ReNew

Issue 126

Technology for a sustainable future

The travel issue

Sustainable travel
the road less ridden

Carrying power
Cargo bikes

Caravans unplugged
PV and battery tips

Buyers guides x 2
Solar PV & DC appliances

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Off-grid home: 10 years on solar
What's watt: electrical terms explained
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← **Cover image: Paul Anthony Judd.** *ReNew* reader Paul Judd's entry in our *ReNew* reader prize on travelling sustainably. In his entry, he writes that he travels by bicycle and train whenever possible, and carbon offsets any international flights. This photograph was taken towards the end of winter at Lake Motosu, near Mt Fuji, on the way to the youth hostel in Fujiyoshida. The next day he cycled the 100+ kilmetres to Tokyo while it was snowing! Page 36.

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Who needs fossil fuels?
Making the solar car commercial

Swinburne University designs a Mad Max-inspired car that could survive in a post-apocalyptic world devoid of fuel or power, writes Clint Steele.

SOLAR cars have been around for more than 30 years. Most *ReNew* readers will have seen at least one story about the World Solar Challenge, the solar car race from Darwin to Adelaide (including in the last *ReNew*!).

Solar cars now readily make this journey every two years. In fact, it may have become a bit passé. There was a time when the event would gain considerable attention, but now it seems less of a challenge and more of a hobby for those with the desire and technical know-how, and the media is less interested.

Perhaps it's time to take solar cars to the next level.

The idea to make a commercially viable solar car—one that can be sold at a profit and so allow for a sustainable business—is not completely new. There is the Venturi Eclectic, for example (see box at right).

Of course, there's a lot more needed than an idea to make something happen. Experience, expertise and commercial nous are essential.

This is the first article in a series about a group of Australians (solar racers, engineering students and business investors) working together to develop a locally produced solar-powered sports car for road use.

↑ A proposed design for Swinburne University's solar car, the Solaris. Surprisingly to many, one of the biggest challenges in car development is the sealing of doors. The clamshell design makes this a bit easier.

The power of solar

Imagine a car that will keep on running as long as the sun keeps rising each day. No matter how far you are from the nearest service station, you can keep driving. That's the strength of the solar car: complete freedom.

Not only can you keep on going, you know that there is no question of pollution while you drive. Standard electric cars need power from somewhere and this might be a renewable source or not. With a solar car, there is no doubt: it's clean.

That was the idea from the chairman of Aurora Solar Racing: a Mad Max-inspired car that could survive in a post-apocalyptic world devoid of fuel or power, and designed to show to the world just how powerful solar power can be.

It is intended that the solar car will look and handle like a sports car, with respectable take off and tight handling, to counter some of the common stereotypes about solar cars (slow, poor handling, more like a golf buggy than a real car) and so demonstrate the wider potential of solar power. The plan is that this is a car that could be used for doing the shopping, but also for more exciting things.

The discipline of engineering

Aurora Solar Racing has more experience in solar car racing than most other organisations. On a shoestring budget, the team has competed around the world with innovation and determination to make things work.

But making a car that can run on the road also needs a lot of engineering discipline and dedicated time. Since 2012, Aurora has been working with a team of engineering students at Swinburne University to refine the design of Aurora's latest solar racer into a commercially viable road-going sports car: the Solaris.

Strategic design

The defining challenge of a solar car is the efficient use of energy to generate speed. At best, a solar car can expect 1.25 kW of power. Compare this to the maximum power of a medium Australian sedan (250 kW) or a small computer (0.1 kW). A solar car is closer to a computer than a regular car when it comes to power.

EV charging demystified
All your EV questions answered

Getting energy from moving electrons is not so easy to see or understand. Bryce Gaton answers some of the common questions about EV charging.

BURNING things to produce heat, light or movement has been with us a long time. From toasting goannas over a fire, to gas lighting in Victorian times and burning petrol in a combustion engine: we can easily see and relate to this form of energy release and use.

On the other hand, getting energy from moving electrons is not so easy to see or understand. A consequence is that more than a few myths and misunderstandings have sprung up about the use and capabilities of electricity as a power source for our cars.

In this article I hope to dispel a few of these myths—as well as probably starting other debates about the capabilities and limitations of electric vehicles!

