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This all-electric Passive House with electric vehicle is saving money and greenhouse gas emissions for its owners, living near Queenstown, New Zealand. In their previous home, they had lower comfort levels and energy bills for house and car approaching $10,000/year. Now, their certified Passive House has year-round internal temperatures of 23°C and their bills are down to $1500/year for both house and car. A large part of their energy usage comes from the sun—their 3.6 kW solar system generates an average of 13 kWh/day, compared to household usage, year-round, of around 10 kWh/day and car usage ranging from 9 to 30 kWh/day, depending on distance travelled. The car is a Mitsubishi Outlander PHEV (plug-in hybrid EV) with an electric range of around 52 km—well suited to their 40 km maximum round trips and total travel of about 60 km/day. As power outages are quite common, the next step for the household is to look at a small backup battery installation. You’ll find more stories about electric vehicle households running off the sun on page 53.
About

ReNew and the Alternative Technology Association

ReNew magazine
ReNew has been published by the Alternative Technology Association (ATA) since 1980. Each issue features renewable technologies such as wind and solar power, along with ways to make our homes more energy efficient. ReNew also includes practical examples of water conservation and reuse, recycling of materials and alternative modes of transport such as electric vehicles. It provides practical information for people who already use sustainable technologies and practices, and demonstrates real-life applications for those who would like to.

ReNew is available from newsagents, by subscription and as part of an ATA membership. ReNew subscriptions start at just $30. www.renew.org.au

Sanctuary magazine
The ATA also publishes Sanctuary: modern green homes which offers inspiration and practical solutions so you can make your home or build more sustainable. The current issue delves into the world of kitchens and bathrooms with 15 profiles of some of our favourites. It also visits four exemplary homes including an impressive passive solar extension, heads outdoors to dip into the world of natural swimming pools and helps you optimise your solar system.
www.sanctuarymagazine.org.au

Advocacy and projects
The ATA advocates in government and industry arenas for policies that support household sustainability. We conduct research into new and emerging technologies and associated consumer behaviour. We also provide consultancy services based on our technical expertise in energy, water, transport and communications.

The ATA is engaging in the multiple enquiries currently taking place around Australia into the National Electricity Market. We have also been appointed by the NSW Government, along with the Total Environment Centre, to produce the first-ever Consumer Guide for Batteries.
www.ata.org.au/what-we-do/advocacy

International projects
ATA’s International Projects Group will be focusing efforts over the next few years on helping light up the 700 homes in Quelicai, a remote and underdeveloped area of East Timor. The campaign to Light Up Quelicai, with the help of a $10,000 matching grant from UKaid, has successfully raised the funds to install the first 130 solar-powered lighting systems with USB chargers and train five technicians, benefitting over 900 people across the region.
www.ata.org.au/ipg
shop.ata.org.au/light-up-east-timor

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Editorial

Transporting ourselves: driving change at all levels

IT’S probably fair to say that most of us who are committed to reducing our household greenhouse gas emissions have yet to completely address the area of transport. With transport emissions accounting for some 18% of Australia’s GHG emissions—6% due to urban car travel—according to BZE’s recent report, it is a sizeable problem that we all need to consider.

Electric vehicles are part of the answer, with their emissions set to decrease even more as electricity grids get greener. But we also need coordinated public transport and town planning—who wants cities built to accommodate grid-locked cars rather than people? We asked several experts in the transport policy arena to give us their thoughts on where we’re heading transport-wise, and the responses range from a discussion of how our cities are driving a reduction in GHG emissions, to how driverless cars aren’t quite the answer, to a healthy upswing in e-bikes—the fastest growing segment of the transport market it seems.

When it comes to electric vehicles (EVs), there are promising lower-cost, longer-range developments from Tesla and GM, but it may be a while before we see them in Australia—our small market and lack of government incentives are really keeping us stuck in the past. Globally, though, there’s quite a bit of analysis to suggest that we’re on the brink of an electric vehicle revolution.

We look at where the EV market’s heading: which carmakers are leading the way, what’s changing in the world of charging and whether vehicle-to-grid is getting any traction. For EV owners or those thinking about buying one secondhand, we also take a look at EV maintenance and battery health.

We gain insights from several EV owners: one who’s maximising the use of solar PV to charge the car, another who’s got a home charging station on the publicly accessible PlugShare network, and another riding an e-bike into his 70s as a symbol of independence and community. They’re great stories that show ingenuity and a bit of (over)dedication to the cause—one EV owner describes a dash to the garage every time the sun came out or a cloud came over, to turn on/off the charger, before he found an automated solution to maximise solar charging!

There’s much more, of course. We address a commonly asked question—what about using hydrogen fuel cells to power our vehicles? We also cover a solar + battery system overcoming barriers for apartment buildings, how to choose sustainable plants for your home garden, using thermal imaging to find leaks (so that you, like the article authors, can look forward to your next winter heating bill!) and much more besides.

Our buyers guide is on efficient hot water systems, potentially one of the biggest energy users in the home. We look at hot water heat pumps, solar hot water, PV diversion and instantaneous electric systems, and talk to a range of people with different systems to get some real-world feedback. We look forward to your thoughts!

Robyn Deed
ReNew Editor

In ReNew 140, out late June
All-electric homes, appliance installation and maintenance, insulation buyers guide

HERE at the ATA we are just getting our feet back on the ground after the inspirational Community Energy Congress. More than 500 people attended the two days of the congress in Melbourne, hearing international speakers, sharing Australian success stories and learning about the tools and resources available to community groups for their projects. There was time for groups to plan and network so that the congress was an opportunity to make connections and start putting projects into action. It even felt like there were partnerships and deals forming in the morning and afternoon tea breaks!

For me the highlight of the event was the formation of the First Nations Renewable Energy Alliance by the Aboriginal representatives at the congress. Fred Hooper, of the Murrawarri Nation, highlighted the massive change of direction: “This congress has opened our eyes.” The power of people to galvanise and make an immediate impact was clear. “What this congress has given us is a chance to get those people in one place and build something for us, in partnership with all of you in the audience today.”

Ghillar Michael Anderson, of the Euhaylia Nation, said the group had already established a steering committee. “Taking ownership of energy security is a huge step forward for our First People. It is a big leap towards tackling poverty and disenchantment. The Alliance is the first step to changing the system.”

The ATA is proud to have helped bring the Australian and Canadian First Nation leaders to the congress and we look forward to working with the Alliance for climate justice.

Donna Luckman
CEO, ATA
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Up front

2020s predicted as the decade of EVs
While OPEC claims that EVs will remain at about 1% of total car sales by 2040, a Bloomberg New Energy Finance analysis of the EV market indicates that electric cars will become as affordable as their fossil-fuel counterparts by 2020, heralding the point of ‘lift off’ for the EV market which, they say, will rise to 35% of the total car market by 2040. This EV revolution, they believe, will be spurred on by continuing drops in the cost of battery production, improvements in range capacity and increased investments in EV technologies and new EV models by car manufacturers (they name Nissan and Chevrolet, as well as Tesla).
www.bloomberg.com/features/2016-ev-oil-crisis

SA hosts the world’s largest solar virtual power plant
Amid blackouts and blaming reliance on renewables for the problem in South Australia, a new venture launched in August 2016 by energy company AGL, with funding support from ARENA and equipment supplied by US company Sunverge, hopes to provide some grid stability while helping customers minimise their power bills and demonstrate a workable model that can be rolled out elsewhere.

When the project’s three phases are completed, it will be the world’s largest solar virtual power plant (VPP), comprising 1000 batteries installed in individual residences and small businesses, interconnected via the cloud to each other and the grid, and providing 5 MW capacity. The first 150 (7.7 kWh) battery storage systems were purchased by energy customers within months of the launch. Phase two was announced early, in December last year, with 350 (now larger, 11.6 kWh) batteries becoming available in specific suburbs of metropolitan Adelaide, which will allow the project to focus on demonstrating grid support capability. AGL customers in SA who are interested in taking part can check their eligibility at www.agl.com.au/powerinnumbers. www.agl.com.au, www.arena.gov.au

Extreme rain events on the rise
A new paper by researchers from the Australian Research Council’s Centre of Excellence for Climate System Science, published in January (Nature Climate Change 7), predicts big increases in rainfall during extreme precipitation events in Australia as a result of global warming.

Using the NSW and ACT Regional Climate Model, and looking at the heaviest 1% rainfall events in Australia across all seasons, the forecast was for an intensification of rainfall in extreme rain events of between 11.3% and 30%, with a 2°C rise in global average temperatures (the limit target of the recent Paris Agreement). This was found to be due to increasing average humidity.

The forecast increased to 22–60% greater intensification with a global average rise of 4°C (which the authors felt was a likely outcome based on current increases in the rate of carbon emissions, and lack of strong policies to counter this trend). So even as some areas of the nation will become increasingly drought-prone, when rain does fall, it will be more extreme and we can expect to see more devastating floods.
Source: University of NSW

Affordable energy independence
Around Australia, bulk-buy campaigns are making solar PV and battery storage systems more accessible, by virtue of the discounts made possible through volume-purchasing, and offering knowledge and expertise to help make choosing the right system easier.

Although the process may be slightly different for campaigns run by different organisations, basically, people register their interest to participate, put down a deposit for their chosen system and, once the offer period is closed, await delivery and/or installation and provide final payment.

At the forefront of this movement has been Farming the Sun, in partnership with Starfish Initiatives. To date, they have completed six bulk-buy rooftop solar campaigns, representing installations worth $6.7m and saving participants up to 33% on their
purchase (based on figures from a recent New England campaign). They are currently calling on expressions of interest from residents, community groups and businesses in the NSW Northern Rivers region to bulk-buy solar PV plus battery storage systems. This campaign is launching March/April, and registrations are via www.farmingthesun.net

Suncrowd has also run six campaigns so far in NSW. A visit to their website allows interested people to either join an open campaign or to request a campaign for their area, and they offer a great ‘guide to make the right decision for solar and batteries’, as well as a calculator to determine your needs. www.suncrowd.com.au

For those in Central Victoria, MASH (the campaign for More Australian Solar Homes) has to date successfully launched three bulk-buy solar campaigns, in partnership with local suppliers/installers, installing PV systems in around 600 households and donating $25,000 worth of free solar systems to community groups in the process. For more information and to keep an eye out for any further offers, see www.mash.org.au

Resident of Melbourne’s City of Yarra are also able to participate in bulk-buy campaigns conducted by the Yarra Energy Foundation, who are rolling out their buy-back program suburb by suburb. Local community groups also benefit from the donation of rooftop solar panels with each campaign. For more info: www.yef.org.au

This movement is likely to grow as more people seek energy independence/security. Check with your local council or community group to find out if there are options available in your area.

**ARENA round-up**

Despite the current Australian Government’s inconsistent approach to renewables, ARENA—its renewable energy funding support program—is continuing to help bring innovations in emerging technologies to the commercial table. Here is a rundown of recent developments.

**ULTRABATTERY**

Storage technology, the UltraBattery, developed by CSIRO offshoot Ecoult with funding support from ARENA, has been chosen by the Institute of Transformative Technologies (ITT) to take part in a trial to provide low-emission, low-cost electricity to rural India. With nearly half a million diesel generators currently powering remote communities across the country, this technology has the potential to significantly improve health, lifestyle and economic outcomes. The UltraBattery has the required capabilities—fast charging, near-zero maintenance, remote monitoring and controlling over the internet, and efficient operation in high temperatures. It was selected by ITT following a successful trial by Ecoult to reduce diesel use at an off-grid telecoms base station south of Sydney in 2014 (savings from which paid for the system within 18 months).

**CO-LOCATED SOLAR/WIND**

Also a funding winner in ARENA’s large-scale solar competitive round, WA’s Emu Downs co-located solar/wind farm (the first in the state) is set for construction, creating 100 local construction jobs and powering 6700 homes on completion. The project will locate solar panels on the existing wind farm site, sharing transmission infrastructure and thereby reducing environmental impacts and costs.

**SUPPORT FOR STORAGE**

A new Advancing Renewables Program (ARP) will see at least $20m of funding from ARENA, with additional significant debt finance support from the CEFC, go towards accelerating the development of flexible capacity and large-scale storage to improve certainty of energy supply and smooth integration of renewable energy sources. Expressions of interest for demonstration projects (focusing on battery storage, pumped hydro, concentrated solar thermal, biomass and demand management technologies) have been called, and discussion of some proposals is already underway.

$1.87m from the ARP has already been allocated to University of Technology of Sydney (UTS) who, with the involvement of a number of industry and government partners, will be undertaking a trial they’re calling Networks Renewed. The project’s aim is to transform the perceived problem of voltage variability in electricity networks from increased solar PV uptake into a commercially viable solution by providing evidence of the positive impact of using ‘smart inverter’ technology to provide network support through improved voltage management.

www.arena.gov.au

![Rural India could be powered with the help of Australian technology, the UltraBattery, if pending trials prove successful.](Image)
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100% renewables feasible?
The article ‘100% renewable grid: just how feasible is it?’ raised many questions for us as residents of South Australia. We support renewable energy, and we were distressed about the bad press for renewables provided by the SA October 2016 state-wide power outage. This letter is to ask about whether the ATA article has the right approach.

1. Australia’s privatised power system is about profitable power delivery to meet immediate demand, not about power security. Power security always requires spare capacity. Particularly with renewable energy, this costs more money. The new money has to be provided by government (i.e. the taxpayer) or by regulatory requirements on private providers (i.e. the customer). It needs to be costed into average power costs more transparently than in the ATA article. Average power costs have important social impacts, including whether businesses can provide jobs, as well as whether the poor can pay the bills.

2. The article said: “The SA blackout in October 2016 showed that existing wind farms can successfully ride-through even very severe grid faults, as long as they are properly configured.” This is not what seemed to happen. Shutting down to protect themselves did not seem like ‘riding through’. If there were parts of the system that succeeded, in the middle of total state-wide failure, then as residents of SA we would have liked to know.

3. Wind generation is a ‘Goldilocks’ exercise: no wind, no power; too much wind, shut down, no power. Goldilock’s porridge still needs to be ‘just right’. Wind generation cuts out in a strong wind event. In stormy weather, solar generation is also likely to be minimal. Storage and stability are key questions from the very beginning.

4. What was the rated wind speed for the interconnectors that failed between SA and the eastern states? We have only been told that “they met Australian Standards”, but so does our farm shed. Building interconnectors to hurricane standards is very expensive, yet another cost of ‘security’ that needs to be met by the taxpayer or consumer. The 1-in-50 year event may not happen just once, or in 50 years time.

5. The ATA article acknowledged the need for stabilisation, which means stabilising both frequency and voltage. The 100% renewables for the island in Denmark works with the necessary stabilisation provided by the cable that also exports power to the mainland. Without the interconnectors, the renewables in SA do not provide the stability that is needed right now. The ATA article’s ‘blue sky’ options gave several potential solutions to meet this need (and there are others too), but they were not costed as part of the inevitable cost of moving to 100% renewables, nor are they available right now. We need to know when they will be available, how the capital cost will be met and the effect on retail power bills. They need to be in position before we head a long way down the 100% renewables path.

6. Predictions of the cost of solutions by 2030 are not a great basis for decisions now. Fifteen years ago, the ‘battery problem’ was supposed to be solved by now. It isn’t. Costs usually drop from high initial prices only following major uptakes. Even if costs drop as predicted, the initial prices still have to be paid—once again, by the taxpayer or the consumer, and once again with social implications.

7. Different security issues also need serious consideration. A terrorist group could take out isolated interconnector pylons. Without power, the mobile phones fail, landline infrastructure can fail too, and fuel pumps don’t work. No communications and no power is not a good place to be. We weren’t at all happy about it ourselves.

As ATA members, we support renewable energy aspirations. As SA residents, we are concerned about the impacts on our neighbours’ jobs and bills right now. It’s distressing even when your own house has solar power. Our societies won’t function unless retaining power security has a higher priority than moving to renewables.

We would like ATA to provide a fully balanced picture, because the credibility of renewables is at stake. The article was a great start, but we need more. We aren’t tempted to rely on a state government to get it right!

Tony and Margaret McKenzie

You’re right, spare capacity is always required to ensure power security and reliability. There must be at least enough spare to cover the biggest generator operating at any time, regardless of its fuel source. Studies on moving to 100% renewables indicate increased costs in the short term, but reduced costs once the transition is complete. We need more in-depth research to confirm this. The article mentions several ways to alleviate bill impacts on vulnerable consumers.

Some wind farms (e.g. Waterloo Wind Farm) successfully kept operating through the faults in SA, until the entire state blacked out. Some wind farms were configured to shut down or reduce power if six grid faults occurred in short succession. The grid operator (AEMO) didn’t know about this setting, and it’s already been rectified on most of those wind farms. This is detailed in AEMO’s third report on the incident at www.bit.ly/SABO2016

Regarding ideal conditions, as detailed in our report the key challenge for a fully renewable grid is a calm, cloudy week. Addressing this requires a mix of solutions beyond current wind and solar farm designs as discussed in the article.

The transmission towers were blown over in ‘tornado’ conditions. You’re right, building a 100% reliable grid is prohibitively expensive, so all countries settle for a less-than-perfect reliability standard. The National Electricity Market is designed for ‘unserved energy’ (i.e. blackouts) of 0.002%,
that is a reliability of 99.998%. See www.bit.ly/NEMRSFS

Regarding stability, if the interconnectors are down SA’s only current option is to curtail wind generation to a moderate level, and burn expensive fossil gas to supply most of its electricity. As an immediate response to cover such contingencies, AEMO has already changed some rules in its computers to operate the grid more conservatively, especially if there’s a big storm coming.

Reliability measures are included in studies estimating the cost of 100% renewables. For example, new interconnectors, a mix of generation sources and flexible demand were all included in AEMO’s study in 2012 (www.bit.ly/2AEMOMO). We agree with you on the need for better planning. With better planning, some solutions could have been available right now, e.g. converting turbines in shutdown coal power stations to increase inertia in the grid, and appliances varying their power levels to assist.

Since power stations have long lifespans, future prices are relevant when planning for a 100% renewable future grid. Regarding batteries, in a few years time households are predicted to be installing them in large numbers for bill savings. If their rollout is planned well, the same batteries can also assist grid stability for little additional cost.

Your concerns regarding security issues apply regardless of the generation source. We recommend households make preparations to cope with blackouts. Options range from minimal camping equipment, up to a solar + battery system that can operate off-grid. Policymakers should similarly be working to make our infrastructure resilient to threats such as terrorism.

Andrew Reddaway, ATA

White roofs make sense
I was disappointed to read in ‘A roof over your head’ in ReNew 137 that many councils restrict how white a roof can be.

Five years ago I painted our roof white using Solarcoat, an Australian-made heat-reflective paint. I have been amazed at the result. I believe it should be compulsory for all new homes to have heat-reflective roofs to not only reduce cooling costs but also to reflect the heat away from the earth’s surface. This is even more important now that snow and ice coverage is reducing at an increasing rate.

The USA and in particular New York are leading the way in painting their roofs with white heat-reflective paint. The Sierra Club has estimated that implementing a white roof program in 11 large cities could save the USA seven gigawatts in power consumption. That’s the equivalent of turning off 14 power plants. It has also been estimated that coating all dark rooftops in New York could result in up to a 11 Fahrenheit reduction of the ambient air temperature. See the Berkeley Lab Heat Island Group website at heatisland.lbl.gov for more information.

This is a low tech step in reducing our impact on the climate. —Kevin Cato

The forgotten grid
One grid that Andrew did not mention in his article ‘Should I quit the grid?’ in ReNew 137 is water—both supply and sewage. I am off-grid for both of these: I have to be as I’m 1.5 km away from the nearest water supply pipeline. I have a homemade composting toilet and harvest water from my shed roof into a 50kl tank. From researching water self sufficiency in Melbourne some years ago, the main obstacle to disconnecting completely from the water grid was bureaucratic, though I hope this has changed. Other problems in cities are space and water quality given air pollution, but it can be done.

Lance M

The range of 12 volt items includes the Weber Baby Q. LPG is an option for some high power users such as electric ovens. Instead of using an electric oven for baking or roasting, use an LPG gas BBQ, something like the Weber Baby Q. LPG is probably dearer, but for short periods and to keep electricity use at a lower level it could be a better option. These BBQs are very portable so can also be used for picnics, camping and caravanning. A friend recently travelled around Australia for four and a half months and used one exclusively. I am sure there are many other alternatives; maybe readers could submit their alternatives.

Neil Atkin

Sustainable remote living
Back in the 1940s many remote farms and villages lived off-grid as there was no grid nearby. Lister brand stationary engines with attached generators chugged away feeding battery banks that looked like car batteries. It all seemed to work well.

Now people live on yachts as ocean-going grey nomads. They have solar and wind alternators, all 12 volt I’m told, and have a wide range of 12 volt items and thermal solar water heating which also gives cabin heating in winter. Caravanners do the same, and those on houseboats too.

Couldn’t us landlubbers also live off-grid like this? What are the best battery types and brands? How about wiring? Where do you buy 12 volt microwave ovens, TVs, small fridges, etc, which sidestep 240 volt inverters for safety reasons, as we’ve lost friends to 240 volt accidents?

Mike Thomas

We have covered many of these subjects previously, e.g. we ran a DC appliances guide in ReNew 126. One of the larger suppliers of DC appliances, including microwave ovens, is Power Hunt (www.power-hunt.com).

Lance Turner, ATA

Article suggestions
I read ReNew 137 on energy storage and was prompted to suggest an article about the long-mooted idea of using EV batteries to tie into the house system. Are current EV cars able to be linked to the house for a two-way flow, and if so, how? If not, can they be in the future? This would be a better use of car batteries that sit idle for many hours and may reduce the need for a battery system exclusively for the house. Also, what about alternatives for some high power users such as electric ovens. Instead of using an electric oven for baking or roasting, use an LPG gas BBQ, something like the Weber Baby Q. LPG is probably dearer, but for short periods and to keep electricity use at a lower level it could be a better option. These BBQs are very portable so can also be used for picnics, camping and caravanning. A friend recently travelled around Australia for four and a half months and used one exclusively. I am sure there are many other alternatives; maybe readers could submit their alternatives.

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Write to us: We welcome letters on any subject, whether it’s something you’ve read in ReNew, a problem you’ve experienced or a great idea you’ve had. Please limit letters to 350 words. Due to space restrictions we can’t guarantee to publish all letters received, and letters published may be edited for clarity and length. Email letters to renew@ata.org.au or post to ReNew, Level 1, 39 Little Collins St, Melbourne VIC 3000, Australia.

renew.org.au

ReNew Issue 139 15
Products

In this section we share info about products that sound interesting, sustainable and useful. Product listings are not an endorsement by ReNew or the ATA of any particular product—they are for reader information only. They are not product reviews and we have not tested the products.

01 All-metal rainwater diverter
Rainwater tanks are just as important as ever—even more so, given the increasing unpredictability of rainfall as climate change progresses.

A well-designed rainwater collection system will use a diverter to screen out larger debris to reduce the contaminants entering the rainwater tank. Most diverters are made from plastic and, while this means they blend in with common plastic downpipe systems, they are not recyclable in many areas due to low levels of PVC recycling.

The Nautilus Filter Diverter is made from recyclable steel instead. Available in ‘blue ridge’ and ‘jasper’ Colorbond colours or stainless steel, it features a removable self-cleaning screen system that removes debris from the water stream. Unlike most other screen systems, the Nautilus is designed to fit to the tank’s overflow outlet, filling the tank via this outlet until the tank is full. The diverter then overflows internally, sending excess rainwater into the downpipe. This eliminates the need for separate inflow and outlet pipes at the tank.

Nautilus Filter Divers are available in two versions to suit wet and dry rainwater tank systems.

RRP: $170.50 for the Colorbond steel units, $192.50 for stainless steel, inc GST. For more information, contact Rainwell, info@rainwell.com.au, www.rainwell.com.au

02 BYD releases new storage options
The domestic energy storage industry is starting to snowball in Australia and one of the largest battery manufacturers on the planet, BYD, has expanded their range of offerings here.

The new B-Box battery range includes a HV (high-voltage) model for both commercial and residential use, as well as an LV (low-voltage) model for residential use. Usable battery capacities range from around 2.5 kWh through to 12 kWh, with the batteries also being parallelable to form battery banks of up to 80 kWh.

BYD’s domestic and commercial storage systems all use the LiFePO4 chemistry, which is more fire-resistant than some of the other lithium chemistries. Cycle life is rated at over 6000 cycles and operating temperature range is 0°C to 50°C, making the batteries suitable for use in most areas of Australia. Ingress protection (dust and water resistance) ratings for the two latest additions to the range are IP55, so they can be installed outside where required.


03 Give boosting the axe
In the colder months, solar hot water usually relies on gas or electric boosting to supplement demand. However, for those with wood heaters or stoves, boosting from this source of heat is a viable option. Unfortunately, wetbacks (water jackets) are not available for many heater models. Axeman has addressed this issue with their high-pressure capable flue-mounted water jackets, which supplement hot water requirements using the heat generated by a wood heater or stove.

The jackets are designed and handmade in Australia from 316 corrosion-resistant stainless steel and feature an external water jacket surrounding a central tube which is made to fit directly into the flue, with no restriction of flue diameter. Water circulates through the system by either thermosiphon or pump.

Axeman fire flues can be coupled to all standard electric and solar hot water tanks, making them ideal for retrofitting to most existing systems, including hydronic systems.

Three standard sizes are available: small (620 mm long), medium (780 mm long) and large (1030 mm long). However, as all Axeman units are made to order they can be customised to fit any flue size. Axeman flues should be installed by a licensed plumber.

RRP: small $600, medium $785, large $960 (for standard 6” diameter flues, freight inclusive). For more information or to purchase, ph: 0421 272 593, axemanfireflue@gmail.com
04 A real solar air conditioner
We’ve seen a number of air conditioners over the years that claimed to use a solar thermal panel to improve operating efficiency. The problem was that they weren't more efficient than a regular air conditioner and they added the complexity of plumbing in a solar collector to the compressor system.

The EcoWorld Solar Hybrid Air Conditioner is much more sensible—it simply uses a dedicated 1kW solar PV array to drive the air conditioner, greatly reducing the energy required from the grid. Indeed, in full sun, the unit can draw as little as 30 watts from the grid while producing its rated 3.5kW cooling/3.8kW heating capacity.

The air conditioner is a standard split system unit and is designed to use a simple array of four common 250W solar panels. The air conditioner is available as a kit complete with the 1kW array or on its own if you have some spare panels or want to source your own.

Warranty on the unit is six years when installed by a qualified air conditioner installer and installations are eligible for up to $600 worth of STCs when used with a new PV array with CEC-approved panels.

RRP: Please check the EcoWorld website for pricing. For more information, contact EcoWorld, ph: 1800 326 967, dean@ecoworld.com.au, www.ecoworld.com.au

05 A very clever charge controller
We are used to seeing larger manufacturers producing high quality renewable energy equipment, but some of the more interesting devices actually come from the advanced ‘tinkerers’ out there.

The SBMS (solar battery management system) from ElectroDacus is a great example. It is a combination solar charge controller and lithium battery management system with cell balancing, designed for use in off-grid solar energy systems where lithium batteries are used for energy storage (although it is also compatible with ultracapacitors).

The SBMS can control battery banks from three to eight cells, making it suitable for both 12V and 24V nominal systems. Maximum solar panel open-circuit input voltage is 47V, so it can be used with common and low-cost 60 and 72 cell panels. Maximum PV input current is 72 A (on the SBMS60) and 120 A (SBMS100), and the controller’s output load terminals can control up to 120 A (or 500 A with an external shunt).

Other features include optional battery temperature monitoring, wi-fi comms, datalogging (up to a year’s worth of data can be stored), an external IO and control port, 2.2” colour LCD and a self-consumption of less than 1W.

RRP: TBA. For more information, contact Dacian Todea, electrodacus@gmail.com, www.electrodacus.com

06 Charge your EV with PV
The Zappi EV charger from Myenergi is a new EV charger design currently undergoing an Indiegogo campaign to finalise manufacture (prototyping and testing are completed). Unlike most electric vehicle supply equipment (EVSE) units on the market, the Zappi allows you to charge your EV with excess energy from your grid-connected PV system, working much the same as a hot water diverter, but charging your EV instead of heating water.

The Zappi has three charge modes—fast, which acts like a regular EVSE up to 7kW, where no export monitoring happens, just full speed charging; eco, where charge power is continuously adjusted in response to changes in generation or power consumption elsewhere in the home, with charging continuing until the vehicle is fully charged, even if power is drawn from the grid; and eco+, which is the same as eco mode but uses no grid energy, only PV.

The charger features energy data logging, an LCD display, adjustable charge current and import power limits, and a five-metre charge cable. You don't actually have to have a PV system to use the Zappi: it's worth considering just for the data logging capabilities. The Zappi measures 362 x 220 x 78mm, and is IP65 rated for outdoor installation.

RRP: £495 (cheaper through Indiegogo). For more information, contact Myenergi Ltd, vibe@myenergi.uk, www.myenergi.uk or see the Indiegogo campaign at www.bit.ly/IGGZAPPI
07 A serious cordless mower

While some great cordless garden equipment has been available overseas for many years, Australia has been slow to catch up. However, the range is increasing and some more pro-level machines are starting to appear.

The latest is the EGO LM2102E-SP self-propelled lawnmower, which uses 56 volt, 7.5Ah lithium batteries to provide up to 50 minutes of run time.

