ReNew

Technology for a sustainable future

Issue 138

SUMMER DIY PROJECTS

SPECIAL FEATURE

100% renewables

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Rooftop evolution

Your greenest options

PLUS

Window shading buyers guide

Zero-waste on Lord Howe

Vertical gardening

Issue 138 January–March 2017
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Water wise DIY: wicking beds
Creative gardening: reuse materials
Earth bricks: make your own
Timber finishes: tricks & traps

WIN a home battery storage system from Enphase

*Australian and NZ residents only; details p85

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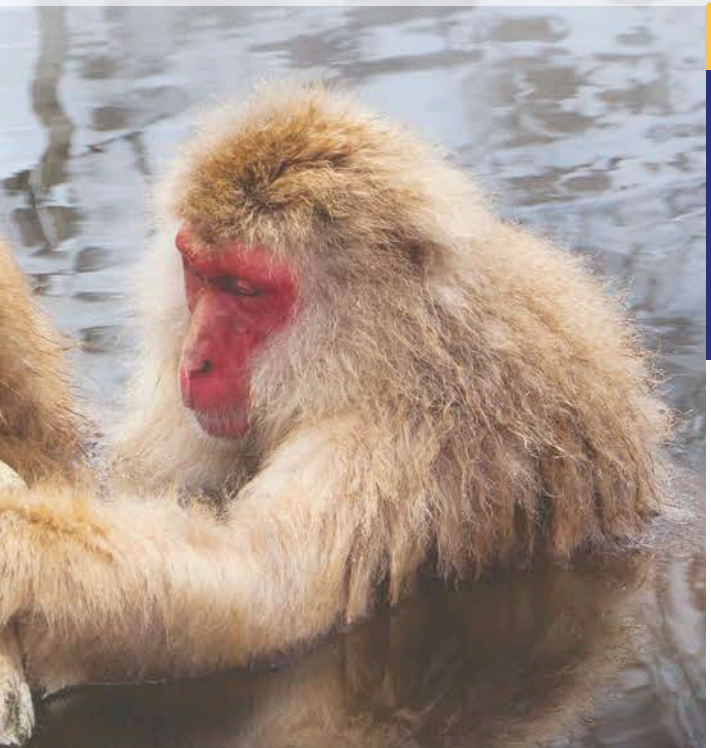

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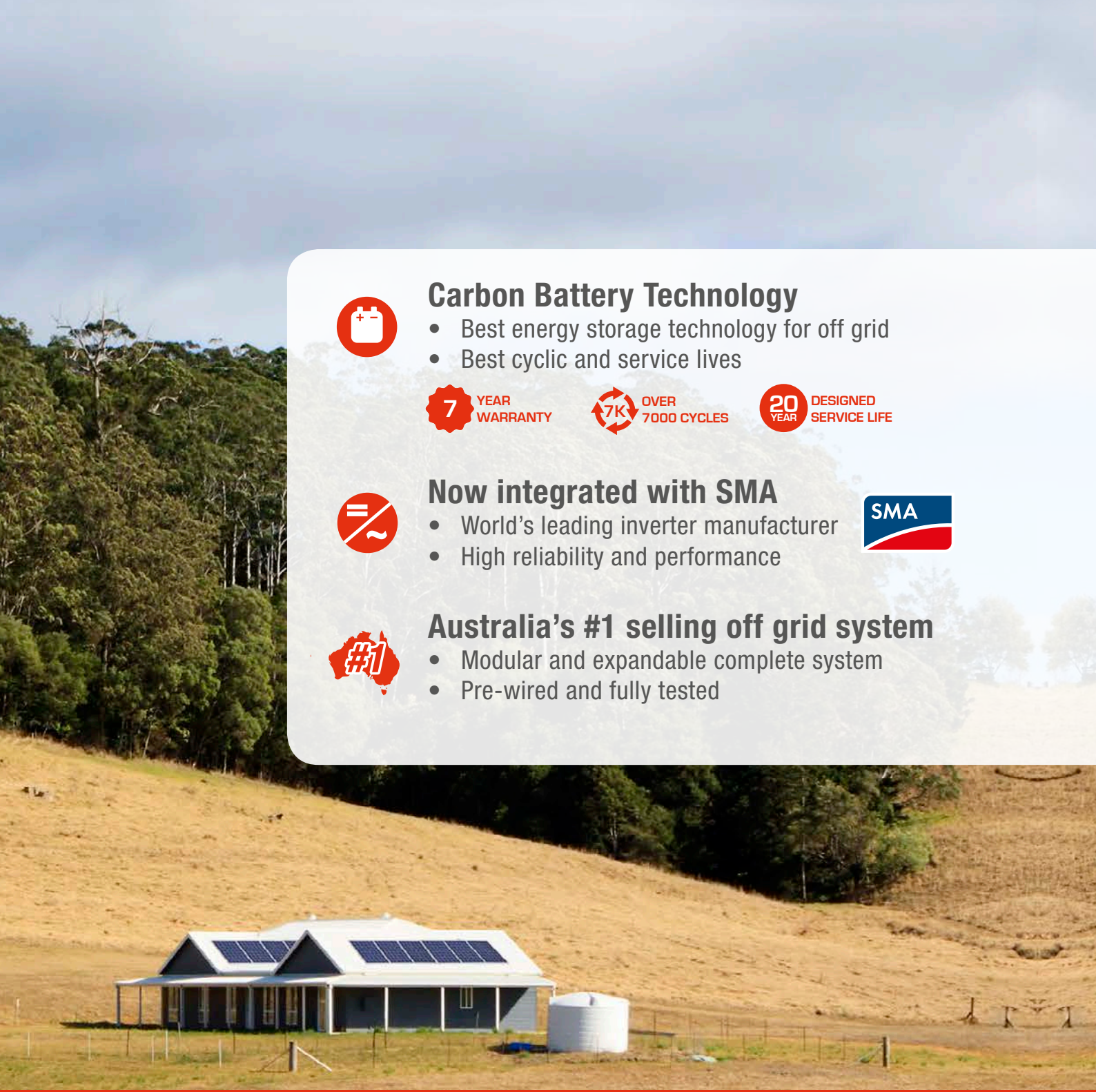

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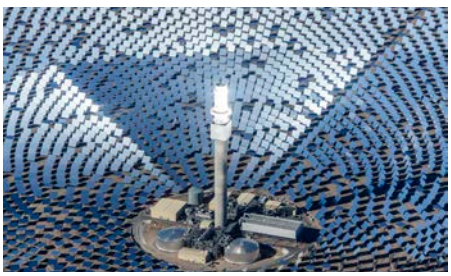
Energy transitions

Sustainable islands, 100% renewables, greener roofs + more



↑ Concentrated solar thermal as part of 100% renewables for Australia? Page 22.

↑ Islands leading the way in sustainability. Pages 30, 33 and 36.

↑ EVs can go anywhere, particularly when tourist destinations begin to provide charging stations. Page 44.

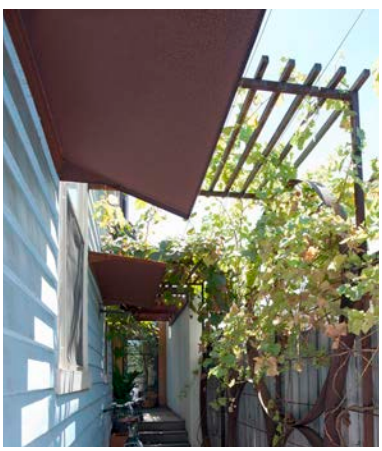
Features

↑ Reduce, reuse, recycle: start a zero-waste movement at your local shops, Page 40.

↑ Vertical gardens: making gardening possible in small spaces and apartments. Page 48.

← **Cover image: Photo by Nic Granleese, house and rooftop garden by Nest Architects**
This issue a lot of our themes come together in our cover image. We take an in-depth look at greener roofing—just what are the important considerations when you're planning the roof over your head? Of course, one option is literally a green roof, like this lovely one from a house design by Nest Architects. Roofing article starts page 52. The solar roofs on the cover also tie in nicely with our special feature on the feasibility of 100% renewables in Australia. Energy experts at the ATA (*ReNew*'s publisher) look at answers to the oft-cited challenges of intermittency and grid stability in a transition to renewables. It's a must-read that helps correct misconceptions and suggests a planned transition is both possible and necessary. We also look at several islands where a transition to renewables is already well underway.

Building materials special



↑ Shade your windows and possibly your walls to keep your house cool. Page 74.

Guides

External shading buyers guide

Reader projects

↑ Solar roofing tiles are getting the Tesla attention, but they've been around for a while. Page 52.

Regulars

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

Alternative Technology Association

The Alternative Technology Association (ATA) is a not-for-profit organisation that enables, represents and inspires people to live sustainably in their homes and communities. Established in 1980, the ATA provides expert, independent advice on sustainable solutions for the home to households, government and industry.

ATA has over 6100 members across Australia walking the talk in their own homes. ATA also conducts research on sustainable technologies and practices, and advocates to government to make it easier for other Australians to live sustainably.

Become a member of the ATA and gain access to a large support network of knowledgeable people and receive a range of services to help you achieve your sustainability dreams. Your ATA membership provides you with benefits such as our free expert advice service, subscription to *ReNew* and/or *Sanctuary* magazines, free access to back issues online and discounts in the ATA webshop and on other green products and services.
www.ata.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 examines three sustainable display homes, including a tiny house in Brisbane. a prefab, off-grid island stunner, tips on using concrete slabs and incorporating clever storage in your home, through to tree selections and green facades. 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 recently commenced three new advocacy projects including: investigation into the introduction of contestable metering around Australia; the impact of the introduction of cost-reflective network pricing in 2017; and an update to our 2014 gas versus electricity modelling, this time including the use of solar PV to drive further cost and carbon reductions for all-electric homes.
www.ata.org.au/what-we-do/advocacy

International projects

ATA's International Projects Group (IPG) has just completed a two-year project to install 600 household solar systems in villages in Timor-Leste, bringing the gift of light to 4249 people. Read the full article in Up Front on p13.

With support from donations, ATA can continue installing solar-powered lighting and USB chargers in the thousands of homes in East Timor that are not connected to the electricity grid. You can make a big difference in people's lives by giving the Gift of Light this Christmas at shop.ata.org.au/gift-of-light
www.ata.org.au/ipg

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Contributions are welcome; guidelines available at www.renew.org.au or on request. Next editorial copy deadline: 20 January 2016.

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Advertising is available for products and services relevant to our audience. We reserve the right to refuse, cancel and withdraw advertising at our discretion. For enquiries email adverts@ata.org.au or call (03) 9631 5412.

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Editorial

Looking up: What's on your roof?

WHEN it comes to sustainable building, there's a lot of material to cover, so we're making our way around the building process, bit by bit. Having previously looked at 'what's in a wall' (in *ReNew 132*), this time we're hitting the roof.

We delve into the various roofing materials and their sustainability, along with the importance of roof pitch, insulation and colour to a house's thermal performance. We also look at green roofs, with great resources for finding out more on this home/urban cooling option (with a lovely leafy example featuring on our cover).

With 1.5 million roofs in Australia also housing solar panels, it could be argued that our roofs (and communities) are leading the way in a renewable transition for Australia. But that's not been without its naysayers and challenges, so ATA expert Andrew Reddaway tackles the issues and solutions needed for a successful shift to 100% renewables. It's a must-read to correct misconceptions about how renewables work with the grid, particularly given the recent blackout in South Australia and discussions around the closure of Hazelwood.

As well as roofs, we also consider windows—or at least ways to shade them. With a warmer than average summer on the cards, it's a good time to make sure your home will cope as well as possible in the heat. Keeping the sun off your windows is an important first step, but it's not always as simple as putting up a blind. In our external shading buyers guide, we look at how to get it right: which windows to shade, how much shade, what materials to use and should shades be fixed, adjustable or even removable to avoid excluding the sun when you need it.

Gardens also provide a cooling benefit, and vertical gardens are a way to get greenery in places where that might not otherwise be feasible. Gardening in pots can be tricky though, so we feature two successful examples, with the message from both being to experiment to get the right plants, and that automatic watering is a must. The other message is that the owners love having herbs and greenery right at the back door!

We hope our article on reusing building materials in the garden will inspire you to find ways to source preloved bricks, concrete tiles or other materials to use for both practical and creative purposes in the garden. The author has been working with high school students to build a permaculture garden from mostly reused materials—and we get to benefit from their ingenuity and enthusiasm with some great examples to copy at home.

Of course, there's much more besides: an EV owner's insights into charging, including the knotty issue of kerbside charging for those without driveways, DIY wicking beds using a waste product, an introduction to timber finishes, islands leading the way in sustainability, DIY pressed earth bricks, and much more! We wish you a happy and safe holiday season and look forward to hearing from you in the new year.

Robyn Deed
ReNew Editor

IT HAS been a whirlwind past few months, with major shifts in global politics like the recent election of Donald Trump as US president and the Brexit vote causing great uncertainty in the area of climate policy.

Thankfully there was a firm commitment from the countries attending the Marrakech Climate Change Conference in November to show the world that the implementation of the Paris Agreement is underway, and the constructive spirit of multilateral cooperation on climate change continues.

While the Australian Government announced ratification of the treaty at Marrakech, it is still unclear how at a federal level we will achieve our carbon reduction commitments. Several states and territories including the ACT, Vic, SA, Qld and NSW are taking the lead, setting more ambitious targets and other mechanisms to combat emissions.

So much uncertainty and change once again highlights the role the community needs to take in not only advocating for effective government policy but getting on with the job. And we need to make sure everyone in the community comes along on the journey.

There is no better example of practical sustainability than community renewable energy. There are now more than 80 community energy groups and 50 projects up and running across Australia. In February 2017, these groups will be gathering in Melbourne for the second Community Energy Congress to share information, develop skills, foster new networks, celebrate success and plan for action. The ATA is proudly one of the organisers of the conference and we look forward to seeing you there. For more information, go to c4ce.net.au/congress.

Donna Luckman
CEO, ATA

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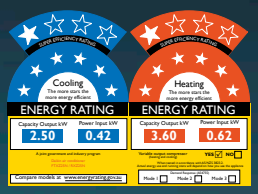

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Up front

A hotter, drier Australia

In late October, the Bureau of Meteorology (BoM) and CSIRO launched their biannual report, State of the Climate 2016. It revealed that Australia's average surface air temperature and surrounding sea temperature have both increased by around 1°C since 1910. Extreme heat events and fires have increased, while rainfall has decreased in the south and increased in the north. Our oceans have warmed and become more acidic. These trends are all set to continue, bringing increased drought and very hot days, and fewer very cool days.

Another report just published by Australian researchers in the Bulletin of the American Meteorological Society has also predicted that the extreme global temperatures of 2015 will become normal by 2030. And as for Australia, that record-breaking summer in 2013 will just be the average come 2035.

Australia's independent Climate Council emphasised that climate change was the key driver behind many of the trends in the BoM/CSIRO report, and Climate Councillor Professor Lesley Hughes said, "Australia's emissions reduction target of 26% to 28% on 2005 levels by 2030 is not sufficient to protect Australians from worsening heatwaves, bushfires and other extreme weather events."
www.climatecouncil.org.au, www.bom.gov.au/state-of-the-climate, www.bit.ly/2gtXKla

Our climate is what you eat

As part of a comprehensive study of greenhouse gas emissions caused by food production, RMIT's Associate Professor Karli Verghese and Dr Enda Crossin, together with Lancaster's Dr Stephen Clune, have compiled a 'league table' of the carbon footprint of different fresh foods, showing which have the greatest impact on our planet.

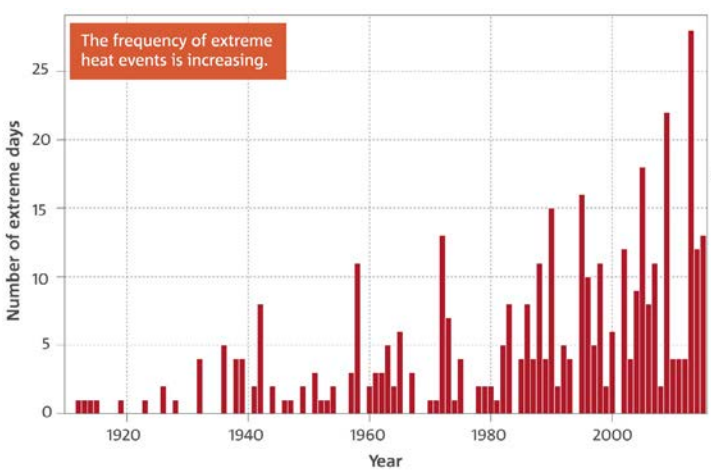
Their report finds that grains, fruits and vegetables cause the lowest climate impact, followed by nuts and legumes, non-ruminant meats like chicken and pork, and ruminant meats like lamb and beef.

As examples, one kilogram of greenhouse gas emissions comes from about 50 medium onions, 20 medium apples, 1 kg of lentils, 800 ml of milk, 290 g of salmon, 244 g of kangaroo or 44 g of Australian beef. Using this information can help caterers and home cooks reduce the environmental cost of their meals, by replacing red meats with other meats, or with plant-based protein sources like lentils and nuts.
www.bit.ly/2eVUoak

Search for pumped hydro sites

ARENA is funding ANU researchers to map potential locations for short-term off-river pumped hydro energy storage (STORES) sites. Each site needs a pair of reservoirs at an altitude difference between 300 and 900 metres, joined by a pipe through hilly terrain. Water will be pumped to the upper reservoir using surplus energy, to be released downhill to provide electricity on demand.

The Atlas of Pumped Hydro Energy Storage Study will prepare a blueprint and cost model for the integration of STORES technology into Australian electricity grids. The ANU's Professor Andrew Blakers said that the low cost and "beautifully engineered" pumped-hydro technology could allow PV and wind energy to reliably reach penetration



→ The growth in extreme high-temperature events between 1910 and 2015. These are the days in the 99th percentile of the mean temperature for that day.

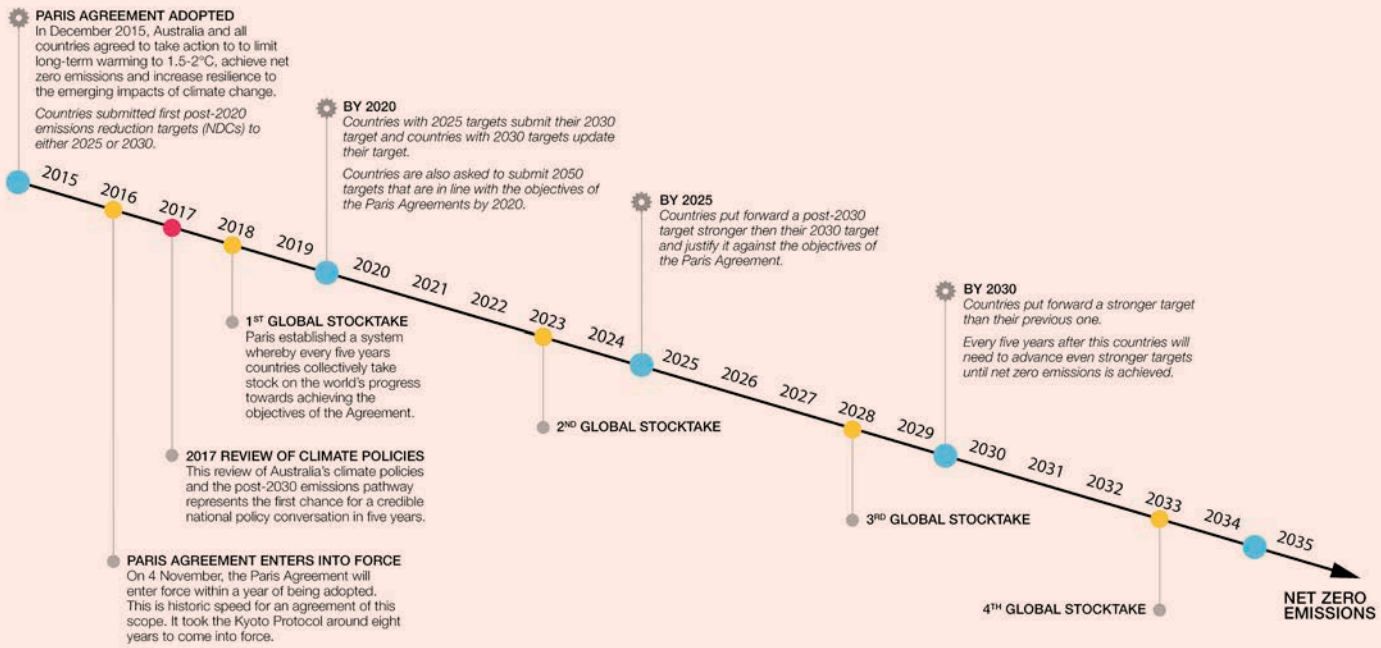
Source: Reproduced by permission of CSIRO Australia, © CSIRO

Climate progress (on paper) at COP22

As part of the implementation of the Paris Agreement, the COP22 follow-up meeting was held in Marrakech, Morocco, in November. Some progress was made, with numerous countries ratifying the document, the UN establishing a 2050 platform designed to provide accountability and assistance to countries, cities and companies, and the Climate Vulnerable Forum (48 countries representing one billion people) issuing their Marrakech Vision to achieve 100% domestic renewable energy.

The Declaration for Health, Environment and Climate Change was also signed by more than 24 global health and environment ministers, to increase health and environment bodies' cooperation and reduce pollution-related deaths, estimated by the World Health Organization (WHO) at 12.6 million deaths annually. Over half (6.5 million) are from air pollution.

Australia ratified the agreement on 10 November. Deputy CEO of The Climate Institute (TCI), Erwin Jackson, welcomed the step and urged the government to "review its 2030 emissions targets with a view to ensuring they are consistent with limiting global warming to 1.5 °C to 2 °C, and set long-term targets to achieve net zero emissions before 2050." The TCI report *COP22—Getting to Zero* also calls on the Australian government to release its 2030 emissions projections this year as promised, and ensure the 2017 review will consider credible policy to help grow a net zero emissions economy before 2050. www.climateinstitute.org.au



↑ The Climate Institute sets out the timeline for compliance with the Paris Agreement, aiming for net zero emissions by mid-century.

Source: The Climate Institute 2016, COP 22 —Getting to Zero

levels above 50% and push towards 100% renewables. The inertial and spinning reserve, which stores energy and can be ready to react at a moment's notice, will help support grid stability as it permits very fast ramp rates from zero to 100% in minutes. This is in comparison to the tens of minutes required for gas systems, or the hours required for coal.

The cost of STORES power is estimated at less than 3c/kWh over and above the cost of buying the PV and wind, which covers the costs of the pump, hydro plant and spilled wind (when the grid operator tells wind farm operators to reduce output because of reliability or other constraints), PV and high-voltage DC transmission, for a total of less than 9c/kWh. Regular reports will be provided until the study is completed in June 2018. www.bit.ly/2eVYdMW

New Zealand EV incentives

While the rest of the world pushes forward on adopting electric vehicles, Australia is feeling like very much a backwater. Even the popular Nissan Leaf is no longer available new here.

At least our NZ neighbours have seen the light, with New Zealand Energy and Transport Minister Simon Bridges stating: "It's clear that electric vehicles are the future. A move from petrol and diesel to low-emission transport is a natural evolution, and it is our aim to encourage that switch sooner, rather than later".

To enable the transition to EVs, New Zealand has announced a target of doubling the number of EVs on their roads every year, aiming for 64,000 EVs by 2021. There are also a number of incentives provided, including an exemption on road user charges on both light and heavy electric vehicles until EVs make up 2% of all vehicles in both categories; a move for government departments to buy EVs for fleets; supporting the development and rollout of public charging infrastructure, including providing information and guidance; a $1 m (annually) nation-wide EV information and promotion campaign for the next five years; a contestable fund of up to $6 m per year to encourage and support innovative low-emission vehicle projects; allowing EVs to use bus and high occupancy lanes on highways and local roads; a review of tax rates to ensure EVs are not unfairly disadvantaged; and establishment of an electric vehicle leadership group across business, local and central government. Oh, for an Australian government this forward thinking! www.bit.ly/NZ-EVs

Up front

Diversifying global energy mix

At the 23rd World Energy Congress held in October, the UN-accredited World Energy Council reported that renewable-based power generation accounted for 23% (5559TWh) of total worldwide power generation (24,098TWh) in 2015. Hydropower represented the lion's share at 71% of renewables, together with 15% wind energy, 5% solar and 9% biomass, geothermal and others. Total renewable-based power capacity doubled in the last decade to reach 1985GW. There has been strong growth in both investment and capacity, as well as high growth in developing countries. Most nations have shown a more diversified energy mix, as well as growth in community ownership and the evolution of microgrids. www.worldenergy.org

Cloud prediction for smarter renewables

Two projects backed by the Australian Renewable Energy Agency (ARENA) are showing the world how solar power and cloud prediction technology can be brought together to supply cheaper, more reliable renewable energy.

SunEdison Australia recently completed a $7.3 million, 1MW solar installation at Karratha Airport in WA, with $2.3 million ARENA support. The City of Karratha has entered into a 21-year agreement to buy power from the solar plant and is expected to benefit from lower electricity costs over this period.

A separate ARENA project, Fulcrum3D's CloudCAM solution, is operating at the site, tracking clouds and optimising the amount of solar power produced at the airport.

CloudCAM employs ground-mounted cameras to track and predict cloud movements and shadows. Combined with control systems developed by MPower, the technology makes solar cheaper and reduces intermittency by giving the operators a clearer picture of the solar resource they can expect in the immediate future. This helps the Australian Energy Market Operator decide when they need to look for other sources of generation or use demand management. www.bit.ly/2giSyhK

Image: Shane Lo

→ Brookfield Energy Australia will provide cooling to the University of Technology Sydney in a district energy system, popular in Europe but rarely seen in Australia.

District energy system to cool UTS

The University of Technology Sydney (UTS) has signed an agreement with Brookfield Energy Australia to receive cooling thermal energy via thermal-delivery pipes from their Central Park development across the main thoroughfare, Broadway, as part of a district energy system which could catalyse further efficient cooling in the area, and in other Australian cities.

By consolidating system construction and supply in one power centre rather than in each building, district energy can improve energy efficiency. The chilled water supply in the Central Park thermal plant comes from absorption chillers powered by grid electricity and cogeneration (gas-fired electricity with waste heat to the absorption chiller).

Around 62% of UTS's total electricity usage goes to heating, cooling and ventilation. While Brookfield's residential customers have peak usage on evenings and weekends, the university's high demand comes on weekdays and hot afternoons in February and November. UTS will purchase chilling energy requirements for a 15-year period and the contract is due to be implemented in 2018. www.bit.ly/2fwh5Oy

Clarification

In our guide to renewable energy training in *ReNew 137*, some of the courses mentioned under the heading 'TAFEs and RTOs' were general interest courses not provided by RTOs; please refer to the online table at www.bit.ly/2fGSlra for all information on course accreditation.

Daikin winner!

Julian Bowker is the happy winner of our recent subscriber prize. He wins a Daikin US7 super-efficient air conditioner. Subscriber prizes are open to subscribers and ATA members current at the time of the prize draw; terms and conditions at www.ata.org.au/prize. Our new prize is an Enphase Home Energy Storage Solution; details page 85.

Image: Flex

↑ The 1MW solar array at Karratha Airport uses CloudCAM to predict the array's output in real time.

Bringing light and power to rural Timor-Leste

The Alternative Technology Association (ATA) has just completed a two-year project to install household solar systems in villages in Timor-Leste. Wrapped up in October, the project was undertaken with two local partners, Centro Nacional de Emprego e Formação Profissional (CNEFP) and the NGO Natiles, who managed the project on the ground. The project was made possible thanks to funding from Google Impact Challenge 2014, four East Timor Friendship Groups and generous ATA donors.

After running pilot programs in two villages in 2015, a total of 607 household solar systems were installed in 12 villages between November 2015 and October 2016. The systems are located across three East Timorese districts: Aileu, Viqueque and Baucau. Each house has an average of seven residents, so the custom-designed Village Lighting Systems (VLS) have had a direct impact on around 4249 people. In each village, Natiles liaised with the community, providing training to a management committee and helping them set up their own maintenance fund for the lighting system, while CNEFP trained 30 local technicians to install, maintain and repair the systems into the future.

The VLS was designed in-house using the Google funding to create a simple, tamper-proof, easy-to-fix system that's suitable for conditions in Timor-Leste. Participating villagers pay a US$10 installation fee, followed by a monthly subscription of US$2, to be held by the management committee to fund ongoing maintenance and repairs. This monthly payment is less than the cost of candles and kerosene families previously used. The change to clean energy also improves participants' health, particularly children at risk from respiratory illness. Lighting has been installed inside and outside the front of each house, and each household also received a USB-rechargeable torch on a wristband.

Villagers' access to VLS—called 'Lampu Diak' or 'Good Light' in the Tetun language—gives them increased connectivity (as they can charge mobile phones via the USB port) and more productive time in the evenings to work or study. The electric lighting makes the villagers feel protected from spirits which are about after nightfall, and particularly increases the safety of women.

Image: Susanna Rossi Photography

→ Rileu householder Maria Martinez turns on her electric lights for the first time.

Over the course of the project, the ATA has worked closely with the Timor-Leste Government and with the United Nations Development Programme (UNDP) on the future of Timor-Leste's renewable energy system, to ensure better coordination, planning and shared learning in renewable energy projects. Thirty-five per cent of Timorese households still have no access to the power grid, and the ATA's contributions to date have made it an important player in the renewable power sector.

The ATA's International Project Manager Kate Greenwood is pleased and relieved that this complex project has been completed so successfully. While previous ATA projects in Timor-Leste involved sending around 50 solar systems to Timor, this one involved an enormous scale-up to 800 systems.

The ATA is proud that it empowered local organisations to lead the project on the ground, and as Kate said, "You're actually at the forefront of building a country, which is quite daunting but also quite exciting." Future projects are currently being planned for Timor-Leste.