← There are several different charging plug types in use for EVs. Here you can see a J1772 plug being used to charge a converted Hyundai Getz.

To sum up

EVs are vastly more efficient in using energy to move a vehicle, but a battery pack simply cannot pack the punch per kilogram that each litre of fossil fuel does. (A second conclusion is that we are incredibly wasteful of the energy in our petrol tanks.)

Question 1: Why can't I get the same distance from an EV battery pack as I can from a petrol tank?

This comes back to why fossil fuels are so popular as an energy source: they are a really energy-dense material that is packed full of energy waiting to be liberated!

To explain why a battery pack is not the equivalent of a full fuel tank, consider the figures in Table 1, showing battery pack sizes and ranges as an equivalent number of litres of petrol. Even the Tesla with its 750kg battery pack only contains the equivalent energy of 8.95 litres of petrol.

That being said, looking at the last column, a standard petrol car at 10L/100km uses something like 5.5 to 8.5 times the amount of energy an EV uses to cover the same distance!

Vehicle	Battery pack size	Approx battery pack mass	Vehicle range	Equivalent litres of petrol in the battery pack	Equivalent L/100km
Tesla model S	85kWh	750kg	484km	8.95L	1.85
Nissan Leaf	24kWh	294kg	175km	2.5L	1.43
Mitsubishi iMiEV	16kWh	200kg	150km	1.7L	1.13
Blade Electron (Hyundai Getz conversion)	16kWh	185kg	100km	1.7L	1.7
Petrol car at 10L/100km	475kWh (equivalent)	NA	500km	50L	10

Table 1: Manufacturers' battery pack sizes and ranges as an equivalent number of litres of petrol.

Notes:

Calculations are based on the average litre of petrol containing 34.2 megajoules per litre (MJ/L). Converting this to watt-hours (Wh)—the normal measurement unit for electric cars—given 1W = 1J/sec, 1 hour = 3600 sec, this equates to $34.2 \times 10^6 / 3600 = 9500$ Wh or 9.5kWh.

Vehicle range: the actual range for Nissan, Mitsubishi and Blade EVs appears to be closer to about 80% of these published figures. Tesla EVs, however, seem to be fairly close to their stated range.

Carrying power
The resurgence of cargo bikes

Can pedal power be used to replace a car? Adam Peck says yes, with his household replacing one car with two electric cargo bikes. He discusses the options.

CARGO bikes are becoming more and more popular these days. This article explains what they are and how to go about choosing one for your needs. It also highlights my family's journey from a two-car family with two garage-bound pushies to our new one-car status with two well-used electric cargo bikes.

Cargo bikes have become very popular in Holland and Denmark. They are often used as a family transport vehicle in these countries' bike-friendly cities—and also just for lugging bulky items around. Most of these are pedal-powered pushies due to the mainly flat roads and short distances.

The case for electric

In Australia, cargo bikes are becoming a more common sight around the roads, carrying kids and cargo. At least here in Perth, it seems that these are often electric cargo bikes. With our more hilly roads and longer distances, an electric cargo bike is more practical, making it more likely that it will be used frequently, and as a car replacement.

Cargo bikes are pretty heavy and the loads they carry can be even heavier, another reason why electric assistance is an attractive option. Most box-style cargo bikes (bakfiets, or box bikes) weigh 30+ kg, and can carry 80+ kg in the box, 40 kg on the back rack plus the weight of the rider—over 250 kg in total! With those sorts of loads, unless you have legs of steel, you might have to get off and push that bike uphill if it doesn't provide some assistance.

Cargo bike styles

There are a couple of different styles of cargo bikes. I nominally split them into three categories: bikes, trikes and utilities.

↑ The Bakfiets can take at least 80 kg in the front box.

Cargo bikes are two wheelers and have a big box in front of the rider. This may be made from wood or have a metal frame with a canvas cover. Most have a bench seat with space for two children and an optional extra bench for more. A rear rack and panniers can hold even more cargo. A stand under the box makes them stable when parked.

Cargo trikes are three wheelers, with two wheels either side of the box. They tend to be heavier than the two wheelers and can take bigger loads. Despite what you might think about the safety of three wheels versus two, three wheels are less stable when going around corners or over bumps.

