EBOOK 9: SUSTAINABLE LIVING SERIES

THE ALL-ELECTRIC HOME

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- Energy storage
- Electric heating, cooling, lighting and cooktops
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WELCOME

The *All-Electric Home* ebook includes the best articles from *ReNew* and *Sanctuary* magazines on modern electric homes including topics such as energy efficiency, appliances and making the switch from gas.

Check out the *Solar Panel Buyers Guide* in *ReNew 134* and the *Efficient Hot Water Buyers Guide* in *ReNew 139* for more detail on those systems.

IT'S TIME TO GET READY FOR AN all-electric home!

The rise of rooftop solar and the availability of GreenPower means that households can use 100% renewable energy to run their appliances.

At the same time modern electric appliances are becoming more efficient and can perform better than gas appliances, while changes in the gas market mean that gas is no longer as clean or affordable as it used to be.

This compilation of articles from *ReNew* and *Sanctuary* magazines covers topics important to electric homes. We look at some of the most energy consuming areas of the home including hot water systems, heating and cooling, fridges and lights.

We also investigate energy storage options that help households to 'bank' any extra electricity generated for use when the sun's not shining.

And we take a look inside some leading examples of modern all-electric homes .

The Alternative Technology Association is here to help households make the switch from gas to electric, so read our magazines and consult our experts for help on the journey.

The ATA team

Keep in touch

If you have feedback about this publication contact jacinta@ata.org.au

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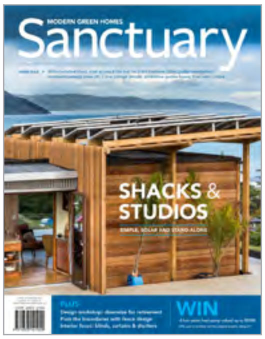

Sanctuary is Australia's only dedicated sustainable house design magazine, providing inspiration and practical solutions for a sustainable home, without compromising on design.
www.sanctuarymagazine.org.au

ATA PUBLICATIONS

The All-Electric Home
The Alternative Technology Association (ATA)

The Alternative Technology Association (ATA) is a not-for-profit organisation which has been promoting renewable energy, sustainable building and water conservation since 1980.

Level 1, 39 Little Collins St
Melbourne VIC 3000, Australia
Ph: (03) 9639 1500 Fax: (03) 9639 5814
Email: ata@ata.org.au
Website: www.ata.org.au

Reg No: A0017411T ABN: 57 533 056 318

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Image credit: Paolo Benini Photography

#1

GET READY

GOING OFF-GAS & MAKING THE MOST OF SOLAR

FIRST PUBLISHED IN RENEW 130

ARE WE STILL COOKING WITH GAS?

MAKING THE SWITCH FROM GAS TO ELECTRIC

ATA gas report author Kate Leslie gives the lowdown on the research and its findings.

THE ALTERNATIVE TECHNOLOGY Association's (ATA) report *Are we still cooking with gas* considers the economic implications of projected retail gas price rises on households, and asks whether there are efficient electric alternatives that are more cost-effective.

Funded by the Consumer Advocacy Panel, the research aims to identify those locations and household types that may benefit from a switch from gas to efficient electric appliance use—or from staying off the gas network in the first place (in the case of new homes or existing all-electric homes). The research also separately analysed the environmental impact of these potential switching decisions.

Much of the emphasis in the gas debate to date (which has been largely dominated by industry) has been on increasing gas production, as opposed to considering potential changes in demand. ATA's research asks whether increasing gas production is the most cost-effective, efficient and sustainable approach.

Gas price rises are already an important issue for residential consumers; according to the Victorian Council of Social Services, "Household gas prices have risen 33 % in real terms since 2008–09, largely unnoticed because all the attention has been on the more rapid growth in electricity prices over the same period (53%)." (www.bit.ly/VCOSSGPR)

Analysts vary on how much gas prices will rise over the next 5 to 10 years, but all agree that more rises are coming.

So what are the alternatives?

Gas is typically used in homes for space heating, water heating and/or cooking. Over the last few years, efficient electric alternatives for all these end uses have become available. The most cost-effective, efficient electric alternatives chosen for the research were:

- heat pump reverse-cycle air conditioners—for space heating
- heat pump hot water systems—for water heating
- induction cooktops and efficient electric ovens—for cooking.

Scenarios

The research considered the economic case for replacing gas appliances with electric options in a range of different 'gas zones', for a range of different house types and under a range of different 'replacement cases'.

Replacement cases include whether or not the house is currently gas connected, the number and type of gas appliances to be switched, and whether existing gas appliances are close to the end of their life (i.e. due to be replaced within five years).

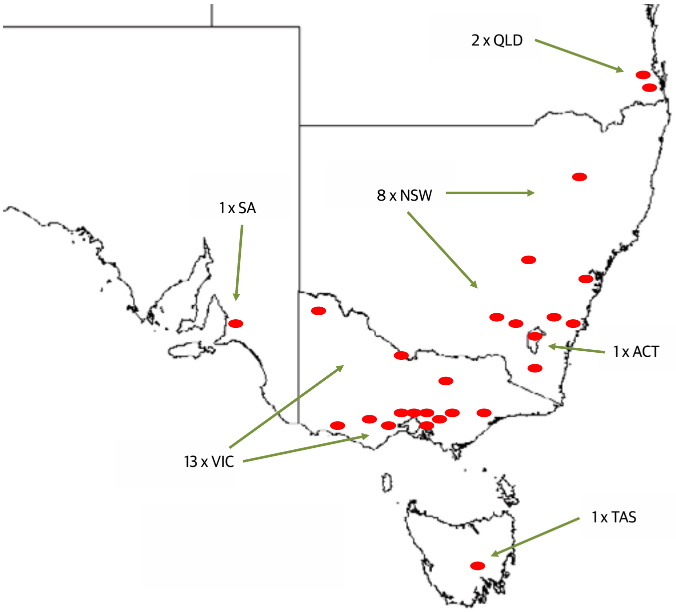
Figure 1 shows the 26 gas pricing zones modelled. The variety of zones meant that the research could take into account the different gas prices and pricing structures that exist across locations, as well as the different space/water heating end-use needs by climate zone; Table 1 shows the heating load assumed per climate location.

The research also modelled six different household types, ranging from small to large existing homes (all assumed to have R2.5 ceiling insulation), a typical public housing home (taking into account relevant energy concessions), and a new 6 Star home (see Table 2). This enabled analysis of households with different space and water heating requirements as well as cooking energy use.

Findings

For new homes, and for existing homes that don't currently have gas, the research found a strong and consistent result: in all gas and climate zones across the five states and one territory modelled, it is more cost-effective to go all-electric than to connect to gas. This holds as long as efficient electric appliances are able to be used (acknowledging the fact that space or building configuration constraints, such as in apartments, may mean that efficient electric appliances can't be installed).

For existing homes already connected to gas, the situation is more complex.



→ Figure 1. The 26 gas pricing zones that were modelled for the study.

Climate Type	City	Scenario 1-5: Existing housing	Scenario 6: New build, 6 Star
Balanced moderate demand	Adelaide	112.8	56.8
Balanced moderate demand	Sydney	78.3	35.9
Heating dominated	Tullamarine	268.8	197.0
Heating dominated	Melbourne	242.4	114.0
Heating dominated high demand	Canberra	321.0	165.0
Heating dominated high demand	Orange	438.4	219.0
Low demand	Brisbane	38.9	15.2

Table 1: Heating load by climate location and housing type (MJ/m2/annum).

Whether it's cost-effective to switch from gas to electric appliances depends on a range of factors including the age of the appliance, the climate zone, whether it's the last gas appliance (so replacing it means the customer can disconnect from gas and avoid the fixed service charge, in the order of $250 to $300 per year) and whether the customer is on mains or more expensive bottled gas.

Tariffs also come into the equation, including the ratio of gas to electricity prices, and the fact that many customers are on a declining block tariff—meaning that higher gas usage is, in effect, rewarded by lower prices.

Specific appliances and climate zones

For existing homes connected to gas, there were some clear findings for specific appliances and climate zones.

Of the three end uses modelled, space heating was consistently the most cost-effective to switch from gas to efficient electric.

In warmer climate regions (including SA, Queensland and some parts of NSW), switching all gas appliances to efficient electric ones and disconnecting from the gas network offers better economic returns than in cooler climates—partly due to the improved performance of heat pump systems in warmer climates, and also partly to the correlation with higher gas prices in those regions.

Heat pump hot water systems were found to be more cost-effective than gas hot water systems where gas prices are relatively high compared to electricity prices; or where the climate is warmer (and so the systems perform more efficiently). Gas hot water systems are more cost-effective in most other locations.

Switching from gas to an induction cooktop and electric oven was found to be cost-effective when combined with disconnecting from the gas network (and

	Scenario 1: Reference home Typical of current housing stock		Scenario 2: Small home Typical small detached/ semi-detached		Scenario 3: Large home Typical 10+ year old		Scenario 4: Public housing Concession eligible		Scenario 5: LPG home		Scenario 6: New build 6 Star build	
Gas usage	Medium		Small		High		Medium		Medium		High	
Gas services	BAU* case natural gas	All electric	BAU case natural gas	All electric	BAU case natural gas	All electric	BAU case natural gas	All electric	BAU case LPG	Mainly electric	Gas option	All electric
Space heating	Ducted gas, replace furnace. Sized to house	Multiple reverse-cycle air cons sized to house	Ducted gas, replace furnace. Sized to house	Multiple reverse-cycle air cons sized to house	Ducted gas, replace furnace. Sized to house	Multiple reverse-cycle air cons sized to house	Two flued gas wall heaters. Sized to rooms	Two reverse-cycle air cons sized to rooms	LPG heater for living room	Reverse-cycle air con sized to room	Ducted gas sized to house	Multiple reverse-cycle air cons sized to house
Hot water	Gas storage, high efficiency medium-sized unit	Medium-sized heat pump	High efficiency instant gas	Small heat pump	Gas storage, large high efficiency unit	Large heat pump	High efficiency instant gas	Medium-sized heat pump	Medium-sized high efficiency LPG instant	Medium-sized heat pump	Gas storage, large high efficiency unit	Large heat pump
Cooking	Gas oven, cooktop 500 MJ/Qtr	Electric oven, induction cooktop	Gas oven, cooktop 250 MJ/Qtr	Electric oven, induction cooktop	Gas oven, cooktop 750 MJ/ Qtr	Electric oven, induction cooktop	Gas oven, cooktop 500 MJ/Qtr	Electric oven, induction cooktop	LPG oven, cooktop 500 MJ/Qtr	No change	Gas oven, cooktop 750 MJ/Qtr	Electric oven, induction cooktop

Table 2. Six different scenarios were modelled, covering typical housing stock, different sizes, concession eligibility and a new build.
* BAU = business-as-usual.

Methodology overview

Developing a methodology to model energy use for both gas and electric appliances across different locations was one of the major challenges for this research. The modelled energy loads had to provide the same level of service, whether delivered by gas or electric. Ten-year whole-of-system costs were calculated, including upfront, maintenance and energy usage costs. The assumptions are fully detailed in the report's appendices, but the major ones were as follows:

Space heating. Heating loads were taken from *Zero Carbon Australia Buildings Plan 2013* for the different housing types and climate zones (as per Table 1). For electric RCACs, COPs (coefficient of performance: ratio of heating provided to electricity used) of 4.0–4.5 were assumed, discounted 0.5 for cooler climates. Capital expenditure was discounted in warmer climate zones given RCAC's cooling capacity. For gas, losses from furnace and ducting were included where applicable, along with fan energy for heating hours, varying by climate.

Hot water. Energy use of hot water systems has an Australian Standard; for heat pumps, usage data was published by Pitt and Sherry in 2012 and for gas hot water by Energy Consult in 2009.

Cooking. Evidence suggests the average household uses 500 MJ each quarter for cooking. ATA assumed 60% is used by the cooktop and 40% by the oven. Efficiency at the point of use was researched and input energy determined.

An example zone

Table 3 shows the results for one gas zone, the Mildura gas zone in Victoria.

Household scenario	Reference home	Small home	Large home	Public housing	LPG home	New build
Switching a gas appliance, within 5 years of end of life, staying on gas network						
Space heating	$2,173	$2,097	$1,812	$2,241	$2,188	$2,397
Hot water	$95	-$524	$282	-$81	$1,820	$862
Cooking	-$161	-$104	-$330	-$103	n/a	-$330
Switching a gas appliance, not within 5 years of end of life, staying on gas network						
Space heating	-$627	-$103	-$1,588	-$759	$688	n/a
Hot water	-$1,405	-$1,724	-$1,518	-$1,281	$620	n/a
Cooking	-$1,961	-$1,904	-$2,130	-$1,903	n/a	n/a
Switching one gas appliance, of any age, disconnecting from gas network						
Space heating	$2,883	$2,546	$2,422	$1,786	n/a	n/a
Hot water	$2,032	$925	$2,603	$1,304	n/a	n/a
Cooking	$533	$517	$549	$201	n/a	n/a
Switching two gas appliances, at least one is within 5 years of end of life, disconnecting from gas network						
Space heating + cooking	$3,833	$2,879	$3,988	$2,984	n/a	n/a
Hot water+ cooking	$1,681	$258	$2,569	$702	n/a	n/a
New & existing homes, not currently gas connected, choosing efficient electric instead of gas*						
All heating + cooking	$7,974	$6,025	$8,729	$6,492	$6,903	$9,192
All gas appliances switched: one is within 5 years of end of asset life, avoiding $2000 upfront replacement costs						
All heating + cooking	$1,554	$955	$958	$172	$3,953	$1,053

↑ Table 3. An example table of results showing cost/benefit for different replacement cases. This is for the Mildura pricing zone in Victoria (gas from Envestra Mildura, electricity from Powercor), with a climate zone of balanced moderate demand.

* Assumes full capital expenditure on both electric and gas sides.

🟨 A positive net present value (NPV) with a payback time of 5 years or less. Definitely choose efficient electric over gas: any extra upfront cost will be recouped through savings within 5 years.

░ A positive NPV with a payback time of between 6 and 10 years. Consider choosing efficient electric over gas: any extra upfront cost will be recouped through savings within 10 years.

☐ A negative NPV over 10 years. Choosing electricity over gas is unlikely to save any money: any extra upfront cost will not be recouped within 10 years.

thus avoiding the gas fixed charge).

The effect of gas prices

The modelling results were not particularly sensitive to retail gas price trajectories of between +5% and +50% from today (in real terms). The research found that the impact of that range of future gas prices on any individual economic case isn't as significant as the relative cost of gas versus electricity in each gas pricing zone; and the relative energy use of gas versus electric appliances.

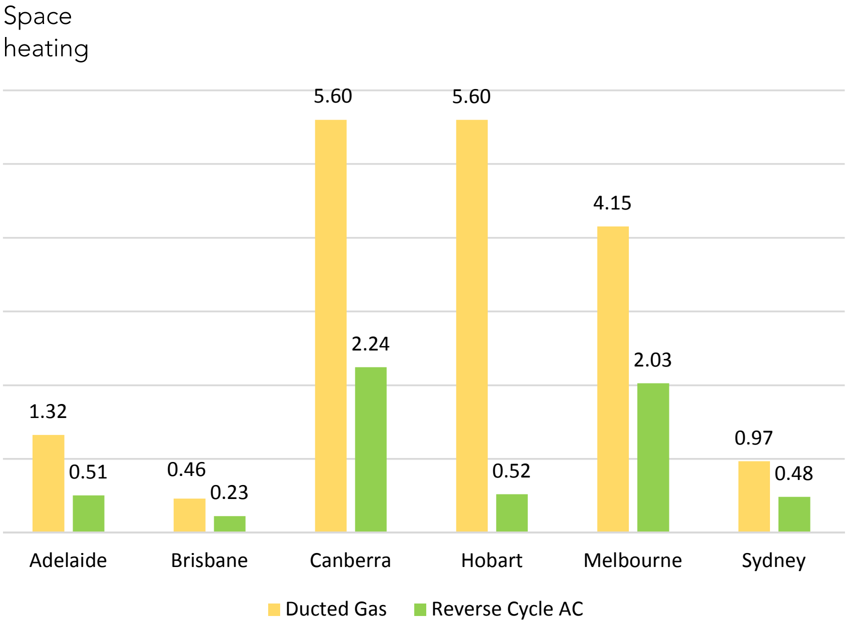
The report notes, "In only a small number of gas zones and for a small number of household scenarios/ replacement cases does the economic proposition for switching fuels change from negative to positive over 10 years on the basis of different gas price trajectories."

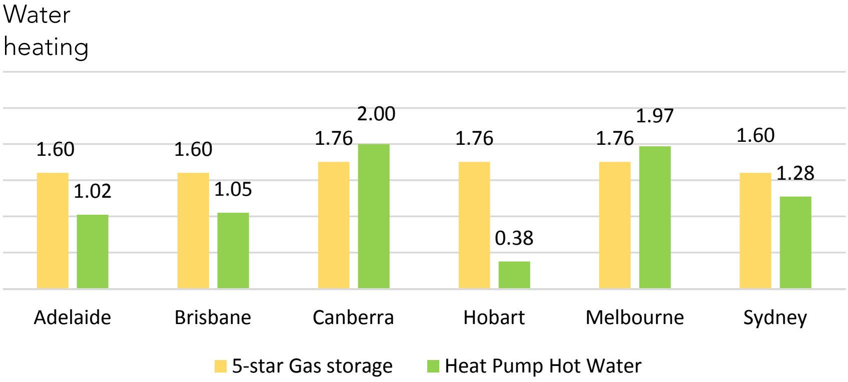
In the majority of Victorian gas zones, where switching was often uneconomic, consumption charges for gas are approximately a fifth of the price of electricity charges on an equivalent energy basis. In parts of NSW and Queensland, where a significant number of economic switching cases were found, gas prices are higher relative to electricity prices—up to around half the cost of electricity.

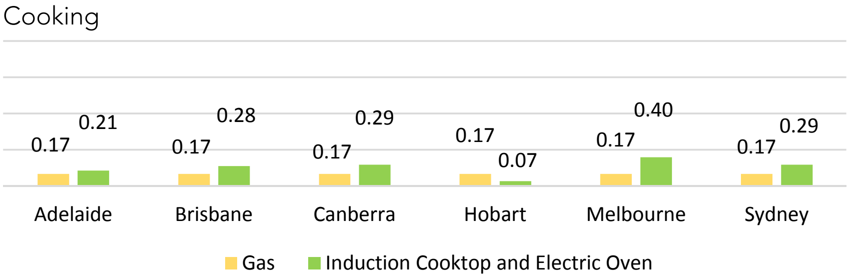
A positive result for emissions

Although the research was primarily concerned with economics, the ATA considered it was also important to determine the greenhouse gas impact of switching from gas to electric appliances. The findings were mostly positive: homes using natural gas for all three end uses will reduce emissions if they switch entirely to efficient electric appliances, regardless of home type or location.

Taken individually, switching to electric space heating has the clearest positive impact especially for the colder

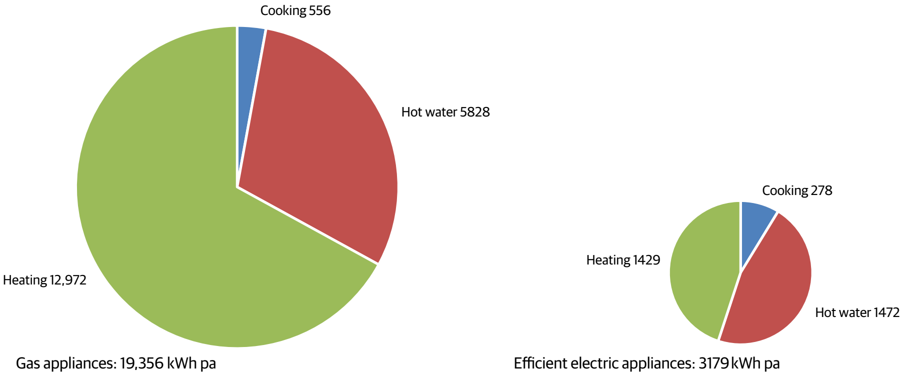






↑ These graphs show estimated greenhouse gas emissions (in tonnes per annum of carbon dioxide equivalent) for space heating, water heating and cooking for the reference home in each capital city.

↑ The report asked the question: given that efficient electric appliances, such as induction cooktops, are now available, what does that mean for the economics and greenhouse gas emissions of gas versus electricity use.



↑ Figure 2. Energy usage for the reference home in Richmond, Melbourne, in kilowatt-hours per annum for gas versus efficient electric appliances.

locations. Results for hot water are less clear—switching from gas storage to heat pump hot water systems may result in slightly higher emissions in ACT and Melbourne. Efficient electric cooking increases greenhouse gas emissions in all locations except Tasmania. However cooking emissions are very small compared to the other uses.

These estimates are influenced by the cleanliness of generation in your state's electricity grid. Victoria's continued reliance on brown coal results in high emissions, while Tasmania and South Australia's emissions are lower thanks to their use of hydroelectric and wind generation respectively. Future increases in grid-connected renewable energy (including rooftop solar) will make electric appliances cleaner to run. Households also have the option to offset their emissions, for example via ATA's Community Climate Chest or a GreenPower plan from their energy retailer.

Data on the climate impact of natural gas is scarce. In addition to the carbon dioxide emitted when gas is burned in the appliance, some natural gas leaks unburnt into the atmosphere from wells, pipelines etc. Even though these 'fugitive' emissions are small, unburnt natural gas has a potent greenhouse effect. In the absence of reliable Australian data, we have assumed a level of fugitive emissions accounting for 40% of the overall climate impact of natural gas, based on international studies. Future escalation of coal seam gas extraction in Australia has the potential to increase greenhouse gas emissions, which would further improve the case for efficient electric appliances.

Conclusion

The research shows that households should no longer assume that natural gas is the cheapest or lowest emission fuel for space heating, water heating and cooking. This is a significant change to the last three decades of consumer, industry and government thinking regarding mains gas.

For virtually all new homes, efficient electric will be the most cost-effective choice.

Existing dual-fuel homes will need to carefully weigh their options. It requires a case-by-case analysis depending on many factors—however, the ATA report provides an excellent guide for consumers to undertake this analysis for their specific situation. Dig into the full report to find the results that apply to you. ■

The research was conducted by the Alternative Technology Association, and funded by the Consumer Advocacy Panel. The full report is available at www.ata.org.au/ata-research/new-report-on-economics-of-gaselectric-appliances

FIRST PUBLISHED IN RENEW 136

LIFE AFTER FITS

WHAT TO DO WHEN YOUR FEED-IN TARIFF EXPIRES

With feed-in tariffs about to drop dramatically for many, what's a solar household to do? ATA's energy analysts Damien Moyse and Nick Carrazzo discuss six steps to consider.

BY THE END OF 2016, MORE THAN 275,000 households with solar PV across NSW, Victoria and South Australia will receive much lower payments for their solar exports to the grid, as several premium feed-in tariff schemes expire. A key question for these households is how to mitigate the financial impact of the reduced feed-in tariff.

Feed-in tariffs are likely to drop to around 5 to 10 c/kWh for these customers, from around 16 to 60 c/kWh. Full details of the schemes affected and the likely new feed-in tariffs are shown in Table 1.

This article considers how to maximise the return for solar generation given low feed-in tariffs. Many of the considerations here apply not only to these existing solar homes, but also to new solar homes as these will also receive these lower feed-in tariffs.

1. Ensure the correct metering

An important first step for the solar homes about to lose their premium feed-in tariff is to ensure they are using net metering (also known as import/export) rather than gross metering. Net metering recognises the use of solar electricity on-site to reduce more expensive imports from the grid. This isn't possible with gross metering.

Victoria and SA both used net schemes, so a metering change is not required for solar customers in these states.

In NSW, the Solar Bonus Scheme offered a gross scheme. Given the new reduced feed-in tariffs—much lower than the grid rates charged—affected NSW customers will need to change to net metering to maximise the financial benefits of their solar system.

The costs and technical requirements

to switch from gross to net metering for Solar Bonus Scheme customers are still under discussion and vary depending on the distribution area (to work out which distribution area you are in, see www.bit.ly/1U6pk0i). As at May 2016 the situation is:

- Endeavour area: Customers will need to install a new meter, at a cost of about $600 if done by the distributor; costs of subsidised options via the retailer are unclear at this time.
- Essential Energy area: Instead of a new meter install (costs similar to Endeavour), customers may be able to use their existing solar meter with a minor wiring adjustment, at an estimated cost of $150, but Essential Energy has not yet confirmed if they will accept this solution.
- Ausgrid area: Instead of a new meter install (costs similar to Endeavour), Ausgrid has confirmed customers can use their existing solar meter after a minor wiring adjustment, at an estimated cost of $150. Ausgrid has also proposed they could use the two existing gross meters to calculate net energy flows, but it is unclear if retailers will accept this option; if this is accepted, no meter change would be required.

Retailers may also offer a subsidised or even free net meter for solar customers. However, at this time little information is available on how much this will cost or the range of tariffs and contracts the retailers will offer in lieu of these subsidised meters.

As noted, the exact solutions on offer are still unclear so ATA advises that customers should review all options at the time of the closure of the scheme, particularly the zero or low-cost options.

The last resort should be to request the local distributor to install a net meter at a cost anywhere near $600.

Note: whether the solution ends up being the replacement of the meter, rewiring or changes to billing arrangements, if these solutions are being offered through an energy retailer, then the customer must ensure they understand the full implications of agreeing to a particular solution as this may have implications for that customer's retail tariff or other related considerations.

2. Use your solar electricity on-site

With lower feed-in tariffs, there is much greater value in using your solar electricity on-site rather than exporting it to the grid. To maximise usage of your solar generation, the aim is, where possible, to shift electricity usage from the evening to the daytime when solar generation is occurring.

Most households, even those with relatively small solar PV systems (e.g. 1.5 to 2 kW), do not use a large proportion of their solar generation during the day. As an example, a 1.5 kW PV system in Sydney will generate around 10 kWh between 9 am and 5 pm in summer and around 5 to 7 kWh in autumn/spring. Many homes consume not much more than 1 to 3 kWh between breakfast and dinner, so even this small system has a relatively high export rate to the grid.

Even those who are at home during the day often run little more than the fridge, a computer or audiovisual equipment, plus maybe an oven, washing machine or dishwasher once every few days.

Running your washing machine, oven and dishwasher during the day is a first step, but there's more you can do. The biggest opportunity lies in shifting the

Image: Lindsay Edwards Photography

↑ More than 275,000 solar homes in Australia will be affected by reduced feed-in tariffs as several premium feed-in tariff schemes expire in 2016. The ATA, *ReNew's* publisher has recently completed modelling and analysis to help advise consumers during this transition.

State	Current tariff	End date	Feed-in tariff rate for 2017	No. affected
NSW	The Solar Bonus Scheme: a FiT of 20 c/kWh or 60 c/kWh for all solar generation	Dec 31, 2016 (started 2010)	No mandated FiT for NSW. IPART determines a benchmark range (in 2015/16: 4.4–5.8 c/kWh), but up to retailer to decide the FiT offer	146,000
Victoria	The Transitional FiT: minimum 25 c/kWh for excess solar electricity fed into grid	Dec 31, 2016 (started 2011)	~5 c/kWh	67,160
Victoria	The Standard FiT 'one-for-one': based on the retail electricity rate paid	Dec 31, 2016 (started 2012)	~5 c/kWh	Unknown
South Australia	16 c/kWh FiT	Sept 30, 2016 (started 2011)	Minimum retailer payment of 6.8 c/kWh	62,742 at end 2015
Total affected				275,902

↑ Table 1: Breakdown of solar customers for whom premium feed-in tariffs (FiTs) are closing in 2016. Note that the Victorian feed-in tariff known as the 'Premium FiT' of 66c/kWh does not expire until 2024.

two largest energy-users—water heating and space heating/cooling—to solar generation hours.

SHIFTING WATER HEATING

Electric water heating can be done using a traditional electric resistive hot water system or a heat pump (both using storage tanks).

If you have either type of electric hot water system, to power it from your on-site solar generation it must be connected to your main electrical circuit, rather than any dedicated off-peak hot water circuit. You must also set it up to operate during the day, when the solar system is generating electricity.

A simple way to do this is to change the timing of the heating cycle to peak solar generation hours (say between 11 am and 3 pm, depending on location, season and shading). Heat pumps generally have timers built in; some traditional electric resistive systems do too, or an electrician can install a timer at relatively low cost.

Another (more expensive) approach is to use a dedicated solar diverter, although most of these are only suitable for powering a resistive hot water system (the SunMate is programmable to divert only if enough power is available, so it is able to run a heat pump water heater if set up correctly).

An emerging technology, diverter devices measure the amount of surplus generation that would normally be exported and divert that energy to an appliance such as a water heater. Examples include the new Powerdiverter, the immerSun and the SunMate. These cost around $1000-$1100 installed, but hopefully prices will fall as the market expands.

Similar in concept to the diverters above, some modern inverters also come with energy management relays that can switch on or off and control certain loads (like hot water) to match excess solar generation. These may be a cheaper option as they come inbuilt in the inverter. However, many customers may not have an appropriate inverter, and it may be best to wait to upgrade if considering batteries in the future.

Note that if you are using solar electricity to heat water during the daytime, then you want the water heater to retain as much of that heat as possible for use overnight and the next morning. Many older water heaters have lower levels of insulation, so it might be worth investing in a highly insulated tank. You can search the Energy Ratings database at reg.energyrating.gov.au/comparator/product_types to find the tank with the lowest heat losses in the size you need. Alternatively, you can super-insulate your existing tank by adding more insulation. Previously, Autex and at least two other companies manufactured cylinder wrap products for this purpose, but these have disappeared from the Australian market. However, there are numerous insulating wraps and materials that can be used to insulate water cylinders; if your cylinder is external then you may need to cover it with a waterproof layer as well. There is a useful instruction page on water tank insulation at http://1.usa.gov/1Pas1lf

PURCHASING A NEW HOT WATER SYSTEM

Heat pump systems are more efficient (up to four times as efficient) as traditional electric systems, but cost three to four times as much to purchase, so which is the better option?

ATA recently compared the cost of purchasing, installing and running a traditional electric resistive hot water system versus a heat pump hot water system for a Sydney home with existing solar PV and about to lose the premium feed-in tariff. Irrespective of PV system size, the analysis suggested that, given maximum possible use of the PV to run the hot water system, most households would be better off or at least no worse off over 10 years with purchasing a heat pump system compared to an electric resistive system.

> "The biggest opportunity lies in shifting the two largest energy-users—water heating and space heating/cooling—to solar generation hours."

Image: Lindsay Edwards Photography

SHIFTING SPACE HEATING/COOLING

Space heating/cooling is the other big energy user (in fact, the biggest in most homes). Electric space heating/cooling can be via a split system air conditioner; ducted reverse cycle; low wattage panel heaters or heat pump hydronic systems.

With many people at work during the day, a lot of space heating/cooling occurs at night or in the morning before work. However, an electric space heating/cooling appliance can be programmed to at least partially run during the daytime, using excess solar energy. The aim is to pre-heat or pre-cool the space and reduce the evening energy requirements.

To do this pre-heating or pre-cooling, you will need to be able to program your heating/cooling appliance to switch on during the day (e.g. at 3 pm), but at a relatively conservative setting (e.g. 16 to 18 °C in winter or 28 to 30 °C in summer). Less energy is then required to bring the house to a reasonable temperature in the evening.

Bear in mind that while many heating and cooling systems can be preset to run at specific times, some will use whatever temperature settings were used previously, so make sure that is set correctly when setting the timer. Of course, this will depend on the system and its degree of programmability.

A key factor is the thermal performance of the building itself. The building must have good draughtproofing and decent levels of ceiling insulation (and potentially wall and floor insulation) for this to work. In addition, curtains/blinds and internal doors should be closed, the latter for zoning.

ReNew 130 modelled the financial and environmental aspects of pre-cooling using Sunulator and found that slow pre-cooling may have a small financial advantage over a year, but a slightly negative environmental impact (as less solar energy is exported to the grid).

In winter, pre-heating the water in a hydronic storage system is also a suitable use of excess solar generation. Just like a hot water system, this may be done through the use of resistive elements or using a heat pump (with an energy diverter suitable for heat pump use, such as the SunMate).

3. Get off gas

With space heating and hot water typically comprising between 50% and 75% of a home's stationary energy needs, it is difficult to maximise solar use on-site if you don't use electricity to power one or both of these loads.

Some NSW, Victorian and SA solar customers will currently be using gas for one or both of these uses. Switching away from gas for space heating and hot water will involve considering the kind of electric hot water and space heating solutions discussed above.