The ATA would like to thank our local partners, CNEFP and Natiles, for managing the project on the ground, and also the ATA volunteers who helped: Michael O'Connell who delivered training and mentoring to CNEFP; Lisa Weber and Ben Purcell who went to Viqueque; and David Tolliday and Maja Gajic who went to Aileu. Lisa also developed the solar mapping database and Alan Hutchinson the VLS technology.
youtu.be/nXAL6SHsNx8, shop.ata.org.au/gift-of-light

Image: Susanna Rossi Photography

↑ CNEFP-trained technician Julião de Jesus, explaining the lighting system to Lourdes Ximenes Moniz and her household in the village of Rileu in Remexio, Aileu.

Letters

Article suggestions

Two articles in the most recent *ReNew* made me think of suggesting topics perhaps worth exploring in a future edition.

Page 22 mentioned students visiting Carnegie Wave Power and them wanting to invest in the company. This made me think an article on 'investing in renewable energy companies' might have merit and be of interest to readers.

Secondly, the article on EVs (p26) and the storage trial (p34) made me wonder what sort of battery technology was being used and how recyclable were they? For example, lithium batteries are said not to be recyclable. Does this mean they cannot be recycled, that recycling them is currently uneconomic or a recycling regime is yet to be set up?

Peter Cook

Just to note that we had an article in *ReNew 137* on lithium battery recycling, with one company now doing this in Australia, and several doing it offshore. Thanks for the ideas and we will keep them in mind for further exploration.

Robyn Deed

DIY off-grid

I have been living off-grid for 30 years and have microwave, washing machine, computers, fridge, a workshop, welder and lights. I use local wood for heating and hot water. My total investment for a one person plus visitors household has been about $11,000 for equipment, and installation by me.

The system is still growing and I have learnt a lot. The 85 amp regulator for 2000 W of solar panels can still be bought for about $130 if you shop around. The Tomahawk or Powerstar7 inverter (which also can be grid-tied) can still be bought for $600 for the 3000W (9000W surge) model. I use four 256 Ah GMS batteries which have been maintenance-free for five years and are still performing like new. They are in a 24V DC system and at $2600 they were and still are great value for money and reliability. They have actually dropped in price since 2010.

Installation can add to costs, so learn a little, become independent, and save a lot. In a remote installation especially, like mine, to pay for or obtain service can be impossible. It just takes an open mind, and a bit of initiative.

So, gang up with the people in your street, town or suburb and just do it. Australia can close most of its coal and gas power.

Kay Schieren

Quitting the grid

In response to 'Should I quit the grid?', (*ReNew 137*), I report my own experience. In May 2014, I installed a 3 kW solar photovoltaic system and purchased a Mitsubishi Outlander plug-in hybrid electric vehicle. I have collected data since that time on the energy flows from the solar panels, to and from the grid, to the car, including petrol, and to the house. I also have data for the previous year, allowing me to do a before and after comparison.

In summary, I cut my CO_2 emissions by 54% and reduced the cost of energy by $1300. The emissions are reduced because of the solar panels. The money is saved because I avoided buying 925 litres of petrol—which will pay for my solar panels in three or four years. Why do I attribute emissions savings to the solar and not the petrol? In Victoria, emissions from brown coal electricity roughly balance emissions from petrol. Saving the 925 litres is offset by the grid electricity of 1.9 MWh used to charge the car.

Peter Horan

Distributed network costs

Electricity distribution is increasingly controlled by big corporations, and yet many environmental NGOs endorse future top-down low-carbon fixes which put ever increasing market power in the hands of this monopoly supply conduit. Private power companies are not public-spirited entities.

Gandhi fought the egregious British salt monopoly by walking to the seaside to gather salt. Australia's home owners now have to turbocharge a mass movement to bring effective demand-side competition to bear on an overpriced national grid. Distributed network service providers' crumbling infrastructure in the sprawling suburbs is already overvalued. Energy industry regulators apparently still think that mains electricity is an essential service, ignoring the fact that efficient households can be self-sufficient all year round. Therefore mains electricity is no longer an essential service in many locations.

The Productivity Commission cannot say "off-gridders must pay for local poles and wires" if home owners can demonstrate economically efficient bypass of the monopoly. A High Court case or a class action may result from attempts at over-extended reach of market power. More here for a fresh take on negawatt empowerment, on or off the grid: www.bit.ly/2gwfKHB

Michael Gunter

A happy reader

I just got *ReNew 137* and you must have been reading my mind. In fact for at least the last three or four issues you have had articles addressing exactly the questions I've been researching. You've had battery tech, off-grid electric vehicles, lithium battery recycling, home UPS and an inverter buyers guide...Brilliant! Actually, *ReNew* is the best magazine I've ever read. I even love the ads! Thanks to you all for the impressively thorough and practical research and information.

Mishael J

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.

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BayWa r.e. renewable energy are fast becoming the world leaders in solar PV, wind, bioenergy and geothermal energy generation and are ideally positioned to meet one of the biggest challenges of our generation: delivering reliable and clean energy. For more on the BayWa r.e. renewable energy network please visit: **www.baywa-re.com**

solamatrix
clean energy systems

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

MPPT charge controller with Bluetooth

If you are setting up a DC-coupled battery-based solar energy system, then it makes sense to get as much energy from the panels into the battery bank as you can. Maximum power point tracking (MPPT) charge controllers can harvest more energy from the solar array than can a series charge controller.

The SmartSolar MPPT charge controller range from Victron Energy (a more advanced version of their BlueSolar range that we looked at in *ReNew 135*) includes models with maximum array input voltages of 150 V (the 150/85 and 150/100 models) and 250 V (the 250/85 and 250/100 models), with battery charge currents of 85 and 100 A. This allows for array powers of up to a huge 5800 W with battery voltage selectable from 12, 24, 36 and 48 V.

The units come with inbuilt Bluetooth connectivity, remote control capability, a configurable output relay, an optional plug-in LCD, fully programmable charge algorithm with eight pre-programmed algorithms, full electronic protections, and the ability to adjust the MPPT voltage setpoint to cater for partial array shading.

The regulators are available with either screw terminals or MC4 terminals for the solar array connections.

RRP: POA. For more information, contact Victron Energy, mleeftink@victronenergy.com, www.victronenergy.com

02

Beautiful inside, hardy outside

Well-sealed double- or triple-glazed windows can considerably improve the thermal performance of a home. Timber windows look nice, but they can be a high-maintenance item when the timber is used outside.

Paarhammer has addressed this issue with their Wood-Alu range of windows and doors, which feature the warmth of timber on the inside and low-maintenance powder-coated aluminium on the outside. This eliminates the need for exterior painting and will extend the life of the window frames compared to all-wood frames.

The Wood-Alu range is available with double or triple glazing and a variety of glass options and timbers, including FSC-certified wood. Frames are custom-made for each installation with the aluminium component available in a range of colours. The internal timber can be factory spray-painted in a variety of stains or solid colours to suit your design.

The range provides U-values from a low 0.9 (R1.1, excellent for a window of any type), no draughts and low air infiltration from 0.05. Noise reduction values of up to 42 dB are possible. The Wood-Alu range includes tilt-and-turn windows, fixed windows, hinged doors, French doors and sliding doors (with bifold doors coming soon).

RRP: POA. For more information contact Paarhammer Windows, ph: (03) 5368 1999, mail@paarhammer.com.au, www.paarhammer.com.au

03

Go with LEDs outdoors too

While most indoor lighting is changing to LEDs, the range of LED outdoor lights has been a bit more limited, mostly cheap Chinese import fittings of variable quality.

Philips has released a range of LED floodlights designed to replace halogen floodlights in the 100 to 1000 W range. The floods come in 30, 50 and 70 W units with 2600, 4300 and 6000 lumen outputs respectively (so around 86 lumens per watt), with a nice 4000 K neutral white light output. Beam angles are 30° vertical and 80° horizontal, so they direct the light in a flat plane to optimise brightness levels on the ground.

The lights are designed to keep the LEDs running cool, even in high ambient temperatures, and the fittings are IP65-rated, making them water- and dust-proof. They are also 4 kV surge protection-rated, making them resistant to failures from mains voltage spikes.

Dimensions are 193 x 143 x 38 mm, 270 x 202 x 43 mm and 316 x 234 x 45 mm, and the units weigh 0.6, 1.2 and 2.0 kg respectively. The lights have a 30,000-hour rated lifespan (to 70% of original light output), which is around 20 years if used for four hours a day, every day.

RRP: POA. For more information and to buy, contact Reduction Revolution, ph: 1800 611 322, www.reductionrevolution.com.au

04

High-efficiency inverter

Inverters just keep evolving, and the HD-Wave series (available early 2017) from SolarEdge is definitely pushing the boundaries.

Using a high-frequency switching topology, the inverters have smaller magnetic components and the new energy conversion system has allowed SolarEdge to replace the weakest link in most inverters—the electrolytic filter capacitors—with much more reliable thin-film capacitors.

An added bonus of the new topology is an increase in conversion efficiency to over 99%, resulting in almost no waste heat. This means much smaller heatsink requirements and an ambient temperature operating range of -20 to 60 °C (derated after 50 °C).

Other features include a 155% solar array oversizing capacity, optional built-in meter with ±0.5% accuracy, an optional self-sustaining power outlet capable of supplying up to 1.5 kW backup power without batteries, and backwards compatibility with existing SolarEdge systems. Connectivity is via RS485, and ethernet, with ZigBee, wi-fi and cellular options available.

The inverters come in a range of output capacities from 2.2 to 6 kW and they are all the same size, measuring 450 x 370 x 174 mm and weighing just 11.5 kg including the safety switch.

RRP: not yet set. For more information contact SolarEdge Technologies, ph: 1800 465 567, australia-info@solaredge.com, www.solaredge.com

05

Hot water from excess solar electricity

Solar diverters monitor your solar system's electricity generation and send excess production to the element in an electric water heater tank instead of to the grid for a shrinking feed-in tariff. However, most diverters cost close to $1000.

The Solar iBoost+ diverter from Marlec in the UK works like other diverters, but costs a great deal less. It has a battery-operated sensor that measures the current flows into and out of the house and transmits that data to the control unit mounted near the water heater. When current flows out into the grid, the controller feeds the appropriate level of power to the tank element, just balancing the excess PV generation.

The iBoost+ has two outputs for dual-element tanks (or two separate tanks), a programmable timer to allow you to heat water at the most appropriate time, an override switch for boosting, LCD and LED displays, and an optional remote display, the iBoost+ Buddy. It has also recently received C-Tick approval, so can be used in Australia.

While the European iBoost+ has a 3 kW maximum output, the Australian version has been specifically designed to work with a standard 3.6 kW tank element. The Solar iBoost+ must be installed by a qualified electrician.

RRP: not yet set, an Australian distributor is to be appointed soon. For more information, go to www.solariboost.co.uk

06

Heavy transport going electric

Despite the dearth of EV offerings here in Australia, if you need a new truck up to 15 tonnes GVM (gross vehicle mass) then you're in luck.

SEA Automotive has two models, the EV10, rated from 9 to 12 tonnes, and the EV14 with a 15 tonne GVM. Both have the same drivetrain, using a 140 kW continuous output (240 kW max) permanent magnet motor which produces up to 2000 Nm of torque. This is powered by a lithium ion battery bank which can be charged at up to 22 kW and can be charged in less than six hours.

Top speed is electronically limited to 100 km/h on both models, with a range of up to 180 km per charge.

The trucks have all the usual features of modern commercial vehicles, including heating and air con, ABS, air-suspended seats etc.

If you are looking for something smaller that you can drive on a regular car license, there is also the E4V cargo van, with a GVM of 4495 kg and a 100 kW (200 kW/1100 Nm max) motor and also a 180 km maximum range—perfect as a city delivery vehicle.

RRP: POA. For more information contact SEA Automotive Pty Ltd, 90–94 Rodeo Drive, Dandenong, VIC 3175, ph: (03) 9706 8489, enquires@seaauto.com.au, www.seaauto.com.au

Products

07

Trinabest PowerCube batteries

We have been seeing a rapid increase in the number of domestic energy storage systems of late, and one of the most recent is the PowerCube range from Trinabest, a spin-off of Trina Solar, the largest solar panel manufacturer in the world.

The PowerCubes come in two models, the 4.8 kWh PowerCube mini and the 7.2/9.6 kWh (depending on whether it is fitted with three or four battery modules) PowerCube 2.0. Both units use lithium iron phosphate cells and are designed to provide on-grid energy storage with mains-fail backup capability, when combined with the Trina PowerBox inverter.

The AC-coupled batteries not only provide grid backup, but can also sell energy back into the grid at appropriate times. They have a rated round-trip DC efficiency of 92.5%, IP54 sealing, so can be mounted outside, and they come with a huge 10-year warranty.

Connectivity is via CAN (controller area network) and RS485 serial interfaces, with a working temperature range of -10 to 50 °C, making them suitable for most areas of Australia, provided they are located in shade outdoors. Weight is 65 kg for the mini and 95/120 kg for the 2.0. The batteries are available in a range of colours.

RRP: To be announced. For more information, contact the sole distributor, MPower, ph: 1300 733 004, info@mpower.com.au, www.mpower.com.au

08

Hybrid solar bore pumps

Solar pumps are great, but they don't work at night unless the system includes batteries. The hybrid solar pump from Commodore Australia is a solar pump powered by solar during the day and by AC power (mains or a generator) at night.

The hybrid solar pump uses a variable-speed motor that can adjust motor speed from 500 to 3400 rpm depending on the power input and the load. The brushless permanent magnet motor, developed especially for the hybrid pumps, features 304/316 stainless steel housings and impellers. A built-in electronic controller contains both a frequency converter and motor controller, allowing the pump to be set to operate at any operating point in the range between the pump's minimum and maximum performance curves.

The hybrid pumps are ideal where you want to use solar panels to do the majority of pumping, while still retaining the ability to pump water during dark hours—such as for domestic water supplies or providing water to stock troughs.

RRP: POA. For more information contact Commodore Australia, 20 Callister St, Shepparton VIC 3630, ph: 1300 669 256, sales@commodoreaustralia.com.au, www.commodoreaustralia.com.au

09

Prevention is better than cure

Plate sulphation is one of the biggest killers of lead-acid batteries. It is caused by inadequate regular charging or storing the battery without regular top-up charging.

Recharge battery revitalizer and conditioner is a phosphoric acid based liquid that you add to the cells of flooded cell lead-acid batteries to prevent permanent sulphation from occurring. It is designed to dissolve sulphation deposits, returning the sulphur ions back into the electrolyte, preserving battery capacity and extending battery lifespan.

While touted as a sulphation preventative, Recharge can also be used to bring back batteries that are failing due to excessive sulphation, although a completely dead battery will probably have crumbling plates and shorted cells, so no treatment will likely resurrect it.

Recharge is available in three pack sizes: the 100 mL bottle (treats one truck or three to four car batteries), the 500 mL bottle treats five truck or 18 to 20 car batteries, and a two-litre bottle for those with many batteries or large battery banks to treat. A car battery can be treated for as little as $5 to $6.

RRP: NZ$28 for the 100 mL bottle, $90 for the 500 mL bottle and $320 for the two-litre pack. Available from a number of outlets in Australia and New Zealand (the two-litre pack is also available by mail order). For more information and to find a local dealer, go to www.recharge.net.nz or email info@recharge.net.nz

10
Recycled plastic furniture

Replas has been making recycled plastic products for many years, but most of their products are more oriented towards commercial applications.

The Brunswick outdoor chair and table set is just as suited to domestic uses, and is available with bar stools, bar seats, plus a table which can be freestanding or fixed. The furniture is available in five colours for both slats and frame—black, brown, grey, blue and green—so you can specify them to your preferred colours. The slats are a solid 40 x 65 mm profile, making the furniture very robust. The setting is easy to clean and virtually maintenance-free and should basically last forever.

The stool/seat height is 740 mm while the table stands 1040 mm high. Weight is 20, 25 and 45 kg for the stool, seat and table respectively.

Another neat piece is the Laguna outdoor lounge, which features a galvanised and black powder-coated steel or stainless steel frame and recycled plastic slats (40 x 65 mm) in brown, grey, blue or green.

The Laguna is 1800 mm long and weighs a hefty 80 kg, so it isn't going to blow away easily and can simply be left in place.

RRP: POA. For more information and to buy, contact Replas, ph: 1800 737527, sales@replas.com.au, www.replas.com.au

11
Fusion Power

Well, not quite just yet, but the Titan SmartStorage System from Fusion Power Systems is a fully integrated energy system with battery backup for solar-powered homes.

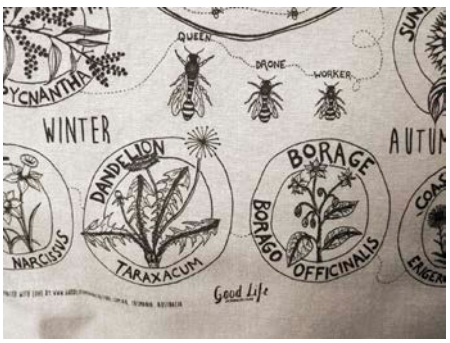
The Titan combines Aquion Energy's 48 volt saltwater batteries with an Australian-made inverter and charge controller to provide a complete energy system in a box. It is suitable for both off-grid homes and grid-connected homes—to allow self-consumption, rather than feeding excess solar energy into the grid.

The Titan is available in three models, the Titan 1, Titan 3 and Titan 5, with inverter capacities of 1.2, 3.5 and 5 kW respectively. The units are supplied with two, four or eight batteries (with maximum capacity being four, eight and 12 batteries), with storage capacities of four, eight and 16 kWh. Maximum solar array sizes are 1.5, 3 and 6 kW respectively.

Maximum solar input voltage is 140V, so if you have an existing grid-interactive system that uses a high-voltage solar array configuration (most domestic grid-interactive systems) then reconfiguration will be required.

The Titan is available in two enclosure types, Atlas (seen on right of photo) or Pallas. Each enclosure can house up to four batteries, so larger systems will require more than one enclosure.

RRP: POA. For more information contact Fusion Power Systems, ph: 1300 911 365, info@fusionps.com.au, www.fusionps.com.au



12
Educational tea towels!

Tea towels are not something most people give much thought to, but maybe we should. Good Life Permaculture has a range of tea towels with detailed educational designs that do more than just dry the dishes.

The monochrome designs were inspired by organic gardening and permaculture principles, and cover five topics—flowers for the honey bee, making sauerkraut, working with and looking after chickens in the garden, the wonders of making and using compost, and how to prune a fruit tree. There's also a colourful poster, printed on uncoated, recycled 300 gsm paper, titled 'Recipe for a good life', which is a simple reminder of the important things in life.

The tea towels are 100% organic cotton, oatmeal in colour, made in India and are 70 cm x 45 cm. The image is designed and drawn by Good Life Permaculture and printed with water-based ink in Hobart, Tasmania.

RRP: $20 for the tea towels, $15 for the poster, plus postage (they ship worldwide). For more information and to buy (via Good Life's Etsy store), contact Good Life Permaculture, 390 Huon Rd, South Hobart TAS 7004, hello@goodlifepermaculture.com.au, www.goodlifepermaculture.com.au

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- Electric or gas boosted models available.
- Prices include all the valves required and freight to almost anywhere in Australia.

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- Strong 2-mm thick stainless steel frames.
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- Subsidised freight to almost anywhere in Australia.
- Electric or gas boosted models available.

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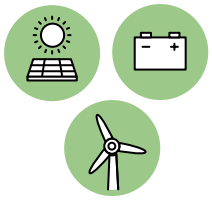


With ongoing discussion by government and media about the effect of renewables on the grid, the ATA's Andrew Reddaway and Damien Moyse consider the feasibility of 100% renewables for Australia.

THE ATA (*ReNew*'s publisher) supports a transition from fossil fuels to renewable generation in Australia's electricity grid. As well as being important to meet our international commitments to fight climate change, this brings other benefits such as improved local health outcomes, greater energy security and more jobs.

However, as this transition progresses we must ensure the grid remains reliable and avoid economic hardship. How can this be achieved as we approach 100% renewables? This article considers the challenges of relying on intermittent generation, ways to address those challenges and a plan for moving forward.

Photo: Flickr user Takver, licensed under CC BY-SA 2.0

↑ The Anglesea coal mine and power station has recently closed, with Hazelwood to follow soon. In the absence of renewables, substantial investment would be required to rebuild or renovate these old assets.

The challenge of intermittent generation

OUR AGEING COAL-FIRED GENERATORS

The average age of a coal-fired power station in Australia is nearly 30 years, and some are operating beyond their design life. For example, Hazelwood started up in 1964. In the absence of renewables, substantial investment would be required to rebuild or renovate these old assets.

Coal electricity's current low wholesale price (about 4 to 5c/kWh) is possible because these power stations were paid off decades ago. Energy from a newly-built coal generator would cost more. The best estimates for future costs are in the Australian Power Generation Technology Report (www.bit.ly/2fPnLdt), which estimates that the average cost of electricity over a new coal plant's lifespan (excluding decommissioning) is about 8c/kWh. Allowing for profit margins, the price would be even higher. This report also found that new power stations fuelled by natural gas will have a similar cost, assuming they are of the most efficient type.

WIND AND SOLAR: THE FRONT-RUNNERS

Wind and solar farms are the cheapest renewable options, generating electricity at around 10c/kWh and 14c/kWh respectively, averaged over their lifespan. Those costs are for 2015, and they're dropping fast, expected to reach around 7c/kWh and 8c/kWh respectively by 2030 (see Figure 1). Operating costs are very low (the fuel is free!), so the dominant factor is capital costs, calculated assuming an 8% cost of debt. Money can currently be borrowed more cheaply than this, assisting new renewable generators to commit to sell electricity below 8c/kWh in Australia and below US5c/kWh overseas.

(With such prices for electricity generation, you may be wondering why you're paying 25 to 35c/kWh for electricity from the grid. The bulk of your bill pays for other factors such as poles and wires, retail billing costs, profit margins etc.)

The main drawback of wind and solar is that they operate intermittently, depending on weather conditions. However, their generation is very predictable using short-term weather forecasting and cloud tracking techniques. Some people worry about the energy required in construction, but modern turbines and panels recoup this very rapidly. For more information, see 'How green is my solar' in *ReNew 135*.

Tidal and wave power are also intermittent renewable energy sources, but their development lags far behind wind and solar.

BASE LOAD VS PEAKERS

Fossil fuel power stations are often called 'base load' generators, meaning that they are not intermittent and can be dispatched as required by the grid operator ('dispatchable'). This is a very useful feature, as our current grid has almost no capacity to store electricity and must be balanced minute-by-minute. The term 'base load' originally referred to the grid's minimum demand for electricity that was always present. Traditionally, coal-fired power stations preferred to never shut down, so electricity demand at quiet times was incentivised; for example household electric hot water tanks would switch on around 1am. Relatively modern coal generators do have reasonable flexibility, such as Loy Yang A which can halve its output in less than an hour.

Natural gas is another fossil fuel that can be burnt to generate electricity. Some gas power stations are reasonably efficient and operate as 'base load' generators. Other types are different: cheap to build, but expensive to run because their efficiency is low so they require a lot of gas. These are referred to as 'peakers', because they can respond quickly to supply demand peaks when called upon by the grid operator. Although these power stations sit idle for most of the time they are still profitable, because they only operate when the wholesale electricity price is high. Hydroelectric generators are also commonly used as 'peakers'.

A CLOUDY, CALM WEEK

The main challenge for renewables is to supply an extended period when wind and sunlight are scarce. In response, plans for 100% renewables tend to employ a mix of solutions. A partial answer is to simply build extra solar panels and wind turbines to maximise generation when the resource is weak. However, dispatchable forms of renewable energy are available.

Hydroelectric generation from large dams is a big, existing, dispatchable renewable electricity source but has little expansion potential as few suitable sites exist in Australia.

A useful dispatchable generation option is biomass, using plant material such as crop stubble, sawdust and woody waste. For example, sugar processing plants have generated electricity for over 100 years by burning sugar cane residues (bagasse) left over after sugar extraction. To mitigate transport costs, biomass can be made into pellets. This fuel can be sustainable as long as the plant material is regrown thoughtfully. Alternative uses for biomass must be considered: if this organic material is normally returned to the soil, taking it for energy instead could eventually degrade the land. Farmland can be used to create renewable liquid fuels, for example ethanol from sugar or wheat, and biodiesel from oil crops. However, heavy use of such biofuel is problematic as it competes with food production.

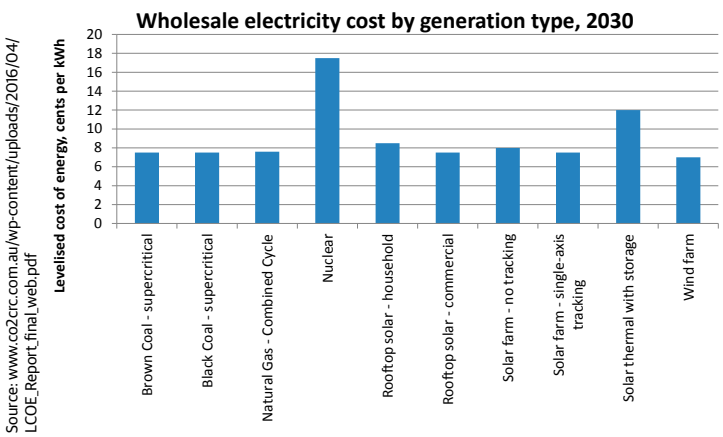
It's already common for landfill sites to collect methane gas (known as biogas) that leaks from the site and burn it to generate electricity. This gas could be captured from many more sources, such as sewage treatment plants and farms. Burning this methane has an additional environmental benefit because if it's allowed to escape unburnt to the upper atmosphere its greenhouse effect is much more potent than carbon dioxide. Biogas can also be created from biomass.

Geothermal power plants draw energy from underground heat sources; Birdsville's electricity is partially supplied this way. Massive resources of deep 'hot rocks' exist in central Australia and Victoria, but the pilot projects run over the past few years to harness this power have not been successful.

Ways to cope with intermittent generation

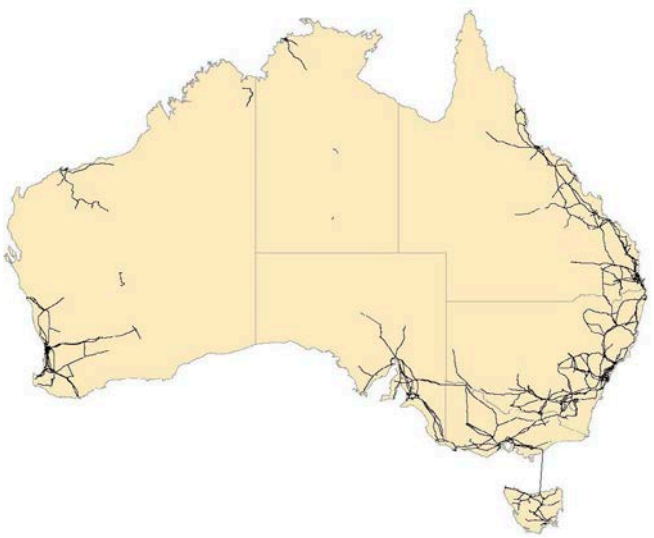
CONNECTING THE STATES

Australia is well endowed with wind and sunshine—the entire continent is never cloudy and still simultaneously. The intermittency problem can be mitigated by dispersing wind and solar farms around the country and sharing their generation. Originally each state's electricity grid was separate, but in recent decades they have all been interconnected to the National Electricity Market (NEM) except for WA



Source: www.co2crc.com.au/wp-content/uploads/2016/04/LCOE_Report_final_web.pdf

↑ Figure 1: Renewable costs similar to coal by 2030? A comprehensive study in 2015 by the CO2CRC and CSIRO found that costs of renewables are dropping fast. This simplified chart shows the mid-point of the range for estimated 2030 levelised costs by generation type.



Source: Commonwealth of Australia (Geoscience Australia) 2015

↑ More inter-connectors needed? One way forward to support renewables is to increase the number and capacity of connections between states. Transmission lines as at 2015 are shown here.

Photo courtesy LMS Energy Pty Ltd

↑ Biogas collection at a landfill site in Hampton Park, Victoria. It's already common for landfill sites to collect methane gas (known as biogas) and burn it to generate electricity. Burning this methane has an additional environmental benefit because unburnt it's a much more potent greenhouse gas than CO_2.

and the NT. Presently the interconnecting cables are few and their capacity is small, so each state can only export a fraction of its generation at any time.

Tasmania is a good example. It has huge generation potential from the 'roaring forties' winds that blow over its land mass and smaller islands. But it's connected to Victoria by just a single cable that failed in 2016 (taking six months to repair) and also failed during a 35 degree heatwave in 2009.

South Australia's grid has only two connections, both with Victoria. To share renewable generation more widely, new interconnectors have been proposed to NSW and QLD. Some plans include connecting WA to SA.

ENERGY STORAGE

It is possible to store energy and then use it to generate electricity during a cloudy, calm period. The biggest existing store of renewable energy is rainwater held in large hydroelectric dams. Few of these can recycle their water; after flowing through and turning the generator it heads away downriver. Ideally this water would be captured in a lower dam and then pumped back to the upper level at windy or sunny times.

You don't have to dam a river to store energy using pumped hydro. According to the Melbourne Energy Institute, the best option is to build a dam on a tall hill or cliff. This height creates strong water pressure, enabling significant energy to be stored with a relatively small dam. Suitable sites are plentiful, and the theoretical cost is $200 per kWh of usable storage capacity. When added to a solar farm, a dam to store five hours of generation would increase the system cost by about 25%.

Concentrated solar thermal (CST) plants collect and store energy like an enormous solar hot water system. Mirrors reflect and concentrate sunlight, heating a fluid such as molten salt up to 300 to 1000 degrees Celsius. The fluid is stored in an insulated tank; when required, the heat boils water into steam to spin an electric generator. This technology has been proven, notably in the USA and Spain, and at Liddell in NSW. Electricity from a plant built in 2015 with six hours of storage is estimated to cost about 24c/kWh averaged over its lifespan. This is projected to halve to 12c/kWh by 2030.