Utility bikes look more like conventional bikes. They usually have a long wheelbase with sturdy rear racks. You can even convert an existing bike into a utility bike with an Xtracycle kit. The ultimate in this group in my view is the Workcycles Fr8, which can take a whopping 120 kg on the front rack!

Choosing a cargo bike

When choosing a bike, most importantly speak to dealers or owners of cargo bikes and ask for a test ride. Most dealers can put you in touch with people in your area who will let you test ride their bike. Some other things to consider are:

- **Usage.** What are you using the bike for? Is it for short or long distances (trike or bike), flat or hilly (pushie or electric), big loads or small (trike for big, bike for medium, utility

Off-grid living
Ten years on solar

Rob Burlington and his wife Liz have been living off-grid for over ten years. He describes their self-sufficient solar and water setup, and the lessons learnt along the way.

MY wife Liz and I live on 100 acres in the Capertee Valley between Lithgow and Mudgee, west of Sydney. We bought the block 17 years ago and would visit on most weekends, escaping from the outskirts of Sydney while we waited for our two kids to finish their education and run away from home and/or get married.

Our first semi-permanent structure was a cabin we built from a donated garage. On this we installed two 30 watt solar panels charging a 12 volt, 300Ah battery through a 4amp regulator to successfully run our lights. We had no hot water but a gas Consul fridge (these are excellent), a small two-burner gas stove and slow-combustion wood heater. The cabin became our full-time residence for the initial 18 months while we built what is now our home.

↑ RAL homes are low-impact, energy efficient and fire-resistant—ideal for the Aussie bush. This is the eastern side of the home with the carport being a non-RAL addition.

A modular and self-sufficient home

Our 'new' (now 11-year-old) house is worthy of a comment or two. After looking at various alternatives we decided on a RAL modular home. It's a little different and creates some local discussion but is very practical and comfortable. The RAL factory is located in Ararat in Victoria and we cannot speak too highly of the quality of the workmanship or the support provided by owner-managers Reiny and Lorraine Loeliger and their staff. In fact, we still occasionally keep in touch even now.

We made the decision to go totally solar for two reasons. Firstly, we had always wanted to be as self-sufficient as practicable and secondly, even though at the time the cost of the panels was three times their current price, it was going to cost us at least $15,000 more to connect to the grid, by the time we paid for a transformer and three poles to connect to the high-voltage line that runs across one corner of our block.

Solar power ups and downs

We ended up with a 1.6 kilowatt system (20 x 80 watt Solarex panels) wired to a bank of 12 x 650 amp-hour, 2 volt Sun Gel batteries through an 1800 watt, 24 volt SEA Voyager inverter. This is controlled by a Plasmatronics PL40 regulator.

All in all we were fairly happy with the setup although in retrospect we should have opted for larger capacity batteries. Even though we weren't over-stressing the batteries, rarely taking out more than the top 20 to 25% of the charge, one of the batteries decided to turn up its toes after seven years.

At this point I decided to buy 12 five-year-old sealed lead-acid (SLA) batteries I saw advertised and make use of the remaining gel batteries on the cabin, which, over the years, we have updated for family and friends' accommodation with larger panels, hot water and a septic system.

The 1000 amp-hour SLAs turned out to be a mistake and within 18 months they had begun to "fall over". To shorten a long story we decided to cut our losses and invest in a new bank of Raylite flooded cell lead-acid batteries giving us a storage of 1660 amp-hours at 24 volts. The 1.6 kilowatt system is enough to have them on float by between 12 noon and 2pm with average usage on a

Traveller tales
ReNew reader prize

We asked *ReNew* readers how they travel sustainably and we got back loads of great ideas and adventures. Whether travelling by road or river, or just finding places to relax, these readers have the ingenuity and technology to use less energy and to capture their own water and solar power. Thanks to all for writing in!