If designed and implemented well, a transition away from gas will allow most NSW, Victorian and SA solar homes to reduce their annual stationary energy bills (for electricity or electricity and gas) to no more (and potentially less) than $1000 per year. This is in the context of the majority of NSW, Victorian and SA non-solar homes currently paying $2000 to $3000 per year for stationary energy.

4. Get the best retail deal

ATA recently conducted an analysis of retail feed-in tariff offers, including their associated consumption tariffs, in NSW, Victoria and SA.

Currently in Victoria, every retailer with 5000 or more retail customers must offer a mandatory minimum feed-in tariff payment to any new solar customer. SA takes the same mandatory minimum approach as Victoria—with regulators in each jurisdiction setting a minimum rate each year.

In NSW, there is no mandatory minimum feed-in tariff rate that must be offered by retailers to any new solar customer under the current NSW legislation. Retailers can choose whether or not to offer a feed-in tariff at all.

ATA's review found that lower pay-on-time discounts were offered to solar customers than non-solar customers, particularly in NSW and SA. Non-solar customers in those markets were offered discounts that were on average 7% higher.

ATA's retail tariff analysis considered only a subset of available offers in each of the three markets so the full range of offers may vary more widely. Irrespective of the solar and non-solar offers in these markets, our advice to existing and new solar customers is the same: shop around to get the best overall deal, taking into account feed-in tariff, consumption tariffs, supply charge, discounts and any other relevant offer elements.

5. What about batteries?

ATA recently conducted modelling to consider the value of installing new lithium-based storage for homes with existing solar PV systems in Sydney, Adelaide and Melbourne. The modelling looked at installation in 2017 and 2020 of both small (3kWh) and large (7kWh) battery storage systems as add-ons to existing small (1.5kW) and large (4kW) solar systems.

The results suggest that retrofitting energy storage to solar is unlikely to be cost-effective for existing solar PV customers prior to 2020, but is likely to become cost-effective in some locations/scenarios by 2020. Specifically, the results suggest that:

- systems with smaller batteries, that have more chance of being fully used over the course of the year, are likely to be economic in these three (and likely other) locations by 2020
- systems with larger batteries, that have less chance of being fully used over the course of a year, may remain uneconomic in these three locations in 2020, and potentially beyond. A key factor will be how much the cost of storage technologies declines over this time frame
- Adelaide offers better economics than Sydney or Melbourne, largely due to higher electricity retail tariffs (approximately 30% higher on average than Sydney/Melbourne) and higher solar insolation levels in Adelaide on an annual basis.

6. Am I battery ready?

The majority of the NSW, Victorian and SA solar customers affected by the feed-in tariff expiry this year will have had inverters installed in 2010–2013. These older inverters will not have the full capabilities of many of the inverters available in Australia now and many will not be suitable for hybrid solar-battery systems.

Given the poor economics of storage in 2016, it is advisable to wait with regards to battery investment and an inverter upgrade and instead:

- ensure you have net metering
- maximise your existing solar electricity by shifting major appliance usage to the daytime
- implement a plan to get off gas
- get the best possible feed-in tariff offer.

These steps may take some time to implement, by which time battery prices will have reduced and your existing inverter may be close to needing replacement anyway.

Following these steps, and with battery prices low enough by 2020, it should be achievable for most solar homes to be consuming the majority of their own solar electricity while at the same time reducing their annual stationary energy bills to below $500 per annum—a reduction of around 75% to 80% on what most Australian households currently pay. ■

Damien Moyse and Nick Carrazzo are energy analysts at the Alternative Technology Association (ATA). This article is based on a report prepared by the ATA for the Total Environment Centre, NSW. The full report Life After FITs is available at the ATA website: http://www.ata.org.au/ata-research/life-after-feed-in-tariffs-report

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FIRST PUBLISHED IN RENEW 130

THE GREENY FLAT EXPERIMENT

SMALL-SCALE, SUSTAINABLE, AFFORDABLE

Andy Lemann shares the principles, materials, results and lessons learnt in building a low-cost, high-efficiency home. Seven months into a one-year trial, the outcomes are promising.

FOR ME, LEARNING TO LIVE IN harmony with the planet means learning to live without fossil fuels. Before I'm accused of gross hypocrisy, let me be the first to admit that my way of life is highly unsustainable: I drive a car, I eat food grown in faraway places, I use fossil fuels. I certainly don't have all the answers, I'm simply attempting to take the first steps towards a fossil-fuel-free future. That is what the Greeny Flat is all about.

The Greeny Flat is a full-scale living experiment currently underway on a quiet street in Mittagong in the Southern Highlands of NSW. We're aiming to see if it's possible to build a small, comfortable, healthy, energy-positive, low-maintenance, fire-resistant, water-efficient, elderly-friendly infill house at an affordable price. Our two primary aims were to make it energy-positive and affordable.

For 20 years I designed and built sustainable houses in the Rocky Mountains of Montana, near the Canadian border, where the winters get down to -40 °C and the summers up to +40 °C. In that climate, attempting to come even close to net zero energy building is a huge challenge. When I returned home to the

↑ The Greeny Flat aims to be both cost-effective and energy-positive.

NSW Southern Highlands a couple of years ago, it occurred to me that building an energy-positive home here should be relatively easy and inexpensive.

I have since learnt that the cost of most things in Australia is much higher than in the States, so making the Greeny Flat affordable has, in fact, proved to be our biggest challenge. Meanwhile, my partner Cintia and I have lived in the house for nearly seven months, closely monitoring its energy performance, water usage, indoor air quality and comfort levels to see whether it actually meets the initial goals.

The perfect site

The Greeny Flat is designed to meet the future needs of my aging parents who, in their infinite wisdom, had found and purchased an excellent site over 20 years ago. There's an existing fibro cottage on the east half of the lot that they rent out, which left the west half available for us to build the Greeny Flat.

It is the perfect site for a passive solar home with a gentle slope to the north-east, nice views to the north, and existing buildings and trees to the west and south providing protection from cold winter and hot summer winds. The excellent solar access is also protected by the street to the north, which means that no neighbour can build or plant anything to block our sun in the future.

Just as importantly, this is an infill site in an already-developed area. This helps to reduce sprawl, preserve open space, agricultural land and natural habitats, maximise use of existing infrastructure, and reduce driving.

On that latter point, all the things we use on a regular basis (including shops, schools, medical centres, the town library, parks, playgrounds, hardware stores and trains to Sydney, Canberra

An all-electric house

The Greeny Flat is all-electric, i.e. it has no gas, petrol or wood-burning appliances. Even our lawn mower and lawn trimmer are electric. This decision was partly due to our desire to be able to clearly compare how much energy we use with how much we produce—a comparison that is much easier when everything is electric.

More importantly, given the broader goal of learning to live without fossil fuels, we can produce electricity with renewable energy systems. In our case, this is a 3kW grid-tied solar power system. Hopefully, cost-effective energy storage systems will soon be available that will reduce our dependence on the fossil-fuel-powered grid for the times when the sun isn't shining.

Meanwhile we try to use electricity when the sun is shining as much as possible. For example, we often use a slow cooker (which uses about 400W) during the day to cook our evening meal, and we mow our grass when the sun is shining.

Choosing an energy-efficient fridge

In the process of moving into the Greeny Flat, Cintia and I decided that we needed to get a new fridge. We'd been using an old fridge we'd borrowed from a friend that had icing-up problems. But it also had a 4 Star Energy Rating sticker on the door and an estimated annual energy usage of 710kWh. This sounded pretty good until I went looking for a new fridge and found one of a comparable size with a 3.5 Star Energy rating that only uses 300kWh per year.

That didn't make much sense to me until I discovered that, a few years ago, the Energy Star Rating system was changed, so newer fridges can be much more energy efficient but have fewer Stars than older fridges. So, if you're comparing old with new, it's best to compare the estimated annual energy consumption, which is also on the label.

The fridge we ended up getting is a Samsung SR319MW Digital Inverter model and it seems wonderfully energy efficient. Our energy monitoring system shows us that when this fridge kicks on, it uses about 60 watts and only for brief periods at a time. Fridges like this one have an inverter compressor that allows the motor to be ramped up and down in stages. Unlike a standard compressor fridge, which is either full on or full off, this fridge can just cruise along and add a little bit of coolth when it's needed. I noticed, when I first turned it on, that it was drawing about 140 watts while it was cooling the whole inside of the cabinet, but now it's using much less power and only in short bursts.

The manufacturers claim that this also ensures a more constant temperature in the fridge, so food will stay fresher longer and, interestingly, we have found that to be the case. It also uses super-efficient LED lighting for the cabinet.

and Melbourne) are within easy walking distance of the Greeny Flat, so we could easily live here without a car. To give an indication of how important this is, the average Australian home with two people uses 16kWh of electricity per day (though the Greeny Flat uses much less). Meanwhile, a commuter, particularly in a regional area like the Highlands, might drive 50km per day using 40kWh of fossil-fuel energy.

Another aspect of infill housing that greatly reduces the overall cost is the fact that the land is already paid for. If we had needed to buy the land to build this house, it could have easily doubled the cost of construction. And, since there are very few vacant lots within the established town area, we would most likely have had to build on the edge of town in a new subdivision that used to be bushland or farmland. We'd be contributing to urban sprawl. We'd be paying a lot more. And we wouldn't be able to live so conveniently close to everything. Thus, infill housing is a good example of a 'triple bottom line' benefit, i.e. something that has financial, social and environmental benefits.

KISS

The first rule for building more sustainably is to Keep It Small and Simple. The Greeny Flat has two bedrooms and one bathroom on a 57m2 footprint. It is a simple, rectangular plan with a gable roof and a concrete slab floor. The kitchen and bathroom are next to each other in order to simplify the plumbing system, and the living spaces face north to make the best use of natural light and sun. The small size means less energy and materials were required for construction, and less energy is required for operation. The simple design made it quicker and more affordable to build, and easier to maintain.

Passive solar design

There are two parts to the energy-positive equation. The first, and most important, is energy conservation. By minimising our energy usage we make it much easier and more affordable to produce more energy than we use via renewable energy systems. The primary way that we reduce energy consumption in the Greeny Flat is by using passive solar design principles.

To summarise these principles very briefly: the northerly aspect, window

↑ The roof consists of corrugated-iron-clad SIPS, making for a quick installation.

↑ Foil/foam composite insulation and thermal breaks improve energy efficiency.

placement, eave overhang, room layout, insulation, air sealing, double-glazed windows, thermal mass floor, summer shading, ventilation, reflective exterior and landscaping are all specifically designed to work together to keep the interior cool in summer and warm in winter without the need for any additional heating or cooling.

In addition to passive solar design, the solar hot water system, low-flow plumbing fixtures and short plumbing runs greatly reduce the amount of energy required to heat water. And the natural lighting, solar clothes drying and energy-efficient electrical fixtures further reduce the overall energy consumption to the point where we can easily meet our requirements with renewable energy.

Because of the experimental nature of the project, we didn't know when we started what size solar power system would be required for us to be energy-positive. So we chose to install a 3kW system which, as it turns out, is over twice as big as we really need.

Results

At the time of writing this article, Cintia and I have lived in the Greeny Flat for seven months. Table 1 summarises the results we have recorded so far. In that time, we have exported nearly 2.5 times as much electricity as we have imported, we have used almost as much tank water as town water, and the interior has stayed pretty comfortable with very little in the way of additional heating or cooling (we did occasionally run a small radiator to keep the bedroom warm in the winter).

Admittedly, there were a couple of times when the interior got down below 13°C when the outside temperature was around -4°C, which many people would find uncomfortable (we didn't mind it and simply put on a jumper and some slippers) and a couple of times when the interior got up around 28°C when the outside was close to 38°C. But we also made plenty of extra energy so that, if we wanted to, we could run a heating and/or cooling system and still be comfortably energy-positive.

Construction cost

During the design and construction of the Greeny Flat, we carefully weighed the upfront costs against the long-term benefits in terms of reduced operating costs, reduced environmental impact and improved quality of life and community.

In total, the Greeny Flat cost $128,000 to build and that has to be considered as cost price, i.e. all the materials, subcontractors and our own labour has been included, with no markup for overhead or profit. In other words, if a builder had built this for us, they would have had to charge more. Table 2 shows the cost breakdown for the project.

The cost per square metre at the end of the table is of particular interest. To put it into perspective, typical building costs in Australia range from about $1000/m2 for the cheapest code-minimum housing, up to $3000/m2 and more for the highest quality, custom homes. So we're somewhere near the middle. Realistically, if a builder were to build this house and make a profit they would have to charge at least $150,000, or $2630/m2.

We were hoping we could build the Greeny Flat for around $1750/m2 (i.e. total cost under $100,000), so we clearly have a lot of work to do to reach that goal. On the other hand, we've looked at a number of other options (such as kit homes of a similar size) and by the time we add double glazing, extra insulation, solar power, solar hot water, rainwater harvesting, etc, the price always comes out to at least $150,000.

When discussing costs, it is important to remember that housing affordability relates to much more than the upfront construction cost. Over the life of a typical home, there will be at least as much spent on running costs like electricity, gas, water and maintenance. So, in the long term, the Greeny Flat will save a lot of money by reducing these ongoing expenses.

Operating costs

So far we've only had one electricity bill, for June, July and August. The total came to $89.51 which works out to $0.98/day and that was for the coldest three months of the year. Of that total bill, $64.76 was for what they call 'Supply Charges' (this is the daily fee that we pay, currently $0.7162/day, just to be connected to the grid) and $14.12 was GST. So we actually only paid $10.63 for the electricity that we used over the three months.

Our bill states that we used 329 kWh for the 91-day period. This is not entirely true because some of the electricity that we use during the day comes directly from our solar power system. What it should say is that we imported 329 kWh from the grid. Our bill indicates that the average usage for a home with two people is 16 kWh/day, so we are taking from the grid around a quarter of the average for comparable homes in our area. And that doesn't factor in the excess power that we produced from our solar panels and exported to the grid, a total of 823 kWh over the same period—an average of 9 kWh/day. On average, we imported just 3.62 kWh/day, so we exported 2.5 times as much electricity as we imported. Since we don't have gas or wood-burning appliances, this accounts for our total energy equation in the home for the three-month period.

Lessons learnt so far

Our testing and monitoring of the Greeny Flat experiment will continue for at least one full year so we have a long way to go and lots more to learn. Nevertheless, there are a few lessons that we have learnt already and will probably do differently in the next project, ranging from using a heat pump or standard electric hot water system (enabling us to use our excess PV generation during the day to heat water for use at night; in turn this would reduce the amount of power that we are putting into the grid, and save a significant amount on the initial cost of the system), through to using a termite barrier that would allow us to insulate the slab edge. But more on that down the track! You can keep up with our project at www.greenyflat.com.au and we're happy to answer questions via the contact form on the website. ■

Andy Lemann is a designer, builder and energy efficiency consultant. During a 20-year stint in the USA, Andy was a LEED-accredited professional with the Green Building Council and a certified building analyst with the Building Performance Institute.

See the next page for the house and system specifications.

	Energy		Water		Comfort			
Month (for 2014)	Energy exported (kWh)	Energy imported (kWh)	Town water (litres)	Tank water (litres)	Outdoor minimum (°C)	Outdoor maximum (°C)	Indoor minimum (°C)	Indoor maximum (°C)
May	268	137	1441	4563	2.2	27.6	14.6	26.5
June	237	101	1109	3201	0.5	26.2	14.2	25.4
July	297	68	3244	1278	-4.0	21.2	12.4	23.7
August	288	130	6899	1169	-4.6	25.7	12.7	23.3
September	326	146	0	7209	0.8	23.4	14.0	23.9
October	399	104	7661	2996	1.4	34.4	15.7	26.2
November	437	78	6664	2494	4.9	37.7	16.6	28.0
Total so far	**2252**	**764**	**27,018**	**22,910**	**-4.0**	**37.7**	**12.4**	**28.0**

↑ Table 1. The results so far: energy export/import and water use, and min/max indoor temperatures.

Stage	Amount
Planning, permitting, insurance and survey	$7,160
Earthworks, services and concrete	$14,240
Solar panels, SHW and rainwater systems	$14,130
House shell, windows, cladding and insulation	$37,830
Interior fitout	$24,740
Electrical	$10,440
Plumbing	$8,230
Exterior porches, patio, paving and raised beds	$10,840
Total	**$127,610**
Cost per m² (size = 57 m²)	$2,239

↑ Table 2. Cost breakdown for the Greeny Flat.

Greeny Flat specifications

Energy conservation: maximum use of north aspect for solar access, eaves sized for maximum winter sun and minimum summer sun, double-glazed windows placed for maximum sun in winter and cross-ventilation in summer, concrete slab for interior thermal mass, day-use spaces on north side for natural light, air-sealed and extra-insulated thermal boundary, landscaping for maximum sun in winter, shade in summer, energy-efficient appliances, solar hot water, two clothes lines (one under cover)

Concrete slab: dark coloured to absorb heat and sealed with non-outgassing clear sealer (Ecocolour's Polyclear). Concrete slab as termite barrier with edge exposed and collars around plumbing penetrations

Wall frames: H2 treated pine using advanced framing techniques to minimise wood use and maximise insulation

Wall insulation: Tontine recycled polyester R2.0 batts plus reflective thermal break R0.3

Roof: Versiclad Corrolink colorbond sandwich panel, shale grey to reflect heat, insulated with polystyrene to R3.7

External cladding: galvanised iron—reflects some heat and is low-maintenance, durable and fire-resistant

Windows and exterior doors: Stegbar doubled-glazed with aluminium frames; metal fly screens for bushfire spark protection

Internal lining: low-outgassing, sustainably harvested Ecoply sealed with zero-VOC Polyclear from Ecocolour

Plumbing: PEX pipe fed from Clark Tanks 5000 L slimline polyethylene rainwater tank with mains backup and Bianco Rainsaver automatic switching device; all plumbing accessible along eastern wall

Drain lines: PVC pipe underneath exterior pavers; double sewer lines installed for possible future greywater system

Solar hot water: Apricus evacuated tube collector on roof with 160 L electric-boosted storage tank in attic above bathroom/laundry

Solar power: 3 kW grid-tied photovoltaic (12 x Trina 250W panels); SMA inverter

Surface-mounted electrical system: accessible in picture rail and exposed conduit to switches, lights and power points

Kitchen: exhaust fan to outside; low-outgassing cabinets; space for dishwasher, electric stove and cooktop; energy-efficient Samsung Digital Inverter fridge

Bathroom/laundry: low water use shower head, taps and toilet cistern; energy- and water-efficient washing machine, no clothes dryer

Ventilation: adjustable-flow continuous exhaust fan in bathroom; fixed-flow exhaust fan in bathroom switched with lights; kitchen rangehood; an air inlet pipe laid beneath the slab to bring fresh, cool air in underneath the refrigerator

Lighting: LED throughout

Elderly friendly: ramped under-cover access to both front and back doors, minimum steps, wide doors to allow for walkers or wheelchairs, lever handles and taps, bathroom rails, raised garden beds

Outside landscape: low maintenance, low water requirement, front patio sized to fit demountable shade gazebo and surrounded by raised garden beds; private sheltered rear courtyard

Understanding energy imported vs energy used and energy exported vs energy produced

The amount of energy we import from the grid is not the same as the amount of energy we use in the house. Nor is the amount of energy that we export to the grid the same as the amount of energy we produce. The difference is that some of the energy we produce from our solar panels goes directly to use in the house.

For example, let's say our lawn mower uses 1000 W and it takes an hour to mow the grass, in total we use 1 kWh of electricity. If we do this on a sunny day then the electricity comes directly from the solar panels and does not pass through either the import or the export electricity meter. So if we used no other electricity during daylight hours but used a total of 5 kWh of electricity for the 24-hour period, the meters would only show that we imported 4 kWh. Similarly, if our solar power system actually produced 18 kWh of electricity on that day, the meters would only show that we exported 17 kWh.

In total, for the first seven months of the Greeny Flat Experiment we have used 1226 kWh of which we imported 797 kWh and we have produced 2786kWh of which we exported 2357kWh. This means that we have directly used 429 kWh of the electricity produced by our solar panels. It also means that our average consumption so far (over 244 days) has been 5.02 kWh/day and our average production has been 11.42 kWh/day. Meanwhile, on average we have imported 3.26 kWh/day and exported 9.66 kWh/day.

If we can shift more of our energy usage to daylight hours we can further reduce the amount we pay for electricity by using more of our solar power directly. The main way that we could do this is to do more of our cooking during the middle of the day since cooking is our biggest energy user, or we could install a battery system to store some of our excess energy during the day for use at night.

FIRST PUBLISHED IN RENEW 133

SMALL CHANGES, BIG SAVINGS

LOW-COST, CARBON-NEUTRAL HOUSING

You don't have to spend up big to get an environmentally friendly home. Glenn and Lee Robinson show us their clean, green cottage based on common-sense principles.

OUR AIM WAS TO BUILD A HOME that was a lot more environmentally friendly than the average in Australia. So we did a bit of homework and found that it's surprisingly simple and economical to build a carbon-neutral house. This article describes what we learnt, how that information was turned into a building and how the house has performed now that we've lived in it for 12 months.

The most important discovery was that most of the techniques for creating a high-performance house cost little more than standard building practices. There are lots of small things in a building that, when done a bit differently, add up to a big difference in comfort and energy use (see our '20 guidelines' on the last page).

Finding the right design

Our goal was to minimise dependence on energy from unsustainable sources and create a comfortable, affordable home suitable for occupancy through all stages of life.

We began the design process by making a list of what did and didn't work in all the buildings we were familiar with, listing the features we would like to incorporate. We set a performance

↑ This net-zero carbon cottage in Bundanoon, in the Southern Highlands of NSW, cost just $1480 per m2 to build!

standard of net-zero carbon emissions and a budget of just $250,000 for the complete project, including house, garage and landscaping.

We looked at the options available with local builders, project home companies, prefabs and kit homes but found nothing that came near our specifications. A few prefab companies in Victoria could meet our performance spec but freight costs pushed the price above our budget. The one 'net-zero' project home available fell short in the performance stakes. The options were disappointing, but, in a country with the world's highest per capita carbon emissions, perhaps not surprising.

By default we were left with the only viable option being owner-building, which has ended up working out well. We started out by looking at the history of efficient buildings and which techniques and ideas have stood the test of time, and which haven't. We really wanted to see if we could avoid over-complication in the design so we researched low-tech ideas that have been proven to work.

We found a lot of good ideas in the layouts of Earthship buildings. They often have excellent room arrangements for maximum sun penetration, but we weren't fans of all their design principles as they require huge amounts of labour to construct and can overheat and leak.

An excellent resource is the website Build It Solar (www.builditsolar.com), where we found the Montague Urban Homestead, winner of the Massachusetts Zero Energy Challenge. We looked far and wide at hundreds of designs and, to us, this was the most elegantly simple, high-performance, economical design. We used this as the basis of our design, but de-tuned it to match our climate and rearranged the layout to suit our needs.

Many building decisions

Our final design was a single-storey detached dwelling of 108 m2 with two bedrooms and one bathroom with a separate toilet. There is an adjacent carport/storeroom of 60 m2. Structures were arranged to allow future addition of a 60 m2 studio/granny flat on the 900 m2 property (which has since been built).

ROOF

We went with a 25° pitched gable roof. A trussed gable roof was selected as the optimum form as it uses minimal resources (no heavy beams), and provides a dead air space to aid insulation, a service access for the length of the building, a north slope to mount solar collectors and a south slope to stream cold southerlies over the building. It also does not suffer the moisture problems that are common with skillion roofs and allows easy long-term maintenance of the ceiling

↑ Classic passive solar design sees the sun warm the interior during winter but be excluded in summer.

insulation. Eave overhang means we are not totally reliant on window flashings to shed water. Insulation consists of R1.5 anticon blanket under the metal roofing and R3.5 batts on the ceiling.

A 25° pitch was used as it gives the highest annual output from the photovoltaic array, drains well but is not too steep to walk on and doesn't need raised brackets for solar collectors. The colour is Colorbond Shale Grey which is the lightest colour we were permitted to use in seeking maximum heat reflection. Bargeboards and guttering are all Colorbond-coated to minimise maintenance.

WALLS

We used 90mm stud walling with studs at 600mm centres. We tried to minimise the number of studs as the insulation level drops to R0.5 at each stud. We investigated using the American advanced stud walling technique to further reduce the number of studs, but framing companies here were unfamiliar with the system and it would have added 60% to the frame price. Insulation is R2 batts and reflective breathable sarking.

The outer cladding uses HardiePlank weatherboards. We looked at many walling systems and decided that none could compare to the HardiePlank boards for installation speed, cost and durability.

Timber weatherboards require preservative and paint applied to every cut (time consuming) and they are expensive, plus they burn. Mud brick is slow, hard work and offers poor insulation, ditto for stone. Strawbale is labour-intensive and the thick walls limit light penetration, so you need bigger windows. We couldn't see the need for R8 walls as most heat loss is through roof and windows, and you end up using extra roof and floor materials to house the overly thick walls.

Brick veneer needs extra footings to hold up the heavy, high embodied energy walls and, being on the outside, they have limited benefit as thermal mass. Reverse brick veneer was considered but we decided the energy involved in adding vertical thermal mass could not be justified for the small increase in thermal stability it would provide. We also looked at structural insulated panels (SIPs), but planning the services got complicated, and we were concerned that the panels might be hard to match if future modification of the building was required.

The HardiePlank cellulose fibre and cement boards cost just $13.60 per 4.2 metre length, are easy to cut with a hand guillotine and don't rot or burn. Working with an experienced carpenter they go up really fast.

WINDOWS AND DOORS

We used Stegbar Siteline windows, with Auralast non-toxic treated pine frames with an exterior Colorbond-coated aluminium skin. Opening windows have a double rubber seal. Glazing is two layers of 4mm glass with a 12mm argon-charged gap. A low-e coating is applied to the exterior face of the inside pane. The final window specs are U<2.5 and SHGC>0.5.

All windows are casement opening; no sliding or double-hung units were used as, in our experience, they don't seal well as they age. North window area was kept under 20% of the floor area to prevent overheating and reduce night heat loss. There are small openable windows to the south for ventilation, no west glazing and a small amount of fixed glass to the east. No clerestory windows or skylights were employed as night heat loss of these elements exceeds daytime gain.

The window frames are painted a pale colour to maximise the light reflected into the room. All windows are insulated at night with a double layer of curtains. The building design allows curtains to be drawn clear of the windows during the day.

FOOTINGS/FLOOR

The concrete slab is a conventional reinforced raft structure 100mm thick. No fixed internal floor coverings are used so internal air can couple with the thermal mass of the slab. As the slab is exposed, 32MPa grade concrete was used for hardness, and reinforcing mesh bars at 100mm centres were used to minimise cosmetic cracking. A 50mm layer of foam

↑ The kitchen is a simple, clean ergonomic design, with walkways designed according to liveability guidelines and an induction cooktop for reduced energy use.

insulation is fitted to the slab perimeter and protected by a metal flashing—this gives an R2 slab. Under-slab insulation was investigated but we decided it was unnecessary in our climate zone (climate zone 7, cool temperate) provided the under-slab area stays dry and can temperature stabilise. This seems to be working as the house is performing even better in its second winter and the only explanation we have is that as time has elapsed since construction the ground under the house is drier and drawing less heat from the house.

ENERGY AND LIVEABILITY SYSTEMS

All lighting is LED and no downlights are used to avoid interruptions to ceiling insulation. Many houses halve the effectiveness of ceiling insulation by the voids created around downlights.

All exhaust systems are shuttered so the building is sealed when fans are off. The ceiling trapdoor is insulated and sealed with a rubber gasket. A maintenance walkway extends for the length of the roof space. The truss bracing was designed for this.

We installed a 22-tube evacuated-tube solar hot water system plumbed to a 250L foam insulated tank centrally located between the bathroom, kitchen and laundry. We avoided a roof-mounted tank as there are losses between the tank and outlets in such systems—we placed the tank indoors as close to outlets as possible. The tank has a mid-level electric booster element so that when we get a few overcast days in a row we only need to warm the top portion of the tank. Interestingly, since we built, the Beyond Zero Emissions study on domestic water heating advises that, over a 12-month cycle, a heat pump water heater would use less electricity.

Space heating is with a Daikin reverse-cycle air conditioner, model RX535LVMA. It's an awesome bit of gear, with a heating coefficient of performance of 4.55. That means for only 0.88kWh of electrical energy in we get 4kWh of heat energy out. We located the condenser (outdoor part of the unit) to catch the early morning sun and improve performance early in the day, but as yet we have not needed it in the morning. Keeping the ceiling to minimum height has been a great contributor to efficiency, as we don't need to heat air that we aren't actually walking around in. Getting this wrong, along with poor building sealing, seem to be the most common thermal shortcomings of Australian buildings.

Cooking is with an induction cooktop, which uses considerably less energy than a standard electric cooktop. It also doesn't produce fumes, unlike gas, and it heats up really fast. For oven cooking we generally use a microwave and finish off in our fan-forced electric oven.

Water for the laundry and toilet flushing is from a 10,000L above-ground rainwater tank. We avoided an automatic rain switch (to change over to town water when the tank is empty) as they don't seem that reliable and we wanted to keep the house simple. We installed a manual mains water filler in case the tanks run low.

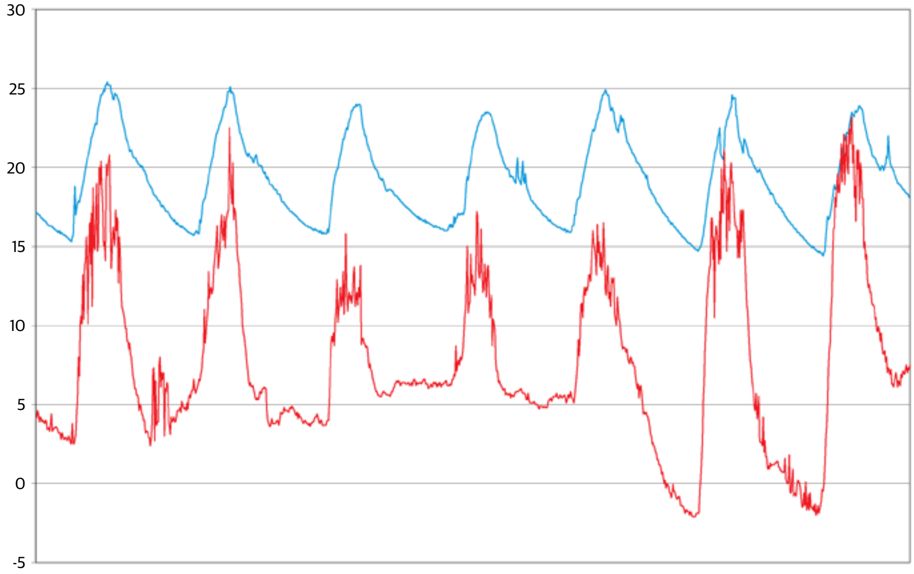
All taps, shower and toilet are 4 Star efficiency rated. The dishwasher and washing machine are water- and energy-efficient Asko units, though we mostly wash up by hand unless doing a lot of cooking. The kitchen is located at the centre of the house for best access and is of galley design to eliminate hard-to-access corner cupboards.

We installed a 2kW grid-connected solar PV array. Over 12 months this has exported almost twice the amount of energy we've imported, even in our all-electric house. We would be interested to know if this has been achieved elsewhere in a house with two occupants—i.e. being carbon neutral with less than 1kW of PV per person.

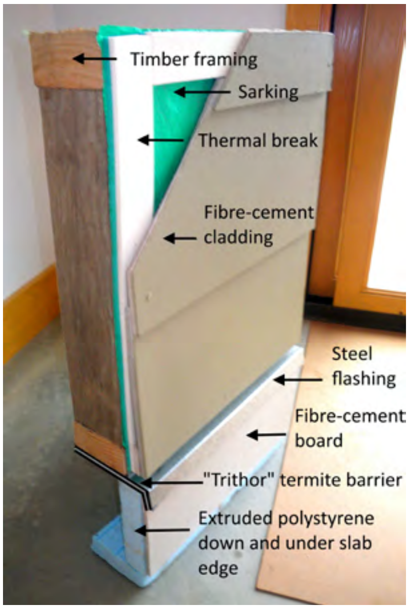
The barbecue and lawnmower are both electrically powered. It is nice to mow using sun harnessed off the roof instead of oil transported all the way from the Middle East. It's also much quieter.

Indoor storage cupboards were built along the south wall to add insulation to the coldest face of the building.

The site had a north slope so we sank the building into the ground to reduce wind exposure and provide a level entry



↑ Inside versus outside temperatures for a week in July. No auxiliary heating was used as the weather was mostly clear. If you look closely you can see the temperature increase when the owners came home and started cooking.