Batteries can be used to store energy either in central locations or distributed close to the point of electricity consumption. Household batteries for solar systems currently cost around $1200 per kWh of storage capacity, which is expected to drop to around $700 by 2030. Larger batteries for industrial and commercial use are cheaper.

Biomass pellets and biogas can also be stored for later electricity generation. In a 100% renewable scenario, biogas could be stored and distributed in the pipeline infrastructure currently used for fossil gas. Renewable electricity can also be used to produce hydrogen gas from water, to be used in vehicle engines, for heating buildings or used for electricity generation later on.

"When added to a solar farm, a dam to store five hours of generation for pumped hydro would increase the system cost by about 25%."

ENERGY EFFICIENCY

Australia has an opportunity for huge bill savings from reduced energy consumption, and this becomes imperative in a 100% renewable world. Heating buildings in southern states is especially important, as this consumes large amounts of energy at times when sunshine is scarce. Retrofits such as draft sealing and insulation pay for themselves very quickly, and are one reason why an average German household consumes only about half as much electricity as an Australian one. Efficiency keeps German residential electricity bills small, even though their tariffs are relatively high. Modern reverse-cycle air conditioners are now the most efficient and cheapest way to heat buildings, fitting in well with renewable electricity generation.

Commerce and industry make up about 70% of Australia's electricity consumption and measures have already been identified for substantial reductions in this sector's energy use.

FLEXIBLE DEMAND

We expect an instant response when we switch on most appliances, but some electricity consumption can be postponed or brought forward to suit available generation. Timers on electric hot water tanks can be changed from night-time to daytime, as is already happening in Queensland. Swimming pool water must be filtered, but this can be done at any time of the day.

Electric vehicle (EV) charging is also a good opportunity, as most people only use a fraction of their car's battery capacity each day. Cars can be plugged in to chargers while parked in home garages or car parks. Drivers could nominate their preferences, perhaps paying less if they allow more flexibility in charging time. If EV chargers can avoid peak times for demand on the grid, their additional electricity consumption will help smooth out peaks and troughs in grid demand. This might even the reduce the tariff you pay for each kilowatt-hour due to economies of scale from higher consumption.

Large opportunities for demand response exist in industrial processes.

What about grid stability?

Even when generation is plentiful, an electricity grid can be blacked out by a brief disruption. The grid operates like a team of people pedalling stationary bicycles to power a building. If some bikes suddenly disconnect (e.g. if their electricity connection is severed), the remaining generators will immediately feel extra resistance and their cadence will slow.

If you look at the label on a household appliance, you'll probably see the term AC for alternating current. This means that electricity is alternately pushed from the grid into your house, then sucked back again in the reverse direction. The frequency of this direction change is 50 cycles per second, or 50 Hertz (Hz), which is the heartbeat of the grid. From Cairns to Melbourne to Adelaide, electric generators and motors spin precisely synchronised to this pulse.

Generators can be damaged if the grid frequency slows below 48 or 49 Hertz, so if this occurs they may switch off to protect themselves. These shutdowns (or 'trips') place extra resistance on the remaining generators, causing further disconnections and a blackout. To keep grid frequency stable, some generators run their turbines below full power, reserving generation capacity to jump in and inject extra electricity as soon as a drop in grid frequency is detected. Part of our electricity bills pays for this service to keep the grid stable, sometimes referred to as 'frequency control ancillary services' (FCAS) or 'spinning reserve'—payments amount to about 1% of the wholesale trade in electricity.

A coal-fired power station that shuts down unexpectedly can create a large disruption to the grid. In recent years coal generators have been closed by bushfires, flooding and coal quality issues. If the grid were instead served by a larger number of smaller, widely-spaced generators, the potential shock would be reduced.

Grid stability is assisted by generators that have heavy spinning parts synchronised to the grid frequency, such as fossil fuel and hydroelectric turbines. Due to their inertia it takes significant energy to start such turbines rotating, but once up to speed they similarly resist slowing down. Thanks to inertia, frequency slowdowns due to grid disruptions occur more gradually. In an emergency the frequency might take 0.5 seconds to drop from 50 to 49 Hertz, rather than 0.2 seconds if the grid had less inertia. This provides sufficient time for protective mechanisms such as FCAS to kick in.

ARE WIND AND SOLAR REDUCING GRID STABILITY?

The blades of modern wind turbines are not synchronised with the grid's frequency. Instead, rotation speed is constantly adjusted to harvest maximum energy from prevailing wind conditions. And solar panels have no rotating components at all. So how can wind turbines and solar panels generate electricity compatible with the grid, pulsing at exactly the right frequency? They use clever electrical components to convert their "asynchronous" generation into electricity with a suitable alternating current. A modern wind generator's electrical output is decoupled from its mechanical input. The blades and hub may weigh over 20 tonnes and rotate 20 times per minute, but this mechanical inertia is not readily available as electrical inertia.

As wind turbines and solar panels replace fossil-fuel generators, overall levels of inertia in the grid are falling. If not managed, this trend could reduce grid stability and make blackouts more likely in the future. Industry is well-aware of this issue, as described in AEMO's 'Wind Integration Studies' in 2011—2013.

Generators are not required to have inertia, but they must be able to tolerate grid faults that arise. For example, if the grid voltage drops to zero for a fraction of a second, standards require a generator to have resilience to 'ride-through' the fault and keep operating, assisting the grid to recover. Similarly, if the grid frequency dips temporarily, the generator must continue operating. Wind and solar farms are installed with smart electrical components to comply with these requirements. The South Australian 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. AEMO, along with other organisations, has been studying future grid stability in detail since late 2015.

"Electricity from a concentrated solar thermal plant built in 2015 with six hours of storage is estimated to cost about 24c/kWh averaged over its lifespan. This is projected to halve to 12c/kWh by 2030."

SMARTER GENERATION NEEDED

There are many possible solutions to maintain grid stability as levels of wind and solar generation increase. One simple expedient to maintain inertia in the grid is to retain steam turbines within decommissioned fossil fuel power stations. They would remain connected to the grid and continue to rotate in synch with

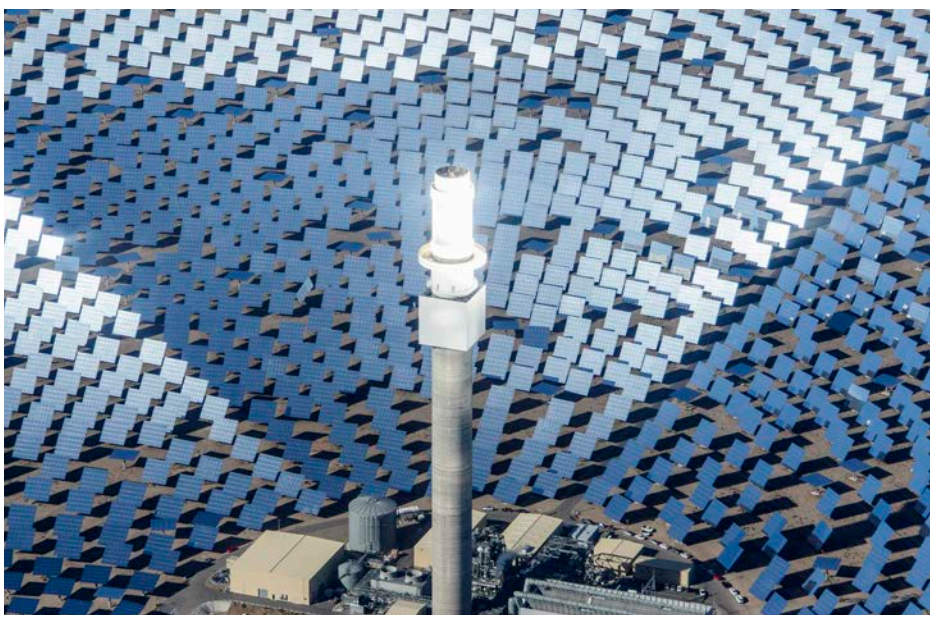


Photo courtesy Solar Reserve

↑ Solar Reserve's 110 MW concentrated solar thermal plant at Crescent Dunes in Nevada; a similar plant is one of the proposals for Port Augusta, South Australia. Mirrors concentrate sunlight to heat a fluid (e.g. molten salt), which is then stored and used as required to boil water to produce steam to drive a generator.

grid frequency, without burning fuel.

Wind and solar farms can be upgraded with more grid support features. For example, when a slowdown in grid frequency is detected, the wind turbine's controller could immediately increase its power output by temporarily sacrificing some blade speed—this approach is termed 'synthetic inertia' and is already required in part of Canada.

Rooftop solar systems are already evolving to help keep the future grid stable. As of October 2016 all new grid-connected inverters must be capable of reducing their generation or export, in response to a signal from the grid operator. Known as demand response mode (DRM), this feature allows solar generation to be curtailed when it exceeds overall demand. Implementation is not expected for many years, and requires an additional device known as a demand response enabling device (DRED) to be plugged into the inverter. Wind farms can already be curtailed by AEMO.

Photo: WEMAG/Stephan Rudolph-Kramer

↑ WEMAG AG recently commissioned this 5 MW battery plant in Schwerin, Germany, the first megawatt-scale battery park in Europe. It is designed to assist with grid frequency regulation (with the same capability as a conventional 50 MW turbine) and grid restoration in case of a major outage. The 1600 battery trays contain 25,600 lithium-manganese-oxide cells.

SMARTER APPLIANCES

Household appliances can assist grid management and stability. Some air conditioners and pool pumps already support DRM, and in Queensland their power level is sometimes reduced during times of peak demand on the grid. Households receive up-front payments for participating in this scheme. Similarly, some hot water tanks can already respond to remote instructions, turning on to heat the water temporarily to a higher temperature than usual. This helps the grid to deal with occasional over-supplies of electricity.

Appliances can also act independently to support the grid frequency. When it detects a drop in grid frequency, a fridge could switch off for 30 seconds and then resume its normal operation. Multiplied over millions of appliances, this reduction in electrical demand can have a very useful effect.

Batteries are especially well-suited to support grid stability, as they can discharge electricity into the grid with zero start-up time. Large batteries have already been installed in the grid for such purposes overseas. Household batteries could also provide this service, as well as delivering bill savings for their owners. Some batteries in Australian households already earn money by exporting electricity to the grid at times of high demand.

Can we cope with such a huge project?

In many ways, building a 100% renewable grid is a challenge comparable to the Snowy Mountains Scheme. The Snowy scheme took 25 years to complete, and its total cost equated to approximately 16% of Australia's annual gross domestic product (GDP) in the commencement year of 1949. By comparison, capital costs indicated by AEMO's 100% renewables report are about 13% of 2016 GDP (see box next page for a summary of this and other studies). BZE's estimated costs amount to 22% of single-year GDP, with the broader scope of decarbonising all energy consumption.

The Snowy scheme involved cooperation between states, employment reform and legislative change. Its successful completion resulted in an important asset that still provides large economic and social benefits today. It could act as inspiration for a modern project to create a 100% renewable grid.

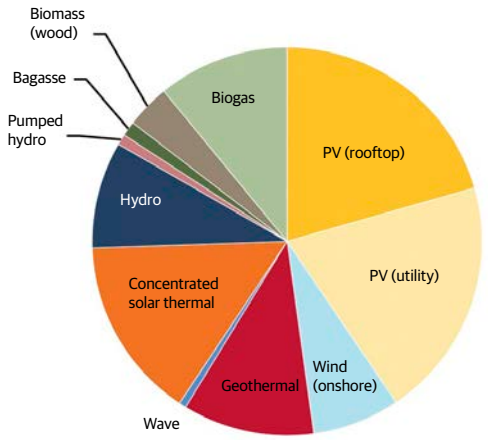
Bill impacts

AEMO's modelling translates into retail bill increases of about 6c/kWh. For a residential tariff of say 30c, this represents a 20% increase. Other studies by BZE, UNSW and University of Technology Sydney gave similar results, especially in comparison to actual increases of about 66% between 2007 and 2012, due primarily to network upgrades. The extra bill cost per kWh is however a more significant increase for large electricity users who may be paying only 10 to 15c per kWh. Bill increases would phase in gradually, over ten years or more. During early stages wholesale prices may be reduced, as found by modelling for the government's review into the current Renewable Energy Target.

In periods when residential bills are rising, it's important to protect vulnerable consumers, such as those on low incomes. This could include subsidised energy efficiency upgrades and targeted increases to income support payments.

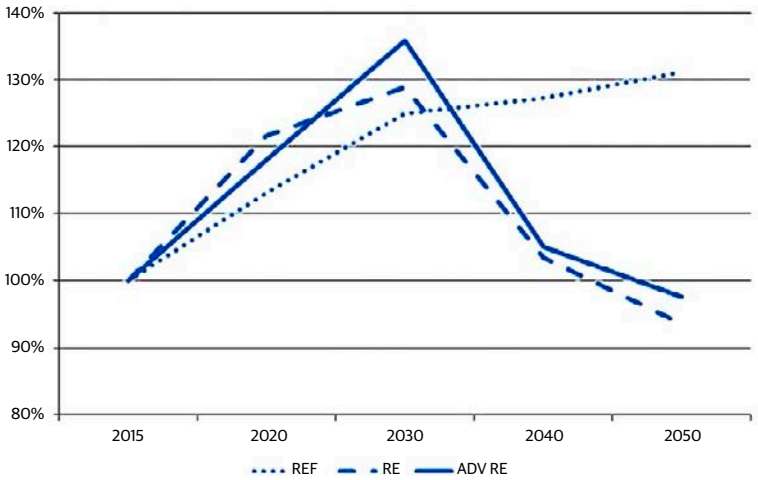
Future 100% renewable bills should be compared against future 'business as usual' bills, which will likely also be higher than today's. The CSIRO study found only minor residential and commercial bill differences between scenarios, especially when expressed as a percentage of household budget. Industrial bills however were significantly more expensive in their 100% renewable scenario. In contrast, the Institute for Sustainable Futures found that, during the transition, overall electricity generation costs could be 5% to 10% higher than 'business as usual', but afterwards would be around 30% cheaper. In a coordinated national project, governments might deploy taxpayer funding, in which case electricity bills wouldn't rise as much.

In the longer term, bills might decline, once the initial capital cost has been depreciated. Running costs are low since most of the fuel is free!



Source: AEMO 100 Percent ReNewables Study – Modelling Outcomes, July 2013

↑ In 2012–2013, the electricity market operator (AEMO) produced a report into 100% renewables, with one scenario investigating a relatively rapid transition by 2030. This pie chart shows the estimated capacity share in 2030 for each of the proposed technologies in their modelling.



Source: UTS report '100% Renewable Energy for Australia – Decarbonising Australia's Energy Sector Within One Generation'

↑ In the modelling done by the Institute for Sustainable Futures, UTS, in 2016, average elecricity costs for each scenario were compared to a 2015 baseline. REF is 'business as usual', RE and ADV RE model different renewable energy approaches. All three models assume a low coal and low gas price.

Existing studies on 100% renewables

Several organisations have studied this issue, finding that a reliable, 100% renewable grid is possible. For proper planning, more studies are required.

Beyond Zero Emissions (BZE)

In 2010, Beyond Zero Emissions and the Melbourne Energy Institute produced a ten-year plan to phase out fossil fuels. Under this scheme, electricity is principally supplied from concentrated solar thermal plants with molten salt storage and wind farms, with a smaller amount from hydro and solar panels. During rare cloudy, calm periods biomass is burned to directly heat the molten salt tanks. Energy consumption is reduced via building retrofits and efficient appliances, interconnections are strengthened (including WA) and the economy is fully electrified, except for a small amount of biofuel for uses such as air transport. Total capital cost was estimated at $370 billion.

CSIRO

In 2012, CSIRO examined a 100% renewable grid in 2050, as one of four scenarios in their Future Grid forum. Cumulative expenditure to that date was about $940 billion, including distribution upgrades. However, this was found to be not much higher than the cost for their baseline scenario ($850 billion), implying a relatively inexpensive transition to a 100% renewable grid.

Energy market operator, AEMO

In 2012–2013, AEMO produced an exploratory report into a potential 100% renewable electricity grid for the eastern states. It assumed increased flexibility in electricity demand, minor energy efficiency upgrades and a moderate uptake of electric vehicles. The report's first scenario considers a relatively rapid transition to 100% renewables by 2030. Via multiple full-year simulations of the national electricity market, AEMO found the cheapest reliable option was to install a spread of renewable generation technologies. New transmission lines would connect population centres to sunny and windy regions. Battery storage wasn't used, as other energy storage options were cheaper. Also, extra wind and solar capacity was built to help cover cloudy, calm periods. Operational issues such as frequency control were found to be manageable.

AEMO's hypothetical capital cost for new generation and transmission infrastructure to achieve 100% renewables in 2030 was $219 billion. This included investments in rooftop solar by property owners. Several costs likely to be associated with the transition were not covered, such as land acquisition and upgrades to the distribution network. After construction, wholesale electricity from the new generators might cost about 11.1c/kWh, and bills might also increase by 1c/kWh to cover the new transmission lines.

UNSW

Also in 2013, the University of New South Wales simulated electricity scenarios comparing fossil gas-fired generation against a mix of renewables including wind and solar panels, concentrated solar thermal plants, hydro and biogas. They found that this mix could meet Australia's electricity demand. Costs were drawn from estimates made in 2012 for 2030. Electricity from renewables and fossil gas was found to cost roughly the same, if the wholesale gas price was high at $12 per gigajoule. (Note: most future gas price forecasts are lower than this, but this price was reached during July 2016.) If a carbon price is included, renewable generation was found to be significantly cheaper than gas.

UTS

In 2016 the Institute for Sustainable Futures at the University of Technology Sydney studied renewable scenarios in a long-term economic model. The grid would be 100% renewable by 2030 and the entire economy by 2050. The generation mix was similar to previous studies, but included the use of hydrogen gas. Estimated investment costs to 2050 would be $650 billion, which is higher than the 'business as usual' reference scenario. This higher investment would be paid off by 2050 due to lower expenditure on fossil fuels. For example, the fuel saving is over $140 billion per year by 2050.

How nimble is the electricity market?

Our privatised electricity system responds very well to the type of event that it was designed for. For example, when the wind dies down, the price of electricity increases and gas-fired 'peakers' pick up the slack. Or if an old coal-fired power station closes in Victoria, more electricity is imported from NSW via interconnectors. This approach harnesses the initiative of many independent companies, each competing to maximise financial returns to shareholders.

On the other hand, the market's response can be poor if the change was unforeseen by its designers in the mid-1990s. The NEM is an energy-only market; participating companies can only get paid for energy they sell (or defined FCAS services). For example, there is no incentive for any participant to maintain inertia in the grid, because low inertia was not anticipated. When a fossil-fuel power station closes, it might make overall economic sense to retain the turbine for its inertia, but that doesn't happen because no individual company can earn money from it.

The market design can be changed, but the process is slow and cumbersome, with rule changes often taking years. Several market reforms conducive to higher levels of renewables have been proposed, only to be rejected or delayed by the rule-making body, the AEMC. These include issues such as demand response, shared solar and market settlement timeframes.

The impacts of our current actions

Our decisions today can help lay the groundwork for a 100% renewable grid, or alternatively can become an obstacle to change. For example, Australians who design or upgrade their homes to reduce winter heating requirements are also easing the toughest task for renewable energy. If we prioritise home appliances that have smart grid-interactive features, we'll be ready to help integrate wind and solar generation by keeping the grid stable (once the grid managers catch up with us!). Installing a home battery also helps to develop an industry and technology that will assist in having a stable 100% renewable grid.

For policymakers, early action on regulations and standards is crucial. For example, tighter enforcement of existing regulations would reduce current high levels of non-compliance with energy efficiency requirements in buildings. Similarly, appliance energy standards should be broadened and tightened. Electric vehicle chargers and home batteries should be incentivised to support the grid by smoothing out peak demand rather than adding to it.

In addition to supporting a transition to renewables, most of these actions deliver a very fast economic payback, so there should be little resistance to their adoption. Similar cases are likely to be available in commercial and industrial businesses.

Conclusion

A reliable, 100% renewable electricity grid is entirely possible, using a mix of technologies beyond current wind and solar farm designs. A coordinated, far-sighted approach is required, which will be challenging under the current energy market design and regulatory regime.

Several studies have indicated that the cost of this transition is likely to be moderate, compared to the inevitable 'business as usual' costs such as replacing ageing coal-fired power stations. Once complete, the transition will put downward pressure on bills and help make them more stable.

However, work to date by authoritative bodies has been exploratory in nature; much deeper analysis is required on a regular basis to confirm the economics, inform policy debate and provide confidence to investors.

Researchers and businesses should be actively supported to develop innovations identified as important to a 100% renewable grid. In electricity generation this includes concentrated solar thermal and biomass. Pumped hydro and batteries are key opportunities for energy storage and grid stability. Perhaps most significant are innovations relating to energy demand, such as smart appliances and electric car chargers, and similar opportunities in commerce and industry.

For long-term economic and health benefits as well as helping to fight climate change, Australia should quickly prepare a plan for a 100% renewable electricity grid, and begin implementing it. ✷

See www.ata.org.au for the fully referenced paper, including additional discussion points.

Other alternatives

What about 80% renewables?

It's possible that Australia could meet its climate commitments while still generating some electricity from fossil fuels. This would depend on decarbonisation efforts elsewhere in the economy, for example locking up carbon dioxide in trees and organic material in the soil. In this scenario, natural gas power stations would help supply electricity demand at cloudy, calm times. UNSW found that the cost increase to go from 80% up to 100% renewables is likely to be only slightly greater than going from 60% to 80%.

What about nuclear?

Nuclear power stations can generate 'base load' electricity without carbon emissions, but have become very expensive and also have other environmental problems. The Australian Power Generation Technology Report estimates that nuclear-fuelled electricity would cost around 18c/kWh, 1.5 times the cost of concentrating solar thermal. This is an average lifetime cost excluding waste disposal and site decommissioning for a generator built in 2030. Since Australia has no existing nuclear power industry, it would take at least 12 years to begin generating. The new British power station Hinkley Point C illustrates the cost: to attract investors, the government had to promise to buy its electricity for about 9p (15c)/kWh, increasing with inflation for 35 years.

What about clean coal?

Carbon capture and storage (CCS), sometimes termed 'clean coal', involves capturing carbon dioxide from fossil fuel smokestacks, compressing it into a liquid, pumping it through pipelines to a suitable location and injecting it deep underground. All these activities require energy, which is supplied by the fossil fuel power station, increasing the amount of fossil fuel burnt by 11% to 40%. Challenges include finding a suitable storage site and the risk of dangerous carbon dioxide leakage. In addition, CCS generally only captures a portion of the emissions and this technology is expensive. In 2030 all types of CCS-enabled fossil fuel generation are expected to cost more than concentrated solar thermal. Despite decades of government support, CCS remains tiny compared to overall fossil fuel generation and its prospects appear dim.

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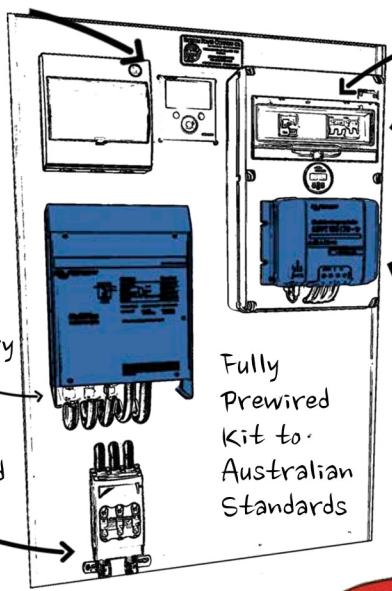

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Island of energy
Community-owned and renewable

Denmark's Samso Island went from complete reliance on imported oil and coal to 100% renewable electricity in just a decade. Jayitri Smiles and Nicky Ison explore the community and government partnerships that made it happen.

DURING the global oil crisis in 1973, Denmark began to think creatively about how to supply cheap energy to their population. As they built their first wind turbine, they were unknowingly establishing themselves as future world leaders in renewable energy.

Today, Denmark aims to have renewable energy powering 100% of their country by 2050 and to eliminate coal usage by 2030. These targets build on a track record of success: since the 1990s Denmark has witnessed the quadrupling of renewable energy consumption.

The creation of the world's first fully renewable energy powered island, Samso, is an exemplar of Denmark's leadership. Not only has Samso become a carbon-negative region, but it has accomplished this world-first using community investment.

↑ More than 500 local residents own or have shares in the local wind turbines and benefit from exporting the energy to other households and regions. Twelve out of 21 onshore turbines are owned outright by local farmers.

The road to renewables

In 1997, Denmark's Minister for Environment Svend Auken was inspired at the Kyoto climate talks. He returned home with a passion to harness the collective efforts of local Danish communities in a way that promoted self-sufficiency in renewable energy. Auken held a competition, which encouraged Danish islands to consider how their clean energy potential could be achieved with government funding and matching local investment.

The most compelling application came from Samso, a small island west of Copenhagen with a population of 4100. This island of 22 villages, at the time run purely on imported oil and coal, was suddenly thrust into the global spotlight and, through a combination of local tenacity, investment and government funding, transitioned to 100% renewable power in just a decade.

At the heart of this energy revolution sit Samso's community-owned wind turbines. Onshore turbines with a generation capacity of 11 MW offset 100% of the island's electricity consumption. Another 23 MW of generation capacity from ten offshore turbines offsets Samso's transport emissions. Most (75%) of the houses on the island use straw-burning boilers via district heating systems to heat water and homes, and the remainder use heat pumps and solar hot water systems.

The extraordinary result is a carbon-negative island and community. The island now has a carbon footprint of negative 12 tonnes per person per year, a reduction of 140% since the 1990s (compare this to Australia's footprint of 16.3 tonnes per person in 2013 and Denmark's overall footprint of 6.8). Not only is the island energy self-sufficient, they now export renewable energy to other regions of Denmark, which provides US$8 million in annual revenue to local investors.

And Samso is not slowing down. Highly motivated, knowledgeable and passionate locals are aiming for the island to be completely fossil-fuel free by 2030. They plan to convert their ferry to biogas and, despite already offsetting their vehicle emissions via renewable energy generation, residents of

Photo: Jergen Bundgaard and Samso Energy Academy

↑ Onshore and offshore wind turbines cover all of Samso's electricity needs and offset transport emissions. The current plan is to completely eliminate dependence on fossil fuels for transport by 2030, via biogas and electric vehicles.

Samso now own the highest number of electric cars per capita in Denmark (see box at end for more on their ambitious transport plans).

Community investment

Community investment has driven Samso's success. Through many public meetings, a positive response from the community was fostered and investment encouraged across the island. While only 50 islanders attended the first discussion, interest snowballed as talk of valuable investments and new jobs spread around the villages.

As a result, twelve out of 21 onshore wind turbines are owned outright by farmers, who can potentially earn over US$4000 a day from exporting energy to other households and regions. Another 500 island residents have contributed to shares in seven other local turbines. Villagers also own one of the heating plants on the island.

Community investment did not happen by accident. The decade of planning, development and community spirit was led by Soren Hermansen, an environmental studies high school teacher and former farmer. His hometown voice and scientific expertise ideally positioned him to collaborate with locals to develop a ten-year master plan on which technologies would work best for Samso's energy needs.

This process took work; indeed, engaging a community of conservative rural farmers and villagers to support and invest in a self-sufficient energy plan was the primary obstacle to overcome when the project started.

Many locals had concerns about modern wind turbines overshadowing the island's natural beauty. Residents were also concerned about potential noise issues and worried about summer vacationers taking their finances elsewhere.

However, the concerns of locals were eased by Soren's empathetic approach and a long-term, step-by-step and thoroughly communicated plan, which focused not just on technology but also considered how it would benefit the local farmers, families and businesses and why they should contribute.

A central part of the plan was a timeline which stepped the islanders through the phases of the development. Whether islanders were looking to be shareholders in community energy enterprises or just consumers of the electricity generated, a growing understanding that wind turbines would integrate well into the island's landscape and operations was the first step towards community acceptance and later pride.

Hermansen also ensured the process remained democratic. For example, turbine locations were negotiated with nearby residents. His patience and belief in community engagement resulted in a large number of residents accepting and/or investing in the project.

Reaping the benefits

Through local investors sharing their sustainable vision, a whole new industry has been created in a region with historically poor economic growth. Like many rural communities, many young people from Samso have moved away and the community is struggling to maintain its agrarian roots in a globalising economy.

While many of these issues persist, taking a punt on community energy was a risk which quite literally paid off. Becoming a sustainability champion has been a positive investment for locals and brought in new jobs and income from the operation of renewable energy, tourism and research.

As a world leader in community energy, Samso now not only attracts tourists, but also welcomes a plethora of media, scientists and politicians from around the world to its shores. Their Energy Academy was built to explain how community power benefits locals and how Samso came to be so accomplished in sustainability.

At a personal level, Soren's mission resulted in accolades including being named *Time Magazine*'s Hero of the Environment in 2008 and winning the Gothenburg Award for Sustainable Development in 2009 (the 'Nobel prize of the environment').

Soren now spends less time in Samso, instead collaborating with other environmental groups to demonstrate how community energy can

play a key part in a clean energy future. He will be visiting Melbourne in February as a keynote speaker at the Community Energy Congress.

A model for the world

Samso's journey from importing oil and gas to exporting renewable energy proves any community can achieve ambitious targets. All that's needed is determination and community collaboration—and a supportive government. Samso sends a message to all communities to follow their lead and be pioneers of sustainability within their nation and beyond.

Jayitri Smiles is a recent journalism graduate currently working at the Climate Media Centre. Nicky Ison is a founding director of the Community Power Agency and lead organiser of the 2017 Community Energy Congress. Soren Hermansen will be a keynote speaker at the congress in Melbourne on 27–28 February 2017. All are welcome, find out more and register at c4ce.net.au/congress.

Photo: Birger Jensen and Samso Energy Academy

↑ An information session at the Energy Academy on clean energy options. Getting the community to engage with the 100% renewables project and feel proud of it was critical to its success. The result? Many island residents invested in the project and there's strong support for the next stage of complete fossil-fuel independence for transport.