WINNER! Solar swagman

The dream was for a solar-powered houseboat. The affordable reality—an aluminium dinghy and a swag roll, with electric trolling motor and solar panels. I planned to travel in the solar boat up the Murray from Morgan to Echuca, powered only by the sun. Others have gone downstream, but as far as I know, no one has tried going upstream under solar power before. I reached Tooleybuc, but had to be towed by a power boat for about one kilometre on a stretch where the current was too strong. I completed the last leg of the journey by travelling downstream from Echuca, so the challenge remains: I'm working on it. **Trevor Toomer**

Congratulations to Trevor who wins a 120 W folding solar panel kit from Low Energy Developments.

Island getaway

French Island is my tip for a green holiday as it feels like a distance destination, but can be reached by public transport from Melbourne. The ferry trip helps to reinforce the psychological break from the 'mainland' and the everyday busyness of life.

Two-thirds of the island is national park, where you can connect with five distinct environments, including remnant forest, wetlands (Ramsar protected) and beaches. Accommodation and other facilities on French Island are mostly powered by solar and wind.

It's a great place to visit (200 bird species can't be wrong). You are also likely to spot koalas and echidnas. You can also enjoy walking and cycling (visitor cars are not allowed—I told you it's green). **Geoff Andrews**

Camp out, green style
Sustainable camping and caravanning

Getting away from it all may be great for our stress levels, but what about stress on the environments we visit? Elizabeth Claire Alberts discusses some important considerations to minimise the impact.

IF YOU'RE a nature lover like me, you'll probably agree that one of the best things to do is set up your caravan or tent in a national park, boil a billy of tea and relax with a cuppa while listening to the magpies. Camping and caravanning can reinvigorate the soul, helping to dissolve the stresses of daily life. At the same time, these activities can place plenty of stress on nature itself. By becoming a more conscientious camper, you can enjoy a better—and more sustainable—relationship with the outdoors, and help protect the environment for future generations.

↑ Camping on a six-day rainforest walk through the Tasmanian Tarkine with bushwalking company Tarkine Trails.

Camp waste-free

Single-use plastics are responsible for choking our waterways, damaging our oceans and killing marine species. It may be convenient to buy a lot of plastic-packaged foods for a weekend camping trip, but a good sustainable camping starting point is to try to avoid as much plastic and other packaging as you can. Apply the 'carry in, carry out' rule to waste, taking it with you to be disposed of properly. And of course, ensure you use refillable water bottles—stainless steel or plastic.

Another way to minimise your waste is to invest in high-quality gear. Don't buy the cheapest tent you can find—the seams might rip after a short while and the tent might end up in the bin. Instead, buy a tent that will last for years, if not decades. If you can't afford decent equipment, rent your gear from a camping shop or borrow from a friend.

Protect wildlife

One of the best things about camping is the opportunity to observe native animals. If you're lucky, an animal may stay still long enough for you to snap a good photo. But chances are, it will scurry away as soon as it catches your scent. Don't follow the animal into the bush, even if it's tempting. Stalking an animal will cause it distress and straying from a trail can damage sensitive vegetation.

It's also important not to feed human food to native animals. It can be harmful to their health and may also encourage them to depend on human handouts.

Leave no trace

Many of the sustainable practices discussed so far (eliminating waste, staying on the trail, not feeding animals) fall under the minimal impact code, which was developed in Tasmania in the 1980s and which every Australian state has now adopted. In addition to the aforementioned practices, the minimal impact code specifies that campers should not clear any plants to set up tents or to construct fireplaces. Campers are also discouraged from digging drainage ditches or using vegetation to build shelters. And once again, when bushwalking, you should stay on the trail, even when it's muddy.

Need to use the toilet? The minimal impact code recommends that all toilet business occurs at least 50 to 100 metres away from streams or lakes. Dishes should be washed using small amounts of biodegradable soap and the dishwater should also be dumped 50 to 100 metres away from waterways. If possible, avoid using sunscreens or insect repellents, which can contaminate waterways if you decide to take a dip.

Low-carbon cooking
Cooking with the sun

Australia's abundant sunshine should inspire more solar cooking, writes Stephen Williams.

I SUSPECT cooking, unlike, say, water heating, is usually regarded as one of those energy uses that we can't do much about. But most of us cook something every day and we often do it at times of peak demand, so this aspect of our lives deserves more attention if we want to reduce our fossil-fuel dependence and greenhouse gas emissions. With more people moving to time-of-use electricity tariffs, it is also worth looking at our options from a financial point of view.