The mower has a wide 52cm (21”) cut capacity to reduce the number of passes required to cut your lawn. It comes with a 56V fast charger that can recharge the batteries in just 60 minutes, so you can mow almost continuously with two batteries and never need to stop with three batteries.

The mower features an integrated load sensor that monitors the brushless motor and regulates RPM based on load conditions. It is weather-resistant and folds flat in a few seconds for easy storage or transport. It also features LED headlights (for when you really want to mow at night), simple pushbutton start, three-position handle height adjustment, six-position spring-loaded cutting height adjustment and a 70L catcher bag.

The mower comes with a five-year warranty on the mower and three years on the battery and charger.

RRP: $999. Available from selected mower stores such as www.allmowers.com.au. For more information, go to www.egopowerplus.com.au

08 The future of farming?

Conventional broadacre farming uses huge amounts of water, fuel and, of course, land. With an ever-increasing demand for food, this has resulted in large areas of natural ecosystems being bulldozed to make room for farms.

The Sprout Stack is aimed at changing that, consisting of either a 20-foot or 40-foot shipping container fitted with LED grow lighting (which only provides the wavelengths needed by plants, for lowest energy use; around 60kWh per day for the larger unit) and a hydroponic watering and nutrient delivery system. In effect, the Sprout Stack is a mini-farm in a big box, all electronically controlled for maximum production.

Each Sprout Stack can produce far more than a typical farm for the amount of land it takes up—a 40-foot Sprout Stack can produce the same food as a full hectare of land.

Other advantages include the elimination of pesticides, no fuel or heavy machinery needed, vastly lower water use (the 40-foot unit uses just 100 litres per week), no soil erosion and water run-off pollution, and the ability to grow food anywhere, eliminating food miles from transportation from farms.

The Sprout Stack containers can be rented or bought outright and if operated optimally can pay for themselves in a year or two.

RRP: $65,000 for the 20-foot unit, $110,000 for the 40-foot. For more information, contact Sprout Stack, www.sproutstack.co

09 Work safer

When working on electrical equipment, you need insulated tools to prevent accidental short circuits and electric shocks. However, finding them is another story altogether—some tools suppliers have a limited range, while others have none at all.

Tolsen makes a range of 1000V insulated tools for electrical work, including spanners, screwdrivers, pliers, wire cutters, hex spanners, knives and even a fully insulated socket set.

The tools are available individually or in full sets and are VDE, GS and IEC 60900 certified for 1000V use, making them ideal for professional and DIY use on solar energy systems and electric car conversions.

Tolsen tools are available from various tool sellers and are distributed by Electrical Factory Outlet.

Jaycar Electronics also has some insulated tool sets, with a screwdriver and plier set and a seven-piece screwdriver set available for good prices ($59.95 and $29.95 respectively), and the screwdrivers and some pliers and cutters are also available separately.

Tolsen tools are distributed by Electrical Factory Outlet, ph:(07) 3411 0303, www.electricalfactory.com.au. Also see www.tolsentools.com. Jaycar’s tools are available from Jaycar Electronics stores, or go to www.jaycar.com.au
10 Go lithium
Making the move to lithium batteries is still a bit daunting for many smaller solar energy system owners, but Victron Energy is making it simpler with their 12 and 24 volt lithium batteries and accessories range.

The 12 volt batteries range from 60 Ah to 300 Ah, while the 24 volt units come in 100 and 180 Ah sizes. While all batteries in the range have integrated cell balancing, to keep the batteries in tip top shape and prevent overcharging and discharging, a battery management system and protection system is available, which is also designed to work with other Victron Energy devices, such as their inverter-chargers.

The batteries use lithium iron phosphate (LiFePO4) chemistry, the safest and most robust of the lithium chemistries. This gives them a long service life (>2500 cycles at 80% depth of discharge for the 12 V units and >3000 cycles at 80% for the 24 V units), while being half the weight of the equivalent lead-acid batteries they are designed to replace.

RRP: POA. For more information and to find the contact person for your state, or your closest dealer, contact Victron Energy, www.victronenergy.com.au

11 Extreme water savings
There are many water-saving devices on the market, but most only go as far as regulations require and often use simple water restrictors inside existing nozzles, giving average results.

The Altered:Nozzle retrofits to existing taps by replacing the existing aerator. It has two settings, ‘mist’ and ‘save’. Mist mode produces a fine atomised mist that gives a good wetting effect while using 98% less water (0.18 litres per minute) than a regular tap. Save mode produces the more common shower-style stream at around three litres per minute.

The Altered:Nozzle is made from lead-free brass and comes with adaptors to fit 20.8 mm, 18.1 mm and 15 mm aerator threaded sockets. The nozzle can operate at pressures ranging from 200 kPa to 800 kPa, so it won’t work on low-pressure gravity-fed water systems. The Altered:Nozzle comes with a two-year warranty.

RRP: TBA. The Altered:Nozzle is set to be released in March 2017. For more information and to sign up for a notification when it becomes available, contact Altered Stockholm AB (Stockholm, Sweden), hello@alteredcompany.com, www.alteredcompany.com

12 Bright lights for big spaces
Whether it be a large shed or garage, or a room with a high-vaulted ceiling, you normally need multiple light fittings to light such areas effectively. While large lights like high bays have been available for years, they were traditionally too large for most domestic situations.

The Vibe high bay LED lights from ANL Lighting are much more compact. They feature high efficiency Philips LEDs to produce copious quantities of light for relatively little energy use. For example, the smallest in the range draws 100 watts, yet puts out over 13,000 lumens of 5000K neutral white light, with a CRI (colour rendering index) of over 80.

There are also 150 W, 18,500 lumen and 200 W, 25,000 lumen units.

Beam angle of these fittings is a nice 120°, so you get even illumination, not a big hotspot on the floor. The lamps have a diecast aluminium housing for good heat dispersion and a high quality Meanwell IP65-rated driver, so the lamps can be used indoors or outdoors. They also have a shatterproof polycarbonate lens, a 50,000-hour rated lifespan and a five-year warranty. The 100 W unit measures 320 mm diameter while the two larger models are 400 mm diameter.

RRP: $473.55, $572 and $748 plus GST respectively for the three models. For more information and to buy, contact ANL Lighting, ph: 1300 300 301, sales@anllighting.com.au, www.anllighting.com.au
Make it. Store it. Manage it. You’ve got the power.

The Enphase Home Energy Solution lets you generate, store, and manage your home’s energy so that you can save money, become more energy independent, and help better the planet.

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STIEBEL ELTRON

Designed for Australian conditions by Germany’s market leader, STIEBEL ELTRON’s new range of hot water heat pumps presents state-of-the-art technology:

A current impressed anode protects against corrosion, a roll bond condenser guarantees maximum heat transfer, and the sophisticated design makes transportation, installation and servicing even easier. Eligible for generous Government rebates for hot water heat pumps, it’s easy to see why it has to be a STIEBEL.
Battery bounty
Saving students money

This innovative project is demonstrating how a solar + battery project can work for both the student tenants and the managing co-op in a low-income apartment complex in Sydney. Robyn Deed talks to the project managers.

GETTING buy-in from all the apartment owners on a solar project in a new apartment building can be hard, but make that a solar + battery project for an existing heritage building used for low-income student housing, and an extra level of energy and commitment is required. But the residents and researchers behind the Stucco Co-operative Housing project in Sydney’s inner-west have achieved just that with a 30kW solar + 42kWh Enphase battery installation designed to reduce the 40 student residents’ energy bills and provide a roadmap for other such projects.

Why is solar so tricky for apartments? “The main issue is the ‘split incentive’, ” says Bjorn Sturmberg, a former resident of Stucco and one of the project managers. If the apartment owner isn’t the tenant, there’s little incentive for them to pay to install solar when the savings will go to the tenant.

How to get solar onto more apartment buildings is an issue the City of Sydney is currently grappling with, so Stucco “hit the bullseye” says Bjorn, when they put in an application for funding to find an approach that would work for the complex of eight units— with the opportunity to research a significant battery storage installation also in their favour. The result was a grant of $80,000 matched with $50,000 from the Stucco co-op. For City of Sydney, the ‘return’ on their grant is a report on just what the barriers are and guidance on how to overcome them.

Making the finances work
The financing model used at Stucco is one where both the tenants and the Stucco management co-op (a not-for-profit charity) get a benefit from the solar + battery system, thus addressing the split incentive. The co-op charges the residents for grid-supplied electricity at the standard retail rate (i.e. what the co-op pays the retailer), while the locally produced electricity is charged at about 20% lower, thus reducing the students’ bills.

Interestingly, passing on the retail rate for grid-supplied electricity without a “fee on top” caused some delays in getting approval from the Australian Energy Regulator. In such an embedded network, commonly used for apartment buildings, caravan parks and shopping centres, an entity representing the building purchases electricity from the grid and on-sells it to the tenants. Accustomed to regulating the cut such entities take, the AER found it difficult to understand the Stucco co-op’s ‘not-for-profit’ approach.

The Stucco co-op gains income from the payments they receive from residents for the locally produced electricity they use. Currently, this goes towards paying back their $50,000 investment in the system, with a likely payback of about seven years. After that time, these payments may be used for maintenance, either on the system or the apartments. Of course, without the grant from the City of Sydney the payback period would have been much longer and the co-op would not have been able to install as many batteries as it desired.
Retrofit first

Another first was retrofitting the system to an existing apartment building without an embedded network already in place. “To our knowledge, no one’s done that in Australia, even just for solar, before,” says Bjorn. Prior to the system being installed, each of the eight units in the apartment complex had their own electricity meter connected directly to the grid, with separate billing. In the new system, there’s a single grid-connected meter, with simple sub-meters in each apartment used to apportion the bills. As a bonus, the single grid connection means there’s only one grid connection charge to pay, rather than eight.

Billing and meter reading is managed by software company SwitchDin. A question that came up in the planning was how to make the billing fair—who gets the advantage of the locally produced electricity, when one unit could be pushing energy usage up requiring more grid imports? They came up with a simple solution: each unit is charged based on the ratio of grid import to locally produced energy required by the whole complex. For example, if 80% of the building’s electricity usage is covered by solar + storage (local energy) and 20% by the grid, then 80% of each unit’s energy use will be charged at the local rate and 20% at the grid rate.

Another potential barrier is getting buy-in from all tenants and owners, but the student residents were all keen participants. Bjorn and the other students see it as future-proofing against the “dramatic changes forecast for the Australian electricity system and the associated risks and costs that may well be pushed onto consumers.” So they were happy to be involved!

From idea to installation

It was a long haul to get the system up and running—15 months from initial idea to installation—with most of that time spent on meeting regulations (supported by pro bono legal work), rather than technology constraints.

Getting approval to install the batteries in an apartment building delayed the project for many months and required a costly report and alterations to alleviate the perceived fire risk. Bjorn says, “There were valid concerns about fire risk from the lithium iron phosphate batteries, but the rules need updating—in a commercial or multi-tenant apartment building, the BCA regulations currently require any battery bigger than an electric bike battery to be enclosed.” With the consultant’s report they were able to avoid that requirement, using fire-proofed gyprock board on the walls and roof of the battery room instead.

The actual installation, in December 2016, was a much speedier affair, taking just three days to install the full 114 solar panels and 36 batteries. There’s a timelapse video (www.bit.ly/STUCCOVID) showing the battery modules being installed on the wall brackets in a total of 11 minutes. Each battery weighs 25kg and could be lifted into place by two people, then it was just a matter of plugging in the already-wired AC cable, a bit like plugging in an appliance. Too easy (and one of the advantages of the AC system used by Enphase!)

The system was sized and configured to meet the building’s average daily usage of 80kWh. It’s being closely monitored by the installers, Solaray Energy, to gain insights into the optimum configuration for charging and to fine-tune its inner workings (such as that the three phases used in such apartment buildings are balanced properly).

The system is currently configured to minimise draw from the grid, with January showing an average daily draw of just 5kWh from the grid, mostly occurring overnight. Enphase’s Enlighten software allows installers to configure for self-consumption rather than grid export, so that unused solar generation is stored for later use. Enlighten also allows charging optimised for time-of-use billing. For example, to minimise draw from the grid at peak early evening rates, the system is programmed to aim to have the batteries fully charged by 4pm.

Significant barriers to projects like this remain, including the legal work and cost to set up such an embedded network. But Stucco serves to highlight such barriers and show a way forward.

You can see the Stucco system’s live generation at www.bit.ly/STUCCOCP. Bjorn Sturmberg is now running a social enterprise start-up, SunTenants, to assist solar installations on rental homes (not apartments), with the benefits shared between landlord and tenant; see www.suntenants.com
Seeds of sustainability
Selecting plants for the home garden

Indigenous, non-indigenous native, or exotic: which plants will grow best in your home garden and which are the most sustainable? Well, it depends whether you’re considering bushland threats, water usage or other factors, says Warren Worboys from the Australia Garden.

ONE OF the roles of the Australia Garden in Cranbourne, Victoria, is to research and promote the growing of Australian native plants in home gardens as well as in public gardens and parklands. The strict selection process we follow in selecting plants for the Australia Garden may help if you’re trying to find the most sustainable plants to use in your own garden at home.

The gardens include a diverse range of natives to cater for the equally diverse tastes and needs of home gardeners. But the selection process is not just a matter of going to the local nursery and buying plants with the prettiest flowers.

Bushland threats
One of the biggest issues for the Australia Garden is the threat to adjacent bushland if plants escape and become weeds or hybridise with the indigenous flora. This is something to consider for home gardens as well.

At the gardens, we’ve established a database which records all Australian plants which have become weedy (anywhere) and all plant species which have shown capacity to hybridise with any plant species indigenous to our site. A new plant species being introduced to the Australia Garden is compared with this list and if there are any known threats which cannot be managed then the plant species is rejected for use in the gardens.

Because such a wide range of plants is grown, many of which have not been grown in cultivation before, a species which has passed this check may later demonstrate itself to be a potential threat, and so be removed. As a general rule, plants with fleshy fruit
which are eaten by birds (e.g. Pittosporum undulatum, or sweet pittosporum) may easily be spread several kilometres, whereas plants with dry seeds which normally just fall to the ground (e.g. Eucalyptus species) will generally only spread a few metres and are thus more manageable.

If your garden is adjacent to bushland, sometimes it is better to grow plants which are easy to distinguish from the local indigenous flora in case they escape to the bushland. If you use native plants which look similar to the indigenous plants it may be difficult to identify that they’ve escaped until it becomes too late. The same species from a different part of the state or even a different part of the country may result in cross-pollination and contamination of the local gene pool.

**Water usage**

Australian plants are generally thought of as low water users but in fact they vary considerably. Rainforest plants like Syzygium (lilly pilly) or tree ferns require copious amounts of water year round to grow well, but desert plants like Eremophila (emu bushes) are extremely drought tolerant.

As climate change continues to affect the plants in our gardens, it is becoming more important for us to find alternative water supplies, such as installing large rainwater tanks or systems which collect our greywater and apply it to our gardens. Keep in mind that a small-sized tree can easily use 60 litres of water per day—or 5400 litres just over the summer months.

You may also want to consider the impacts of projected climate change when selecting

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**Mulches**

Using mulches can help in many ways with the management of a sustainable garden but the various types have pros and cons.

**Green mulches—e.g. groundcover and low-growing plants:**
- help suppress weed growth
- help with moisture retention in the soil through shading
- help keep the soil cool
- help keep the whole garden cool
- a great diversity of suitable plants with a range of flower colour and foliage types
- readily allow rainwater to penetrate through the foliage
- are very sustainable
- require normal garden attention and maintenance.

**Organic mulches—e.g. wood chips, chipped garden prunings, bark, leaf mulch:**
- help suppress weed growth
- break down and help improve soil structure, and encourage worm activity
- help with moisture and nutrient retention as they break down
- help keep the soil cool
- come in a variety of colours, textures, and base materials, providing a diversity suited to many garden styles
- may be applied too thickly resulting in the prevention of water penetration to the soil. Ideally they should be about 50 mm thick in total. It is worthwhile raking back organic mulch in winter, in lines which follow the contours of the garden, to allow rainwater to reach the soil and recharge the ground water
- need to be topped up intermittently as they break down
- generally acidify the soil as they break down
- generally are made from recycled materials and thus more sustainable.

**Inorganic mulches—e.g. stones, pebbles:**
- help suppress weed growth
- won’t break down readily thus require little topping up
- help with soil moisture retention
- help keep the soil cool
- come in a variety of colours, textures, and base materials, providing a diversity suited to many garden styles
- coarser materials, greater than 20 mm diameter, readily allow rainwater to penetrate and do not require raking back in winter
- worm activity in the soil may result in the mulch slowly sinking into the garden soil thus requiring topping up
- may affect the soil pH depending on the base material
- generally are made from quarried materials and thus less sustainable
- are valuable for use around the house perimeter in fire-prone areas.
plants. For example, projections for the Melbourne area suggest that selecting plants (in particular trees, due to their growth rate and eventual age) which are currently more suited to the growing conditions of Bendigo, or even Mildura, is more appropriate for future-proofing your garden.

Again, sometimes using non-native plants may be more appropriate, e.g. rose bushes are very drought tolerant, compared to some natives.

**Built environment**

Through shading, trees help keep buildings and gardens cooler, some reports suggesting by up to 15°C. However, in climates with cool winters, such as in Victoria, it is just as important to keep buildings warm in winter. Therefore, trees that lose their leaves in winter are valuable as they allow the sun to reach buildings. Australia does have several deciduous tree species, but they all lose their leaves in the summer, to reduce water loss, rather than in winter. Use of non-native deciduous trees in closer proximity to buildings will assist with thermal conservation in summer and winter. Of course, you will want to take into account whether the falling leaves will block roof guttering etc.

In bushfire prone zones, regulations may require trees to be kept back from buildings. As a broad rule, winter deciduous trees are less likely to contain the volatile oils of our native trees.

**Final selection**

In the long run, selection of plants for your home garden is going to come down to your tastes and the amount of time and resources you can put into the garden's care. The questions below are ones only you can answer.

Watering is essential to keep any plants strong and vigorous, providing a lush, green garden. Do you have a sustainable large supply of water to keep plants growing well all year? Alternatively, you may be happy to have a garden that shows signs of drought stress during the summer.

Indigenous, non-indigenous native, or exotic? There are many pros and cons. If you live near bushland or in a non-urban environment then indigenous plants are generally more adapted to the local soils, microhabitat, pests and diseases, and thus will grow more reliably. However, you may wish to have more diversity and colour than your local native plants, in which case it is best to consider the points mentioned in the ‘Bushland threats’ section above. If your garden is in an urban environment, aesthetics may be more important to you and the broad variety of non-indigenous natives and exotic plants available will provide this, without necessarily being less suited to the growing conditions.

As a broader general rule, selection and use of native plants will attract and provide habitat for a diversity of native birds and animals. How much time do you have to maintain your garden? Weeds are a problem for every gardener and mulches will help suppress weeds. Pruning is important to keep plants vigorous and promote flowering the following season. A garden with a large diversity of plants is generally more time-consuming to maintain than a simple garden with little diversity. Unless you want a bowling green standard, a lawn generally takes less time to care for than garden beds, but is more subject to drying out in summer.

Remember, your garden will provide you with the chance to escape life's pressures and lose yourself in the pleasures of nature including the rewards of an attractive garden which may entice our native fauna.

Warren Worboys is Curator, Horticulture at the Australia Garden in the Royal Botanic Gardens Victoria, Cranbourne.

“Sometimes using non-native plants may be more appropriate, e.g. rose bushes are very drought tolerant, compared to some natives.”

![Image](far left) The WA groundcover plant *Eremophila ‘Kalbarri Carpet’* tolerates a range of soils in Melbourne.

![Image](left) *Chrysocephalum* (golden buttons), *Anigozanthos* (kangaroo paw), *Lomandra* (mat rushes) with grass-like foliage and *Rhagodia* (salt bush) with grey foliage at rear display a range of plant colours and forms which may be used as green mulch.
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Sub-tropical build
Bringing nature back

Richard Proudfoot and his partner have brought nature in to their suburban block, at the same time as reducing energy and water use. He describes their house and garden build, and the satisfying birdsong-filled results.

IN 2008 we sold our small cottage in inner-city Balmain, in Sydney, and moved to Bribie Island, just off the Queensland coast between Brisbane and the Sunshine Coast.

Why a life on Bribie Island? My partner Fiona was born and raised near Royal National Park, just south of Sydney. I was born and raised in the Australian outback. We both appreciate the bush and as we neared retirement, we looked for a simple, sustainable life in a leafy setting. While we loved the inner Sydney vibe, it could never be called simple, and true sustainability was always going to be difficult to achieve.

Bribie also has arguably Australia’s best climate. In summer, the temperature rarely exceeds 29°C, while in winter the temperature range is 15°C to 25°C, and annual rainfall is 1.2 metres. It is a great environment to use passive solar design techniques to build a sustainable, more self-sufficient house.

We bought an ordinary suburban (650 m²) block (of sand!), 200 metres from the beach, bordered by neighbours on three sides. Much of the time, a cool sea breeze from the Coral Sea blows across our block. The block runs east-west and has many mature trees on the back boundary.

So what kind of house to build?
Working closely with the builder, we came up with a design based on their classic Queenslander kit home. The house is elevated to catch the sea breeze and there is always cool air flow under the floor. It has verandahs on all four sides. It has high ceilings with a fan in every room, essential for sub-tropical days and nights. Most of the windows are north facing. There is very little glazing on the south and west sides, to provide maximum protection from the many storms which come in from the south-west. Every room opens onto a verandah, including the bathroom.

We wondered about building on sand, but our builder allayed our concerns. He used about one metre (depth) of concrete per footing. He couldn’t go much deeper because the water table starts about two metres below the surface. To date we have not observed any cracks in the walls, so our initial concerns appear to have been unwarranted.

We enquired about greywater and blackwater systems, but were told by the Moreton Bay Regional Council that because of the sand, such systems were not permitted. A lot of the island’s drinking water is sourced from underwater aquifers so the whole island is treated as a catchment area. Burial of humans and animals is strictly forbidden: crematoriums do well in this part of the world!

Other passive solar design features include: verandah width calculated to let sun in on winter days but to keep all sun off the walls in summer; strategically selected lowered internal walls to permit airflow throughout the house; bi-fold doors and windows on the north and east to maximise airflow; a gable in the roof structure that faces the prevailing breeze; a solar-driven extraction fan in the...
roof that means the cavity temperature gets only marginally warmer than room temperature; house sited so that large trees on the western boundary block most hot afternoon sun from 2 pm.

Our final spend on the build ended up being about $280,000 (kit price was $140,000), about 10% above that of an average-priced medium-sized project home.

Energy use
A 1.8 kW solar array provides enough electricity to cover our use; on average we use around 6 kWh per day, with our current grid import around 3.8 kWh and export 6 kWh per day—resulting in an annual rebate from our energy retailer.

All power points (except those in the kitchen and one in each room) are wired to a central switch which is turned off at the end of each day. This leaves no unnecessary electrical device drawing power through the night. This single feature has turned out to be the biggest saver of power in our home.

Our electricity use is 25% of the average household, with little inconvenience—the only one being that we have to reprogram our TV tuner each day.

At the end of 2015, we replaced our 12-year-old fridge with a new, high Star-rated model, which made a big difference to our energy use (reducing it by about 1 kWh a day).

Water and gardens
We purchased our two 25,000 L tanks from Allcast Precast based in Woombye, Queensland. We chose concrete because we wanted to bury the tanks and knew that the water table was only two to four metres from the surface (depending on rainfall). We also knew that we would eventually have quite a lot of vegetation around the tanks and past experience showed me that aggressive roots can eventually break into plastic tanks. To overcome the water table problem, when we lowered the tanks into the holes (each three metres deep), we partially filled them with clean water in order to increase the weight and avoid them floating.

The tanks are fed from the 15 m x 12 m roof over the main house. We elected to have wider guttering to improve rainwater capture, particularly in storms. Because we retain rain that falls onto the roof area and there are no hard surfaces on the block, there is no rainwater runoff into the street: what rain falls on the block stays on the block. Leaf traps (which are easily accessible for regular cleaning) and first flush filters ensure that the rainwater is clean as it enters the tanks. Filters on the extraction hoses and at drinking water taps provide further sieves. For the first eight years here we used only tank water, but this year we have had to use a combination of mains and tank due to the lingering El Nino.

We have 12 vegetable garden beds, each 2.4 m x 1.2 m. These provide half our vegetables throughout the year. Because our place is built on sand, we had to initially bring in our garden soil and we renew this regularly with our own compost. We make about one tonne of soil per year from composting. The secret to keeping the garden healthy in our hot climate is to use mulch. This keeps the beds moist, free of weeds and breaks down over time to further enrich the soil.

Because of the high humidity, we struggled with some ‘European’ vegetables; too much effort for too little return. Now we only grow ‘Asian’ and humidity-tolerant vegetables. Happily, our banana, avocado, mango, macadamia, guava, black Genoa fig and citrus trees all flourish in this environment.

By making our own sourdough bread we also estimate our grocery bill has reduced by around $400 per year.

Humidity control
In a humid climate, mould in confined spaces, e.g. wardrobes, can be a problem. To help overcome this, we have an air vent in the floor and ceiling of every room. This helps to keep the air circulating even if the house is shut up, such as when we are away on holidays. Being a Queenslander in style, the house is on stilts and so air tends to flow upwards from the cooler sub-floor zone to the warmer roof cavity. Such a vent system behind the refrigerator helps reduce our energy usage because the heat behind the unit is taken away immediately, allowing the compressor to operate more efficiently.

We have no air conditioner and until recently had thought we would never need one. However, since late 2016, coastal south-east Queensland has experienced 30 days of temperatures over 30°C, humidity levels in excess of 70% and no relieving rain. We have never experienced anything like it in our eight years here. Inside the house, the temperature remained a constant 29°C, but humidity was a problem. By opening up all windows and doors to the verandahs we caught the breeze off the sea and we had the fans in the living room on 24 hours a day. We also moved the start of our day to 4 am when it was cooler.

As a result of living through the undoubted
early effects of climate change, people I know who had sworn never to put air conditioning in their house are queuing up to get it. As our solar system covers our electricity use, we may be tempted to air condition one room, but not before seeing if this warming trend continues next year. With 16 of the last 17 years being the hottest ever, it’s a fair chance that we will join the queue.

Because we have no concrete thermal mass on our site, we’ve found we don’t suffer from lingering radiated heat when the sun sets. Our neighbours who do have heat sinks such as brick-veneer walls, concrete slab floors and driveways often choose to stay outside until well after dark when the heat has dissipated.

Bringing nature in
As the bush is very important to us, we’ve tried to make the verandahs part of our living space. The bi-fold doors and windows are part of this. By opening them up, we not only let the outside in, but we also funnel the prevailing coastal breeze through the house. We have installed large fully retractable insect screens (they either open inwards or roll back into a cassette) over each bi-fold opening.

This means our lounge room is often full of the sounds of songbirds including the magpie, the pied butcherbird and ubiquitous kookaburra.

Western boundary to increase the shade and protection from western sun. The emerging understorey rainforest plants and shrubs provide habitat for small birds, something that is critically missing from most of our modern suburbs.

Maintenance
There has been some maintenance required. The exposed timber on bargeboards, verandah floors and verandah uprights need regular oiling to protect from the harsh sub-tropical sun. The Hardiplank cladding on the house will need painting at some stage, but I try to protect it as much as possible from the ravages of storms and salt air by regular cleaning with a high-pressure hose.

A note on size
Our modest two-bedroom, 1½ bathroom suburban house is 160m² when the verandah space is included. After nearly eight years here, we have never felt that we needed more space and never felt a lack of privacy, even though we have neighbouring houses on three sides.

Our challenge in building on a low budget was to get the smallest house that would provide acceptable comfort. Small houses mean minimal maintenance, minimal cleaning and minimal build cost, three important factors for people like us who are approaching retirement. Well-designed houses can mean no assisted climate control, pleasing external views and adequate privacy.

“... Their elevated Queenslander-style house under construction. Note the extra-wide gutters to improve rainwater capture. The house has leaf traps and first-flush filters to keep the rainwater clean as it enters the sub-surface concrete tanks.

Renewable energy system
- 30 x 60W (1.8 kW) Kaneka thin film panels
- SMA Sunny Boy SB-1700 inverter
- System designer/installer: Solar Shop (now defunct).

Water
- Two x 25,000L concrete rainwater tanks from Allcast Precast, Woombye, Qld, fed from 15 m x 12 m house roof.

House features
- Ceiling insulation: R5 pink batts, 200mm thick
- Solar Star solar-driven fan on the roof extracts heated air from roof cavity—temperature in the roof cavity is never more than 2°C higher than in the living space
- Windows and glazing: Stegbar powder-coated aluminium frames, safety glass. Insect-proof screens open inwards or roll back into a cassette
- Window coverings: Venetian blinds on French doors, curtains on bi-fold doors and windows
- Heating: Oil-filled column heater (used just five or so times a year)
- Cooling: Three-speed Heller ceiling fans. High ceilings (2.7m) mean air is distributed more uniformly
- Lighting: LEDs in table and standard lamps, and oyster wall lights. Cupboard fluoro lights in the kitchen. Light switches and power points installed at 1m height to facilitate growing older in place.

Pleasing result
For us, the sustainable building approach has proved itself financially and improved our comfort. Building small meant lower upfront costs, and our renewable energy system and sustainable building mean lower ongoing costs. Finally, the personal enjoyment and satisfaction we get from living simply and sustainably cannot be overstated. This factor often features in lifestyle satisfaction indicators conducted in wellness and ageing research, and having lived this way, I fully concur.