Photo: Franseska Mortensen and Samso Energy Academy

Timeline to Samso's clean energy future

1997: Samso is awarded government funding to become Denmark's first self-sufficient, renewable energy island. Soren Hermansen begins to plan with locals.

2000: 11 land-based wind turbines are constructed.

2001: Solar panels (on homes) and biomass boiler plants are constructed.

2002: 10 offshore wind turbines are constructed.

2003: The island is officially self-sufficient for electricity from renewable energy sources. It also begins to export renewable energy to the mainland.

2007: Samso is 100% carbon neutral.

2030: Samso aims to be completely fossil-fuel free.

2050: Denmark hopes to be powering 100% of the country with renewable energy.

Technology used

Eleven onshore and 10 offshore wind turbines, totalling 34 MW. Each 1 MW wind turbine powers approximately 630 homes.

Solar panels and solar hot water on homes.

Straw-fired biomas cogeneration plants for heating.

Transport plan

The plan is that coal, oil and gas used for energy and transportation purposes will be phased out by 2030. By 2020, 50% of cars will be electric and 40% to 50% of local commercial transport will be electric or using biofuels. Public transport will also be free of fossil fuels. Targets increase to 80% by 2030. By 2050, the plan is for 100% electric cars, with a reassessment of commercial transport options in 2030. Ferries will use gas, preferably biogas, by 2020, and biogas or electricity by 2030.

"Becoming a sustainability champion has been a positive investment for locals and brought in new jobs and income from renewable energy, tourism and research."

Other islands going renewable

The idea of moving to renewable energy generation is proving attractive to many smaller communities, particularly island-based communities. Other islands planning a move to renewables include:

Kangaroo Island: Currently powered by a 15 km undersea cable from mainland SA which is nearing the end of its design life, one option, moving the island to renewable energy generation, has been examined by UTS Institute For Sustainable Futures. The outcome of the study was that the cost of replacing the undersea cable would come in at $77 m whereas a local wind/solar/diesel hybrid system was estimated at around $87 m. However, once ongoing costs such as network charges are factored in, costs for the new cable option rise to $169 m, compared to $159 m for local supply. The system would likely include doubling the existing 8 MW diesel generation capacity, installing between four and eight wind turbines, adding five hectares of solar farm and around 800 solar rooftops. The end result would be 86% renewable and 14% diesel generation. www.bit.ly/KangUTS100

Isle of Eigg, Scotland: In 2008, the island's electrification project was switched on, providing 24-hour power for the entire island. Previously, electricity had been provided by individual households using their own generators, resulting in excessive noise, pollution and high maintenance burdens on individuals. The project included laying of 11 km of cable and installation of three hydroelectric generators—100 kW at Laig on the west side of the island, with two smaller 5 to 6 kW hydros on the east side. Four small 6 kW wind turbines below An Sgurr and a 50 kW photovoltaic array round out the system. There are also backup generators for periods of low renewable input. To prevent overloading of the grid, each house has a maximum power draw of 5 kW, and 10 kW for businesses. When excess renewable energy is being generated, the electricity is used to heat community buildings. www.islandsgoinggreen.org

Bruny Island: As looked at in *ReNew 136*, the CONSORT Bruny Island Battery Trial is an ARENA-funded project to install up to 40 battery systems on the island, with the view to stabilising the grid and reducing the use of diesel generation during the peak season. Households that participate in the trial will be provided with a large subsidy to install solar power and a smart battery storage system. They will also be able to sell their stored energy into the electricity market via Reposit Power. So far, the first round of participants have been selected. www.brunybatterytrial.org

Rottnest Island: The Rottnest Island Water and Renewable Energy Nexus project involves the construction of a 600 kW solar farm to complement the existing 600 kW wind turbine, which was installed in 2005 and already produces around 30% of the island's electricity needs, saving more than 300,000 litres of diesel a year. The solar farm is expected to push the renewables portion to 45%, further reducing the need for diesel fuel. Funding for the project will be jointly provided by the Rottnest Island Authority ($2 m) and ARENA, which will provide $4 m. www.bit.ly/RottnestSust

King Island: The King Island Renewable Energy Integration Project (KIREIP) aims to increase the island's renewable energy generation to around 65%, and up to 100% at times, while reducing the reliance on diesel fuel. By adding energy storage and energy flow control, the system allows greater contribution of power from renewable sources. Integration of smart grid technology provides the ability to control customer demand to match the available renewable energy supplies. The storage system, the largest electrochemical battery ever installed in Australia, is capable of producing 3 MW of power and storing 1.6 MWh of usable energy. www.kingislandrenewableenergy.com.au

Island of Ta'u: The island of Ta'u in American Samoa lies around 6400 km off the west coast of the USA. Until recently it was entirely diesel-powered, with diesel being delivered by ship. Disruptions to deliveries had at times resulted in severe electricity restrictions—not great when you rely on electric pumps for basic water requirements. Ta'u now has a solar power and battery microgrid that can supply nearly 100% of the island's electricity requirements from renewable energy. The new microgrid has all but eliminated power outages and greatly reduced the cost of providing electricity to Ta'u's almost 600 residents. The system consists of a healthy 1.4 MW of solar generation capacity from SolarCity, which feeds into 6 MWh of grid-grade storage from Tesla (Tesla recently aquired SolarCity) consisting of 60 Tesla Powerpacks.
The project was funded by the American Samoa Economic Development Authority, the US Environmental Protection Agency, and the US Department of Interior. It is expected to offset more than 400,000 litres of diesel per year. blog.solarcity.com/island-in-the-sun

↙↓ The island of Ta'u has a new 1.4 MW solar array coupled to a 6 MWh Tesla battery storage system.

Images: SolarCity.

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Howe it's done
Waste not, want not

Don Batson and Sophie Liu's dream holiday on Lord Howe Island included a tour of the waste management facility—that's a *ReNew* kind of holiday! They describe the amazing work done to reduce waste on this pristine island.

↑ Meticulous sorting and compacting reduces the volume of waste that needs to be shipped back to the mainland. A life cycle assessment of everything brought onto the island happens "almost unconsciously" and reduces unnecessary waste.

WHEN you live on a crescent-shaped island 11 km long and only 2 km across at its widest, you need to be mindful about limited resources—and as we found out, that can lead to innovative sustainable solutions for all sorts of things, including how you think about and manage waste.

Recently we were lucky enough to have a holiday on Lord Howe Island, a tiny speck in the Pacific, 600 km east of Port Macquarie, with a population of 360 plus a maximum of 400 tourists at one time. It's an island with UNESCO world heritage status and we were drawn there to experience this pristine environment with its unique plants and animals. The last thing we expected to be excited about was the waste management setup! Yet somehow, on our third day there, we found ourselves having a three-hour tour with John, the manager of the island's waste management facility.

Towards zero waste

From speaking with locals, we got the sense that a life cycle assessment of everything brought onto the island happened almost unconsciously, by necessity. The high cost of bringing in a product and shipping out any waste requires a less 'disposable' approach to purchasing. For example, to bring a new car onto the island, you must first arrange to have the old car removed.

"Some locals told us that they'd saved money and reduced trips to the centre by giving their food scraps to a neighbour with chickens—and they were receiving eggs in exchange for their contribution!"

The island also has a wonderful food cooperative— a great community and social enterprise. It offers bulk foods for sale in recycled and reusable containers, so there's less packaging to be disposed of. This was 'zero-waste' heaven, with all sorts of nuts, dried fruit, grains, flours, cereals and even spices sold in bulk. They also had dairy items bought in bulk then portioned up for sale, homemade dips and locally made cakes and biscuits. We were in awe of the simple, effective system set up so customers can return empty jars and containers, which are then washed and reused. As visitors, we were actively encouraged to participate.

Recycling for tourists too

Our curiosity about the recycling systems began at our accommodation. The kitchen had three bins: one for non-recyclable rubbish, one for recyclables such as glass, cardboard and plastics, and a small bin for food waste (with pictures noting that meat scraps and fish bones could be added). Intrigued, we asked one of the staff there about the food waste: did they compost all this on site? Melissa explained that it went off for processing at the waste management facility on the island. And, she added, if we were interested we could get in touch with the manager, John, and perhaps arrange to see it.

The next day, planning our week's activities at the information centre, we asked the

↑ Compacted landfill waste wrapped in plastic, with stockpiled shredded cardboard in the background.

↑ Lids and labels from glass bottles, machine separated.

helpful Bronwyn on the desk whether we could find out more about the island's waste processing. "Of course!" was the answer, "John is my husband, here's our home number, call tonight to arrange a tour!"—a perfect example of the friendly, hospitable nature of everyone we met on the island.

Costs sorted out

On our tour, the first thing John told us about is the pre-sorting that everyone gets involved in. Rubbish needs to be pre-sorted by the 'disposer'; if it isn't, you incur a higher charge. In this way, cost helps encourage desirable behaviour! Waste from the island's tourist accommodation is sorted and checked by staff in case the guests don't divide recyclables from landfill waste correctly.

The waste is pre-sorted into compostable, recyclable, reusable, incinerable and general streams. The four or so staff at the facility then further sort and process the waste to reduce the volume that needs to be shipped back to the mainland. All food waste, cardboard and incinerable items are processed and kept on the island. Everything else gets sent back to the mainland for recycling or landfill. Recyclables are stockpiled until enough of one type is collected to fill a boat-friendly bin, saving space and costs for shipping.

From paper waste to compost

Cardboard and paper are shredded (using a machine acquired just this year) and used in food waste processing. They first need to manually remove plastic tapes from any boxes. Wax boxes have a separate recycling stream as they can't go through the shredder and composter—the wax clumps up and reduces the air flow. Glossy magazines are also recycled separately as they attract a rebate on the mainland.

They stockpile the large volume of shredded paper and cardboard and add it to the food waste for composting. The composter is a vertical unit with three chambers.

John outlines the recipe for the compost: 120 L of food waste and 80 L of cardboard. They previously also added gypsum or lime but found it wasn't needed. With mixing and aeration the chambers can reach temperatures of up to 80 °C! They use a macerator to pulverise large bones and fish before they go through the composter.

The resulting compost gets mixed with more shredded cardboard and added to the green waste. It's then watered and the mix turned over. The processed compost waste that results is used to fill depressions or as mulch in areas outside the sensitive environs of the park preserve (which makes up 70% of the island).

As the composting machine is 16 years old, the island has funding for a new unit. There are hopes it will compost hot enough to decompose nappies, so they'll no longer need to ship them off the island. As an added advantage, it will use less energy than the current composter.

Recyclable returns

Further sorting means they can get the best value for the recyclables. Metals can attract a rebate, so they manually separate out the steel and aluminium. They also sort out the light globes, printer cartridges, batteries and plastic containers and when there is enough volume of any of these, they are baled for shipping. They strip the labels and lids off glass bottles and jars and then crush them into three grades of finer and finer particles for recycling on the mainland. Cooking oil is also sent back for recycling, and engine oil as well—it's picked up by a company for reuse on the mainland, though they still have to pay to ship it.

Reuse first

Any good reusable items such as clothes or books are donated to the Red Cross (there's free shipping for these charity items). They also separate out some items to be sold in the 'tip recycle shop'. Bikes with serviceable parts are taken by a group on the mainland who turn them into wheelchairs and donate them to developing countries such as Sri Lanka.

Space-saving compaction and sorting

Everything else that is left as landfill waste is put in the compactor to make large blocks, which are wrapped in plastic and left in the sun to kill any flies and maggots before they are transported back to the mainland. The compactor is also used to crush the plastic recyclables into bales; plastic bags are also baled up and compressed.

Everything is meticulously sorted and packed to reduce volume. Large pieces or odd-shaped building waste are used as lids on the skip bins of materials. For example, we saw a bin of whitegoods which had been crushed or taken apart to better use space and then lidded with a flattened old water tank.

Aluminium window frames are salvaged

↑ Glass granulated ready for recycling on mainland.

from building waste and the window glass broken down. Steel cans from household waste are crushed into bales and added to a skip bin where steel from building demolition, such as roof gutters, can be mixed in too. Ovens, barbecues and old heaters are squashed down so their metal can be recycled. Larger items are dismantled and their components put into the correct waste stream. For example, when they pull apart a couch, the untreated timber goes to the bonfire, the metal springs go to recycling and the foam is compressed and added to landfill waste. E-waste is collected until there is enough for a pallet.

Untreated timber makes up the majority of the incinerable waste stream. It is stockpiled over a year and what hasn't been recovered and reused is then burnt in a bonfire, to save the expense of shipping it off the island.

For some items there is not enough volume for recycling to be economically viable, such as polystyrene and tetrapaks. The scale is too small to warrant a special compactor for the polystyrene, so unfortunately this ends up in the landfill stream.

Waste water

The majority of the island's waste water is handled via regulated septic systems, and when these and grease traps are pumped out, the facility has holding tanks and filtration systems to handle the output. These include settling tanks, aeration tanks, evaporation beds, sand filters and reed beds. The evaporation beds have clear lids to enable the sub-tropical sun to speed up evaporation and also expose the contents to natural UV treatment. The final step in the treatment process for waste water is the reed beds; for the solids, they pass through the composter.

Saving money by reducing waste

Three times a year, audits are conducted over a two-week period to calculate the amount and types of waste being disposed of, and set the rates for waste disposal for domestic and commercial users. The rates include a flat fee, but the majority of charges are volume-based. Some locals told us that they'd saved money and reduced trips to the centre by giving their food scraps to a neighbour with chickens—and they were receiving eggs in exchange for their contribution!

The more readily recyclable your waste is, the cheaper it is to dispose of. While clean rubble is taken for free (as it can be used for roadworks to fill in any gaps or holes), a mix of metal and wood with building rubble will mean more handling by the facility staff and therefore a larger fee. In another example, John mentions that one of the tourist accommodation facilities has their own glass crusher for bottles so they can reduce their volume and hence cost. In such a small community there is also the opportunity to educate hospitality staff to sort the waste and remove bottle lids first to improve the ease of recycling. They can even tell when new staff or a new chef starts at a restaurant, as the format and volume of the rubbish changes. It doesn't take long though and everyone is humming to the same waste management tune.

It's a pity that we on the Australian mainland aren't also in tune with this successful waste management approach. We could learn a lot from this little island and its approach to reducing waste and improving recycling (with a landfill diversion rate of over 80% compared to 62% for NSW in 2012/13). It may be a necessity on such a small island with high shipping costs, but it's also something that the islanders are clearly proud of and happy to be involved in.

It could even be a case study for the rest of the population: Earth is an island too, and it's all we've got! ✱

Sophie Liu and Don Batson both work at the ATA, *ReNew*'s publisher.

Renewables on Lord Howe

It's not just waste recycling that Lord Howe residents do sustainably—energy generation is also being looked at.

An Energy Generation Road Map has been developed to look at reducing Lord Howe Island's use of fossil fuels, in particular diesel used for electricity generation. The road map recommended a combination of solar panels, energy storage and wind turbines, and the more recent Technical Feasibility Study suggested that 450 kW of solar panels and two 275 kW wind turbines, combined with a 400 kWh battery, would reduce the island's diesel consumption from 518,000 litres per year to around 180,000 litres per year—a 66% reduction. This system, dubbed the Lord Howe Island hybrid renewable energy project, would also provide 67% of the island's electricity needs, exceeding the target set in the road map.

However, there have been a number of concerns put forward regarding impacts of the turbines. Public submissions were taken until 28 October and the board is currently collating the submissions and is set to release a consultation report soon (no date yet set).

So far, the solar panels, battery and control system elements of the project are going ahead, and these alone would reduce the Island's annual diesel usage by 193,000 litres a year—a 36% reduction. www.bit.ly/LHRERM

↑ Lord Howe's electricity currently comes from diesel imported from the mainland—the diesel tank and building that houses the three diesel generators is shown here—but a plan is in place to transition to a mix of renewables.

All inclusive weeks: 28 January - 4 February, 25 February - 4 March,
25 March - 1 April & 22 - 29 April 2017
Bird week with Ian Hutton: 18 - 25 March & 11 - 18 November 2017

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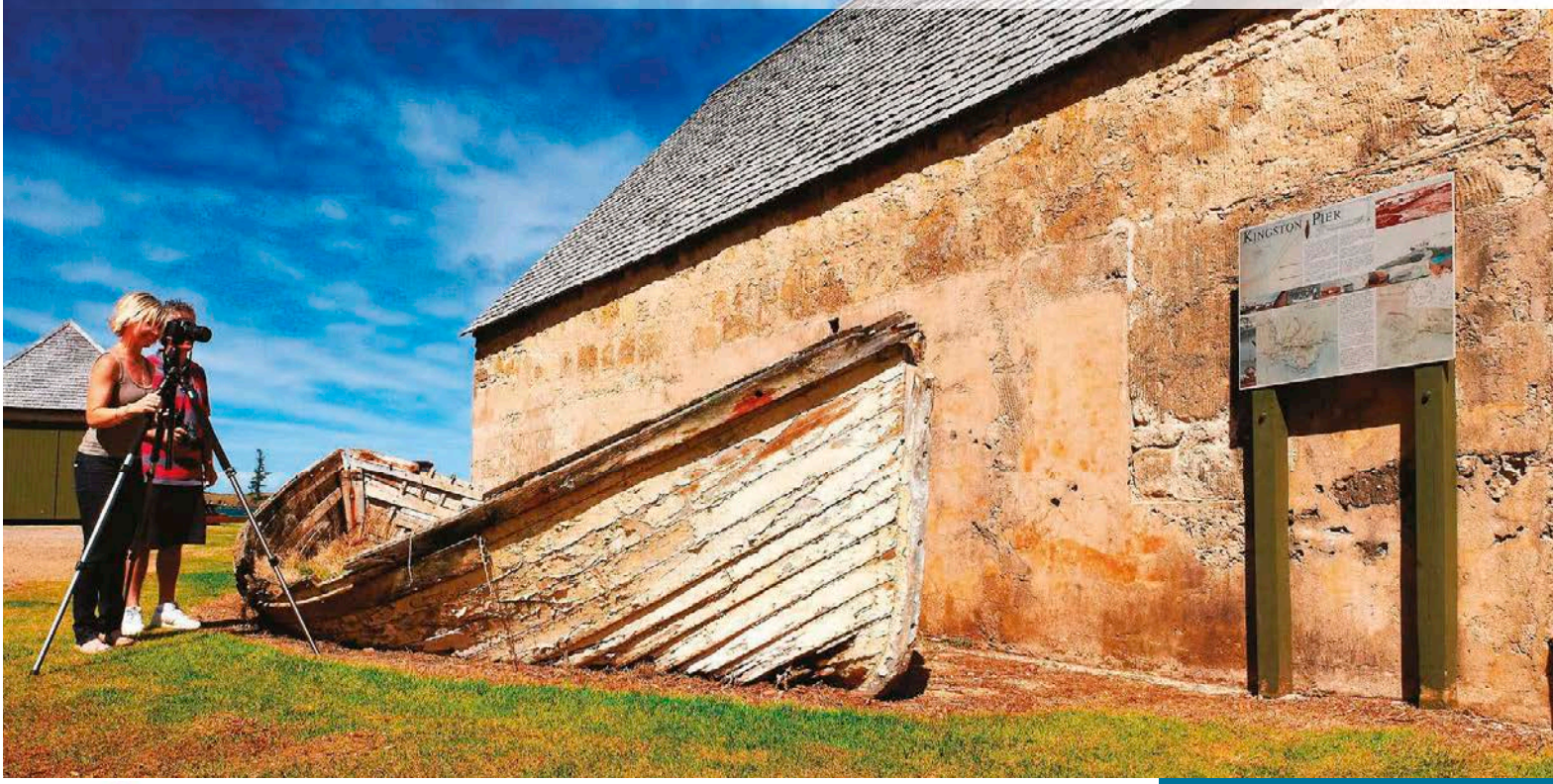

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Change in store
Zero-waste, no bulk

Do you like the idea of living plastic-free and zero-waste, but feel discouraged by the lack of bulk stores in your area? Tammy Logan shares ways you can still reduce your plastic waste, while lobbying for change at the same time.

I AM yet to find a one-stop bulk store in Gippsland, Victoria, the area where I live on a dairy farm with my family. The closest is in Melbourne, at least one hour away by road or rail. I was discouraged by this, but I was determined not to give up on my zero-waste plans.

There are a number of things I do to make up for the lack of bulk stores, which you can do too. I won't lie: it does require effort, organisation and time, as any lifestyle change does, but it is totally doable and very fulfilling.

While I have taken advantage of the benefits of living in a rural area, this guide applies to anyone wishing to significantly reduce their waste.

Now our family of four produces just one handful of landfill and one large bucket of recycling per week. There is still stuff we're working on, but we're getting there.

Look harder and talk more

Word of mouth and searching through numerous local stores has helped me find many things that *are* sold in bulk or package-free. I am ashamed to say that I had lost touch with small local businesses and no longer knew what was available in the towns surrounding me. As a society we have become used to shopping at one-stop giant convenience stores. While it may be handy (I have kids so I get it), you can still find all you need at other shops. Shopping at local small shops I get to feel good about spending my money in the stores that are owned by the people I went to school with.

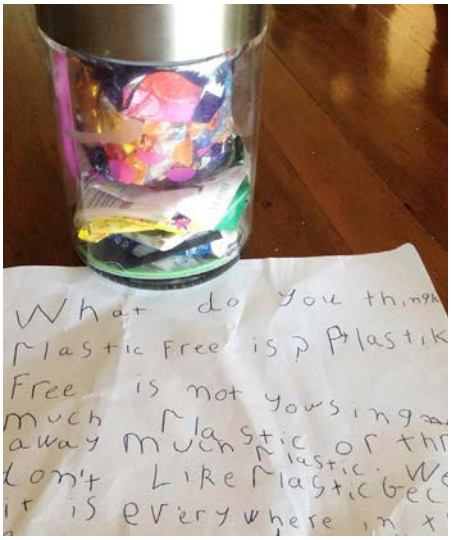
So far I have found five stores in a 30-minute radius from where I live that are meeting my needs. I tie my visits in with other trips we need to make and I buy as much as I can to last a few weeks or even months to save fuel and time. It can make zero-waste living seem more expensive, but I've found it to be cheaper in the long run.

There is a risk of wastage when you buy food in large amounts, but if you store the food in jars and containers most of it will last a long time; many fresh foods, such as berries, can be frozen to extend their life; or nuts can be refrigerated. Of course, it is important to find what works for you. I have found having a pantry full of ingredients means I can make things whenever I feel like it.

↑ Support stores that provide bulk buy options, like this one, the Grow Lightly Food Hub, Korumburra. You may not be able to find a one-stop shop, but you can often find stores selling certain products in bulk. Talk to your local shopkeepers too as they may be willing to provide bulk options even if currently they don't.

When in doubt, find out

Make friends with the butcher, the baker, the grocer, the delicatessen and other local store managers and owners. Tell them about your needs; they are always willing to help if they can. I have solved so many of my problems, like finding cheese plastic-free, by asking questions and having a conversation.



↑ Tammy's five-year-old daughter's 'rubbish bin', containing a year's worth of landfill waste (just hers). She took it in with this note for show-and-tell at school.

↑ There are many local initiatives for sharing food. Ripe Near Me is a free initiative that enables people to advertise their excess backyard food, either for free or at a low cost. Darebin Council in Melbourne runs a Backyard Harvest Festival in November each year. Produce swaps are another great way to trade your excess—and you'll often get information on food growing and meet lovely people. Find them via your local council, sustainability or Transition group.

I discovered that some stores, such as health food shops, do the packaging themselves and are happy for you to bring your bags and containers to collect from the bulk quantities of goods out the back. I've also had several local product manufacturers suggest I collect their product direct from them before it gets packaged, for example, washing powder and cleaning products. If more and more of us start requesting no packaging then change will happen, and at the local level it can happen quicker.

Rediscover markets

I love the thrill of a zero-waste discovery and markets have not disappointed. At one market I found someone who lives very close to me and sells her natural cleaning and body care products in bulk. I also found blocks of unpackaged beeswax direct from the beekeeper. It's easy to find gifts and other package-free items, often beautifully handcrafted and sometimes secondhand. Farmers markets have the added benefit of getting your produce without plastic stickers and other packaging. And markets give you a valuable opportunity to know who made the product or grew your food, and how.

Go direct to the producer

Before I found beeswax at the market (I use it in various beauty product recipes), I looked up beekeepers to find out who would be willing to sell their beeswax to me.

We used to buy bags of frozen berries and plastic punnets of strawberries so I went straight to the berry farms to collect the berries in our own containers. We freeze them in jars so we can enjoy them for as long as possible.

There are other farmers such as apple and nut growers who offer farm gate sales too. Being in Gippsland, we are in the heart of food production. Resources such as the Southern Gippsland Food Map show producers in our region; similar resources may exist for you—ask your local council or google it!

Have a go at growing your own

We generally have more space for growing in rural areas, but there are many examples of how to grow in small spaces, as well as community gardens you could join. It's definitely worth having a go. I'm trying to grow a lot of food, but one thing I really wanted to do was grow lots of peas to keep in the freezer. I have a few recipes that I like to use peas in, but I have been leaving them out because I'd have to buy them frozen in a plastic bag. Unfortunately, I haven't done too well with growing them so I'm thinking about how to get around this issue by talking to my grocer. I also love cherry tomatoes but they always come in plastic punnets; it's so good to be able to pick them fresh and gobble them up. Keeping chickens is also worth considering as they provide eggs and consume food scraps—and you won't be using up egg cartons.

Trade

While I might not be good at growing peas, others might be, so I can trade with them something like my kombucha, which I am good at making. I also trade seeds and plants with friends which avoids the plastic pots they come in at garden shops. Anything is up for trade and the value of items depends on the people involved in the transaction. If you are growing your own food and have excess you can also take it to a produce swap to trade for something you do need more of. The swaps usually operate very informally and

are a great source of growing and cooking tips too. If you can't find one near you, start your own. That's what I did in Poowong and it ran for four years.

Forage

Who doesn't love the thrill of foraging? Finding wild food for yourself or free food offered by someone else connects you with your local environment and community. There are websites like Ripe Near Me (www.ripenear.me) helping to facilitate access to free food.

↑ Inside Tammy's pantry, showing the salvaged jars used for storing items in bulk. She says, "Having more on hand means we cook more from scratch."

↑ One way to avoid waste is to avoid buying too often! Tammy and the family wear their shoes in well. Tammy is also on the lookout for shoe recycling programs and shoes made from sustainable materials. That's just one bit of info you can find on her post at www.bit.ly/TAMZWSC

Work together and create bulk buying groups

Don't wait for someone else to provide you with bulk options. Use your initiative and make it happen. A friend of mine told me about some women working together to bring plastic-free, bulk toilet paper to our area. I could have ordered the toilet paper online myself, but by joining the bulk buy group I got a rather large discount. I've also been able to find friends in my town who are interested in similar projects and we're hoping to organise bulk deals for other things.

Connect with local sustainability groups

Local sustainability groups provide a wealth of information. If you are in Gippsland you could use the Sustainability Gippsland directory to help you find groups you are interested in. The Baw Baw Sustainability Network in my area is working on organising a bulk buy group. Why not start one with your local sustainability group?

Make it from scratch

Finally, there is always the option of making things from scratch. When we went zero-waste, I started making muesli bars, potato crisps, slices and so on. I can't find these sorts of treats unpackaged like you might do in a bulk store, so if we want to eat them, I need to make them. That's another advantage: the reduction in processed, packaged foods has made our diet healthier.

I hope this article has revealed how many other social, environmental and economic benefits come from a zero-waste lifestyle. It makes you shop more locally and eat more seasonally. It reconnects you with food production and your community. You find like-minded people and forge new friendships. This is fulfilling and it helps maintain the momentum for zero-waste living on a bigger scale. ✷

Tammy Logan blogs at gippslandunwrapped.com on ways to reduce waste. The blog includes practical information and discussions of such issues as "is it legal to bring my own takeaway container?" Highly recommended!

Sourcing plastic-free milk

If you don't have your own cow, you will be wondering about how to get plastic-free milk. Milk does exist in reusable glass bottles in some rare places around the country: La Latteria in Carlton, Melbourne, is an example of this in Victoria, and Elgaar Farm is an example in Tassie. But most consumers will need to consider the following alternatives.

- Reduce your consumption of milk. Do you really need as much as you use?
- Talk to a cheesemaker or other dairy producer with a large supply of pasteurised milk about buying a refillable bucket of milk. I've had a lot of success avoiding packaging just by asking producers and store managers for a solution.
- Buy one-litre paperboard cartons of milk. These have less oil-based plastic than the plastic two- and three-litre bottles of milk, and the paperboard has a high likelihood of being recycled into paper (the paper and plastic components can be separated in the recycling process). For any form of packaging you should look for a way to reuse it before recycling it.
- If you are not happy using paperboard cartons of milk, and provided you aren't going to waste it (you can freeze milk), buy the largest bottle you can find because the ratio of milk to packaging is more favourable than for smaller bottles. Find a way to reuse your packaging before recycling it.
- If you only use small amounts of milk, consider buying package-free nuts to make nut milk.
- If there is a bulk store near you with package-free milk powder, you could use that.

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Driving change
One EV owner's insights

From what it's like to drive an electric vehicle (EV) to where to charge at home and abroad, happy Tesla owner Jeff Challis answers some frequently asked questions about owning an EV.

Why did you choose an EV?

Our impetus to buy an electric vehicle (EV) came after we installed our home solar panels in 2007. I started thinking of other ways that we could use the solar-generated electricity to reduce our impact on the environment. If households could adopt solar and reduce the need for high carbon usage power stations, then surely EVs would reduce the need for oil. This led me to research a now well-known US company that had created its first EV, a two-door sports car, in 2008, with grand ambitions to expand and mass produce four-door EVs too. This company is of course Tesla and I have been following their progress intently for the last eight years.

In June this year (2016), the delivery was imminent. I filled up my internal combustion engine (ICE) car with petrol for the very last time and a week later we became the proud owners of a Tesla Model S70D hatch.

