C and then to use either radiant or conduction heating to fine tune the heating so that heat supply = heat demand. Over winter 2017 we used virtually no convection heating in our house. We relied almost exclusively on radiant and conduction heating – while the greatest energy use was for radiant heating, the use of conduction heating (which uses no, or very little, energy) was an extremely important contributor to us staying warm.

Note 3 Health Issues [Return]

Is living in a house where the air temperature is continuously around 13^{o}C damaging to health? I must admit this is a question that I continually asked myself over the winter. I had no intention of reducing our energy use at the expense of either our comfort, or more importantly, our health.

I certainly had no difficulty in finding advice on this topic on the internet. As far as I can ascertain there seems to be general agreement that if the air temperature in a house is above 18^{o}C there are no potential health impacts. There also seems to a broad consensus that if the air temperature is continuously lower than about 10^{o}C then there is a risk of the house occupants getting hypothermia. A temperature of 13^{o}C clearly sits in a grey zone as far as the widely accepted health impact levels are concerned. However, as far as I can tell the 'health temperature criteria' quoted do not take into account what the house occupants are wearing, or whether they are using PHDs. I am sure that I would feel terrible, and make myself ill, if I sat around for long periods wearing no clothes in a house with an air temperature of 13^{o}C.

It seems to me that any conclusions about room temperatures in a house being good or bad from a health perspective only make sense if we also have information about how warm the occupants are. As I indicated in NOTE 1, there is little correlation between room air temperature and the comfort of the individual. I have found it interesting that over the last winter, even though we have used our primary heaters much less than in previous years, I personally have been much warmer because I have really focussed on what clothes and/or heaters I need to wear/or put on in order to keep warm. From my subjective observations, even though we had many more cold nights over winter in Canberra than usual, the temperature in our house was fine.[22] This year our family seemed to largely avoid even the usual sniffles and minor colds, despite it being a winter where a lot more people than average got the flu.[23]

Another question I kept asking myself was 'Do I feel fine because I am keeping myself much warmer (with my PHDs) or am I just habituating to colder temperatures? You can find some interesting

[22] *Winter 2017 – A season of extremes*. SkyNews. 31 August 2017. http://www.skynews.com.au/weather/weather-blog.html

[23] *Fast-mutating flu prompts calls for more immunisations.* The NewDaily. 8 September 2017: http://thenewdaily.com.au/news/national/2017/09/08/killer-flu-mutating-immunisations/?utm_source=Responsys&utm_medium=email&utm_campaign=20170908_PM_Update

studies into temperature habituation on the internet if you wish to pursue this topic.[24] My subjective feelings were that I was habituating over winter to colder temperatures. At the beginning of winter, a room at 13ºC felt cold if I wasn't using a PHD. By the end of winter a room at this temperature felt much less hostile.

Another point on the topic of habituation I find interesting is the variation in domestic room temperatures you find between countries. I very well remember being in Japan over winter some years ago. I found the temperatures inside the houses and hostels absolutely freezing!! This 'cold house regime' was of course normal to the Japanese and they didn't appear to be in any discomfort. Japan is a very affluent society with a highly advanced engineering capacity and there is little doubt that their houses could be much warmer if this issue was seen as a problem. I can only surmise that having warm homes in winter is not a particular priority. It is also worth noting that the Japanese are renowned for their longevity so maybe we could gain some health benefits by living in cooler houses?

Note 4 Insulation / Draughtproofing [Return]

Installing adequate insulation and carrying out draughtproofing are fundamental to the efficient performance of convection heating systems. Installing high level insulation such as double and triple glazing and wall cavity insulation can be costly. These are costs that can largely be avoided, or at least minimised, if a home heating regime is based on radiation and conduction heating. When these latter two ways are used to keep people warm, the air is not a primary carrier of heat (there can be secondary convection effects) and the feelings of warmth are largely independent of air temperature (see NOTE 1).

In mid-July we added another layer of batts in our roof to take the ceiling insulation rating from R3 to R6. This was a long-planned step and was not directly related to our PHD project. Nevertheless, since I was logging the temperature within the house it gave us a good chance to gauge the effect of adding the new batts. Subjectively adding the additional insulation made no perceptible change to the temperature within the house. When I examined the output of my temperature monitoring in detail I was not able to determine if the additional insulation had had any effect – I would have needed to carry out a thorough examination of both the internal and external temperatures if I were to do a robust comparison. It is possible that if we had been injecting heat into the house (rather than into ourselves) the effect of installing the additional R3 may have been noticeable.