↑ A mockup of the wall construction materials showing the various components.

to the north. We are also fortunate to have a neighbouring hedge giving extra protection to the south.

The building's wind rating was raised from N1 to N2 to prepare for increased strong winds in the future. Non-combustible exterior materials were also selected in anticipation of increased bushfires in the future.

Low-VOC paints were used throughout, with the exception of the floor as we wanted a super-durable finish.

Project costs

The breakdown of building costs can be seen above. Adding a cost for Glenn's labour brings the house cost to around $160,000, or $1480/m2. The land cost $150,000.

The complete project costed after 12 months with garage, fencing, driveway and gardens came to $198,600. This includes about $4000 extra to connect services such as sewer, water, phone and power due to the building's long setback from the street (to leave room for a future granny flat closer to the street, now built).

Things we could have done better

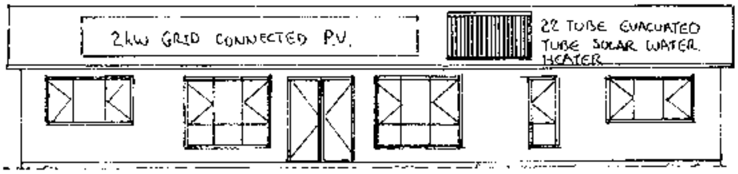
If doing it again we would replace four of the opening windows on the north facade with fixed glass as they are not needed. We'd also use extruded rather than expanded foam for slab insulation as it's tougher, and we'd install a 12 mm synthetic thermal break on the outside of studwork as this is a cheap way to boost wall insulation.

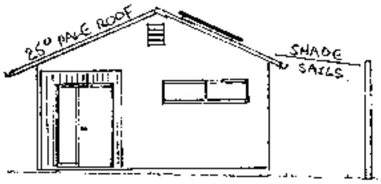
We also have a wishlist of changes to the building industry in general so we can stop being the slackest western nation on earth. The first would be to match England in requiring all new homes to be Net Zero by 2015—fairly simple in our climate. We'd also like to see stronger regulations enforcing legal access to sunlight: currently there is little to deter vegetative shading of PV panels.

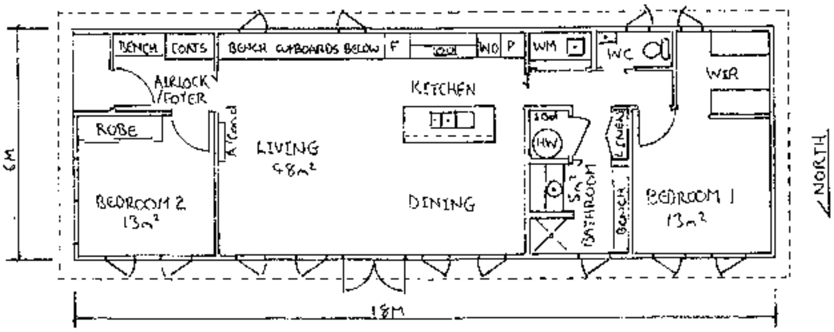
As a society, we also need to do more to demonstrate and value the reduction in energy use that comes with sustainable building. One way to do this would be to require that energy bills, perhaps over two years, be attached to house sale contracts. This would include all energy use—electricity, town gas, firewood, BBQ propane, mower petrol etc. That way, prospective purchasers could see the true operational costs of a property. ■

Lee Robinson is a fitness trainer specialising in helping elderly and disabled clients,which makes her aware of the ways that buildings can help or hinder those with disabilities. Glenn is a non-practising electrician who runs the local YHA hostel. He is passionate about preserving what remains of the earth's resources and creating the best future he can for his grandchild.

↑ The slab insulation, before pouring of the slab.







→ The house layout is simple and effective with no wasted space in hallways. There are minimal windows on east, south and west walls. The heavily windowed north wall is designed to make best use of the incoming winter sun.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FIRST PUBLISHED IN RENEW 137

HYBRID HAVEN

ALL-ELECTRIC DREAMS COME TRUE

John and Elizabeth Heij have created their dream retirement home on the coast south of Adelaide: comfortable, all-electric, running almost entirely from solar + batteries, and with an EV to boot.

IT'S FAIR TO SAY THAT 80-YEAR-OLD John Heij and his wife Elizabeth are early adopters. It was 2004 when they first installed a small solar + battery systetm to run lights and computers in their home in the Aldinga Arts EcoVillage, on the coast south of Adelaide in South Australia. Then, in 2013, they designed and built a new house (in the same village), and as part of that, installed a larger hybrid (grid-connected) system to run their entire all-electric home and electric vehicle (EV). In addition, they're effectively off-grid for water, with two 22.5 kL in-ground rainwater storage tanks that have supplied all their water needs for the last three years.

Their power system comprises 9.6 kW of Canadian Solar panels, two 5 kW Kaco/Selectronic inverters, a Selectronic SP-Pro inverter-charger and 32 kWh of Sonnenschein sealed lead-acid gel batteries, configured in an AC coupled system.

The size of the system means they import "less than half a kilowatt-hour per day" of electricity from the grid—a tiny proportion of the average import of 19 kWh/day in their area for two-person homes (as noted on their most recent 'bill'—or rather, credit—from AGL). Of course, their actual energy usage is higher,

↑ John and Elizabeth's home with almost 10 kW of PV and PV-boosted solar hot water. The shade in front of the solar hot water system is retractable for winter warming of the internal thermal mass.

with most of their 7 to 18 kWh daily usage (based on June to August 2016 usage figures, higher when charging the EV) coming from the PV panels or the batteries.

The system cost between $30,000 and $35,000, but John notes that they would have done it "no matter the cost". It's a philosophical issue for them: "if the powers that be aren't going to remove coal and gas, we have to do something about it ourselves," he says.

Solar diverter

One of the interesting features of the system is the inclusion of a Sunnymate diverter (now called the SunMate) which optimally directs the solar energy. It starts by first charging the batteries, then diverts to the solar hot water system's electric water tank element, then to the heater in the house. Elizabeth notes: "The air conditioner has to be managed manually as the Sunnymate doesn't seem to handle motor-driven equipment. This apparently can be overcome by using relays but we haven't gone that far yet. It handles the heater well as it is a resistive load."

Since installing the system, they've never had to heat water from the grid: "even on the dullest days, it always manages to heat water." John adds that they never get a full day of rain in their area, so there's always some generation.

The Sunnymate can also control charging of their electric car. They only charge the car during the day and most of that charge is from solar. "We're a bit different than some people as we're retired and can organise our energy use for during the day," notes John.

Driving range

Their car is a Nissan Leaf with a 25 kWh battery. As "homebods", they've found the car's 145 km range not a problem at all. They use it for shopping and local trips,

↑ Charged using PV electricity, John and Elizabeth's Nissan Leaf suits their minimal driving needs.

↑ The neat installation of the Selectronic myGrid system using Sonnenschein sealed lead-acid batteries and an SP-Pro inverter-charger.

with a recharge usually taking up to four hours at about 2.7 kWh per hour; they rarely run the car battery down below about 60% state of charge. The car's range varies according to headwinds and hills—and the weather. "Batteries don't like the cold, a bit like me," says John. They have an arrangement with a friend to swap cars if they need to go on a longer trip.

The system is set up to export energy to the grid, though after installing this newer system they lost their 25c/kWh feed-in tariff, and now get paid 8c/kWh, reducing again to 5.6c/kWh soon. The system prevents export from the batteries, as to date that's been "frowned on by the network operators."

Working the house

The house is super-insulated, with double glazing and windows oriented for winter heat gain. They have internal thermal mass in a stone wall, which absorbs the sun's warmth during the day, along with heat from a 4 kW Derby ceramic heater, and then re-emits that heat at night. Usually the ceramic heater only runs when excess energy is diverted to it by the SunnyMate, and they find the house stays cosy overnight.

In summer, they do the opposite. They cool using their ducted reverse-cycle air conditioning from 11 am to 3 pm, generally enough for the house to stay cool overnight, when combined with using fans and opening windows to access the "gully winds" from the hills or sea breezes.

"To run a sustainable home you need to work the house," says John—to open it up when needed, or shut it down, and heat/cool at the best times of the day for that.

When it comes to cooking, they "hardly ever use the oven" as they find it uses too much energy. Mostly they use their microwave and induction cooktop—Elizabeth used to love cooking with gas, but now prefers induction. "It only took about five minutes to adapt," she says, adding that it's even quicker to respond than gas.

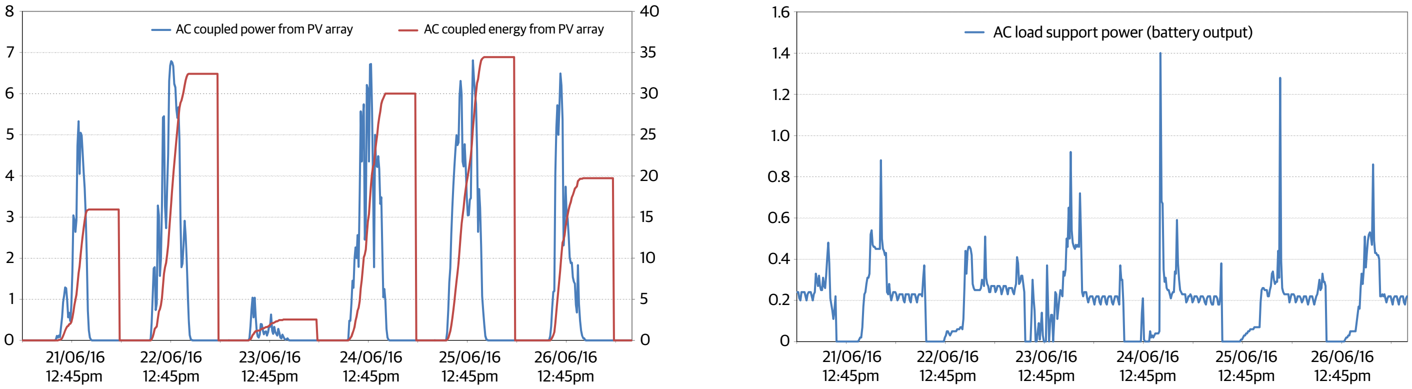
Monitoring

They do little monitoring of the system other than to check every couple of days that the batteries are charged and the inverters are on, just when "walking past them in the garage." They have an electrician friend who does occasional more thorough checks on the system for them.

They did have a fire at one stage in the DC switch: a small self-extinguishing fire, caused by a manufacturing fault. The DC switch was quickly replaced and has been taken off the market. John suggests that microinverter systems will go further to eliminate that risk.

As at their last electricity 'bill', they're $275 in credit—they get their credits paid to them yearly, usually in November. Early adopter is a badge John and Elizabeth wear with pride, both to show what's possible and to enjoy retirement without ongoing bills. ■

Elizabeth is a retired scientist, having worked in both agricultural plant science and sustainability across disciplines. John is a retired nurse and nurse manager. Both are now involved as volunteers in the Aldinga Arts EcoVillage in South Australia.



↑ Left graph shows PV generation in both instantaneous power samples (kW in blue) and accumulated energy for the day (kWh in red) over a winter week in June this year. Right graph shows that same week and how much of the household load is being supported by the battery.

#3

ENERGY STORAGE POTENTIAL

MAKING THE MOST OF BATTERIES

FIRST PUBLISHED IN RENEW 137

JUST ADD BATTERIES

CONSIDERATIONS FOR HYBRID SYSTEMS

There's more to consider than just the brand or size when adding storage to a solar system. Damien Moyse and Nick Carrazzo highlight some of the issues to consider in a field with ever-evolving technology.

THERE ARE MULTIPLE WAYS THAT batteries can be added to an existing or new solar PV system. These different configurations will influence the system's capabilities so it's important to carefully consider the approach you take. This article covers the most common approaches currently available in Australia, but note that technology and options are developing rapidly so we will be updating this advice regularly.

The majority of solar PV systems currently installed in Australia are unlikely to be 'battery-ready'—an existing solar customer cannot simply purchase a lead-acid, lithium ion, flow or sodium battery and have it retrofitted to their existing system.

The solar panels can be retained, of course, but an additional or replacement inverter and charging components will likely be needed to charge and use the batteries.

One approach (DC coupling) involves replacing the existing grid-interactive inverter with a new hybrid inverter; such inverters can both control charging of the battery and conversion of electricity from DC to the AC required for household use. As a cheaper alternative, in a fairly recent development, the replacement of the grid-interactive inverter can be avoided through fitting a DC to DC converter between the solar array and the battery bank—thereby negating the need to replace the existing grid-interactive inverter.

A second approach (AC coupling) requires installation of a second battery-dedicated hybrid inverter (with integral charger controller), with the existing grid-interactive inverter retained.

As such, almost all the new battery products currently on the Australian market are either sold with a new inverter (some as part of an integrated 'all-in-one' storage unit and some with the inverter separate from the battery) or require an inverter to be purchased separately.

Thus, most existing solar customer will need to replace their existing grid interactive solar inverter, add a secon inverter or add a DC to DC converter t their system. Which approach is take depends on whether the system uses AC or DC coupling and the capabilitie required of the system. Coupling refe where within the system the batterie connected.

DC coupling

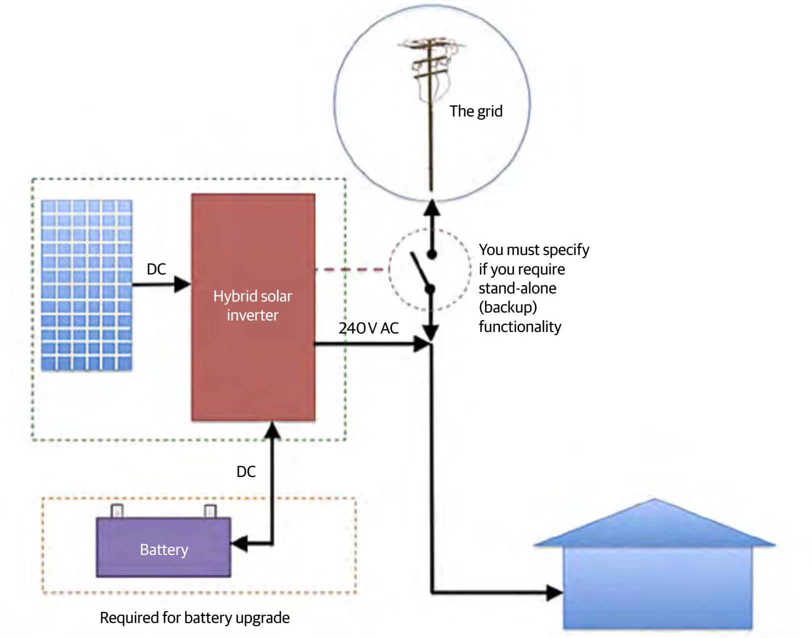
DC coupling involves siting the batter on the DC side of (or indeed plugging directly into) the solar inverter (see Fi 1).

The wires connecting to the battery on this side of the solar inverter carry DC electricity, so the solar-generated electricity can be used to charge the battery prior to it being converted to AC for household consumption or export to the grid.

This approach means that the solar inverter will need to be a 'hybrid' inverter, which has a higher level of functionality than a traditional grid-interactive 'string' inverter. A hybrid inverter converts the DC power from the panels and battery to AC and also takes care of the required battery control and switching functions. Given this increased functionality, hybrid inverters are more expensive than traditional string inverters.

Another key component of the system is the isolation switch. This enables the system to operate in the event of a power outage on the electricity grid. Standard solar and solar-battery systems do not have this capability.

As an alternative to replacing the grid-interactive inverter, a DC to DC converter, such as the GoodWe BP series, can be fitted between the solar array and the battery bank (note that the GoodWe requires a 48 V battery). This enables the battery to charge directly from the solar array. When the battery discharges the DC to DC converter steps the battery voltage back up to a nominal voltage that meets the requirements of the grid-interactive inverter. The main disadvantage of using this DC to DC converter approach is that the system cannot run without the grid, so battery backup isn't available.



Diagrams courtesy Solar Quotes: www.solarquotes.com.au

Figure 1: DC coupling configuration. DC solar is fed through the hybrid inverter for charging of the battery or conversion to AC for use by the household. The hybrid inverter also controls use of the DC electricity from the battery. In a fairly recent development, an alternative approach to DC coupling involves using a standard grid-interactive solar inverter with a DC to DC converter.

AC coupling

AC coupling involves siting the battery on the AC side (the grid or household side) of the solar inverter. This means the wires connecting the battery to the solar system are 240 VAC (see Figure 2).

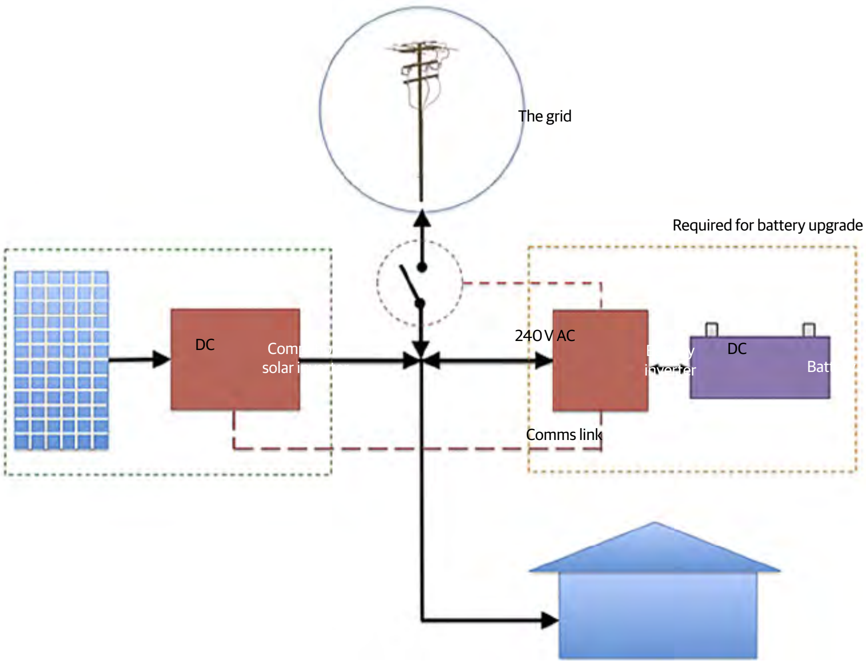
Given all batteries operate in DC, this AC coupling requires a second battery-dedicated inverter which includes the ability to charge the batteries, adding to the cost of the overall system. This inverter needs to:

- convert the battery's DC to a household/grid compatible AC
- convert the solar inverter's AC output to DC in order to charge the battery
- control the charging so that the battery is not damaged
- charge the battery with solar electricity or electricity from the grid, e.g. during cheaper off-peak times
- only discharge the battery when the household/site requires it—and not back to the grid, unless you have a system enabled to sell electricity from your batteries to the wholesale energy market via a retailer, such as offered by Reposit Power.

Once again, it is important to note the need for an isolation switch to enable operation in the event of a power outage on the grid. This is not included in a standard AC coupled system.

A situation where AC coupling is unavoidable is where the solar array is fitted with microinverters, which are tiny grid-interactive inverters attached to each panel. The panels themselves are effectively AC output devices, so DC coupling isn't possible.

How easy it is to add storage will depend on the microinverters used. For example, Enphase microinverter-based



↑ Figure 2: AC coupling configuration. DC solar is converted to AC by the solar inverter for use in the household or fed through the battery-dedicated inverter-charger for charging of the batteries. A communications link is needed between the solar inverter and the inverter-charger to allow the PV production to be controlled when the system is running in backup mode.

systems can have the Enphase AC battery added to the system without a separate hybrid inverter, as each battery module has its own Enphase inverter and battery charger built in, and all of the Enphase devices can communicate with each other for simple system setup.

Other batteries could be used with Enphase or other microinverter brands, but the specifics of how the added components communicate with the existing ones will need to be addressed on a system-by-system basis.

Considerations for existing PV owners

For consumers with existing grid-connected solar PV considering retrofitting batteries to their system, and for whom the economics of the project are of primary importance, ATA would suggest waiting for storage prices to drop and the market in Australia to consolidate around the most optimal technologies and systems.

For consumers with existing solar PV wanting to retrofit batteries now, irrespective of the economics, they will need to consider the following.

First, they will need to consider whether they want their retrofit battery system to provide power in a blackout. If so, then an isolation switch (costing $250 to $450 + installation) will be required along with a new hybrid inverter and communications system that can handle system operation in the event of a power outage. Note that not all hybrid inverters can operate in a grid-islanded situation.

Should back-up power not be desired, a DC to DC converter may be an option, allowing the retention of the existing grid-interactive inverter.

Even for a system involving a DC to DC converter, it will still be difficult to establish a retrofit project for less than $10,000 installed in 2016, even for a system involving a relatively small battery.

Next, existing PV owners need to consider whether they want the system to be able to charge from the grid. Some new inverters (for example the SolarEdge inverter) have an AC to DC charger and can facilitate battery charging from the grid. Grid charging facilitates the use of cheaper electricity (e.g. overnight off-peak tariffs) as a supplement to charging from solar on low solar resource days. However, optimising this approach requires the use of weather and electricity consumption forecasting, functionalities that aren't available without additional software to control battery charging (e.g. through the Reposit Power software, costing about $800).

Considerations for homes without existing PV

For consumers considering investment in a new solar and storage system, the above choices regarding backup and grid charging equally apply. The main challenge for these consumers will be choosing an inverter for their new system.

Given 2016 battery prices are still relatively high, many prospective solar+battery system owners are waiting for prices to come down. In the meantime, however, many will be keen to purchase and install a standard grid-connected solar PV system to start realising the benefits of such a system, prior to installing storage.

If the solar customer later decides to add storage and this requires replacement of the originally purchased grid-interactive inverter, this replacement would likely occur part way through the usable life of the solar inverter. The lost value is offset to an extent by the initial saving from installing a standard solar inverter as compared to a hybrid inverter (a saving in the order of $1500).

Alternatively, should this customer decide to purchase a more expensive hybrid inverter initially as part of their grid-connected solar PV system, there is a risk that this hybrid inverter may be obsolete or unnecessary (due to an increasing prevalence of DC to DC converters) within three to four years. It may not be able to support new and improved battery technologies available at the time of adding storage. In addition, the functionality of battery systems is continuously improving and legacy hybrid inverters may not provide functionality required by the market at a future point in time.

Although both decisions involve pros and cons, ATA would advise that the risk of technology obsolescence is too great at this point in time to recommend the latter option. In theory this could lead to a freezing of the solar market over the next few years, but in reality consumers will continue to make decisions on the basis of other reasons besides economic rationality and system optimisation (e.g. early adopter, peer competition) as experienced in the solar PV market in the late 2000s/early 2010s.

Daytime load

Another important factor in the economics of storage is the consumer's daytime load, with the most beneficial load profile contrasting that of the most beneficial load shape of solar-only customers.

For consumers not on premium feed-in tariffs, solar PV without storage offers the greatest potential benefit where significant electricity consumption occurs during the daytime, during solar generation hours.

By contrast, a load shape with lower daytime and higher night-time consumption will realise greater benefits from a solar+battery system. A consistently high daytime load leads to solar generation being used directly on-site, leaving insufficient excess solar left to charge a battery for use in the evening and overnight.

Charge/discharge rate

The discharge rate is the time, usually expressed in hours or parts of an hour, it takes to discharge a battery before it is fully discharged. Expressed as the 'C' rate, this is the theoretical capacity of the battery when charged or discharged at the consistent rate over time.

The capacity of some batteries (specifically lead-acid technologies) is reduced if the battery is discharged over a shorter period. In the case of lead-acid, C10 to C20—discharging over 10 to 20 hours—tends to be the highest level of discharge without significantly reducing the capacity of the battery.

At higher discharge rates, the energy output capacity is reduced as well as the asset life (which is expressed as an absolute number of charge cycles before the battery fails or suffers significant depletion of capacity). This is an important consideration for households or businesses who may wish to access the energy stored in a battery relatively quickly (e.g. during a daytime or evening peak).

Newer technologies (e.g. lithium ion batteries) do not suffer from these charge/discharge constraints in the same way, improving their effective operation. Hence the discharge rate of lithium batteries can comfortably exceed C1, with the capacity of other components potentially being the limiting factor, not the battery.

Image: Envirogroup, www.envirogroup.com.au

↑ Your existing electric hot water service, either resistive element or heat pump, can provide energy storage at much lower cost than a battery.

Battery utilisation

Battery utilisation is another important factor in the overall economics of storage. Battery utilisation is the average daily discharge of the battery (on an annual basis) as a percentage of its usable capacity.

Although a battery may have a certain usable capacity (e.g. 10 kWh), this does not necessarily mean that the entire storage capacity will be used on any given day, or indeed consistently across many days of the year.

Battery utilisation is a function of the ability of a certain-sized solar system (or the grid in AC coupling) to fully charge the battery to its rated capacity, as well as the consumption profile of the individual customer. Both of these involve significant variability as weather patterns change and the behaviour of the

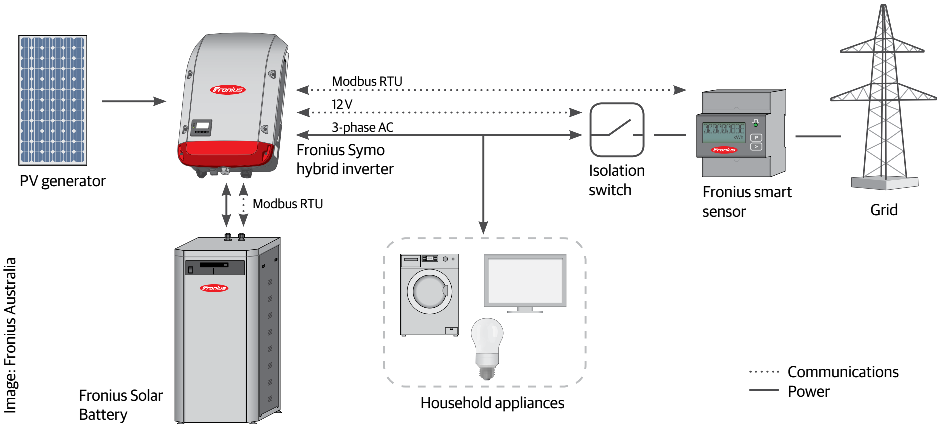


Image: Fronius Australia

↑ When starting from scratch rather than adding batteries to an existing grid-interactive PV system, the number of components, and hence system complexity, can be reduced. This example uses a matching Fronius Symo inverter and Fronius Solar Battery which is DC coupled to the inverter, as is the PV array. The end result is a full hybrid system with battery backup capabilities. The only drawback with the Fronius system is that it is currently only available for properties with 3-phase power connected.

household changes over days, weeks and seasons.

Standards

There are several existing Australian standards relating to battery design and installation within buildings. Most relate to traditional lead-acid technology and do not address recent product innovations including the increasing prevalence of lithium-based chemistries and hybrid (grid-connected) solar+battery installations.

Given a lack of standards specific to emerging battery technologies and configurations, in April 2016, the Clean Energy Council (CEC) and the Australian Energy Storage Council (AESC) separately released interim guidelines for battery installation and safety. Both note these guidelines should be considered stop-gap measures until formal standards are finalised.

Both the CEC and AESC note that the Australian standards do not address the following innovations in the residential storage market:

- the increased energy density of lithium-based cells (in particular) which significantly exceeds that of lead-acid and nickel cells
- improvements in grid connection equipment (e.g. inverters)
- packaged or 'all-in-one' systems, which combine the battery, inverter and other control equipment into a single unit with pre-engineered connections.

In response, Standards Australia commenced public consultation on the development of Australia's first comprehensive set of industry standards for battery storage in May 2016. Standards Australia is working with the COAG Energy Council to develop new standards and support the safe and efficient uptake of new storage technology in Australia.

Storage alternatives

The current capital cost of energy storage in batteries is likely to remain too high in the short to medium term (i.e. prior to 2020 and potentially after) for many existing and new solar customers.

With many higher feed-in tariffs nearing the end of their legislated lives around the country, some level of renewable energy storage will be beneficial for solar homes to maximise the value of their solar-generated electricity. There are other ways to store renewable energy, which are cheaper and just as effective as using a battery.

Thermal energy storage (for example, as heat in water) is a concept that has been around for a long time. Electric heating and storage of water for domestic use is broadly done in two ways :

- by using a traditional electric storage hot water (ESHW) system, which uses single or multiple resistive electric elements in a tank to heat and store water
- using a heat pump, which involves the compression and expansion of a refrigerant through a heat exchanger to extract heat from ambient air (which creates multiple units of heat output for each unit of electricity used), heating water stored in a tank.

Both of these systems use electricity as an input to the system and can be powered directly from solar PV, provided the home or business is configured for net metering, the ESHW or heat pump is connected to the main electrical circuit (i.e. not a separate, dedicated circuit established for off-peak hot water), and the ESHW or heat pump operates during the day (i.e. when the solar system is generating electricity).

ESHW and heat pump systems offer the potential for existing (and new) solar customers to maximise the usage of their solar-generated electricity, without the need to invest in as yet expensive chemical energy storage in batteries.

Summary

Energy storage systems are more complex both technically and economically than solar PV systems.

System configuration and battery management both have a significant impact on the overall consumer experience. A consumer's location and consumption pattern also makes a significant difference to their personal economic outcome.

Products in the current Australian storage market do not as yet provide the full range of potential options for system configuration and battery management. This means the most optimal strategy for any individual household may not yet be available for them to take up.

All of this complexity will make decision-making difficult for consumers, particularly during the early phase of evolution in this market. Consumers will need assistance with simple, accurate and independent information and advice to help them navigate the Australian storage market as it evolves. The ATA is committed to providing this information via its websites and publications such as *ReNew* and *Sanctuary*, so stay tuned! ■

Damien Moyse and Nick Carrazzo are energy analysts at the ATA, *ReNew's* publisher.

More info:
Inverter buyers guide, *ReNew 137*
Battery installation guidelines CEC and AESC www.bit.ly/2bQbTI0 and www.bit.ly/2bAUEoH
Storage systems table by Solar Quotes—all currently available storage systems, regularly updated: www.solarquotes.com.au/battery-storage/comparison-table

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FIRST PUBLISHED IN RENEW 137

A STORY OF STORAGE

AUSTRALIA'S FIRST POWERWALL HOME

Nick Pfitzner and family are the proud owners of the first Tesla Powerwall home in Australia. Nick Pfitzner describes their configurations and the lessons they've learnt so far.

OUR HOUSEHOLD HAD THE privilege of the first Tesla Powerwall installation in Australia (maybe the world, they say). It has been a very interesting experience so far, and we've learnt a lot about what makes the house tick from an electricity point of view. I've also had the opportunity to discuss the energy generation landscape with several organisations developing similar energy storage technologies.

As a self-described Elon Musk fanboy, I became seriously interested in energy storage for our house after the Tesla Powerwall launch in 2015. I knew about other home storage systems, but mostly associated them with lead-acid systems and off-grid enthusiasts. We had previously got a quote for an off-grid AGM lead-acid system at one point, but we didn't have the finance or space to make the BSB (big steel box) happen at that time.

However, by late last year with our finances more in order, we decided to take the plunge with the Powerwall. We chose Natural Solar as the installer. They had advertised themselves as the first certified installer of Powerwall in Australia and helped guide us through the options available.

We opted for 5 kW of Phono solar panels with a SolarEdge inverter and, of

Photo: Natural Solar

↑ Nick and family with their Tesla Powerwall installation, the first in Australia.

course, the Powerwall, for a total cost of $15,990 installed.

Was this the most financially sound use of our money? As a simple case, we put the initial cost of installation up against our largest asset, the mortgage.

At current interest rates, if we used that same amount of money to reduce our mortgage, the offset savings would be around $750 in the first year, compounding into subsequent years.

Our household electricity usage bill was just over $1900 for the previous 12 months, not including the fixed daily supply charge of about 85 cents per day (i.e. that's just looking at usage, the part that we can change by installing solar and battery).