↑ Public charging provides extended range for EVs. Note the use of an adaptor lead so that the Tesla can charge using a standard J1772 outlet.

What is it like to drive a Tesla?

We feel the Tesla must be one of the simplest cars to use and drive. There are no remotes or keys needed to unlock the car. You just walk up to the car with the fob in your pocket and the door handles come out to greet you! Hop into the car, put your foot on the brake and push the lever on the steering column down to select forward, or up for reverse. There are many driver-assist features, such as auto-steer for freeway driving, auto headlights and auto-park when needed.

What features do you enjoy?

Owning a Tesla is a not a compromise. Not only does our car have the same features, handling, performance and range as a traditional vehicle, it also offers benefits beyond those of a normal car. An EV has instant torque from zero and is typically much faster to accelerate when compared to the ICE equivalent. The Tesla can also download software updates, allowing the car to be made safer and smarter over time. And of course, they are extremely quiet with zero tailpipe emissions.

Does the range affect your trips?

In the few months we've owned the Tesla, we have not been constrained by range at all. We've completed trips from Melbourne to Mt Hotham (385 km), Euroa (175 km), Apollo Bay (190 km), Creswick (120 km), Christmas Hills (75 km), Yarra Junction (90 km) and the Mornington Peninsula (110 km). Many of these trips included other side trips and a return on the same day. I often didn't even need to do a full charge beforehand, if the available range (indicated on the console) was enough to cover the distance.

Are people interested in your car?

Yes! Quite often when I'm getting in or out of the car, I'll get asked questions about it and I often end up taking people on a mini tour of the car. I open the hatch and they almost always comment on how much room there is. I also open the 'froot' (front boot) where

↑ More businesses are realising the advantages of providing EV charging points—soon you will be able to get a charge almost anywhere.

↑ Range anxiety isn't an issue when your car tells you how to avoid it. The Tesla gives you an estimated range available on remaining battery charge.

most people are surprised to see another storage compartment instead of an engine bay. I also show them the main cabin with the impressive 17-inch screen and lack of a drive shaft hump in the back, providing even more room. I'm not able to show either of the car's two motors as they are neatly hidden away.

How long does it take to charge?

An EV is not like a petrol vehicle where you must stand there holding a bowser pump hose while waiting for it to fill. It's more like your mobile phone where you plug it in before going to bed in the evening. The charging options are varied and it's best to think of how many kilometres get added to the car per hour.

The Tesla superchargers (a network of highway chargers, currently eight in Australia) provide around 270 km range of charge per 30 minutes, or about 50% charge in 20 minutes and 80% charge in 40 minutes. The supercharger option is fantastic when doing longer road trips; we just stop and grab a cup of coffee for a quick break before continuing the drive. [*Ed note:* They are free to current Tesla owners, though a small charge will be applied to new owners from 2017.]

My home charger adds about 43 km per hour. This is more than enough to put the car on charge overnight at 10 pm when the cheaper tariffs apply and to be fully charged for a 6 am start to go swimming! This is the same charging rate we get from public, non-Tesla charge points too.

Charging from a standard household power outlet adds about 10 km per hour. We've found this to be useful when staying at a country B&B, for example.

How do you plan longer trips?

For many people, including us, the Tesla's range is more than enough to cover daily needs. In fact, it's probably enough to last more than a week of typical usage. So, it's only when we need to do a longer trip that we need to consider our requirements.

The Tesla model S70 is enough for me to travel from Melbourne to Mt Hotham (385 km), 'supercharge' at Euroa on the way, top up to full overnight in Mt Hotham (at our hotel charge point), and then return a few days later with a quick charge (not even enough time to finish my coffee!) in Euroa. I decided we didn't need the larger or faster Tesla models and have not regretted this decision post purchase. If I were to drive from Melbourne to Sydney, coffee/meal stops for a quick supercharge along the Hume Highway would allow us to travel longer distances without being inconvenienced.

When calculating range there are several important considerations, including the weight of the cargo, any headwinds, elevation and outside temperature. Colder temperatures degrade the range. And note that the rated range published by the manufacturer represents the range under ideal conditions. There is also typical range and this reflects a more realistic scenario. For us, the rated range is 440 km and the typical is 360 km. In addition, to make sure the batteries remain in ideal working condition, the cars are normally charged to 90% for everyday use and 100% for special trips.

Charging

AT HOME

About one month before taking delivery, we picked up our home high power wall charger from Tesla. This can be installed by any electrician, but we chose to use a Tesla-recommended one and were very happy with the result.

We had a 40 amp circuit added and dedicated to the wall charger. This can provide us with charging at a rate of 43 km of charge per hour, more than adequate for a full charge overnight. The cost of this installation was $750 + GST.

WHEN AWAY

Tesla also includes a charge cable that will work from a standard 10 amp wall socket. We use this when travelling or staying overnight at locations that don't have a nearby higher powered charging station. This adds about 10 km of charge per hour. I also keep an extension lead handy when travelling in case I can't park close enough.

We also have a J1772 cable adaptor (to adapt from Tesla's proprietary plug to those used by standard charging stations) and have used this several times at public charge stations. I purchased this from www.evnomics.com.au for $295.

We also purchased three-phase plug adaptors, but haven't used them yet, though am likely to on an upcoming trip to Adelaide.

↑ One incentive to help with the uptake of EVs is destination charge points, such as this one in a public carpark.

How do you manage the range calculations?

Range calculations might seem quite complex but in the real world you just put your destination into the GPS and it will tell you how much energy you are going to use. If the car thinks that you are going to run close to empty or low charge, it will re-route you via a charger or suggest actions such as slowing down. I'm one of those people who likes to know more about the statistics and usage, and I've found a useful website for this: www.evtripplanner.com. It allows me to run different scenarios such as extra cargo weight and a change in outside temperatures, and see the results.

Is it easy to find destinations with charge points?

When planning trips, we prefer to visit and stay at places that are encouraging EVs to promote a safer and cleaner future. We notice that many organisations and businesses offer free wi-fi as an inducement to use their services, but we think a new opportunity for them would be to offer destination chargers. Tesla has been quite proactive as a car company in doing this, along with other enterprising organisations. A great way to find these charge points and read reviews about them is through www.plugshare.com. Many rural councils have had freeways bypass them and are now using this as a way of encouraging visitors back.

What incentives should be in place for EVs?

There are a few things that I've been lobbying our local council about, including that they could:

- provide or encourage local destination charge points, including charge points as part of new developments, shopping centres, train station car parks, beach car parks and tourist attractions
- provide a way for houses with no off-street parking to access kerbside charging (see box)
- look at mandating a high amperage circuit for new buildings so they are EV ready.

There is plenty of opportunity for all levels of government to create incentives that can help encourage EV adoption. These could include making EV cars more affordable by reductions in stamp duty, luxury car tax and registration and increasing the depreciation threshold (see *ReNew 137* for more on this).

Other countries have already implemented many incentives that are not available here, such as rebates, mandating no new fossil-fuelled cars by a certain date and allowing EVs to travel in transit lanes. A few incentives will go a long way to creating a better future.

How do you envisage the future?

We've been embracing and enjoying our electric vehicle daily since purchase. It has provided us with an opportunity to reduce our carbon footprint, to help provide a more sustainable future for the next generation, foster a new industry and to help clean up air quality and in doing so reduce health costs. The benefits are many, but as with all changes, a consumer-driven change is a lot slower than a government-driven change. We originally purchased our solar panels when the federal government started offering rebates and it has been a great pleasure to see the price of solar drastically reduce and Australia start to lead in solar adoption. We would like the same principle to happen with EVs too.

We are starting to see new EVs announced for the Australian market, with many being more affordable, 'no-compromise' EVs. We'd like to share the joy of EV ownership and hope others will think about an EV for their next car purchase for a cleaner and quieter future. ✱

Jeff Challis is a director of a cloud-based IT consulting business and has a keen interest in sustainable technology.

"We notice that many organisations and businesses offer free wi-fi as an inducement to use their services, but we think a new opportunity for them would be to offer destination chargers."

Kerbside charging: councils need to lead the way

In older parts of our Australian cities, many houses do not have access to off-street parking and so it is difficult for them to plug in an EV to charge overnight at home.

I've been lobbying our local council to be innovative and thought leaders in this area. I've volunteered on their environmental advisory groups, brought this up at council meetings, submitted budget requests for funding, asked questions at council meetings, spoken with councillors and written letters. Unfortunately, the only response I've had so far is that they have no policy in this area and that they know of a developer who is creating a private EV charge point.

However, I believe other councils are starting to make progress in this area, and that the possibilities for kerbside charging are being considered in terms of how to recoup the costs.

There is also an excellent white paper prepared by Ecolane, a UK-based low-carbon transport consultancy (www.bit.ly/RSEVCRG), which details some sensible options to enable kerbside charging. These include:

1. cable channels and guides which could safely route cables across footpaths
2. drop kerbs which would enable owners to add a small driveway to the property
3. pop-up power units and power bollards to provide hidden (possibly retractable and below-ground) low-power points accessible by key only
4. sharing of power supplies with street lighting
5. shared EV parking; for example, local businesses could provide EV charging stations for use out of hours.

Straight up
Vertical garden lessons

The last thing you want is to spend a lot of money on a vertical garden system and then have it fail. Jenny and Bevan Bates provide advice and inspiration from their own living walls—five years old and growing strong!

THE inspiration to garden vertically is not new. The Hanging Gardens of Babylon, if they are more than legend, may have been an early precursor, built to bring luscious greenery to the ancient city's terraced buildings. Your grandma's hanging pots are a more down-to-earth example, as are vines on a trellis.

More recently, the idea of living walls has become a popular trend, in part in response to higher density living and homes with small gardens. For Jenny and Bevan Bates, their move to a new house with a small courtyard—and a stark black brick wall facing their living area windows—was the reason they started experimenting with gardening on a wall.

"You have to be prepared to experiment," says Jenny. In fact, their first vertical garden was a failure. "We tried a $100 system, but the pots were too small and it dried out too quickly; it was hard to keep anything alive in it," she says.

However, they persevered and they now have five vertical gardens providing cooling, colour and herbs, which adds interest to their home. The black brick wall in fact sets off one of the vertical gardens nicely—the colour they didn't like turned out to be complementary to the planting!

That particular garden was their first success, says Jenny. It's now five years old and thriving (see photo above). It's on a south-facing wall overlooked by the north-facing living area windows—a lovely sight.

They created the garden using Woolly Pockets, a product which at the time they needed to get delivered from the USA (though there are now retailers in Australia).

The pockets are composed of long troughs of recycled polyethylene (PET, from milk bottles for example). That recycled aspect was important to them; "You need to think about the full life cycle; for systems made from virgin plastic, there can be a lot to dispose of at end of life," says Jenny.

↑ Instead of a black brick wall, this is now the view from Jenny and Bevan's living room. Plants in this vertical garden include begonias, fuchsias, nandina, dianella, clivea and various bromeliads and ferns. The pots in front can be moved to bring a ladder in for maintenance.

Which plants they use has evolved over time; some plants grew bigger than expected, shaded other plants or didn't like the position.

Seeds of success

Jenny and Bevan note that the critical things to consider for success are: aspect, dictating how much sun the plants will get and when; a good growing medium; containers of sufficient size so they don't dry out too quickly; an automated watering system as hand watering can be tricky with so many pots; and appropriate plant selection.

Jenny suggests that using a west-facing wall with its harsh sun will be difficult—a vine grown in the ground rather than many small pots would likely work better. But on other walls, the array of plants can add more interest and diversity than a single vine.

Their south-facing vertical garden looks lush, but there have been challenges along the way. The plants at the top get a lot of sun in the morning and afternoon during summer, so they need to be hardy. They lost several plants in the top row in the first year, so they now shade it in summer with an overhead blind made of white shadecloth.

The vertical garden on their north-facing

← The Woolly Pockets prior to planting (far left) and after three weeks (left); the result five years down the track is on the previous page. Jenny and Bevan have experimented with different plantings to suit the amount of sun, potting mix, size and watering regime. Jenny says they originally planted a bit too close together, so they ended up thinning out the plants to just two per pocket.

fence is also a success, but needed to overcome challenges too. It gets full sun in summer, but very little in winter, so they've had to be careful in their plant selection. They've planted parts of it seasonally, with annuals that will grow for just the summer season and then a second set for the winter season. Abutilons, nandina, kalanchoe, sedums and a small correa have coped better here.

Watering required

An automatic watering system supplies water to each growing pocket and is programmed to water for three minutes a day in summer, less in winter. They also periodically water manually in summer to ensure the plants get a good soaking (dry potting mix can become hydrophobic), and flush the pots at least once a year to avoid a build up of salts.

Jenny notes that they even need to water in winter as one of their vertical gardens is under the house eaves, and the bottom pockets of all of the gardens tend to miss out if relying just on rainfall; though the northern-facing eaves do provide useful shade in mid-summer.

The growing medium should be a quality potting mix (not soil as it's heavy and doesn't drain well in pots) with sufficient nutrients for the types of plants grown. Jenny adds a handful of water crystals when first planting as "extra insurance", providing additional water-holding capacity for up to six months: "I just throw a bit in, it's not a science; I have occasionally used too many and then they ooze out the side!" She also fertilises at planting and as required with slow-release pellets.

Weighty matters

Supporting the structure needs thought. "There's a fair bit of weight involved, with the container, growing medium, plants and water. You also need to factor in that the plants will grow!" says Jenny. That growth can exert a force out from the wall, as well as the weight pulling down on the wall. Some people use perlite and vermiculite to reduce the weight of the potting medium even further.

They had a couple of early failures with fixing the pockets to the brick wall. It's a neighbour's wall, so they used a product called Brick Grip, which clips onto the brick without any drilling required. It "sort of worked" but then several pockets started to fall. In the end, they used epoxy resin to attach the brackets as well as a couple of Dynabolts in key spots. A couple of the Living Wall Planters drilled into their own eastern wall came off too (these are a newer product from Woolly Pockets, with more rigid individual planting containers): the plastic wall plug holding the screw into the brick wall broke apart. They replaced them with fatter wall plugs and screws, and that's all working fine so far.

Another must is to include a plastic sheet behind the garden to keep moisture off the wall. You'll also want to consider height—so you can reach herbs or vegies—and space in front to enable access by a ladder for maintenance (such as deadheading, replanting, pruning, replenishing potting mix and fertilising). Some systems have pots that can be removed, but that can be tricky given the weight of the pots.

Plant selection

When it comes to plant selection, you need to choose plants that can cope with the conditions. They're in small pots, so those with an extensive root system won't work well, and they need to be able to cope with the amount (or lack) of sun.

Jenny says she aims for "spillers, fillers and thrillers: spillers hang down, fillers fill out the space, and thrillers provide flowers or different leaf colours or shape."

Jenny has tried strappy plants such as mondo grass, bromeliads, liriope and small dianellas and found they make good fillers. Many common houseplants such as syngonium, maranta, philodendron 'Xanadu', and a small crow's nest and other ferns also grow well lower down. Fuchsia, clivea, alstroemeria, nandina and begonia provide flowers and leaf colour.

↑ This is another style of planter from the Woolly Pockets company, called Living Wall Planters. These have a water reservoir in the bottom which reduces watering requirements (and they can also be used inside as they don't leak). Here, Jenny and Bevan are using them for herbs on a northern wall.

They also grow herbs, such as rosemary, sage, thyme, chives and parsley (which do well in the hotter conditions up the top), and mint (which does well in the shadier, cooler spots at the bottom). They grow some native plants too: groundcovers such as correa, native geraniums, scaevolas and brachyscomes.

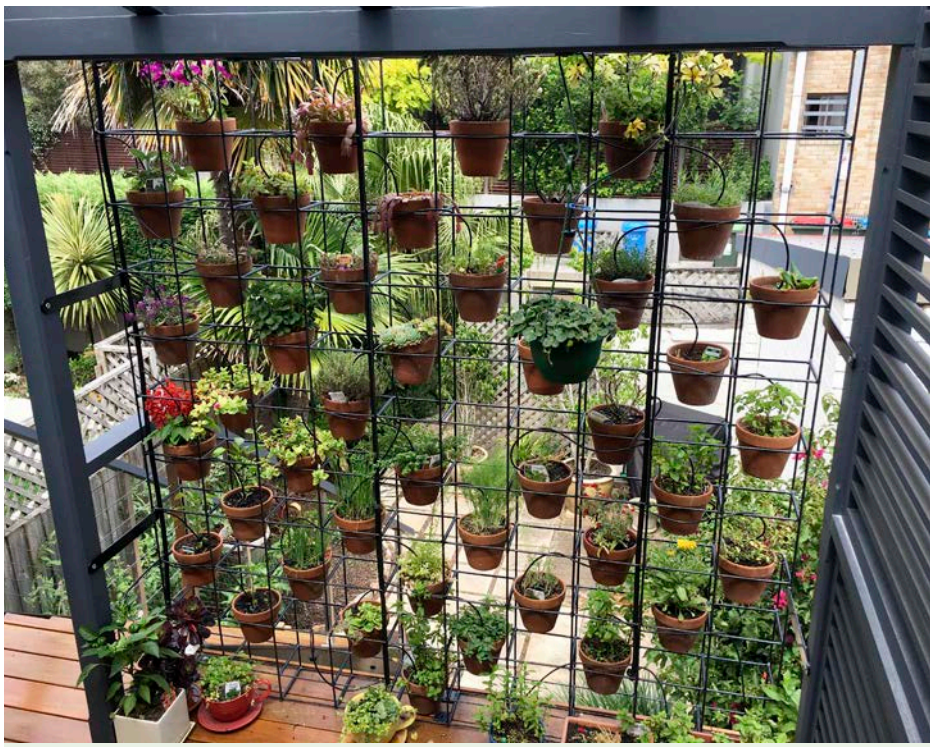
It's great to see these wall gardens doing so well. Vertical gardens can be a boon for those with small spaces that might otherwise be heat traps. Done right, they have the potential to add both aesthetics and cooling to our higher density cities, not to mention bringing in insects, bees, lizards and birds for biodiversity and plant pollination. ✱

This article is based on a presentation by Jenny and Bevan to the Adelaide branch of the ATA (*ReNew's* publisher), with input from Nick Thwaites from the Productive Garden Co. Jenny and Bevan live in the award-winning Lochiel Park green village and they are also involved in a community garden.

More info:
Some ideas: www.greencities.net.au/gallery
Carbon-positive house with sliding edible garden walls: www.bit.ly/CPHWVG
Woolly Pocket and other vertical garden products: www.sowwhat.com.au
Woolly Pockets: www.gardenbeet.com.au
Various wall hangers: www.brickgrip.com.au

Jenny and Bevan's system cost: $40 for a single pocket; $1000 for a wall of 25 pockets; plus potting mixes, irrigation and plants (and installation if not DIY).

↑ The pockets are screwed into a Modwood rail for support (six screws for each row—one at each reinforcing strap between each pocket) which in turn is attached to the Brick Grip brackets (in grey below chalk X) using the same screws. Thus, there is a bracket behind each screw.



Going to Reo

ATA members Sharon McGann and Paul Worth describe their pot-based vertical garden.

We saw a vertical garden we liked at a café in Melbourne, which inspired our version made by a local steel fabricator. Since then a local product Reogro has featured on *The Block*, and there are a number of providers; see www.reogro.com.au.

Building the wall

We tossed up between the rusty look, using untreated steel reo, or the painted look. We chose the coated version as we live near the sea. The build was fairly simple—two sheets of reo held apart with metal rods welded to the sheets. The fabricator then had the entire wall hot dip galvanised to prevent corrosion and sprayed with black enamel. It cost us $680 all up.

Filling the wall with plants

We found some standard 16 cm diameter terracotta pots for $2, so we purchased 30 of them. Friends told us we would get better water retention if we painted them, but we haven't done that yet.

We started in spring with a 'herb party'. We received quite a mix of herb seedlings, vegies, some flowers and succulents. The wall is west facing and gets the full Sydney summer sun all afternoon, so we needed hardy things.

We went to a course with a Sydney woman, Toni Slater: The Veggie Lady, www.theveggielady.com. She gave us great advice about setting up pots with organic potting mix and fertiliser brands.

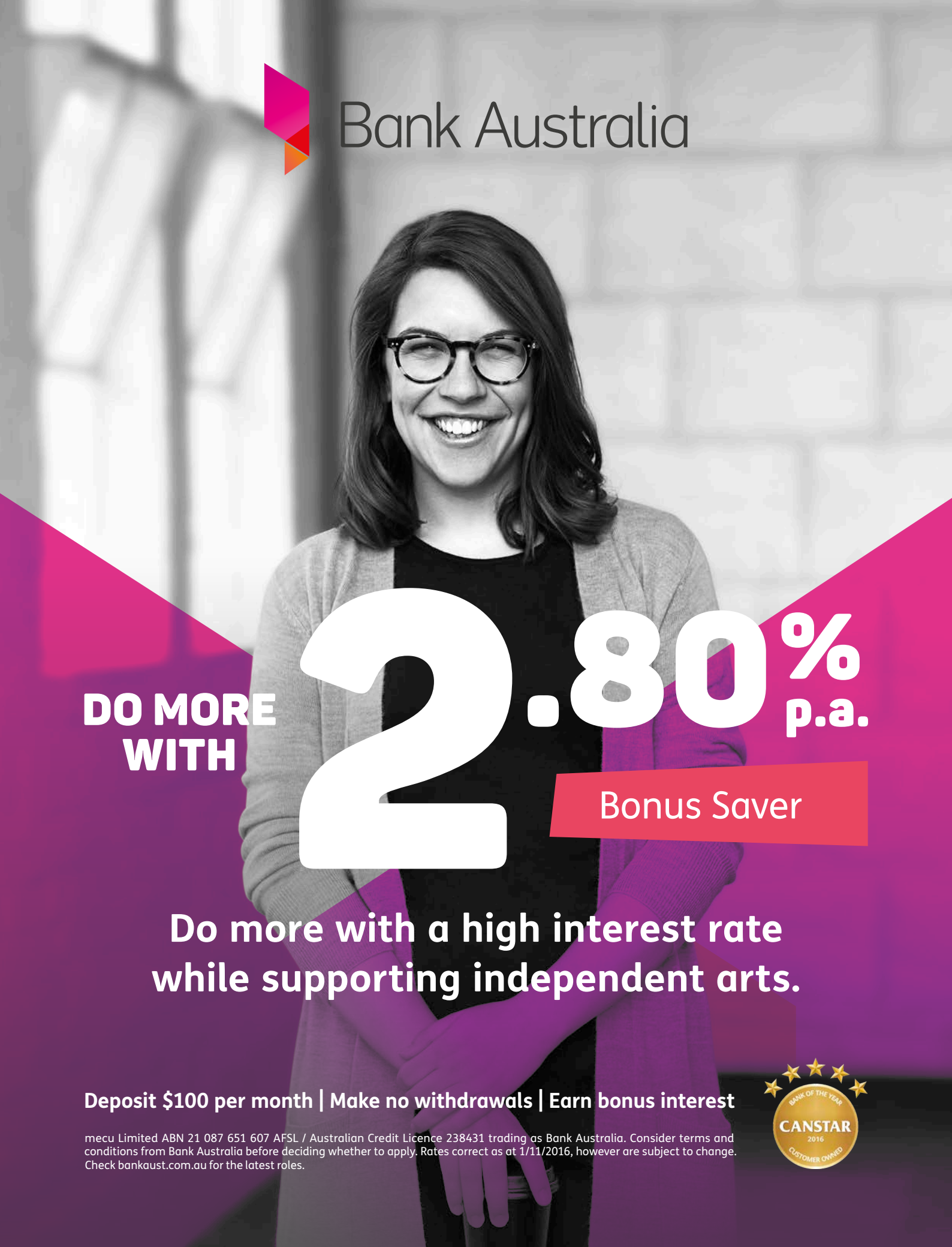
We do a fair bit of travelling so after a month we hooked up a watering system. It's on a timer to water at 6 am and 6 pm.

The lessons

Adjusting the drips is an ongoing effort. We are learning which plants need more water and putting them at the bottom so they get more water—the excess flows down. Choosing herbs and flowers that love full sun and like living in pots is another thing we're learning.

The verdict

We've had it now for a year and we love it as a decorative and alive privacy screen. We enjoy seeing the plants through our back door. And we love walking out the door and cutting a few herbs to sprinkle on eggs in the morning or salads in the evening.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A roof over your head
Choosing the right roofing materials

There are many different roofing materials to choose from, but what are the advantages and disadvantages of each, and how sustainable are they? Lance Turner surveys the market.

IN *ReNew 132* we looked at options available for walls when building a home or extension. But of course there's more to a home than just the walls—roofing is equally important as it not only protects the rest of the building, but also has to withstand the most intense levels of solar radiation of any part of the home, as well as considerable forces from wind, rain and hail.

The roof must also be able to support added structures such as solar panels and solar hot water systems, satellite dishes, ventilation and air conditioning systems, as well as the weight of people walking on it while installing and maintaining such systems. Plus it's used to collect rainwater for your home and garden.

There are many different roofing materials available, including corrugated iron and Colorbond steel, concrete, ceramic, metal and composite tiles, slate, shingles and even load-bearing panels such as SIPs (structural insulated panels). Each option has its advantages and disadvantages, each has its own particular look, and each comes in a range of options for that particular material.

Which roofing you go for will depend in part on the materials and the general look of the rest of the home, as well as your personal preference, which may be determined by a number of factors including appearance, the eco-credentials of the material, the range of colours and styles available, the building method (some roofing materials need more structural support than others), the level of maintenance you are willing to give to the roof, the fire resistance level required, and, of course, the location and hence surrounding environment of the home, including heritage or aesthetic requirements of your local council. Let's look at each material in turn.

Image: Master Roofing Australia

↑ Colorbond sheet is a very popular roofing material as it is light, durable and comes in a wide range of colours. This roof, in Annerly, QLD, was replaced after hail damaged the previous roof. Note how the edges of the roof capping are cut to match the corrugations in the sheet. This reduces weather ingress and keeps out pests.

Sheet materials

GALVANISED IRON/COLORBOND STEEL

These materials are made from thin steel sheet (typically less than 1mm thick) and are coated in either zinc (galvanised iron), an aluminium/zinc/magnesium alloy (Zincalume) or paint over zinc alloy (Colorbond) coating. There's also a stainless steel-based version of Colorbond for extreme coastal environments.

Steel sheet materials come in a wide range of profiles (the shape, corrugated or otherwise, when viewed end-on), including the common corrugated iron, the mini version (such as Lysaght Mini Orb, which is usually used on walls but can be used as a roofing material), as well as profiles more commonly used for commercial roofing although also suitable for some domestic projects, such as Trimdek, Klip-Lok and numerous others. See www.steelselect.com for information on the sorts of profiles available.

Sheet steel products are all used in a similar manner: they are either screwed (or sometimes nailed) to wood or steel battens, or they are clipped onto concealed brackets which are screwed to the battens. Both methods have the edges of the sheets overlapping to prevent water ingress, but concealed fixing systems eliminate piercing of the sheets associated with screw or nail fastening and provide a more reliable weather

"All sheet steel is easily recycled through well-established recycling systems, so there is no reason for these products to end up in landfill at the end of their useful life."

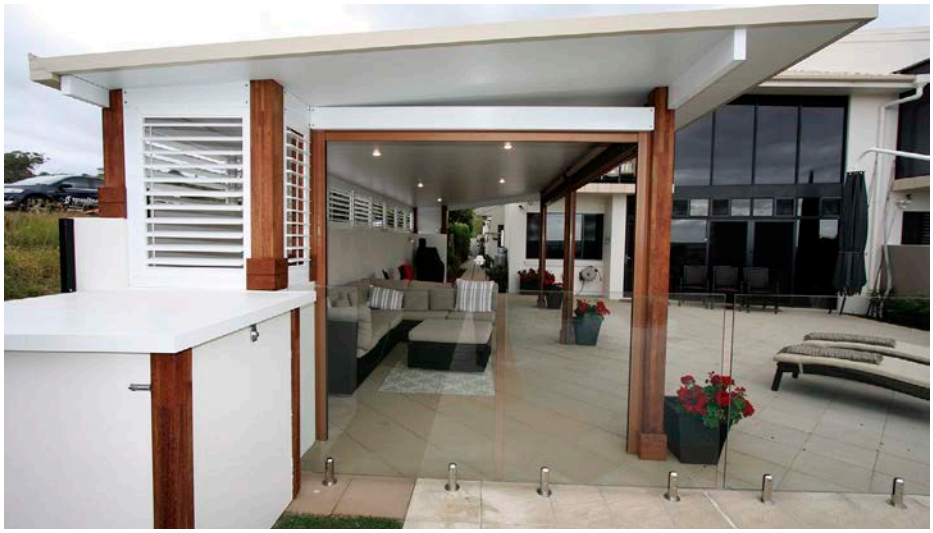


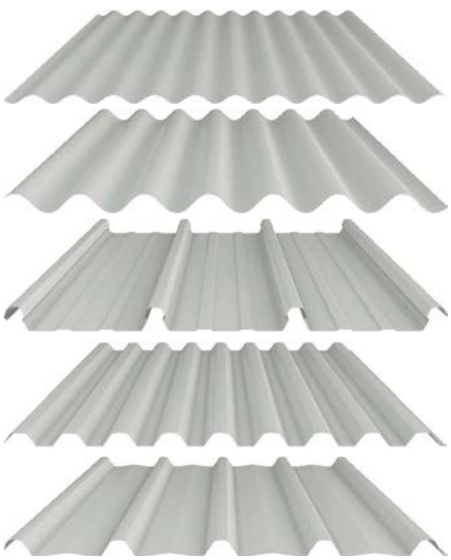
Image: Versiclad

↑ Structural insulated panels (SIPs) such as these from Versiclad can make an almost instant roof, complete with ceiling and insulation.

seal. Ridges are finished with purpose-made capping and, typically, various designs of gutter complete the eaves' detailing to provide a neat and clean finish to the roof.