Richard is a semi-retired computer scientist. Over the last 20 years he has been actively involved in conservation and sustainability.
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The energy detectives
Thermal imaging pays off

Knowing that double glazing can be compromised by incorrectly sealed window frames, Jean and Barry Lambert used affordable thermal imaging technology to check and rectify the installation—and find other sources of house heat losses.

LIVING in Canberra’s cold climate you need to think carefully about heat loss. We’ve done work on our house to improve its insulation, glazing and heating system efficiency. But that doesn’t necessarily translate to the best possible thermal performance if there are gaps or weak spots in the insulation—and that’s where we found a thermal imaging camera came in handy.

Some background on our house
Located in an inner suburb of Canberra, our four-bedroom brick house was built in the 1970s. The major axis runs north–south, with the living area to the west (giving views to the Brindabella mountains) and the bedrooms facing east.

Canberra of course has quite a wide temperature range (it’s in climate zone 7). Outside temperatures on winter mornings can fall below zero, while summers are usually dry and warm.

Canberra’s cold winters dictate that insulation is a priority to reduce heat loss. We insulated the walls with R3 rockwool and we topped up the existing ceiling insulation to an R5 rating. We replaced the original oil heating with ducted gas, and added deflectors on the floor vents to direct hot air away from windows. By varying the airflow rate using the outlet dampers in the floor vents, around a 50°C outlet temperature is maintained, giving a comfortable 18°C to 20°C temperature inside the house.

First thermal imaging success
In March 2016 we decided to get double glazing with low-e glass installed on all windows and a large west-facing sliding door.

An article in ReNew 115 on the installation of double glazing stressed the need to correctly seal window frames to prevent air leaks.

Using the advice of technical staff at the ATA (ReNew’s publisher), we purchased a FLIR TG165 thermal imaging camera and, once the installation was completed, we checked the windows. The camera identified leaks around most window frames. Armed with this information, we convinced the installer to rectify these problems.

A comparison of our most recent heating bill with the same winter period in 2015 shows pleasing results, with savings of 30%.

Next up: the ducted heating
Impressed with the camera’s performance we then decided to inspect the effectiveness of the insulation around the ducts in our heating system.
Images of the wall penetrations showed severe leakage around the furnace outlet because of the lack of insulation.

The trunking is supported throughout by plastic tape and in some areas the binding is too tight, compressing the insulation and increasing the heat loss.

The second last junction splits off to the bathroom and bedrooms. The lack of insulation on this and the other junctions results in significant heat loss.

In our system, an outdoor furnace feeds two ducts, one 18 metres long with three sub-junctions for eight floor vents, the other 25 metres long which feeds ceiling vents.

We found significant losses around the furnace outlet, duct entry points and the junctions between ducts. Examples of the problems found can be seen opposite, such as uninsulated junctions and the furnace outlet, but also less obvious issues such as support straps being too tight and crushing the insulation, making it less effective and increasing heat loss.

What an eye-opener: if I'd had the camera 12 years ago when the system was installed, there would have been a number of recalls to the installer to rectify the problems. I have started to insulate each of the offending areas.

What next?
The thermal imaging camera highlighted considerable heat loss from our home caused by faulty window sealing and sloppy installation of the heating ducting. I recently carried out a similar inspection in the roof and found many places where insulation had been moved and not replaced around our roof vents. Having fixed this up as well, we almost look forward to receiving our 2017 winter heating account!

Barry and Jean are keen DIYers and are in the process of restoring an old farmhouse in southern NSW. The Melbourne and Adelaide branches of the ATA (ReNew’s publisher) have FLIR cameras available for hire; see community. ata.org.au/flir.
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Phasing out fossil fuels
Are we winning?

Professor Peter Newman contends that our cities are driving a change which is reducing greenhouse gas emissions from both coal and oil.

IN 2016 the International Energy Agency announced that the world had changed. For the first time in hundreds of years the world was producing less greenhouse gas (GHG) emissions than the year before without this being caused by an economic crisis. In 2015 the amount of GHG emitted to the world’s atmosphere decreased by around 0.5% while economic growth continued at more than 3%. A few scientists had predicted this, but mostly the fossil fuel lobby had been in complete denial over its possibility.

As Figure 1 shows, for the first time the industrial world was producing wealth without this meaning more fossil fuels and more emissions. Despite its huge implications for a world that has faced the global climate issue for decades without much good news, the world’s media were virtually silent.

China is now decoupling their economic growth from GHG very rapidly as shown in Figure 2. This provides great hope that the process will now spread to the whole emerging world. China invested $90 billion in renewables in 2015 (more than 60% of their investment in energy), so much of their continuing growth will be based around solar and wind rather than the fossil fuel-based economic growth of the past 15 years.

The data on developed nations (Denmark, the USA and Australia in Figure 3) indicates that the global decoupling is likely to continue.

How is this happening?
In my analysis, the decoupling is driven by the world’s cities. For both coal and oil this is due to a combination of increased energy efficiency and increased use of renewable energy.

COAL
Energy efficiency is removing coal-fired power stations in conjunction with the dramatic increase in renewable power investment, now more than double the investment in fossil-based power world-wide. In Australia in the past five years the dramatic growth in rooftop solar has created a significant market that was not considered likely for decades. 1.5 million homes purchased rooftop solar in five years with much lower subsidies than previously. In Perth solar is now on 25% of homes; the 550MW produced is the largest power station in Western Australia. This has led the WA Minister for Energy to suggest this will grow to 70% of households by 2020 and the utilities will never again need to purchase a coal- or gas-fired power station. Batteries are the next rapid deployment technology in this transition which will also make electric vehicles more mainstream.

OIL
The reduction in consumption of oil is also being driven by cities at a faster rate than many anticipated. The collapse in oil and coal prices appears to be due to both demand and supply issues. Demand for coal will continue to drop as renewables take over, especially as battery storage becomes cheap. Demand for oil is expected to decline as vehicle fleets are electrified; however, it has already gone down despite there being only a few percent of electric vehicles. The reason why this has happened appears to be a city issue: for the past 150 years cities have been spreading as they have followed first trains and trams then automobiles, but now they are coming back in.

My group’s research on cities has shown that there is an inverse exponential relationship between urban density and car use/fuel use as illustrated in Figure 4. If cities have begun to increase in density rather than decrease then they will drop...
...down the steep curve quite quickly creating exponential decline in car use. This is what we are now seeing in all the world’s developed cities. The phenomenon is being called ‘peak car’, as car use per capita has peaked and is in decline. Indeed it is very similar to the decoupling phenomenon described above. Many cities are now seeing that their economic growth is dependent on them reducing their car use. Hence cities like Washington DC and Portland, Oregon, have demonstrated that their wealth is decoupling from car use.

It should be no surprise that this strong decoupling is associated with cities that have invested in good urban rail systems in recent decades. The decoupling is closely associated with this as our data also shows that urban traffic is slowing in all the world’s cities and urban rail is now able to out-compete cars as they can go around, over or under the traffic. Most Australian cities have a high priority rail project or three on their agenda when a decade ago it was hard to even support the old crumbling rail services. Sydney is building three new rail lines and is clearly seeing major economic growth associated with this as urban development focuses around the stations. Governments play a big part in this transition as they are needed to help plan, though not necessarily finance, such large-scale infrastructure. However, business and the community are also critical as they are responding to a new economic process associated with the knowledge economy. Many businesses that are part of the new innovation economy are locating in city centres where their professionals can have creative face-to-face contact with people from various backgrounds and professions. These new jobs are generally for the young millennials but also older wealthier professionals. As a result there is a social movement that has rediscovered inner and central city living. The market demand for dense urbanism that is not car dependent has therefore grown dramatically in the 21st century city.

The same phenomenon of peak car has been found in Shanghai and Beijing which are now carrying 8 and 9 million passengers a day on their new Metro systems, enabling a significant reduction in the relative use of cars. This rapid change into decoupling growth in wealth from growth in car use is happening in such emerging cities because they have an urban fabric that is not suited to large-scale growth in car use. The building of 81 electric urban rail systems in Chinese cities and 52 in Indian cities is indicative of how the switch away from oil is happening before many expected.

There are some big surprises in all this data as we are led to believe change cannot happen quickly on these issues. I believe we will look back at this period of history and recognise dramatic change set in with very significant impact. We are indeed winning.

Peter Newman is the Professor of Sustainability at Curtin University. He sat on the Board of Infrastructure Australia and is a lead author for transport on the IPCC. His books include Green Urbanism in Asia (2013), Resilient Cities: Responding to Peak Oil and Climate Change (2009) and The End of Automobile Dependence (2015).

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Who’s at the wheel
Driverless cars and transport policy

Will driverless cars transform our cities for the better? Dr John Stone explores what’s driving the development of driverless cars and what they might mean for sustainable urban transport.

THERE IS a lot of talk about emerging transport technologies such as driverless cars. Much is being made of their potential to disrupt urban travel in ways we have not seen since Henry Ford’s black automobiles began rolling off his new assembly lines in 1913 and utterly transformed urban life. What futures—utopian or dystopian—might be unfolding in the boardrooms and laboratories of Google, Tesla and Volkswagen? What alternatives might the new technologies offer us?

An electric future is possible
Alternative propulsion for the standard car or truck is already available. With new battery storage or hydrogen fuel cells, we can begin to imagine a future where electric motors allow us to leave dwindling oil stocks in the ground and stabilise the global climate without disrupting our hyper-mobile urban lives. I’ll leave to another time the debate on whether we really can generate sufficient extra renewable energy for this sort of transition, but powering well over a billion cars and trucks across the planet is no trivial task (see box). Analysts like Damon Honnery at Monash University say that motorised transport, if made sustainable, will be dramatically constrained whatever our power source.

But better policy is needed
In any case, there are many serious problems in our cities that mass transition to electric power won’t fix: electric vehicles don’t strengthen urban growth boundaries or reduce demand for parking that eats up valuable urban land, they don’t make driving safer, they don’t make the life of the city any more accessible to anyone with few options other than to live on the urban fringe, and they don’t provide the daily exercise that helps prevent heart disease and diabetes.

Progressive urban communities around the world continue to press planners and politicians to halt the march of freeways, to build networks for public transport, cycling and walking, and to locate jobs, schools and hospitals in easy reach of housing. Success is relative: few cities in the developed world have created transport systems in which private cars play a minor role. However, some have made significant moves in that direction.

Tokyo, Hong Kong and Seoul provide models for minimising car use in large, high-density urban environments.

In Australian cities, most pundits have long told us that we can’t have both backyards and effective alternatives to the car. But, the late Paul Mees eloquently demonstrated that our densities should not condemn us to car dependence. The key to the alternative is to create public transport that, by linking services into a seamless network, allows people to move across the city with the same freedom promised to drivers. Vancouver used this model to reduce rates of car use in its inner and middle suburbs during the 1990s and early 2000s. They complemented an effective public transport network with a refusal to build inner-city freeways and citizen participation in debates over urban intensification.

The most efficient and effective public transport networks are found in the cities and suburbs of German-speaking Europe. In Vienna, Munich and Zurich, planners have coordinated development with high-quality public and active transport networks.

The RAC Intellibus trial in Perth gave the general public the opportunity to experience driverless public transport first-hand. The vehicle is a NAVYA ARMA from France (see www.navya.tech) and is 100% electric, with a top speed of 45 km/h. The Perth trial is not the only one for NAVYA, with a number of their vehicles operating around the world, including at Christchurch airport.
A prototype driverless car from Waymo, formerly the Google self-driving car project. Waymo cars use LiDAR technology in a cone on top of the vehicle; this sends out lasers that bounce off objects to create a high-resolution map of the environment in real-time.

“This is fertile ground for promoters of new technologies who promise an end to traffic snarls and the frustration of searching for a parking spot.”

‘Thinking like a passenger’ is not just a slogan but is central to the way the systems are designed from ticketing technologies to station layout and timetable coordination to real-time information on your phone.

By contrast, back in our Australian suburbs, the freedom a car offers is often an illusion. Congestion at weekends in some areas now matches afternoon weekday peaks, and state governments stand or fall on their record on freeways and public transport. This is fertile ground for promoters of new technologies who promise an end to traffic snarls and the frustration of searching for a parking spot.

Are driverless cars the answer?

Rapid advances in IT and communications mean that the ‘autonomous vehicle’ is now being trialled on streets from Adelaide to San Francisco. The communications giants are already deploying the laser sensors, cameras and centimetre-perfect GPS that will allow a vehicle to navigate the streets of your town without a driver. Using this technology, three distinct forms of driverless car are emerging, each with its own corporate proponents and target markets; and its own, often competing, demands on citizens, regulators and planners.

The first group of corporate players are the traditional carmakers who are adding ‘driverless’ technology to their existing heavy, high-performance, multi-purpose, comfort-driven products. They have no compelling interest in changing the current individual ownership model. Their target consumer is likely one who values private vehicle ownership and enjoys driving. Their challenge is to win over drivers who might be sceptical about ‘their’ car doing things they can’t control, whether that is behaving differently in traffic or performing unescorted journeys instead of remaining safely in the parking lot.

The second group of corporate interests are the IT disruptors like Google and Uber for whom driverless technology is the basis for new transport economies: new types of vehicle and new patterns of ownership. They are aiming to build lightweight, utilitarian vehicles designed for shorter journeys and available to the young, old and disabled who currently cannot drive. These would be owned by a corporation and rented by the trip, with travellers using phone apps or their next-generation successors. This, in the jargon, is ‘mobility as a service’. The ambition of these digital entrepreneurs is to replace private cars, shared cars/taxis, conventional public transport and even non-motorised transport. Sustainability or social objectives might be part of the pitch, but the profit motive is dominant.

The third interest group includes the operators of existing public transport systems.

In cities where public transport occupies a central place in economic and social life, these agencies are much more powerful and proactive than in Australian cities. They can see opportunities and challenges in driverless technologies. Already, Vancouver reaps the benefits of lower operating costs of its driverless elevated rail system. European operators understand that new vehicle technology is only valuable if it is used to improve the network’s effectiveness.

Winners and losers

Many of the claims for the benefits of driverless technologies rely on the complete transformation of the existing vehicle fleet. But the transition will not be smooth or uniform: winners and losers in the competition between the different interest groups will depend on many factors, from patronage by Donald Trump to the organisation of citizen action.

Freeways are likely to be the first spaces for features that enable flexible charging—at least a simple timer function. Apart from through to all consumers as increases in grid tariffs. On the other hand, smarter car chargers can avoid peak periods, perhaps charging the car during the early hours of the morning or during the sunny part of the day. In this scenario, EVs put downward pressure on electricity bills, as they increase utilisation of the grid without increasing peak demand. If you’re purchasing an EV, it’s good to look for features that enable flexible charging—at least a simple timer function. Apart from the grid benefits, this may also reduce your bills by taking advantage of overnight off-peak tariffs or your own solar generation.

EVs and the grid: demand management needed

The ATA’s Andrew Reddaway notes: Charging an EV requires a lot of electricity compared to other household appliances. As more people switch to electric cars, this will start to affect overall demand for grid electricity. In most residential areas, maximum demand on the grid occurs in the evening as people return home and switch on appliances. If EV charging is unmanaged, households will plug in their cars during this peak time. The extra demand would likely require expensive grid upgrades, flowing through to all consumers as increases in grid tariffs. On the other hand, smarter car chargers can avoid peak periods, perhaps charging the car during the early hours of the morning or during the sunny part of the day. In this scenario, EVs put downward pressure on electricity bills, as they increase utilisation of the grid without increasing peak demand. If you’re purchasing an EV, it’s good to look for features that enable flexible charging—at least a simple timer function. Apart from the grid benefits, this may also reduce your bills by taking advantage of overnight off-peak tariffs or your own solar generation.
in which the new vehicles will be able to operate. Promoters of the new technology might join forces with drivers of conventional cars to demand separate new lanes for the new vehicles. This will conflict with the hopes of some sustainability advocates, who will want to use the fact that driverless cars could travel much closer together than conventional cars to argue for reduced space for mass movement of cars.

In any case, problems of congestion and competition for space at any popular destination will not be resolved. And, if drivers are freed from the burden of attention to the road rules, many will be free to choose to travel further, leading to an accelerated march of suburban expansion.

After the freeway network, the next objective will be to make our city streets available for the operation of driverless cars. This will require complex systems of sensors and cameras, some of which are about to be trialled in inner-city Melbourne. The ambition is to allow cars, bikes and pedestrians to share road space much more safely than they do today, with the effect that more people will choose not to drive. But, if a driverless car or bus will never hit a jaywalker, what will stop pedestrians and cyclists from simply using the street as they please? Some analysts are even predicting that the new vehicles will be slower than conventional driving, partly because the current balance of fear will be upset. While this might be attractive to cyclists, will it affect the marketability of Google’s new products?

With huge reserves of cash and consequent lobbying power, Google and its ilk will be in a strong position to demand concessions from governments and road authorities. You can just imagine the pitch: we can save you billions on public transport operations, but we need fences to keep bikes and pedestrians out of the way of our vehicles in busy urban centres.

Lost in the enthusiasm for the new, is the simple reality of the limited availability of urban space. Every serious transport planner recognises that the ‘liveable’ city requires high-capacity mass transit routes with much greater reach than we now have in Australia. New technologies of driverless trains may reduce costs and allow us to improve the quality of the service, but only if that is the focus of investment and innovation.

I would urge readers of ReNew, who I know are great lateral thinkers and inventors, to turn their minds to the real alternative technologies we need in urban transport. Rather than follow the individualist model which directs our attention to the technology of the vehicle, let’s turn our attention to the ‘technology of the network’. How can we build on the insights of the Europeans and Canadians and use the potentials of IT and electronics to build better collective transport systems that connect all of us to the life of the city without consuming all the space we need to live and grow.

Dr John Stone is a lecturer in transport planning at the University of Melbourne, with a research focus on improving public transport performance in Australian cities.

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**How do autonomous vehicles work?**

To navigate the road safely, and deal with potentially hazardous situations, autonomous vehicles use a number of sensors and data inputs. These are used to create a real-time picture of what is happening around the vehicle, which, combined with detailed maps of roads and intersections etc., allows the vehicle’s artificial intelligence to decide whether to continue on with the task of travelling from A to B, or to take action to avoid a hazard.

Different manufacturers are using different systems to collect data, including LIDAR (light detection and ranging, where a laser beam bounces off objects to tell the object position and direction), RADAR (similar to LIDAR, just using radio waves), stereoscopic cameras (dual cameras to provide depth perception and image structure, just as animals have two eyes for the same purpose), GPS data, motion and orientation (compass) sensors, inertial measurement sensors such as accelerometers and gyroscopes, and data collected by other autonomous cars which is stored in centralised servers.

Tesla uses eight cameras and twelve ultrasonic sensors, in addition to forward-facing radar, to provide the ability to operate at SAE Level 5 (fully autonomously).

Google’s Waymo uses a 360-degree LIDAR system to generate a detailed 3D map of its immediate surrounds, which it compares with existing high resolution maps.

All of this data enables the car’s computer to distinguish between different types of obstacles, such as stationary vehicles, moving vehicles, bikes and pedestrians, as well as detect road signs, traffic lights, road lane marking and barriers. Plus, of course, those unforeseen little hazards, such as one Google autonomous car came across one day—a woman in a wheelchair chasing a duck with a broom in the middle of the road.
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Changing lanes
The emergence of e-bikes

Worldwide, electric bikes are one of the fastest growing segments of the transport market. Dr Elliot Fishman breaks down the numbers and explains how e-bikes can make transport cleaner and greener.

TRANSPORT systems and behaviours are difficult to change. Although only constituting a fraction of vehicles, there are now many more e-bikes on our roads and bike paths than ever before. In recent years, regulations in Australia have been brought in line with those that exist in the EU, meaning Australian consumers are now afforded greater choice in the types of e-bikes available. The new legislation allows motors with a power output of 250 W and assistance cutting out at 25 km/h.

Electric bicycles (e-bikes) represent one of the fastest growing segments of the transport market. Commercially available e-bikes originated in Japan in the early 1980s, but technological and cost factors limited market attractiveness until the early 2000s. Improved battery and motor technology, component modularity and economies of scale have meant e-bikes can now travel longer distances and are more affordable than at any time in history. In the past decade more than 150 million e-bikes have been sold, the largest and most rapid uptake of alternative powered vehicles in the history of motorisation.

China leads the world in e-bike sales, followed by the Netherlands and Germany. It is estimated that some 95% of the world’s e-bikes are in China, but these are almost entirely of the scooter variety, without functional pedals. The Dutch and German markets are dominated by pedelecs, in which engagement with the pedals is required for the electric motor to function.

Very little is known about Australian e-bike sales, as there are no official databases kept on imports or sales. While we do not know the number of units sold, we do know a little about the demographics of e-bike users (at least those willing to respond to university research projects). Researchers from Monash University found a disproportionately high concentration of respondents within the 41 to 60 age band and almost half earnt more than $100,000 per year, substantially higher than the population average. Almost all (94.4%) of respondents owned a car.

Why the growth in e-bikes?
The key benefit of e-bikes is that they can maintain speed with less effort. This helps to overcome some of the most commonly cited barriers to traditional bike riding, such as distance, topography and time limitations. High temperatures, poor air quality and rain also push riders towards e-bikes over bicycles. There is some evidence that e-bikes provide mobility to those with physical limitations that prohibit cycling. Overall, the electrical assistance has, for many riders, made cycling fun again and this is likely to be a major reason underpinning the growth in e-bike sales. Importantly, numerous studies have found that while electrical assistance makes cycling easier, the physiological benefits are still sufficient to protect against diseases of a sedentary lifestyle, such as diabetes and heart disease.

Given Australia’s cities are very often hot and sprawling, and in places hilly (e.g. Sydney, inner western Brisbane), e-bikes may offer a potentially attractive alternative to a crowded train or bumper-to-bumper peak hour congestion. Indeed researchers have found that the ability of e-bikes to maintain speed with less effort has led to people replacing...
issues, have been overcome and therefore it cycling, such as infrastructure and safety public benefits.

The extra physical activity has been shown to with sales forecast to reach 47.6 million by Over 40 million e-bikes were sold in 2015, Global sales growth car trips, providing a range of individual and public benefits.

Households may be able to get by with one car instead of two, saving thousands per year. The extra physical activity has been shown to provide additional years of healthy life. E-bikes emit just 2.5% of the carbon dioxide of a car travelling the same distance. The greenhouse benefit is likely to be even more for the many Australian households with solar power, as charging the battery during sunny periods offers the possibility of a sun-powered bicycle. And of course, an e-bike used as a car replacement reduces congestion, air and noise pollution, helping to make our cities more liveable and productive.

Global sales growth

Over 40 million e-bikes were sold in 2015, with sales forecast to reach 47.6 million by 2018. Available data shows China accounts for some 93% of global e-bike sales in 2012 (see Table 1) with approximately twice as many people owning an e-bike than a car.

According to a 2013 article in The Economist, one in six bicycles sold in the Netherlands is an e-bike, with another report putting this figure lower, at 9%. The Economist also reported that in France traditional bike sales fell 9% in 2012, but e-bike sales increased 15%.

There appears to be a relationship between e-bike sales and general riding. For instance, as described in my co-authored article 'E-bikes in the Mainstream' in 2015, the Netherlands and Germany have the highest e-bike sales per capital in Europe and are also the countries with the highest rate of general cycling. A possible explanation for this is simply that many of the barriers to general cycling, such as infrastructure and safety issues, have been overcome and therefore it is these countries that offer the most fertile market for the introduction of the e-bike.

What’s needed to get more people using e-bikes in Australia?

The major factor limiting e-bike use (and general cycling) in Australia is a lack of integrated, cohesive networks of safe bicycle lanes and paths. Until bicycle lanes become ubiquitous in Australian cities, it is difficult to see e-bike levels (or general cycling) making a significant contribution to the transport task (only 1.5% of Australians use a bicycle to get to work, according to the 2011 Census).

It is encouraging, however, that within the small pockets of Australia that have invested substantially in bicycle-friendly design and higher, mixed-use density, usage levels are around those found in many European cities. For instance, areas of Melbourne’s inner north have some 12% of commuters choosing cycling as their preferred mode. Opening up this choice through the provision of quality bicycle networks will enable Australian cities to become more productive, cleaner, healthier and more sustainable. Once our cities support the choice to cycle, retrofitting car parks to include charging stations will enable batteries to be charged while people are at work, as is now commonplace in Dutch cities. Financial incentives that help make e-bikes more affordable and normalise their choice are also important. The challenge for Australian governments will be to develop the courage to make tough decisions about the allocation of road space based on prioritising sustainable modes of transport.

Dr Elliot Fishman is director of transport innovation at the Institute for Sensible Transport (www.sensibletransport.org.au), a Melbourne-based consultancy that works with government on policies to increase sustainable mobility options in Australia. This article is based on one co-authored with Associate Prof Christopher Cherry from the University of Tennessee.

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Table 1: Global e-bike sales (estimates). Source: E-bikes in the Mainstream: Reviewing a Decade of Research by Fishman & Cherry.
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Market acceleration
Electric vehicles at home and abroad

Around the world, the electric vehicle market has grown phenomenally in both sales figures and vehicle options since our last update barely six months ago—though not so much in Australia. Bryce Gaton outlines what to expect.

IN THIS article, I explore what to expect around the world and in Australia for electric vehicle (EV) and associated equipment releases and updates. I’ve also included some predictions on what we’ll see less of as some of the competing systems start to die away. Sadly, for most of the new releases around the world, I also give the automaker’s reasons for not yet bringing their EVs to Australia.

Cars and vans coming in 2017
Hailed as a game-changing lower-cost, high-range EV, the Chevrolet Bolt (an all-electric 5-seat/4-door hatch, with a real-world 350 km range on the US EPA test cycle and a pre-rebates US price equivalent to AU$48,000) is now rolling out to customers in California and six other US states, and will be available for order across all 50 US states by July this year.

Even international deliveries have commenced with the first Bolt delivery in Canada happening in January this year. It was also exhibited at the 2016 Paris motor show last September as the Opel Ampera-e, to go on sale in Europe sometime in 2017. Unfortunately, this first-generation Bolt will not be built in right-hand drive, so we will have to wait for the next generation Bolt before we might, possibly, see it in Australia.

Also at the 2016 Paris motor show, Renault announced a doubling of the range of its all-electric Zoe. Based on the Nissan Leaf and developed as part of the Renault-Nissan alliance, the Zoe was launched in 2013 with a real-world range of around 140 km. The Zoe has been the biggest selling EV in Europe since 2015, outselling its cousin the (now ageing) Leaf with its attractive styling and modern interior. With the doubling of the Zoe’s range to around 280 km, it should sell even more.

On our side of the world, the Zoe has even reached the shores of New Zealand. In August 2016 it was released there, but with an eye-watering driveaway price of around AU$71,500 (compared to AU$30,000 to $45,000 in England), I doubt they’ll sell many. Sadly for Australia, Renault still maintains they will not do much about selling EVs here until the government introduces incentives for them. Given the current Australian government’s approach to the auto industry, we are likely to be waiting a while.

On the topic of Renault, at the Brussels motor show in January this year, Renault made two major announcements. The first was an addition to their EV line-up with a 200 km (European test cycle, see box on EV ranges) battery range Master ZE. The Master is a 1.5 to 2 tonne van (a common-sized van used for local deliveries in Europe), so an EV Master makes a lot of sense there. The other announcement from Renault was an increase to the battery range of the smaller Kangoo ZE electric van to around 270 km (European test cycle).

The Kangoo ZE is also listed as “will soon be available in Australia” on the Renault Australia website—as it has been now for well over a year. Meanwhile Tesla (arguably the initiator of the other automakers’ recent rush to EVs!) has started deliveries of the Model X in Australia, with several seen on the roads here recently. And just around the corner is the production of the Model 3, slated to start production in July this year (and pre-production in February), with the first US deliveries planned for later in 2017.

Mind you, Tesla is also renowned for never failing to miss a deadline it has set for itself. The other announcement from Renault was an increase to the battery range of the smaller Kangoo ZE electric van to around 270 km (European test cycle). The Kangoo ZE is also listed as “will soon be available in Australia” on the Renault Australia website—as it has been now for well over a year.

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Mind you, Tesla is also renowned for never failing to miss a deadline it has set for itself. Given the Model X was first promised for early 2014, began deliveries in the USA in late 2015 and is only being delivered here in January 2017, it seems the Model 3 is unlikely to be

↑ The Chevrolet Bolt is a full EV with a 350 km real-world range, but unfortunately is not available in Australia.
In Australia, BMW has now released the increased range i3 with an Australian-quoted range of 300 km—or 183 km according to the more realistic US EPA test cycle. One vehicle that won’t be updated in 2017, unfortunately, is the Nissan Leaf. Once the flagship for the resurgence of EVs (it is still the highest selling EV ever), it has not had any significant changes since it was released in 2011. It is rumoured that there will be an all-new Leaf in 2018 (see www.autoblog.com/2017/02/10/next-gen-nissan-leaf-spy-shots), but little is known about it, including whether it really will happen!

**EVs by 2020**

On the slightly further horizon are announcements by a slew of carmakers for 2018 through to the early 2020s. VW for one is trying to make amends for ‘dieselgate’ by announcing it will be marketing a full range of EVs by 2025 (up to 30 models), including plans to sell over one million EVs within 10 years. However, VW’s plans may be more hype than substance as they currently only sell the pure electric e-Up and the e-Golf, and in the USA these are regarded as ‘compliance cars’. Compliance cars are vehicles available only in those US states with tough emission laws in order to massage down the ‘average emissions’ figure calculated across all of that manufacturer’s new vehicle offerings. However, Audi (a VW group marque) does have more definite plans with the Audi e-tron all-electric SUV due for release in 2018 and prototypes of the e-tron on display at several recent international motor shows.