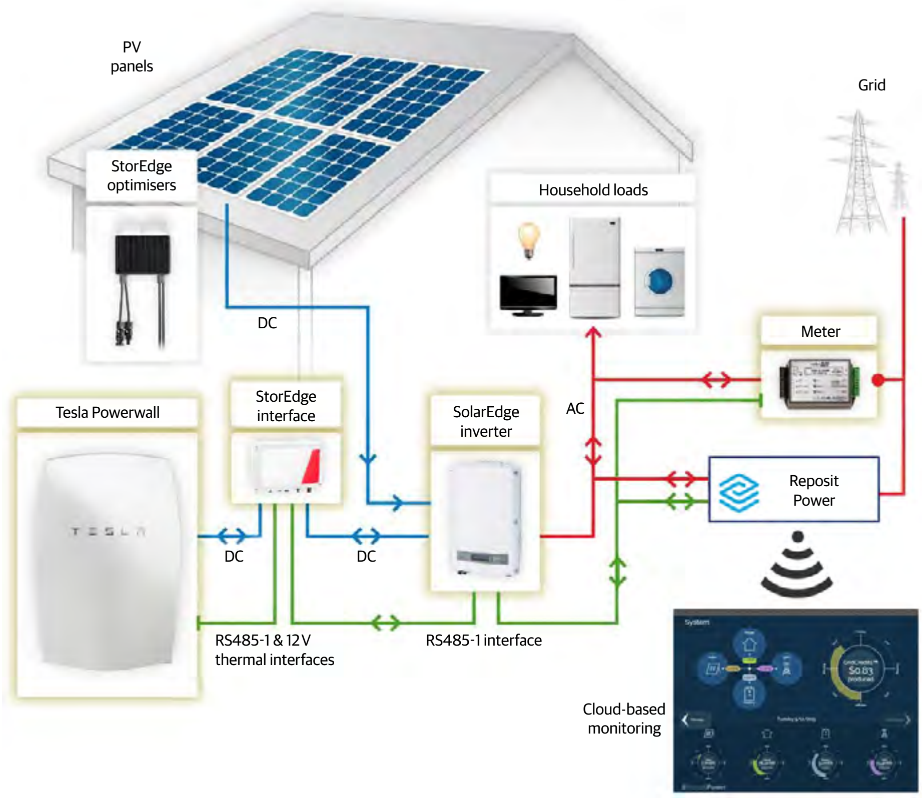
A reduction of around 80% in our usage charges would save us approximately $1520 over a year; more than double the value of the money in our mortgage offset, and equating to a payback of around 10 years on the investment value. However, we would no longer offset our interest payments to the tune of $750 per year, pushing the payback time well beyond the Powerwall's warranty period. Considering we were just as likely to use the money on a family holiday as an interest offset, over the longer term, I opted to install the system and reduce my running costs today. To date, we have seen a 90% decrease in our electricity bill, year-on-year, or around $450 per quarter.

And add Reposit grid credits

Natural Solar also informed us about Reposit Power, a software package designed to maximise the benefits of home storage for the consumer. In a nutshell, Reposit is a software-based controller for the entire system. It learns the household usage patterns, gathers weather forecast data and interfaces with the inverter to make decisions about import or export of energy based on two important concepts:

Tariff arbitrage. This is the practice of switching to a time-of-use grid tariff and charging the battery at times advantageous to electricity pricing. This may occur when solar PV generation predictions for the next day are poor or where energy storage has been used up overnight. In either case, off-peak power can be imported for use the next morning.

GridCredits. This is an ARENA-supported project to investigate the use of intelligent storage and distribution of power via consumer-level battery



→ Nick's DC-coupled system includes Reposit to control charging and discharging of the battery, to make best financial use of the solar and stored energy using weather forecasting and consumption patterns.

Diagram: SolarEdge/Natural Solar

systems, with the aim of reducing network infrastructure costs in future. Consumers are rewarded not through feed-in tariffs based on intermittent solar generation, but rather guaranteed power delivery from the battery. When the wholesale market for electricity is especially high, the electricity retailer discharges electricity from the battery into the grid, paying the consumer $1 per kWh.

These two factors could assist with the financial equation, so we figured it was worth the add-on cost of installing Reposit—an extra $800 at the time.

A learning experience

Being 'the first Powerwall' involved a lot of learning for all parties. While the technicians from Natural Solar certainly had their training right, there was a suitable level of caution in their approach. With the publicity surrounding the event, you want everything to run smoothly!

Once the system was installed, the knowledge gathering from a consumer perspective started almost immediately via the SolarEdge web portal. It was really interesting to understand the ins and outs of energy usage on a schedule more frequent than the quarterly bill.

We learnt several lessons very quickly, none more important than how expensive it can be to run a ducted air conditioner. The system came online in the last week of January and the SolarEdge technicians were amazed to watch the energy flows between meter, battery and inverter as the air conditioner cut in and out.

If you're building a house and think ducted air con would be nice, make sure you look at the system efficiency! We bought the house as-is nearly three years ago, so didn't get that choice.

Using energy during the day, cutting standby power

The solar PV generation showed me where we should be using more of our required energy, in order to take advantage of what we'd otherwise be exporting. Devices such as washing machines and dishwashers already come with timers, and aligning our energy usage with the sun required just a small shift in our thinking.

This is one of the key areas that solar PV owners already know, particularly those who are on the lower feed-in tariffs that are now standard practice. The logic of load shifting is undeniably sound, as the electricity you export at a few cents per kWh is never as valuable as avoiding import at over 20 cents per kWh.

As newbies to solar PV, we now had to formulate plans to use as much power as we could during the day, top up the Powerwall and export the rest to offset costs.

We still had to wait a couple of weeks for the old meter to be changed over in order to have export totals counted, so we set about addressing the efficiency and smarts we could immediately control.

Education was the first point, with all the standard things like minimising use of the air conditioner, not leaving lights or TVs on and ensuring devices were only charged as required.

We'd gradually installed LED lights over the previous two years, as well as ceiling fans in key areas, and insulation on our west-facing garage door. There are further measures on the list, like window awnings for preventing heat entering the house in summer.

Timers were put in place to cut standby power usage overnight and during the working day, mainly relating to audio-visual equipment. Modern electrical devices, particularly those with internet-ready modes, have increased their requirements for 'phantom' power as the price of convenience.

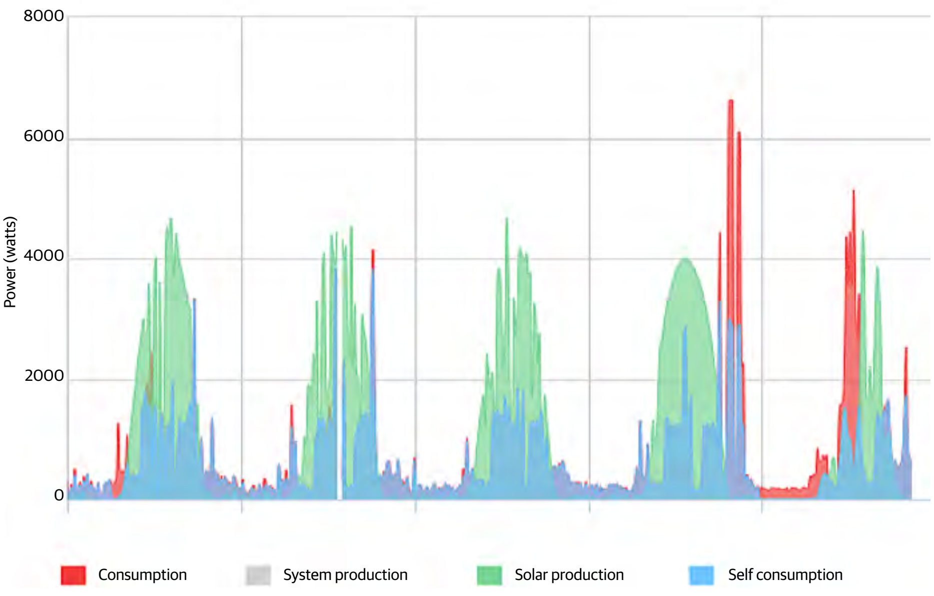
At this point, while asleep, the house typically uses between 100 to 200 W continuously as the fridge cycles up and down and a few devices are on standby—or about 1.2 to 1.5 kWh between 11 pm and 7 am. This allows a full Powerwall at sundown to get us through to breakfast fairly regularly, though not always.

High-draw power usage

One spanner in the works is irregular high-draw activity, like using the oven to bake dinner. While we have gas hot water and a gas cooktop, the electric oven is a major drain for baking or roasting. I have observed the Powerwall's stated 3.3 kW maximum flow during these times, as both oven and other devices are pushing the battery to its limits.

With the Powerwall having a capacity

→ Sample chart from the SolarEdge web software—note red consumption spikes from the ducted air conditioner, but that most consumption is supplied from the solar or battery.



of 6.4 kWh when full, this kind of power usage will deplete it rapidly. Typically these peak usage events don't tend to last long, and you can't say no to a good roast!

The ducted air conditioner is reverse-cycle, so is also used for heating. The power consumption in winter is similar to summer, and we've found we start to import electricity when we're using it as the ducted system pushes household power above the 5 kW limit of the inverter.

This is a key thing to note: generally your inverter will not be able to contribute more power from the solar PV or storage than its stated capacity, even if the sun is out and the battery is full. Ensure you research your inverter to identify what this maximum output capacity is.

Where to turn when the battery is depleted?

This is where Reposit comes in for tariff arbitrage. If you can access off-peak energy to charge the battery overnight, irregular events such as using the oven can be catered for through a combination of cheaper shoulder rates once the peak period is over, and use of smarter import/export of energy via Reposit.

Historically, we have always been on a flat electricity tariff, mainly because we've never bothered to look into off-peak options. To get access to the necessary time-of-use and GridCredits tariff, we required a newer, better meter than the basic one installed back in February.

The first GridCredits event has already happened, with Diamond Energy offering a very generous $1 per kWh to consumers on their current plan. Projects like GridCredits could mean that energy networks use consumer-level storage to offset the cost of building new generation or delivery infrastructure.

With that kind of relationship on the horizon, why would anyone want to be off-grid? There is a chance for everyone to contribute, be paid fairly and allow the network to smooth the peaks and troughs.

If there is one major lesson so far, it is that knowledge equals power (pardon the pun). What we learnt, even in the first month, is that the data you collect on yourself can aid you in becoming more efficient. You can push a good solar PV system to the next level with load-shifting, using those precious photons in the evening rather than just when the sun is out.

For us, the financial numbers have proved good enough to get into a home storage system, and start to see benefits straight away; it isn't all tied up in cents per kilowatt-hour on battery purchase price. This is especially true for a lot of people in NSW, who are about to see their gross feed-in tariff scheme come to an

A bit more on Reposit: optimising battery charge and discharge

Reposit is a home energy management system designed to maximise the value of a household's battery. A Reposit 'box' is connected to the battery inverter and communicates directly with Reposit's software online. Reposit learns the household's consumption patterns over time and will charge the battery from either the solar PV system or from the grid during off-peak periods.

The software makes decisions on the optimal time to charge the battery based on weather forecasts, expected PV generation, market energy tariffs and the forecast household consumption. In this way, the battery is always charged from the cheapest available source in anticipation of the expected demand from the household. If sunny weather is expected, then Reposit will charge the battery from the solar PV system. If cloudy weather is expected, Reposit will supplement the PV charge with off-peak electricity.

Reposit's app also allows the customer to view the expected consumption levels for the next day allowing them to track the accuracy of Reposit's forecasts. Variations between forecasts and actual generation/consumption are factored into future forecasting calculations, helping to improve the software's accuracy.

During periods of high demand on the network or excessive wholesale prices, Reposit allows electricity retailers to draw on the home's battery to supplement network supply. As compensation for this access, the householder earns a generous payment, known as a GridCredit. There are currently two retail providers who have entered into an agreement with Reposit to provide GridCredits: Diamond Energy and Powershop. By signing up to a GridCredits plan with one of these retailers, the homeowner is giving the retailer authority to draw on the battery. Reposit ensures that the battery only responds when it makes financial sense for the customer.

end, and are looking at options to keep running costs low.

At this point, six months into ownership of a solar PV system with Powerwall and Reposit Power, we are very happy. We made an investment in our property value, reduced immediate running costs and made a dent in our carbon footprint. The addition of time-of-use tariffs will enable Reposit to give us even more benefit, and possibly then reduce that payback time further.

Now I just need to find a way around that ducted air conditioner... ■

Nick blogs about his Powerwall journey at www.unleashthepowerwall.com

Editor's note: Nick's bill savings are due to the combined effects of solar panels, battery, switching grid tariff, energy efficiency measures and changed behaviour. Based on previous ATA modelling. Nick's battery is probably contributing a relatively small proportion of these savings while representing a large portion of the system cost. Nick's analysis shows around 25% of the savings came from the batteries, 50% from solar PV, 15% from behaviour changes and 10% from change of retailer, though he notes the last two percentages are approximate as he didn't previously have something as accurate as Reposit tracking his usage. Until battery prices fall further, we are recommending their uptake by early adopters such as Nick, rather than people looking purely for economic benefits.

	2015 autumn quarter	2016 autumn quarter	% change
Daily usage (average)	17.95kWh	14.5kWh	19%
Import per day	17.95kWh	2.84kWh	84%
Export per day	0	8.55kWh	
Cost per kWh (ex GST)—pre discounts	$0.236	$0.193	18%
Supply charge (ex GST)—pre discounts	$0.776	$0.749	3%
FiT per kWh	0	$0.08	
FiT paid per day (average)	0	$0.684	
Cost per day (average, inc discounts & FiT)	**$4.95**	**$0.59**	**88%**

Table 1: Electricity bill cost per day pre and post installation of the solar + battery system. As Nick notes, a significant part of the savings (approx 75%) come from solar, behaviour change and lower rates with a new retailer. Figures are shown as daily averages for the two bills as the bills cover a different number of days.

FIRST PUBLISHED IN RENEW 131

NOT JUST TRANSPORT

YOUR EV'S OTHER LIFE

Electric vehicle by day, powering your home by night? Kristian Handberg explains how EVs could help in the energy storage equation.

FOR THOSE WITH SOLAR PV SYSTEMS getting paid next to nothing for their surplus generation, the day is fast approaching when they might store this energy for later use. But should they use a stationary battery or an electric vehicle?

The situation for stationary batteries is changing rapidly. Battery costs are coming down and electricity market rules are changing to accommodate new business models for energy sellers who use storage[1]. Solar homeowners may soon be offered energy supply agreements that include a battery located on their property but owned and operated by their electricity retailer[2]. Homeowners will see the benefits via reduced electricity costs and supply agreements that avoid the complexity and risk of owning and operating a grid-connected energy storage system.

Right now, however, solar homeowners must deal with these challenges themselves. High upfront costs and long paybacks, risks associated with new technology and warranty commitments, and complicated energy management strategies are all reasons to delay on battery investment or look for alternatives.

One of these alternatives may be to use an electric vehicle as storage—if an electric car works for your transport needs, why not also use it to get better value from your solar investment.

While vehicle charging can be managed in line with solar production, at present there are no electric cars in the Australian

Photo: Evan Krape/*LA Times*

↑ The future is now…a fleet of Mini-Es being used by the University of Delaware to supply power back into the grid when it's needed most.

market that allow charge to be extracted for other uses. Equipment is sold in Japan that allows emergency backup power to be obtained directly from the vehicle (see box on this page), along with vehicle-to-home (V2H) charging solutions that can provide backup and solar PV optimisation. Combining a standard charger with a bi-directional inverter (supporting both the vehicle charging and discharging) and an energy management controller, these V2H systems currently cost around $1000/kW (or around $4000 for a 16A V2H unit, as compared to $500-$1000 for a standard 16 A charger).

These costs can be expected to decrease as the technology improves and the plug-in vehicle market grows. Driven by these changes and the results of trials currently underway, the analysts Navigant are forecasting that V2X-enabled vehicles (vehicles which support discharging activities) will be launched internationally in 2016 alongside improved V2H systems3.

As the technology evolves, there will be opportunities for householders, within the context of wider considerations.

The first issue relates to when and how the car is used for transport, as this determines when it will be available for charging (and discharging). For those who want to know more, create a travel diary to get a better understanding of your vehicle movements/availability before making any significant investments.

For electric cars parked mostly at home during the day, surplus solar generation may be preferentially directed towards the vehicle at a saving compared to charging using grid-sourced energy. Integrated EV charging/home energy management technologies are emerging4 that can deliver this outcome in line with user preferences. With a travel diary and net metering data (available from your energy provider), it's possible to investigate how surplus solar PV generation would likely match the vehicle availability for charging, before another dollar gets spent.

For cars parked mostly at work during the day, there may be an opportunity to make use of surplus solar generation at the location where the vehicle is parked (for example, your employer). And should charging use grid energy, electricity costs are still likely to be lower for workplaces than they are for most households.

Once it is also possible to extract charge from the vehicle, drivers with workplace charging are best positioned to benefit. For the average Victorian who drives 35 km per day[5], existing plug-in vehicles with a range of around 120 km could be charged at work, driven home, discharged to support overnight household electricity demand, driven back to work, and charged again. Workplace charging is currently free for drivers in advanced markets such as California[6], although arrangements will continue to evolve as EVs become more popular.

The bigger picture for vehicles-as-storage relates to their role in supporting the grid. For homeowners this is evolving out of their participation in electricity demand management programs[7], suggesting that charging management services will one day be offered as part of energy supply agreements.

As reforms to the Australian electricity market increasingly promote demand-side participation[8], the foundation will be in place for electric vehicle drivers to be paid to manage their charging in line with network needs (otherwise known as 'smart charging', see box next page). These changes are likely to unfold in parallel with the advent of V2X-enabled vehicles, suggesting that EVs might be used as grid storage in Australia by 2020.

To overcome the uncertainty related to the competing uses of the vehicles as transport and storage, energy service providers will use 'big data' methods to aggregate vehicles and participate in the wholesale electricity market. Owners will make decisions on their vehicle use that reflect financial incentives for agreeing to managed charging and discharging.

So for those looking to invest right now in home energy storage as either a battery or electric vehicle, the costs and risks are high and the choices are few. But as our electricity market rules continue to evolve, the situation will change rapidly through the efforts of energy providers—old and new. While the choice between stationary and vehicle storage options will need to take into account individual circumstances, we're well on the road to electric cars playing a significant role in a more sustainable energy future. ■

Kristian Handberg is a principal consultant with Melbourne-based cleantech start-up Percepscion. From 2010 to 2013 he designed and delivered the Victorian Electric Vehicle Trial.

EVs for emergency power

In the event of a wider network failure, the storage capacity of electric vehicles could potentially provide emergency power for several days. This valuable application of electric vehicles as storage came to prominence in the aftermath of Japan's Sendai earthquake in 2011.

In its simplest form, the use of EVs as a source of emergency backup power can be achieved through devices that allow electricity to be supplied directly from a vehicle to small appliances, such as lighting or mobile phone chargers. This equipment converts the DC charge from the vehicle into a usable, if small, AC power supply approximating mains electricity independent from a hard-wired electricity network.

While Nissan and Mitsubishi have been offering this equipment to Japanese EV owners for some time, the technology is not currently offered for sale in Australia. Based on the lessons from the US market, it may be left to after-market equipment providers to help realise this potentially life-saving benefit of EV ownership.

Photo: Mitsubishi Motors

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Photo: Masami Morita, www.yuruyakana.com

← Nissan's Leaf-to-Home bi-directional charging system is capable of supplying up to 6 kW of AC power drawn from the Leaf's 24 kWh battery. This system is currently available for Japanese EV drivers at a cost of around $5000 before a government rebate (which effectively halves the purchase price).

Smart charging: an alternative path developing

While we can hope, as Kristian suggests in his article, to be able to use EV batteries to power our homes and contribute energy to the grid in the not-too-distant future, a related technology that may happen sooner is that of 'smart charging'.

With smart charging of an EV, utilities can control the rate at which they charge and the load they're drawing on the grid, so they can make them draw more or less load when it's desirable, e.g. to avoid peak demand times.

Dr Andrew Simpson, who's worked as a research fellow at Curtin University's Sustainability Policy group, in R&D for Tesla and the US government, and now runs his own consultancy focusing on EV policy and strategy (www.verdantvisiongroup.com), says, "While smart charging is achievable with onboard computers that vehicles already have, what's lacking is the way the vehicle can talk to the smart meter or utility directly to provide that control. This interface is what's being trialled now by the largest utilities and car companies overseas."

As outlined in an article by Marcus Brazil and Julian de Hoog in *ReNew 129*, even modest uptake of EVs in Australia (say 10%) could cause a number of issues for the grid (peak demand, voltage drop and phase unbalance), and it makes sense to put measures in place to prevent these problems occurring. Smart charging is a key to addressing all these issues, as it would mean EV charging could be activated remotely in off-peak times such as overnight, rather than at times when households are already drawing maximum energy from the grid. Shifting to this model means existing grid infrastructure can absorb increasing uptake of EVs for some time, without the need for additional investment.

Testament to the emergence of this demand-side management model has recently come in the form of a large-scale trial by San Diego Gas & Electric (SDG&E) (as reported in *T&D World* magazine, 24 Feb), in bidding a group of energy storage systems and EV fleets directly into the Californian energy markets. These markets include those that address short-term imbalances in electricity supply caused by such things as intermittent renewable energy. The EV fleets and the distributed storage systems are remotely controlled using software that both balances the cars' charging needs and identifies opportunities to provide demand response services at the grid level.

The pilot project finishes at the end of this year, and with 13,000 EVs currently on the road in SDG&E's service territory and 1.5 million zero-emission vehicles in California estimated by 2025, it's undoubtedly an important testing of the 'smart charging' waters.

For something more local, Andrew Simpson has a simple version of smart charging in operation at his home in Brisbane. Energex has residential controlled-load tariffs to time the operation of hot water systems to best suit the electricity network's needs (avoiding peak, improving grid utilisation at night)—and they've also applied this to Andrew's (and others') EV. His charging circuit is enabled/disabled by Energex: "It is switched off occasionally between 6.30–8.30am and 4.30–8.30pm on weekdays, but in practice it's available most of the time." It's a win-win: they get a cheap rate to charge their EV and Energex gets demand-response to help manage their network constraints.

OFF-GRID IN THE SUBURBS

EV POWER TO THE HOME

One *ReNew* reader has used his electric vehicle to take most of his energy consumption off-grid. He explains how he did it.

I WAS KEEN TO INCREASE THE SIZE of my PV system as my house was using more energy than the system produced in winter. This meant I was importing energy from the grid at 29 c/kWh (100% GreenPower, I hasten to add!).

I was also keen to experiment with going off-grid. I considered going completely off-grid, but that would mean losing the perceived reliability of supply from the grid, requiring a leap of faith for a suburban consumer like me.

Off-grid economics

My solution, instead, was to install a separate off-grid PV system. I now have two PV arrays with separate inverters, one connected to the grid and one off-grid, with the house running (mainly) on the off-grid system.

The idea of going off-grid with battery systems was featured in ReNew 128. One article suggested that price parity with a grid connection is yet to arrive, particularly in metropolitan areas, as PV may now be cheap but batteries are still expensive.

However, I already had a good-sized (8 kWh) lithium ion battery in my plug-in Prius conversion. I was able to use this battery for my off-grid system, with it providing around 6 kWh storage at 75% depth of discharge. So, even though I live in metro Melbourne, the economics worked out well for me.

Technology needed

My system required some technology: I

purchased a 4 kVA Ecotronics unit from Commodore Australia that does it all. It is a MPPT (maximum power point tracking) PV controller, battery charger, AC inverter and grid UPS all in one (see Products, this issue).

It is designed to run off a 48 volt battery, the same as my Prius PHEV conversion system battery. The conversion system, from Enginer in the USA, uses a 48 volt battery and a DC-DC converter to step the voltage up for the Prius's drive system.

The Ecotronics unit can also automatically revert to grid power if there is not enough sun or the battery is low. It can even be set up for load levelling—i.e. charging the battery bank on night-rate mains power then supplying power during the day. However, with a relatively high night-rate tariff (19 c/kWh), the economics for this are marginal for me—a 10 c/kWh saving over the day rate of 29 c/kWh.

↑ This is the plug-in Prius conversion kit in the Prius's boot. On the left is the 48 volt mains battery charger and on the right is the 48 to 240 volt DC–DC converter, which takes power from the add-on battery (the large silver box underneath everything else) and steps it up to match the Prius's system voltage. Alan's home power system runs from the 48 V battery. The small box in the middle is the battery's management system.

The Ecotronics unit simply connects to the Prius conversion's 48 volt battery via a large Anderson connector (a high current rated two-pole connector popular in DC systems). When not running the house loads, the Prius battery can either be charged from the Ecotronics unit's built-in battery charger or the charger that came with the Prius conversion kit.

Powering the house

My total house load (house plus granny flat) is about 6 kWh per day. The larger loads are intermittent and flexible; the heat pump hot water system is around 1 kW (used only for winter boosting of my evacuated tube solar hot water system) and the PHEV charger is around 1.3 kW. I use a simple timer to ensure they don't run concurrently. This ensures most of the PV power is used directly when produced so that I don't need a larger house battery, and so I still have some PHEV battery for when I need to drive the car. The other high house loads include the microwave, water pump (we are off mains water), toaster, kettle etc.

The off-grid PV power is distributed to three points around the house: the kitchen for appliances, the heat pump hot water system and the lounge for computer and TV/DVD.

I've left the house lights on the grid as their consumption is negligible, although I have a lamp in the lounge running on the off-grid system for use when reading for extended periods. As most of the heavy loads are off-grid, the total grid load is quite small, mostly the lighting and a few small devices. Of course, any loads still on the grid are fed by the grid-connected PV system during the day, offsetting retail-priced grid power.

Cost

For me, this system was a cheap solution. Total cost was around $4500, which consisted of:

- 1.5 kW PV: $1600
- Ecotronics unit: $1700
- PV rack mounts/misc bits: $500
- electrician's fee: $600
- main battery: free!
- extension leads and power boards: $100.

This system works cost-wise for me because I didn't need to buy a battery: I already had the Prius battery, which was sufficient for my needs as I optimise using the PV-generated electricity as it is created.

I like this system so much I am considering adding another 1.5 kW of PV panels so that the system has the capacity to supply an induction cooker and heat pump space heater—the final hurdles to my house/flat going fossil-fuel free. I might also consider a larger battery which would be external to the Prius to help increase the life and reserve capacity of the PHEV kit battery.

Warnings

Please check with your energy retailer before upgrading or installing a new renewable energy system, as it may affect your eligibility for feed-in tariffs or your peak/off-peak rates. Tariffs and rates vary from state to state and also between distributors in each state—further research is required with your personal circumstances taken into account.

All mains wiring should be done by a qualified electrician to both ensure safety and compliance for home insurance.

When working with high DC voltages such as found in electric vehicles, safety precautions must be taken, including using insulated tools, removing all jewellery and disconnecting battery banks before doing work such as wiring changes. Never attempt to work on such systems unless you are sure you know how to work on them safely.

Vehicle-to-grid: coming soon?

Using EV and plug-in hybrid vehicle batteries to provide energy for homes is not a new idea—some EV enthusiasts have been doing it for years. However, doing it on a commercial scale is a more recent development.

A number of EV manufacturers have looked into using the batteries in their EVs to either provide backup power for the home or to provide energy storage for the mains grid for peak load levelling.

Nissan has been trialling their 'Leaf to Home' system in demand-response testing at several of its sales outlets to assess the effectiveness of EV batteries when used for energy management. During peak times, the Leaf batteries will be providing some of the energy for lighting the dealership showrooms, thus reducing grid load. In domestic situations, the goal is to use the EV's battery to provide some of the energy for the home during peak times. This reduces grid load without affecting the EV owner's energy use. See www.bit.ly/Leaf2Home

It's not just EV manufacturers investigating this technology. The University of Delaware has a vehicle-to-grid (V2G) research group that has developed technologies and policies to enable V2G systems. They ran a trial last year using 15 Mini Cooper EVs that had been fitted with V2G equipment. See www.udel.edu/V2G and http://nyti.ms/1vkd7OO.

Rocky Mountain Institute in Colorado has developed the Smart Garage concept involving the seamless integration of vehicles, homes and offices via the electric power grid. www.rmi.org/The+Smart+Garage+V2G

Photo: Evan Krape, University of Delaware

And the US military, who have a good understanding of the vulnerability of being locked into oil use, have just created the largest operational V2G project in the world, with Los Angeles Air Force Base to replace its entire general-purpose fleet with 42 electric vehicles, 36 of which will be V2G capable. www.bit.ly/LAAFBV2G

While there have been some concerns about reduced battery life caused by increased cycling of vehicle battery packs, the cycle depth in proposed V2G systems is quite shallow and is unlikely to significantly affect battery life.

The main advantage of V2G systems for the electrical distribution system is the reduction of peak loads (load levelling) and hence the potential elimination of fossil-fuel powered spinning reserve generators, with a corresponding reduction in generation emissions. Further, increased grid storage can invalidate the argument that intermittent energy sources such as wind and solar cannot provide baseload power.

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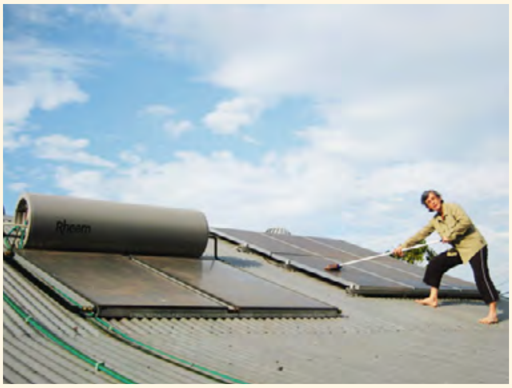

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#4
APPLIANCES & LIGHTING

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FIRST PUBLISHED IN RENEW 134

IT'S IN THE STARS

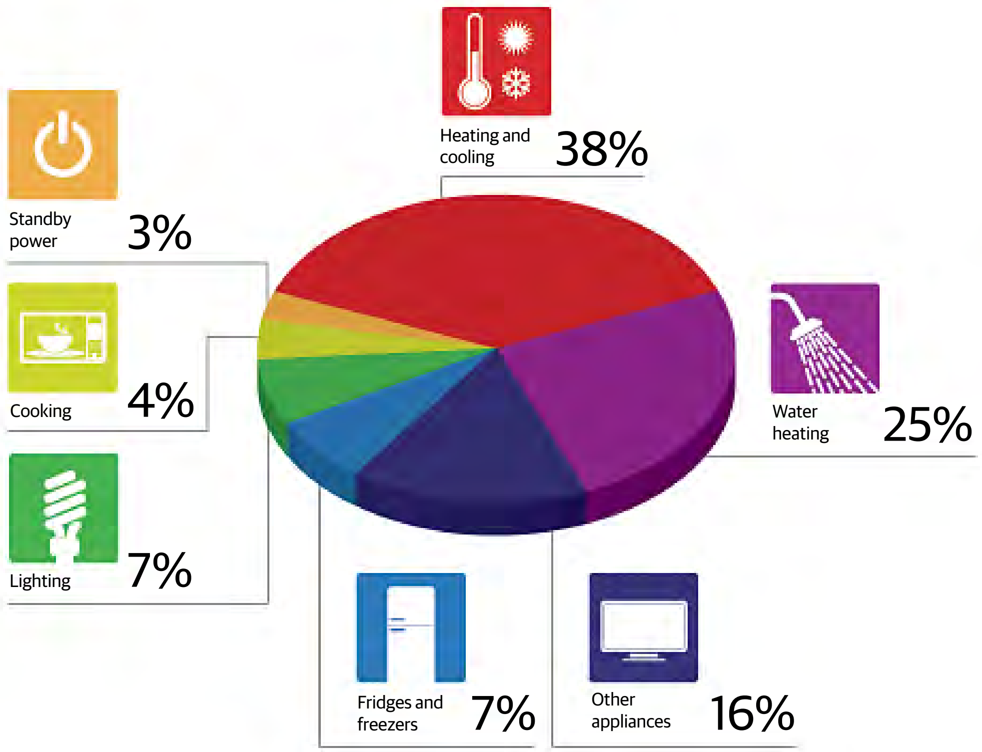
THE IMPORTANCE OF EFFICIENCY RATINGS

With household appliances the main contributors to a home's energy use, it makes sense to 'buy smart' and 'use smart'. Eva Matthews investigates how to achieve savings and help save the planet.

WHEN BUYING ANYTHING FOR THE home, the item's upfront cost, look and functionality are prime considerations. For some of these—furniture, for example—this is where the buck stops. But when it comes to 'big ticket' household items such as whitegoods, computers and home entertainment systems, heating/cooling units and hot water services, another element comes into the mix: ongoing running costs. Whether powered by electricity or gas, these costs accumulate over the life cycle of an appliance or system, and so the energy efficiency of these items becomes an important consideration in the purchasing decision. It's not just about the money, of course—greater energy use means greater greenhouse gas emissions.

Energy efficiency is determined not only by the inherent mechanics and technology of an item, but also by its location (in Australia, as well as within or around the home), its age, the use of its various features and its level of maintenance. Achieving the best energy efficiency, then, becomes a combination of buying the item that uses the least amount of energy to achieve the functionality you require, as well as operating it in a way that maintains optimal efficiency over its life cycle.

A 2008 Australian government study on residential energy trends forecast ongoing growth of around 5% per annum in appliance energy use. However, the latest study suggests consumption will be fairly flat: our appliance efficiency programs and other factors are working. But to maintain and improve on this trend we need to keep working to improve efficiency to offset population and economic growth.