Another technique which uses sheet roofing is the 'standing seam' method. Sheet metal 'trays' are formed from flat sheets with folded vertical edge seams which interlock and are then crimped down to complete the seam. This allows for very long tray panels to be used (up to 10 metres long) and is suitable for larger roofs and roofs with concave or convex curves. The disadvantage of the system is that once panels are locked together, they are harder to separate compared to sheets that are simply screwed down.

Advantages of sheet steel products are considerable. They are light and relatively easy to handle (although extreme care must be taken during windy days), are easy to fasten and quick to install (for professionals, at least), are very strong and, if installed correctly, will last for decades with minimal maintenance. They are also extremely fire resistant, although heat and sound travels through sheet steel products with ease.



↑ Roofing sheets come in many profiles, such as the range from Lysaght (approximately to scale), which includes (top to bottom) Custom Orb, Custom Orb Accent 35, Klip-Lok Classic 700, Spandek and Trimdek.

Sheet products have very few disadvantages, but poorly installed sheeting can become a sharp hazard when cleaning gutters if the sheets extend too far into the gutter.

Many sheet steel products contain recycled steel (check datasheets for recycled content and other sustainability features, as it varies between products and manufacturers), and all sheet steel is easily recycled through well-established recycling systems, so there is no reason for these products to end up in landfill at the end of their useful life.

INSULATED PANELS/SIPS

These consist of two sheets, usually coated or painted metal such as Colorbond sheeting, which are bonded to each side of a layer of insulating foam. They are similar to structural insulated panels (SIPs)—indeed SIPs can be used as roofing—but roofing panels such as Ritek's Custom Roof Panel, Stratco's Cooldek and Versiclad's insulated panels range are specifically designed for roofing applications.

They are very strong, lightweight and easily installed, and may provide the first level of both thermal and acoustic insulation to a home. These types of panels are available in thicknesses of 125 mm or more, so insulation levels can be considerable. A quick look around will find domestic-grade SIPs ranging from around R2 to R5 or so.

Maintenance requirements are minimal, much the same as regular sheeting products.

Tiles

Tiles have been a popular option in Australia and the finished result is preferred by many homeowners. All tiles, regardless of the material they are made from, have the advantage that they can be easily replaced if they suffer damage, such as from falling tree limbs, being walked on etc. Unlike with sheet materials, you only need to replace the area that has been damaged, not an entire roof section from cap to gutter. There are quite a few materials used for tiles nowadays, so let's look at the more common ones.

CONCRETE TILES

As you might expect, concrete tiles are made from cast/pressed concrete, which is a mixture of cement, sand and pigments. They are available in a wide range of colours and patterns, including traditional styles, flat slate-like tiles, bevelled and textured tiles.

Concrete tiles are relatively fragile as they usually have no internal reinforcing like structural concrete does. They are fairly easily broken if walked upon after being incorrectly fitted (a common problem after rooftop work, such as fitting roof-mounted devices, has been done) or dropped during installation, or if they suffer impacts from falling tree limbs and the like.

Concrete tiles can have a very long lifespan, up to 50 years or more, and if care is taken when a house is deconstructed, concrete tiles can find a second life in another building project. Old tiles can also be recycled by crushing, for use as fill material in new concrete or for other building works.

"All tiles, regardless of the material they are made from, have the advantage that they can be easily replaced if they suffer damage, such as from falling tree limbs, being walked on etc."

One disadvantage with concrete tiles is that they are heavy, so while concrete has a relatively low embodied energy per kilogram compared to other roofing materials (see www.yourhome.gov.au/materials/embodied-energy), the high mass per unit area covered compared to sheet and similar products results in a fairly high embodied energy for an overall roof.

Also, this high mass means roofing structures must be able to support the weight of several tonnes of tiles for the life of the building. As tiles are relatively small, roofing battens must also be fairly closely spaced, resulting in more materials use for the roof structure, and more time to install compared to sheet products.

Acoustically, at least two manufacturers stated their tiles will reduce outside noise through the roof by as much as 30 dB, which is considerable, so if noise is an issue then tiles are a good candidate for a roofing material.

Image: Westlinks Services, www.westlinks.co.uk

↑ Tile roofs require a batten row for each tile row, and are relatively time-consuming to install.

CLAY TILES

Clay tiles are usually made from terracotta clay fired to around 1100 °C, resulting in a waterproof vitrified tile. They are available in a range of colours and profiles and will have a very long life if cared for. Because they are fired, they can have an embodied energy of around 6.5 MJ/kg (University of Bath, UK, see en.wikipedia.org/wiki/Embodied_energy). While this is lower than steel sheet products, like concrete tiles, clay tiles' high mass per unit area comes into play, so clay tiles will have a higher embodied energy per total roof area than sheet products.

Being a ceramic, they are quite brittle and easily broken if badly treated, so care must be taken when handling and installing them. Like concrete tiles, broken ceramic tiles can be crushed and used as filler in new concrete or elsewhere as they are an inert material.

Like concrete tiles, clay tiles have a reasonable sound-reducing effect on outside noise, so may be more appropriate in high noise areas such as near main roads and airports. Also like concrete tiles, clay tiles are heavier than sheet roofing materials and so need appropriate supporting structures in the roof, which may add slightly to construction time and costs.

METAL TILES

As you might expect, metal tiles are made from pressed sheet metal and designed to look like more traditional ceramic/concrete tiles. They have the advantages of being lightweight, stronger than masonry tiles and more easily replaced than sheet materials should they be damaged.

Pressed metal tiles are usually either painted, like Colorbond, or have a textured coating that makes them look like a concrete tile. Both coatings can become damaged over time, from falling debris, foot traffic and heavy hail impacts. Metal tiles can also be dented to the point of needing replacement if someone walks in the middle of the tile instead of the top and bottom edges (where the battens are).

One advantage of metal tiles is that a single large tile can take the place of several concrete or ceramic tiles, making for faster installation.

Being predominantly metal (steel or aluminium), these tiles can be recycled through regular metal recycling channels.

Note that there are very few suppliers of metal tiles in Australia, but a hybrid style metal tile/sheet is available from at least two suppliers (Metile and Austech Roof) which consists of Colorbond sheets pressed to look like strips of tiles. The result is a roof that is easy to lay like sheet steel products while producing the look of tiles.

SLATE TILES

Slate gives a nice look to a roof, but slate is relatively fragile and heavy and requires a skilled roofer with slate installation experience to install it. If considering slate, you should find a slate supplier/installer with long-term experience.

While embodied energy of slate production is quite low, nearly all roofing slate in Australia is imported, adding to the energy debt of the material. Further, slate quarries can cause considerable damage to their local environment. However, slate has a very long lifespan if installed and cared for correctly.

COMPOSITE TILES

These are made from reinforced plastic composites, much like recycled plastic decking that has become popular in recent years, although composite tiles use virgin resins (not recycled) for longevity.

One example, Monier's Elemental series, comes in four sizes—the Slate (326 x 300 mm), the Shingle (450 x 350 mm) the Square (750 x 750 mm) and the Ultra Panel (1500 x 750 mm)—with a slate or stone finish which gives a slate tile/shingle look to the finished roof.

Some composite tiles are made to look exactly like traditional slate, but are lighter and easier to use. An example of these is the SVK slates from Premier Slate in NSW, made from fibre-cement sheet. Another slate-like

tile range is Tapco's Inspire slates, made from recyclable plastic and dolomitic limestone, and available in Australia from Bellstone. Yet another option is Authentic Roof slates from Authentic Roof Australia.

Composite tiles are much lighter than clay, concrete or slate tiles per unit of area (Authentic Roof slates, for example, are a quarter of the weight of actual slate) and much stronger, and are resistant to UV and hail. Monier provides a 30-year warranty on their Elemental range, while Tractile also provides a 30-year warranty and a stated lifespan of up to 50 years. Authentic Roof slates come with a 50 year warranty.

While the embodied energy of composite tiles is relatively low compared to other materials, they are less reusable/recyclable due to being a mix of plastic and reinforcing fibre. Currently there are no readily available composite material recycling systems in Australia, although it is worth contacting the respective manufacturers of these systems regarding future recycling plans.

ASPHALT SHINGLES

These are common in the USA but not so much in Australia. They are made of thin sheets of felt material impregnated with asphalt, then coated in another layer of asphalt on both sides. Mineral stabilisers are added to increase fire resistance and durability, and the top surface is coated with coloured crushed rock to produce the final finish.

Asphalt shingles are not a structural roofing material in themselves, but more a final finishing material, being laid over sheets of marine-grade ply that provides roof rigidity and support. There is usually another layer of asphalt-impregnated felt or similar material laid down over the ply before the shingles, to improve weather resistance of the final roof, so their installation is more complex than most other roofing systems.

However, because the shingles are light, thin and flexible, and roof capping is done using the same shingles folded over ridges, asphalt shingles are easy to work with, making them suitable for DIY use—although their installation can be a little time-consuming.

If installed according to the supplier's guidelines, lifespan can be 50 years or more, and they come with warranties of up to 40 years. There is debate as to the safety of using rainwater collected from asphalt shingle roofs. There seems to be no definitive resolution

Building-integrated solar energy

If you are looking to re-roof your home and don't yet have solar panels for electricity generation, then you should seriously consider building-integrated photovoltaics (BIPV). These are solar panels that take the place of some, or even all of the roofing material, providing an integrated look to the solar array. There are now at least four suppliers of BIPV systems in Australia:

- Stratco's Solatile (available in SA and Qld). www.stratco.com.au
- Monier's SolarTILES, which integrate with Monier's range of flat profiled concrete roof tiles, the Horizon, Madison, Georgian and Cambridge. www.monier.com.au/Products/Solar
- Star 8 Solar supply solar roof tiles that are compatible with the majority of Australian tiled roofs. www.star8.com.au/solar-tiles
- Tractile's Eclipse solar roof tile, which integrates with their Eclipse composite and Eclipse Thermo roof tiles to form a complete roof system that not only provides solar electricity, but solar hot water as well. Tractile also has a tile, the Horizon tile, with combined PV and hot water collector that integrates into existing roofs fitted with Boral concrete roof tiles. www.tractile.com.au

Tesla has been expanding operations by moving into the energy storage and generation markets, and recently released a range of four different solar tile products designed for complete roof integration. They are made of impact-resistant glass with a solar PV layer and a special optical layer so that they only look like PV panels from above, not from the ground.

The really interesting aspect of these tiles is the price. Tesla CEO Elon Musk has stated that the price of a Tesla solar roof will be the same or cheaper than an equivalent non-solar tiled roof (so, for example, a solar slate roof versus a regular slate roof). This has been made possible by streamlining the supply chain compared to regular roofing materials, as well as the tiles being lighter than masonry tiles. However, no pricing information has been released, so actual pricing is unknown—we expect that it will only compare directly on price with the most expensive roof types, such as slate tiles.

The tile range is expected to be released some time in 2017. www.tesla.com/solar

While you might think that combining both the roofing material and the solar panels would reduce costs compared to a regular roof with panels added on top, this generally isn't the case yet. However, total costs vary for each method of PV installation, the advantages of BIPV such as the more integrated and neater installation, elimination of roof penetrations, and reduced roof debris buildup and hence easier cleaning can more than make up for a slightly higher cost over a separate roof plus PV installation.

Just as conventional solar panels have reduced massively in price with the increasing uptake of the technology, BIPV systems will become more cost effective than regular systems as their popularity grows.

BIPV panel efficiencies vary and the tile systems generally have lower efficiencies than regular PV panels as their construction requires extra area for the roof integration component. For example, Stratco's Solatile measures 1662 x 995 x 5.5mm with its integrated 205W polycrystalline panel, giving it an efficiency of around 12.4%—somewhat less than most polycrystalline panels.

For the 33W Monier SolarTILE, which is around 0.25m² once fitted, the efficiency is around 13.2%, so approaches conventional polycrystalline solar systems.

However, the smaller panel sizes of some BIPV systems can allow for more flexible panel placement compared to the much larger panels found in on-roof PV systems.

↑ Tesla Energy has recently announced their roof-integrated solar panels, which take the form of glass tiles of varying styles and colours, with PV cells embedded inside them. There are four styles so far—Tuscan, Slate, Textured and Smooth. At time of writing, details on how the tiles are connected to form larger arrays was not available, nor was pricing.

Image: CSR Monier

↑ Composite tiles are more robust than regular tile but look as good or better.

of this debate, although a 2010 report from the Texas Water Development Board (www.bit.ly/TWDB_2010) showed that asphalt roofs are similar to other roofs such as steel and tiles, especially when used with a first flush diverter (as all roofs should be).

WOOD SHINGLES AND SHAKES

Timber shingles and shakes (a thicker shingle, sometimes with a coarse textured surface) are arguably the most sustainable roofing material as they are completely renewable and biodegradable, provided they come from suitably sustainable sources.

They are simply pieces of timber cut into tile-sized boards of a fixed height but variable widths, usually between 10 mm and 14 mm thick at the butt (the thick end), or up to 25 mm for shakes. They are simply nailed into place and then given a coating of wood oil or other preservative if desired, although some can be left au naturel.

Like asphalt shingles, wood shingles are usually fixed over a plywood substrate, which provides the majority of roof strength, as well as a continuous surface to nail into, so shingles can vary in size without complex batten systems.

While most other tiles are made in a factory, timber shingles can be made from any suitable timber and even cut on site with the right equipment. However, they are also available pre-made and at least one supplier, Cedar Sales, can provide western red cedar shingles with FSC and GreenTag certification.

Transparent/translucent sheeting

Often used for verandahs or garages, transparent or translucent materials transmit light into an area and fall into three common types: polycarbonate, PVC and fibreglass.

They are all used just like regular sheet products, and indeed have the same profiles, so that one or more sheets of steel roofing can simply be replaced with transparent sheets.

Because of their lower strength compared to steel sheets, they usually require load-spreading washers specifically designed for their profile to prevent screws pulling through the sheet during high winds.

Polycarbonate sheets are the most common form of light-transmitting sheets used for domestic roofing. They are available in a range of profiles and a wide range of tint colours and light/heat transmission ratings, from completely transparent through to almost opaque. Polycarbonate roofing can be expected to last at least 15 years in most situations, and often a lot longer.

A variation on polycarbonate sheeting is cellular sheeting, which consists of two or more parallel sheets separated by small walls to form many parallel tubes. This material is generally flat rather than profiled, and ranges from 3 mm thick to 40 mm or more for commercial grades. It is commonly used in greenhouses and commercial facades but has also found use in domestic light walls (in place of windows but more robust and private, for example, www.bit.ly/2fth9B0) and feature walls. Typical materials include Suntuf Sunlite and the Ampelite range of domestic- and commercial-grade sheeting.

Cellular polycarbonate sheeting does offer some insulation capability. The air trapped in the cells of the material forms an insulating blanket similar to double glazing and some of these panels may offer quite a high thermal insulation performance, helping to reduce heat loss from interiors—one reason they are used in some commercial greenhouses. One manufacturer, for instance, claims that their 10 mm Suntuf Sunlite Twin Wall Polycarbonate sheeting has a U-value of 2.9, which compares well with a U-value of 2.7 for an air-filled double-glazed aluminium-framed window.

PVC is similar to polycarbonate, just cheaper and more environmentally damaging to produce. It is also not generally recommended for full sun exposure and so isn't used extensively.

Fibreglass sheeting comes in a range of profiles, colours and light and heat transmission levels, much like polycarbonate sheeting. However, having glass fibre reinforcement can make it stronger than other light-transmitting sheeting products. Many readers will have seen degraded fibreglass sheeting and consider it to have too short a lifespan, but products such as Ampelite's Wonderglass GC, which has a chemically bonded UV resistant coating that virtually eliminates surface degradation and loss of light transmission, have addressed this issue.

The main environmental drawback with virtually all light-transmitting roofing sheets is the lack of recyclability at end of life. Very little recycling of polycarbonate and PVC is done in Australia; roofing sheets are usually too degraded by weather and UV damage to be recyclable in regular recycling streams, even if recycling schemes are available. Fibreglass is even more difficult to recycle as it is a composite material consisting of polyester resin and glass fibres.

Untinted transparent roofing sheets also transmit a great deal of the infrared radiant energy falling on them, so they have almost no insulation capability. Tinted roofing sheets, which come in a number of colours and light transmittence levels, can be more effective at reflecting heat. Some materials, such as Suntuf SolarSmart, are designed to pass a good percentage of visible light while reflecting up to 85% of infrared, depending on the tint.

As these materials are usually used outdoors, some heat transmission is generally

not a problem, but when used on garages or hybrid living spaces, such as sheds converted to living spaces, the ingress of high levels of heat can be a problem, so the stronger infrared reflecting materials should be used. In summer, even a small amount of infrared entering through the roof can make a room unlivable. This can be mitigated by the use of an external blind or shutter, but in general, transparent roofing sheets are not suitable for use in enclosed living spaces unless your home is located in a very cool climate.

What's the best roof design?

There is no simple answer as it depends on a number of factors, including the design of the rest of the house, the house location and orientation, climate, and the need to accommodate other roof-mounted equipment such as solar arrays.

The roof design will influence the range of suitable roofing materials. For example, near-flat roofs must usually use sheet metal or SIPs-type materials as tiles will suffer from water ingress, due to rain being blown back under the tile edges in high winds. It is possible to seal behind tiles for such situations, but flat roofs generally look better with sheet products—tiles just don't suit a flat roof.

Roof angle should be carefully considered. Flat roofs, while simple, have some disadvantages. For a start, they often don't allow much space for good levels of insulation, although this can be solved with better design or using SIPs. However, in areas that experience high temperatures, a flat roof is rarely the best option. Flat roofs also usually require solar panels or solar water heaters to be mounted on tilting frames, which can be unattractive and add to the cost of installation, as well as substantially increasing wind loading on the roof.

Another issue with flat roofs, at least in high rainfall areas, is whether they are able to shed water rapidly enough. Steeper roofs shed rain more easily, and this results in other debris such as accumulated dirt, leaves etc being removed more readily than with a flatter roof.

The common roof styles found in most Australian suburbs involve roof angles of between 15 and 30 degrees, although it varies. In years gone by, the standard roof pitch (known as a quarter pitch) was 22.5°, but nowadays anything goes, depending on the requirements of the homeowner, builder and local council (some councils have a minimum requirement, such as 25°).

Roof pitch can also have an effect on the cost of the overall build, with higher pitched roofs seeing a greater wind loading and so needing to be structurally stronger, as well as having a larger surface area and so needing more roofing materials. So, while that high-pitched roof might look nice, consider what it is doing to the building budget. Of course, if you design the house such that the steep roof can accommodate a living space instead of adding a conventional second storey, the equation changes and the higher pitch may actually reduce the build cost.

Thermal properties

With the exception of SIPs, the insulating abilities of most roof materials are minimal compared to the overall insulation requirements for a thermally stable home, so the slightly higher insulation abilities of one material over another should not be a deciding factor in roof material selection. The insulation inside the roof cavity, such as reflective foil sarking and bulk insulation, has a much higher R-value than most roofing materials.

Sheet steel and metal tiles have almost no insulating properties of their own. The exception to this is products that are very light coloured, or have proprietary heat-reflecting coatings, such as Colorbond Thermatech, which can reduce the incoming radiant energy into a roof cavity.

While concrete, clay and composite tiles have a greater insulating ability than metal products, this will still be low. Slate has a high thermal conductivity and therefore low insulative value. For example, 25mm slate is rated at a very low R0.1 (US units) or R0.018 in SI units (used in Australia).

Concrete, clay and slate tiles have a high thermal mass, which means they store heat quite well. This is generally a disadvantage in warm months when that results in a hot blanket of material on top of a house which is desperately trying to cool down! The low mass of roof sheeting products means that although they may absorb heat quickly, they also radiate it quickly, unlike concrete or ceramic tiles. Composite tiles can be expected to perform better thermally than concrete or clay tiles, and without the high thermal mass. Because of the plywood substrate, and the insulating ability of the shingles, asphalt and wood shingle roofs have a small but measurable amount of insulation ability.

Keeping the house cool

INSULATION

As mentioned above, roof design must allow for adequate insulation to be installed to enable the house to perform well thermally. Most roofs with an accessible roof cavity will contain bulk insulation on the ceiling as well as foil sarking under the roofing material.

VENTILATION

Another heat reduction strategy for cavity roofs is good ventilation, which can be in the form of passive or forced ventilation. In passive ventilation, vents are positioned at opposite sides of the roof to allow for cross-ventilation from breezes. A common but fairly ineffective form of forced ventilation is the rotary ventilator, which is spun by the wind and uses either a set of fan blades or the venturi effect to try to extract hot air from the roof cavity. However, hot days are often still days, with insufficient wind strength to extract enough hot air from the roof cavity to make any difference.

A better option is a suitably sized solar ventilator, which uses a solar panel coupled to a DC fan to extract hot air. To be effective, any ventilator must be able to extract the entire volume of the roof cavity every 10 minutes or so, and even faster on very hot days, so you need an appropriately sized ventilator, or several smaller ones. If a home already has a solar array fitted to the roof, it is simpler and more cost-effective to use a mains-powered ventilator, as it will draw its power requirements from the solar array anyway (barring any large loads like air conditioning, which might absorb all available solar power).

Ventilation isn't used just for temperature control, it also reduces moisture buildup and the associated problems, such as mould growth and rot occurring in structural timber. However, how much ventilation is required, and when it should be active, depends on the design of the home, its level of air tightness, and the local climate. For example, a well-sealed home will benefit from a well-sealed roof cavity in winter as it will help contain warm air inside the building envelope and reduce thermal losses from the living spaces, especially on cold, sunny days.

All of the ins and outs of roof ventilation are too complex to go into here and should be addressed when the home is designed. For homes being re-roofed, then an inspection should be made to determine if moisture has

Table 1. Roofing materials, advantages, disadvantages and sustainability considerations.

Material	Advantages	Disadvantages	Longevity	Insulative ability	Fire resistance	Embodied energy/m²	Material sustainability/ recyclability	Maintenance level	Sound attenuation	Construction time	Cost
Sheet steel/ Colorbond	Strong, light, durable	Sharp edges so must be installed carefully. May rust if damaged	15 to 50 years, depending on location	Very low, unless IR reflective coated	High	Low to medium	Almost infinitely recyclable. May contain some recycled material. Materials mining can be damaging	Very low	Low	Fast	Medium
Concrete tiles, clay tiles	Long lifespan	Heavy, fragile	50+ years	Low	High	Medium to high	Can only be reused or downcycled. Easily reused if undamaged. Broken tiles can be crushed and used as fill/ aggregate. Materials mining can be damaging	Low	Medium	Slow	Medium
Composite tiles	Strong, light, long lifespan	Possibly not recyclable	30+ years	Low	Medium	Medium	Recyclability depends on material and manufacturer. Uses petrochemical plastics	Low	Medium	Slow to medium	Medium
SIPs	Strong, durable	Probably not recyclable	15 to 30+ years	Medium to high	Medium to high	Medium	Petrochemical foam core is hard to recycle. Steel recyclable if can be separated from foam core	Low	High	Very fast	Medium
Asphalt shingles	DIY compatible	Can off-gas, roof ventilation required	15 to 40 years depending on climate and quality of tile	Low (complete system including plywood backing)	Low	Low to medium	Not easily recycled yet. Mostly natural materials, but it is a composite material with petroleum base	Medium	Medium to high	Slow	Low to medium
Wood shingles	DIY compatible	High maintenance, short lifespan if not maintained, prone to pest damage	5 to 25 years, depending on wood used, finish etc	Low (as above)	Low	Low	Biodegradeable unless treated with chemical treatments. Medium to high sustainability but depends on wood source. Hardwood may be unsustainably logged	High	Medium to high	Slow	Low to medium
Slate tiles	Long lifespan	Heavy, fragile, requires a skilled installer	100+ years	Low	High	Low to medium (mostly transport miles)	Reusable if undamaged. Broken slates can be crushed and used as fill/aggregate. Sustainability depends on eco credentials of quarry. High transport miles	Low	Low to medium	Slow	High
Solar tiles	Light, makes for neat PV system, may be cheaper than regular roof + PV	None	25+ years (design life)	Low	Medium to high depending on materials	Medium	Recyclability depends on tile design, materials and manufacturer. Some use petrochemical plastic substrate	Low	Low to medium, depending on materials	Medium to fast as tiles are usually large	High

been a problem, and appropriate levels of ventilation included to address any issues.

ROOF COLOUR

While insulation in the roof cavity will greatly reduce heat ingress into the living spaces, it makes sense to reduce heat ingress into the cavity itself as much as possible. In general, light-coloured roofs will reflect more heat than dark colours, although many councils have limits on how light a roof can be—white roofs are often frowned upon or simply not allowed.

Some materials, such as Colorbond sheets, have infrared reflective coatings that can help reduce the roof cavity temperature by reflecting more infrared than regular paint or tiles of a similar shade, despite still appearing quite dark. While there is no magical substitute for a lighter-coloured roof, such coatings can reduce the heat load of a home somewhat.

Note that there are thermally reflective paints that can be used to reduce heat ingress on dark roofs. A typical example is Thermoshield (www.thermoshield.com.au) which uses hollow ceramic beads in a white binder to produce a paint that reflects a higher proportion of the solar radiation that falls on its surface. These types of paints mean that you end up with a white roof, so check with your council as mentioned above.

SHADING

Of course, shading will also greatly reduce the level of incoming heat, but if you plan to fit solar panels to your roof, then shading is not an option. However, the panels themselves can provide a degree of heat reduction. While they will heat up and reradiate some of that heat from their rear surface towards the roof, the amount of heat reradiated will be considerably less than from direct radiant sun on that portion of the roof. On a sloping roof, with a reasonable gap between the panels and roof (at least 50 mm), convective airflow between the panels and roof can occur, helping to reduce temperatures for both panels and roofing.

In summary

We hope this brief introduction gets you started with thinking about the materials and design for your roof—there can be a lot to consider to ensure you get the roof that performs to your requirements. As a handy reference, we've included a summary of each material's advantages and disadvantages in Table 1. ✱

General roofing info and resources:
Roofing Tile Association of Australia: www.rtaa.com.au
Metal Roofing and Cladding Association of Australia: www.mrcaa.com.au
Master Builders Australia: www.masterbuilders.com.au
Note that individual states may also have their own roofing associations.

"The insulating and thermal mass properties of a green roof can help stabilise internal room temperatures and reduce sound ingress. Other advantages include the reduction of the urban heat island effect, reduced stormwater runoff, improved air quality and creation of habitat for wildlife."

Green roofs

The vast majority of roofs on Australian homes are conventional—Colorbond/galvanised, tiles, slate or shingles. However, there is another type of roof that can perform better thermally than any conventional materials—a green roof.

A green roof is simply a roof designed to grow plants. A layer of growing medium—soil or lightweight aggregate—is laid on a suitably prepared and designed roof structure, which may include waterproofing, root barrier and drainage system. The roof is planted out with appropriate plant species.

The insulating and thermal mass properties of a green roof can help stabilise internal room temperatures and reduce sound ingress while helping the house to blend into the surrounding landscape—ideal for homes in wilderness areas.

Other advantages include the reduction of the urban heat island effect, where large surfaces of concrete and bitumen absorb heat rather than reflecting it, reduced stormwater runoff, improved air quality and creation of habitat for wildlife.

Green roofs fall into two main categories: extensive and intensive.

Extensive roofs are those with growing medium thickness under 200 mm. They have a relatively low roof loading of up to 120 kg/m² and use low mass plants like sedum or other low growing succulents, ground covers and mosses, grasses and small ferns. Extensive green roofs are normally designed to require minimal care and are usually only accessed for maintenance, so most extensive roofs will only grow simple plants that require little effort.

Extensive roofs can be laid on lightweight roofs using structures not much different from those suited to Colorbond roofs, for instance, and in some cases, subject to structural limitations, can be laid on top of existing lightweight roofs.

Intensive green roofs use a growing medium depth over 200 mm with much higher roof loads of up to 700 kg/m² or more. They can include high mass plants like large shrubs and small trees, and are designed to be used and maintained regularly, so they can even be used for growing herbs and vegies.

Photo: Nic Granleese, Architect: Nest Architects

As you might expect, only certain structures are suitable for green roofs due to the high mass on the roof. Buildings made of concrete and stone or other materials with high compressive strengths are required—heavy steel or timber structures can be suitable, but the engineering must be carefully calculated.

Green roofs can be either flat or near-flat (the usual format for an intensive roof) or sloping. A sloping roof increases the water run-off from the roof during rain, so less water is retained and waterproofing is less critical. In an intensive roof, waterproofing must not only last the life of the building, it must also be able to withstand plant root penetration from more aggressive plants such as small trees.

This leads us to the costs of green roofs. A simple extensive roof may cost up to a few hundred dollars per square metre, not including any building permits and fees, roof strengthening or moving of roof infrastructure. An intensive roof can easily cost into the thousands of dollars per square metre due to the high structural strength and levels of waterproofing and root barrier required—and the cost of the much thicker layer of growing medium and more expensive plants than extensive roofs normally have. Actual cost will depend on many factors.

For most domestic situations, an extensive roof is probably the best option, but if your garden space is otherwise limited, then an intensive green roof can double as an outdoor living space, potentially offsetting the higher cost of this sort of roof.