So what are the options? Gas is not the benign fuel many once considered it to be and who wants to shell out thousands for an efficient induction cooktop. And even an induction cooktop (assuming you have the required type of pots and pans) doesn't help when it comes to cooking in an oven. Could solar cookers come to the rescue?

↑ A good solar oven can reduce or even eliminate the need for a conventional oven. Here in action, Heather Stevens from Sun Cooking Australia cooks biscuits in a solar oven. From left to right, you can see the SunCook oven, the SunRocket (used to heat water) and the Global Sun Oven.

Cooking with solar radiation

With Australia's abundant sunshine, it seems we could easily use direct solar radiation more for cooking.

There are two main ways to cook using direct solar radiation. Parabolic mirrors concentrate heat to a focal point and are good for relatively quick cooking like frying or barbecuing. Solar ovens, on the other hand, are better for slower cooking and baking. This article focuses on solar ovens.

How they work

A solar oven is essentially a well-insulated box with a glass top (sometimes double-glazed) to let solar radiation in. Reflective panels direct the sun's rays into the box. You place the food to be cooked in a thin, dark-coloured metal container, and place that in the oven. You then angle the oven to take best advantage of the sun's position; you can move it during the day to track the sun, but this is not always necessary.

Good ovens can reach temperatures of around 180 °C and so can eliminate the need for a conventional oven for most uses. They can be used at any time of year, as long as there is sunshine; ambient temperature is not critical, but food will cook faster in warmer weather.

What can you cook in them?

You can cook anything in a good solar oven that you can cook in a conventional oven or on a stovetop, except for cooking that requires frying or grilling. Baking bread, biscuits and cakes are obvious uses. Baked (or roasted) meats and vegetables are another mainstay. A solar oven will also do a slow-cooked stew or curry that you might otherwise cook on a conventional stovetop.

A solar oven will also boil water for cooking rice, pasta and so on, or do slow cooking of legumes such as chickpeas. Rather than have them simmering on the stove for hours, just leave them in the solar oven until done.

You can also use a solar oven as a food dehydrator by lifting the lid slightly to let the moisture out.

Fans of solar ovens say you cannot burn food in them as the heat is evenly distributed through the oven and baking dish, and the cooking is often long and slow. Nor does food tend to dry out as moisture is generally contained (depending on the oven's design).

Solar on the move
Providing power to mobile abodes

Collyn Rivers has a long history of self-sufficient caravanning. He explains some of the traps when designing solar systems for caravans.

THE number of caravans, motor homes and camper trailers currently registered in Australia is estimated at about 450,000. Many such recreational vehicles (RVs) are bought with solar panels factory-fitted while some have solar retrofitted or added as an expansion to an existing system.

However, feedback (from readers of my books, TAFE lecturers and auto-electricians I deal with in my business) suggests that many of these mobile solar systems fail to meet user expectations.

The problems are in many cases particular to mobile systems. Both exaggeration of what's feasible and overly optimistic user expectations have a role to play in user disappointment, but there are also easily fixable issues that often are not addressed in the design and setup of such systems.

A major problem is that many RV solar systems assume that users will have overnight access to a 230-volt supply for recharging of batteries and overnight electricity usage. Most RVs include solar/battery systems sized for daytime use only, with only occasional (single) nights away from mains power (or without alternator charging via driving).

However, a substantial proportion of RV owners 'free camp', without access to mains power, often for many days on end. One estimate suggests that half of all regular RV travellers avoid staying in caravan parks whenever feasible. This type of usage is rarely allowed for in standard production RVs.

Installing mobile solar systems is also very different from domestic practice. Domestic installers rarely understand the complexities of RV electrical systems, in particular of interfacing solar with alternator charging, and the need to keep voltage drop (see box at right) under 0.02 volt.

↑ Camping in the Kakadu—made easier with the right electrical system.

Prior to around 2000, most alternators generated 14.2 to 14.7 volts (the latter being adequate for efficient auxiliary battery charging) but many are now only 13.8 volts and post-2014 may be as low 12.7 volts. To cope with this, dc-dc alternator chargers accept whatever the alternator produces and, by juggling volts and amps, optimise the output to best suit the charging regime of the auxiliary battery used.