Other manufacturers are making more concrete plans and announcements. Jaguar has promised the I-Pace 4-door (a Tesla model S competitor) for 2018, and possibly even an all-electric SUV to be released late this year. Mercedes has plans to release several EV models between 2017 and 2020 and BMW has a number of models in the pipeline for release over the next few years.

**Charging technology and infrastructure into the near future**

Charging standards for rate of charge and type of plug have been in a state of flux for some years. In Europe, the USA and Japan several competing standards are still fighting it out. In Australia, there are only three main plug types in the car—J1772, CHAdeMO and Tesla—and most EVs sold in Australia (other than Teslas) carry the first two.

**EV ranges explained**

The range estimates for EVs made using government standard test cycles in Europe and the USA vary enormously, yet for the most part they’re exactly the same EVs. The reason is the European (NEDC) test cycle is far kinder and produces ‘ideal’ range estimates—much to the annoyance of purchasers as these ranges are virtually unobtainable. In the USA, the EPA test cycle is far stricter and is known for producing reliable estimates of what you’ll actually get on the road. A case in point: press reviewers of the Chevrolet Bolt regularly reported as good as or better than EPA range figures in their road-test reviews. Another example: the Tesla P100 EPA range is 539 km, which is accepted by owners as reflecting their experience, yet the NEDC range is 632 km. So what does Australia use? Our figures are close to the NEDC test cycle results, so if you’re looking for real-world figures when comparing EVs sold here, check the US EPA figures for the same model/specification or you will likely be disappointed! Alternatively, subtract about 20% to 30% as a good rule-of-thumb when looking for real-world figures if you’re viewing European NEDC or Australian range estimates.

" Subtract 20% to 30% as a good rule-of-thumb when looking for real-world figures if you’re viewing European NEDC or Australian range estimates. "

**Image: Renault Groupe**

The Renault Zoe compact is hugely popular in Europe. It won’t be coming to Australia any time soon due to the lack of government incentives. This image shows where the battery pack/controller/motor unit fits into the car.

" The Renault Zoe compact is hugely popular in Europe. It won’t be coming to Australia any time soon due to the lack of government incentives. This image shows where the battery pack/controller/motor unit fits into the car. "

**Image: Renault Groupe**

The latest addition to Renault’s EV range, the Master ZE which is a full electric van. It does have a rather small 33 kWh battery though, making it best suited for city deliveries. Unfortunately, it isn’t available in Australia.

" The latest addition to Renault’s EV range, the Master ZE which is a full electric van. It does have a rather small 33 kWh battery though, making it best suited for city deliveries. Unfortunately, it isn’t available in Australia. "

“Subtract 20% to 30% as a good rule-of-thumb when looking for real-world figures if you’re viewing European NEDC or Australian range estimates.”
J1772 has become the default plug type for charging at both Level 1 (maximum 10 A, drawn from a 10 A or 15 A power point depending on the plug fitted to the lead that comes with the car) and Level 2 (up to 32 A drawn from a fixed EVSE, or Electric Vehicle Supply Equipment). A CHAdeMO plug is the norm for Level 3 (up to 80 A) fast charging.

Tesla uses its own plug types, but adaptors are available to convert from J1772 or CHAdeMO.

Thus, the charging options in Australia are fairly fixed at present.

- Tesla: At home, Tesla owners can use their own Tesla Level 2 EVSE, or charge using a J1772 EVSE (Level 1 or 2) with an adaptor. Away from home, Tesla is aggressively rolling out their (Level 3) SuperCharger network with the Melbourne to Brisbane corridor being completed in late 2016 and further expansion plans to come. Tesla is also encouraging the installation of Tesla Level 2 ‘destination’ chargers at hotels, shopping centres and other places.

- Non-Tesla: At home, non-Tesla owners can use their Level 1 or Level 2 charging equipment, but they can’t charge on Tesla chargers, either at home or away. Compatible Level 2 and Level 3 chargers are being installed as ‘destination’ chargers by ChargePoint and PlugShare.

As the current plugs are already installed in reasonable numbers around Australia and other systems from overseas (CCS, Menekes or even three-phase AC charging plugs, to mention a few) would have significant regulatory hurdles to overcome, I predict that changes in standards or plug types will be slow from here.

Contactless (induction) Level 1 and 2 charging systems are another possibility. These work by transferring power from a charging coil in or on the floor to a matching coil mounted under the car’s floor, much like wireless charging for mobile phones. They have been in the experimental phase for some time, but one US company (Pluglesspower.com) has recently released an aftermarket system suitable for the Leaf and Volt, with a Tesla system to come. Some commercial electric buses also use inductive charging to give them a partial fast charge at some stops to extend daily range.

It seems unlikely that inductive systems will be available here any time soon, however. Mercedes has confirmed it will offer an optional OEM plugless charging system for one of its models, but neither the car (nor the EVSE) will be available until 2018.

Early iterations of induction charging had considerable losses over wired charging, often more than 30%, but Plugless state that their system is around 12% less efficient than corded Level 2, 30 A, 240 V charging systems and around 7% less efficient than corded Level 1 charging systems. So, even if you use PV generated electricity for your EV, an induction charging system could still be a good option.

Battery technology

Lithium batteries have become the norm for EVs. With the opening of the Tesla ‘Gigafactory’ for battery production in 2016 and the other large lithium battery factories currently under construction by several manufacturers, the future of lithium as the major battery type for EVs seems pretty much assured for now. There is too much money invested in lithium battery technology to see much else being used for the next decade or two. However, I’d expect incremental improvements in battery charge capabilities, energy density and discharge/recharge rates over the next few years.

Vehicle-to-grid (V2G)

I’d also expect to hear less of this in 2017 and beyond—experimentation with V2G is continuing albeit at a much lower level than when it was first touted 5 to 10 years ago. Batteries in cars are optimised to be lightweight and have high charge/discharge rates with an associated lifetime limit on the number of charge/discharge cycles. Many commentators suggest the cost of vehicle-to-grid is likely to be higher in reduced battery pack life, infrastructure and car system costs than the benefit of returning power to the grid. Further, the advent of home battery systems that are optimised to lower charge/discharge rates, efficient self-use and grid return, plus better charge/discharge lives means that home battery packs have replaced the vehicle-to-grid option before V2G ever became a real option.

Bryce Gaton is a member of ATA’s Melbourne EV branch and the AEVA. He teaches in electrical trade/renewable energy systems and his current EV drive is a Nissan Leaf.
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Fit for purpose
Keeping your EV battery healthy

In the first of a series, Bryce Gaton looks at the core part of the EV, its battery pack, and how to give it the longest possible life. In later articles, he will explain the options for testing and monitoring the battery pack in your EV.

WE ARE all familiar with the ways to prolong the life of an internal combustion engine (ICE) vehicle—regular service, monitor the oil, etc—but EVs are a whole new ball game. What do they need to maintain them in tip-top working order? And how can we test them to know if things are going wrong?

While in general EVs need less maintenance than conventional cars, there are some considerations which will help keep the car performing well for longer and reduce maintenance costs. The battery pack is the component that is both the costliest to replace and the most within our control to keep healthy.

For example, for an ICE vehicle converted to battery electric, replacing the battery pack can cost from $110 to $300 per lithium cell with the battery pack size ranging from 30 to 100 cells—at a cost of $3300 to $33,000. For a Nissan Leaf, replacing the 24 kWh battery is around $6500 fitted (AUS equivalent to US$ replacement cost—Leaf replacement batteries are not necessarily available here).

What is an EV battery pack made of?
All the pure EVs and hybrids on the market now use variations of a lithium ion chemistry. A common one is lithium iron phosphate, commonly written as LiFePO4. Lithium offers many advantages over previous battery technologies. In particular, it allows for much lighter batteries than lead-acid, which is what EV batteries used to be made from.

Lithium batteries have some features that need to be taken into account in the design of the car and charging systems. If they are overcharged or discharged (below 2.5V or above 4V), they will likely be destroyed (although LiFePO4 are more abuse resistant and may be recoverable). And, in some formulations, they can catch fire. This is particularly a problem for the super light, very energy dense ones in phones and the like: think Samsung Note 7. EV batteries are now made with formulations that are more resistant to starting or maintaining a fire.

To allow for these issues, modern EVs and hybrids include a battery management system (BMS). The BMS is a complex set of electronics that manages the charging of each cell, as well as controlling the current available to drive as the battery discharges.

What problems can an EV battery have?
All lithium chemistry cells age, slowly losing capacity with each discharge/recharge cycle. Generally this equates to only a few percent a year. Careful use and good battery management can reduce this loss, but it is a function of lithium cell design and cannot (yet) be fully eliminated. For example, Nissan states that expected battery capacity loss for a Leaf is around 30% over 10 years.
However, some factors can accelerate battery ageing. For batteries without extensive internal cooling/heating systems (mainly the Leaf and iMiEV, which only have air cooling, or converted EVs with no cooling), driving in hot weather can cause quicker than average capacity loss. For instance, Leafs driven in hot climates such as in Arizona, USA, have been found to have double or more the expected battery ageing rate. Note that Tesla, GM and Ford EVs all use circulating liquid battery heating/cooling systems and slightly different lithium battery chemistries to reduce this effect.

Cold weather can cause either transitory or permanent loss in capacity. In Australia where severe cold climates are rare, winter driving will cause a temporary drop in the range due to the cold affecting the efficient conversion of chemical to electrical energy. However, as the weather warms up, the range returns to normal. Overseas, it has been found that regular EV driving in extreme cold can cause similar issues to driving in extreme heat: accelerated battery ageing through forcing the charging process when it is naturally slower in cold conditions.

The other issue, particularly for home-built conversions, is poor battery management. If every cell in the battery is not maintained at the right rate of charge and kept within the minimum and maximum voltages, the cells will be seriously damaged. For mass-market EVs, this isn’t a problem as they have excellent BMS units and multiple built-in safeguards. Unfortunately, many home-built conversions do not have sophisticated BMS units or all the safeguards implemented, leading to significant shortening of the battery life.

Tips for maintaining battery capacity
With these factors in mind, you now have the basics to understand what you can do to reduce loss of battery capacity, and therefore range. Note all the following tips relate particularly to EVs without extensive battery cooling systems, but the tips listed will help maintain the life of the battery in all EVs.

General tip
Don’t regularly run your EV until empty before recharging
Power = Voltage x Current
Result: If you lower the voltage, you need a higher current to get the same power. Thus, an almost flat battery (which is at its lowest voltage) will pull more current at the outset of the charge. High current = higher cell temperatures = accelerated battery ageing. Lithium cells don’t have the memory effect that was seen in NiMH and NiCd cells, so there is no need to worry about recharging when they are only partly discharged.

Hot weather tips
Avoid 100% charges (especially for a Leaf, i-MiEV or converted EV)
It is the nature of all batteries that charging creates some heat inside the cells. The last 15% to 20% of a charge is harder to do and creates even more internal heat in each cell than charging up to 80%. Combined with the longer overall time to a full charge, a 100% charge will create significantly more internal battery heat than an 80% charge. In cooler temperatures (but not severe cold, see ‘Cold weather tips’ below) this can be helpful, but hot summer charging to 100% of those EVs without extensive battery cooling (e.g. Leaf, i-MiEV or converted EVs) can significantly accelerate battery ageing. Note that not fully charging a lithium battery does not cause any damage to the battery, as it did with older chemistries such as lead-acid.

Avoid heavy acceleration
High current flowing through a cell heats it up. On really hot days in cars where the battery has only air cooling (Leaf or i-MiEV) or no cooling (converted EV), keep an eye on the current you draw as you drive and accelerate more slowly.

Park where it’s cooler
Where possible, on hot days park under a tree or in a covered car park. This keeps the battery temperature lower, as well as allowing it to cool off before the next drive.

Charge when (or where) it’s cooler
During hot weather, charging overnight or in an underground car park are good options. In Melbourne, if you don’t really need to charge, avoid charging on that hot night—the next one is likely to be cooler!

Avoid faster charges (especially for a Leaf, i-MiEV or converted EV)
The faster the charge, the more heat is generated. On hot days this can result in very high heat build-ups in batteries without adequate cooling. Slowing the charge to Level 2 (16 to 32 amps), or even Level 1 (10 amps) by plugging your EVSE into a power point, is kinder to your battery on those days.

Cold weather tips
When it’s really cold, don’t charge in the coldest place or the coolest part of the night
As noted earlier: recharging lithium batteries is less efficient at cooler temperatures, so charging in a cold place (for example, outside rather than in a garage, or in the coolest part of the night) will make the battery work harder to recharge, which is another path towards battery ageing. The same goes for fast charging (Level 3) in really cold weather.

Next time: When buying a secondhand EV, it would be good to know if the battery is in top condition and has plenty of life left or has been subjected to conditions that may have reduced its capacity, as well as be able to measure what that capacity is. In the next article of this series, I will look at ways to assess the battery in your potential EV purchase (or daily EV drive) starting with the Nissan Leaf.
Charging directions
EV owners tell all

From a plug-in Prius conversion to an electric vehicle charged from the sun to an e-bike as a vehicle for change, EV owners describe how they’ve made an EV work for them.

From plug-in Prius to Leaf on PlugShare

Tim Johnston shares his electric vehicle experiences so far: converting a standard Generation 2 Toyota Prius hybrid into a plug-in hybrid electric vehicle (PHEV), becoming an owner of a 2011 Nissan Leaf in 2014 and registering their home as a charging station on PlugShare.

Our family of two adults and two kids is very energy conscious and concerned about environmental issues. In 2009 we needed a second car and we wanted that choice to be as carbon-neutral as possible. We also wanted a car that was large enough to carry the kids comfortably, had the latest safety gear and cost less than $20,000.

We’ve always had an interest in electric vehicles; my brother-in-law has had one for a while so I’d seen that electric vehicles were a practical alternative. A test drive of a Nissan Leaf and Mitsubishi i-MiEV at an RACV event in 2009 further piqued my interest.

However, a new EV was well beyond our budget, and options were limited at the time. As a compromise, in 2010 we purchased a secondhand 2006 Prius i-tech and so began our electric vehicle journey.

Converting a Prius to plug-in

The Prius is a hybrid vehicle that uses the efficiency of an electric motor/generator system to improve fuel economy. The 2006 Prius can be placed into full-electric mode (using an EV mode button on the dash), but the small high-voltage 1.3 kWh nickel-metal-hydride battery means it can only travel short distances in this mode. I researched ways to increase the battery size and settled on a 4 kWh plug-in hybrid electric vehicle (PHEV) conversion kit, produced by a company called Enginer.

The Enginer kit is a rechargeable battery pack that supplements the Prius OEM high-voltage battery. In Australia, the kit was rebranded by NilCO2 as K40 and was suitable for both the Gen 2 and Gen 3 Prius and came in 2, 4 and 6 kWh sizes. In 2011, we purchased the 4 kWh kit for approx $5000. We bought it mainly for environmental reasons and as a bit of a hobby, so we didn’t expect to recoup the cost on savings in petrol.

Compared to other more expensive units (e.g. Plug-in Supply), the Enginer kit was fairly basic; it didn’t remove the original battery or alter the Prius on-board computer software.

The kit is contained in a stainless steel box that is secured in the spare wheel compartment. Within the box are two 2 kWh lithium ion (LiFePO4) battery packs, a battery management system (BMS), a DC–DC 5 kW converter and a charger. I’m no electrical engineer but I’m fairly practical, so after several hours viewing the installation instructions on the DVD provided and looking at various forums, it took me about 12 hours...
(total) to install the kit securely into the vehicle. I also got valuable assistance from ATA Geelong EV branch members.

The on-board charger requires only a standard three-pin 10 A domestic extension lead to connect to the car and a full charge takes about five hours. The battery pack can only be recharged by plugging in, not by the regeneration system in the vehicle.

The 4 kWh battery pack ‘trickle charges’ the OEM high-voltage battery, providing about 25 km of electrically assisted or blended EV/petrol driving per charge, sufficient for most daily commutes.

Even with the kit, to get the driving experience of a pure EV, you need to press the EV button on the dash frequently to force the vehicle into EV mode. In EV mode, the Prius’s 50 kW electric motor draws more than 100 amps, but the DC–DC converter in the kit can only supply a maximum of 14 amps to the original battery. If you keep your speed below 45 km/h you can get about three kilometres of pure EV before the OEM Prius battery is depleted, needing time to recharge from the kit battery—this got a bit frustrating.

In our experience, average petrol consumption with the kit for suburban driving within town was around 3.5 to 4 L/100 km, compared with 5 L/100 km with the kit turned off. We never achieved the claimed 100 mpg (2.8 L/100 km). The best figure achieved in trips over 100 km was 3.5 L/100 km.

The Prius software is not altered by this installation and, once depleted, the additional battery switches off automatically, leaving the vehicle to perform as a standard Prius.

Ultimately, the plug-in kit didn’t provide the pure EV driving experience that we were after and so I had my eye out for a used Nissan Leaf. Issues with the reliability of some of the kit components, particularly the battery management system, also meant it was time to move on. In 2014, we had the opportunity to purchase a fully electric 2011 Nissan Leaf from the Melbourne EV trial and sold the Prius in December 2014 without the conversion kit installed.

Leaf convert

Our Leaf is primarily used by my wife for daily work commutes, shopping, occasional school pickup and weekend trips of less than 100 km. For trips greater than 100 km we usually use our diesel-fuelled vehicle due to the lack of charge stations in rural areas. We occasionally travel to Melbourne (approx. 90 km) and recharge at the destination or visit a DC fast charger in Hawthorn, if it’s operational. If the DC fast charger isn’t working and we need a quick return, we use our diesel vehicle instead.

We’ve found the Leaf fantastic to drive due to the instant torque, making it zippy in city traffic. It is easy to charge, requires minimal maintenance compared with a fossil-fuelled vehicle, is very comfortable and is cheap to run.

We’ve owned our Leaf for over two years and have travelled about 15,000 km over this time. As the vehicle is a first gen 2011 model, there has been some decline (10% to 15%) in battery capacity, so we need to be careful when considering trips longer than 100 km. To better monitor the health of the battery pack and battery range, I use an application for iOS and Android called Leaf Spy Pro. This app provides valuable information about the battery status that is not available on the vehicle’s dashboard screen.

Our Leaf is charged usually two to three times a week, 95% of the time at home. On weekdays, charging takes place at home during the night as the Leaf is usually at my wife’s workplace during the day. We purchase our electricity through Powershop and pay a premium for 100% GreenPower. On weekends we try to charge during the day to take advantage of our homemade ‘green power’ from our solar PV system.

We have a 15 amp socket installed in our driveway, enabling us to use a Level 1 15 amp electric vehicle supply equipment (EVSE) (aftermarket add-on) to charge at a rate of...

Warning

Working with electric vehicle batteries carries a significant risk of electrocution from the high voltages involved, so we advise that installation of the Prius conversion kit should be performed by suitably qualified electricians or engineers only. You should also check that the addition of the kit does not affect the Toyota warranty. The kit should be noted on your insurance policy as an auxiliary drive battery charger kit.
about 18 km of range per hour, or about six hours from empty to 100% capacity. A 100% charge can provide range of around 100 to 130 km, depending on driving conditions.

**PlugSharing**

When outside our normal locality, we use the PlugShare app to locate suitable charge stations. We have used several Level 2 public chargers in Melbourne or en-route to Melbourne to top-up the vehicle, including one in a shopping centre. Level 3 fast DC charging stations (30 minutes to 80% battery capacity) are useful for a rapid charge and turnaround, but there are very few of these in Melbourne for Nissan Leaf, BMW i3s etc that use a CHAdeMO connector. Tesla Superchargers are becoming more common, particularly on the Melbourne to Sydney route, but these are not compatible with non-Tesla electric vehicles.

When I mention to people that we drive an EV, one of the first questions I get asked is “how far can you get on a charge?” Range anxiety is probably the number one concern of potential EV buyers—the fear that they will run out of battery charge and become stranded. However, as EV owners gain experience with the capabilities of their car and as they become aware of the locations of compatible charge stations through applications like PlugShare, with a bit of planning, range anxiety turns into range confidence, even with a short-range electric vehicle like the Leaf.

PlugShare is a very useful free application for iOS, Android and web ([www.plugshare.com](http://www.plugshare.com)) which allows EV owners to find and review charging stations. The PlugShare map not only includes public charge stations installed by local councils and businesses, most of which are managed by the ChargePoint network, but also residential charge stations shared by PlugShare members. It includes details about each charger: description, cost, hours of accessibility, photos, types of plugs present and user feedback. ChargePoint, the most common charging network in Australia, also has a useful app to locate and show the availability and functionality of their charge stations. To access ChargePoint charge stations, you need to register on the ChargePoint website. Currently, charging is free to all ChargePoint users.

In the Melbourne vicinity, there are approximately 45 charge stations listed on PlugShare, including public stations (Level 2), three DC fast chargers (Level 3) and several residential chargers shared by PlugShare members. However, as you move out of metropolitan Melbourne into rural areas, the spread of chargers becomes sparse.

Residential charge stations are essentially EV infrastructure backed by the power of crowdsourcing. We listed our property as a residential charge station as we wanted to help support and promote the use of EVs. It’s also great to have a chat with visiting owners about their experiences with their EV. To access residential stations, EV owners can message the owner via the PlugShare app to ensure that the charge station is available for use. Sometimes visitors offer some money or a six pack of beer for the trouble, but although gratefully accepted, it’s not needed.
Towards a fossil fuel free EV: charging from the sun

Based in Canberra, Dave Southgate and his family are aiming to be a ‘fossil fuel free family’. Transport is a big challenge in that arena, but Dave found a smart way to maximise solar charging of their EV. Dave explains the system.

When we bought our electric vehicle, a Nissan Leaf, at the beginning of 2014, my immediate thoughts were on how I could run the car on renewables. I didn’t want to be simply moving from a car run on oil to one burning coal. [Ed note: See ReNew 120 for a comparison of EV and petrol greenhouse gas emissions, which shows that EV emissions when charged from coal are lower or comparable, depending on the vehicle class.]

At that time I saw two viable options. Firstly, we could simply buy green energy to cover the amount of grid electricity we were using to run the car. This is an option adopted by many EV users. I have no philosophical objection to this and I think it does provide carbon-neutral motoring, but for me it was too intangible—I was looking for something a bit closer to home which I could directly control. We went with Plan B.

**Offsetting using our own solar PV**

Our approach was to install an extra 2kW solar PV system on our roof at the same time as we bought the EV (we already had a 2kW system). I figured that this would more or less produce the same amount of electricity in a year that we would use in our car. This was not a bad estimate: in our first year we used an average of 7.1kWh/day in our EV and we generated 7.3kWh/day with our new 2kW solar PV system. We had a carbon-neutral EV.

We were using the Leaf as our main family car and travelled about 14,000km in that year, about the OECD average. This is around 40km/day. We used the EV solely as a city car; when we wanted to go out of town we used our small petrol car, a Hyundai i30. We did all our EV charging at home, almost exclusively using off-peak electricity. It was very simple: I set up the computer on the car to charge at night; I just plugged the charger into the car when I got home and walked away; and the car’s onboard computer did the rest—in the morning the car was fuelled ready for another day.

I had discovered to my great satisfaction that fueling an EV is so much easier and quicker than fueling a petrol car. At that stage we were using a Level 2 charger (the one on the right in the above photo). If you’re interested in technical details you may wish to look at a report I wrote on our first seven months with the EV at www.bit.ly/PIEVCAN.

**Moving forward—solar charging by hand**

In 2015 we began to get really serious about not using fossil fuels and initiated a program aimed at us becoming a ‘fossil fuel free family’ (www.bit.ly/BAFFFF). If we were to be fossil fuel free it meant fuelling our EV without using any grid electricity. To get things rolling I started to solar charge our EV by hand.

I could see from monitoring our energy consumption that most days there were many times that I could put our solar PV electricity into our car rather than exporting it. So, rather than simply charging at night, I began to closely monitor our electricity export from the house and whenever we reached a point where our level of export equalled or exceeded the power draw of our charger I would go into our garage and turn on the charger. If big banks of clouds came across I would quickly go and turn the charger off until they had passed. It was all a bit demanding, and of course I couldn’t manually charge the car when I was out of the house, but it worked reasonably well—I estimate that in the last three months of 2015 about 70% of the energy used by our EV came from our solar PV system.

**Automatic solar charging**

As the summer came to an end in early 2016, I was looking for a way to improve our charging performance and was able to put in place a system for automatically solar charging the EV. In mid 2015 we had installed an energy diverter (an Immersun) for hot water heating (see p. 85 for more on this) and I was able to use a relay function on the diverter to automate our solar charging.

Given that we already had an energy diverter for our hot water and had a spare EV charger (a Level 1 device that came with the car, shown on the left in the photo), the costs of marrying the Immersun with the Level 1 charger were quite moderate (about $500 for an electrician to do the wiring required). The technical details can be found at www.bit.ly/DIVEV. Note that we used the Level 1 charger as it had a lower power requirement and thus could be used at a lower level of excess solar generation.

At the start of each day, as the sun rises and the solar PV system cranks up, the Immersun unit progressively diverts the increasing amount of excess solar PV electricity into our hot water system until the power diverted reaches 2.5kW. At this point, the relay in the Immersun is then triggered and the solar charging of the EV automatically starts (any excess generation above 2.5kW is still diverted to the water heater).

After 15 minutes the relay automatically breaks the charging circuit to check that the electricity divert/export is still at least 2.5kW (in essence it is checking whether clouds have impacted on the level of PV production). If the divert/export is still more than 2.5kW, the relay closes and the charging recommences. If clouds have reduced the solar output, the Immersun unit will only restart the charging if/ when the threshold level is reached again.

This process continues throughout the day without any intervention until the battery is fully charged, or I disconnect the charger in order to use the car.

At the time of writing this system has been in place for about eight months and is working brilliantly. Figure 1 shows how the
level of solar PV in our charging varied over 2016. I estimate that over a year this setup will achieve about 60% ‘grid independence’—about 60% of the energy used by the EV will come from our solar PV system.

Next steps
How do I improve on this? Clearly there are limitations on how much solar PV you can use in an EV if you don’t have a home battery. On some days, in fact quite often, I come home in the evening with the EV battery pretty low and I need to use the car early the next day. In these circumstances my only option is to charge the car from the grid overnight.

I think that the 80% grid independence level for EV charging that I’m now achieving in summer is about my limit given my current car usage patterns. Even if I add more solar PV I probably won’t achieve a great improvement in my summer solar charging performance, although I think it would be beneficial for charging in winter.

I am now in the process of installing a Tesla Powerwall 2 home battery + 4kW more solar PV. Given that my average input into the EV is about 7kWh/day and that the Powerwall 2 battery capacity is around 13kWh I would hope that this will take me to well over 90% grid independence during the summer (when we export a lot of solar energy). I am not so sure what will happen in winter when our solar production collapses and there will be competing demands on the home battery—particularly from our space/personal heating.

Without going into details, the battery option does have its downsides. If you use one battery to charge another battery you can get significant energy losses.

Will this work for you?
This charging system works for us because my EV is at home for quite a few hours each day during daylight hours. Obviously, there will be little opportunity to directly input solar PV from your own system if your car is not at home during the day.

If this is the case, you’ll need to either fall back on one of the two charging options I mention at the beginning of the article (recognising that neither of these are fossil fuel free) or jump straight to the battery option. The battery option will almost certainly be quite expensive at the moment but I can see no technical reason why you couldn’t run your EV totally on solar PV if you go down this route.

Future PV charging
The company that developed the Immersun went into liquidation in mid 2016 and, although another company has taken over the product, it seems the devices can’t be purchased in Australia anymore. However, I understand there are other energy diverters on the market in Australia which could possibly be used in the same way that I am using the Immersun.

An interesting development is the advent of solar PV chargers. The engineers that developed the Immersun have now formed a new company and are in the process of releasing a solar PV EV charger (see box below). This is very new. I have no details of the specs or prices, but I imagine this will be a marked improvement on my relay-based system.

Solar PV EV chargers
The idea behind a solar PV electric vehicle charger is that it allows you to use your excess energy generation to charge your EV, rather than sending it to the grid, much as a PV diverter allows you to use it to produce hot water.

The charger would operate like a normal EVSE unit but would also monitor the energy production from the PV system, either using a current sensor on the mains grid connection or by talking to another device, such as a hybrid inverter, that is monitoring energy flows in the system.

So far, the only dedicated PV EV charger we know of is the Zappi from Myenergi in the UK. See the Products section of this issue for more information on that charger.

“I estimate that over a year this setup will achieve about 60% ‘grid independence’—about 60% of the energy used by the EV will come from our solar PV system.”
E-vehicle for change

Indigenous elder, actor and educator Uncle Jack Charles is a long-time e-bike rider. He spoke with Eva Matthews about the joys and value of this mode of transport.

RESIDENTS of the inner-Melbourne suburbs of Richmond, Collingwood and Fitzroy, and folks along the bayside roads from St Kilda to Brighton, are quite probably used to seeing the dashing figure of ‘flash’ Jack Charles (sedately) zooming around on his e-bike. These have been well-worn routes of his for the past nine years.