A useful guide on planning a green roof, the *Growing Green Guide*, is available at www.growinggreenguide.org
Your Home green roof page: www.yourhome.gov.au/materials/green-roofs-and-walls
Green Roofs Australasia: www.greenroofsaustralasia.com.au
Wikipedia green roof page: en.wikipedia.org/wiki/Green_roof

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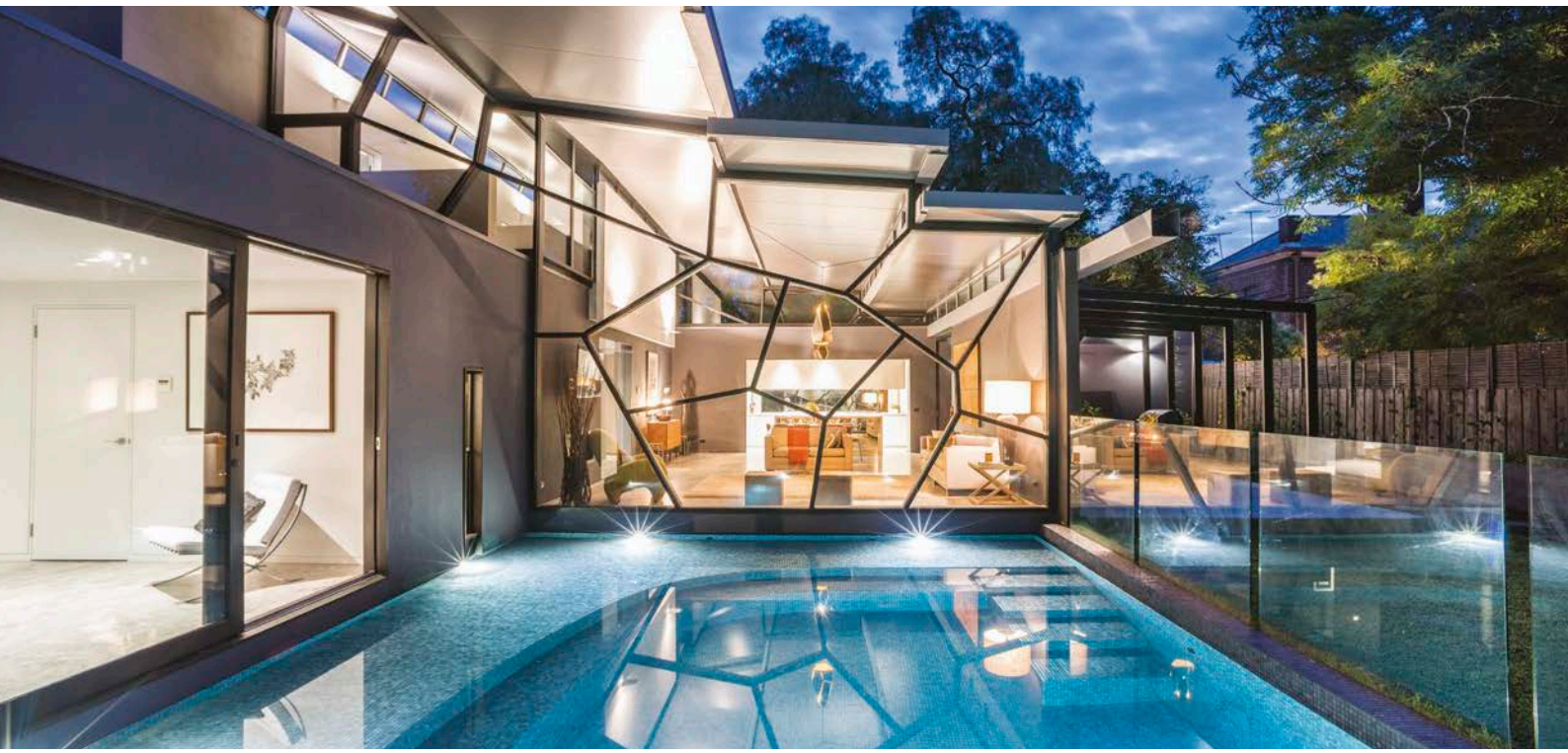

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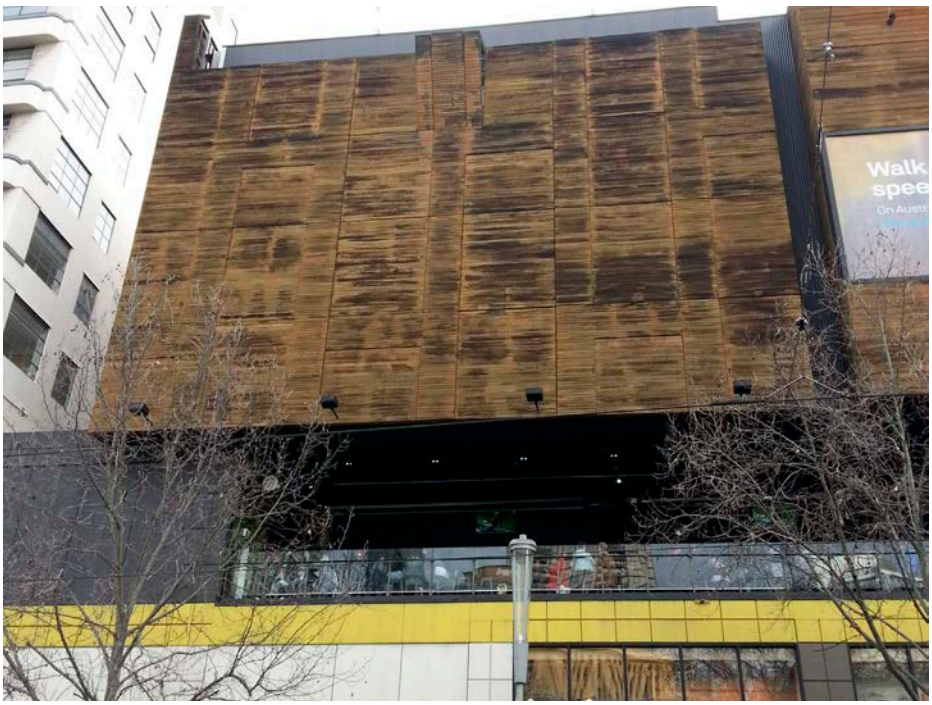
Revealing work
A brief guide to timber finishes

Choose right, prepare well and work with the timber's properties: Peter Smyth delves into the issues to consider when selecting and using timber finishes.



← When timber finishing doesn't go as planned: uneven application followed by too long between maintenance reapplication means that achieving even weathering or an even level of finish will be very difficult without completely stripping the finish from this building and starting again. Where maintenance access is difficult (such as here on Swanston Street in Melbourne), it can be better to choose a timber and finish combination that requires less frequent renewal.

WHAT are we talking about when we say we are finishing timber rather than painting it? Perhaps the most fundamental and obvious difference is that we care what the underlying timber looks like. We have gone from regarding the timber purely as a functional substrate to using it for its aesthetic properties.

This has a number of consequences. The first is that how we prepare the timber for the finish is of much greater importance; this includes obvious points such as not filling holes with an undesirable colour, to more subtle concerns such as how we sand the timber. Second, we are often using the finish not just to preserve the timber but also to enhance its look, so the timber and finish must work in a kind of symbiosis. This relationship is at the heart of what we are trying to do when we finish timber and there are a multitude of ways it has been approached over the years.

Timber selection

Not all timber is created equal and through all of what follows it is worth bearing in mind the importance of appropriate timber selection. This is particularly important in outdoor applications, with some species being more susceptible than others to weathering, termites and other forms of ageing and decay. A wealth of information exists in this area; see links at end.

Penetrative vs surface finishes

Timber finishes fit on a spectrum between those that are penetrative, such as traditional oil finishes which soak into the timber, and those that are film or surface finishes which sit as a layer on top of the timber, as seen with the plastic-like resin finishes. In practice most finishes both penetrate the timber and leave a surface film: it is just a question of the degree to which they do each.

In using penetrative treatments we are seeking to protect and preserve the timber through the finish curing and hardening within the outer surface of the timber. Such finishes do not necessarily protect the timber from impact or staining as effectively as some of the more superficial treatments, but done well they can be both attractive and protective, and are generally easy to use, renew and repair.

Surface treatments are often harder for non-professionals to apply than penetrative treatments and are more likely to be based on (less desirable) high-VOC solvents, although improvements have been made in both these areas in recent years. They are often more impact-resistant than penetrative finishes and many of them can nearly completely prevent water and other liquids affecting the underlying timber. They can be hard to repair, particularly if they are not maintained properly.

Photos: Fiona Bowie

↑ An oil finish being applied by hand with a rag to a benchtop. Oiling a floor or a deck is quite similar, although everything is scaled up. All oil-based finishes will darken timber somewhat, which may be desirable, but on pale timbers it can appear as an unattractive yellowing. Water-borne finishes have less of this effect.

← Sanding, be it by machine or by hand, should be done along the grain. Understanding of grain is perhaps the most fundamental concept of timber working and finishing.

Preparation

There can be more work in preparing timber to take a finish than in applying the finish itself. While the actual amount of preparation depends on both the product to be applied and the item being finished, finish preparation is worth bearing in mind whenever you use timber. This article can't look at how to prepare timber in great detail, but there are a few (almost) universal rules.

No matter what you are doing, work along the grain, with rare exceptions. This is the most universal rule of all and is particularly important when sanding and applying a finish.

In general, the more time spent smoothing and preparing timber, the higher the quality of the eventual finish. There are exceptions to this and as always there is a compromise between effort expended and benefit gained.

Contaminants on the timber should be avoided: anything oily, silicone sealants and steel shavings are particularly problematic. Be careful what gets on timber when you are working around it: cleaning contaminants from unfinished timber can be extremely difficult.

Fillers, stains and the like must be compatible with the finish that is to be used. Read the instructions or research the finish before starting.

Application

There are a number of ways finishes are usually applied, dependent on the particular finish. The simplest is to use a rag, mop or sponge to wipe a finish on, a technique which can be used effectively by anyone.

Many finishes are brushed or rolled on, in a similar fashion to paint, which requires a greater level of skill and the visible brush strokes that can be left behind are often more noticeable than in the application of paint.

Finishes that are sprayed on are often of very high visual quality but require equipment that is potentially expensive, somewhere appropriately set up to do the work with adequate ventilation at a minimum, and a reasonable level of skill—spraying is not generally recommended for the casual DIYer.

Maintenance and weathering

Often considered much later in the process than it should be, maintenance will make or break the finishing of timber, particularly in situations that require high durability, such as outdoors or on floors. It needs to be accepted that timber is an organic material and it is extremely difficult to completely stop it changing over time. Outdoor timber particularly will noticeably change with time, regardless of finish. It is much better to accept and work with this than to try to avoid it.

When selecting a finish it is very important to ascertain how often it must be reapplied or maintained. While it may not be much of an issue with furniture, climbing up a ladder every six months to re-oil window frames is probably not something you want to do. It is worth being conservative here—if a manufacturer states that a finish needs maintenance every five years it is safer to plan to renew it every three or four. It is also worth understanding the consequences of imperfect application and maintenance, and this information can be hard to get from the manufacturer. Talk to others who have used the finish and research online as a start.

Some important things to bear in mind with outdoor timber are:

- Surface finishes such as varnish can flake, particularly if they are not refinished in a timely fashion. This can be very hard to repair without completely stripping the finish and starting again.
- Uneven application of the finish can be hard to spot when it is new but can lead to blotchy and uneven weathering.
- Weathering is unlikely to be uniform even with the perfect application of a finish, particularly early in the weathering process and particularly if some is exposed and some sheltered, such as under eaves.

Ecological and health concerns

Many of the products aimed at the professional market have good health and environmental information surrounding them. At a professional level it is possible to specify and use water-borne low-VOC products even in areas such as high-traffic commercial floors. In this way, the situation is not terribly different to the paint market. As with paint, there are several schemes and standards that define what a low level of VOC actually is. Look for products which state actual numbers and/or the scheme they conform to. GECA has a paints and coatings standard that is relevant here.

As discussed in the 'Eco-paint Buyers Guide' in *ReNew 136*, all VOCs, regardless of source, are contributors to smog. However,

not all VOCs are equally problematic for health; it varies from product to product, but the all-natural finishes will tend to contain less hazardous VOCs than synthetic ones.

The most notable VOCs in natural finishes are generally of the terpene family, either d-limonene, which is found in citrus-based products among others, or one or more of the pinenes, which are found in products containing gum turpentine. These are generally considered non-toxic, although they can be an eye and skin irritant in concentrated form. So, the lower the VOCs, of any type, the better. Also, there has not been an enormous amount of research looking at the long-term effects of these VOCs, but what does exist suggests that longer term chronic exposure to them has detrimental effects on the respiratory system and that they react very readily with other pollutants such as ozone to produce substances that have more immediate health effects. These particular VOCs dissipate rapidly and it seems unlikely that these issues will affect those with intermittent exposure, such as those finishing their own furniture or doing DIY work around the home, but the potential for harmful effects is certainly worth taking seriously by those using these products daily.

Aside from the issues surrounding VOCs, it is worth being aware that this product area, like any other, is susceptible to greenwashing. It is well worth quizzing manufacturers, consulting relevant material safety data sheets and otherwise researching what is in a particular product, particularly if you are likely to be using a significant amount of it. Manufacturers that are willing to name all of their product's ingredients, have clear and up-to-date safety data sheets and who make information like this freely available should generally be given preference.

Cleaning up

There are various methods that have been published for the cleaning of painting materials that apply equally to timber finishes (see the resources at the end for one of these). An additional thing to bear in mind in the timber-finishing realm is that some oil finishes such as linseed and tung oil may be applied with a rag, particularly when used on furniture. These rags can then spontaneously catch fire if left in the open, particularly if they are heaped. Put oil-soaked rags like this in a tin that can be sealed with a lid to keep out oxygen, rather than storing or disposing of them loose.

Do your research

All of this gives you a starting point for thinking about finishing timber—the key from here is to research. Read as much as you can and talk to manufacturers and suppliers about what you want to do. With the right approach, you can then have good-looking timber that lasts a long time.

Peter Smyth is a Melbourne building designer and timber worker, with a particular interest in sustainable design and practice. He has been working with timber for over 20 years.

More info:
www.geca.org.au—Relevant standards include those on paints and coatings, floor coverings and furniture (levels A and B)
www.ecospecifier.com.au
www.globalgreentag.com
www.woodsolutions.com.au—aimed at industry, but an array of information on preparation and application; registration required.
www.resene.com.au/homeown/problem-solver/cleaning-brushes-and-rollers.htm—a good paint (and finish) cleaning method.
www.bit.ly/2016-RPG—Table of eco-paints and wood finishes, first published in *ReNew 136* in July 2016.

Note: Many years ago the only turpentine available was a plant extract. These days the common form of turpentine is a petroleum product usually referred to in Australia as mineral turpentine, which is often used as the solvent in oil-based paints and finishes. Natural turpentine, normally sold as gum turpentine, is still available and is used in a number of natural finishes, both factory-made and DIY. See the article text for a discussion of its VOC properties.

⚠ Warning

Ensure you have adequate ventilation and follow all manufacturer guidelines during application of finishes. Dust (particulate) masks are needed when sanding wood or old painted surfaces, and a respirator mask with a gas vapour filter cartridge (A-AUS or better) should be used when painting with high-VOC products. Hydrocarbon solvent-based products are usually flammable, so always make sure there are no ignition sources when using them, particularly if using them indoors. Follow the manufacturer's cleanup procedures and dispose of waste cleaning solutions in an appropriate manner, not down the drain.

Photo: Fiona Bowie

↑ French polishing, as seen here, requires a very high level of skill and a great deal of time and effort. On top of that it's not very durable. Finishes like this are consequently not common but they can look extraordinary when the piece warrants it.

Treatments to increase durability

There are a number of non-finish treatments that modify timber to increase its durability and longevity, which are applied by a manufacturer and can't be applied by an end user. They include treatments that have been used for many years such as copper chromium arsenic (which makes treated pine look green and has health concerns), but also include newer, less well-known treatments that are more suitable for instances where aesthetics matter. These include thermally modifying timber (Lunawood or Thermowood is the most common product), acetylated timber (Accoya is a well-known brand) and a number of specialised impregnating treatments. Most of these newer treatments are still uncommon and it is important to discuss your use of these products and their subsequent finishing with the supplier. Some of these treatments change which products the timber may be finished with, which is important to be aware of. A good starting place to learn more is www.bit.ly/WSNFT

Table 1: Types of timber finishes.

Type	Example names	Use	Penetrative/ surface	Appearance and durability	How applied	Maintenance	Enviro/health	Notes
Natural oils	Tung, linseed	Indoor and outdoor. Furniture to flooring. Very versatile	Entirely penetrative	Can be hard to achieve anything but a dull surface. Can be very durable but may still stain	Easy. Rag, brush, roller etc. Then wipe off and buff	Easy. Lightly sand, clean and reapply	Generally enviro and health friendly. Even edible in food-safe form	Often thinned with natural or mineral turpentine
Modified oils	Decking oil, flooring oil, external cladding finish	Flooring, decking, cladding, furniture, kitchens	Largely penetrative. Many contain surface finish components	Appearance varies by manufacturer from matte to semi-gloss. Very durable	Easy. Rag, brush, roller etc. Follow directions	Generally easy. May need some proprietary cleaning or prep. Then reapply	Generally good though many contain anti-bacterial agents and UV filters that can be hazardous. More care required than with natural oils	Some appear at first glance to be 100% natural but are not, e.g. Tung Oil Finish often contains dryers and other additives
Varnish—oil-based or water-based	Polyurethane, poly, others marketed as varnish, Estapol, lacquer	Indoor and outdoor. Furniture to flooring. Very versatile and extremely common	Surface, with some penetration, depending on product	Matte to gloss. Generally durable, may chip, scratch and otherwise wear	Brush, roller, spray or rag. Can take some practice to get right. Eventual appearance is very dependent on quality of application	May require full stripping and re-preparation, particularly if allowed to partially peel before reapplication. Otherwise sand and reapply	Often high VOC content in the oil or solvent based form, and often of significant hazard level. Otherwise reasonable. Mineral turpentine based varnishes can be used similarly to oil based paints	Originally an entirely natural and organic product, now extremely rare in this form. Polyurethane is a common sub-type of varnish
Danish oil	Danish oil, Scandinavian oil, teak oil	Furniture and joinery	Mostly penetrative but with a small level of surface film build	Traditional look of mid 20th century Scandinavian furniture. Medium durability	Rag or brush and then rub back and buff	Easy. Reapply	Generally similar to mineral turpentine varnishes and paints	Essentially a varnish variant with high level of oils and low level of resins
Hardwax	Hardwax, hardwax oils	Flooring, joinery and furniture.	A hybrid, both penetrative and surface	Matte to gloss. Very durable	Rag, brush, roller or pad. Generally easy	Easy. Reapply	Generally reasonable, although can be hard to ascertain all ingredients even if based on natural ingredients. Can have significant VOC level	Not yet a very common finish, information can be scarce
Wax—traditional	Carnauba, bees. Often sold as furniture polish	Furniture and joinery	Surface	Very attractive high gloss. Final application on top of other finish. Not durable	Rag and buffed	Easy. Reapply	Very good if used with natural solvent. Chronic exposure may be problematic	Normally mixed into a paste with turpentine or similar. Can be homemade
Shellac	French polish, when applied specially	Sealer, polish, a component of some grain fillers	Surface	When used as French polish very attractive. Heat, UV and scratch sensitive. Not durable	Rag or brush as a sealer. With a great deal of skill as a polish	Difficult	Very good. Solvent is normally pure alcohol, methylated spirits, etc. Natural animal product	'Dewaxed' shellac should be used when it is used as a sanding sealer

Landscaping with impact
Reuse in the garden

Permaculture gardener and teacher Drew Barr has loads of experience with reusing materials in the garden—even getting high school students involved in creating quirky but useful structures.

BUILDING materials can be expensive, and many have high embodied energy and other environmental burdens attached to them. Sadly, old building materials can end up in landfill as they may not be suitable for use in new builds. But there are many other uses for them, particularly in the garden. Here are some options for masonry, metals and other materials—and some examples of how I've been using them alongside students to build a permaculture garden at Templestowe College in Melbourne's north.

Image: Laura Varrasso

↑ The gates to the Templestowe garden set the scene: this is a garden dedicated to making an impact with less.

Masonry

BRICKS

Bricks are useful objects. Durable and cheap, their regular shape means they can be stacked or laid in patterns. Almost all bricks have the same dimensions, although older handmade bricks may be slightly smaller. The size and shape are designed for easy one-handed handling by an adult.

Bricks are energy-intensive to manufacture and transport, but will last hundreds of years, and can be used over and over again.

When reusing bricks, you'll need to clean them to remove the mortar. This is dirty and laborious work and seems very slow to begin with, but once you have mastered the knack you will be surprised how fast you can clean bricks. The best tool for this is a scutch hammer, which has replaceable toothed blades called combs. Chip at the mortar where it meets the brick and it will come off in big chunks. Wear gloves and a face shield though as flying mortar chips really hurt.

BROKEN CONCRETE SLABS

Concrete is also a very energy-intensive material to manufacture, and similarly highly durable and strong, and ideal to reuse.

Concrete slabs, sometimes referred to as 'urbanite', can be reused to make crazy paving, or stacked without mortar to form low retaining walls. When sourcing slabs make sure you get only non-reinforced slabs such as from council footpaths or old driveways. Reinforcing steel in the concrete is very difficult to cut, and as it rusts it will swell up and split the slab.

Councils often replace footpaths and must dump the slabs of concrete they remove, and they will usually be happy to dump it at your place for free.

Concrete can be sawn with a concrete cutting saw to give a smooth sawn edge, but the saws are expensive, noisy and dangerous. For crazy paving, breaking the slabs with a sledge hammer yields interesting odd-shaped pieces; resist the temptation to break them too small, as they are more difficult to get level and stable when laying. For retaining walls more regular shapes are better and the best way to cut them is with an electric jack hammer.

PRE-MADE CONCRETE PAVING SLABS

These are usually square in shape, and about 40 mm to 50 mm thick, with sizes ranging from 200 mm to 600 mm square. They are often pulled up and thrown out so they are readily available. They can be laid hard together or with a space between and sown with a herb lawn. Or they can be grouted with mortar and decorated with broken crockery and tiles.

They are also useful around fruit trees to

stop chooks scratching up roots and damaging them. I have used them in a chook forage system, where slabs are laid on sticks, weeds and food scraps in the chook yard, and then turned over after a week or two to provide a feast of insects for the birds! And, if you lay slabs on kikuyu grass with chooks running over the top, the chooks will keep picking the green tips, and gradually weaken the runners. Remove the slabs after a month or so and the chooks can then penetrate the soil where the runners have thinned out, making it easier to prepare the area for planting.

CLAY PAVERS

These are the same size as a house brick, but thinner. They can be laid in different patterns—herringbone, basket weave or stretcher bond—but they can't be mixed with bricks, because of the different thicknesses. They don't have holes or depression like a house brick, but the two sides often have a slightly different texture. They are readily available on eBay and Gumtree, usually for free.

BLUESTONES & OTHER CUT STONE

Bluestones are now valuable items, usually priced at $5 or more per piece. However, they are heavy to move and sometimes people have to clear them quickly so they can be obtained more cheaply. I recently got about a tonne for free from my neighbour who needed to clean out in a hurry after selling his house.

ROOFING TILES

These are handy for garden edging if dug in on their end, allowing free-form curves.

ROCKS AND STONES

Nothing beats using natural rocks and stones, particularly if they come from your property, and the quality is good. Unfortunately, where I live the stone is soft mudstone which falls apart when handled. Carting stone long distances is energy intensive, and costly.

FASTENING TO BRICKS

Brick walls are great to grow vines and climbers on. They provide great thermal mass for microclimates and the vines can also help cool the house as well as looking good.

Fastening trellis and other items to brick walls is a great skill to have. You'll need a hammer drill, and Dynabolts or masonry plugs.

For screws/plugs, you drill a hole where you want the screw to go in, insert the plug and then screw through the trellis into the plug with suitably sized screws. For Dynabolts, you drill the hole in the trellis the same size or slightly bigger than the Dynabolt, then use a masonry bit to drill the hole in the wall, insert the Dynabolt to the right depth and tighten it up with a spanner or screwdriver.

Image: Laura Varrasso

↑ Masonry can be reused to make very nice paved areas—even broken concrete produces a nice effect.

Metals

Our society uses a lot of things made from steel and aluminium. Reusing is a great way to access their durability, strength and versatility, without the environmental cost.

ROOFING IRON

Roofing iron is perhaps the most common and useful metal for use in the garden. It can be used as a wind barrier (on an appropriate frame), or to make small buildings like animal shelters or tool sheds, raised garden beds, fences, gates and barriers or retaining wall reinforcement—even funky artworks and furniture if you have the right tools.

Traditional corrugated iron is galvanised, which increases its resistance to rust. Galvanising is best suited to above-ground applications in roofing and wall cladding, but galvanised iron will still last quite a few years when in contact with soil. It can be used for garden beds, compost bins or subsoil barriers against weeds or foxes. High quality secondhand iron will command a good price, but sheets with rust or deformation can be obtained for free.

Cliplock is a form of industrial roofing made from the same material, but with a different profile, with a flat pan about 200 mm wide, and a tall rib between. It is designed to be fixed without puncturing it, and is often available in six-metre-plus lengths. It is often thicker than standard corrugated iron, but because it lacks the traditional look of corrugated, can be obtained cheaper and often free. By cutting the ribs, the sheets can be easily bent and a wooden support post or rail fixed in the V left by the cut ribs to make structures such as garden beds or animal enclosures.

Galvanised roofing is fixed with capping to waterproof the joints. This can be used to cover the sharp edges of metal sheets.

A newer form of galvanised iron is Colorbond, where a paint material is bonded onto the metal. You may want to use Colorbond where you need a particular colour on the finished project, but don't want the hassle and ongoing maintenance of painting it.

WHITEGOOD CABINETS

Whitegoods cabinets (e.g. washing machines) can yield handy heavy sheet metal panels. The 90-degree fold on the edge of a cabinet can be used to create a 45-degree pitched roof for a dog kennel or small chicken house. Hot water service cabinets are also handy for this.

CAR PANELS

Cars panels use sheet steel carefully pressed to shape to form the distinctive curved shapes of the car. Because they are curved, they are harder to use as a stock material to cut desired

shapes and lengths, but their curve and often underside bracing give them rigidity. Bonnets, boot lids and doors also have pre-installed heavy fixing points.

Perhaps best, they are instantly recognisable, and so underscore the recycled look of your garden (if that's what you want). Identical panels can be obtained in a variety of bright colours, to really make a structure such as a garden shed or garden furniture stand out.

Entire car and even truck bodies can be used as garden planters or chook houses. Older models, preferably already well patinaed, are best for this application, but might be difficult to find, and expensive if in restorable condition.

Other car parts can be used. Wheels (without tyres) make handy hose reels and internal parts provide a complete palette for garden art if you are lucky enough to have a welder.

WATER PIPE

Before the advent of plastic water pipe, water was often pumped through galvanised steel pipe. When replaced, this is routinely discarded and can be reused for all sorts of applications. If you have a welder you can use it to make gates. If you don't, you can still cut it into short lengths and use it as pegs to hold sleepers on a slope for garden beds.

STAR PICKETS

These metal fence posts can be reused time and time again. When the bottom part is rusty they can be cut down and used to secure sleepers. Best of all, they come pre-drilled with holes, so timber or poly pipe can easily be secured to them with roofing screws.

Other items

BATHTUBS

Bathtubs may not look pretty sitting in the scrapyard, but they are designed to sit supported on a low wall, which is then tiled over. They can be installed in this fashion in the garden, with old posts and hardwood rails to support the edges, and old palings, corrugated iron or brush fencing as infill. They can be used as frog ponds, water gardens, wicking beds, stock troughs, duck baths—almost anything to do with water.

They can also be buried so the rim is at ground level, but it is tricky to get them level. A trench and pipe to a lower position would also be required if you need to make them self draining.

↓ When working with masonry materials, gloves and eye protection are a must.

Image: Maia Choat

↑ Old cliplock sheets have many uses, such as creating composting bays. Just make sure you cap the edges for safety, as shown here. The gates on the front are old shelves from steel shelving units.

Image: Laura Varrasso

↑ They've used broken concrete from footpaths to make a neat retaining wall around a large duck pond.

WIRE NETTING

The old hexagonal-shaped chicken wire is hard to source secondhand in any state worthy of using for its intended purpose. It is useful, however, as a substrate for render on earth buildings or as reinforcing in concrete work.

The more modern 'welded wire' netting, which has heavier wires (2mm) welded in a rectangular grid pattern is more robust for reuse. It can be simply coiled in a hoop to form a self-supporting compost bin, or can be easily secured for a temporary chook fence by threading a garden stake through the top and bottom holes. ✷

Drew describes himself as a mid-life corporate refugee. He is also a qualified permaculturalist and passionate junkscaper. Drew runs masterclasses on using recycled materials in the garden through Sustainable Gardens Australia.

⚠ Warning

Protective equipment should always be used when working with building materials. When cutting, drilling or hammering, especially on masonry materials, which are prone to chipping and fracture, eye protection, and preferably full face protection, should always be worn. Appropriate gloves should also be used where sharp edges or rough surfaces are involved. Also be aware that some recycled materials may contain toxic or hazardous substances, such as paint with lead pigments, and possibly even asbestos fibres, depending on where the material was sourced and whether the building was deconstructed correctly. If old paint, dust or fibrous material is present on the building materials, wear a dust mask and eye protection and seek experienced advice on the safety of the material.

Avoiding unseen heat loss
The importance of slab-edge insulation

Insulating under slabs has become commonplace, but slab-edge insulation can be just as important. But how do you do it and still provide good termite protection? Dick Clarke explains the physics and a simple design solution.

IT'S not so long ago that Australian homes were built without any insulation. Anywhere. Extraordinary thought, isn't it? What's more extraordinary is that I am talking 2003 here, not 1960. The introduction of Section J of the Building Code of Australia in 2003 has made it impossible for houses to be legally built or renovated without some form of insulation in walls and roofs. But floors have so far been a low priority for the government regulators.

Insulating beneath concrete slabs has become widely accepted practice in Australia and some structural systems like waffle pods provide it as a matter of course. But adding insulation to the edge of concrete slabs is still an unusual feature.

One issue is that the available thermal performance software cannot model the performance of slab-edge insulation adequately, although both NSW's BASIX and the National Construction Code (formerly BCA) mandate slab-edge insulation if any form of heating is to be installed in the slab.

Why do we need it?

Under-slab and slab-edge insulation benefits come from moderating the temperatures at and just below ground level. Ground-level surface temperatures move through a large range in most populated parts of Australia.

Surface temperatures are linked to the deep temperature of the site, perhaps at 50 m down, which may be a consistent year-round 21 °C or so (assuming no tectonic activity).