↑ Figure 1. Breakdown of average household energy use for the whole of Australia, based on Baseline Energy Estimates 2008; percentages will differ by state/climate and fuel types. This graph includes all fuel types; note that electricity is under half of total household energy. An updated report has been released in 2015; heating and cooling has increased to 40%, water heating reduced to 23% and appliances (including fridges and freezers) increased to 25%.

Buying efficient appliances

So how do you buy energy-efficient appliances and then use them most efficiently?

Regulatory measures have been put in place to encourage manufacturers to improve the efficiency of the products they send to market, and to help consumers make the best choice to meet their needs. These are the Minimum Energy Performance Standards (MEPS)—which specify the minimum level of energy performance required of appliances, lighting and electrical equipment before they can be offered for sale or used commercially—and Energy Rating Labelling, which uses the 'Star' energy rating system to help consumers compare like products in terms of their energy efficiency.

Australia was among the first in the world to introduce mandatory energy rating labelling, pre-dated only by Canada (1978) and the USA (1980). It was introduced in Victoria and New South Wales in 1986, and a national scheme agreed to in 1992. However, it was only 15 years ago, in 2000, that it was fully legislated in each state and territory.

We are all familiar with Energy Rating Labels (ERLs)—the red 'rainbow' filled with stars, atop a yellow box, stuck to the front of a dishwasher, fridge or other major appliance. Indeed, a review of their effectiveness, completed in March 2014, reported that 97% of surveyed consumers recognise the ERL. Further, it noted that 62% use the ERL to research an appliance's energy use, and 80% use the information on the ERL to compare appliances when making their purchasing decision.

The key pieces of information on an ERL are the number of Stars (up to 10)—the more Stars, the more energy efficient the appliance—and the energy use of the appliance in kilowatt-hours (kWh) per year when tested to the relevant standard. The Stars give you a quick visual cue as to an appliance's energy efficiency, while the kWh rating gives more detail as to its actual average energy use. It's important to consider the energy use figures, rather than just the Stars alone, as the Star rating is a measure of 'efficiency' for a given sized appliance. Thus, a larger appliance may be given the same Star rating as a smaller version, but use more energy.

The website www.energyrating.gov.au and its associated mobile app can be used to calculate the running cost of various models of appliances across the categories included in the ERL program (air conditioners, clothes washers and dryers, fridges and freezers, dishwashers, computer monitors and televisions). You

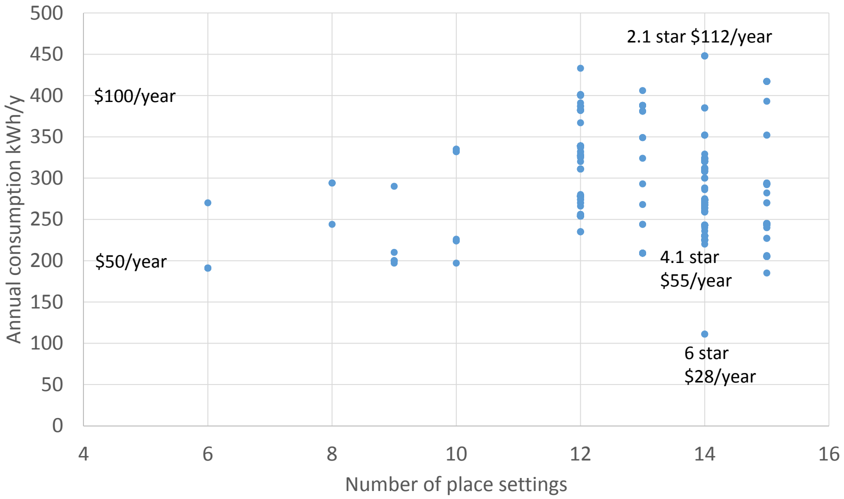


Figure 1: Dishwasher energy consumption. A 4 Star unit could save $60/year over a 2 Star. Units must meet a cleaning performance standard for the program used in the test, but may use more energy on other programs. Older dishwashers could use 900 kWh/year, costing over $200/year, so it's well worth testing yours with a power meter.

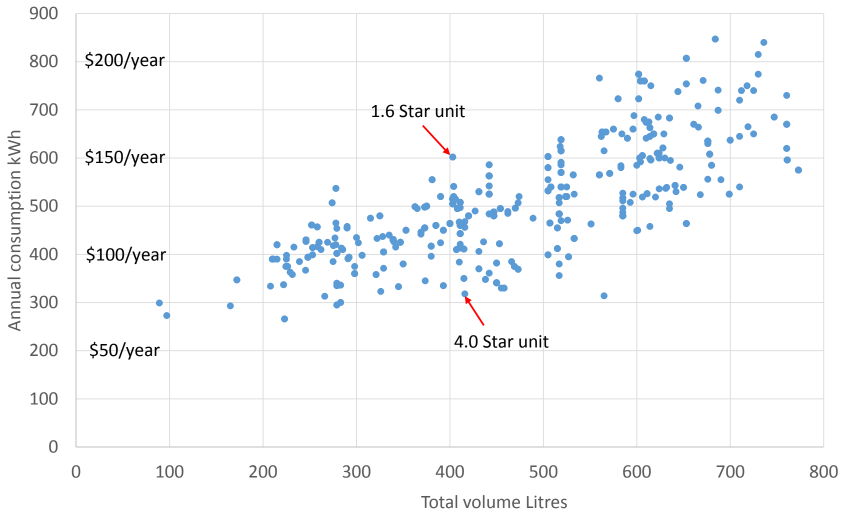


Figure 2: A 4 Star 420 L fridge would save $70/year compared with a 1.6 Star model; over a 15-year life that's over $1000 saving. A typical two-door early 1990s fridge used 1100 kWh or around $275/year, and many older fridges are faulty, using up to three times their rated energy, so, as for dishwashers, it pays to check yours.

can select the models you're considering purchasing, key in your electricity cost and choose the likely life cycle of the appliance, and the yearly running costs are calculated for you, allowing you to make an easy comparison between the models (noting that actual cost will vary per household, depending on how and where you use the appliance).

The Energy Ratings website also includes a list of all models of a particular appliance type with their Star ratings, which can be useful as a starting point to find the best options available; access it by the button 'Registration database' on the website's home page.

There are numerous other sites hosted by energy retailers and suppliers, and state governments, that have online running cost calculators for appliances in the ERL program, as well as lighting, heaters, hot water services, pool pumps and small appliances. For example, see www.smarterchoicecalculator.com.au and www.switchon.vic.gov.au. These all vary slightly in terms of the data they're based on, the search/input options they provide and what information they require from you, so it's worth checking them out. The good thing about these is that they allow you to key in your specific frequency of use, which can give a more realistic running cost for your household. If you're a subscriber to Choice (www.choice.com.au), or have access to a library that subscribes, you can also get standard life cycle running costs for various models of the appliances they've tested, alongside the features and specifications, to help you with your purchasing research.

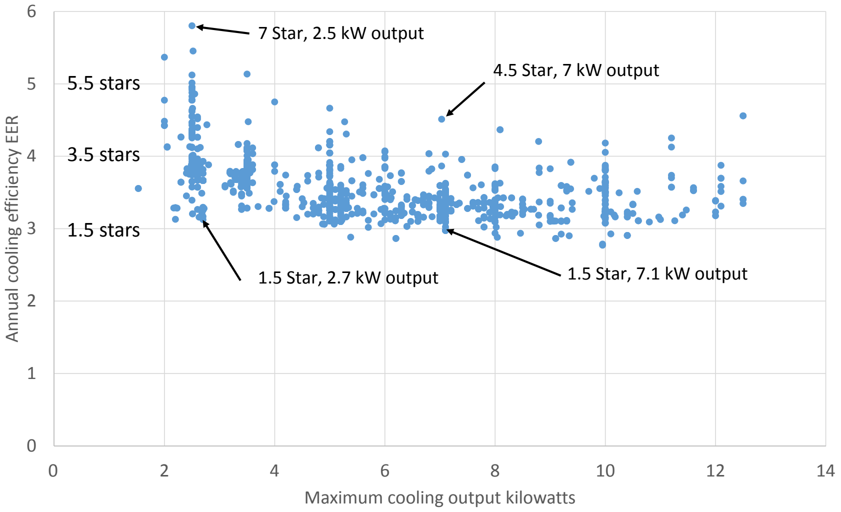
Another useful calculator is the EPA greenhouse calculator (www.epa.vic.gov.au/agc/home.html), which allows you to compare behaviour and installation factors as well as equipment energy efficiency. It only reports greenhouse gas emissions, not running costs, but you can convert as described in the Assumptions link on the home page.

It seems sometimes that the more energy efficient an appliance is the more it costs up front and this may, at first glance, dissuade you from buying it. However, when you take into account the life cycle running costs, you may find that (with the money you'd save over the long term) it's worth paying a little more up front for the more efficient model. And, even for appliances at similar, middle-range purchase prices, there can be big differences in energy running costs, so it pays to do your homework. For example, see Figures 1, 2 and 3 for the performance ranges for air conditioners, fridges and dishwashers. As you can see, selection of size also matters!

Operating appliances efficiently

While ERL information and running cost calculators can help you 'buy smart', you can also optimise the efficiency of the appliances you own by the way you operate them.

There are a number of factors that affect how efficiently an appliance will run. Some are common to all, and some specific to particular types. Common ones include its age, how well and often it's serviced, what time it's used,



↑ Figure 4: The majority of reverse-cycle air conditioners have an energy efficiency rating (EER) of 3 to 4 for cooling—for 1 unit of energy used, 3 or 4 units of cooling are produced. However, there are outliers, now reaching 5 to 6 EER, e.g. a 7 Star unit (EER 6), with 2.5 kW output and max running cost 11 cents/hour; an equivalent 1.5 Star unit (EER 3), with 2.7 kW output has a max running cost of 22 cents/hour. There's also a 4.5 Star unit, 7 kW output, with a max running cost of 39 cents/hour, compared to a 1.5 Star 7.1 kW unit, max running cost 60 cents/hour.

Image: www.energyrating.gov.au

↑ Most products have a label with a maximum of 6 Stars. The labels on televisions, refrigerators and air conditioners, though, can show a maximum of 10 Stars. The scales were tightened in 2010; what was 5 Star then is now 3 Star. Remember to check the energy consumption as larger appliances can have the same Star rating as smaller ones, but will use more energy.

which features are utilised and how much air is able to flow around it. For air conditioners, location within/around the house and whether it's in the tropics or in colder regions make a difference. Air conditioners or heaters will be affected by a home's design, draughtproofing and insulation. Some of these factors may be beyond your control—for instance, you may be renting and therefore can't do anything about the home's insulation—but there is still a lot you can control to make sure your appliances operate most efficiently. The box at the end of the article lists some of the key tips. The same websites that have the 'running cost calculators' also include further handy hints for using appliances wisely, as do www.yourhome.gov.au, www.yourenergysavings.gov.au and www.sustainability.vic.gov.au.

A word on standby power

Leaving appliances on when they're not being used can account for up to 10% of household electricity usage. This is not insubstantial! A microwave oven, for example, can use more energy in standby mode—powering the clock display—than it does to cook/heat food over the course of a year. So, 'running appliances efficiently' is also about considering when they can/should be turned off (an EcoSwitch, see p.82, can help with this). As noted in the latest Residential Energy Baseline Study: Australia, August 2015 (www.energyrating.gov.au/document/report-residential-baseline-study-australia-2000-2030), standby power has been dropping for new appliances, but it can still be significant.

Replacing old appliances

Even assuming you do everything you can to operate your appliances efficiently, in some cases the best thing you can do—for your hip pocket and the environment—is to replace old with new. In general, the older the appliance, the less efficient it will be and the more it will cost to run. Even though you'll need to outlay substantial cash to buy a new unit, the savings you'll make from cheaper running costs will go a long way to offsetting the changeover cost.

For example, if you have a 15-year-old fridge, it probably has five years before it will need to be replaced. Conservatively, it is likely to cost you $100/year more to run this fridge than a new, efficient model. So, you could put the $500 you'd save over that time towards a new fridge now, and also enjoy the extra features it will offer over the old one. (See sidebar for how you can calculate the actual energy use of your existing appliances, and therefore get an accurate picture of likely savings.)

And when you are ready to get rid of an old appliance, dispose of it thoughtfully—talk to your local council about recycling programs in your area. Planet Ark's website www.recyclingnearyou.com.au also has a useful search function that provides a list and contact details of recyclers in your area (including council waste transfer stations, scrap metal businesses and charities). ■

Eva Matthews is a professional writer and editor who, when she's not semi-regularly contributing to *ReNew*, is busy building her sustainable home in the Yarra Valley.

This article is based on a 2015 Powerpoint presentation by Alan Pears, with permission.

Find out what to consider when buying and using an appliance on the following pages.

Considerations when buying and using appliances

Air conditioners for heating & cooling

When purchasing:

- Aim for at least 4 Stars, although Star rating does tend to decrease as size goes up; small to medium 6 or 7 Star units are now available
- Size appropriately for the area you are aiming to heat/cool—considerations include room size; your home's insulation and external wall materials; number and size of windows and their shading/orientation; www.fairair.com.au can help you estimate the capacity you need for cooling based on these parameters; 'A tale of two heaters' in *ReNew 133* has a discussion of sizing issues
- Consider whether the whole house, or just individual rooms, need heating or cooling; central heating/cooling may waste a lot of energy heating/cooling rooms that aren't in use, so consider whether you really need it, or at least purchase a well-zoned system
- Location, location—where you live in Australia (and therefore the climate) will determine both the best type of air conditioner for cooling (evaporative or heat pump) and also how well it will operate; in cooler climates, some units' capacity declines and smaller units may not be able to heat your home as effectively as in warmer regions; a regional label is currently being worked on to help with this
- See 'Towards guilt-free cooling' in *ReNew 122* for more discussion of cooling options

Operating:

- Install external components on the shady side of the home (or create shade, while also ensuring adequate air flow)
- Clear the air filter regularly so the fan doesn't have to work too hard
- You can set the thermostat 2–3 °C higher in summer if you also run a ceiling fan, saving around 20% energy; in general, set the thermostat at 18–20 °C in winter, and 25–27 °C in summer
- If possible, improve the home's insulation and seal draughts to improve heating and cooling efficiency
- Only heat/cool the rooms being used, keep doors closed and turn off when the room is not in use for any length of time
- When heating, close curtains at night
- In winter, wear warm clothes so the thermostat can be set lower
- If you have solar, see 'Pre-cooling your home' in *ReNew 130* for pros and cons of turning on your air conditioner before you get home.

Other types of heaters

When purchasing:

- Choosing the right heating solution for your home can be a complex matter; see the 'heating and cooling' pages on www.yourhome.gov.au for guidance and the article 'Winter comfort: not just a heater choice' in *ReNew 127*

Operating:

- Ensure ducts and pipes are adequately insulated to minimise heat loss
- Regularly clean any air intakes, outlets and filters to remove dust.

Fridges/freezers

When purchasing:

- Select preferred size range (don't go bigger than what you actually need) then use kWh data to compare—and look for inverter models (with variable-speed compressors)
- Avoid LPG/electric multi-fuel fridges and 'thermo-electric' coolers—they cost a lot to run
- Units with the freezer on top are generally more efficient than those with a freezer at the bottom

Operating:

- Position away from direct sunlight and other heat sources (oven, dishwasher, heater)
- Set fridge to 3–4 °C, and freezer to -15 to -18 °C (every degree lower uses 5% more energy)
- Provide at least 75 mm around top, back and sides to allow air flow; restricting ventilation can add 15% to running costs
- Keep the door closed as much as possible, and check/replace damaged seals to prevent cold air escaping
- Keep coils at the back of the fridge dust-free as dust acts as an insulator and works the unit harder.

Dishwashers

When purchasing:

- These can last for more than 10 years, so buy the most efficient model you can afford; at least 3.5 Stars for energy and water consumption; every extra Star will save you another 30% on running costs
- Models with 'eco' options can save 30% on running costs
- Models with delay-start option mean you can make use of off-peak electricity tariffs, or time use with solar generation

Operating:

- Wash only full loads as much as possible
- Keep filters clean
- Scrape dishes clean rather than rinsing under the tap first—running the tap for 2–3 minutes can use the same amount of water as a dishwash cycle

Washing machines

When purchasing:

- Look for at least 3.5 Stars for energy and 4 Stars for water consumption
- Front loaders generally use about 50% less energy than top loaders (though some top loaders may be just as efficient if using cold water—check the ERL for 'cold wash' energy-use figures)
- Choose models with automatic load-sensing technology if possible and delay-start to make use of off-peak tariffs or solar generation

Operating:

- Modern machines and detergents can wash well with cold water (dissolve powder detergents first to improve performance); warm washes can use 10 times more energy

- Wash full loads as much as possible
- Adjust water levels to suit the load size if you don't have auto load sensing.

Dryers

When purchasing:

- Look for at least 2 Stars
- Consider heat-pump dryers, as these are 50—66% more efficient than standard dryers; they're more expensive to buy, but frequent users will benefit from reduced running costs
- Auto-sensing models adjust drying time as suits the load; they don't just keep drying until a timer stops
- Unvented dryers can be a major source of moisture that causes condensation and mould growth

Operating:

- Clean filters after every load
- Don't overload, and don't mix heavy and lightweight items
- Use the clothes line as much as possible!
- Use in conjunction with washers that have high spin speeds (usually front loaders), as these leave clothes drier to start with.

Televisions

When purchasing:

- Look for at least 5 Stars
- OLED and LED backlit LCD TVs are more efficient than plasma sets
- The larger the screen, the more energy it uses (for a given technology)—consider what size you really need

Operating:

- Consider watching programs on your tablet or laptop when possible—these use far less power than the average-sized TV (60–100W for a 40"; 100–150W for 50")
- Turn off when you're not watching; with older sets, turn off at the powerpoint as standby modes for older TVs use much more power than newer models
- Reducing screen brightness can cut power use by 20%.

Computers

When purchasing:

- The larger the monitor, the more energy it uses; these now have energy labels and there can be big differences
- Consider tablet (1–4 W)/laptop (5–45 W) over desktop (30–250 W, but typically over 80 W)

Operating:

- Turn monitors off when not in use—screen savers still draw considerable power
- Turn computers and related equipment off at the power point (using a power-saving board/controller can make this an easy one-click operation, or even do it automatically)—TVs and IT account for 60% of household standby use.

Lights

When purchasing:

- Consider alternatives to minimise use of lights during the day—light tubes/shelves or glass bricks; the upfront cost of these will be offset by energy savings
- Go for task lighting (e.g. reading or table lamp) rather than overall lighting where possible
- Choose fittings/shades that let much of the light through, so lower wattage is required
- LEDs can be more expensive to buy than halogens (though their costs are falling), but they last 5–10 times longer and only use 10–20% of the energy
- Avoid recessed downlights if possible, as they compromise your insulation; even LED downlights require some ventilation, which reduces the building's energy efficiency or requires the purchase of downlight 'mitts' to allow the required airflow; pendants or tubes cast the most light, so fewer are needed and they also don't compromise your insulation
- See the 'LED Buyers Guide' in *ReNew 133*

Operating:

- Turn off when not in use
- Dimming lights saves energy; if you dim most of the time, consider installing lower-wattage lighting.

Ovens and cooktops

When purchasing:

- Fan-forced, double- or triple-glazed and well-insulated ovens are most efficient
- Induction cooktops are about 25–30% more energy-efficient than standard electric, and 30% more efficient than gas
- Electric ovens are roughly twice as energy-efficient as gas ovens

Operating:

- Check/replace damaged oven door seals
- Don't pre-heat unnecessarily; keep lids on pots and oven door closed as much as possible
- Reheat food with a microwave
- Consider investing in a thermal cooker such as the Billyboil, used in conjunction with your cooktop but allowing you to save up to 80% on cooking energy usage.

Hot water systems

When purchasing:

- Solar hot water and heat pump systems are efficient choices, but choose the right system for your climate, household size and usage patterns; Compare climate applicability by checking the number of STCs per system in your climate zone at www.bit.ly/hotwaterSTCs; higher is better
- see 'Efficient Hot Water Buyers Guide' in *ReNew 129*

Operating:

- Ensure pipes/fittings are well insulated
- Set temperatures to no higher than required (60 °C for storage types, to prevent growth of Legionella bacteria; 50 °C for continuous flow types)
- Use less hot water, e.g. fit water-efficient showerheads or flow limiters, take shorter showers, leave mixer taps in the cold water position
- Service according to manufacturer instructions.

FIRST PUBLISHED IN RENEW 130

IT'S HEATING UP

ENERGY EFFICIENT COOKING

What do you need to consider when looking at the energy and environmental aspects of cooking? Alan Pears begins the discussion.

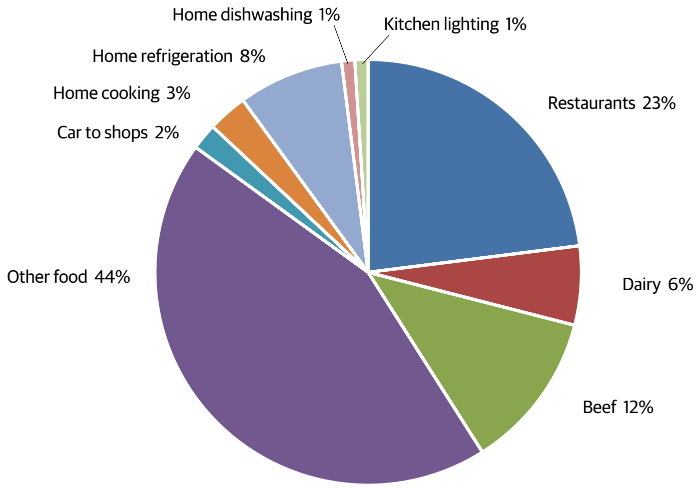
IN ENERGY AND ENVIRONMENTAL terms, cooking is just one part of a complex system in the food supply chain. The food system accounts for around 25% of greenhouse gas emissions in Australia. Of that, cooking is a small part, about 3% (see Chart 1). The other factors such as the production, transport, sourcing and types of ingredients are major issues that we don't have space to tackle here.

Even though energy use from cooking is a relatively small portion of food-related energy use, it can still be significant. An average Australian home uses around 600 kilowatt-hours (kWh) of electricity each year for all-electric cooking (costing $150 or more), while gas cooking typically uses 3 to 5 gigajoules (GJ), costing $60 to $250 depending on usage and gas price. Many homes use a gas cooktop and electric oven. Most homes also have several benchtop cooking units such as microwave ovens, toasters, electric kettles and rice cookers.

Energy use for cooking is particularly an issue for households that are off-grid. Many off-grid homes use gas for cooking rather than electricity (because of the high loads from electric cooking appliances), yet this still has a greenhouse gas impact, and can be expensive when it's LPG rather than natural gas.

Electric cooking can also be a major contributor to evening peak electricity demand. As electricity suppliers introduce time-of-use pricing or peak demand charges, it will be important to manage cooking demand. Gas prices are also increasing, while LPG is already very expensive.

So energy-efficient cooking and reduction of peak energy demand for cooking are important. This article looks at these issues.



Restaurants, dairy, beef and 'other food' include all emissions from supply chain up to point of retail sale.
'Other food' includes all other food such as vegetables, processed foods etc.
'Car to shops' calculation assumes 8 km/person/week at 10 L/100 km.

Lighting calculation assumes 200 watts of lights for 3 hours/day.

↑ The Flare Pan range from Lakeland in the UK feature fins to increase the surface area of the pot which improves heat absorbtion on a gas cooktop by up to 40%.

Where is energy wasted in cooking?

As with all energy efficiency analysis, standby energy use can be an issue. The way you heat up (or defrost) food can also affect energy use, as does the way you manage cooking post the 'heating up' phase. And then, the appliances themselves (such as ovens, grillers etc) all have their own efficiencies and optimal usage patterns.

The energy use of kitchen lighting and non-cooking appliances (fridges and dishwashers) should also be considered, but they have been well covered elsewhere so won't be discussed here. But, just as an example, lighting a kitchen with six halogen lamps for two hours a day uses half as much electricity as cooking.

Standby energy

Luckily, gas cookers no longer have pilot lights that cost a lot to run. But many cooking appliances use energy when on standby for clocks, 'smart' features, electronics and in some cases keeping components hot, ready for action. Standby consumption is declining, but older equipment and even some new products, such as coffee makers (see 'Check your coffee machine'), can have surprisingly high standby consumption.

A good rule of thumb: if you're not confident an appliance has standby power under 1 watt, switch it off at the power point.

Heating up

Heating things up from room temperature or, even more significantly, from below freezing point, can constitute a large proportion of cooking energy. To heat a kilogram of food on a cooktop from room temperature to 100 °C requires around 0.85MJ of gas or 0.15 kWh of electricity. An empty pot or casserole dish weighs from one half to two kilograms. Heating up a one kilogram frying pan can require a third as much heat as defrosting that amount of food. Heating up a pot or frying pan without a lid also dramatically increases energy costs, as air is heated, then rises to be replaced by more cold air: effectively you are cooling the pot while trying to heat it.

Boiling off water uses nearly seven times as much energy as heating it from room temperature to boiling point: evaporating a litre of water when cooking uses around one kilowatt-hour of electricity. To minimise this waste, use minimum water, put lids on pots, and simmer gently instead of boiling.

See Table 1 for a summary of energy use for all these key cooking activities.

Defrosting

Defrosting food can be energy-intensive. To defrost a kilogram of food requires as much energy as to heat it up by around 70 °C! Defrosting in a microwave oven or using a gas or induction cooktop is cheaper than defrosting on a standard electric hotplate or in an oven, but defrosting in the fridge is by far the best strategy. Not only does this save defrosting energy, but the 'coolth' from the defrosting food provides free cooling to cut fridge running costs. Cooking frozen food in an oven can also double cooking time and increase the health risk if the centre of the food is inadequately heated.

Steady state heat losses

Once the food, its container and the appliance are heated, the rate of heat input can be reduced, as only the steady state heat losses must be replaced. One study measured the heat losses from a saucepan with lid on at around 70 watts: after adjusting for hotplate efficiency, this is around 120 watts of electricity—costing around four cents an hour. A larger pot or container loses more heat due to its larger surface area.

With no lid, running costs can jump by up to five times. And, if water is being vigorously boiled off, running cost could reach 50 cents an hour! That water vapour will recondense on kitchen walls, ceiling and windows, adding heat to the room initially, but then removing heat as it evaporates over time. If this moisture reaches other rooms, it can encourage mould growth. If you use a rangehood fan to remove this water vapour, it will draw large amounts of outdoor air into the building, potentially adding to heating or cooling energy needs.

Cooking appliances

COOKTOPS

A cooktop's energy performance depends on its design, the energy source, the pot used and user management.

Traditional electric cooktops are slow to respond and only part of the heat produced actually gets into the pot, due to contact resistance and heat losses in other directions: claimed efficiency is typically around 60%, but heat wasted during cool-down can reduce this. Halogen cooktops respond faster. Electric induction cooktops are very efficient (over 80%) and fast-response (even faster than gas), as they directly generate heat in the pot base itself, but they require magnetic cookware.

Gas cooking relies on the efficiency of heat transfer from the flame to the pot. Typically this is estimated to be 35% to 40% efficient. Gas offers rapid response and is cheaper and has a lower climate impact than most non-GreenPower grid electricity. However, its lower efficiency means more heat is dumped into the kitchen, and it is a source of indoor air pollution.

At present, gas cooking on a cooktop is 20% to 50% cheaper than conventional electric cooking, depending on energy prices and cooking practices. Induction cooking can be slightly cheaper than gas to 40% more costly. If cooking is the only activity using gas, you will also pay up to $250 annual fixed supply charges, making induction cooking look very attractive (see 'Are we still cooking with gas?', ATA's economic analysis of gas versus electricity for more, p. 32).

From a climate perspective there is discussion about the overall impact of gas, with increasing numbers of people using near zero emission solar electricity or buying GreenPower instead. For non-GreenPower grid-sourced energy, induction cooktops range from similar to gas to 35% higher impact, depending on which numbers you use and how you cook. Traditional electric cooktops can't compete.

Running burners and elements unnecessarily hot also wastes energy.

Using a pressure cooker on your cooktop saves energy in two ways—it has a much shorter cooking time and it wastes less energy evaporating water. On the other hand, it does weigh more, so start-up losses are higher, and ongoing losses are higher because of its larger surface area. So it's best to use pressure cookers for bulk cooking.

OVENS

When using an oven, a large mass of metal must be heated from room temperature to around 180 °C. Heating up an electric oven can consume as much as 0.5 kWh—more than it takes to run the heated oven for an hour. So it makes sense to cook several things in an oven once it's hot. A fan-forced oven can usually run at a lower temperature, saving energy overall despite the fan energy use, as the air movement in the oven improves heat transfer to the food. It also evens out the temperature, so you can cook more things at a time.

I measured my gas oven using almost 2 MJ of gas to heat to 180 °C in about 12 minutes, then a similar amount per hour of operation. Some information sources suggest oven gas usage is higher. Electric ovens can take a bit longer than gas to heat up, but use less when running. European studies suggest a good oven uses about 1 kWh for an hour's operation, including warming up.

Check your coffee machine

Many coffee machines have surprisingly high standby power usage: often they will keep water hot in uninsulated tanks or heat coffee-making components for long periods, in case you want another coffee. *Choice* magazine has tested coffee makers and found some use up to 30 watts on standby and other research has estimated up to 340 kWh/year if left on all the time—that's more than an efficient fridge! The most efficient coffee maker available in Europe uses 35 kWh/year, compared with a 'standard' product using 194 kWh (http://bit.ly/toptenCM).

A good quality electric oven will consume a few hundred watts after it is heated up, so it is equivalent to two or three pots on the cooktop in terms of energy use; but it may run for longer periods, increasing total energy use.

Gas ovens tend to have higher heat losses, as combustion products must be allowed to escape. As with cooktops, gas ovens are generally cheaper to run with lower greenhouse gas emissions than grid electricity.

A lightweight, well-insulated oven will save energy. And where the door is insulated and triple glazed with heat reflective coatings, it will be much cooler—and less of a safety hazard.

It is important to defrost food before oven cooking: cooking time can be more than twice as long for frozen items.

GRILLERS AND BBQING

Grilling (like BBQing) is a very energy-intensive way of cooking. A griller can have a power draw of up to 3 kW, equivalent to an electric fan heater. So toast things in a toaster or sandwich maker and use a frypan in preference to a griller. Sandwich-type grillers use much less energy than open grillers because they cook both sides at the same time and lose less heat.

BBQs are very inefficient. They have large burners, and usually require a significant heat-up time. For example, even a small two-burner BBQ on high may use up to three times as much energy as the built-in griller of a stove. And that is already very inefficient!

	Gas			Electricity*		
	MJ (kWh)	Cost (low)	Cost (high)	kWh	Cost (low)	Cost (high)
Heat 1 kg food to 100 °C on a cooktop	0.85 (0.24)	1.7	4.25	0.15	3	8.25
Heat a 1 kg pot to 180 °C (pre-heating pots and pans for frying etc)	0.25 (0.06)	0.5	1.25	0.04	0.8	2.2
Heat 1 litre of water to 100 °C on a cooktop	1 (0.27)	2	5	0.16	3.2	8.8
Evaporate 1 litre of water on a cooktop	6.5 (1.8)	13	32.5	1.1	22	60.5
Defrost 1 kg food in microwave	n/a	n/a	n/a	0.15	3	8.25

*Induction cooktop energy use is approximately two-thirds of a typical electric cooktop. All costs in cents.

Table 1. Key cooking activities and the energy and cost involved for different cooking methods.
Assumptions: Gas cooktop efficiency 35%, electric 60%. Electricity cost 20–55 c/kWh. Gas cost 2–5 c/MJ (LPG is high end). Assumes heating all items from 20 °C room temperature.

MICROWAVE OVENS

Almost all homes now have a microwave oven, and it can be a time- and energy-saver. Microwaves vibrate the water molecules inside food (to a depth of about 25 mm) to heat it. So it is useful for fast defrosting and reheating, and fast cooking of foods with significant water content. A typical microwave oven is around 70% efficient. Reheating portions of food in it is more efficient than using either the cooktop or the oven.

When used in convection mode, a microwave oven is quite inefficient if used for long periods. This is because they have no insulation. In Europe there do seem to be moves towards requiring insulation for benchtop ovens, so this situation may change.

BENCHTOP APPLIANCES

Benchtop appliances vary widely in their operating energy use, and it is very difficult to find reliable energy data for them.