Jack bought his first e-bike in 2008—“a little after Bastardy was screened at the Melbourne International Film Festival.” He had come into a sum of money; compensation for the abuse he’d suffered as a child of the Stolen Generation, while being raised at a boys’ home in Box Hill. He decided to spend some of that money on an e-bike and gave the rest (of the “blood money”) away. “That’s the best thing I’ve bought,” he says. “I used to joke I was a green blackfella!”

And he hasn’t looked back. His second e-bike was a Puri—of Chinese manufacture, sold from a shop then in Collingwood (since re-located to Heidelberg). These days he rides a yellow Puri, with Aboriginal and Torres Strait Islander flags flying—having traded-in for a new version every two years. (Not because there was anything wrong with them—flat tyres are about the only problem that crops up from time to time—just because he likes to.)

He has no need for a car—longer journeys always find someone offering to drive him, or a hire car is provided to take him where someone needs him to be. Jack says some people worry about him taking his e-bike to the theatre, so “sometimes I don’t ride in to rehearsals or performance nights.” Apart from that, he rides everywhere. He particularly loves riding down to Brighton—“I feel like I’m patrolling my mum’s land on my bike.”

Jack lives in a block of units, with other elderly residents. He is able to take his e-bike up the lift and into his unit quite easily. He enjoys the fact that his chosen transport has saved him lots of money on Myki fares, uses “clean energy” and that it doesn’t cost much to run. He thinks it’s “fantastic” that he can go 90 km on one charge, which allows him to “reach so many different people” so easily and generally only plug in every couple of days.

Apart from the joy he gets from riding his e-bike—the cool breeze whistling up around his legs as he pedals (taking normal throttle speed of 16km/h up to 32 km/h), the ability to reach his destinations (the theatre, his community and friends) so easily and whenever he wants (not having to wait for public transport, especially on a weekend where it runs less frequently)—it has also served as another way in which he, as an Indigenous elder, can fulfill his heartfelt role as educator.

In the early days especially, the police would sometimes stop Jack to question the legality of his transport. He would point out that the Road Traffic Authority had declared auxiliary-powered bikes to be legal and not requiring registration or special licence. He also spoke to the registrar at his local Neighbourhood Justice Centre and had them write to the sergeants at his three local police stations, making them aware of the legal status of e-bikes and asking them to “stop harassing older people who ride these bikes.” He adds, “I’ve had a win there”—he’s had no trouble from police since.

He still cops a bit of road rage “from people in Lycra, yelling and abusing as they pass me by (on their pushbikes).” In response, he says, “I explain to them that these bike lanes are shared between Indigenous people of the land and yourselves. I get a bit of a laugh out of that for myself.”

Jack also takes as many opportunities as possible to talk about his e-bike and the benefits it brings, and he particularly enjoys sharing his experience with those in his community who are still struggling with addiction to drugs or alcohol. He says, “My presence in my community says a lot. They see a lot of value in me stopping by and proudly boasting about my new bike. I tell them, ‘this is the way to go fellas, but you know you’ve got to stop using.’”

He adds that he’s noticed “a lot of older gentlemen riding these around here; they’re all grey-haired, bearded, and many of them, I notice, just look right on that bike!” He says that, as long as you have good eyesight, good balance, understand the road and bike laws, watch out for car doors and don’t go too fast, e-bikes are a really good transport option for the elderly—safe and cost-effective. More broadly, he believes e-transport like this is “the way of the future”.

Now at 74 years of age and “blessed with a fine sense of balance,” Jack Charles can’t imagine swapping this mode of transport for a long time to come. He says, “It’s value-added to my life and made a remarkable change to my life.”

“I explain to them that these bike lanes are shared between Indigenous people of the land and yourselves. I get a bit of a laugh out of that for myself.”

← Uncle Jack Charles in his element: on his Puri e-bike, getting out and about in his community.
Accommodating EVs in strata

How do you charge 15 Teslas in one apartment building that’s not wired for EVs? Resident Gordon Streight spoke with Eva Matthews about this interesting conundrum.

JACKSONS Landing is a huge, mostly residential, development constructed on the old CSR sugar refinery site in Pyrmont, NSW, near Sydney’s CBD. With development starting in 1998, before electric vehicles (EVs) were even a blip on the radar, wiring for EVs was never part of the construction plan. Now, with 15 Tesla owners residing in the Landing, the issue of how to accommodate the electricity needs of these vehicles has become a hot topic of recent discussions at strata group meetings.

Gordon Streight is a resident of one of the terraces within the Jacksons Landing development. Although not a Tesla owner himself, his role as representative of his strata group (one of 22) to the Landing’s community association has seen him become actively involved in trying to solve the EV charging conundrum. He explains that, quirky as such a concentration of EVs in one location may seem, the number of Tesla owners has steadily risen over the last few years, and other EVs (mostly hybrid types) are also in evidence.

“That’s great,” he says. “Everybody likes the idea of green energy and electric cars, but, coming down the road is a wave of EVs... and, historically, there has been no provision built into large buildings, like apartments, for charging these vehicles.”

Currently, EV-owning residents of the freestanding terraces simply plug in to their own power points at home and are charged for the electricity they use. Those in the apartment complex, however, where it is impossible to provide power from within their unit, run extension cords from common-use power points across the garage/driveway to their car. Not only can this be a health and safety issue, to-date these people have been enjoying energy subsidised by all other residents, including the majority who don’t own EVs.

On another apartment building that Gordon is involved with, an electrician was called in to put meters on the distribution board, to monitor the residential vs common/building electricity use. Combined with capacity data from Energy Australia, that means they were able to work out “how much is spare for charging cars.” He further notes that the technology exists for monitoring EV electricity use and usage patterns and then automatically distributing the electricity to either trickle-feed or supercharge the EVs as required when they’re plugged in—with energy charges going directly to the EV owners.

The first and relatively inexpensive step in a solution, then, could be the installation of some common charge points (with a dedicated circuit) in the garage, which would work on a first-come, first-served basis and allocate costs to the individuals who use them. The question remains of whether the money for this should come out of the common funds paid by all residents for maintenance and upgrades, or just from EV owners.

The longer-term more expensive step that may be needed is to upgrade the substation supplying electricity to the complex, if they do reach the building’s energy capacity. Current estimates cost this at around $1m. Gordon says, “We think we can get away without upgrading the substation for a few years. As we get more electric cars, however, the queuing and energy load required would become issues that would need to be addressed. It’s a challenge!”

These conundrums facing Jacksons Landing currently all point, Gordon observes, to the much larger issue of there not being enough of a focus—among developers and the governments that regulate their operations—on what a future full of electric vehicles will require. The technology for EV charging (such as for ‘smart’ monitoring/distribution of energy at charge points) exists currently and is readily available, yet few developments are even provisioning for the future by at least laying down the required cabling during construction. He notes, “It will be much more costly to retrofit later on.”

In addition—as a property investor himself for over two decades, and with a consultancy business dedicated to improving building efficiencies, costs and value—installing smart technologies into new developments, such as capacity for EV charging, solar, water and waste management, makes economic sense for apartment owners and investors. And, fortunately or unfortunately, when it comes to sustainability issues, it’s often the economics that end up turning alternatives into mainstream applications.

Gordon says this is something apartment owners (and developers) should be thinking about, and perhaps even themselves demanding, before they put their money on the line. *
EV stories, two years on

With their stories first shared with us two years ago (‘Best EVer Stories’ in ReNew 131), Eva Matthews caught up with first-time EV owners Linda Hamilton and Ross Ulman to see how they’ve been getting on.

Linda’s story: Running on auto-pilot

TWO years on, Linda Hamilton says she is still “very much” overjoyed with her Tesla Model S P85, which she’d ordered as soon as its pending availability in Australia was announced. She says, “It was a fantastic car to start with, but it’s actually much better now.” This is due to the free software updates, which install themselves “while we are sleeping”, and have added an auto-pilot function, self-parking, a better music system (now with a Spotify account), improved navigation and battery utilisation. She notes that these improvements are a direct contrast to the experience of buying a ‘normal’ new car, which generally involves a downward spiral of degradation and devaluation.

Interesting observation!

Linda says the auto-pilot is not great for anything other than highway driving (where roads are relatively straight, have a consistent speed limit and clearly marked lanes). She tested it on the serpentine roads between Emerald and Belgrave in the Dandenong Ranges, east of Melbourne, and found that a speed of less than 40 km/h was required for the car to negotiate some of the route (and only where the centre and edges of the road are marked). On a drive up to Canberra, however, she found it very useful and safe, “like having an extra person looking at the road all the time.” She is able to set her preferred distance from other cars (e.g. four car lengths), input her destination and the upper speed limit, sit back and let the car do most of the work to get her there (the auto-pilot keeps her on the main route, but she must negotiate required turn-offs).

Legally, a driver must keep their hands on the wheel when the auto-pilot is on. Linda explains that she can feel the steering wheel turning automatically as required to follow the road and, though the sensation of the car driving itself was strange to start with, it was akin to that when you first start using the cruise control on a standard vehicle. As with cruise control, you can easily override the auto-pilot. Putting your foot on the brake disengages it completely; just taking over the steering wheel temporarily allows you to adjust your course while the car keeps taking care of acceleration/braking.

Linda notes that “Tesla’s Elon Musk reckons that in two years time, you’ll be able to summon a car from New York to Los Angeles with no one inside it!” She adds that, currently, she can drive her Tesla using her phone, from outside the car, to a distance of up to 12 metres (limited by local regulations).

Since last we spoke to her, Linda reports there have not been any issues of concern, apart from “a little air noise from the driver-side door.” She thought this might be due to the window not winding up fully, but it turned out to be a faulty door seal, which Tesla replaced at no charge. She adds, “Tesla has the most amazing customer service.”

Her Tesla now reads 37,000 km on the clock, and the brake pads have hardly worn due to the regenerative braking (which slows the car down as soon as the foot is taken off the accelerator) and the fact that she generally calls on the brakes only in the last few metres before stopping at traffic lights. When she test-drove the Tesla initially, she was told by the sales rep that the pads should last 200,000 km, so it appears that is on track.

Linda and her husband mostly use the car around where they live in the Dandenong Ranges, and charge it from their grid-connected solar power system at home. She says they charge it overnight from the grid, when electricity rates are cheapest. She adds that they have been offsetting their household use of grid-powered electricity via their energy retailer.

And Linda’s thoughts on the future of EVs in Australia? As a member of the Dandenong Ranges Renewable Energy Association, and an avid EV fan, Linda reports that the group is “right behind EVs” and has held numerous related events. “People are very interested,” she says and believes that the Tesla Model 3, the release of which should occur in the next year, will mark the next step in accelerating EV uptake in this country.
Ross’s story: Running a Leaf off-grid

ROSS Ulman bought his first-generation Nissan Leaf secondhand in late-2014, with 10,000km on the clock. It’s now at 18,000km. “Not a massive increase in two years,” he acknowledges, and explains that this is due to two factors. One is that he doesn’t have a need to travel much, nor long distances. The other is that, as his home (where he charges his car) is powered by off-grid solar, his use of the car is restricted in the winter months, where solar generation is relatively low. “My first priority is my household battery integrity, and I don’t want to do deep discharges on the battery to charge the car.”

However, he happily adds that “something new and terrific has happened” that will alleviate this issue. In late 2016, Hepburn Wind—Australia’s first community windfarm, located not far from his home on the outskirts of Daylesford, around 120km northwest of Melbourne—funded a two-bay Level 2 charging station, which has been installed on the main street of the town just outside the Town Hall. At a cost of around $16,000, it was purchased from ChargePoint, who look after it, and paid for by the Hepburn Wind community cooperative.

With Ross being one of very few EV drivers in the region, the charging station was installed largely in the hope it will further boost tourist numbers, becoming either a destination or stop-off point for EV drivers on a longer road trip. This will, of course, be good for local businesses, but for Ross it means that “this coming winter I will be able to charge my car there, so this will make a big difference.” It won’t deplete his home battery, it will be twice as fast as he can charge at home (around 4.5 hours instead of 9, for a full charge) and it will allow him to make use of his EV in months where he’s otherwise had to rely on his fossil-fuelled car.

In terms of how the car has been performing over the last two years, Ross notes that he lost a ‘bar’ of battery capacity on the Leaf dashboard display at around 16,500km. He acknowledges that all batteries degrade over time and depending on their use, so “as an EV driver, it’s just one of those things that you have to expect.” It means he now has around 10km less range (down to around 110km), which is not a big deal for him given the short distances he generally drives. His 24kWh Leaf battery started with 12 bars capacity and Ross believes he could lose up to three more bars before it would become problematic. He further notes, however, that Nissan offers to replace damaged cells if the battery loses four bars within five years of manufacture, which he imagines would cover most drivers, including himself.

The other issue that has cropped up is that the telematics (the system that connects the car with Nissan’s web portal, which can tell drivers how their batteries are performing) are not currently working. They were on Telstra’s 2G network, which Nissan informed Ross would be disconnected in December last year. They also told him they will upgrade the telematics to 3G for free in Australia (they have apparently charged for this in other countries), but he’s had no further word on when this will actually happen.

As an early adopter, Ross accepts “there are some wins and some losses in that.” Despite the relatively minor issues he’s had, Ross says he loves the experience of driving his Leaf: “Stopped at the traffic lights, there’s no sound, no vibration, and on take-off it just glides away.”

As for the future of EVs, personally Ross is keenly waiting to see what longer-range models will come onto the Australian market. Apart from the new Tesla Model 3, “the immediate future looks like what we’ve got now, just in updated versions.” As to which he would trade in his current Leaf for, Ross is still undecided. His main requirement is that it would have a range of at least 250km, to allow him to easily travel to Melbourne and back on one charge. He says he is slightly disillusioned with Nissan, as he feels they are pushing their internal combustion engine cars harder than their EVs, “so they’ll have to work hard to bring me round to buying their new one.”

In a broader sense, Ross says, “there are some exciting things happening, but we don’t have a government that has any coherent policy towards EVs; there are no incentives and the charging infrastructure is still light-on.” He adds that it’s disappointing, from an environmental perspective, that Australia hasn’t been more progressive in this sector: “It’s a bit of a backwater at the moment; it’s frustrating.” He also notes that, with so many auto manufacturers shutting down in this country in the last couple of years, “It would have been nice to get some local EV manufacturing going; use the empty factories and the lost expertise.” Thousands of retrenched workers would likely agree.

“Stopped at the traffic lights, there’s no sound, no vibration, and on take-off it just glides away.”
Charging regime and V2G

Consultant at Beyond Zero Emissions and energy expert, Richard Keech takes us through charging the Holden Volt and the potential for backup electricity to the home.

Charging at home and away

MY FAMILY has had a Holden Volt for two years now as part of our efforts to reduce our carbon footprint [see ReNew 131 for the full story on Richard's adoption of EVs and the effect on his carbon footprint]. Here I'm giving a brief update on our approach to charging.

The Volt has a standard charging socket. Like most first-generation plug-in cars, it can charge from a regular 10A power point using a portable adaptor unit, which is provided with the car—this is Level 1 charging, and takes about eight hours to fully charge. The car can also use public Level 2 chargers, such as those from ChargePoint. These charge the car at 15A.

Fast (Level 3) charging is not an option with the Holden Volt, as it doesn't have the required (CHAdeMO) charging socket.

The portable charging adaptor I use is designed to be carried in a hatch in the boot for use wherever you may need it. However, we keep it clipped to the wall of our garage as we rarely need to change away from home. Some people may choose instead to get a third-party charger unit installed.

I keep track of the home-charging energy via a metering unit on the charging circuit (visible on the wall above the charger). This little meter has an LCD display of kilowatt-hours used, which I log once per month.

One of my favourite capabilities of the Volt, when it comes to charging, is that it can be configured to know your peak/off-peak times. So, in my case, whenever I plug it in, charging is deferred until 11pm on weekdays to take best advantage of the off-peak electricity tariffs.

The Volt used 1797 kWh last year, which is 20% of my purchased grid electricity. With all of that charging energy being off-peak, that’s $207 worth of energy to travel. In that year I travelled 20,000 km and, as a plug-in hybrid, the car also used $673 of petrol. So, overall the operating fuel and energy cost was 4.4 c/km.

Poor man’s vehicle-to-grid (V2G)

Much has been written about the potential for EVs to integrate with a smart grid and send power back to the grid on demand. Currently EVs can’t do this, because the public charging points send energy in one direction only and the grid isn’t smart enough yet.

However, I’ve been interested to hear about the kits from EVExtend.com which take advantage of small, 12V low-power DC-AC inverters that are common in camping and 4WD situations, which enable the small 12V battery in some current EVs to be charged from the main battery pack via a DC-to-DC converter, even when the car is turned off.

The EVExtend kits were built with Holden Volts and Nissan Leafs in mind and involve additional connectors on the battery 12V and ground lines, an inline fuse and a high-current DC quick connector plug (Anderson plug) in a convenient location in the vehicle.

This means that it’s possible to indirectly get AC power from your EV batteries if you plug a small inverter into the 12V battery. This presents an opportunity to get backup AC power without the need for a petrol generator, perhaps to keep your fridge and a few lights going in case of a blackout—with the help of a long extension cord from the garage.

Solar + batteries powering a factory, home and two EVs

Electrical and plumbing services business owner Mark Nicholson talks EVs and excess energy with Eva Matthews.

FIVE years ago, when Mark Nicholson wanted to put on a solar PV system at his factory on Melbourne’s Mornington Peninsula, he found himself confused by all the claims about performance and advantages of different types of systems. An analysis of his electricity bills indicated that a 15kW system was needed to cover the factory’s power needs of 60kWh/day on average, so, in true DIY spirit and drawing on his expertise as an electrician, he decided to install a number of different PV types (monocrystalline and polycrystalline panels with/without microinverters), to meet that need and also determine what worked best.

Solar and batteries—trailing lead-acid, AQuion and Enphase

As Mark found other solar products he wanted to test, he installed those too, ending up with a 26kW system. This trial not only gave him valuable information that he could then pass on to his client base, and even open up a new service offering for his business, he found that the energy generated from the rooftop solar more than powered the factory; it produced an excess that was sold back to the grid—reducing electricity bills and helping pay back the cost of the systems.

But the journey of discovery didn’t stop there. Mark next delved into the world of battery storage. He followed a similar ‘testing’ process with the battery setup at the factory. Initially he installed 7kWh of lead-acid batteries with a Selectronic inverter and he was happy with their performance. Then, two years ago, a customer wanted to have a new saltwater battery, manufactured by AQuion, setup at his home. Not knowing this product and, “not wanting the customer to be the guinea pig”, Mark decided to install it and test it at the factory first. He says, “I liked the engineering and chemistry of these,” so he ended up replacing his lead-acid batteries with 12 AQuion batteries (totalling about 30kWh).

At about this time, Mark also purchased a new home and applied all he’d learnt about
solar and batteries there, installing a 10 kW grid-connected solar system on the roof, backed up and managed by the Enphase AC battery storage system—another example of him trialling different systems! This comprises the Envoy-S energy meter, which interfaces with a 4.4 kWh, four-battery pack (rated as 4 x 1.2 kWh, but provides 4 x 1.1 kWh usable). Mark says he loves the Enphase system: “it’s like Lego blocks; it’s great for residential and small commercial applications as you can add on other battery packs easily as you need them.”

Excess energy for EVs
With his electricity needs at home and in the factory sorted, and both premises now generating in excess of their energy needs, Mark decided it was time to use some of that energy in an electric vehicle. In 2015 he bought his first EV—a Holden Volt, a plug-in hybrid. That purchase turned him into a “true believer” and so he bought a second EV that same year; this time, the BMW i3 REx. Both are used for work and Mark notes that they are “a great talking point with clients.”

In preparation for receiving the Volt, Mark’s DIY spirit kicked in once again, resulting in a unique charging point solution (using an E-Station 7kW charger that his business now supports). Rather than just “making the charger look like a box on the wall with a lead, retrofitting a petrol pump came to mind.” Bought from an antiques yard in Castlemaine in country Victoria, Mark pulled out the existing workings of the bowser from the bottom to make it safe, put the charging components inside where the normal pump mechanism was situated, routed the charging cable the same way as the old petrol hose had been and, voila, a 7kW fast charger (Level 2) was born. He repurposed a second old bowser for the factory to accommodate the second EV, and a third to enable him to charge one of them at home if required.

Providing 32 A of power (compared with a normal 10 A power point, providing around 2.5 kW), the cars’ batteries (Volt 11 kWh, i3 18 kWh) take around three hours to charge from flat to full. They are plugged in whenever the cars return to the factory from jobs. So, during the day, they mostly draw their power direct from the solar generation, while overnight charging draws on the battery storage and then the grid, if required (for example, where a run of cloudy days has diminished solar generation, most often during winter). Both EVs have range-extender petrol engines, so range anxiety has not been a problem.

Mark reports that the Volt has used only around 456 L to travel 50,000 km and the i3 just 50 L to travel 42,000 km. With the EVs being charged mainly from solar and batteries and using only minimal petrol, he is saving around $10,000/year that was previously being spent on fuelling his work cars.

Mark is keen to add further EVs to his fleet, but notes that, while the the Renault Kangoo comes close to meeting his needs, it doesn’t have the range he requires on the job nor a range-extender engine. So he continues to wait for the day when suitable EV utes (or other light commercial vehicles) come onto the market. I’m sure he’s not the only one.

“In 2015 he bought his first EV—a Holden Volt, a plug-in hybrid. That purchase turned him into a ‘true believer’”

Further info and resources on electric vehicles:
‘All about EVs’ in ReNew 131
ATA EV branches in Melbourne and Geelong: community.ata.org.au/branches
Australian Electric Vehicle Association: www.aeva.asn.au
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My Electric Car: www.myelectriccar.com.au
Electric Highway: www.electrichighway.net.au
EV Photo Album: www.evalbum.com
EV World: www.evworld.com
Endless Sphere EV forums: www.endless-sphere.com/forums
EV Obsession: www.evobsession.com
Wikipedia EV page (many links): en.wikipedia.org/wiki/Electric_vehicle

Charging at work and at home: Mark’s two EVs (Holden Volt, left, and BMW i3, right) plugged in to the repurposed bowser at the factory; and the i3 plugged in at home. Makes quite a garden ornament! Both chargers provide Level 2 charging, and both are powered by a grid-connected solar + battery system. The charging logic is: support the site usage with PV, if there is excess PV charge the batteries, if there is still excess PV export. If the site’s usage is greater than the PV get the balance from the batteries; if the site’s demand is greater than PV and batteries combined get the balance from the grid.
Travelling far and wide
The future of long-distance travel

We regularly look at the future of shorter range personal transport options, but what about long-range and public transport options? Lance Turner takes a look at where long-distance and public travel is headed.

TRAVELLING locally is already becoming more environmentally friendly, with the introduction of electric cars and public transport running from renewables. But what about long-range transport: what’s happening there? There is a global push towards reducing emissions in long-range transport options, be they rail, air transport or shipping, but there are significant challenges. Let’s look at what’s happening around the world, and how we may be getting around in the not too distant future.

Trains
According to the European Environment Agency (www.eea.europa.eu), emissions from all passenger rail (with an average of 156 passengers per train) in Europe are around 14 g of CO₂ per passenger kilometre. Compare that to a large car (four passengers) of 55 g, a regular bus (12.7 passengers) of 68 g and aircraft (88 passengers) of 285 g. These figures will vary depending on the type of trains, cars and buses, as well as the source of generation for the electricity used (Europe has lots of renewables and nuclear compared to other regions such as the USA and Australia), but the indicators are clear—we need fewer planes and more trains.

HIGH SPEED RAIL
High speed rail (HSR), where trains run at speeds above 200 km/h (for existing lines, or 250 km/h for new lines) between major population centres without stopping, is common in countries such as China (which has some 22,000 km of HSR network) and Japan, and throughout much of Europe. However, Australia has never managed to get a high speed rail network off the ground, despite many concepts and plans being put forward. One problem here has been a lack of political will for such long-term projects. Another problem, specific to Australia, is the huge distances between cities and our smaller population. In short, the cost per taxpayer for a high speed rail network is much higher in Australia than in most other countries, making it a difficult sell (see en.wikipedia.org/wiki/High-speed_rail_in_Australia).

Central to the lower environmental cost in HSR systems is the use of electric trains. Being able to derive power from renewable energy sources rather than on-board diesel engines means that high speed rail becomes an even cleaner transport option as the percentage of renewables in the grid mix increases—just like any EV. Further, the cost of transport is no longer tied to that of fossil fuels so, as renewables become cheaper, the cost per kilometre travelled can fall.

The majority of high speed rail networks still use steel wheels on steel rails, but some of the fastest HSR projects use a more recent technology—maglev, or magnetic levitation, where strong magnets are used to lift the train just above the track, eliminating most sources of friction and allowing for higher speeds. Indeed, the fastest HSR train in regular service is the Shanghai Maglev Train, which runs on a 30.5 km track from Shanghai Pudong International Airport to the outskirts of central Pudong.

TRAVEL IN TUBES
First touted by Tesla’s Elon Musk, the science-fiction-like hyperloop concept consists of a tube that runs between destinations inside which magnetically levitated and driven pods
travel at up to supersonic speeds (1200 km/h).

While it sounds like it could be an adventure park ride, the hyperloop concept aims to provide an alternative to air travel between cities (or land-linked countries), moving people and freight faster and with much less energy use than commercial aircraft.

The levitation of the prototypes so far has been done using electromagnets as part of the drive system, although the final hyperloop system will most likely use passive air cushion levitation of the pods—much of the air inside the tube is evacuated meaning little air resistance, but enough will remain to act as a cushion around the pod. Regardless of how they are driven, the low mechanical friction due to the pods being levitated means energy use per kilometre travelled is potentially low, despite the high speeds. Further, the use of renewables is inherent to the concept and modelling has shown the hyperloop to be around one-tenth the construction cost of conventional high speed rail (and at least twice as fast).

At least two companies are developing working systems—Hyperloop One (www.hyperloop-one.com) and Hyperloop Transportation Technologies (HyperloopTT, www.hyperlooptransp.com).

So far, Hyperloop One has built basic test tracks to test the electromagnetic drive system and has started building their first full test track (or, more accurately, test tube), called the DevLoop, in North Las Vegas, Nevada. The initial propulsion system test accelerated from zero to around 180 km/h in just over one second, in free air with a very un-aerodynamic test bogie, proving that the system can provide the required motive force.

Around the world, a number of places, including Nevada, Quay Valley California, Slovakia, Abu Dhabi and Moscow, have expressed interest in the concept and have signed agreements with either HyperloopTT or Hyperloop One. The latter company has started the Hyperloop One Global Challenge, a competition which invites teams to put forward a case for their regions/countries to host the first hyperloop networks. Interest has been considerable, with 38 semi-finalists being announced, including a proposal for a tube between Melbourne and Sydney.

There are challenges, including the reliability and safety of sending small pods of people through a tube at near the speed of sound, but they shouldn’t be insurmountable. After all, there were many naysayers when Tesla said they would revolutionise the car industry and SpaceX said they would take over from NASA for rocket launches. Both have happened, and in a shorter timeframe than many pundits expected.

OTHER RAIL

There are plenty of other rail projects that are moving towards zero emissions. In Germany, fuel cell powered trains are being implemented to replace diesels on non-electrified rail lines (see ‘Hydrogen as a fuel’ on p. 68), while in the Netherlands, all-electric trains are now 100% wind powered, after the Dutch railway companies teamed up with energy company Eneco. While the demand for wind energy in the Netherlands exceeds local supply, the balance of wind-generated electricity for the project comes from newly built wind farms in Belgium and Finland.

Even Byron Bay is getting in on the move, with the Byron Bay Railroad Company converting an old 100-seat diesel loco to pure solar-electric power for a 3 km shuttle route between Northbeach Station in Sunrise Beach and the Byron Beach platform (see www.byronbaytrain.com.au).

Road

BUSES/COACHES

It seems many bus fleet operators are waking up to the fact that electric buses are much cheaper to run than internal combustion engine ones and require far less maintenance, with the added advantage of producing no local pollution. Below is a list of just some of the recent developments:

- Sales of electric buses in China rose to over 115,000 vehicles in 2016, with China being by far the biggest electric bus market on the planet, according to Cleantechnica
- Dutch cities Eindhoven and Helmond have changed their entire bus fleet to cleaner vehicles, including 43 all-electric articulated buses, and by 2025, all new buses in the Netherlands will be either pure electric or fuel cell
- Belgian cities Charleroi and Namur have ordered 90 Volvo 7900 hybrid electric buses, with 12 ABB fast charging stations
- The city of Luxembourg has five of the same Volvo buses, along with two ABB fast chargers
- London has a fleet of 51 single-decker pure electric buses/COACHES

These six BYD all-electric buses at Sydney airport are part of services supplier Carbridge’s 200-vehicle fleet. They are about to be joined by 40 more, making more than 20% of the company’s fleet purely electric.
electric buses and plans to increase that to all 300 of its single-decker buses by 2020, while converting all double-decker buses to hybrids by 2019

- Lion Bus (www.lionbuses.com) has unveiled the eLion electric school bus, developed with the government of Québec and the California Governor's Office, with the bus being used in Quebec and California
- Blue Bird (www.blue-bird.com) has been awarded $4.4 million by the US Department of Energy to develop an electric school bus with vehicle-to-grid technology
- King County, Washington, announced that King County Metro Transit will acquire 120 all-electric battery buses by 2020
- Long Beach Transit, California, has committed to buying 10 BYD K9 electric buses for local routes
- US large e-bus manufacturer Proterra, which saw sales increase by 220% last year over the previous year, has secured US$140m for the expansion at their facility in Greenville, South Carolina, and their new factory in Los Angeles County
- Microvast delivered more than 7500 fully electric and electric-hybrid buses in 2016, with more than 15,000 of the cleaner buses now on roads globally
- The University of California Irvine is buying 20 electric buses from BYD to upgrade its campus shuttle service
- Sydney airport services supplier Carbridge has recently added six BYD electric buses to its fleet. They are about to be joined by 40 more, making more than 20% of the company's fleet purely electric.
- AVASS Group plans to manufacture electric buses for the Australian market, with a trial of their buses slated for the ACT this year.