I show a plot of the breakfast and evening time temperatures inside our house in **Figure 9** (**Figure 8** shows the location of the temperature probe)**. Figure 16** is a plot of average monthly internal temperatures within our house across all hours over winter 2017. It can be seen that the average temperature was around 12ºC. [It should be noted that we were away on holiday for two weeks in late June and early July. I only commenced temperature logging in late May so the value for May represents about one week of monitoring.]

[24] *Habituation of thermal sensations, skin temperatures, and norepinephrine in men exposed to cold air.* J. Leppaluoto, I. Korhonen, and J. Hassi. University of Finland. Oct 2000. http://jap.physiology.org/content/jap/90/4/1211.full.pdf

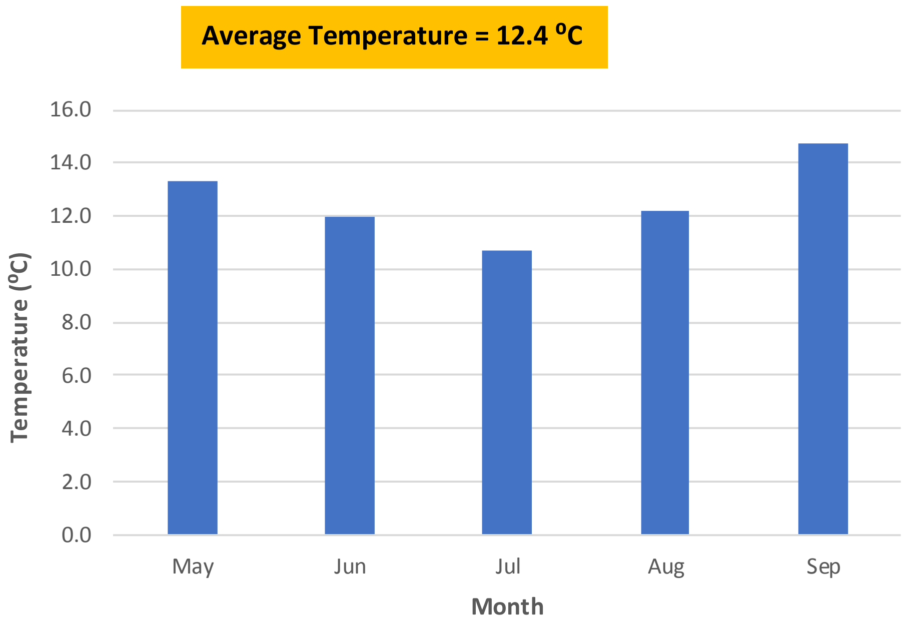


Figure 16: The average temperature within our main living room across winter 2017

Draughtproofing

One issue that I have been concerned about for some time is the uncontrolled draughtproofing of houses. It is not uncommon to read about households that go to great lengths to close off every last gap in the fabric of their house in order to maximise the efficiency of their convection heating. I have rarely noticed these articles/posts showing any caution about lack of ventilation. Given my interest in air quality, in late 2016 I purchased a CO_2 monitor to check on our indoor air quality in our house before embarking on serious draughtproofing. I had imagined that we would be fine, because I had only carried out some very preliminary draughtproofing, but I was surprised to find that even in our poorly draughtproofed house the air quality in our bedroom exceeded the recommended standard for CO_2 on every occasion that I monitored.[25] Given this, I undid some of the early draughtproofing I had undertaken and stopped worrying about looking for gaps to seal. As noted earlier this did not impact on the effectiveness of our PHD heating regime (given the lack of correlation between indoor air temperature and personal warmth using PHDs).

I would strongly recommend anyone contemplating draughtproofing to undertake some indoor air quality monitoring before they start.

Note 5 Accuracy of Data [Return]

Every day I read and record 10 data points for our electricity production and use (I have been closely monitoring our household energy performance for several years). For winter 2017, as I was focussing on heating energy use, I put in place automatic data logging on our two primary sources of heat – the FIR panels in our main living room and the array of PHDs in my wife's 'study nook' (energy use dominated by the wall mounted FIR panel) (an example of the monitoring system output is shown in **Figure 15**).

I have only one what I would call 'gold standard' source of data – our mains electricity meter. This is a high-grade device and I am confident that the readings I am getting are accurate (if I wasn't I would be going to my electricity provider to query our bills/credits!). Therefore I am highly confident that

[25] *Monitoring indoor CO_2 levels: Enjoying fresh air in your home*. Dave Southgate. Dec 2016: https://sway.com/TZEOpQgj6Xi1FWdc

the information I have on our total household electricity consumption and on our total electricity solar PV exports are accurate.