Slow cookers seem to be increasing in popularity as they are convenient and can produce tender food. They typically use 150 watts or more for quite a few hours (1.2 kWh over eight hours), so their overall consumption may be similar to a conventional oven. If they were insulated, it would be a different story. According to Choice, multi-cookers use about half as much energy as slow cookers when doing the same task (a multi-cooker can do some or all of steam, saucepan, slow cook, fry or deep fry).

Some benchtop appliances do offer energy savings. Small ovens/grillers can cook small quantities quickly. Sandwich makers and similar 'sandwich' grillers can also be very efficient, as explained earlier. Cookers that use little oil to cook chips, and multi-layer steamers also seem capable of saving energy. But they would be better with insulation!

A recent paper suggests that modern rice cookers are way ahead for cooking rice compared to a saucepan on a cooktop or a microwave. It seems modern rice cookers have sensors that precisely manage power input to stop when the rice temperature starts to increase—an indication it is cooked. Presoaking the rice for an hour or so also shortens the cooking time significantly and improves taste.

Other options

A widely used traditional approach to cooking is the 'haybox'. Food is heated then the container is placed in a box lined with hay—or insulation as a modern equivalent (see, for example, the 'billyboil' and DreamPot in Products, this issue). This keeps the temperature high, so cooking continues.

Solar cooking is also increasing in popularity, particularly in sunny developing countries.

Efforts are being made to improve efficiency of existing cookware. A fluted pot has been designed to improve heat transfer from gas burners (www.gizmag.com/finned-flare-pan/32945 and www.lakeland.co.uk/19505).

The 'efficooker' (bit.ly/efficooker and bit.ly/efficooker-pdf) is a well-insulated cookpot with a resistive element and precision controls built into it so that little heat is lost.

Other options such as steam cooking and 'sous vide' may save energy, but the outcome depends on the effectiveness of insulation and precision controls.

Effective insulation and reduction of mass of cookware are obvious options for improvement. Inclusion of the heating element within the insulation layer is also a way of minimising losses. And precision controls and sensors, so heat can be accurately managed, will also make a big difference to cooking performance and user satisfaction. ■

FIRST PUBLISHED IN SANCTUARY 30

NOW WE'RE COOKING... WITH INDUCTION

Going off gas can make both environmental and economic sense. Sophie Liu considers what this means in the kitchen.

IF YOUR HOUSEHOLD HAS ALREADY switched space heating and water heating from gas to efficient electric, adding all-electric cooking to your home could help you save further on bills and greenhouse gases. And, if you offset your emissions, buy 100 per cent accredited GreenPower, or install solar PV, you could reduce your emissions to zero.

The popularity of induction technology is on the rise, with celebrity chefs and reality TV cooking shows spruiking the flat shiny surfaces to primetime audiences. But, aside from the hip pocket and environmental impact, are induction cooktops a good product choice?

There has traditionally been a preference for gas hobs over conventional electric cooktops, particularly among the more culinary-minded. And it's easy to see why: traditional electric stovetops are slow to respond and offer none of the subtlety needed for a risotto. That is, until induction technology, which can offer a wider range of settings, dramatically improved energy efficiency and halved cooking time when compared to conventional electric varieties.

We last looked at induction cooktops in Sanctuary 17. Since then, the choice of products and features has grown substantially, as has the range of price tags. Here we offer a few points to consider when looking for an induction cooktop to suit your budget and your kitchen.

↑ Induction cooktops offer a wider range of settings, dramatically improved energy efficiency and halved cooking time when compared to conventional electric varieties. Image courtesy of Kleenmaid.

Advantages

ENERGY EFFICIENCY

Induction cooktops work by creating a magnetic field that induces an electric current in the pot, thus heating it. Heating the base of the pot directly in this way conserves energy compared to when heat is transferred via an element or flame to the pot and then the food. And by cutting out the middle man, induction cooktops are over 80 per cent efficient (by comparison, conventional electric is around 60 per cent, and gas only 35 to 40 per cent).

COOKING TIME AND RESPONSIVENESS

Induction cooktops heat up fast, with changes in temperature occuring instantaneously.

SAFETY

Gas can go out when turned down to the lowest level on an old gas hob, and, not only is this dangerous, it's also a frustration for the cook and hungry hordes when dinner is delayed. As the heat is generated directly in the pot, the induction cooktop surface can remain relatively cool too. Although it may heat up after prolonged use, most models indicate when there is residual heat and have other safety settings, such as shutting off when the pan is removed or boils over.

MORE PRECISE CONTROLS

Electronic power level contols, rather than finicky knobs or dials, provide more control for cooking tasks like melting chocolate or cooking rice.

ENERGY SAVING

Smart features such as pan detection and pan size recognition switch off the power when the pan is removed and apply only the required power for the size of pan or part of the pan in contact with the cooking zone.

EASY TO CLEAN

The glass cooktop surface, which has no grooves or nooks, can be wiped clean easily. While the cooktop will heat up after prolonged contact with a pot, it is unlikely to be hot enough for spilt food to be burnt onto the surface. Many models have an auto-shutdown feature in case of overflow or overheating, to allow the cook to wipe up spills, then recommence cooking.

→ The flat surfaces and safety features of induction cooktops allow them to double as bench space. Image courtesy of Miele.

Disadvantages

NEEDS COMPATIBLE COOKWARE
As induction works via a magnetic field, it requires ferromagnetic cookware (e.g. cast iron or some stainless steels). Check the label when shopping for cookware and take a magnet along to test; if it's attracted, it will work with induction cookers. Test the whole base surface to ensure it is entirely compatible and don't trust labels alone, as the ferromagnetic material could be limited in area and result in patchy heating. A conversion plate or induction disk of magnetic material can be used with non-compatible cookware, but this reduces the energy efficiency.

NEEDS HIGHER AMPERAGE ELECTRICAL CONNECTION
This is something to double-check if you are renovating and are unable to have an electrician install a dedicated connection for the higher load. Some induction cooktops may also have too high a draw for those off-grid with a solar and battery system.

SENSITIVITY
Some users report their cooktop shutting down due to safety settings if, for example, clothes brush against it, or a tea towel is left on the control area surface. Controls may also not work with wet fingers. ■

What to look for when selecting an induction cooktop

While there is currently no energy rating system for cooktops, there are many energy efficiency features available that should be considered (see points below). Some models claim efficiency by using residual heat, but check with manufacturers, as this kind of functionality may rely more on the cook than an actual setting on the cooktop. How you cook and use your kitchen appliances impacts on your energy use

- Size - how many cooking zones do you need? Size appropriately to your cooking habits and compare the size of your cookware to the cooking zones' shapes and areas
- Electrical load - this may be quite high depending on the cooktop's number and size of cooking zones (eg a 7kW four-zone cooktop will need a 30 amp connection, and larger cooktops may need up to 42 amp connection)
- Standby power - check the rating, but remember you can turn it off at the wall if you have an isolation switch installed
- Easy-to-use controls - does it have a separate control for each zone? If not, is it easy to switch between each zone? Touch button versus more responsive touch and slide?
- 'Stop & Go' features - allow a pause when the cook is interrupted, resuming at the same power level
- Safety features - such as child lock and auto-shutdown if a pan boils over or overheats
- 'Bridge' function - to link two separate zones to allow large pans or griddles to be heated, and controlled together as one zone
- Bevelled glass edge versus metal trim - bevelled is easier to clean but more vulnerable to damage if a pot is dropped on a corner or slid into an edge without the trim
- Timers - improve cooking control and energy efficiency, and reduce risk of overcooking!
- Residual heat - some models have the smarts to indicate different levels of residual heat that can be utilised after the zone is switched off.

NOMINATE YOUR SUSTAINABLE HOME

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SUSTAINABLE HOUSE DAY

SUNDAY 17 SEPTEMBER 2017

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Nominate your home or register to attend:

www.sustainablehouseday.com

FIRST PUBLISHED IN SANCTUARY 27

KITCHEN & BATHROOM APPLIANCES

ENERGY SAVING 'BIG TICKET' ITEMS

Substantial energy and water efficiency gains can be made (and lost) in your kitchen and bathroom. Here, we consider some of the big ticket energy and water using appliances for the kitchen and bathroom.

APPLIANCES AND EQUIPMENT IN our kitchens and bathrooms use around 33 per cent of all the energy used in our homes. Water heating follows closely as another large energy user, accounting for a further 21 per cent. Meanwhile, water savings are most achievable in the bathroom and laundry.

An environmentally and socially responsible kitchen and bathroom are not just about energy and water-efficient appliances, though. Keeping an eye on how you use the water and energy-using products in your home is vital, as is choosing appliances that are appropriately sized. It's also important to consider the social justice credentials of any product.

01
Refrigerators

An energy efficient fridge will have considerably lower annual running costs than its more energy hungry counterpart. For example, a 1.5 star-rated 350L fridge uses around 550kWh/year while a 3 star-rated 350L fridge uses only 350kWh/year.

To keep your fridge running as efficiently as its rating indicates it can, make sure it's in a cool spot away from cooktops and sunlight, with a 75mm ventilation space around the fridge's back and sides. For older fridges, door seals should hold a piece of paper tightly when shut – they need to be replaced if they don't. Set the thermostat to between 3 °C and 5 °C, remembering every degree lower will require 5 per cent more energy.

If you are throwing out an old fridge, make sure you dispose of it properly to keep CFCs out of the atmosphere. A great way to do this is to look for fridge recycling schemes in your area.

Energy Ratings

Australia's Energy Rating Labelling Scheme ensures that many appliances have a rating telling you how much energy they use in kilowatt-hours per year. Take a look at www.energyrating.gov.au to compare the energy use of different models.

An appliance's energy rating is the estimated amount of energy that appliance will use in an average home based on typical use in one year. The more stars an appliance has (on a scale from one to six) the more energy efficient the product is compared to similar appliances.

02
Cooktops

Induction cooktops have the fastest heat-up response of all cooktops and, being electric, can be powered by renewable energy. Induction cooktops use a magnetic field to induce an electric current in your pot, so it is the pot that heats and cooks the food. They use less energy than a standard electric cooktop but still might produce more emissions than gas, depending on your electricity source.

It is important to note that induction cooktops must be used with ferromagnetic pans, such as cast iron or magnetic stainless steel. For other types of pots, a disk of magnetic metal called an induction disk can be used between the cooktop and the pot.

Energy efficiency expert Alan Pears has compared a portable induction cooktop with gas and found its heat-up response to be similar if not better than using gas. Alan believes the boost feature of many induction cooktops is not needed, particularly as it can require an increase in wiring capacity back to switchboard.

↑ The SMEG DWA315 dishwasher has a 6-star WELS rating and a 4-star energy rating.

03
Dishwashers

There is a good range of energy and water-efficient dishwashers on the market that use around 11–14 litres of water per load and around 200–245kWh of energy a year when used every day. Look for dishwashers with high star ratings in both these schemes and check reviews to ensure the dishwasher will last.

To be water savvy, only run the dishwasher when it’s full and scrape rather than rinse plates clean before you place them in the dishwasher. Buying a size that fits your needs will also save water and energy.

↑ The Siddons Bolt-on heat pump.

04

Hot water heat pumps

Heat pump hot water systems are the most efficient electric water heaters available. Compared with their electric counterparts, heat pump systems use at least 50 per cent less energy, a figure that can climb to as much 75 per cent depending on your climate and the type of heat pump installed. Heat pumps extract heat from the surrounding air/ground, operating a little like a fridge but in reverse. They work best in warm, humid climates although there are some models designed for cooler climates.

A few heat pump systems we've found to be energy efficient are listed here. For much more information on heat pumps, read our article in Sanctuary 26 and online.

Siddons Bolt-on heat pump

If you already have a hot water system that is relatively new and you don't want to replace it to make energy efficiency gains, the Siddons Bolt-on is a heat pump unit that connects to an existing tank and can save up to 75 per cent of your electricity costs compared to a regular resistive electric water heater.

Sanden heat pump

The Sanden Eco Hot Water Pump System is two separate components, a heat pump unit and a stainless steel storage tank. These can be installed up to four metres apart. The system is suitable for families of three to six people. There are also smaller models available.

Water efficiency

WELS is Australia's water efficiency labelling scheme. It requires products to be registered and labelled with stars representing their water efficiency. Out of a maximum possible 6 stars, tapware can be a maximum of 6 stars, toilets reach a maximum of 5 stars and the most efficient showerheads available are 3 stars. www.waterrating.gov.au

There are dollar savings associated with water-efficient technology. An investigation by Sanctuary's publisher, the ATA, found that in Victoria, where water prices can be high, water-efficient shower roses, taps and toilets will pay back their cost in less than 10 years. To read the report, go to www.ata.org.au/news/saving-water-means-saving-money

FIRST PUBLISHED IN RENEW 139

GETTING INTO HOT WATER

ELECTRIC HOT WATER SYSTEMS

Two very different approaches to hot water; one ReNew reader tells us about his heat pump hot water system here, and another shares his experience with a resistive electric hot water system on page 80.

Jonathan Prendergast shares his quest to reduce his hot water bills by switching to a heat pump.

AFTER 15 YEARS OF INNER CITY living, we moved to the quiet leafy suburbs of the Sutherland Shire, along the south coast of NSW, in 2015. We were used to low electricity bills in our apartments, of around $150 per quarter with usage around 6 to 7 kWh per day. We were shocked when I checked our meter a couple of weeks in to see we were now using 30 kWh per day.

Granted, we used to get our hot water and heating with gas, so our previous low figure was just for lights, refrigeration and appliances. But it shocked us into action, starting with disconnecting half the downlights. Coming out of winter into spring, we saw our consumption drop down to around 16 kWh per day, which was better.

We have our hot water supplied on a different meter which made it easy to track energy use. It is on an off-peak service and only turns on at night to ensure household hot water does not exacerbate network peak demand. We measured that of our 16 kWh per day, our electric element hot water tank system used 6 to 8 kWh per day. Almost half!

I had heard of hot water heat pumps and started researching them. Our action was brought forward when the existing hot water system failed. I ordered a heat pump and new tank from a supplier I know, and contacted the local plumber to arrange installation.

The (approximate) costs were:
new tank $1000
heat pump $2200
installation $800
government rebate $1000

The net additional cost of choosing a heat pump over an element hot water system was approximately $2500, after the rebate.

The $1000 to $1200 rebate is from the federal government as part of the Renewable Energy Target. Why do they qualify? Heat pumps are just a pump. They don't heat the water directly. They absorb heat energy from the ambient air and use pressure and refrigerant to transfer the heat into the water. This is very efficient, using around 75% less electricity than an electric element hot water system. The majority of the energy comes from ambient air heat, which is provided by the sun and so is renewable.

The results?

Our hot water heating now only uses around 2 to 2.5 kWh per day, so about a 75% energy saving as expected. In the graph below, you can see our hot water electricity usage and general energy usage over time. You can see the few days we went without hot water when our previous system failed and we organised the new tank and heat pump, but more importantly, you can see the reduction in electricity use.

We buy GreenPower using Powershop, which costs us around 30 cents per kWh. So the heat pump's daily energy saving of 5 to 6 kWh saves us $1.50 to $1.80 per day, or around $550 to $650 per year.

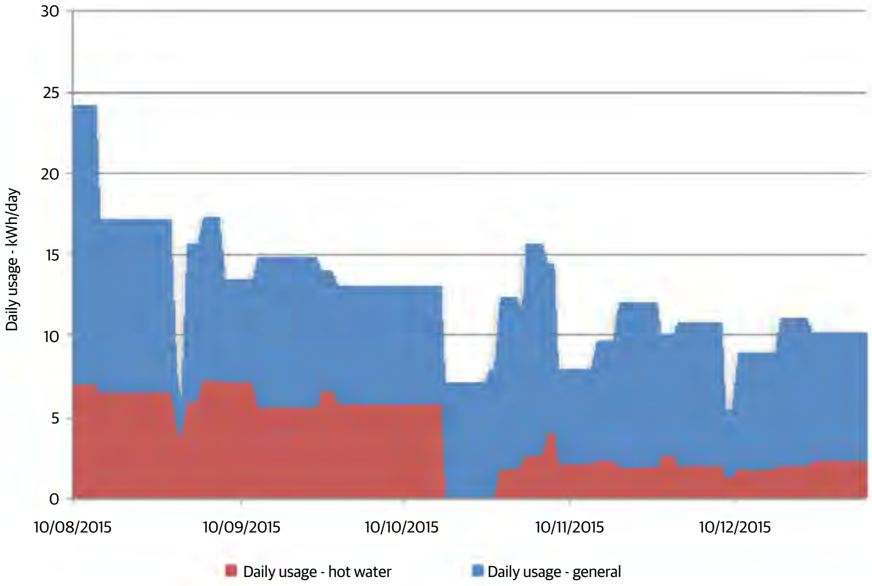
Other considerations

The heat pump fan does make some noise. Ours currently runs at night on the off-peak circuit and I don't think it is noisy enough to bother anyone. In any case we are getting solar soon so will switch it to the general circuit and program the heat pump to run from 10 am each day; a little noise certainly won't be a problem in the middle of the day.

We got a Siddons Bolt-on heat pump as it is what the company I knew supplied. It has a good efficiency rating with a COP of 3.6. There are other heat pumps available that are even more efficient, but while efficiency is important, to me it doesn't matter too much if it is using 2.1 kWh per day rather than 2 kWh per day (a 5% or $10/year difference).

Eighteen months later, we are happy with our heat pump and cheaper electricity bills. ■

↑ Here is what our system looks like, with the heat pump in the foreground and the tank behind it.



→ In this graph, you can see our hot water electricity usage and general energy usage over time. You can see the few days we went without hot water as our previous system failed and we organised the new tank and heat pump, but more importantly, you can see the reduction in electricity use.

For Dave Southgate, converting to an all-electric house did not involve using a heat pump for hot water. Here's what he did instead.

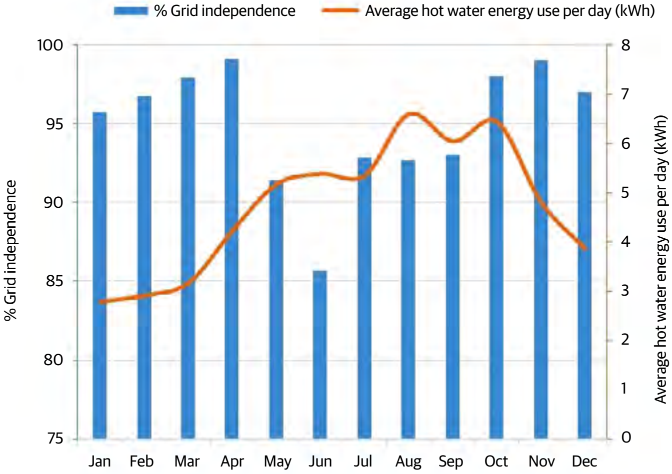
In 2015 I decided we had to do an energy makeover of our house in Canberra. Among other things I wanted to get rid of gas and move seriously to solar PV. At that point we used gas for heating, hot water and cooking. Making this transition is of course now pretty commonplace. While I started out thinking that we would go down the heat pump route for both hot water and space/personal heating for our new energy configuration, in the end we did not use heat pumps (read more about it in my 2015 report, listed at the end).

Opting for resistive element hot water

My initial reason for not choosing a heat pump for hot water was because of noise concerns—the location of our hot water tank meant that the heat pump would be just a few metres from our neighbours' main living area. But I was also very interested in energy diversion devices: devices which divert solar-generated power that would otherwise be exported to the grid, instead using it for various uses on site, including to heat water via a resistive heating element. It seemed to me that these would be a great way to optimise the use of solar PV power at home and I was keen to see how well they work. At that time there were a few available on the Australian market but in the end I chose a UK-made device, the Immersun, because it appeared to be the most well developed of the available options and provided an excellent energy monitoring system. Energy diverters typically cost around $1000.

We replaced our gas hot water system (about 200L) with a standard 250L electric element system. We had to replace the 3.6kW element with a 3kW element because of power constraints in the Immersun. I set the thermostat to

↑ The Immersun unit



← Overview of our hot water energy use for 2016. % grid independence is the proportion of electricity use that came from solar PV. Note % grid independence axis starts at 75%.

60 °C.

When opting for the resistive element approach I was aware that this would involve using more energy than if I chose a heat pump, but my prime aim was not to reduce total energy use; I was looking to minimise the use of grid electricity.

How well has it worked?

We are a family of four, living in Canberra, and the system works perfectly for us. We generally use our hot water for showers in the evening and have never run out of hot water even when we have had house guests. We normally use cold water for all our washing.

Deciding to go down the energy diversion route was also very good for us since, as well as taking care of most of our hot water needs, it opened up the potential for direct solar charging of our electric vehicle; see p. 56.

We have 6.5 kW of solar PV available to the Immersun and I have set it up so that if we have a bad solar day the hot water reverts to grid electricity at 3 pm to top up the heat. On nearly all days the water is hot well before 3 pm (in summer it is commonly hot before 10 am even though I have set up the system to give EV charging priority over water heating).

In 2016 about 95% of our hot water came from our solar PV, a much higher proportion than would normally be reached with a thermal solar system (usually about 80%) and most likely more than I would have achieved with a heat pump.

The proportion of grid electricity we use for hot water is of course not uniform across the year—the graph shows the extent to which our performance dropped over winter 2016. On average, we used 4.7 kWh per day for hot water during 2016. Maybe we would have used 2 to 3 kWh per day less if we had used a heat pump?

Next steps

I am planning to install an additional 4 kW of solar PV and a Tesla Powerwall 2 over the next few months. I'll be very interested to see to what extent this will improve our level of grid independence for our hot water.

Maybe this is a bit of a purist's point, but being a retired engineer I love 'non-moving parts' solutions. We now have a household energy/transport system based on solar PV, resistive heating hot water, far infrared (FIR) space/personal heating and an EV. Not too many moving parts there! I've yet to work out an equivalent solution for cooling (we use fans) but maybe it's worth thinking about. ■

Dave Southgate is the author of Our Household Energy Transition: Becoming a Fossil Fuel Free Family: http://bit.ly/2l1V9wF

Efficient hot water buyers guide

This article is an edited version of *Getting into Hot Water*, published in *ReNew 139*, where readers share stories on five different hot water systems. That same issue includes the *Efficient Hot Water Buyers Guide* which goes into further detail on heat pump and solar hot water systems, as well as newer hot water options such as PV diversion and Direct PV.

Visit shop.ata.org.au/shop/renew-issue-139 to buy a PDF or print copy of *ReNew 139*.

FIRST PUBLISHED IN RENEW 135

STAY WARM THIS WINTER

A HEATING BUYERS GUIDE

Heating can be a large proportion of energy use in the home. Lance Turner looks at what efficient options are available, including hydronic and reverse-cycle air conditioners.

OUR PREVIOUS HEATING BUYERS guide looked at heat pumps (commonly called reverse-cycle air conditioners) due to their high efficiency, low cost and simple installation. Later in this guide we take another look at reverse-cycle air conditioners and their advantages, and list the most efficient units currently available.

However, there is another form of heating that not only lets you choose a heat pump as the heat source, but other energy sources as well if they are more appropriate. That system is hydronics.

Hydronic heating

THE BASICS

Hydronic systems consist of a heat source (commonly called the boiler) to heat water, and one or more pipe circuits which have the heated water flowing through them. Each circuit incorporates one or more radiators, which emit warmth into the room.

Most hydronic systems have multiple circuits, so you can heat all or only part of a home, allowing you to leave unused, closed-off rooms unheated to reduce energy use.

Water is circulated through the system using low-pressure pumps, and circuits are turned on/off by electrically operated valves, usually controlled by an electronic controller. The controller enables a system to be programmed to heat certain parts of a home at particular times—for example, heating the living areas during the evening and the bedrooms just before bedtime.

Hydronic systems are recognised to have a number of advantages over other


Image: maramicado via iStock

↑ Hydronic heating systems produce radiant warmth that many people (and critters) prefer.

forms of heating. The heat being either underfoot or close to it (through the use of skirting radiators or panel radiators mounted at floor level) means that you get the feeling of warmth with lower ambient room temperatures than with space heating. Also, there is generally very little air movement with hydronic heating, reducing the potential cooling effect of airflows produced by convective heating such as reverse-cycle air conditioners or ducted gas systems.

Depending on the boiler used, some hydronic systems, such as heat pump systems, can also provide cooling in summer. Another advantage is that some hydronic boilers also provide domestic hot water, eliminating the need for a separate water heater.

Hydronic systems also have some disadvantages. First is the cost. A complete system can easily cost $10,000 or more, depending on the boiler, the number of circuits and type of radiator. The cost is likely to increase if fitting a hydronic system as a retrofit to an existing home if pipe runs are difficult to install due to lack of space. However, prices have dropped over time due to increased competition as hydronics have become more popular. Indeed, we have seen complete hydronic heating packages for under $7000, but larger heat-pump systems can exceed $20,000, and geothermal heat-pump systems can be considerably more than this.

The next disadvantage is complexity. Hydronic systems can end up using a maze of pipes and valves, so you need a space for all this equipment. This is usually housed in a cupboard or the laundry, out of view most of the time, so the thought of complex piping really shouldn't be a deterrent. Further, 'partage' boxes, such as those from Immergas, are designed to take most of the control pipework from a multi-zoned system and place it all inside a neat box, hiding it from view, giving a much cleaner installation.

Another issue, that only applies to in-slab systems, is thermal lag—the time it takes from when you turn on the heating until you start to feel the warmth underfoot. This occurs because of the high thermal mass of a concrete slab, which takes quite a while to heat up. So if you are away from the house for most of the day and only need heating for an hour or two in the morning and evening, an in-slab system may not be a good choice. People with in-slab systems tend to leave them running all the time due to the lag, so often use heating more than they need to. A system using wall or skirting radiators allows you to turn the heating on and off at will and get heat within a minute or so from these types of radiators.

RADIATORS

Aside from the afore-mentioned in-slab systems, there's a vast array of radiators available, from the traditional standing radiators through to towel rails, bench seats, skirting boards (such as

ThermaSkirt), mirror surrounds, in-floor trench convectors (radiators embedded in steel boxes fitted into the floor, covered by a grille, used where above-floor radiators are not suitable), ceiling radiators, and even decorative wall art. Which you choose will depend on your needs, but there's certainly no shortage of variety.

We should mention here that the operating system temperature will vary depending on the type of radiator. For example, in-floor heating usually uses water temperatures up to 40 °C or so, whereas wall-mounted radiators may run at 70 °C or more. It is possible to have a mixed system with both water temperatures running in the same system, but not all boilers and system designs can accommodate this. Your hydronic system installer will be able to provide more information on mixed temperature systems.

WHICH FUEL?

So, you've decided to install a hydronic heating system, but which fuel is right for your situation? If you have mains gas (LPG is simply too expensive to use for heating) then you might consider a gas boiler. The options here are either a storage system, much like a large gas hot water system, or an instantaneous boiler. The latter will be more efficient as it has no standing losses like a storage tank does. It also takes up a lot less room, requiring no tank other than a small expansion tank.

But even if you have mains gas, is it the best option? The price of gas is more closely linked to the international pricing system now, so prices have been increasing. Further, as more gas comes from coal seam deposits and by fracking, gas is becoming a dirtier fuel. For more information on getting off gas, see '*Are We Still Cooking with Gas?*' earlier in this ebook, and the associated report available at www.bit.ly/1R6eLZx.

For most people, the two main alternatives to a gas boiler are boosted solar and heat pump systems.

Both systems work like large versions of domestic hot water systems of the same technology. Solar systems have roof-mounted collectors that provide a proportion of the water heating, while backup can be done with instantaneous gas, heat pump or even solid fuel heat sources. Bear in mind though, that heating is required at times of the year that provide the least solar input, so a solar system really can be thought of as a solar-assisted system, and the 'backup' may well do the majority of the heating.

Heat pumps use a refrigerative system to extract heat from the outside air and concentrate it into the water tank. Even air that feels cold to us contains a lot of usable heat, although the colder the ambient air, the lower the overall heat pump efficiency. Systems that take heat from the air are called air-source heat pumps; there are also ground-source heat pumps that extract heat from the ground, but these are generally more expensive. See the 'Heat pump basics' box and the 'Efficiency of heat pumps' section for more on how heat pumps work and the efficiencies available.

It should also be noted that the initial upfront cost of even air-source heat pump hydronic boilers is considerably more than gas boilers at the current time, although as more homes go all-electric and more systems enter the market through greater demand, prices should fall.

Solid fuel boilers, such as the Gasogen wood gasification boiler, can also be used to provide heat hydronically, if no other fuel source is available or you have a low cost source of solid fuel, such as fallen timber on a large property. Pellet boilers are also available, although the price of pellets in Australia is still quite high.

Arguably, the most greenhouse-friendly and lowest cost to run system would be a high efficiency heat pump combined with a suitably sized photovoltaic array. If you already have a large solar energy system which generates excess energy during the day, then you would do well to install a heat pump hydronic system, which would be partially or in whole powered from your PV array. In such cases, running costs can be quite low compared to all other fuel options. It should be borne in mind that any PV array is likely to produce far less usable energy in the colder months, but this can be partially mitigated by installing a larger array. In some areas, winter insolation can be quite high. If you live in one of these zones, a heat pump system is a no-brainer.

While most heat pump hydronic systems use dedicated hydronic heat pump units, some heat pump hydronic system installers use multiple DHW (domestic hot water) heat pumps to provide the required hot water.

Although there are some disadvantages to such a system, such as increased standing losses from having multiple smaller tanks, the advantages include the ability to use CO2 refrigerant systems (see box on refrigerants) as well as having a degree of redundancy built in—if one of several heat pump units fails, you still have the rest to keep you warm—you are not stuck without heating until a repair can be effected, as you are with a single large boiler. However, multiple smaller heat pumps will cost more for the same heating capacity as a single large system. Note that several DHW heat pump manufacturers specifically state that they don't recommend their systems for hydronic heating use—although none actually gives a reason that we could find!

RETROFITTING AND DIY HYDRONICS

If you already have a gas hydronic system in place but running costs are too high due to it being an older, inefficient system (or maybe the system is nearing the end of its lifespan), then you should be able to have your system's boiler replaced with a heat pump or other fuel system. Just

↑ Hydronic radiators are not limited to the plain versions of old. These three fixtures are all hydronic radiators from the Hunt Heat designer range of radiators.

select a boiler with a heat output similar to what you currently have in the desired fuel type. In most cases, the best option will be to move to a heat pump system.

We should also mention that some suppliers have complete kits ready to install by competent DIYers. If this is your thing and you want to save a considerable amount on installation costs, look out for DIY kits and talk to the supplier to find out what's involved.

However, note that it is illegal to install any mains-pressure plumbing system yourself unless you have the appropriate qualifications. Should a DIY system leak and damage your home, your insurance company may also have grounds to reject a damages claim. Licensed installers should be employed to install hydronic systems as hydronic systems fall under the same regulations as other domestic plumbing.

Reverse-cycle air conditioners

Hydronic systems can provide wonderful warmth throughout the home, but there may be reasons why they are not suitable for you, be it a lack of access for pipework, a dislike of their complexity (some people just prefer things to be simple), a limited budget, or perhaps you just prefer a different form of heating. Whatever the reason, an energy-efficient heating alternative is the reverse-cycle air conditioner, which uses a heat pump to heat (or cool) the air in your home.

Heat pumps are all around us; as already mentioned, they can be used to heat the water in a hydronics system, for example. Your fridge is a heat pump, but it only works in one direction. True heat pumps are bidirectional, and when used for space heating and cooling are known as reverse-cycle air conditioners.

People often think of electric air heating as inefficient. And it can be: many forms of electric heating use resistive elements to turn the electricity into heat directly, and can only ever be 100% efficient.

However, reverse-cycle air conditioners use heat pumps and these are much more than 100% efficient, in fact, up to 550% efficient, meaning that they use a lot less energy to produce the same amount of heat. How can that be? As its name suggests, a heat pump pumps heat from one place to another. Instead of turning energy from one form (electricity) into another (heat), it uses electric energy to move heat from one place to another. Because heat is relatively easy to collect and move, heat pumps can move a lot more heat energy than the electric energy they use. For a brief explanation of how heat pumps work, see the 'Heat pump basics' box.

EFFICIENCY OF HEAT PUMPS: COP AND EER

↑ The Immergas partage box makes for a neater piping installation in multi-zone hydronic systems.

The efficiency of heat pump systems is given by a coefficient of performance (COP). This is a ratio of the heat moved to the electrical energy input. As an example, if your heat pump uses 1 kWh of electricity to move 4 kWh of heat from outdoors to inside your home, then it has a COP of 4. Note that when a system is cooling a home, its cooling efficiency is referred to as its energy efficiency rating (EER), while when heating it is called the COP—they are effectively the same thing.