Auto electricians have been hindered by RV electrics and solar not being included in their training (although I understand this is now being considered by several TAFEs).

This article explores the issues with mobile solar and offers some solutions. Despite the above-mentioned issues, adding solar to RVs (and boats) can work well, provided the installer understands what's required. Most top-grade systems are by owners who have really done their homework or by a few specialists who do excellent work in this area.

System sizing—how much energy?

To correctly size the panels and battery for a mobile system, you need to first take into account the available solar energy.

Sizing for domestic systems usually proceeds in the other direction, based on the

Early adopters
Using lithium batteries on the road

Rodney Dilkes of EV Power Australia explains how he got into using lithium batteries for better caravan energy systems.

↑ Jim Jones in the outback with his lithium-battery-powered Kimberley Karavan.

IN 2005, as an enthusiast, I wrote an article for *ReNew* about my electric Mighty Boy car conversion. At the time I used lead-acid batteries to power the car, but in the article I mentioned the coming-of-age of lithium batteries large enough to power cars. A year or so after that, I imported some lithium iron phosphate ($LiFePO_4$) cells for the same car and used my rudimentary electronics knowledge to build a battery management system to balance and monitor them. As far as I know, that car, now sold, is still running on those same lithium batteries.

From those beginnings, grew a small business, EV Power Australia, importing cells and manufacturing lithium iron phosphate battery packs for other enthusiasts and businesses. Initially, the main use was for electric vehicle conversions, but these lithium batteries also became popular as storage for renewable energy systems of many kinds—including mobile systems.

It was 2010 when Jim Jones contacted me inquiring about lithium batteries for his caravan. I think at the time he talked his mate into buying and testing them first! After the mate had quality checked them, Jim bought a set for himself and installed them in his van. He was one of the first of our customers to apply $LiFePO_4$ batteries to caravans.

Since that time, EV Power has supplied quite a number of batteries for caravans, in particular for Kimberley Karavans. Their caravans are factory fitted with sealed lead-acid (SLA) batteries: nine 30 Ah batteries, weighing 11 kg each, for a total of 270 Ah and 99 kg. We developed a replacement $LiFePO_4$ battery of 260 Ah capacity weighing just 36 kg—which, in fact, results in considerably more usable capacity than the SLA batteries.

The main benefits of $LiFePO_4$ batteries for caravans (and other storage uses) are:

- high energy density, so more amp-hours in a smaller, lighter package than SLA (half the weight of equivalent capacity SLA batteries)—important for caravans given the need to minimise towing weight and space used
- higher voltage under load (12.8 V nominal) with minimal voltage sag at deep discharge rates
- a high cycle life of 2000+ discharge cycles to 80% depth of discharge
- more usable amp-hours than SLA; 80% depth of discharge on a regular basis is no problem compared to a maximum of 50% for SLA
- capable of a high discharge rate; e.g. discharging in one hour can still deliver the full battery capacity
- safe chemistry with non-toxic, non-corrosive recyclable components.

As a supplier of batteries, safety is an important concern. Lithium iron phosphate batteries are good in the safety department, especially when compared with other lithium chemistries, but they are not infallible. Neither, for that matter, are lead-acid batteries. So, we generally supply batteries prefabricated with a cell balancing/monitoring management system that can switch off the battery if there is a problem.

We have been early adopters of lithium technology and have done a lot of work to overcome some teething troubles. At this time the major international manufacturers are showing serious interest and will eventually dominate the market. Hopefully there will still be a niche market for small Aussie businesses like us. ✷

Know your renewables
Electrical terms (part 1)

There are many technical terms associated with electrical systems, but what do they mean? Lance Turner explains the most common terms you are likely to come across.

YOU don't need to have a working knowledge of electrical systems to own a renewable energy system, but knowing the basic terms can help you understand your system—as well as enable you to explain problems to installers in a more cogent manner.

Electricity and electron flow

Electricity in a circuit is the movement of electrons (a subatomic particle with a negative electrical charge) through a conductor. A conductor is any material, often a metal, that allows electrons and hence electricity to flow easily through it.