I am also confident that my temperature readings are very solid because of the quality of the datalogger and the temperature sensor I was using and also because of the excellent correlations I was getting between the datalogger readings and the temperature readings on the numerous thermometers strewn around our house.

The main uncertainties arise when it comes to breaking down the total energy use between the various energy components such as heating, hot water, the EV, etc. In order to get a sense of the level of confidence I can have in my data, I compared the heating energy use reported by our datalogging system with spot checks of the energy consumption of each of the individual heating devices that we were using. These spot checks included monitoring with separate meters and also checking on the manufacturers' power ratings for each individual device. This indicated that the datalogging system was giving readings that were about 5% low.

I am keen to be conservative and do not want to understate our heating energy use. Therefore the total heating energy values I have reported in the document (which I've gathered from the datalogging system) represent my equipment readings plus 5%. This is clearly an approximation but I believe I have erred on the side of over-reporting, rather than under-reporting, our total household heating energy use.

As a sanity check on the accuracy of the quantum of our heating energy use I have also broadly computed a value for the main components of our household energy use over the winter period – heating, hot water and the EV – and cross compared this with the total amount of electricity used by our house over the same period (readings from our electricity meter). These figures are reported on a per day basis in the Table:

Energy Component	Energy Consumption: May to Sep 2017 (kWh)/day
Heating	**3.7**
Hot Water	**6.2**
Electric Vehicle	**7.5**
Other	**6.7**
TOTAL HOUSEHOLD	**24.1**

I am confident that my readings for daily hot water and EV energy use are reasonably solid (you can find details of my monitoring of these components in my earlier documents). The value for the energy use for 'Other' in the Table has been computed by difference – this category includes cooking, lighting, the fridge, washing machine and electronic equipment such as the TVs and computers. Based on my knowledge of the power rating, and usage levels, of the 'Other' devices, and on computations I carried out for my 2016 Annual Report on our household energy transition,[26] I believe the value of 6.7 kWh/day for this component, over winter, is reasonable. I am therefore comfortable that the energy breakdown shown in the Table portrays a robust picture of our

[26] *2016 Annual Report. Our Household Energy Transition.* Dave Southgate. Feb 2017: https://www.slideshare.net/davesouthgate/2016-annual-report-household-energy-transition

household energy use over the winter – most importantly I believe that the values I have reported for our heating energy use over winter 2017 are broadly sound.

Note 6 International Context

I always find it interesting to compare the amount of heat we use to keep ourselves warm in Australia with that used by households in other countries. I found a paper discussing residential heating energy consumption in Europe particularly useful since you can find a range of countries in Europe with a winter climate that is not too dissimilar to that found in the various different parts of Australia.[27] In my experience houses in Europe tend to be of much more solid construction, and much better insulated, than houses in Australia. If you look at the information in the reference, you will see that the annual heating energy use in our household when we used the gas ducted system (around 6,000 kWh/annum), just crept in at the bottom of the range of 'typical house' heating energy consumptions for Europe. Given this, it is not surprising that our 2017 household winter heating energy use was very low compared to even the warmest European countries.

Note 7 Personal Cooling

While not directly related to the topic of this paper, the thinking surrounding personal heating can be equally applied to personal cooling. 'Cooling people: not spaces' is certainly a topic gaining some attention.[28] On the face of it, applying personal cooling would appear to be somewhat more difficult than applying personal heating. Nevertheless, this is a topic that is attracting research and is producing some promising results. [29] Clearly if we could avoid cooling large volumes of air we could save a great deal of energy (and avoid significant investment in little used electricity generation/distribution infrastructure).

---

[27] *How much energy do you use to heat your home?* OVO Energy. https://www.ovoenergy.com/guides/energy-guides/how-much-heating-energy-do-you-use.html
[28] *Fans cool people, not spaces.* Energy Providers of Southern California. http://conserveenergysocal.com/fans-cool-people-not-spaces/
[29] *This Air Conditioner Can Fit In Your Pocket.* Sciencr. September 2017: https://sciencr.com/this-air-conditioner-can-fit-in-your-pocket/

About the Author

Dave Southgate retired from the Australian Government Public Service in July 2012 after a 31-year career as an 'environmental bureaucrat'.

In 2014, frustrated by government backsliding on climate change, Dave began a household energy transition and started his family down the road to becoming 'Fossil Fuel Free'.

Unable to escape the ingrained habits of his science/engineering training and his years as a Canberra public servant, he is closely monitoring the progress of his family's energy transition and is releasing reports from time to time as he writes up his findings.

You can find the collection of Dave's reports on his family's energy transition, and other papers, at his website at https://electricvehicleaustralia.com/household.