Although both reverse-cycle air conditioners and heat pump hydronic systems use heat pumps, hydronic heat pumps usually have a COP of no more than 4 (less at lower ambient outdoor temperatures), whereas reverse-cycle air conditioners can have COPs as high as 5.5. The actual running COP of both systems depends on numerous factors, including the temperature differential between outdoors and indoors (or outdoors and hydronic water temperature for a hydronic system), the refrigerant and compressor type used, and overall system design.

While talking about temperature effects, some heat pumps can have their COPs reduced to low levels (less than 2 in some cases) as the ambient temperature approaches 0 °C. If you live in an area that sees close to zero winter temperatures, make sure you check the efficiency curve (a graph of COP versus ambient temperature for a given output temperature) if available (some manufacturers will just supply COPs for several outdoor temperatures), of your prospective heat pump units, whether they be hydronic or reverse-cycle air conditioner.

SPLIT SYSTEMS AND INVERTERS

All of the reverse-cycle systems in our guide tables are split systems, where the indoor unit and outdoor unit are separated and linked by flexible or rigid high-pressure hoses or pipes.

Split systems have the compressor and one set of coils in a box outside, often mounted against a wall. The part inside the home is called the air handling unit and consists of the other set of coils, a fan to force air over them and the electronic controls for the system.

Air handling units are usually ‘wall

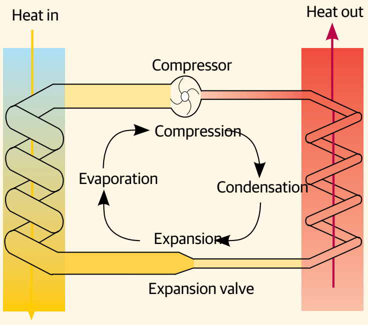
Heat pump basics

Heat pumps use a refrigerative system to move heat from one place to another, usually concentrating it (raising the temperature) in the process. Air-source heat pumps extract heat from the outside air and concentrate it into usable heat, which might be used to heat a room directly or to heat water in a hydronic system.

A variation is the ground-source heat pump, which instead extracts heat from the ground (or a body of water if available). The advantage to this is that the ground is a more stable source of heat and is usually at a higher temperature than ambient air in winter, so system efficiency can be higher. However, given Australia’s mild winters, the greater cost of installing a ground-source heat pump (due to the requirement of boring many deep holes or digging deep trenches) may be hard to justify.

Heat pumps use a closed system that contains a liquid with a low boiling point, called the refrigerant. A compressor adds energy to the refrigerant as well as increasing the pressure, forming a superheated vapour. This enters a set of coils known as the condenser where the vapour forms back into a liquid, giving up some of its heat energy in the process. It then flows through an expansion valve where the pressure is abruptly reduced, causing some of the refrigerant to form a vapour. It then flows into another coil called the evaporator where it absorbs heat, flows back to the compressor and the cycle repeats.

In a cooling-only air conditioner, or a fridge or freezer, the evaporator is inside the house or fridge cabinet and the condenser is outside. This is why the back of the fridge gets warm. In a heating-only heat pump, such as some hydronic systems, the condenser is inside (in the storage tank) and the evaporator outside.



In a reverse-cycle system, the system uses a reversible expansion valve and so the inside cooling coils can be either evaporator for cooling or condenser for heating. The same applies for the outdoor coils. This applies not only to reverse-cycle air conditioners, but also to hydronic systems that can heat and cool.

← Split system reverse-cycle air conditioners are compact and simple to operate and modern units generally have high operating efficiencies.

hung' but there are other types, including floor-mounted and 'cassette' types, which are mounted in the ceiling.

Virtually all high-efficiency split system heat pumps are of the inverter type. What this means is that instead of the compressor motor simply being on and off (remember the clunk when your old box air conditioner switched its compressor on and off), the compressor is controlled by a variable-speed drive or inverter. This allows the compressor to only run as hard as required, making the system more efficient and reducing electricity use.

The split system has several advantageous features—the air handling unit is quite compact, they only need a couple of small holes in the wall for piping and cabling, the separation of indoor and outdoor units eliminates leakage of heat from the hot side to the cool side, thus improving system efficiency, and they are quiet, as the compressor is outside the home.

REVERSE-CYCLE SYSTEM FEATURES

As reverse-cycle air conditioner technology has improved and manufacturing has become cheaper, a number of features have been added to systems. These include improved filtration (such as long-life filters that only need washing every six months), air ionisation (to disinfect the air), high efficiency fan designs to reduce energy use and fan noise, variable-speed compressors (usually using DC motors), remote controls with timer functions, adjustable airflow patterns, economy modes, infrared sensors to reduce operation when rooms are empty, humidity sensors, and many other features, which may or may not be of use to you.

When looking for a system, don't get too excited about all the built-in gadgetry—after all, how much of it will you actually use, and how much of it will you forget about after the first week. There's no point paying for extra features if you really don't need them.

However, some features can be worth paying extra for, such as humidity control. Many people find that reverse-cycle air conditioners cause the home's humidity level to sit outside the best comfort range of 40% to 50%. One air conditioner designed to address this issue is the US7 (Ururu Sarara 7) range from Daikin. These units have pretty much every feature you could ask for in a reverse-cycle air conditioner, including humidity control, high efficiency DC motors, very high COPs, two-stage air filtration, and self cleaning. Of course, you also pay extra for these features.

Another useful feature is the inbuilt timer. Most units have these now, and they allow you to turn on heating before you wake up, or turn on cooling before you get home from work.

Some units also feature internet connectivity (often via an optional wi-fi adaptor) to enable you to control the unit using a smart phone or tablet in the home, or from almost any device via the internet. The advantage to this is that you can turn the unit on before you get home, or turn it off remotely if you forget.

Many units also feature adjustable airflow patterns, allowing warm air to flow across walls and ceilings rather than onto occupants. In summer, random airflow changes are supposed to simulate the natural variations of a cooling breeze.

IMPROVING AIR CONDITIONER EFFICIENCY

There are actually a number of things you can do to improve the efficiency of your reverse-cycle air conditioner. The smaller the temperature differential between the condenser and evaporator, the more efficient the system will run and the less

↑ The compressor unit of a split system. Mounting it in full sun with a deciduous tree or eaves for summer shade can improve system efficiency.

energy it will use to move a specified amount of heat.

The first thing to consider is the placement of the compressor unit. It should be placed outside in full winter sun if possible, but should be shaded with a deciduous tree or shrub during summer. This allows it to be heated by winter sun and so collect heat more efficiently, thus improving system efficiency when heating in winter.

In summer, the compressor will be shaded by the vegetation and so will be more effective in expelling heat. This simple trick can improve efficiency and reduce running costs. The same applies to a heat pump hydronic system—siting the outdoor unit in the sun will increase efficiency in winter, but if it is also a cooling unit then it should be shaded in summer.

Air conditioners have filters inside the air handling unit to remove dust from the air. These should be cleaned regularly when the unit is in use, although some systems are now self cleaning or have filters that only need to be washed every six months. They can usually just be washed with warm soapy water, rinsed and dried.

MULTI-HEAD OR MULTIPLE UNITS?

Most manufacturers allow air conditioner components to be mixed and matched to some degree, or at least provide several options for each system. For instance, if you only want to heat one room then you might buy one standard air handling unit and the appropriately sized compressor, but if you need to heat more than one room then many systems are available as a larger compressor unit that can have two or more air handling units connected.

Alternatively, for heating multiple rooms, fitting a number of single-room units may allow for better overall efficiency as system COP is usually better for the smaller systems. Multiple smaller units also gives a better level of redundancy—you won't lose all heating capacity should a compressor unit fail.

The downside to multiple small air conditioners is that you increase the required wiring, as each unit needs to be wired in. Also, you will have one outdoor unit for each air conditioner, which takes up more space and may be harder to hide visually. Many units use power for their crankcase heaters (low power heating elements used to prevent refrigerant mixing with crankcase oil when the unit is off, and to prevent condensation of refrigerant in the crankcase of a compressor), at least in the cooler months, thus increasing standby

Refrigerants

Hydronic/hot water heat pumps and reverse-cycle air conditioners use a refrigerant to do the work of moving heat from one place to another.

In the past, all sorts of environmentally damaging fluids were used, including CFCs (chlorofluorocarbons, the ozone destroyers), HCFCs (hydrochlorofluorocarbons—better for the ozone layer, but strong greenhouse gases) and many others. For a full list of the many refrigerants, see en.wikipedia.org/wiki/List_of_refrigerants.

The most common refrigerant in domestic heat pump air conditioners seems to be R410a, which is a mixture of difluoromethane (CH_2F_2, called R32) and pentafluoroethane (CHF_2CF_3, called R125). While it is ozone-layer friendly, it has a high global warming potential (GWP) estimated at around 1430 times that of CO_2. Some systems also use R32, with a GWP of 675. See en.wikipedia.org/wiki/List_of_refrigerants for more.

Similarly, hydronic heat pumps tend towards refrigerants such as R134a, ozone-layer friendly but with high global warming potential—they are strong greenhouse gases.

Domestic hot water heat pump systems, sometimes used in hydronic systems as mentioned earlier, have progressed towards more environmentally sound

← Multi-head split reverse-cycle air conditioners use a single compressor to drive two or more indoor units, which may be wall-mounted units, console units or ceiling-mounted cassette units. Refrigerant hoses run from the compressor to each unit, limiting the distance between the indoor units and the compressor, often to around 10 metres, although longer runs can be installed if extra refrigerant is added. Of course, the pipes should always be well-insulated, regardless of the pipe length.

load considerably. The standby load may or may not be listed in brochures and datasheets, so if it is not listed for your preferred model, contact the manufacturer or the installer/salesperson, but the latter may not know about this issue.

AIR CONDITIONER COMPROMISES

To keep costs down, some manufacturers compromise designs to some degree, which can reduce system efficiency.

One such compromise is the use of the same size air handling unit on compressor units of different sizes. If you look at the specifications of the different models in some manufacturers' ranges you will see that the air handling units of systems with progressively larger compressors are the same. The manufacturer increases compressor size and therefore heating and cooling capacity, but uses the same sized air handling unit for all models. This means the larger capacity models in the range will be less efficient; you can see this when looking at specifications. A manufacturer might compromise efficiency like this to save manufacturing costs—it's a lot cheaper to produce one size of air handling unit rather than a different one for each model. So bear this in mind when checking specifications.

Are hydronic or reverse-cycle systems cheaper?

There are two sides to the economics equation when choosing a system.

First is the upfront cost. Generally, a hydronic system will be more expensive than even a top-level reverse-cycle air conditioner, although you would require more than one of the latter to provide the heating capacity of the typical hydronic system; so the cost to purchase several air conditioners to heat a whole home could be similar.

One advantage with going with reverse-cycle air conditioning is that you can start small, by installing a single unit, and then adding more as the budget allows. With a hydronic system you really need to buy a boiler and ancillary equipment sized to suit the entire heating requirements of the home.

With a reverse-cycle air conditioner, you also get cooling without having to buy a separate system; then again, some heat pump hydronic boilers can also provide cooling, or an optional chiller can be fitted to the system.

The other part of the economics equation is running costs. It can be difficult to compare the two approaches. A single efficient reverse-cycle air conditioner will certainly be cheaper to run than a whole-of-house hydronic system. Even if you install several reverse-cycle air conditioners to allow you to heat the whole house, you are probably unlikely to run them all at once as they are separately controlled—you may be less likely to heat the bedrooms for much of the day, for example—and so your running costs may also be lower. However, a well-zoned hydronic system can help reduce costs for hydronics. Comfort comes into the equation here as you may be more comfortable heating a larger part of the house, even if that costs more with either type of system.

Running costs will depend on many factors including the size of the system and its efficiency, so be sure to look at the COP for heat pumps, whether for a hydronic system or a reverse-cycle air conditioner, and the size of the system. A primary factor determining running costs is the thermal efficiency of the house—the heating system only replaces the heat lost by the housing envelope, and the rated capacity of the heating system is its maximum capacity; it doesn't produce this much heat continuously. For a given level of heat loss in a home, a system with higher COP will use less energy to maintain required temperatures.

When looking at gas system running costs, you are comparing the efficiency of gas systems. Comparing gas running costs to an equivalent-sized heat pump requires that you compare the cost of gas to produce a certain amount of heat to the cost of electricity a heat pump would use to produce that same heat. Gas is metered and charged in megajoules (MJ), but you can calculate the equivalent kilowatt-hours by dividing by 3.6. Hydronic gas usage will vary depending on climate, operating time, home thermal efficiency and unit efficiency. A gas system that uses 300 MJ per day and has an efficiency of 80% is producing (300x0.8)/3.6 or around 66.6 kWh of heat for the home. To quickly compare this to a heat pump, just divide by the heat pump's COP. For example, a system with an average COP of 3.5 would use around 19 kWh per day of electricity to do the same job as the gas unit. Compare them financially by looking at the cost you pay per MJ for gas and kWh for electricity. Note that this quick comparison doesn't take into account different operating modes as discussed previously, or that you could eliminate your gas connection fee if you disconnect from the gas network.

If you have excess PV-generated electricity, you could use this to offset some of the running costs for heat pump hydronic systems and reverse-cycle air conditioners. The systems are running in winter, with lower insolation levels, but an oversized solar system can help to some extent. A hydronic system with a large water tank could mean you could heat the water during the day from PV to give some heating into the night. With a reverse-cycle air conditioner, you could pre-heat the home using excess PV-generated electricity for when you come home from work, but the savings are likely to be small (see 'Pre-cooling your home' in ReNew 130 for our modelling of doing this for cooling; the results are likely to be similar, although there is likely to be less excess solar in winter). A battery could power the system at night, but currently the bill savings won't offset the battery cost.

Many other factors come into operating costs. Hydronic systems tend to feel more comfortable at lower temperatures than reverse-cycle air conditioners as the heat is at floor level, and there is no cooling effect from air movement. With heat pump hydronics, you might also be able to access a cheaper off-peak tariff to heat the water, at least for part of the day. This will depend on your system's design and your energy company's tariff usage requirements.

As mentioned previously, given that gas prices are now tied to international prices, and that those prices are steadily increasing, the future costs of running a gas boiler, even an instantaneous one, can be difficult to predict. There's also the issue that natural gas is becoming dirtier as more is sourced from fracking and coal seams.

Each home's situation is different, so you need to evaluate the economics of the systems based on your own particular circumstances.

Sizing a system

All hydronic boilers and reverse-cycle air conditioners have a rated heating capacity (and cooling capacity, for reverse-cycle air conditioners), so you need to have a basic idea of how much heat is flowing into and out of your home.

Doing such an assessment is beyond the scope of this article, and is really something an energy assessor should help you with. There are many assessors available who can provide such services, and a number of online resources available to help you find one in your area, such as the ABSA website (www.absa.net.au) or the NatHERS site at www.nathers.gov.au.

However, if an assessment is not in the budget, then you can make an educated guess with a bit of basic knowledge.

For instance, if you are heating just one or a few rooms and find that a 2400 watt fan heater can keep up with heat losses in each room, then you know the minimum heating capacity required. Indeed, as crude as it sounds, this is actually one of the simplest ways to find out how much heat you need. Set up a fan heater or two on a cold day and see how it goes. If the room is still cold after half an hour then you have some more insulating and/or sealing to do. If it is nice and toasty warm then simply buy the most efficient system with a rated heat output of at least that of the fan heater(s).

Once you know the heating requirements then you should also know the cooling requirements, to a reasonable degree, as the temperature differential between the room and outside in the coldest days of winter will be similar to the differential on the hotter summer days.

You might want to size based on cooling requirements, using the FairAir calculator at www.fairair.com.au. However, as discussed in *ReNew 133*, many system size calculations are based on having the temperature higher/lower than many people need, or don't take into account all factors regarding the house's insulation, so consider whether a smaller system could do the job just as well. However, one advantage of a slightly oversized system is that you can heat (or cool) rooms more quickly—something to consider if you often come home to a hot home after a day out. Also be aware that some installers may tend to oversize based on past experience with less than well-insulated homes. If your home performs well thermally then make sure the person quoting understands this.

Sizing a hydronic system can be a fairly involved task as it usually means sizing a system for the whole home while matching radiators for each room size. Hydronic system sizing is probably best left to the system designer/installer.

What about ducted air conditioning?

If you decide on reverse-cycle air conditioning, you might be tempted to go the whole hog and install a ducted system. Ducted systems sound great in theory—you can keep the entire home at a comfortable temperature. However, there's a large price to pay for this, and that's energy consumption. After all, you can only use one room at a time, and most people, even families, will tend to spend most of their time in one room or another, such as the lounge room or study. Heating all the other rooms, whether they are used or not, will add unnecessarily to energy use and cost.

If you need heat in rooms you visit for a few minutes each day, such as the bathroom, then use spot heating such as radiant heaters. A 1kW radiant heater used for 15 minutes uses just 250 watt-hours of energy—much less than if you were to heat that room continuously, even with a heat pump.

Of course, modern ducted systems have zoning controls, just like hydronic systems, so efficiency can be enhanced if the householder uses those controls correctly.

The biggest problem with ducted systems is that they can lose a considerably amount of heat through the ducting, both as radiant heat loss and if the ducts become damaged by critters (or people working in the roof). Ducts are rarely cleaned or checked for damage, and ducted systems usually end up costing more to run over time as efficiency degrades.

If you need to heat more than one room, get either several smaller high-efficiency heat pumps, a high efficiency multi-head split heat pump, or go for a multi-room hydronic system with smart zoning controls.

Reduce leaks too!

Of course, any heating system will use less energy if the home it is trying to heat doesn't leak heat like a sieve. The more efficient your home at preventing thermal transfer, the less energy your system will use and the more comfortable you'll be.

This means that you need to take all the usual efficiency measures, such as insulating roofs and walls (and under floors if possible), sealing draughts, and insulating windows with either double glazing, curtains and pelmets, or both. Remember, the better insulated the home, the less energy needed to heat and cool it, and the smaller, and therefore cheaper, the heating system you need to install. In short, spend some money on energy efficiency measures up front and you will save in both the long and short term.

About the tables

There are two tables—hydronic boilers (and complete packaged systems where available), and reverse-cycle air conditioners. Full tables are available at www.bit.ly/1Ucfvm6.

The reverse-cycle air conditioner table covers many of the systems available in Australia and New Zealand with COPs of 4 or better. Note that most of these units are split systems with single wall-hung air handling units—that tells you a lot about the efficiency of such a design. Heating capacities range from just over 2kW to more than 25kW—which should be more than enough to heat even the largest well-sealed and insulated home. The hydronics table covers boilers and systems that are aimed at the domestic market, and range up to 50kW capacity or more. ■

More info:

'Winter comfort: not just a heater choice' in *ReNew 127.*

'A tale of two heaters: gas vs electric' in *ReNew 133*.

Are we still cooking with gas?', ATA report at www.bit.ly/CAP_GAS and in *ReNew 130*.

PRE-COOLING YOUR HOME

GOOD IDEA OR NOT?

Does running your air conditioner to pre-cool your home make environmental or economic sense? Andrew Reddaway, energy analyst at the ATA (*ReNew*'s publisher), examines the issue—with a little help from Sunulator.

IF YOU'RE OUT DURING THE DAY AND have an air conditioner (AC), you've probably considered running it on a timer so that the house is cool when you come home in the evening. Compared to turning it on when you get home, pre-cooling will:

- provide more comfort
- use more energy, as the AC will be running longer
- emit more greenhouse gases
- reduce demand on the grid at peak times; this helps reduce future bills for everyone by delaying grid upgrades.

But could pre-cooling reduce your bills?

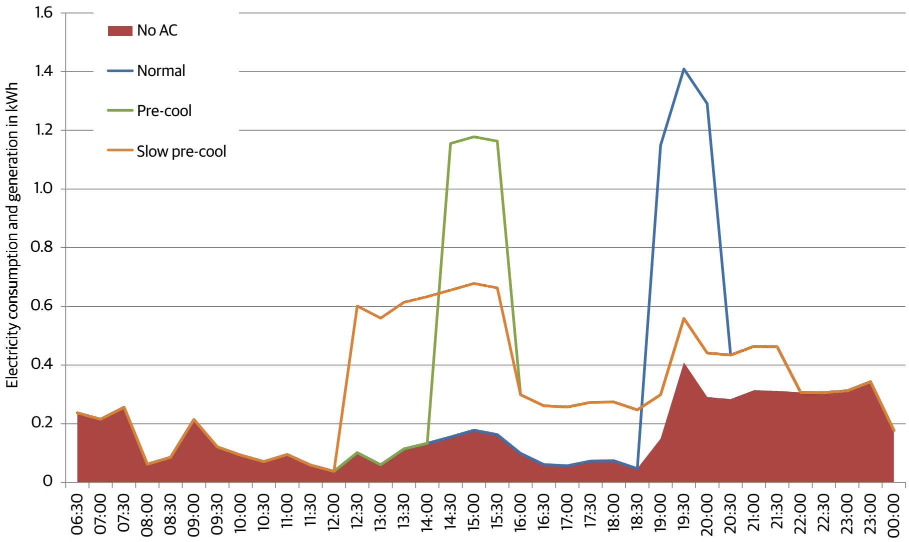
Based on an analysis of a hypothetical house in Sydney, we found that you might save some money if all the following conditions apply:

- You have a grid-connect solar system.
- Your AC is not too big compared to your solar system.
- You have high grid consumption tariffs during the evening and a low feed-in tariff.
- Your AC can keep the house cool using only 20% of its maximum cooling capacity.

Your AC's energy consumption depends on how well your house is sealed, shaded and insulated. It also depends on the AC's efficiency, including how well it was installed. For example, ducted AC systems with thin duct insulation tend to perform poorly in hot weather. Take note of how your AC cycles on and off on a hot day. If it needs to run more than 20% of the time, pre-cooling will probably not save you money.

Other situations

If you're off-grid and have daytime



↑ Figure 1. Consumption by half-hour interval on a sample day.

electricity going to waste, go ahead and pre-cool! Daytime loads are gentler on your batteries than evening loads.

If you are using grid electricity and have no solar system, pre-cooling will be unlikely to save you money, unless the difference in grid tariff between afternoon and evening is larger than around 30c/kWh.

Other locations

Locations in the western part of each time zone have an advantage, since the sun sets later. For example, the sun sets about half an hour later in Melbourne than Sydney, as it is further west. However, Victorian peak electricity tariffs are generally lower than Sydney's, reducing the benefit of pre-cooling. States without daylight saving are disadvantaged; since people arrive home later in the day, their AC will have to maintain the pre-cooled temperature for longer. By the clock, the summer sun sets two hours earlier in Brisbane (no daylight saving) than in Melbourne.

Analysis using Sunulator

Our analysis used Sunulator (www.sunulator.org.au, ATA's tool for calculating the economics of solar installations), running simulations for a situation favourable to pre-cooling:

- Sydney location
- house is well-insulated and sealed
- time-of-use grid electricity tariff of 54c/kWh from 2pm to 8pm (Origin standing rates in the Ausgrid area)
- net metering with a feed-in tariff of 6c/kWh
- pre-cooling on weekdays from November to March
- residents return home at 6.30pm
- 2kW solar system facing north, 30-degree tilt
- 5kW air conditioner consuming 2kW of electricity when at maximum power.

Scenarios

Scenarios were compared for three different weekday AC schedules, as follows.

Normal: Turn on the AC at 6.30pm, running for 1.5 hours at 2kW to cool down the house, then 1.5 hours at 0.3kW.

Pre-cool: Turn on the AC at 2.30pm, running for 1.5 hours at 2kW, three hours at 0.4kW and then three hours at 0.3kW to maintain temperature.

Slow pre-cool: Turn on the AC at 12:30pm, running for three hours at 1kW, three hours at 0.4kW and then three hours at 0.3kW to maintain temperature.

As noted above, these AC loads were selected to represent the threshold at which pre-cooling can be economical. It would be possible to estimate AC cooling requirements for different house types using software such as AccuRate, but that was beyond the scope of this analysis. You might reduce cooling energy by running the AC even earlier during a cooler part of the day, but this would require longer running to maintain the temperature, and was not modelled.

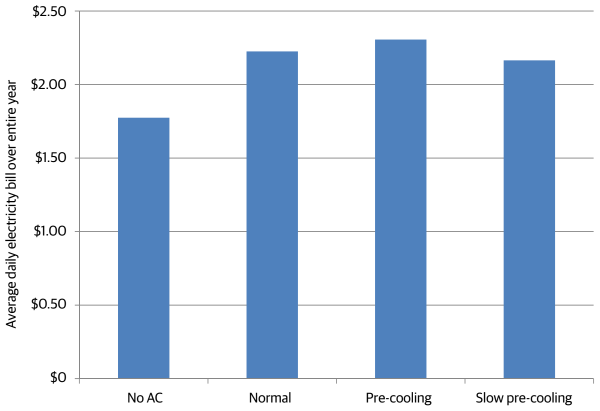
Household electricity consumption data

We used actual half-hourly consumption data over a whole year for a Melbourne house with no air conditioner, gathered by the smart meter. For each scenario, AC loads were then added to weekday consumption from December to March.

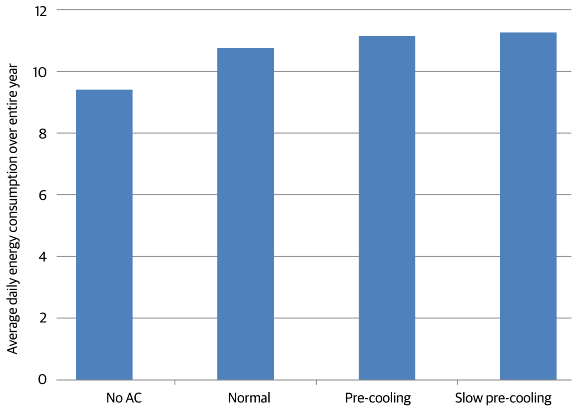
Scenario comparison

In Figure 1, the red area is consumption excluding AC. Most electricity is consumed after people get home in the evening. The blue line shows consumption with the 'normal' AC load added. Green and orange lines are alternative AC loads, for 'pre-cooling' and 'slow pre-cooling' respectively.

With the assumptions noted above, the 'slow pre-cooling' scenario performed best financially, saving about 3% of the annual bill compared to 'normal' AC



↑ Figure 2. Bill cost by pre-cooling scenario.



↑ Figure 3. Energy consumption by pre-cooling scenario, in kWh.

running, or about $22 over the year. The 'pre-cooling' scenario cost about 4% more than normal.

Pre-cooling consumes more energy than 'normal' AC running. Over a whole year, the 'pre-cooling' and 'slow pre-cooling' scenarios consume 4% and 5% extra energy respectively. 'Slow pre-cooling' consumes 185 kWh more per annum than 'normal' AC running.

Your AC may not be consuming grid electricity while it's running off the solar system, but it is reducing solar exports to the grid that would have offset fossil fuel generation. On an Australian average basis, the 'slow pre-cooling' scenario emits approximately an extra 170 kg of carbon dioxide due to increased grid generation, which could be offset by about $8 of GreenPower carbon certificates (at a price of $48 per tonne).

Matching an air conditioner to a solar system

The 'slow pre-cooling' scenario had the best financial result because most of the AC load could be supplied instantaneously by the solar system. On the other hand, the 'pre-cooling' scenario resulted in a mid-afternoon load of 2.4 kW, which exceeded the output of the 2 kW solar system and required expensive electricity import from the grid. Allowing for losses, a solar system should generate about 80% of the panels' rated power under good conditions. Pre-cooling will give best results if the total household load is kept below this level.

When checking AC specs, look for the electrical input power in kilowatts, which will be much lower than its cooling capacity. Typically, in hot summer conditions, an efficient AC's input power would be about one-third of its rated cooling power.

For example, if you have a 4 kW solar system, on a sunny summer early afternoon you might be generating at a power level of 4 x 0.8 which is 3.2 kW. Allowing 0.5 kW for other appliances leaves 2.7 kW for the AC. The biggest AC that can be powered wholly by this solar generation is approximately 2.7 x 3, which means an AC rated at 8.1 kW of cooling power. If you wish to allow for cloudy periods too, the maximum AC would be maybe half that size.

Solar panel orientation

We also ran additional scenarios in Sunulator with solar panels facing west. Compared to north-facing panels, this generated less electricity over the entire year, but more in the summer afternoon and evening. West-facing panels do provide a better match for air conditioning load. With pre-cooling, west-facing scenarios showed a slightly better return on the solar investment than north-facing ones.

Controlling your air conditioner

Most modern ACs have a timer function that you can set in the morning on a pre-cooling day. Also investigate temperature limits and economy settings to mimic our 'slow pre-cooling' scenario. This allows a larger air conditioner to be powered by a smaller solar system, without imports from the grid.

Some ACs can now be turned on and off remotely over the internet. This may be useful for last-minute decisions to set or cancel your pre-cooling.

Recommendations

Pre-cooling is a personal choice involving comfort, energy consumption and cost.

If your grid tariffs are favourable, you have a solar system and your AC can keep your house cool without using much energy, pre-cooling might have a slight positive impact on your electricity bill.

To minimise energy consumption and climate impact when pre-cooling, we recommend that you prioritise hot, sunny days and watch out for energy wasted when you are delayed from returning home. You could also choose to offset the additional energy consumption incurred in pre-cooling, for example via ATA's Community Climate Chest (C3) or a GreenPower plan with your electricity retailer. ■

FIRST PUBLISHED IN RENEW 133

NEW CHOICES IN LIGHTING

AN LED BUYERS GUIDE

The move to LED lighting has become mainstream, with more options appearing constantly. Lance Turner takes a look at what's available.

FOR MANY HOMES, LIGHTING IS ONE of the most overlooked aspects. Incorrect lighting can make a room unpleasant to be in, or make it more difficult to perform tasks such as reading or cooking. Getting it right can take a bit of effort, and though this guide won't answer all your questions about lighting design, hopefully it will give you a headstart when thinking about the types of lighting to use and the questions to ask.

With almost all lighting technology moving towards LEDs, this guide focuses on LED bulbs. Even the reasonably efficient technologies such as fluorescent tubes and compact fluorescent lamps are rapidly being replaced by LED lighting. It's likely that within 10 years, most other light sources will have disappeared in favour of the robustness, longevity and energy efficiency of LEDs.

What is an LED?

LEDs (light emitting diodes) are unlike any other lighting system. They contain no glass tubes or heating filaments, instead using a small piece of semiconductor material (as used in computer chips) that emits light directly when a current is passed through it.

LEDs produce light in a range of colours, without the need for coloured filters; thus, to get white light, a phosphor is used over a blue or UV LED chip, similar

→ It looks like a regular oyster-style fitting, but the XL-LED 18 watt Circular Ceiling Light from Crompton Lighting produces 1100 lumens of 4000 K neutral white light or 1200 lumens of 5600 K daylight white light from a maximum of 18 watts.

to what's used in a fluorescent tube.

Note that the LED is actually the small light producing element(s) in a light bulb or fitting, but most people now erroneously refer to LEDs as the entire bulb or fitting.

LED specs

There are a number of specifications that are useful to consider when buying LED lights.

BULB WATTAGE

All light bulbs have a wattage rating, which measures how much power they consume. This is where LEDs have a shining advantage over older, more inefficient technologies. For domestic LED lights, the rating is usually between one and 20 watts, compared to a typical incandescent rating of 25 to 100 watts.

LIGHT OUTPUT: LUMENS, LUX AND BEAM ANGLE

Many LED bulbs include an 'equivalent-to' wattage rating, showing the wattage of the incandescent bulb that the LED bulb is equivalent to in terms of light output. For example, a six watt LED bulb might be rated as putting out the same amount of light as a 50 watt incandescent.

This 'equivalent-to' rating is based on the light output in **lumens**. The lumen rating of an LED bulb, usually included on the packaging, measures the total light output, relative to the response of the human eye.

For bulbs that are suitable for general room lighting—those with wide beam angles, above 60 degrees, but preferably 90 degrees or more—matching lumens for lumens should give you the result you need. Thus, for these types of lights (these are generally found in the common Edison screw, bayonet or 'oyster' fittings), the 'equivalent-to' rating should be all you need to determine if the bulb is a suitable replacement.

For directional lights, often known as spot lights, it's a bit different. These are lights with a smaller beam angle, up to around 60 degrees. Such lights are generally used for task lighting, directed onto a desk or work area. Halogen downlights are an example of these—it's because of their small beam angle that so many of them were needed to light a room! For these spot lights, small differences in the beam angle can make a big difference in how bright the light appears. Many people have had the experience of buying an LED bulb which was meant to be equivalent to a 50 watt halogen, but found that it appears much less bright. The lumens may have been lower, but more likely the beam angle was narrower, creating a bright light directly under the light but darker patches around it.

So just what is the **beam angle?** Beam angle is the angle at which the light is dispersed—usually considered to be the angle at which intensity, or brightness, falls below 50% of the brightness directly under the light.