Electricity in conductors (electrons) flows from negative to positive (called electron flow), but most people talk about current flowing from positive to negative (called conventional current). Electricity may also be a flow of positive ions (an ion is a charged atom; a positive ion is an atom with one or more electrons missing), usually inside batteries, where ions flow through the electrolyte. For most purposes, especially when talking about electrical circuits with appliances attached to power supplies by cables, we are talking about a movement of electrons.

Another two terms often used (and confused) when talking about electricity use and generation are power and energy.

Power

Power is the rate at which energy is generated or used to do work, and is measured in joules per second (see box *Joules and coulombs)*. Power has been assigned its own unit, the watt (W), but it's important to remember that it is a rate, a bit like measuring your travelling speed in km/h. It's an instantaneous measurement, at a particular point in time.

Energy

Energy measures the total amount of work done by a particular level of power over a period of time. The work may be producing heat or illuminating a light bulb or turning a motor. Energy is calculated as power multiplied by the duration of use, a bit like calculating distance as speed multiplied by time.

The usual units used to describe electrical energy are the watt-hour, equal to one watt of power used for one hour, and the kilowatt-hour, equal to one kilowatt (or 1000 watts) of power used for one hour.

Your electricity bill is measured in kilowatt-hours, although some energy companies just call them 'units'. If you use 500 watts of power for four hours, you'll have used 2000 watt-hours, or two kilowatt-hours, of energy—or 7,200,000 joules (500 joules used for 4 hours = 500 * 3600 * 4). Larger energy quantities are measured in megawatt-hours (1,000,000 watt-hours) or gigawatt-hours (1,000,000,000 watt-hours).

To sum up, power is the *rate* at which energy is generated or used, and energy gives the *amount* generated or used over a period of time.

Appliance power ratings, instantaneous power and average power

There are a number of different power ratings that apply to appliances and devices. Often, an appliance will have a **rated power** and this is usually the maximum power the device will draw in normal operation. For example, a heater with two settings might have a rating of 2000 watts. If used on low it might draw just 1000 watts, and might only draw 2000 watts if used on high. No appliance should ever draw more than its maximum rated power for any length of time.

However, many appliances do draw considerably more than their rated power for very brief instances when first turned on. This is due to a number of factors, including the high level of power required to get a motor moving from rest, or because heating elements have a lower resistance when cold than when at operating temperature. This is called the **surge rating**, and should only occur for a second or two at most.

When you measure the power of an appliance with a meter you are measuring the **instantaneous power**. This can vary, depending on the type of appliance. Simple things like heaters may draw the same power continuously, but more complex devices such as computers and other electronic devices may draw different power levels at different times, depending on what they are doing at the time. Indeed, this is how energy meters work. They measure the power being used by the device many times (sometimes as often as many times each second) and average it out over the measurement time period to calculate the energy used.

This leads us to **average power**. For example, if a device draws 1000 watts for half an hour and then reduces to 500 watts for another half hour, its maximum power would be 1000 watts, but the average would be 750 watts. The average power is simply calculated by measuring the energy the device used and dividing this by the time it was run for.

Voltage and current

So where do volts and amps come in, both terms that you'll hear a lot about when dealing with renewable energy systems?

Voltage is often described as the electrical 'pressure' of electricity. Technically, it

PV power
A solar panel buyers guide

We've contacted photovoltaics manufacturers for details on warranties, cell types, size and price to help you decide which solar panels are best for you. Our listing of panels starts on page 72, plus find out the features to look for in the following article.

SOLAR photovoltaic (PV) panels have a range of uses from powerful grid-interactive or off-grid rooftop installations to small DIY applications such as for camping or pumping water.

Over the last few years, grid-interactive rooftop installations have emerged as the most popular use of PV in Australia. Well over a million homes are now enjoying reductions in their electricity bills. Worldwide, demand from rooftop systems and solar farms has produced economies of scale leading to significant reductions in panel prices, especially for the larger panels used in such applications.

A solar installation consists of several components, depending on the application. This guide focuses on panels. For information on other components, system sizing and economic returns, see 'More info' at the end of the article.

↑ Even tiny homes can have solar!