TRUCKS/FREIGHT TRANSPORT

Even the trucking industry is joining the EV world, with a number of manufacturers already testing hybrid and pure EV heavy freight vehicles.

Daimler is planning a small run of urban electric trucks, with a select group of customers to use the new all-electric large trucks in a 12-month trial. The trucks have a 12.8 tonne payload capacity and use a 212kWh battery pack driving twin electric motors (providing a combined 250kW), giving a range of around 200km per charge. Daimler (via their Fuso brand) is also supplying a smaller electric truck called the Canter E-Cell, a small number of which are being used in a 12-month trial. While these are just trials, a Fuso diesel-electric hybrid version of the Canter is already available, even here in Australia (see www.fuso.com.au/Canter-Hybrid)—they've even been spotted in Tasmania!

Long-haul freight is also getting interesting, with the recently released Nikola One fuel cell hybrid truck. This combines a hydrogen fuel cell system with a 320kWh battery to produce a full-size semi-trailer rig with more power (1000hp) and torque (2710Nm) than a typical diesel rig, yet producing far less emissions and with half the operating cost, according to Nikola Motors. See www.nikolamotor.com

Heavy shipping

According to the Third IMO (International Maritime Organisation) GHG Study 2014, international shipping produced around one billion tonnes of CO2 equivalent emissions in 2012, down a little from previous years, but still around 2.5% of total man-made emissions, and predicted to increase between 50% and 250% by 2050, depending on future economic and energy developments.

A big part of the problem is the type of fuel used—high sulphur fuel oil, or ‘bunker oil’, which has a sulphur content up to 50 times higher than the cleaner diesel used in land-based transport. Indeed, it has been calculated that just 16 of the world’s largest ships produce more sulphur pollutants than the entire global car fleet.

In 2011, the IMO adopted the Energy Efficiency Design Index, which sets compulsory energy efficiency standards for new ships (by 2025, new ships must be 30% more efficient than those made in 2014), and the Ship Energy Efficiency Management Plan, a management tool for ship owners.

However, there are technical improvements already happening, such as hybrid drive systems and drive-boosting systems using giant kites, wing sails and rotary sails, such as Enercon’s E-Ship 1, used to transport wind turbine components.

In December 2013, Mitsubishi Heavy Industries (MHI) launched its new LNG carrier, called Field Pea, which is 25% more energy efficient than previous models. This was achieved by covering the spherical tanks with an aerodynamic shroud and installing a more efficient drive system.

Global transportation company NYK Group is developing the NYK Super Eco Ship 2030, an advanced container ship which will use a combination of lighter weight, a new loading system and a fuel cell drive system enhanced with both sails and up to 9 MW of solar panels, plus improved route planning to take advantage of prevailing weather and ocean current conditions. It is expected that the Super Eco Ship will achieve a huge 70% reduction in CO2 emissions compared to existing ships.

It is early days yet for the global shipping industry, and much needs to be done, particularly in the area of sulphur and nitrogen oxide emissions.

Aircraft

With such a regulated industry as the aviation industry, you would expect changes might take a while, and that is proving to be the case. Very little has changed with the big manufacturers in regards to fuel efficiency improvements of airliners.

Airbus seems to be still tinkering with their E-fan project, using small electrically powered prototypes to test the possibilities of electric flight, but progress appears slow. They also had the VoltAir concept, of a fully electric...
airstream using a large ducted fan at the rear of the aircraft, but this design was released almost six years ago and very little has been heard about it since. They have, however, more recently signed agreements with electrical giant Siemens to jointly develop electrical propulsion systems for aircraft, so things are not at a complete standstill. See www.bit.ly/2kEJGTT for the current status of their electric/hybrid propulsion programs.

Boeing is still working on reducing emissions by up to 70% over today’s airliners with their SUGAR Volt (SUGAR stands for subsonic ultra-green aircraft research) hybrid aircraft concept, which would use engines that can run on conventional jet fuel for takeoff or function as large electric ducted fans while cruising. However, their plans are long-term, aiming to meet these targets by the middle of the century.

While Boeing and Airbus move slowly in this direction, expect smaller aircraft companies and possibly new startups to not only develop more advanced aircraft, but get them flying much sooner, such as has happened in the electric vehicle industry.

Regardless of who wins the electric aviation race, there are many hurdles to jump, including improving battery energy density and providing a method for rapid charging of the massive battery bank an electric airliner would require—you can’t have an airliner sitting idle for hours while recharging. In the interim, hybrid electric aircraft are likely to be a good stepping stone solution, allowing rapid refuelling while still providing considerable reduction in fuel consumption. But given the now rapid development of batteries due to the accelerating EV revolution, who knows what battery developments will happen in the near future.

While going electric would be the ultimate emissions reduction strategy for aircraft, the industry is already looking at ways to reduce emissions, including using larger aircraft, flying slower and optimising aircraft speed, less idle time on the ground, improving aircraft routing and changes to air traffic control systems, using electric drives for taxiing instead of the main engines, alternative fuels such as biofuels, aircraft weight reduction by eliminating unnecessary components and making aircraft parts from lighter materials, and improving engine and airframe efficiency (for instance, changing the aircraft body design to reduce aerodynamic drag, see www.bit.ly/BBCRadPlanes for a list of proposed designs). So far the improvements have been incremental, and what improvements have been made in reducing emissions per passenger-kilometre have been eclipsed by increased demand for air travel.

**Autonomous developments**

While electrification of transport is going to be one of the big game changers in the next few years, there is another technology that will revolutionise transport, both long and short range, equally as much—autonomous vehicles.

We have already seen numerous trials of private vehicles, public transport and even heavy haulage vehicles using varying degrees of autonomy to improve efficiency and safety, such as the European Truck Platooning Challenge (www.eutruckplatooning.com) which took place last year. In this exercise, trucks from a number of manufacturers were fitted with autonomous technology that allowed them to drive several different international routes through Europe, delivering freight in the process.

Platooning, where two or more trucks drive single file closely together to reduce fuel usage, is possible to do safely only by autonomous or semi-autonomous systems. The autonomous systems on the trucks can all work together, constantly communicating, and should an incident occur, all vehicles respond (by braking, avoidance or whatever action is required) at the same time, with no delays—the platoon acts like one large vehicle.

Platooning is also possible with existing trucks and human drivers, once the appropriate equipment is added to each vehicle. Omnitracs, a fleet management solutions company, has partnered with Peloton Technology, a developer of connected and automated vehicle systems, to trial platooning technology that can be retrofitted to existing diesel trucks to reduce fuel use, and hence emissions.

The technology synchronises braking and acceleration between pairs of trucks through vehicle-to-vehicle communications, using radar-based collision avoidance systems to allow the trucks to travel safely at aerodynamically advantageous distances. The Peloton system produces a 4.5% fuel saving for the lead truck and 10% for the following truck in a two-truck platoon, according to independent testing by the North American Council for Freight Efficiency.

Other autonomous heavy vehicle trials include trucks delivering freight in Nevada, and a number of bus and rail trials and systems, all of which aim to improve safety and reduce energy consumption.
Hydrogen as a fuel
Is it really viable?

Is the hydrogen economy ever going to happen and are fuel cell vehicles really a viable alternative? Lance Turner cuts through the hype and takes a realistic look at using hydrogen for transport and energy storage.

ANYONE interested in renewable energy will have come across numerous articles on hydrogen fuel cells, and in particular, their use in cars and other transport as a potentially greener replacement for conventional internal combustion engine (ICE) drivetrains. However, to date there are very few fuel cell vehicles on the roads, apart from a few in demonstrator fleets, all subsidised by either the government or vehicle manufacturers.

So why haven’t we seen the fuel cell revolution as promised? There are a number of reasons, but let’s first look at the basics of fuel cells.

What is a hydrogen fuel cell vehicle?
In its simplest form a hydrogen fuel cell consists of two electrodes (an anode and a cathode) separated by an electrolyte. Hydrogen gas is introduced at the anode and oxygen from the air at the cathode. The two combine to produce electricity, heat and water.

In a fuel cell vehicle, hydrogen is stored in high-pressure tanks and delivered to the fuel cell at a reduced pressure, while air is passed through the fuel cell stack (the common term for a number of fuel cells in a single unit) courtesy of an electrically driven compressor system. By varying the rate of gas flow through the stack, the electrical output of the fuel cell system can be controlled.

The electricity then normally passes through a DC to DC converter to produce a voltage suitable for the vehicle’s drive motor and battery bank (or ultracapacitor bank).

The resulting electricity powers one or more electric motors, which propel the car—exactly like a battery-based electric vehicle.

As mentioned, fuel cell vehicles include a battery or large ultracapacitor for temporary energy storage. This is required as a fuel cell takes a small amount of time to respond to gas flow rate changes. In a vehicle this would be an unacceptable delay—imagine putting your foot down only to have the car do very little for a couple of seconds. The battery and/or ultracapacitor store a relatively small amount of energy but they can deliver it immediately as a large amount of power. They also provide extra power when the total demand exceeds that available from the fuel cell stack (which usually has a lower maximum power output than the motors are rated for) such as when overtaking and hill climbing.

Indeed, the main difference between a purely battery electric vehicle (EV) and a fuel cell vehicle (FCV) is that the FCV has a combination of fuel cell system and small battery rather than a single large traction battery—in most other respects they are quite similar.

To store a usable amount of hydrogen in a small space, such as required for a vehicle drive system, you need to compress it enormously. How much does it have to be compressed? To gain acceptable ranges comparable to a typical petrol car or current long range EV (400 km or more), the level of compression is many hundreds of times atmospheric pressure.

Both Honda with their Clarity FCV and Hyundai with their ix35 vehicle use a maximum tank pressure of 700 Bar, or around 700 times normal atmospheric pressure, 70 megapascals, or over 10,000 psi in the old
terms. In more common terms, that’s 700 kg of pressure per square centimetre of tank surface area.

As an example, a tank that holds 5 kg of hydrogen (a typical full charge for a fuel cell car) requires about 125 litres of volume. Assuming that tank is a metre long, then it is around 400 mm in diameter. This means the total force inside the tank is around 8800 tonnes. To hold such enormous pressures would require unworkably heavy tanks if they were made from steel, so hydrogen tanks are made from carbon-fibre composites for strength, often with an aluminium liner.

Even so, the weight of the tank considerably outweighs the weight of hydrogen that the tank stores—the twin tanks (two tanks are used for strength and to fit the available space better) in the Toyota Mirai weigh 87.5 kg in total and yet hold just 5 kg of hydrogen.

The rest of a fuel cell system consists of equipment such as control systems, cooling systems (fuel cells run hot, so need active cooling like an internal combustion engine vehicle), the air scrubber (the air entering the fuel cell stack needs to be very clean) and air compressor systems.

**Where does hydrogen come from?**

While many people refer to hydrogen as a fuel, this is actually incorrect. As there is very little freely accessible hydrogen on Earth, it has to be manufactured, so it’s an energy carrier: it requires energy to make it which it then liberates when used.

Most hydrogen is made by reacting methane from natural gas, a fossil fuel, with high pressure steam into hydrogen, carbon monoxide and carbon dioxide (a process known as reforming, see en.wikipedia.org/wiki/Steam_reforming). This requires a lot of energy to do, in fact more energy than you can recover from the resulting hydrogen that’s produced.

The other method of producing hydrogen is to use electricity to break water into hydrogen and oxygen. While this might seem like a good solution, the process is usually less than 60% efficient (en.wikipedia.org/wiki/Electrolysis_of_water#Efficiency) and expensive, so the vast bulk of hydrogen produced is from natural gas.

**Process efficiency**

Once produced, hydrogen must be stored, and this can be at high volume and low pressure, or low volume and high pressure. Compressing hydrogen, like compressing any gas, requires quite a lot of energy (think of the size of the motor on a workshop air compressor), and also produces heat. Because hydrogen must be compressed so much, it produces a lot of heat and so it takes more space than it should (the hotter a gas, the greater the volume for a given pressure). To get effective compression to the desired final pressure at ambient temperature, the hydrogen must be cooled during compression. This also requires energy use.

There is another issue when dealing with compressed gases. When the gas decompresses, it requires heat input. Thus, when hydrogen flows from a fuelling station into a FCV pressure tank the fuel must be heated, or the system must recognise that the gas entering the vehicle’s tank is cold and will later expand, or risk over-pressurising the tank.

The overall need to compress hydrogen (possibly more than once, if it is tankered to fuelling stations rather than being produced on site) results in a quite low ‘wheel to wheel’ efficiency in the hydrogen fuel cycle. The amount of energy required to compress hydrogen to 700 Bar can range up to 20% of the total energy stored in the hydrogen (efficiency depends on many factors, including the type of compressor and compressor motor used, rate of compression, ambient temperatures etc). Regardless, this level of energy requirement makes a dent in the already not-so-great efficiency of hydrogen production.

However, like all technologies, there have been efficiency improvements over time. Recent work has focused on improving the electrolysis process using different catalysts to increase efficiency and using renewable energy sources to reduce the carbon footprint of the produced hydrogen. So far, there have been a lot of theoretical solutions, but no commercial ones, and hydrogen is still almost entirely fossil fuel derived.

**Advantages**

So fuel cells aren’t sounding great, considering the source of their ‘fuel’. But are there any advantages over ICE vehicles or EVs?

Arguably the greatest advantage of fuel cell vehicles over current EVs is that of rapid refuelling, similar to fuelling an ICE car. While there were some initial teething problems with cars in some FCV trials failing to fill completely, these and some other teething problems seem to have been fixed, with fuel cell cars like the Toyota Mirai filling in around four minutes.

An advantage of fuel cell vehicles over ICE vehicles is that of low local emissions. The tailpipe emissions are simply water vapour, so pollution levels in cities would dramatically decrease if the majority of vehicles were to transition to fuel cells. Of course, the same advantage applies to EVs.

Another potential advantage of FCVs over EVs is driving range on a full tank. The current 2017 Honda Clarity, for example, has a US EPA range of 589 km and the Toyota Mirai has an EPA range of 502 km. These compare with the highest range of any EV available, the Tesla P100D, which has an EPA range of 539 km.

So currently FCVs are on par with the range of the best EVs, but with EV batteries improving rapidly in capacity while dropping in price (for example, the new US$37k Chevy Bolt has an EPA range of 383 km), it seems the
advantage FCVs have over EVs in this area is likely to disappear in the next few years. And bear in mind that the true cost of both of those fuel cell vehicles is unknown. Many people in the industry believe Honda and Toyota sell their fuel cell vehicles at a loss, with estimates of the real cost of each vehicle varying widely.

**Disadvantages**
The overall fuel cycle efficiency of hydrogen generation, transport and use in vehicles is rather low compared to electricity transmission and battery charging in EVs. Quoted figures vary depending on who you ask, but the overall efficiency for a fuel cell vehicle, from well to wheel, is around 30% due to the aforementioned issues of gas compression and cooling, the relatively low efficiency of hydrogen production and the efficiency of fuel cells themselves. Compare that to EVs, which have a well to wheel efficiency of 70% or more due to the high efficiency of battery charging equipment and the very high efficiency of lithium batteries when charging and discharging. This doesn’t include the efficiency of the electrical generation itself, but given the grid in most countries is moving towards renewable generation, the overall efficiency for EVs improves every year—something that won’t happen with FCVs due to physical limits of the hydrogen production and use processes.

However, there are a few companies working on better hydrogen production processes. One example is HyperSolar (www.hypersolar.com) who are developing a new kind of electrolysis unit that uses sunlight directly rather than electricity. It’s still early days yet, but if they can commercialise their technology and produce hydrogen cheaper than existing methods, that would improve hydrogen’s carbon footprint.

Lack of infrastructure is also a problem, although hydrogen filling stations are starting to pop up in a number of countries including the USA and the UK. However, hydrogen filling stations are very expensive—according to Toyota’s US national manager of fuel cell vehicles, Ed La Rocque, it costs US$1 million to set up each refuelling station. The California Air Resources Board is funding 50 new hydrogen filling stations to kickstart the hydrogen FCV market and these 50 stations are expected to cost over US$90 million. Compare that to a few thousand dollars for an EV fast charger or a few tens of thousands for a supercharger or equivalent.

In addition, hydrogen infrastructure, which relies on large high-pressure tanks and pumps, is more expensive than EV infrastructure—which is mostly electronics. We should also look at the cost of the fuel for both EVs and FCVs. Hydrogen is sold by the kilogram, and in the USA, the cost to refuel a Toyota Mirai is up to US$50—compare that to the cost of recharging the largest EV battery currently available (with a similar range to the Mirai), that being in the Tesla P100D, of under $30 for a full charge (at typical Australian domestic electricity rates). That is assuming, of course, that EV owners are not generating energy onsite locally for charging. Many EV owners also have their own PV arrays, reducing charging costs considerably.

Fuel cell vehicles also suffer in the performance stakes compared to EVs. While the best fuel cell cars have a total drive power of less than 150kW, the best EVs are capable of producing several times this power. Indeed, the Tesla Model S P100D is the fastest accelerating four-door production car ever produced (either EV or ICE). The reason for this lack of output power is two-fold. Firstly, fuel cell stacks used in cars are generally rated at less than 120kW. Secondly, the batteries used in FCVs are much smaller than those in pure EVs (for example, the Toyota Mirai uses a tiny 1.6kWh battery), so much less instantaneous power can be drawn from them.

**What’s happening with biofuels?**
A few years ago there was much enthusiasm over biofuels and their potential to replace fossil fuels in the transport sector. However, even while they were being touted as a less greenhouse gas intensive alternative, many analysts were pointing out some flaws in this analysis.

One issue is the large amount of space needed to grow enough biomass to replace a sufficient portion of the current fossil fuel market. Then there are the fossil fuels, fertiliser and water required to grow the crops, as well as the energy required to harvest, process and transport the fuel. Add to that the competition between biofuel crops and food crops for land and the potential deforestation to make way for biofuel crops, and biofuels in general were not looking so good.

But arguably the largest issue was that of the final use of biofuels. Simply replacing liquid fossil fuels in conventional internal combustion engines results in an inefficient and high carbon outcome, because internal combustion engines are so inefficient—there’s little point developing low carbon fuels, requiring large amounts of biomass to manufacture, if 75% or more of the resulting biofuel is wasted due to engine inefficiency.

In recent years there has been a move in focus away from producing biofuels from land crops and towards using algae reactors to produce biofuels, due to the higher sunlight collection and conversion rate and greater space efficiency. However, there is still a lot of work to do to make production economically viable and sustainable.

That’s not to say that biofuels are dead. There are a number of biofuel companies that produce not just oils, but other fuels as well. Algenol in the USA use cyanobacteria to produce ethanol directly, and then converts the spent algae into ‘green crude’, producing two different fuels from the one process stream. The inputs to the process are, as Algenol states, “algae, sunlight, carbon dioxide, saltwater, all on non-arable land.”

There have been numerous trials of biofuels in road, water and air transport, and there is still a lot of interest in a shift to biofuels from some quarters, particularly the US military. The US Department of Energy recently funded six projects to the tune of US$12.9m aimed at producing biofuels, bioproducts (materials and products derived from renewable biological resources) and biopower (power from biomass) (see www.bit.ly/2A1MDOE).

Ultimately, the problem with biofuels still comes back to the overall inefficiency of the entire fuel cycle of such systems, especially when used in existing fuel-burning machines. As battery technology continues to improve, fuel, and ultimately biofuel markets, will continue to shrink.
Another possible disadvantage of FCVs is that of the tanks themselves. While they have been engineered to be as safe or safer than conventional ICE fuel tanks, even in crushing accidents, the perceived danger of high-pressure tanks may be an issue for some.

Fuel cell vehicles are touted as being more reliable than ICE vehicles, but the newness of the technology is yet to prove this one way or another. However, with their far greater complexity than EV drivetrains, FCVs are unlikely to be as reliable as EVs, and will likely require more maintenance as the fuel cell stacks, pumps and compressors age.

**Where hydrogen might work**

Despite the negatives of FCVs outweighing the positives, car companies such as Honda and Toyota are still pushing for fuel cell vehicles to become the vehicles of the future. For personal vehicles, I’d argue that this isn’t going to happen, EVs have too many advantages over FCVs and they will ultimately be cheaper to buy and much cheaper to run.

However, fuel cell vehicles may eke out some form of market in the private vehicle sector, even if it is a small one, and for public transport, where vehicles have to run continuously; they have the advantage that they can be refuelled rapidly—although vehicles such as electric buses can recharge on the fly using wireless charging at key stops.

In the future we may see fuel cell buses and maybe even long-haul trucks, assuming hydrogen refuelling infrastructure is broadly implemented—still not a certainty at this stage of the game—although there’s nothing to stop companies installing their own hydrogen fuelling stations for fleet vehicles.

One area where hydrogen may be more useful is for grid load levelling. Excess electricity could be used to manufacture hydrogen, which is stored in large volume, low-pressure tanks, eliminating the need for high levels of compression. At times of greater grid demand, the stored hydrogen would then be used in fuel cells to produce electricity to bolster the grid. In short, hydrogen may become a viable option for applications where hydrogen can be produced and used again at the same location.

However, even stationary applications of hydrogen fuel cells may be superseded by large-scale battery storage before too long, with systems such as Tesla’s recent installation at Mira Loma in California—this 20MW/80MWh grid storage system is the largest on the planet, and it was built in just three months. (www.bit.ly/BITESML)

More information and related articles:
- Battery electric cars are a better choice for reducing emissions than fuel cell vehicles, Stanford study finds: www.bit.ly/2SFCEVS
- Liquid hydrogen? Normally to cause hydrogen to take a liquid form requires cryogenic cooling—something totally impractical for transport infrastructure. However, engineer and inventor Dr Roy McAlister of Arizona State University devised a method of producing hydrogen from methane (or other hydrocarbons such as waste biomass) and then storing that hydrogen in a liquid form at room temperature and atmospheric pressure. This was achieved by splitting the methane into hydrogen and solid carbon, then combining the hydrogen with CO₂ and nitrogen taken from the air to form a liquid.
- Called Metrol, the liquid fuel can be transported and pumped like petrol using existing petrol station infrastructure, eliminating the need for expensive compressed hydrogen fuelling systems. Even more interesting, a conventional ICE vehicle can be used with a converter that strips the CO₂ and nitrogen from the Metrol to reproduce gaseous hydrogen which can then be burned in an ICE or used in a fuel cell. The ICE car would need its exhaust system replaced with a heat exchanger.
- So far, Metrol is not yet available to the public, although it is planned to be available in 2018. Whether it takes off remains to be seen—the added steps of combining hydrogen with other elements and then separating it for later use add even more complexity to the hydrogen fuel system.
- And, of course, being able to easily transport hydrogen, while it has many advantages over compressed hydrogen storage, does not address the inherent lower efficiency of a fuel cell compared to batteries in an EV, or the far greater inefficiencies of internal combustion engines, or the much higher maintenance requirements of both fuel cells and internal combustion engines compared to batteries.
If your old hot water system has seen better days, maybe it’s time for an efficient replacement. We show you how solar and heat pump hot water systems work, what’s available and how to choose one to best suit your needs.

ONE of the biggest energy users in any home is water heating—it can account for around 21% of total energy use (on average, according to YourHome), at a considerable financial cost each year. Water-efficient appliances are one way you can reduce energy use—for example, you could replace an inefficient showerhead (e.g. some use 20 litres per minute) with the most efficient, which uses less than 5 litres per minute, saving water and water heating energy each time you shower. But far greater energy reductions are possible if you replace a conventional water heater with a heat pump, solar thermal or solar electric system.

Such systems have the added advantage of reducing your greenhouse gas emissions. For example, for an average family the reduction can be as much as four tonnes of CO₂ per year—the equivalent of taking a car off the road!

### What we do and don’t cover

From an efficiency and environmental point of view the future of household energy is electric. The rise of rooftop solar and the availability of GreenPower means that households can use 100% renewable energy to run their appliances, including hot water systems.

This means we don’t cover efficient gas hot water options such as gas instantaneous in this guide, although the solar thermal hot water systems listed do have gas boost options. Gas used to be seen as the cleaner energy choice, at least when compared with burning coal, but there are better non-gas appliances available to households now. And changes in the gas market mean gas prices are on the rise. Replacing a hot water system with a modern solar thermal or electric one is often the first step in disconnecting from the gas grid, and the associated costs and greenhouse gas emissions.

We cover systems designed for household hot water that can run from renewable energy, including electricity, and ambient and solar thermal heat. These include heat pump, solar thermal, electric instantaneous and the newer kids on the block, PV diversion and direct PV water heating systems. Heat pump systems can be designed for other purposes in the home such as pool heating or hydronic heating, but these are out of the scope of this guide.

### HEAT PUMPS

#### How do they work?

A heat pump moves, or ‘pumps’, heat from one medium into another. Air conditioners and refrigerators are the most common forms of heat pumps. Heat pump hot water systems concentrate low-grade heat from the air (which is why they count as renewable systems for STC rebates, see box next page) and dump it into the water storage tank. They are much more efficient than conventional resistive electric water heaters (although they do still use electricity to operate): compared to resistive heaters, they are capable of reducing...
year-round energy requirements for hot water by at least 50%, and by as much as 78% depending on the climate, brand and model.

The most common systems are air-source heat pumps where heat is extracted from the air. Ground-source heat pumps (which use buried coils to take heat from the ground) can be even more efficient than air-source heat pumps and might be an option if you’re considering both water and space heating systems. They are a great deal more expensive than air-source heat pumps though, so often aren’t viable. We looked at ground-source heat pumps in ReNew II2.

Heat pump features and considerations

TO SPLIT OR NOT

Heat pump hot water systems are configured as either one-piece (integrated) or split. In an integrated system, equipment such as the evaporator and fan is mounted on top of or beside the tank and integrated into a single unit. In a split system, the heat pump mechanism is housed in a separate unit plumbed to the tank at installation time. Depending on the design, the pipes between the tank and the external unit will carry either refrigerant or water.

An integrated unit has the benefit of simplicity of installation and compactness, whereas a split system allows greater flexibility in locating the two components. For example, you could locate the tank indoors and the heat pump mechanism outside on a wall.

Rebates and STCs

Currently only SA and Victoria offer state government rebates for solar thermal and heat pump water heaters, but STCs (small-scale technology certificates) are still available across Australia for installations of such renewable energy technologies—each STC is equivalent to the one megawatt hour of electricity the system will displace over a 10-year period.

STCs can save you a great deal on the cost of a new heat pump or solar thermal hot water system. The rebates and STCs are usually arranged by the supplier so you don’t need to do any paperwork to receive the discount. The price will probably still be higher than a similarly sized conventional water heater but savings on running costs can pay for this difference in 5 to 10 years in most cases.

→ Diversion systems, such as the Catch Power Green, send excess solar generation to a hot water system, rather than into the grid, and can greatly reduce water heating costs. Here you can see the main diverter unit (the big green box) and the current flow sensor (bottom right) and its associated transmitter with boosting control.

PERFORMANCE

Heat pumps are much more efficient than conventional resistive electric water heaters. Typical heat pumps have a coefficient of performance (COP) of around three: these are three times as efficient as a resistive unit; for every unit of electricity used, they move three times this much energy into the water.

However, it should be noted that COP varies with ambient conditions; when the air temperature is higher, the heat pump can more easily draw the heat energy from it. The way COP is measured and reported is often not consistent, so currently the best objective performance indicator is the number of STCs the system earns in a given climate zone (see the ‘Which system suits my climate’ section).

REFRIGERANT

The global warming potential (GWP) of refrigerants used in heat pump systems is often very high, which becomes a problem if they leak or are dumped illegally. This is an issue broadly for the refrigeration industry; the simplicity and size of domestic heat pumps means it is less of a problem for them.

Most of the current generation of refrigerants are hydrofluorocarbons (HFCs) which have very high GWPs; e.g. many systems still use refrigerants such as R134a which has a GWP of 1430. Increasingly systems are becoming available that use low-GWP refrigerants such as hydrocarbons (e.g. propane, or R290, with a GWP of 3.3) or carbon dioxide (R744), with a GWP of 1 (Sanden heat pumps use this).

Australia has signed up to a phase-down of HFCs which will accelerate this transition.

BOOSTING

Heat pumps are designed to run whenever the tank temperature falls below a preset level (e.g. 60 °C). Some heat pumps struggle in air temperatures approaching freezing, and so may use a resistive electric element as a booster in these conditions. If you live in an area that sees regular near-freezing temperatures, look for a system that will operate under such conditions without the need for a resistive booster.

You may also have your heat pump on a timer, so that it can make use of daytime PV generated solar, for instance. However, extra hot water may be needed at other times, so most timers have the ability to be overridden for just such requirements.

NOISE

Like the outdoor unit of an air conditioner, heat pumps make some noise (although some are noisier than others—check the decibel rating), so thought should be given to their location. Avoid fitting them close to bedrooms unless they’re on a timer and only run during the day.