When comparing directional lights, you can compare both the **beam angle** and lumens to give you an idea of the lighting levels the lamp will produce. A spot light with a small beam angle (say 30 degrees) will concentrate its light intensity in a small area directly underneath and 15 degrees either side of the light. A spot light with a larger beam angle (say 60 degrees) will spread its light output over a much larger area, and thus the intensity will be lower, even if it has the same lumen rating.

So, when shopping for replacement/retrofit spot lights, look for bulbs that have similar beam angle and lumen figures as the bulbs you are replacing. That way you are assured of similar brightness and light distribution.

However, we should mention that the limitation experienced with halogen downlights of beam angles generally not being available wider than 60° does not exist with LEDs. While many LED downlight retrofit bulbs have narrow beam angles like halogens, you can also buy LED downlight bulbs with wide beam angles, such as those from Click, with a 100° beam angle. Wide-angle bulbs are ideal replacement bulbs for general illumination where multiple downlight fittings have been used to light a room. The end result is more even illumination, with less pooling of light. Just make sure you choose bulbs with adequate lumen ratings to provide appropriate illumination levels.

This leads us to the measure of light intensity, which is **lux**. For an example of how beam angle affects lux levels, see the diagram below. Lux diagrams are sometimes included on spot light packaging, but if not, you can calculate it based on lumens, distance from the light source and the beam (or lens) angle of the light. See www.bit.ly/1NbqDsE and www.bit.ly/1LxK2Ex for two such calculators.

While the desired level of light intensity is subjective, there are standard recommended lighting levels for particular situations, which can be found

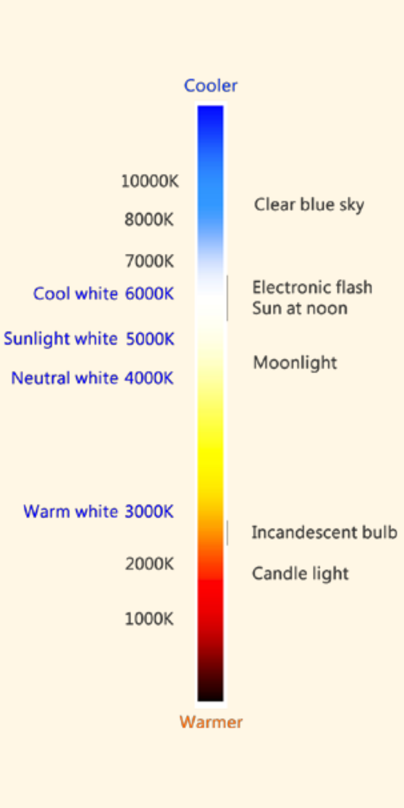


Image: www.buenoopto.com (modified).

↑ Colour temperature varies from low to high, corresponding to warmer to cooler. Warmer light is usually better for lounge rooms, or rooms frequented after dark, whereas cooler light is often more suited for work areas and kitchens. But ultimately it comes down to personal preference.

in the Australian/New Zealand Standard for Interior Lighting AS/NZS 1680. Typical levels can be found in a range of publications and websites, such as www.bit.ly/1TvHokf.

EFFICACY: LUMENS PER WATT

The number of lumens produced per watt of electricity used gives you a way of comparing the efficacy (or efficiency) of LED lights. For instance, if you have two LED bulbs, one producing 500 lumens and one producing 600, but both using six watts, then you immediately know which is the more efficient. Generally, the higher the lumens per watt, the better, although the light also needs to be fit for purpose, in terms of beam angle and light quality. Currently, a baseline is to aim for at least 60 lumens per watt (making them at least as good as the best compact fluoros), although that will continue to improve over time. There are some lights already available providing 100 lumens per watt.

LIGHT QUALITY: COLOUR TEMPERATURE AND CRI

Beyond the light output, there are two important aspects of light quality that will affect the light's suitability, including the colour temperature and colour rendering index (CRI).

The light's colour temperature, usually specified in Kelvin (K), tells you the type of light you will get. Warm white is generally any number up to 4000 K. Neutral white is 4000 K to 5500 K and cool white or daylight white is 5500 K and above. Different manufacturers use different ranges, but remember that the lower the number, the warmer, and redder, the light, and the higher the number, the cooler and hence bluer the light. Warm white is the colour many of us are used to from the original tungsten incandescent lights, but neutral or cool whites may be better for close-up tasks or where higher contrast is required. (See en.wikipedia.org/wiki/Color_temperature.)

Another important measure of light quality is the colour rendering index, or CRI. This is a number from 0 to 100 that tells you how well the light will render colours, with 100 being the best. Most LEDs are above a CRI of 80 nowadays, and this is considered good enough for domestic lighting. Some high-end fittings will use LEDs with CRIs over 90, but these fittings tend to cost a bit more. But if you are using LED lights in your art studio, for instance, then you probably want the highest CRI lights you can find.

LIFESPAN AND LUMEN MAINTENANCE

The rated lifespan of LED lights is given in thousands of hours, just like other forms of lighting. Normally you will see figures somewhere between 10,000 and 100,000 hours, depending on quality, design, and how realistic the manufacturer is with these figures. But what does that lifespan number actually mean? Will the bulb die after that many hours?

Like other lighting types, LED lights lose a small percentage of their light output over time. The rated lifespan usually refers to an output in lumens of 70% of the original figure. So if a light is rated at 1000 lumens and 20,000 hours, then at 20,000 hours it should still produce at least 700 lumens. This is the lumen maintenance figure.

Unlike other lighting types, which tend to suffer complete failure before too much degradation of output has occurred, LED lamps that have reached their technical end of life can still be used where less light is required, giving them an even longer lifespan. They will still draw the same power, so their efficacy will have dropped, but this may not be an issue, for example, if they are moved to rooms such as bedrooms and laundries, where they see only short-term intermittent use.

Retrofitting LED bulbs

If you are building or renovating, you are not limited in which LED fittings or lamps you decide on, as your favourite light fitting style can be integrated into the new build. But if you are looking to use LEDs in an existing home then there will be some limitations, depending on the amount of work you are willing to do and your budget.

HALOGEN DOWNLIGHT REPLACEMENTS

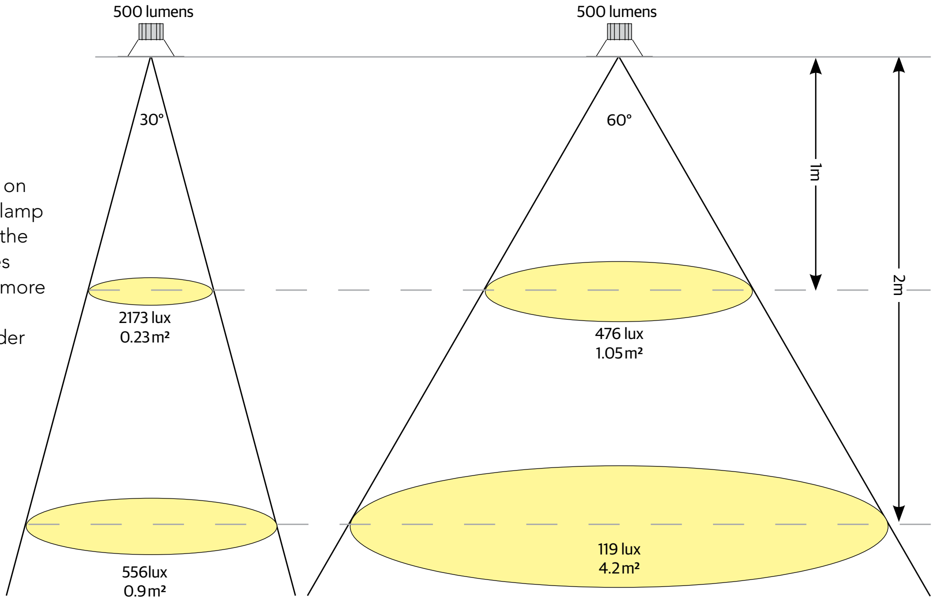
Replacing inefficient halogen downlights is where the domestic LED lighting industry started, at least here in Australia. The easiest retrofit for halogen downlights is a direct plug-in LED bulb for the original halogen bulb.

Halogen downlights come in two styles—12 volt MR16 (which include a voltage transformer) or 240 volt GU10—and there are LED replacements for both styles. It will be printed on your bulb which type it is—you can also tell by looking at the connector. The biggest problem with LED halogen downlight replacements is that they can run hot in the cramped space of a halogen downlight fitting, and heat can be damaging to the electronics in LED bulbs. However, improvements in LED efficacy and smarter bulb design mean this is becoming less of a problem (see box 'Keeping your LEDs cool').

Another consideration is the transformer. For GU10 bulbs, which run directly from 240 volts, there is no transformer—you simply fit the LED bulb and you're done. But for MR16 12 V halogens you may have to look at a transformer replacement for each bulb.

The transformer's function is to drop the 240 volt mains voltage down to 12 volts. Being nothing more than a heating element, halogen bulbs are rather forgiving in the type of power they receive. But, as electronic devices, LED bulbs are not always compatible with the average halogen transformer.

Electronic transformers (supplied with most newer MR16 halogen fittings) are smaller, lighter and more efficient, but they are not really designed for the small loads LED bulbs place on them, and many will malfunction, resulting in lights that flash or turn off after a brief period. When retrofitting with LED MR16 bulbs we highly recommend using transformers designed specifically for running LED bulbs. This requires the old transformers to be removed and new ones fitted—usually a job for an electrician. However, if your fittings do currently have electronic transformers, try the new LED bulbs with them and see if they operate correctly—you might be able to avoid swapping all the transformers. You are unlikely to cause any damage to either bulb or transformer and it will be immediately obvious if there is a compatibility problem. We don't recommend that any LED bulbs are used on the old ferromagnetic transformers as the transformer may be wasting more energy than the LED bulb is actually using! A better solution is a complete fitting replacement to eliminate the need for transformers altogether. The old fittings can be replaced with either GU10 fittings and GU10 LED bulbs, or, preferably, dedicated LED fittings (see 'Dedicated LED fittings' later in this article).



→ Lighting intensity levels (lux) depend on both the total light produced by the lamp (in lumens) and the beam angle. For the same light output, wider beam angles result in lower illuminance levels but more even illumination, so go for narrower beam angles for task lighting and wider angles for general ambient lighting.

These two downlight retrofit bulbs from Crompton Lighting look similar, but are quite different. The bulb on the left has a GU10 base and runs straight from mains voltage, so requires no transformer. The other bulb has a GU5.3 base (commonly referred to as an MR16 lamp) and requires 12 volts and hence the use of a transformer.

GLS BULB REPLACEMENTS—BAYONET AND EDISON SCREW FITTINGS

GLS stands for general lighting service—in short, the standard-sized incandescent bulbs that everyone knows about, that were phased out with the first stage of the lighting MEPS (minimum energy performance standards). If you have standard light fittings that take bayonet (BC15 or BC22) or Edison screw (ES14 or ES27) sized bulbs, then using LEDs may be as simple as swapping bulbs—with some considerations.

GLS lamps fall into two broad categories. The first type, a power LED bulb, uses a small number of power LEDs (LEDs fall into three broad categories—low power, under 100 mW, medium power, up to 0.5 W, and power LEDs, which are generally 0.5 W and above), or a greater number of lower power LEDs, such as the common 5050 (5 x 5 mm) sized devices. The LEDs are all mounted on one (usually circular) circuit board with a diffuse or clear dome over the top. This type of bulb usually has a metal or ceramic body with lots of heatsink fins for cooling.

The other type is known as a corn bulb. This type get its name from its appearance, as a corn bulb consists of dozens to hundreds of low-power LEDs, usually surface mounted, fitted to multiple circuit boards that are then assembled to form the body of the lamp. Corn lamps may or may not have a plastic cover to protect the LEDs. Units without a cover pose more of an electrical shock hazard and so only fully enclosed units should be used.

Many retailers of power LED bulbs will dismiss corn bulbs as being cheap and low-grade. While this can be true, many not only perform well, but their driver designs are amazingly simple, so there's very little that can go wrong.

FLUORO REPLACEMENTS

Despite their relatively high efficiency, even fluoro tubes are being replaced by LEDs. Reasons to do this include flicker elimination, dimmability and the reduction of toxic materials (fluoros use mercury, LEDs don't).

Replacing fluoro tubes can be done with a simple tube replacement with an equivalent LED tube (sometimes requiring bypassing of the fluoro fitting's ballast), although for a nicer appearance a complete replacement LED panel fitting is often the best option. LED panel lights have a diffuse lens and smooth integrated appearance and generally look a lot nicer than the fluoro fittings they replace.

Dedicated LED fittings

When building or renovating it's best to consider dedicated LED fittings. Unlike retrofit lamps, these are a complete fitting designed as an LED light from the ground up.

The fitting usually has an array of LEDs mounted on a circuit board which is attached to the base of the fitting. Also included is a matching driver (see 'LED drivers' section for more on drivers), usually also mounted inside the fitting. The metallic circuit board is attached to a heatsink or the metal fitting itself to dissipate heat. So, while an LED fitting may look like a regular fitting that uses replaceable bulbs, inside they are very different—there are no bulb sockets, and the LED array is designed to last the lifetime of the fitting (anywhere from 15,000 to 100,000 hours of runtime). While both the LED array and driver can usually be easily replaced by a suitably experienced electrician (or a competent DIYer), this is rarely needed.

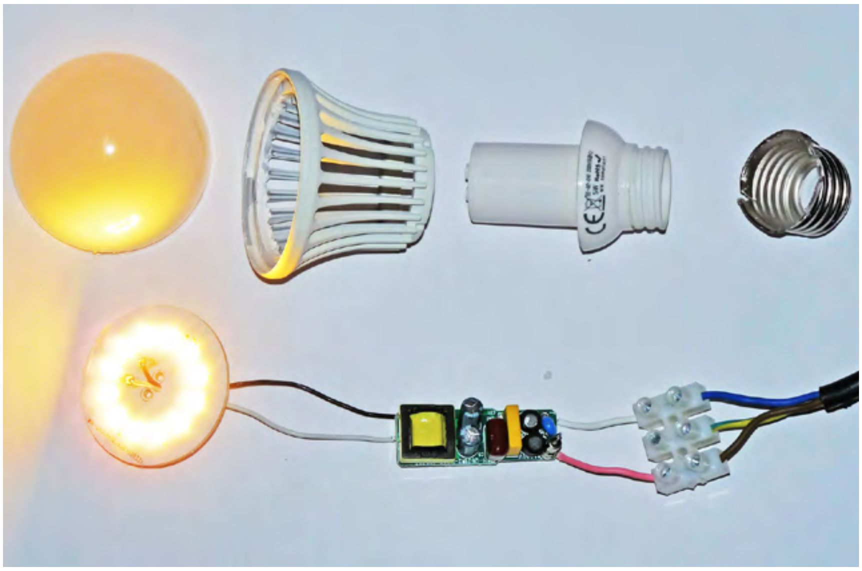


Image: Wikipedia user Dmitry G

↑ Inside a typical LED Edison screw replacement bulb. Clockwise from top-left (ignoring the terminal block, which is not part of the bulb) are: plastic diffuser dome, metal heatsink, plastic body/insulator, screw base, LED driver, and LED array.

↑ High-output GLS bulbs are few and far between in Australia, but this is slowly changing. This 18 watt unit from Philips puts out 2000 lumens and should be available here by the end of the year.

Dedicated fittings come in a large variety of shapes and sizes, from flat panels for office lighting, to flush-fitting downlights, wall washers, uplighters, oyster fittings (see example p. 70) and even outdoor floodlights.

Driverless LED arrays are also available. These consist of strings of many low-power LED chips bonded to a ceramic substrate. There are so many LEDs in each string that they can handle full mains voltage without the need of a driver. They do have a maximum input voltage, above which they can be damaged, but most driverless arrays can handle voltages typically seen in most homes. These arrays have mainly been seen in outdoor floodlights so far, although they could be used in any light fitting.

Even if you are not renovating or building, using a dedicated LED fitting will usually give the best result, regardless of the type and style. However, replacing a complete fitting rather than just swapping a bulb will cost more and usually needs an electrician, increasing the cost considerably.

Halogen downlight fittings are usually easily removed from the ceiling and there are LED equivalents that simply slide into the same hole. Unless the new fitting requires a larger hole, the only onerous requirement is that an electrician might be needed to make the electrical connection (although some just plug in to power points in the ceiling).

The same applies to surface-mounted fittings such as oyster fittings and the like—dedicated LED versions are usually available and they just need to be installed by a qualified electrician.

LED RIBBONS

LED ribbons and strips are available by the roll where they are just unrolled, stuck into place and power applied. These are ideal for hidden lighting above cupboards and pelmets.

The other advantage with LED ribbons is that they are a DIY solution. Because they run from extra-low voltage DC, such as 12 or 24 volts, you can install them yourself and power them from a suitable mains power supply or plugpack, which are readily available from electronics stores.

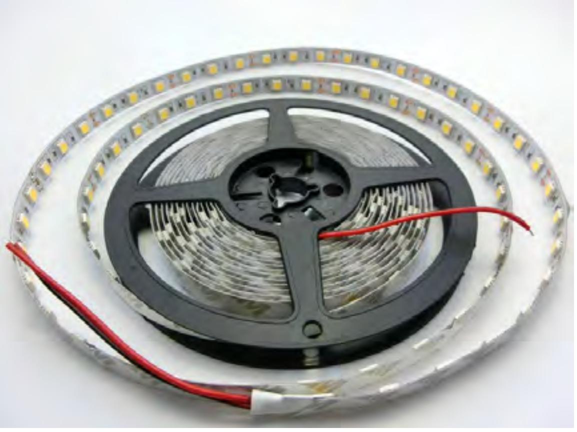
LED strips are also available in complete kits precut to shorter lengths, say 300 mm or 500 mm. They usually have short leads with plugs and sockets already fitted and you simply stick them in place, plug them together and plug them into the matching power supply supplied in the kit.

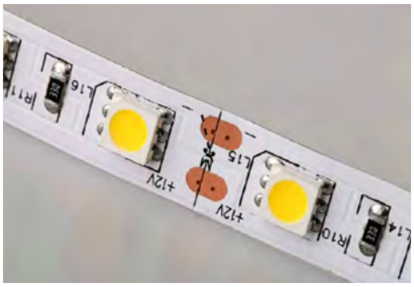
OUTDOOR LIGHTING

Outdoor lighting is also rapidly becoming LED-powered, with halogen floodlights and spotlights being replaced with LED equivalents that use 20% of the power and put out more light. Other forms of outdoor LED lights include deck lights (like downlights, but recessed into the deck to point upwards instead), highlighters (for specific garden features such as interesting plants or statues), path lights, bollards and every other type of light that previously used halogen or incandescent lamps.

There are also solar-powered lights which, while often low-powered units, can make it easy to light areas with no access to electricity.

On the commercial level, there are large ES40-based streetlight lamps, waterproof outdoor floodlights, commercial bay lighting and just about any other form of lighting you can think of. And, of course, lit signage is almost completely dominated by LEDs nowadays. Even neon has largely been replaced with flexible LED 'neon' materials.





↑ LED ribbon or strip on a roll usually comes with short flying leads already attached. Connection to a power supply is done either using a terminal block or screw-on sockets, which mate with the plugs used on most 12VDC general-purpose power supplies. LED ribbon can be cut every three or six LEDs (depending on the ribbon design, see the cut point at right) using just a pair of scissors, although you will need to solder new wires to the cut ends, so some DIY skill is required (solderless clips are available but they are less reliable than soldered joints).

Special features

Nothing comes close to LEDs for special features. Because they are electronic components, you can easily control them to do pretty much anything you like.

Bulbs and fittings are available that can be operated using remote controls, or even over wi-fi or Bluetooth via your phone or tablet. Functions include dimming, soft start (where the brightness ramps up over a second or two), colour temperature adjustment and complete colour selection, depending on the bulb design and the LEDs used. Most devices like this use controllers that remember the last settings used, even when turned off. This is a level of versatility not seen outside of commercial lighting controllers until LED bulbs hit the market.

There are several proprietary systems that allow control using a home's wi-fi network and apps on smartphones and tablets. A typical example is the Philips Hue system (www.meethue.com), which uses smart bulbs that talk to a hub (also called the bridge as it links the wi-fi to the bulb control network). The bridge can handle up to 50 bulbs and allows them to be operated over the web, so you can control your lighting from anywhere.

There are a number of similar systems, including some with wi-fi enabled bulbs that don't even need a bridge, simplifying the system further, such as the Ilumi smartbulbs (www.ilumi.co).

Lighting can also be controlled using a broader smart home system such as the Clipsal C-Bus system, which controls lighting, environmental systems, security, home theatre and even keyless entry. If you are planning a smart home then check to see what lighting control options are included.

Of course, all of these smart control systems require that the light switches are left on so that the bulbs or fittings have power. There is a small standby power draw for each bulb, fitting or hub, although standby for each unit is generally less than 1 watt. However, if you have many such lights, the total standby may be several watts in total, adding a small but measurable amount to energy consumption; but this is tiny compared to the energy savings from using LEDs over other forms of lighting.

Many newer LED bulbs, including retrofit replacement bulbs, are also dimmable using standard triac dimmers (the dimmers used for incandescent bulbs), although some work with a particular type of dimming only, such as leading-edge or trailing-edge dimming. If your bulb has these restrictions then you must use the correct type of dimmer. Also bear in mind that some dimmable bulbs may flicker slightly when dimmed down to a low light level.

LED drivers—integrated or separate

Most LED lighting has a driver built-in. LEDs require careful control of the current flowing through them, so an electronic circuit called a driver is used to do this.

For retrofit bulbs, the driver is built into the bulb, so you don't have to worry about it. With dedicated fittings, the driver may be integrated as part of the fitting or separated from it.

Having the driver separated from the LEDs means that it will not be affected by the heat the LEDs generate (and any heat it generates won't overheat the LEDs)—provided the driver is not mounted on top of the heatsink as is the case with some fittings! It also means the LED fitting and the driver can be replaced individually should there be a problem with either, thus reducing replacement costs.

Because LED configurations usually fall into specific voltage and current ranges and many after-market drivers have flexible output voltage ranges, you don't have to use a driver identical to the original in order to repair a failed fitting—often a generic off-the-shelf driver will do, provided it has the same current output as the original and its output voltage range encompasses the LEDs' forward voltage requirements.

LED limitations

LEDs do and don't have limitations. That sounds silly, but generally issues with LED lighting are the result of poor (or compromised) design of the LED bulb or fitting rather than the LED light sources themselves. Indeed, LEDs are the most versatile lighting by far—they can be used in places that were simply impossible for other lighting technologies.

The limitations tend to be in the low-cost consumer-oriented bulbs and fittings. For example, there is a tendency for bulb manufacturers to make their GLS bulbs with a beam angle of around 180° so that light is emitted out of the end of the bulb. This is done as most of these bulbs are used hanging down in pendant and similar fittings, so they light the lower half of the room, where the occupants are, quite well. It also allows lower wattage (and hence cheaper to make) LED bulbs to produce illumination levels in the lower half of the room similar to a higher wattage incandescent than would otherwise be expected by comparing total lumen outputs. However, if you prefer the lighting to be more even, without the upper part of the room being dingy, then you will need to choose a LED bulb that has a wider beam angle—at least 270°—and a more appropriate total lumen output rating.

In Australia we still don't have the full range of retrofit bulbs that are found in other parts of the world, and many are more expensive. For example, we don't have the fantastic GLS bulbs made by Cree for the US market. They retail for under US$20 (and less than US$10 after government incentives!), have a wide beam angle and even light distribution and are similar in size and light output to a regular 100 watt incandescent—they are even dimmable.

↑ Corn bulbs should always have full insulating covers for safety.

While all electronic devices are required to have C-Tick approval for electrical noise emissions, there is still a problem with some LED bulbs in that they may emit electrical noise that interferes with other devices, especially with radio and TV reception.

It's possible to buy bulbs that have

Keeping your LEDs cool

The primary consideration when using LED retrofit bulbs is heat dissipation. Incandescent lamps are designed to run hot, but for LEDs, heat is the enemy.

Most LED bulbs have adequate heatsinking, provided they are used in fittings that allow for some convective airflow. However, there are still bulbs pushing the limits, with too much wattage and too little heatsink surface area to dissipate the generated heat. This problem is most common in downlight replacement lamps, usually in the 12 volt MR16 and GU10 types, but some Edison screw/bayonet, candle style and 'fancy' style (the little round globes used in chandeliers and the like) replacement bulbs have less than adequate surface area.

However, provided you have a good-quality, well-designed bulb, the main issue to be aware of is the type of fitting you are using it in. There's no point having lots of heatsinking if the bulb is used in a fitting that simply doesn't allow the heat to dissipate. This is less of a problem nowadays, as LEDs are more efficient and so produce less heat per rated watt, but it's still something to be mindful of when selecting bulbs and fittings. Fittings with at least a few cooling holes near the top to let warm air escape should be used. If you have sealed fittings such as oyster fittings, you are better off replacing the fitting with a dedicated LED unit, as the entire metal base of the fitting is used as a heatsink.

Heatsink material and finish also play a role. There are still some manufacturers making bulbs with chrome-plated heatsinks. Shiny surfaces like chrome plating do not emit heat well and a chromed heatsink may cause a lamp to run 20 °C hotter than the same heatsink in a black anodised or high emissivity finish.

Some (although very few) LED bulbs use tiny integrated fans, allowing LED lamps up to 10 watts to be used in a standard downlight fitting. The disadvantage of this is that you introduce the problems experienced with all fan-cooled devices—fan noise, bearing wear and dust build-up.

Another method of dealing with heat is to make the lamp much longer than the original halogen bulb. This is how the Brightgreen retrofit bulbs work, as do many others including low-cost Chinese models. This only works in fittings with an open back, with the bulb connector on a cable rather than fixed to a bracket. For fittings where the bulb connector is fixed in place you can only use replacement lamps the same length as the original halogen.

↑ It may look like an incandescent lamp but it uses LED 'filaments'—thin metal strips with many series-connected LED chips on them. There's a small driver in the bulb base. While you might think the LED filaments would overheat, they are designed to handle high running temperatures while giving reasonable service life and efficacies of 100 lumens per watt or more. We can attest that these sorts of bulbs work well and look great, although lifespan is unknown as they are quite new to the market.

C-Tick and other compliance stamps, but that have not undergone testing. As a regular LED product buyer, I have had numerous overseas suppliers offer to print on their products whatever compliance marks I require, and some will even provide fake compliance certificates. While most Australian suppliers are selling certified products, the question for most consumers is 'how do I know?' The short answer is that you don't, not with 100% certainty, so it's something to be aware of.

If you buy an LED bulb or fitting and it produces electrical interference on other devices, you can simply take it back. A C-Ticked light fitting should have been tested and been shown to not interfere with other appliances. If you really like that particular light then you can have noise suppression fitted in the form of clip-on ferrite beads—these can dramatically reduce emitted noise when fitted on the cables close to the light fitting.

Most currently installed light fittings are designed to be used with incandescent bulbs, so LED lamps, which generally require ventilation so their internal electronics don't overheat, may have reduced lifespan in unventilated fittings. Some fittings, such as bulkhead and oyster fittings, have limited space for ventilation, so the bulb needs to be sized so that it isn't generating more heat than can be dissipated by the fitting.

Mains power quality can also have an effect on some LED bulbs and fittings, especially dimmable ones. Of particular concern is the use of control tones (ripple signals) on the mains waveform to control particular appliances at off-peak times, such as electric water heaters. These tones have been in use for decades and have generally not been an issue with previous forms of lighting, but LED lights not designed with immunity to these tones may flicker or audibly buzz, making those lights useless when the tones are being generated. Currently only NSW and parts of Queensland use ripple tones, and the effect of the tone seems to vary

Zero-energy options

While this article deals with electric lighting, there are a couple of other options that should be considered. Skylights and light-pipe systems can provide more than adequate lighting levels with no use of electricity at all and, if well placed, won't heat the room unnecessarily.

An alternative to the conventional skylight is the solar skylight. These use an LED light fitting (usually a circular or square panel) directly connected to a small solar panel on the roof. This allows much greater flexibility of placement of the light panel and can allow solar/LED lighting in rooms that would not be able to use a conventional skylight—with zero running costs. The Illume system from Kimberley is a good example of such a system.

Another option is the tracking mirror, or heliostat. While normally reserved for large-scale solar thermal power systems, there are domestic-scale heliostats designed to reflect sunlight into rooms that normally have no solar access, such as south-facing rooms. The Sunflower from Wikoda (see *ReNew 120* or www.wikoda.com) tracks the sun and reflects it in through a window onto a fixed spot in the room, usually on the ceiling. On a reasonably bright day, one Sunflower can reflect several thousand lumens of light into a room, completely eliminating the need for artificial lighting.

A second similar option is Lucy (www.solenica.com) and while new and as yet a bit of an unknown, it looks simple enough that it should be fairly reliable.

inversely with the distance from the substation, so if you are in an affected area and close to a substation, make sure you ask your lighting supplier about this issue, and get a guarantee in writing that the lights are unaffected by control tones.

Buying advice

Don't just settle on the first LED light you find that matches your requirements. Find several and compare specifications, talk to the suppliers and see if they have any recommendations. And check out online information sources such as forums and review websites—it's surprising how many people write about their light fittings!

With the explosion of the LED lighting market, you can buy most sizes and types of LED light fittings here in Australia, at a price that probably makes buying from overseas no longer worthwhile—especially when you factor in that overseas fittings will not have Australian approvals, and electricians will not fit them.

There are three good reasons to buy from Australian suppliers: warranty, insurance and safety. Australian sellers are bound by Australian consumer laws, and the lights they sell are required to have Australian approvals. With regards to home insurance, should you have a fire that can be traced back to an imported, unapproved LED bulb or driver, your insurance company may not cover your claim.

Warranties vary widely, from three months to several years, with the higher quality units usually having longer warranties. For any half decent LED bulb or fitting you should look for at least a one-year warranty, preferably longer.

You should also keep your receipts for your LED lighting as you will need them in case of an early failure a year or two down the track. Because of their higher initial cost and long-rated lifespans (and hopefully decent warranties), you should treat their purchase more like that of an appliance rather than a disposable item.

Overall, before you buy any LED bulbs or fittings, look at them closely and look for any signs of poor design, cost cutting and the like—these things are usually fairly obvious—especially poor finish such as unprotected sharp edges on cable entry holes. Generally, buying brand names such as Philips, Cree, GE, Brightgreen and Osram will ensure you buy a safe, good quality bulb or fitting, although there are many other lesser know brands that are also equally good, such as Verbatim, Mort Bay and Megaman. You should also check out review websites such as Choice (choice.com.au) and LED Benchmark (www.ledbenchmark.com).

Safety

Like any electrical device, there are safety issues involved with LED lighting. The most common issue is with inadequate insulation of the internal components of LED bulbs and fittings from the external metal case/heatsink, which has been a problem for some imported devices. Another issue is that of electrical isolation (between the incoming mains and the output that drives the LEDs) of LED drivers, which are often a separate part of the fitting.

Some cheaper imported bulbs have excellent insulation around their internal driver and mains voltage components, while others have less than adequate insulation. Unless you have electrical/electronics experience it can be difficult to tell if a bulb is safely designed or not, so we recommend that you stick with Australian suppliers—bulbs and fittings from Australian suppliers should all comply with the relevant safety standards so this shouldn't be an issue with most purchases.

As for fittings that use separate drivers, or when buying replacement drivers for an existing fitting, all Australian-supplied drivers should be tested and approved and therefore safe. If you are buying fittings directly from overseas suppliers, there are good ones and bad ones. We can't recommend that you buy LED fittings from other than local suppliers, but if you do, make sure you research safety issues such as isolation and earthing before buying.

Dedicated fittings can also have some less than ideal designs. Some fittings have the mains driver built-in and the mains wiring enters the fitting through an uninsulated hole in the middle of the heatsink. This means the wiring is not only vulnerable to the sharp edges of the heatsink hole, but also the heat from the LEDs, which can soften insulation and degrade it. Again, fittings with separate drivers will eliminate this issue.

Resources:

Minimum energy performance standards (MEPS) for lighting: www.energyrating.gov.au/products-themes/lighting

Lighting Council Australia, including their quick and easy LED buyers guide, a guide to replacing MR16 Halogen Lamps with LEDs, and a guide to choosing LEDs and LED suppliers: www.lightingcouncil.com.au

LED lighting reviews: www.ledbenchmark.com


HEALTHY
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CARAVANS
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WATER
EFFICIENCY
AROUND THE HOME
GREEN HOME
COOLING
GREEN HOME
HEATING
OFF-GRID
HOMES