Photo: DOE/NREL 15679/groSolar

How solar cells work

Solar cells produce DC electricity, similar to that from a battery. The amount of current produced by a panel of cells is proportional to the amount of light hitting the panel.

The basic mechanism of operation for a solar cell is as follows.

A solar cell is made of a thin slice of a material such as silicon. The silicon is modified by a process called doping with elements like boron and phosphorus to form what's called a semiconductor P-N (positive-negative) junction inside the cell.

As photons in light strike the solar cell, they cause electrons (electrically negative sub-atomic particles) to cross the P-N junction, causing a voltage across the junction.

By connecting a load from one side of the cell to the other, the electrons will flow through the load, allowing the electrons to be harvested as an electric current.

The different technologies

A typical solar cell only produces around half a volt, which is too low to be of much use. Photovoltaic panels are made of a group of solar cells, usually with the cells connected in series to produce a much higher, usable voltage. There are three common types of solar cells: monocrystalline, polycrystalline and thin film.

Both mono- and polycrystalline cells are made from slices, or wafers, cut from blocks of silicon. Monocrystalline cells start life as a single large crystal known as a boule, which is 'grown' in a slow and energy-intensive process. Polycrystalline cells are cut from large blocks of silicon rather than single large crystals.

Thin-film technology uses a different technique that involves the deposition of layers of different semiconducting and conducting materials directly onto metal, glass or even plastic. The most common thin-film panels use amorphous (non-crystalline) silicon and are found everywhere from watches and calculators right through to large grid-connected PV arrays.

Other types of thin-film materials include CIGS (copper indium gallium di-selenide) and CdTe (cadmium telluride). These tend to have

Warm sun, cool house
Solar-powered evaporative cooling

Martin Chape describes how he put an old evaporative cooler to good use, automating the system in the process.

LAST year I promised myself that I was going to try and use the excess heat that my solar hot water system generates to cool my home. It was my intention to do this by extracting the heat from the hot water tank, either directly or with a heat exchanger replacing the redundant electric heating element, and use either an absorption or adsorption cooling process.

However, after one or two unsuccessful experiments, I put this idea aside for a while and instead decided on a much easier build: an evaporative cooler using solar PV to power it directly.

My plan was to source a discarded evaporative cooler rooftop box and replace the AC-powered fan and pump with 24 volt DC versions to be powered by a solar PV/battery system. I would also add a control system for monitoring and controlling the system remotely. Evaporative coolers are simple devices that draw air through wet absorbent pads. This cools the air through evaporation, and has the advantage of using a lot less energy than a refrigerated air conditioner. The main issue with using a second-hand unit is the cost of replacement pads, as they degrade over time and may become mouldy if unused for a while.

↑ The converted evaporative cooler is powered by two of the solar panels.

Step 1: sourcing the cooler rooftop box

I figured there ought to be plenty of those evaporative cooler rooftop boxes discarded after they wear out, break down or folks switch to other forms of air conditioning. I put the word out and within days my nephews had dropped off the parts for a Bonaire Brivis they'd found on the side of the road!

However, I ended up deciding to use a Bonaire Celair instead, which I bought for $50, as the Celair has thicker pads than the Brivis and the cost of pad replacement is lower.

Step 2: replacing the fan

I decided to source a fan used in the automotive industry, an 18 inch (457 mm) 24 volt DC fan, commonly used to cool the radiators of the big haul pack mining trucks.

The Celair's removable fan mount made modifying it easy. However, the original fan was larger (19 inches), so I got a plastics company to make me a spacer to close the gap at the outer edge of the blades.

Step 3: replacing the pump

I first considered using a bilge pump but found these are not warrantied to run continuously for the number of hours the system would need. Pond pumps were the next obvious contender as these can run 24/7 as long they're kept cool underwater. After mistakenly buying an AC (rather than DC) pump from a pond shop, I ended up sourcing a submersible 24 volt DC pump from China that would manage 20 litres per minute (the flow rate that Bonaire advised for the original pump, and that many of these pumps run at).

When it arrived I was particularly pleased as it included a speed controller which meant I could vary the flow rate, which would allow me to tweak the system for best performance. I wired it through a float switch so it cannot run unless the water chamber is full, to prevent any damage to the pump.