RATE OF RECOVERY

This refers to how quickly the heat pump can reheat the water in its tank to a particular temperature. If you are big water users or have guests staying regularly, you should buy a unit that has a relatively fast rate of recovery.
**ELECTRIC PV DIVERSION**

*How does it work?*

Electric diversion systems use excess energy from existing grid-connected solar panels to heat water in an electric storage water heater. When electricity starts flowing out to the grid, the controller turns the diverter on and feeds that energy into the water heater. For example, if your PV system is exporting 500 watts of excess generation to the grid, the diverter will start feeding that 500 watts to the water heater instead.

Diverters are generally fully variable in their outputs: they don’t just turn a load on and off at full power. They match the power fed to the water tank element with the excess generation in close to real time, measuring potential export and adjusting accordingly.

Some diverters, such as the AWS SunMate, have adjustable thresholds which enable them to divert only when the excess generation reaches a desired level. This is useful when the load is a heat pump water heater rather than a resistive element. The threshold can be set to be equal to the average running power of the heat pump, so that the heat pump runs from excess solar generation whenever possible. Boosting times will need to be included (usually programmed into the diverter), for days of low generation when the threshold is never reached.

Installing a diverter usually means that a clip-on sensor must be attached to the main lead into the home’s switchboard. This sensor talks to the diverter either via a wireless link, a hard-wired cable or even via powerline communications, where data is sent over the mains cables in the home (such as with ethernet over power, or EoP networks, which are common in homes now). Generally, an electrician is required to install a diverter.

The advantage of using a diverter is that, rather than getting paid just a few cents per kilowatt-hour by the energy company for your excess generation, you get to use it on-site, offsetting energy from the grid that would cost you a great deal more.

Diversion is now becoming a feature of some grid-interactive inverters, although inverter capabilities in this regard are generally more limited—often being a simple on/off output once a set export threshold is reached, with no ability to vary the output into the load. However, as PV diversion becomes more popular as a means of using excess generated energy on-site, we expect to see many, if not most, grid-interactive solar inverters with some form of diversion capability in the near future.

The average cost of a diverter is around $900 or so, depending on features, although units range up to around $1700. As they become more popular, prices will come down, but for now you need to weigh the extra cost of the diverter against using a simple timer to run your heater during the day, although a timer gives far less flexibility.

**ELECTRIC DIRECT PV**

*How does it work?*

In such systems, solar PV panels are connected directly to a traditional electric resistive water heater via a maximum power point tracking controller/inverter (which ensures you get the most energy possible from the PV panels). The PV panels may be connected to the bottom element in a two-element tank or the single element in a standard single-element tank.

However, at present, very few solar installers/electricians will have wired such a system, so you will need to use the installer recommended by the system supplier.

When using direct PV systems with a mains pressure tank it is important that the controller is also an inverter so that the element is fed AC power—the wiring rules require that the over-temperature thermal cutout (OTTC) is wired in series with the element. Direct PV systems that produce DC output must not be connected to a mains pressure tank, only open-vented tanks, as these don’t require an OTTC. You cannot use the tank’s original thermostat to switch the DC power from the PV array as these thermostats are designed for AC power, not DC, as the latter is much more prone to arcing and burning of switch contacts.

While some direct PV systems are sold as a controller and you supply your own solar array, others (such as the Easy Warm Hot PV system) are sold as a complete package of solar array and inverter to simplify installation.
and ensure the system complies to the safety standards.

Direct PV systems can cost as little as $300 for a simple DIY controller, through to several thousand dollars for a complete package.

**PV diversion/direct PV considerations**

**BOOSTING**

For days with inadequate input from the solar PV, boosting will be required, just as with a solar thermal hot water system (see next page). Boosting might use the electric element in the tank for overnight heating from mains grid power (via the settings on the diverter in the tank for overnight heating from mains page). Boosting might use the electric element in the tank for overnight heating from mains grid power (via the settings on the diverter in the tank for overnight heating from mains page). Boosting might use the electric element in the tank for overnight heating from mains grid power (via the settings on the diverter in the tank for overnight heating from mains page).

It is important to consider how much boosting you are willing to pay for over winter. Water heating requires more energy input in the cooler months due to higher tank losses (heat loss rate is proportional to the temperature difference between the tank and the ambient air) and higher hot water demands. Plus this is the time of year when solar input is lowest. Consider whether it is worth increasing the size of your solar system, especially if you are already upgrading or adding a direct PV array, to cover some of this extra energy requirement. Your energy bills should have the export component listed, so compare this figure to what your expected water heating usage will be (this might be listed separately on your bill if you have an off-peak tariff for water heating) to get an idea of just how much you are likely to gain from a diversion setup over winter.

Also consider appropriate boosting times, especially if you use most of your hot water at night. If you have a day of low solar input, but the next day is forecast to be sunny, and will therefore provide all the energy needed to reheat the hot water tank, you don't want the booster running and preventing the PV from heating the water the next day.

One solution is to have the PV heating the bottom element of the tank, while the boosting only heats the middle or top element, leaving plenty for the PV to do the next day, while still supplying adequate hot water.

Everyone's hot water usage patterns are different, as is the output from PV systems, depending on time of year, local climate and personal preferences, so you may need to work out a boosting regime that works best for you. Just make sure the boosting element is on a timer so that you can experiment to find the right balance without needing an electrician.

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**Tanks**

Most tanks used in heat pump and solar hot water systems are mains pressure tanks, much like the tanks used in regular gas and electric water heaters. The entire tank sits at mains pressure and is filled with the water to be heated.

For mains pressure systems, the tank must be strong enough to hold pressures of 1000 kPa and above. This means they must be made of steel. Some companies use marine-grade 316 stainless steel while others use mild steel with a coating of vitreous enamel (glass).

Glass-lined tanks must have a sacrificial anode fitted (a metal rod inside the tank, usually magnesium or aluminium) which is designed to be eaten away by galvanic, or corrosive, action in preference to the tank material. The anode should be checked at regular intervals to assess wear and be replaced if required; with good quality water this replacement time may be every five to seven years. If the water quality is poor then the replacement time will be much shorter.

Failure to replace the anode when required will generally result in premature failure of the tank and may void the warranty.

Some systems use constant-pressure tanks (often called gravity-feed). These are usually copper tanks placed in the roof and are open vented (open to the outside air via a small vent pipe). Because they contain no pressure they can be directly connected to the heat exchanger on a wood stove as there is no explosion risk if they boil. They are suitable for most water conditions and can give many years of service before failure, usually due to corrosion or failed seams.

A heat exchange coil can enable a constant-pressure tank to deliver mains pressure hot water. The potable water for the house passes through a heat exchanger in the tank (basically a large coil of copper pipe) and is heated by the tank water. This eliminates the need to keep the tank at mains pressure, resulting in tanks that generally last longer than mains pressure tanks.

**Tank insulation**

Tanks are usually insulated with polyurethane foam. The industry standard foam is CFC-free. Some manufacturers make their horizontal tanks for close-coupled systems so that the insulation on the top is thicker than on the bottom, as the hottest water is at the top of the tank.

On ground-mounted electrically boosted or heat pump tanks it is possible to add extra insulation in the form of a tank blanket; however, the only product designed specifically for this task, the Eco Wrap Hot Water Cylinder Blanket from Autex, is no longer available. Alternatively, there are a number of bulk/foil laminate insulation products, such as Bradford Anticon and Fletcher Permastop, suitable for use on indoor-mounted tanks (see our Insulation Buyers Guide in ReNew 127). There is a real hole in the market here in Australia for a product like the Mayplas cylinder jacket from the UK (www.mayplas.co.uk). The other option is to locate the tank itself in an insulated ‘cupboard’. You will need to ensure you can still access the safety valves.

**Legionella**

Traditionally, storage tank temperature has been set at a minimum of 60°C to kill Legionella bacteria. However, standards now allow smart control with daily or weekly heating of the whole tank to 60°C.
Solar thermal hot water systems

How do they work?
Usually called solar hot water, a solar thermal hot water system uses heat directly from the sun and consists of a hot water storage tank connected via pipework to solar collector panels. These collector panels are placed on a (preferably) north-facing roof, although a west-facing roof will also work well in many cases. The tank can be situated immediately above the panels on the roof (a close-coupled system), above and a small distance away from the panels within the roof cavity, or at ground level (a split system). For split systems, a pump and controller are required to circulate water through the panels.

The collectors are usually mounted at an angle of no less than 15° from the horizontal (the minimum angle for close-coupled systems to ensure correct thermosiphon operation), although often a lot steeper to optimise the system performance for winter.

As the sun shines on a collector panel, the water in the pipes inside the collector becomes hot. This heated water is circulated up the collector and out through a pipe to the storage tank. Cooler water from the bottom of the tank is then returned to the bottom of the collector, replacing the warmer water.

Some systems don’t heat the water directly but instead heat a fluid similar to antifreeze used in vehicle cooling systems. This fluid flows in a closed loop and transfers the collected heat to the water in the tank via a heat exchanger.

Evacuated tube collectors either heat the water directly or use copper tubes called heat pipes to transfer the heat to the tank or a manifold at the top of the collector.

Solar thermal hot water features and considerations

To split or not?
For close-coupled (non split) systems, the circulation of the water through the panels and tank occurs naturally as the heated water rises, by the process of thermosiphon. With no pump required, these systems are simpler than split systems, with less maintenance required.

However, the storage tank does need to be above the collector panels, and the roof must be able to support the full weight of the tank.

In split systems, a pump and a differential temperature controller are used to circulate the water. Split systems have a slimmer roof profile and are more convenient should tank maintenance be required, but the pump and controller do add complexity and have more potential for failure.

Collector types
There are two common types of solar thermal collector panels: flat-plate and evacuated tube. Which type you use depends on personal preference and your climate. Evacuated tubes tend to work better in the cooler months in colder climates, but in warmer climates, either type of collector will perform well. If selecting an evacuated tube collector, check to see how easily tubes can be replaced if broken. Many collectors can have tubes removed without having to drain the collector or affecting operation of the rest of the system.

Boosting

Virtually all solar thermal hot water systems on the market incorporate some form of boosting for times of insufficient sunshine.

Electric elements in the tank are the most common boosting option. They fit in well with cheaper night-rate tariffs and are cheaper than gas boosters. If you opt for electric boosting and plan to buy accredited GreenPower, make sure that your night-rate electricity is also GreenPower.

It is even possible to have a solar thermal hot water system that uses a heat pump for boosting, giving you the lowest energy use water heating system. However, you would need to add a bolt-on heat pump system to a regular split system tank and the added cost may mean this is not economically viable.

Gas boosting is now mostly in the form of instantaneous booster units that are connected to the outlet of the storage tank. If water from the tank is below the required temperature, the gas booster fires up, heating the water to the desired temperature. The advantage of this system is that there are lower standing heat losses compared to a system where the entire tank is heated to full temperature.

Instantaneous gas heating may, however, require a higher capacity gas line as it burns a lot of gas to heat water quickly. Solar compatibility requires the booster to be able to operate with a low temperature differential between the hot water coming in from the solar system and the final hot water temperature desired at the taps. Some gas instantaneous heaters are designed specifically for solar thermal hot water boosting, and come as a package with the system.

While gas has previously been thought of as a fairly good option environmentally, that view has changed as the full life cycle analysis and resulting greenhouse gas emissions from gas have become more fully understood. In many cases, electric boosting is likely to be the greener option, especially if it is 100% GreenPower or locally generated renewables.
There are a small number of instantaneous electric water heaters that can be used as solar boosters, such as the Stiebel Eltron DHE AU series, so if you have a suitable electrical connection, this might be a good option.

In rural areas where firewood is plentiful, the hot water system can be boosted by a solid fuel heater or a slow-combustion stove, but this has greenhouse gas and air quality considerations. Using this method requires some special system and plumbing considerations. A slow-combustion heater is an uncontrolled heat source and any hot water tank connected to it must be open-vented, not mains pressure. It is highly dangerous and illegal to connect a mains pressure tank directly to an uncontrolled heat source, although you can still add solid fuel boosting if you convert the mains pressure system to gravity-feed by adding a header tank.

FROST PROTECTION
All manufacturers offer frost protection on at least some solar thermal hot water models. This is important for anywhere that a frost may occur.

For close-coupled systems there are several frost protection methods. Many systems use a heat exchange fluid which flows through the panels and into a heat exchanger in or around the storage tank. The fluid in this outer circuit contains propylene glycol, an antifreeze additive, and does not freeze under any conditions likely to be experienced by the collectors. However, the fluid level in this circuit must be checked regularly and replaced after an interval as recommended by the manufacturer. This fluid is more slippery than water and has been known to leak out through the panel connectors. Owners should look out for this and replace the seals and fluid before irreparable damage is done to the panel.

In a split system using flat-plate collectors, the controller will usually have a freeze-protection mode. It will turn the pump on when the sensor at the top of the collector shows a temperature of 5°C to pump warm water from the tank through the collector, preventing freezing. The pump will only run until the top of the collector is warmed by the water, so only a small amount of heat is lost with each pump cycle.

Evacuated tubes often use heat pipes to transfer the heat from the tube to the tank or collection manifold. As this type of evacuated tube does not contain circulating water, there is none to freeze. In frost-prone and colder areas, a heat pipe evacuated tube system should be considered.

Another method is the use of dump valves. These are only used in flat-plate close-coupled systems that use water in the panels instead of a heat exchange fluid. The valve works by opening as the water temperature approaches freezing, allowing warmer water from the tank to enter the panels, which also causes the valve to reclose. This method is not common nowadays but may still be found on lower cost or direct-import systems.

TEMPERATURE CONTROL
Under the plumbing code AS3500.4, it is a requirement that all water heaters connected to an uncontrolled heat source, such as solar collectors and wood stoves, must have a tempering valve fitted. This valve limits the maximum temperature for hot water to the bath, shower or hand basin to a maximum of 50°C by mixing cold water with the hot water coming from the solar water heater. No solar thermal water heater should ever be installed without a tempering valve. However, PV diversion and direct PV systems use the water heater’s original thermostat (or temperature monitoring in the controller) and so operate like a regular controlled heat source system.

Retrofitting existing systems
It is possible to retrofit an existing electric storage hot water system to use solar thermal heating, provided it is in good condition (five years old or less). For a split mains pressure system, a fitting can be installed on the cold water inlet. It is not advisable to connect solar to gas storage hot water systems because they are designed for the gas to reheat the water as soon as some is used, so the sun can’t really contribute any heat.

There are add-on heat pump systems that can be connected to an existing gas or electric water heating tank. The original heating source (gas or electric element) is disconnected and the heat pump system takes over all heating, greatly reducing the heating energy requirements. Almost any hot water storage tank can be retrofitted using these systems. The Siddons Solarstream Bolt-on heat pump is an example of such a system.

It should be noted that STCs and other rebates are invalidated by retrofits. If looking purely from a cost perspective it’s usually advantageous to install a complete new system as the rebate more than covers the cost of a new tank.

Of course, for PV diversion and direct PV systems, you need an existing electric storage water heater (or heat pump unit) in good

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**Using hot water well**

To optimise the performance of a solar system (either solar thermal or PV powered), hot water usage should occur in the morning as much as possible. This means showers in the morning and possibly putting on a load of washing as well as the dishwasher (if they have a hot water input or can handle hot water at the cold inlet) before going to work.

This way the sun has the first go at heating the water before the booster kicks in at night. If the sun has done its job well the booster may not be required. However, other patterns can work well depending on factors, such as the number of people in the house, the size of the tank compared to this, the type of boosting used and whether it is controlled by a timer, and even the location—areas that require little boosting will allow for water usage at all times.

For heat pumps, it is also possible to put your heat pump system on a timer so that it only runs during off-peak periods, making it cheaper to run. Alternatively, it can be run only during the day to make best use of the energy from your solar power system (this is a low-cost alternative to a PV diversion system if you have an existing heat pump water heater), to improve its efficiency due to the higher ambient temperature, or if compressor noise is a problem at night.
condition, preferably a tank with both top and bottom elements, with the solar powering the bottom element and boosting powering the middle/top element.

### Installation

The installation of any system should be carried out by appropriately qualified and experienced tradespeople to make sure it is properly sized and installed. The Clean Energy Council’s solar hot water and heat pump fact sheet has some useful tips and an installation checklist, see www.bit.ly/CECSHWFS. The ATA, ReNew’s publisher, is also compiling a list of questions to address quality considerations and installation; find them at www.renew.org.au/energy-efficient-hot-water/installer-questions.

### Warranties

The warranties offered on heat pump and solar hot water systems vary from one manufacturer to another and should be carefully scrutinised when buying a system. Generally, the tanks (and collector panels for solar thermal systems) are warranted for five to ten years while the associated valve work will carry a 12-month warranty only. Read the warranty conditions carefully, especially those concerning labour.

### What size will I need?

Determining the required size of a water heater is the most important aspect of system selection. Sizing is a trade-off between cost and performance. A key element of performance is the level of risk of running out of hot water.

The system should be sized for the dwelling, not necessarily its occupants. People sell houses and move on but the hot water system stays. It is generally accepted that each person will use around 50 litres of hot water per day. In a storage system it is good to have 1.5 days capacity. A three-bedroom house can comfortably accommodate four people and so it should have a 300-litre tank, even though it may currently be occupied by a retired couple.

Another consideration in choosing the best tank size is to determine whether the dishwasher and washing machine need plumbed hot water. Increasingly the design of these appliances is tending towards in-device water heating, so household hot water storage requirements may be reduced.

### SOLAR THERMAL

Solar thermal systems are configured as a tank and collectors. The number of collectors or evacuated tubes for a given tank size may vary, depending on climate zone and expected water usage patterns. An undersized system will be a disappointment to the user and will require excessive boosting, increasing running costs and possibly environmental impact. An excessively oversized system will overheat in summer which may damage the system and cause significant dumping of water to relieve the built up pressure.

For the highest proportion of the total energy required to run the system to be provided by solar, choose a winter-optimised collector which is large relative to the tank.

If using an electric element tank, these have both a rated and actual capacity. The rated capacity is the quantity of water above the element: a system sold with a 300-litre tank may have a rated capacity of only 250 litres above the element. However, it will have 300-litre capacity under solar, as this method heats the whole tank. If your system is likely to need considerable boosting during certain times of the year, then you should size for the rated capacity.

The collectors should also be sized based on usage. On average, one square metre of panel (or evacuated tube collector) is required per person, and panels are generally approximately two square metres each in size. This means a 180-litre system will have one collector panel and is suitable for one or two people, a 300-litre system will have two panels and is suitable for three to four people and a 440-litre system will have three panels and is suitable for five to six people, or for a home with more than four bedrooms.

### HEAT PUMPS

With heat pumps, the smallest tank size will nearly always give the lowest energy use, but at the risk of running out of hot water. Often sizing is based on very conservative assumptions, leading to large tanks which might only be required very rarely, if at all.

Since heat pump systems can heat efficiently at any time of day, you may be able to select a smaller tank than required for a solar hot water system; each manufacturer has their own recommendations, so refer to those for guidance.

### PV DIVERSION/DIRECT PV

Solar PV diversion systems are usually used with an existing electric resistive or heat pump system, so it may not be possible to change the tank volume. If you are replacing an existing system because it has reached the end of its useful life, or you are ‘ditching’ gas for cleaner electric water heating, then you have the opportunity to size the tank appropriately. Sizing in these cases is similar to sizing a solar thermal hot water system.

When using PV-generated electricity to heat water directly, it’s important to ensure that your solar array has enough capacity to provide the majority of hot water needs. For example, if you only have a small 1.5kW solar array, and export, say, 3kWh a day on average, then unless you are using a heat pump for your hot water or your hot water needs are very small, you will need to do a lot of boosting at night.

It takes 1 calorie (4.184 joules) to heat 1mL of water by 1°C, so to heat, for example, 300 litres of water by 50°C requires 300 x 50 x 1000 x 4.184 = 62,760,000 J or 62.76 kWh, which is equal to 17.4kWh. This doesn't allow for heat losses from the tank, which can add at least another 2kWh per day. However, it is rare that you will need to heat an entire tank from completely cold, so the actual energy required will usually be less than the theoretical maximum, probably around half.

However, knowing this figure means that you can calculate how much energy might be needed to provide your hot water needs, given the size of your hot water tank and the average tank temperature just before heating starts.
MAKING A CHOICE
Solar, heat pump, PV diversion—which one suits my situation?
A hot water system is a big investment and one that won’t be replaced too frequently, so a household should consider a number of factors when making a choice. The main considerations are the environmental benefits of a system, how a water heater works with their existing power supply, the upfront cost and the cost to run, along with other factors such as reliability, climate and complexity of installation and the system.

WHAT ABOUT THE ECONOMICS FOR A HOME WITH EXISTING PV?
With lower feed-in tariffs in place there is greater value in using your solar electricity on site rather than exporting it to the grid. The biggest opportunity lies in shifting a large energy user, such as water heating, to solar generation hours via a heat pump or a traditional resistive hot water system.

A solar household choosing a resistive electric hot water system would set it to run during the day and use solar electricity to cover it for a good part of the year. The hot water system alone will need at least 2kW of solar to minimise use of grid electricity, depending on your hot water use and location, of course—it will need more in cooler locations, particularly if wanting to minimise grid import in winter months. [Ed note: If you want to discuss the optimal size for your situation, the ATA has a paid advice service that can model energy use and generation for your area over the year; see www.ata.org.au/what-we-do/member-services]

It’s hard to go past a heat pump for energy use though. Heat pumps are up to four times more efficient than resistive electric systems, but cost three to four times as much. In 2016, the ATA 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 and about to lose the premium feed-in tariff. Irrespective of solar system size, the analysis suggested that, given maximum possible use of the solar to run the hot water system, most households would be better off or at least no worse off over 10 years with a heat pump compared to an electric resistive system. (Full report at www.bit.ly/2c8agon).

HOW CAN I DECIDE BETWEEN A HEAT PUMP AND SOLAR THERMAL HOT WATER?
Each type of system has advantages and disadvantages. Solar thermal systems require either a strong or reinforced roof for close-coupled systems, or require regular pump maintenance for split systems.

Integrated (one-piece) heat pumps, being fully ground-mounted and not having water pumps, require neither of these. Split system heat pumps usually have water pumps for circulation between the compressor unit and the tank, but have the advantage that the tank can be inside while the compressor is outside—reducing heat losses from the tank in colder climates and making for flexible installation and ease of adding extra insulation.

Being refrigerant-based systems, heat pumps can require regassing from time to time, although if the system is properly sealed this should not occur any more than every 8 to 10 years. After all, how often do you have to regas your fridge or air conditioner?

Heat pumps can be run on a timer, either to make use of low off-peak tariff prices or to run more efficiently during the day due to higher ambient temperatures or to use excess solar PV—they are more flexible than solar thermal water heaters in this respect.

However, heat pumps must always use electricity, even during summer, whereas solar thermal systems may be completely solar-powered during the warmer months—and in warmer climates, this can be most of the year. In cooler climates, they can still provide good savings, particularly if usage is well managed to suit the solar heating cycle (see ‘Using hot water well’).

In situations where shading is a big problem for solar thermal systems and drastic tree surgery is not an option (or shading is caused by the neighbour’s house), a heat pump may be the best option.

There can be an argument for using heat pumps based on a more even energy usage profile over the year. Comparative energy use examples of heat pumps versus boosted solar thermal can be seen in Figure 1.

WHEN WOULD I CONSIDER DIRECT PV?
Direct PV is a bit like an off-grid system dedicated to heating water, so only works for specific situations. If you’re already on solar then it’s probably more efficient to use that power to run a heat pump or resistive electric system than set up a new stand-alone system dedicated to water heating. However, if you’re grid-connected and can’t add solar panels because you’ll lose your feed-in tariff, then you might consider a direct PV option. And off-grid households with limitations on how they can expand their solar electricity system might consider direct PV.

You might consider a direct PV or a PV diversion system if you have an existing electric storage water heater running from peak rate power (there may be no off-peak rates available) or where installing a solar thermal system would result in long pipe runs or cause other problems. The PV array doesn’t need to be close to the water heater storage tank, as the connection between the PV array and the tank is an electrical one, not hydraulic, so energy losses are minimal.

WHICH SYSTEM SUITS MY CLIMATE?
Certain types of hot water systems are more suitable in some climate zones than others. For
Reliability and simplicity

No one wants a sudden cold shower and a failed hot water system is usually an urgent problem. So which types are most reliable?

A relatively simple choice is a close-coupled solar thermal heater with flat plate collectors. However, being exposed to harsh conditions on the roof, the valves and pipes must be robust and the system must cope with boiling and freezing. The booster heater (e.g. an electric element) introduces complexity, but also useful redundancy. If the solar heating fails, you can still get hot water from the booster. Automatic boosting is nice, but has a downside. If the solar heating fails, you might not realise until you get your next electricity bill! Adding further complexity, in some weather conditions the water might get hot enough for a shower, but not hot enough to suppress Legionella bacteria. So the booster must be operated in a way to eliminate this. Other types of solar thermal hot water introduce extra levels of complexity. If the water tank is at ground level, the pump and its controller become another potential failure point.

Electric resistive water heaters have no moving parts and electric cables are less affected by weather conditions than plumbing. But you're reliant on the electricity grid (unless you have an off-grid or hybrid solar system). A heat pump is a relatively high-tech machine, like a fridge or an air conditioner. But its operation is simple otherwise—there's no boosting required and no plumbing on the roof.

Many hot water failures are due to installation errors. Solar thermal systems are perhaps most prone to this (e.g. Ewan Regazzo's case study later in this issue), so it's important to use a trusted installer. On the other hand, heat pumps are dependent on quality control in manufacture, so a trusted brand and model is crucial.

Consumer reports on reliability vary widely for each of these options. Ultimately the decision may depend on consumer preference and availability of products and trusted installers in your local area. It's best to do your homework early, before a cold shower forces a snap decision!

example, evacuated tube solar thermal systems usually work better than flat-plate systems in colder areas that see heavy frosts and/or snow. In tropical and subtropical areas, both types of system work well, although in warmer regions evacuated tubes can over-produce and the system must be set up to cater for this.

Direct PV and PV diversion system performance relies on the available output from the PV array, which relies directly on solar insolation. For diversion systems, this depends on what other loads are using electricity in the home during daylight hours, so it doesn't just come down to climate. Looking at your energy bills and seeing how much you export each day or quarter, will give you a good idea of the ability of the PV array to provide hot water. Whether this amount will be enough to provide the majority of your hot water needs (you should be looking at producing more than 50% from solar, on average), will depend on your hot water usage. For more information on calculating your hot water energy requirements, see the ‘PV diversion/Direct PV considerations’ section in this article.

There is something of a myth regarding heat pumps and their lack of suitability in colder climates. There are a number of heat pumps available, especially those that use CO₂ as a refrigerant, that are suitable for use in climates with even sub-zero temperatures. So regardless of where you live, heat pumps are almost always a viable option—but check the efficiency curve, which is usually part of the brochure or datasheet (if not, contact the manufacturer or supplier) of the proposed system for suitability in your climate.

One way to compare the climate applicability of systems is to check the number of STCs that apply to the system in your climate zone (for systems where STCs apply, such as solar thermal and heat pump systems). You can find the register of STCs by climate zone at www.bit.ly/HW_STCs. The higher the STCs for your zone, the better.

Note that there are different zones for solar thermal and heat pumps (cold-climate zone 5 applies only to heat pumps), so you will need to separately determine your climate zone for solar thermal hot water and heat pumps.

A table of suppliers and systems is available online at www.renew.org.au/hws-guide-2017

Resources

ATA modelling of heat pump, electric resistive and gas hot water systems is due mid 2017: www.ata.org.au
Solar thermal and heat pump zones and STCs: www.bit.ly/HW_STCs
Energy Ratings hot water systems page including fact sheets: www.bit.ly/ER-HWS
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A tale of two solar hot water systems

Jen Gow has tried out both flat plate and evacuated tube solar hot water systems, and discusses the differences.

Flat plate thermosiphon solar
The first time we used solar hot water was in 1999, when we lived outside of Maitland in the Hunter Valley in NSW. We installed an Edwards flat plate thermosiphon unit with a 200-litre tank on a north-facing roof. The booster ran on a time-controlled circuit that cut power during the evening peak. We used this with a time switch that turned on at 3 pm so that if the tank was under-temperature after the main period of sunlight, it would heat for a couple of hours until the control relay turned the power off (usually sometime around 5 pm). The time switch ensured that we maximised the solar contribution before using the booster. We could bypass the switch if necessary or switch off booster power completely. With this setup we could usually run on full solar for seven months of the year, from late September to late April. The only maintenance the system needed was to occasionally clean dust off the flat plate collector panels.

Evacuated tube solar
When we moved into our current place in the western suburbs of Brisbane in 2008, we installed solar PV power (initially 1.4 kW of panels feeding a 2.5 kW inverter) and a Hills Esteem Solar EB-E22 solar hot water system with a 250-litre ground-located tank linked to a 22-tube evacuated tube collector. The tubes are installed at a 25-degree tilt. The tank and collectors cost $5217 minus rebates for RECs of $1032 and Brisbane City Council Rebate of $400, for a total cost to us of $4307.

The only maintenance issues we have experienced with the HWS is replacement under warranty of the pump controller six months after the system was installed, and more recently we replaced the pump when it failed due to a power surge during a thunderstorm. Replacement by a tradesperson cost around $350.

Initially we ran the booster on the existing HWS off-peak circuit. We had the relay removed and switched the circuit to regular power because our energy supplier had a minimum off-peak consumption charge, yet for most of the year we drew no booster power. With this system we can manage more or less full solar for ten months a year, from mid-July to mid-May. During this period we may have to switch on the booster after three or more overcast days. For the other two months we leave the booster switched on.

I think the superior performance of our current system compared with our old one is partially explained by the greater solar energy available in Brisbane compared to the Hunter region. The evacuated tubes with their insulation and ability to collect solar energy from shallow angles may also be a factor. On hot summer days water in the return line can get as hot as 100 °C, but this hasn’t caused any problems. The water in the tank would be pretty hot, but the hot water outlet has a tempering valve installed to limit the temperature to the taps by mixing in cold water. At the other end of the heat scale, to avoid the possibility of Legionella we have a thermometer probe installed on the return line from the collector. If the temperature drops below 55 °C we switch on the booster, but it rarely happens.

The solar hot water system does a great job supplying more than sufficient hot water for a household of three most of the time, and more if we have guests.
Don’t dismiss resistive element hot water

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 3.6 kW element with a 3kW element because of power constraints in the Immersun. I set the thermostat to 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 3pm to top up the heat. On nearly all days the water is hot well before 3pm (in summer it is commonly hot before 10am 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 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 4.7kWh per day for hot water during 2016. Maybe we would have used 2 to 3kWh per day less if we had used a heat pump.

Next steps

I am planning to install an additional 4kW 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.

How to save money with a hot water heat pump

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.
Troubleshooting issues with solar hot water

Ewan Regazzo’s electrical engineering background put to good use troubleshooting a faulty solar hot water installation. It’s now working well, but there were several issues along the way.

WE HAVE a near-new solar hot water system (SHWS) on our recently built house in East Maitland, near Newcastle in NSW. The system works well now, but it’s been a long road.

Our original intention was to follow our builder’s recommendation and install instantaneous gas hot water. However, during the house design phase, I found a Bosch induction cooktop at a ridiculously low price. This made going all-electric, including solar hot water, more financially attractive—despite the SHWS costing $2000 more than a gas system (after a $1000 rebate).

We chose a Thermann evacuated tube system (TE-250-GL-BOT-22) with a roof-mounted array and a ground-mounted 250L storage tank. The boost is electric (3.6 kW element at the bottom of the tank).

Getting the location right

Unfortunately, there were several installation issues. Firstly, the builder sited the SHWS storage tank where the original gas hot water heater would have gone—at the gas outlet. To keep the water piping between the array and storage tank as short as possible, the array ended up on the eastern roof. Not an ideal situation! The builder agreed to move the array to our north-facing roof, but this got delayed until cooler weather and a suitable time for the plumber. The unconnected array remained on the roof, soaking up the sun’s heat, but not able to transfer that heat to any good use.

But still not working

Finally, the array was moved to the correct location and it was now time to move in. But at this point, close examination of the wiring next to the storage tank showed the roof-mounted temperature sensor was not actually connected to the SHWS controller. There was confusion about whether it was a job for the electrician or plumber, but eventually the sensor was connected and the system was declared operational—array on the northern roof and the controller happily tuning the pump on and off.

Unfortunately, the performance was woeful. Over the next fortnight, despite sunny winter weather, I had to boost every two days. Regular monitoring showed that despite the array manifold heating up, the tank temperature at best remained constant throughout the day and usually dropped.

The plumber came and looked at the system, but couldn’t find anything wrong. Out of frustration I contacted the manufacturer (Apricus, who look after the Thermann brand). A technician came out and together we started fault-finding. The first issue we found was with the adjustable flow valve, which sets the rate at which the water flows through the array manifold. It had been set to zero flow, so no water had been flowing through the manifold—ever! The next issue was a build-up of air in the system, so we went through the purge procedure.

It was with a great deal of excitement that I went to check the temperature after the next day of decent winter sun. My hopes were dashed though, as it seemed there was still little heating occurring.

A problem for an electrical engineer!

To make fault-finding easier, I decided to make a wireless controller to read the controller’s data bus and extract the water tank upper and lower temperatures and array manifold temperature. I could then log this data to help determine what was (or was not) happening with my system—oh, the joy of being an electrical engineer!

With the data logging capability up and running, I began comparing my system to what other people were experiencing with their SHWSs. For most people, once the pump came on in the morning, it would remain on all day until the sun went below a certain angle (or clouds obscured the sun). In my case, the on/off cycling occurred throughout the day, which indicated that insufficient heat was entering the system at the array manifold or excessive heat was being lost in the system through the pipes between the array manifold and storage tank.

I discussed this issue at length with the builder, pointing out that the SHWS had not been installed in accordance with the manufacturer’s instructions. Happily, the builder agreed to remove it and reinstall it. I was also pleased that the local Apricus technician was willing to attend and provide some expert guidance to the plumber.

Here you can see performance of the system on two typical days, one when the system was not working correctly (top) and the other after the faults were corrected. Note in the top graph how the collector temperature was constantly cycling, with very little heat input happening during the day (the lower tank temperature barely moved).
Reinstall becomes reassembly

The day of the reinstall eventually arrived. With the evacuated tubes down from the roof, it became clear what had happened to the system. The heat transfer pipe in each evacuated tube—a small, copper tube filled with a transfer fluid—had completely overheated. The shiny copper surface was almost black and the fluid had managed to leak out due to extreme pressure caused by the high temperature inside the tube. Although the SHWS is designed to withstand full sun and no water flow, it still needs water in the array manifold. The months my array had sat on the roof in the summer sun with no water in it convincingly destroyed those small pipes and rendered the system totally ineffective.

The technician and I replaced the heat transfer pipe in every evacuated tube and reassembled the array. We purged the system and checked that everything was working properly. After months and months, was now the time it would finally work? I sat back in the late afternoon after the tradespeople left and looked at the temperature in the tank. Slowly, it began to rise and finally, six months after moving in to my new house, I had my first sun-powered shower!

The next day I saw the SHWS exposed to a full day of sun. I was reassured to see the manifold temperature stay well above the tank temperature instead of cycling above and below it and the tank temperature solidly rise. When the tank reached 75°C the manifold temperature began to rise rapidly as the pump switched off, the controller had reached the set temperature for the storage tank and water was no longer flowing through the manifold. When enough hot water was used during the day to measurably lower the temperature in the storage tank, the pump turned on and the manifold temperature dropped as water flowed through the manifold again. Finally, it was all working as it should.

It has now been more than two months since the system was reinstalled and we haven’t had to use the booster once. With fairly low hot water demand for showers, dishwasher and occasional white clothes wash, we’re yet to run out of hot water.

As you can see, it’s been a frustrating, but illuminating, journey. I’ve learnt more than I expected about the controller in my solar hot water system and how solar hot water systems work in general. I also gained insight into the workings between different trades and how poorly they sometimes understand each other.

Resistive versus gas

Linda and Mike Dahm were surprised when the energy costs for their dual occupancy homes, one with solar PV and an electric resistive hot water and one with gas hot water, worked out about the same. Here’s what happened.

WE BUILT a dual occupancy in northern NSW: two similar houses with two bedrooms and an office each. The first house was set up with instantaneous gas hot water and a gas cooktop, with an option to add solar panels later. The second house was set up with 3kW of solar panels and a Fronius Primo 3 inverter so that batteries could be added later (when the price falls). We decided to go all-electric with this house. But when we compared the total energy costs for the two houses, they were very similar.

The company who sold us the solar PV setup suggested an 80L electric resistive element hot water system would be enough to meet our needs (2 to 3 adults in the household, with regular visitors since we lived in a holiday area). We decided to get a Rheem 160L but even this size turned out to be too small.

We had the electrician fit a timer so that the hot water system only came on between 10am and 3pm so that on most days it only used electricity from the solar panels. The problem with this was that if we all had showers in the evening, on days when we used the washing machine and/or dishwasher the hot water would run out, usually during the last person’s shower! So we ended up having to manually switch the hot water booster on at times, and then we had to remember to turn it off again, which of course we didn’t always do. So our electricity bills were somewhat higher than we had hoped for.

We used 11 to 14 kWh per day from the grid in the all-electric house with solar PV, with higher usage in winter. The cost of electricity was $3.18 per day in summer to $3.29 per day in winter, plus the supply cost of $1.50 per day. In the house with gas hot water and gas cooktop and no solar panels we used 4 to 8 kWh per day (higher usage in winter). The electricity cost was $1.60 per day in summer to $2.00 per day in winter plus $1.50 per day for supply. LPG use came to approx $1.50 per day.

That adds up to $4.96 per day for energy use in House 1 (gas and electric) and $4.76 in House 2 (all-electric with solar). But in House 2 we still fed back into the grid around 2000 kWh over one year, so if feed-in tariffs improve or we could work out ways to use that excess power produced (installing batteries, not leaving the hot water switched on, etc) we could reduce the energy cost and use of the grid for House 2.

It’s a little difficult to write definitively about our electric hot water setup, as we didn’t stay in the house long enough to sort out the issues. But it is still interesting to look at what we did and what we will change next time. The biggest lesson we learnt for our next house is to buy a heat pump (greater than 160L) for heating our water.

ATA’s energy policy expert, Andrew Reddaway, has this to say:

It looks like your main problem is a too-small tank. The best option when using solar electricity with a resistive element tank is to get a big hot water tank with two elements. You connect the bottom element on a day-time timer or smart switch like Immersun, or one included in the solar inverter (investigate whether your inverter has this function). It heats up the whole tank during the day, mostly from excess solar. The element would need to be sized to the solar system, e.g. a 1.8 kW element rather than the usual 3.6 kW.

The top element can be on a night-time timer, using a cheap off-peak or controlled-load tariff if possible. This will switch on only if the top of the tank is below temperature, which should be rare. And it will only heat up the top part of the tank. This setup should avoid running out of hot water, while minimising use of mains power. For further savings you can add extra insulation around the tank (making sure the safety valves still work and can be inspected). You could also consider adding more solar panels to cover more of your hot water usage.

Several of these case studies were found via My Efficient Electric Home’s Facebook page, a good source of stories and information on all-electric homes and appliances.
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The Pears Report
Don’t mention the war

Tony’s war on renewables may be ongoing, but what has been the effect?
It’s not such an easy war to win, writes Alan Pears.

TONY Abbott did his best to kill off renewable energy when he was PM—and he’s still trying it seems. But it is interesting to look back at the consequences of his efforts. The war on renewables was meant to reduce electricity prices. But it has done the opposite—and a lot more.

The big negative for renewables has been the uncertainty created by the war led to a collapse in investment in large renewable energy projects. And the compromise 2020 large-scale renewable energy target (LRET), reduced from 41,000GWh to 33,000GWh, is now driving much less renewable energy development.

However, even the reduced LRET still means a lot of renewable generation capacity has to be built fast, from a near standing start, to generate 55% more renewable electricity than was produced in 2016, by 2020.

A report for the Clean Energy Regulator (www.bit.ly/CERMTRET) estimates an additional 6000MW of generation capacity will be needed to meet the reduced 2020 target—a doubling of the renewable generation capacity installed since 2001. This has driven up the price of large-scale generation certificates (LGCs) from a long-term price of $30–$40 to $80–$90 (see box).

So it is now very profitable to build new renewable generation capacity under the LRET, and we are seeing a boom. Of course, Mr Abbott can now complain about the high price of renewables—that he caused by frightening investors which, in turn, has led to a shortage of new renewable capacity and LGCs. As in all markets, a shortage has driven up prices.

But Australian media have noticed that renewable energy prices for new generation everywhere else, and in bids for ACT government auctions (which are outside and additional to the LRET), are falling. Without the LRET uncertainty, LGC prices should have been stable or even falling as more new, cheaper generation was built.

Effect on prices
The LRET cost does not appear in wholesale electricity prices; instead energy retailers pay and pass on the cost to their customers—adding up to a cent per kilowatt-hour to retail electricity prices in 2016. Large industrial consumers are largely exempt.

The impact of the war goes beyond the LGC price. Wholesale prices are also higher than they would have been with more renewables.

Today, renewable energy has less capacity to depress electricity spot market prices (the ‘merit order’ effect acknowledged even by Abbott’s hand-picked Warburton review panel) because we have less of it than we would have had. Renewables bid into the electricity market at very low prices, so they tend to replace high-priced generators. The last generator chosen sets the price for all generators operating at the time, so all generators operating make more money when there is less renewable generation available.

On top of this, the government’s failure to effectively manage the gas industry has meant that, when gas power stations are the marginal generators, high gas prices drive wholesale electricity prices sky-high.

Electricity generators, sensing that the media hysteria has done a great job of building a community expectation of higher electricity prices, have also raised their wholesale price bids, further increasing profits—that’s how markets really work: prices reflect ‘sentiment’ not actual production costs!

So the overall outcome of Tony Abbott’s war on renewables has been much higher electricity prices and, after a blip, a booming renewable energy industry.

We also need to remember that inflated network costs (now almost half of retail electricity prices) and, in some states, retailer profits are the big drivers of retail electricity price increases. Many governments have failed to fix that.

And some surprising effects
Some other ‘surprises’ have also emerged.

State governments know that there are lots of votes in supporting renewable energy. And with renewable energy costs crashing (well done ARENA, CEFC and ACT government!) even sceptical treasuries can be convinced that state-level targets and programs make sense. Led by the ACT, state governments are ‘filling the vacuum’ using the ACT auction model.

Increasing numbers of businesses, local governments and universities with high consumer profiles are also installing or funding renewable energy projects because it helps with their image. Image is worth far more than any cost associated with renewables. With declining renewable energy prices (if they buy outside the LRET) and exploding grid electricity prices, renewable energy looks cheap, and provides insurance against future price hikes. An organisation whose customers are concerned about the environment would be mad not to join the rush.

And network operators in rural areas have finally overcome their cultural block, encouraged by declining energy storage costs, and the realisation that they risk being left out in the cold. They are beginning to roll out fringe-of-grid renewable energy and storage, which is much cheaper than extending or even maintaining the grid when you have few customers per kilometre, high resistive losses,
“Most people and business leaders who accept climate science just want to get on with the transition. The business risk is in moving too slowly, not too fast, towards a zero carbon energy future. As is the political risk.”

high maintenance costs, bushfire risks, etc. In Western Australia, the cost of such subsidies has even been recognised by treasurer, energy minister and ex-Institute of Public Affairs anti-renewables campaigner Mike Nahan. He knows he needs fringe-of-grid renewable energy and storage to cut costs.

Independent energy analysts, many large energy companies and some media have reacted by raising the profile of renewable energy, and have presented enormous amounts of factual data that demonstrates even more clearly that an energy-efficient renewable energy future is the cheapest and most likely path to meet our climate obligations and goals while growing the economy. Disappointingly, few have mentioned that energy efficiency is key to minimising energy costs and accelerating change—but I’m used to that.

Policy must reflect reality
Both the electricity industry and business energy consumers want policy certainty. That means policy will eventually have to reflect reality. That’s a problem for anti-climate change, anti-renewable energy politicians. And for those who don’t recognise the significance of energy efficiency.

Mr Abbott’s ongoing efforts to shut down the LRET are causing serious problems for the government, but not for renewable energy. He is just confirming the fragility of national energy policy under the present government, and reinforcing the view that no one can rely on stable federal government energy policy. So the renewables industry will rush to capture the LRET opportunity in the short term, while state governments, business and communities will be even more determined to take independent action.

The ACT’s ‘contract for difference’ approach is actually much better for the long term than the LRET model, as it provides much more certainty for project proponents, governments and other project funders. Project developers bid in auctions, and the cheapest ones receive guaranteed prices under long-term contracts. This approach can also be applied to investing in storage, demand side and ‘system reliability and security’ outcomes. And it could underpin an LRET policy successor beyond 2020.

State Coalition parties will have to distance themselves from Tony Abbott and the federal government, if it doesn’t change policy, or lose votes.

It would have been better for everyone if Tony Abbott had received some reality therapy, and stepped back from his war. But, in the long run, his efforts have cemented progress towards a clean energy future. On the one hand he has incentivised change by making investment in new renewables more attractive, and increasing profits for existing renewable generators, even though this has come at a cost to consumers. He has also provoked states, business and communities to take independent action. On the other hand, he has added to the policy uncertainty that is limiting investment in traditional fossil fuel driven, centralised energy systems. These have long lead times and face increasing business risks from rapid technology change and climate issues.

And most people and business leaders who accept climate science just want to get on with the transition. The business risk is in moving too slowly, not too fast, towards a zero carbon energy future. As is the political risk.

Maybe Donald Trump should look closely at, and learn from Tony’s example. *

Alan Pears, AM, is one of Australia’s best-regarded sustainability experts. He is a Senior Industry Fellow at RMIT University, advises a number of industry and community organisations and works as a consultant.

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What is an LGC?
Large-scale generation certificates (LGCs) are the ‘currency’ of the national RET: they represent the ‘renewableness’ of a MWh of electricity. All electricity retailers have a legal obligation to surrender enough LGCs to match their share of each annual target (see www.bit.ly/L-sRET).

Annual targets are set to progressively increase up to 33,000,000 LGCs by 2020—see www.bit.ly/ATATRPP—with each LGC equal to 1 megawatt-hour. The price of LGCs is set by competitive bidding, just like the stock market, and by long-term contracts between individual generators and retailers. So if there is a shortage of LGCs, competition drives the market price up, which drives up futures’ prices. This in turn drives up the price in new contracts. Energy retailers pass the cost of buying LGCs on to their customers.

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↑ The Abbott Effect on large-scale generation certificate spot prices: if all LGCs were sold at this price, it would add over $10/megawatt-hour (1 cent/kilowatt-hour) to retail electricity prices. The spot price drives the price for new long-term LGC contracts and contract renewals. The cost impact on overall electricity cost is further diluted because in 2016, the number of LGCs required was only 12.75% of total electricity consumption; see www.bit.ly/ATATRPP. Source: www.bit.ly/CERCES
**Q&A**

Do you need ideas for getting around heritage restrictions, what to do with dead solar panels, or how much energy using the internet uses? Ask ReNew your question via renew@ata.org.au.

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**Heritage hassles**

**Q**—
A friend is living in a flat in Newcastle, in a very large, heritage-listed, 19th century woolstore conversion. Their flat is on the west side and the living area windows are well shaded, being deep inside a verandah that is built into the building. Unfortunately, two west-facing bedrooms have windows with no shade at all. The rules stipulate that there be no exterior additions of any kind.

I was asked what would be the most effective way to keep the heat out of the bedrooms, using interior screening. Reflective film would not be allowed as it is visible from outside. The only thing I could think of would be insulating curtains, sealed all round to the walls. Please could you advise what would be the most effective barrier in a case like this?

—Richard Stanford

**A**—
Those are pretty restrictive heritage requirements: there’s not much difference between a reflective material like Renshade or a white blockout curtain. You could look at cellular insulated blinds, such as www.blindsonline.com.au/honeycomb-blinds. These have a silver foil inner core to slow down heat transfer and act as total blackout blinds. The ‘snow white’ version would probably work best. Other options include www.iseekblinds.com.au/honeycomb-blinds.html, www.kresta.com.au/custom-made-blinds/cellular-blinds, www.bit.ly/VBHCBO (which also have the foil lining) and www.honeycombblinds.com.au. There are plenty of others, but not all have the foil lining which I think would be critical here. There are also the Luxaflex Duette blinds, which have multiple pockets but no foil lining. Another option that’s only available from the USA are the dual layer cellular blinds with integrated foil from www.cellularwindowshades.com. There’s a bit of a risk in buying from the USA if you have problems though.

—Lance Turner

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**The cloud’s energy footprint**

**Q**—
Thank you for continuing to produce a quality magazine—it is still one of my favourite magazines! My question relates to the many internet data centres around the world consuming large amounts of electricity (directly and indirectly).

Stephen Graham in ‘When Infrastructure Fails’ writes: "... without the ‘dirty’ world of fossil-fuel extraction, refinement, transport and use, the supposedly virtual worlds of new media—the hail of electrons and pixels on screens—would instantly cease to exist. The internet, covertly, is one of the fastest growing polluters on the planet."

What are your estimates of the carbon footprint of a simple web search, a more complex web search, using Skype for half an hour, viewing a video online for half an hour, or any other internet use?

—Ashley Campbell

**A**—
We don’t have the data on how much each particular action you mentioned uses. However, the total energy consumption of data centres globally in 2015 was around 416 terrawatts (TWh), or around 3% of total energy consumption and around 2% of greenhouse gas emissions, with the amount of energy used by data centres doubling every four years, according to Professor Ian Bitterlin, Visiting Professor, Leeds University (see www.bit.ly/2TIDCEU).

In recent years, there have been considerable improvements in energy consumption in data centre servers, as there has been with all computers—the amount of work done and data stored and served per kilowatt-hour consumed is higher than it’s ever been. But with data growing almost exponentially (the world has gone from sharing 100 gigabytes of data a day in 1992 to 28,000 gigabytes per second in 2013, according to Popular Science, www.bit.ly/IIAHES), the problem is not likely to go away unless there is a breakthrough in data compression and storage, and that isn’t likely as this data is already highly compressed.

Efforts already being used by large data centre operators include housing the centres in cold climates to dramatically reduce the energy used to cool them, as well as running the centres on 100% renewable energy.

Recognised as a big part of the problem are the vast numbers of photos and videos uploaded to social media platforms, and the size of those images, caused in large part by the proliferation of high megapixel cameras in smartphones, with almost every image uploaded far larger than it needs to be. Individual users can help here by reducing the size and number of images and videos uploaded—one suggestion to fix this is a tax on images uploaded to social media, though no government would implement this!

Another issue is the internet of things (IoT). While still in its early days, more and more devices are becoming connected and streaming data constantly to remote servers for storage. This is particularly a problem when that data is video, such as from security cameras.

It’s unlikely this problem is going away, but to manage it we need a combination of better compression, automatic resizing of images and video by apps, improvements in processor and storage system efficiency and the shift to large scale renewables (make it mandatory for every data centre to cover their roof in solar panels, for example).

—Lance Turner

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**Thermoelectrics**

**Q**—
Is it possible for you to enlighten us on the practicability of thermoelectric cooling. I refer to units that are sold for use in automobiles as car coolers. Perhaps you have already done this in an edition of ReNew? Is there a practical way to efficiently maintain the power requirements to run them?

—Billy Lahn
Thermoelectric devices (Peltier devices) are generally quite inefficient. For example, to move one unit of heat, they usually take two or so units of electrical input. Compare that to a compressor system, where the numbers are reversed and usually better as well, for example one unit of electrical input might move three units of heat. So, generally, you are looking at efficiencies of a quarter (or less) those of compressor systems; thus, thermoelectric devices need a much greater amount of energy to do the same amount of cooling.

The other issue with them is that they need to be powered all the time. When you turn the power off, the thermoelectric device becomes a heat conductor, quickly allowing heat back into the cooled compartment. You can reduce the power to the devices using pulse width modulation (PWM) control in order to have them maintain a desired temperature; this enables you to reduce the energy consumption compared to running at full power, but they are still very inefficient.

These devices are commonly used as car coolers as they are cheap, robust and there’s a continuous source of electricity available from the car, at least while the engine is running. But for any system requiring high efficiency cooling, thermoelectric devices aren’t practical. —Lance Turner

Another alternative, if the glass is still intact, is to reuse the panel for another use. Panels are structurally quite strong and have many uses, from novelty coffee tables through to making animal enclosures or window awnings. You can even make small sheds out of them, if you have enough of them. I’m sure readers would have other ideas as well. —Lance Turner

Wood heater wetbacks

Q —
We are building an off-grid house in south-west Australia and have been gathering information and advice on many aspects. ATA membership has been really useful for this. We cannot easily locate, however, makers of ‘fireplaces’ that use heat exchange—allow piping for water to be heated through the fireplace. We are after a lounge-room type fireplace (wood-burning), not a pot belly stove. Would you have any providers you could suggest?
—Heli Donaldson

A —
Wetbacks may be restricted in regular wood heaters now due to emissions laws, but they are allowed in ovens etc. A couple of heaters with this option are the Nectre Bakers Ovens, see www.nectre.com/wood-fired-ovens and the Christo from Metal Dynamics (WISE Living), see www.metaldynamics.com.au. However, a simpler alternative may be a flue heat exchanger and there is an example of one in the Products section of this issue.
—Lance Turner

Inverter or generator

Q —
We are in the process of ordering an off-road van and have a question about the solar setup. The van is being supplied with three 150W solar panels and Victron 100/30 MPPT controller. It does not have an inverter supplied as generators come with them these days. The batteries are three 120 Ah Fullriver units.

The Fullriver is absorbent glass mat rather than lithium. Does it matter what battery type is used for caravanning? Also, is having an inverter on the van not necessary these days?
—John and Robyn Stacy

A —
Not supplying an inverter is a problem. Generators are the most expensive, noisiest and polluting form of power generation. Normally you would include a decent sinewave inverter in the system.

Generally, the aim is to use solar for everything and if you are low on solar input, run the generator to charge the batteries at a high rate until they reach 80% charged or so. This reduces generator use and lets the generator run at a high load, so it runs more efficiently. Running generators at low loads is simply wasted fuel. In a system where generators are used predominantly, generator efficiency, from fuel in to electricity out, can be less than 1%.

Now, having said all of this, it is important to make sure the solar system is sized correctly. There is a trend in the caravan industry to just fit standard systems of a particular size and tell owners to use a genset for larger loads, simply because the solar system was sized incorrectly. This makes it simpler to build systems into vans, but it doesn’t give the owner what they actually need, so it’s important to understand your usage to some degree and adjust the system accordingly, if the van builder allows it, and if not, upgrade it yourself or get a solar installer with caravan experience to do it.

Re battery type, lithium are much lighter for the same capacity, and also more efficient, although AGM are a well-understood tech and you can abuse them a bit more. For lithium batteries, having a reliable battery management system is critical, but if you are satisfied that the system has a good BMS then probably go for lithium as the battery bank will be less than half the weight. —Lance Turner

Recycling solar panels

Q —
I was just wondering if you knew of any company that recycles solar panels here in Victoria. I have contacted the Ballarat City Council but they have advised me the place where they send their recyclable material does not handle PV panels so they would have to go to landfill. It seems a waste, but if there is no alternative at the moment it may be the only option. Any help would be gratefully appreciated.
—Michael Omeara

A —
The only option we know of is Reclaim PV at www.reclaimpv.com; I would contact them to see if they have a collection point near you.
When selecting any service provider, get two or three quotes and check accreditation/references.

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DR WENDY Miller and her husband Ray have been part of the ATA family since 1997 when a renewable energy subject at the local TAFE made them keenly aware that what they were doing now impacted on their children’s future. As a family of five, they decided to try to get their all-electric house’s stationary energy consumption down to one kilowatt-hour (kWh) per person per day. This meant renovating their hot 1970s house as finances allowed: installing ceiling insulation, changing roof colour, adding external window shading, purchasing energy-efficient appliances when replacements were needed and installing solar hot water and solar PV.

Over time (about eight years) this resulted in a reduction in electricity consumption from 22 kWh per day to 5.7 (with four adults): about 1.4 kWh per person per day. For a short time their solar PV system (installed in 2000) was even an officially registered power station on Australia’s energy network! Wendy remembers: “That was an interesting time at the start of the rooftop solar revolution. I remember, perhaps not so fondly, the robust discussions with government and the network to get ‘permission’ for our system to be connected. But it did lead, a number of years later, to being invited to Queensland’s feed-in tariff discussions as a consumer advocate.”

In 2008, as ‘empty nesters’, Ray and Wendy took advantage of a move to the Gold Coast to take their sustainability drive to the next level and construct their 9 Star ‘eBay House’—so called because much of the construction and fitout (including the kitchen sink!) was purchased secondhand.

Wendy talks proudly of the rainwater collection, water and waste recycling system, the rooftop solar system and revegetation of the once bare block to not only produce food, but to support indigenous native plants and encourage bird, marsupial and reptile life. Energy-wise their total daily consumption is about 4 kWh per day—and all of that is well and truly met with their 1.7kW PV system. “I’m really pleasantly surprised at how the price of solar has decreased: in 2000, a 1.5kW system cost in the vicinity of $16,000. Now you can buy a system three times as big for a quarter of the price!”

However, she is quick to state: “The more you do, the more you realise what needs to be done.” In terms of the built environment she says that we need to think differently, and question just why Australia has settled on the standard “two adults, two kids, granite benches and air conditioning” type house. “I’ve got nothing against granite benchtops,” Wendy says, “but ideally we should focus first on getting the building envelope as good as we can, rather than focusing on bling and gadgets. If your house is designed and constructed well, it (like a boat) should not be leaky. Like a bilge pump, the air conditioner should be considered a ‘safety mechanism’ for extreme events, not an everyday item to make up for poor quality design and construction.”

Her career as a senior research fellow in energy efficiency and housing at the Queensland University of Technology has meant exposure to the world. In Europe, she’s seen new approaches to designing housing for non-traditional groupings, such as communities of single people all buying together, or collectives of families leading their own residential development. In the USA there is the Tiny House Movement.

Wendy believes the ATA and its publications provide essential services. Apart from the chance to share an idea or ask a question, the ATA is a voice for the people, a chance to be heard at governmental level, she says. Wendy was a long-time Brisbane branch member and convenor, before shifting down the coast.

As the weather heats up, and other houses’ ‘bilge pumps’ get switched on, in eBay House Wendy and Ray are walking the talk, now sailing their ‘boat’ into their grandchildren’s future.

Wendy and Ray’s grandson, Costa, is a major driver of their passionate involvement in sustainability: “CO₂ from our activities will remain in the atmosphere for at least 70 to 100 years and therefore affect future generations, with the accumulated CO₂ changing the climate perhaps irreversibly.”
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