However, this 'push' of stable temperature suffers a 'pull' of variable temperature in changing seasons and weather at the surface. An extreme example might be Alice Springs, where the air temperature consistently varies between sub-zero in winter to 40-plus in summer. These extremes work their way into the soil (or rock) at the surface, such that the first half a metre or so might vary between 5 °C and 35 °C seasonally, with the range narrowing the deeper you go. Alpine regions and the south island of New Zealand have surface temperatures which are consistently too cool for comfort.

Under-slab temperatures

Most house-sized slabs will attract earth temperatures from about three metres deep up to the surface of the slab. In some climate zones this is a lovely annual average, and no under-slab insulation is required. But in most of southern Australia and pretty much all of New Zealand we see a net annual benefit from under-slab insulation (see box for more).

Slab-edge temperatures

Most concrete floor slabs have a floor level 100 mm or more above ground and this exposed edge is subject to these surface temperature fluctuations, even if there is under-slab insulation. Putting aside the relatively few houses built in truly benign sub-tropical climate zones, this means 98% of the Australian and New Zealand population live in buildings with uncontrolled heat flows right around the perimeter.

This also applies to apartments, even those well above ground level. Any slab that has heating installed (hydronic or resistive) exaggerates the temperature differences, and it becomes not just beneficial but critical that the edge is insulated.

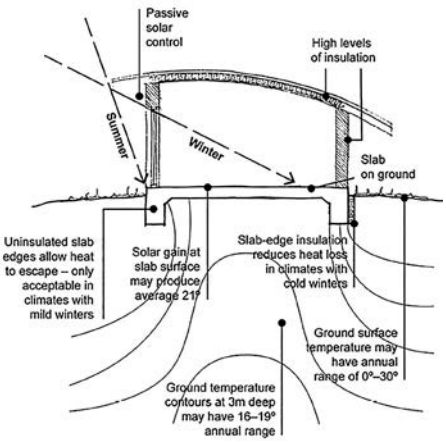


Image: Your Home, www.yourhome.gov.au/materials/concrete-slab-floors

↑ Soil temperatures vary depending on depth, with surface temperatures varying considerably throughout the year. Slab-edge insulation can reduce thermal losses in winter.

What happens in colder climates

In seriously cold climates like Germany, Switzerland, Canada and the mid-west of the USA, the benefits have been obvious for decades, and these jurisdictions have regulations requiring floor-edge insulation, and they have tradies, products and systems that are well adapted to dealing with the issue. For instance, there is a German product that allows a concrete slab to be cantilevered from the main structure with a complete thermal break (insulation) at the point of cantilever. This product has a distributor in Australia and New Zealand, but I am unaware of any building using it yet.

Beating termites

Of course, what mainland Australia has is a persistent little critter whose sole purpose is to clean up all the dead and rotting timber

↑ Waffle pod slab before (left) and just after the concrete pour. Note the termite barrier under the waffle pods, as per the ISEG.2 approach.

↑ Newly completed slab edge including insulation and termite barrier using the ISEG.2 approach.

on the face of the continent. This delightfully diligent creature is the termite. A decade ago Minimum Termite Risk construction techniques were adopted in Australia, which principally relied upon an exposed slab edge if no other mechanical barriers (such as Granitgard or Termimesh) were used—and none of these termite solutions solved the slab-edge insulation issue. And so we have a dichotomy: a non-hazardous non-chemical physical termite barrier causing poor thermal performance. Or to put it the other way around, excellent thermal performance being hampered by safe termite barriers.

A first generation approach

However, as persistent as the termite is, the human is more inventive. So the following strategy was born in my design practice—let's call it Insulated Slab Edge Gen 1 (or ISEG.1):

- concrete slab on ground (with or without under-slab insulation as dictated by the location) and foundations to AS2870 Masonry Code (to resist cracking), with a minimum 100 mm of slab edge exposed above the finished ground level
- closed cell high density foam insulation (typically R1.5) from bottom of slab edge beam to ground level, permanently in place
- a removable strip of foam between ground and bottom of insulated wall cladding, which enables any termite tunnels ('leads') to be easily seen during a twice annual inspection (the Australian Standard!)
- a strip of cladding material that covers and protects the foam from UV and physical damage (from line trimmers etc), held in place with a robust clip or other device.

Under-slab insulation

Ground coupling in mild climate zones such as Perth, Brisbane or coastal NSW allows the floor slab of a well-insulated house to achieve the stable temperature of the earth: cooler in summer, warmer in winter. In winter, added solar gain boosts the surface temperature of the slab to a very comfortable level.

In areas with low winter temperatures such as southern Victoria and Tasmania, the deep ground temperature is too low to allow passive solar heating to be effective, increasing the energy use required for comfortable room temperatures.

In areas with milder temperatures and higher ground temperatures, under-slab insulation is often not required, and not insulating the slab will often result in more stable indoor temperatures. One interesting study of a building with no under-slab insulation, yet which still performs very well, is the Greeny Flat (www.greenyflat.com.au and profiled in *ReNew 130*) in Mittagong, NSW, around 100 km south-west of Sydney and 30 km from the coast.

To decouple the slab from the ground, under-slab insulation is often used. This usually takes the form of polystyrene or polyisocyanurate foam insulation or polystyrene concrete forms (used to reduce the amount of concrete used), such as waffle pods. Alternatively, arrays of linked polypropylene domes such as the Cupolex Building System may be used.

Under-slab insulation also works well in warm zones with higher soil temperatures. If a home is to be air conditioned then under-slab and slab-edge insulation will reduce the amount of air conditioning required by reducing heat ingress through the slab, and should be used.

If in-slab heating (or cooling) is to be used, then the slab should be fully insulated, both underneath and along the edge, to reduce the energy losses from (or gains to) the slab.

Note that different soil conditions can affect the way the slab interacts with the ground temperature. Also, reactive soils prone to movement may not be suitable for particular slab construction and insulating techniques and this should be addressed at the design stage.
www.yourhome.gov.au/materials/concrete-slab-floors

Image: Chris Norman Architecture, www.chrisnorman.co.nz

↑ Regular slabs can be fully insulated as well, and there's a range of foam products designed specifically for under-slab use.

The main problem with ISEG.1 is the removable strip for inspections—it is hard to find a good robust system. It also relies on inspections, although any physical barrier system is the same: at least with a physical barrier, if you inspect you know all is well. With chemical barriers, because you are relying on unseen elements, all you can do is assume, and hope; and worry about what to do when it runs out of potency.

A better approach—ISEG.2

A number of designers toyed with ISEG.1's shortcomings and trialled different solutions that didn't require a removable part for inspections. We were able to do this when a termite barrier came on the market (Homeguard TMB or Rentokil product) that embeds the termiticide into poly sheets and plastic fittings at the molecular level. This means that the active agent doesn't leach out and is safe in the environment, while it also remains potent: termites are repelled on contact. Our new detail, let's call it ISEG.2, looks a bit like ISEG.1 except that:

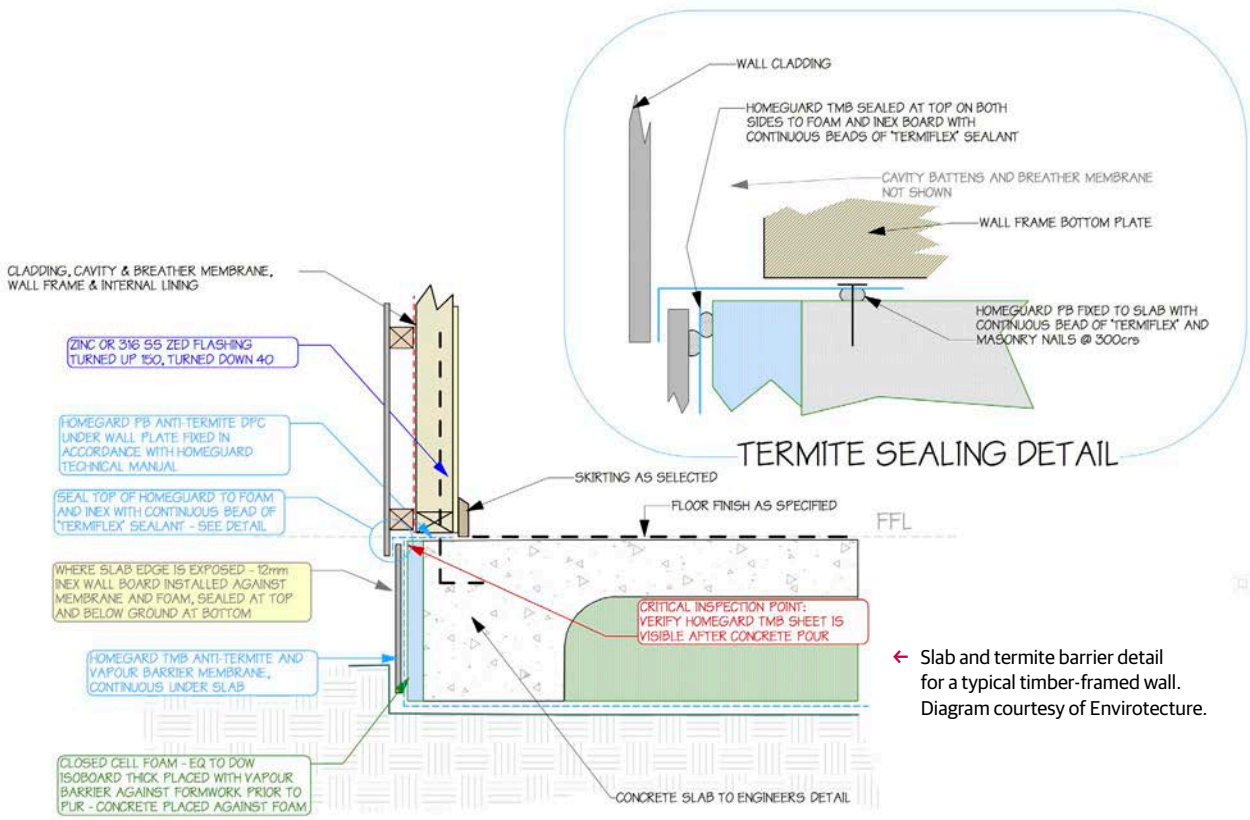
- the termite barrier is the slab's vapour barrier sheet (such as Homeguard TMB), which wraps up the slab edge, and is exposed at the top for the 'critical stage' certification inspection
- R2.0 (typical) high density closed cell foam is placed against the inside of the vapour/termite barrier, which is held against the edge formwork and sealed at the top with a continuous bead of Homeguard Termiflex, before the concrete is poured
- 24+ hours after pouring, the formwork is stripped and the barrier sheet checked for integrity. Then, a sheet of magnesium oxide cement (MgO) is permanently fixed to the outside, for UV and physical protection during the remainder of the works and ever after (MgO can be left in ground contact, and saturated), sealed at the top with a continuous bead of Homeguard Termiflex
- alternatively, the MgO sheet can be installed before the pour, tight against the formwork, sealed to the Homeguard TMB sheet with a continuous bead of Termiflex
- when cladding or wall finishes are installed, a stainless steel 'Z' flashing is added to cover the top of the MgO and foam, or the wall cladding is extended down 40mm; usually all wall finishes are flush, but that is an architectural detail which can be varied to taste.

Note that the base of the wall structure must be protected by flashings in accordance with Australian Standards, but this can be integrated into ISEG.2.

It is frustrating that the NatHERS house energy rating software has not in the past been able to model the benefit from slab-edge insulation and successive governments have failed to ramp up the stringency of the building regulations sufficiently. That is now changing, and it is the leaders of industry at the forefront, with CSIRO and others also making big strides. Cleverer people than this writer have calculated the physics of slab-edge insulation's benefits from first principles, finding that, in Sydney or Melbourne for instance, it can reduce heating bills by hundreds of dollars per year.

ISEG.2 is quick to install and the materials are inexpensive, so the payback in dollars can be quite short. The payback in comfort and lifestyle is so good it's hard to put a price on. ✱

Dick Clarke is a Sydney-based building designer and regular contributor to *Sanctuary* and *ReNew* magazines.



← Slab and termite barrier detail for a typical timber-framed wall. Diagram courtesy of Envirotecture.

Keep your cool
External shading buyers guide

With summers getting hotter in many parts of Australia, keeping the sun off your windows and out of your home is becoming even more important. Anna Cumming looks at the options for external shading, for both new builds and retrofits.

Photo: Meg Warren

↑ A relative newcomer to the external shading market, the folding arm awning has "taken the market in Australia by storm" according to Joe Turner, president of the Blind Manufacturers' Association. These awnings can be up to 7m wide and can extend out up to 4m, without support poles.

THERE'S been quite a shift from pre-industrial times when glass was an artisan-crafted luxury item, and homeowners were taxed according to the number of panes they had. These days, our houses are getting bigger and so are our windows—often to the point of comprising entire walls. Windows and glazed doors frame views, admit natural light and breezes, and allow a connection with the outdoors. In a well-designed house, they also admit the sun's warmth in winter to assist passive thermal performance.

However, from a thermal efficiency point of view, windows are the weak link in a home's building envelope: *Your Home* notes that up to 40% of a home's heating energy can be lost and up to 87% of its heat gained through windows. Efficient double-glazed windows with thermally broken frames (preventing heat conduction through the frame) perform considerably better—advanced glazing solutions can exclude up to 60% of heat compared to plain single glazing—but will still allow more heat to enter in summer and escape in winter than the adjacent wall.

Internal thermal blinds or curtains can help a lot in preventing heat loss through windows in winter, but to tackle unwanted radiant heat gain in the hotter months, it's far more efficient to stop the sun hitting the glass in the first place with appropriate external shading.

Location and orientation

There is a huge variety of options for keeping the sun at bay, from carefully chosen deciduous plantings and simple solutions like a piece of shadecloth on a frame, to awnings, shutters, blinds, and even pergolas with sensor-operated louvre roofs. To choose the best solution, firstly it's important to consider your location and the orientation of your windows.

In most of Australia, shading is needed on windows on the north, and also the east (to prevent summer sun heating the house from early in the morning) and west (to block hot late afternoon sun). North of the Tropic of Capricorn, thought should also be given to shading windows on the south side of your house, as the sun's steeply angled path in summer means these windows will also receive direct sun. Helpfully, the Geoscience Australia website (www.ga.gov.au) allows you to find your latitude and calculate the sun angle at any time of the day, on any day of the year.

Even at the same latitude, different local climates will mean different shading priorities. Perth-based architect Sid Thoo points out the importance of protecting east and west windows in his part of the country: "Summer morning and afternoon sun can be very harsh in WA." However, a house at a similar latitude in alpine NSW might instead prioritise maximising solar gain for winter.

Because of the angle of the sun through the day, one size does not fit all when it comes to shading for all of the windows in your house. For windows within 20°W and 30°E of solar north, it's easy to exclude summer and admit winter sun using simple horizontal devices, including eaves and awnings. This also applies to south-facing windows in the tropics. It's reasonably straightforward to calculate the optimal width and height of

Photo: Alexander McIntyre

↑ Shade sails are a cost-effective and flexible option: they can be removed during winter if required. They are also available in coated fabric for some rain protection. This tensioned sail shades the large back deck of a renovated home in Newcastle by Derive Architecture and Design.

Photo: Ben Hosking

↑ Architect Tim Angus designed horizontal aluminium sun shades with fixed angled blades for the north and west windows in this Melbourne renovation. They provide shading and passive design benefit without sacrificing views of the sky.

eave that will stop the higher angle summer sun from hitting the window and yet allow welcome lower angle winter sun to penetrate deeply inside the room; *Your Home* provides a rule of thumb (see www.yourhome.gov.au/passive-design/shading).

For east and west windows, however, a different approach is needed as the low-angle morning and afternoon summer sun from these directions is more difficult to block. Angled or vertical shading is most effective here, and often an adjustable solution is best so it can be deployed only when needed.

Shading options

External shading products and structures fall into two broad categories: fixed and adjustable. Fixed solutions have the advantage of simplicity, and with no moving parts, are usually easier to maintain and last longer. However, they need to be carefully designed to avoid compromising solar access in winter. In addition, in southern Australia there is a month or so in late summer when temperatures are still high but the angle of the sun is low enough to peep under even optimally sized fixed eaves, and another period in late winter when the sun's warmth is still desired but is already being blocked.

Adjustable shading allows a house's occupants much more control over how much direct sun to admit. Such systems can be manually operated or motorised; fitted with sensors to allow them to respond automatically to sun, rain and wind conditions; and even integrated with comprehensive smart home automation systems.

An energy rating scheme for window coverings, WincovER, has recently been developed by the Blind Manufacturers' Association of Australia (BMAA)—see box at the end of this article for more information.

FIXED SHADING

Eaves and overhangs: If you're at the design stage for a new house or a major extension, don't miss the opportunity to think about fixed shading as part of the design. Sid Thoo points out that including simple and appropriately sized eaves or second-storey overhangs is a very straightforward, cost-effective solution. "External shading can also form part of the design aesthetic," he says.

Shaila Divakarla, architect and Standards & Technical Manager at Good Environmental Choice Australia (GECA), agrees. "If you're clever, you'll integrate it as part of the design. Many things can be done that provide shading and also enhance the aesthetics of the house, or fulfil another function at the same time: a porch that also gives shelter from rain, or a pergola that also provides

Electronic window tinting

Commonly known as smart glass (although not to be confused with Viridian's SmartGlass product), electronic window tinting involves the use of an electrochromic polymer film, either applied to existing windows or embedded in new window glass, that uses liquid crystals within the film to provide a degree of window shading.

The film is connected to a power supply/controller, which may be operated manually, by a remote control, via a phone app or it may even be part of a whole-house smart house system.

When the film is off, the liquid crystals inside the film are all at random orientations. This causes incoming light to be partially reflected inside the film, making the film translucent. This is the 'shaded' (sometimes called fogged) mode, providing privacy. To make the film transparent, a small electrical charge is applied, the liquid crystals line up inside the film and light can much more easily pass straight through the film.

For the add-on type films, the main advantage of these products is privacy—reflection of incoming heat varies between products, and manufacturers' claims can be pretty vague. We don't recommend these films as your only source of window shading.

Where the films are embedded inside glass, the abilities of the products range from simple privacy fogging as for the add-on films (examples include Switch Glass, www.switchglass.com.au and Polytron Glass, www.polytron.com.au), through to deep shading ability, such as Sage Glass (www.sageglass.com, available from George Fethers and Co, www.gfethers.com.au) which has a very high degree of light and heat blocking ability (down to just 1% light transmittance) and can provide up to three different tint zones on a single pane of glass.

The main issue to be aware of is the energy consumption of these films. They are typically rated at up to 20 W/m², which can add up rapidly if you have multiple large windows.

Photos: David Johns

↑ Different shading options help regulate the internal temperature of this Brunswick, Melbourne, renovation by Baker Drofenik Architects. On the west, sliding timber shutters shade the kitchen and are operated manually from inside. On the east, decidous vines grow over pergola structures, providing shade in summer. The fixed awnings are primarily for sheltered bike storage, but also provide some wall shading.

extra outdoor living space. This is a better use of resources and money."

As eaves and overhangs are essentially part of the house or extension, they are usually made from the same materials as the structure, requiring negligible extra investment.

Fixed awnings: If you don't have the luxury of designing from scratch and including eaves, an option for shading north windows (and south windows in the tropics) is a fixed horizontal or angled awning. These can be made from a wide variety of materials including steel, timber, corrugated sheet metal, cement sheet and rigid polycarbonate sheet. They should extend past the sides of the window to keep the sun off the glass for longer.

Fixed louvres/blades on window: Usually made from metal or timber, louvres or blades are fixed in a frame or rack against the window and can be placed running horizontally or vertically. They are particularly useful where privacy is needed or to comply with overlooking regulations.

Pergola with fixed angled blades: Pergolas are an enduringly popular feature in Australian gardens, but striking the balance between having a great shady outdoor living space when it's hot, and still letting sunlight and warmth into your house when it's not, can be tricky. Roofing your pergola with fixed blades set at an angle designed to optimise winter sun access is one option; others include translucent but thermally effective polycarbonate sheet roofing (see box for case study on Shaila's pergola), and simply growing a deciduous vine over it.

Shade sails and umbrellas: Made from knitted polyethylene fabric that's available in a range of different light blockout levels (there will often be separate, and usually different, visible light and UV blockout ratings), shade sails can be bought off the shelf or custom designed for specific spaces—or even made at home. They are reasonably easy to install yourself, although they require firm fixings. If some rain protection is required, sails and umbrellas also come in waterproof coated fabric.

ADJUSTABLE SHADING

Retractable awnings and blinds: Pivot arm, folding arm, horizontal awnings on wires, roller, vertical drop—retractable awnings and blinds come in many styles. They can be closed up when not needed, allowing full winter sun access. With no support poles or attachments when extended, folding arm awnings in particular are quite susceptible to wind damage, but they can be fitted with sensors that close them automatically when bad weather hits.

"The development in awning technology recently has been huge," says Joe Turner, president of the BMAA. "One of most popular new styles is the stainless wire guide awning; it's a vertical drop awning that runs down fixed wires and locks in at the bottom. The system keeps the blind really taut."

Adjustable louvres/blades on window: They are a pricier option, but metal louvres reflect more heat than fabric shading options, and adjustable versions offer scope for fine-tuning light levels inside the room. "Our external venetian blinds bounce the light into the room, giving soft diffuse light without the heat," explains Bryce Hedditch, from blind and shutter supplier Sonnenschutz. This style of shading is also good for privacy without sacrificing too much daylight.

Pergola/solar roof with adjustable blades: Another big ticket item, pergolas with adjustable blade roofs such as those offered by Vergola can be completely rainproof when closed, turning your outdoor living area into an all-weather space.

Shutters and screens: External shutters and screens—hinged, bifold, sliding or roller—are usually made from Thermalite (a high density plastic foam), timber or aluminium, and sometimes steel. As they are fitted very close to the window, "they stand up to all sorts of weather," says Joe Turner. Depending on the material and style chosen, they can also perform insect screening, security and bushfire ember protection functions.

DECIDUOUS PLANTS

Don't overlook the option of using deciduous plants to provide shade to your house. Depending on the space available, this could be a vine growing on a freestanding frame or pergola, or a tree planted to block

"If your budget for external shading is tight, spend the money on the areas that you use the most. Living areas are the most important as this is where you run the heating and cooling the most."
—Shaila Divakarla, GECA

western summer sun. Be careful to match plant characteristics (such as foliage density, canopy height and spread) to your shading requirements, and choose local native species with low water requirements where possible. Plants can also be used to shade your walls: see 'Green facades' in *Sanctuary 37* for more.

Materials

Many different materials can be pressed into service as external shading, depending on the application and desired characteristics. Rigid materials include timber (for pergolas, fixed awnings, shutters), aluminium and steel (fixed and adjustable louvres, fixed awnings, shutters, screens), polycarbonate sheet (pergola roofs, fixed awnings), and even concrete (for formed window surrounds).

For flexible shading (blinds, adjustable awnings), traditional canvas is still available but it's been joined by more high-tech PVC, polyester and even fibreglass fabrics. "I'd rate these newer sun screen fabrics very highly," says Joe Turner. "They incorporate small holes that let light in and views, they breathe, and they have a better shading effect than canvas." According to Joe, while cotton canvas is made here, no acrylic shading fabrics are made in Australia; they are all imported from Europe (mainly Spain), China and the USA, meaning that the sea miles to get them here needs to be taken into consideration in any life cycle analysis.

Photo: Simon Wood Photography via *Your Home*

↑ Pergolas or verandahs fitted with adjustable blades provide rain protection, and shading that can be fine-tuned for the time of year. They allow for wider roofed outdoor areas without compromising winter solar gain to interior spaces.

As always, making an environmentally responsible choice is a matter of considering many factors including renewability of raw materials, the manufacturing process, recyclability, durability and expected lifespan, maintenance requirements and end-of-life disposal. Shaila Divakarla sums it up: "There are plenty of choices available at the moment. Every material has some advantages and disadvantages, so requires careful consideration of your particular needs and location. Think of the life cycle—where is the material coming from? Does it have any toxic components? How much energy does it take to make it? What happens at the end of its life?"

As external shading products are exposed to harsh environmental conditions, natural materials are often not suitable or would have a greatly reduced lifespan. Sid Thoo explains his approach: "Durability can be an issue—I try to avoid things with moving parts, or that will require sealing or repainting over time. They might look great when first installed, but if they are then hard to access or maintain, this can become an issue over the life of the building."

Bryce Hedditch also advocates looking for durability. While the manufacture of the aluminium for Sonnenschutz's external venetian blinds is energy intensive, "they will last for 25 to 30 years and can then be restrung, and keep going." Aluminium is also easy to recycle when the blinds eventually reach the end of their useful life.

"Think about it as a system," suggests Shaila. "For example, timber is renewable, but think about the finishes you'll need to protect it and extend its lifespan in an external shading context. Are the finishes eco friendly? What maintenance will be needed?"

Unfortunately, GECA does not yet have a standard and certification process for shading products, but Shaila says it's on their wishlist. GECA is part of a 25-member international community, and Shaila's team is looking at fast tracking and adapting an existing standard for Australian use.

Case study: Shaila's pergola

Photo: Shaila Divakarla

Shaila Divakarla was looking to install a pergola to shade her verandah and north-west-facing windows in Cheltenham, Sydney. "We wanted to enjoy the outdoors protected from rain and sun, but at the same time not diminish light into the kitchen and family room, as there is lot of tree cover around and a double-storey house to our north," she explains.

"Translucent perspex sheet was an affordable option, but I looked for a material that had better thermal properties, looked more aesthetically pleasing and was also stronger. I chose Danpalon, a polycarbonate sheet with a honeycomb structure in the sheet, good thermal properties and the strength to withstand hail. The best part is that the construction system is 'nail-less' as the panels just click into connectors, which means that leaks are unlikely and also that the panels can be deconstructed and reused later if required."

Danpalon comes in varying thicknesses and tints to suit various applications; Shaila chose the very light grey to admit maximum light. She also opted for a pergola construction company that knew Danpalon, could source it and understood its construction method.

"The pergola was almost 1.5 times more expensive than normal perspex sheet would have been, but I think we have more than made up for it with a really 'cool' verandah (pun intended!)," says Shaila. "As for running costs, we seldom need air conditioning in our living room and also have rarely used our clothes dryer since installing the pergola, so we have already got our payback on it."

Other considerations

Along with shading type, choice of material, and whether fixed or adjustable is best, there are many other factors to consider before selecting your external shading.

Space: The optimal shading solution for a given window just might not fit in the space available, especially if the window is built very close to a boundary. Perhaps consider a combination of a different external shade and an internal blind instead.

Visibility and permeability: Older-style canvas blinds and awnings are effective shading, but also cut off views to outside, block breezes and dramatically reduce daylight. Louvres, perforated screens and shutters, and blinds and awnings made from more modern high-tech mesh fabrics, allow airflow and diffuse daylight through while still blocking a significant proportion of direct solar heat gain.

Ease of operation: Consider how your windows open: will your external shading get in the way? Install vertically-hung or angled shading far enough away from casement windows to allow them to open. Can manually-operated shading be reached easily from inside by opening the window, or will it require a trip outside? Is it easy to operate by yourself? If your shading is tricky to operate, it's likely it won't be used optimally to regulate solar access, reducing its energy efficiency contribution.

Mechanisation: For shading on hard-to-access windows, particularly those above the ground floor, manual crank or pulley systems are a possibility; otherwise, mechanisation using a switch or remote control—or even, these days, a smartphone app—can make a lot of sense. It does add complexity though, so it's worth weighing up against the expected energy efficiency gains of better-performing shading.

Joe Turner nominates better mechanisation as the next big thing in shading. "It's much easier these days—you can retrofit a house with existing blinds. One of the big problems used to be getting power to external awnings—now there are options to put in a solar motor or a rechargeable battery-operated motor."

Double duty: Think about whether your shading solution could fulfil another function at the same time—perhaps wind protection, privacy screening, insect screening or protection from ember attack during a bushfire. For example, Sonnenschutz's range of aluminium external venetian blinds includes a style whose blades can be tilted past horizontal

Case study: DIY awning

Jenny Backholer and Ed Smart describe their courtyard awning solution.

Our inner Melbourne house, built in 2010, is designed around a central courtyard—around 4 x 7 m—which brings the north sun into the living area, located on the south side of the house. With windows on three sides, the courtyard also provides cross-ventilation in summer. It has a Japanese garden theme with a pond, pebbles and lush foliage designed to create a cool feel when viewed from the house.

Although the north-facing windows are shaded from the summer sun by eaves, we found the courtyard was holding the summer heat, causing some of the plants to wilt—just like the human occupants.

While looking for a solution, we discovered sliding horizontal awning blinds (like Roman blinds) made from a polyester PVC-coated mesh. The blinds are supported by horizontal wires and are extended manually using a simple hook on a stick. We installed two 2.4 x 3 m blinds; each has a series of thin, lightweight rods, spaced about 300mm apart, with three metal eyelets. The wires thread through the eyelets to support the rods.

The standard wires provided with the blinds were too short for our courtyard, but we measured the required length and ordered new ones online from All Things Stainless (www.allthingsstainless.com.au). This company makes them to size, and fits them with a turnbuckle adjustment which you adjust when you install them.

We have been really happy with the blinds. They create an instant shaded courtyard on hot days, which can be easily converted back to an open sunny courtyard on cooler days. The two blinds cover about half of the courtyard, without restricting the tall bamboo and wisteria which are growing on the perimeter. When not required, the blinds can be pushed back under the eaves and out of the way. If it rains while the blinds are extended, the open weave fabric lets most of the rain through. We've found the 2.4 x 3 m size to be quite manageable, including when wet, but larger sizes could be more challenging.

The blinds were available from the wholesaler by special order at Bunnings, but unfortunately the product has now been discontinued. This is a pity as it's such a simple and effective design. It may be possible to find similar blinds elsewhere; alternatively, a creative *ReNew* reader or a shadecloth supplier could make them to size.

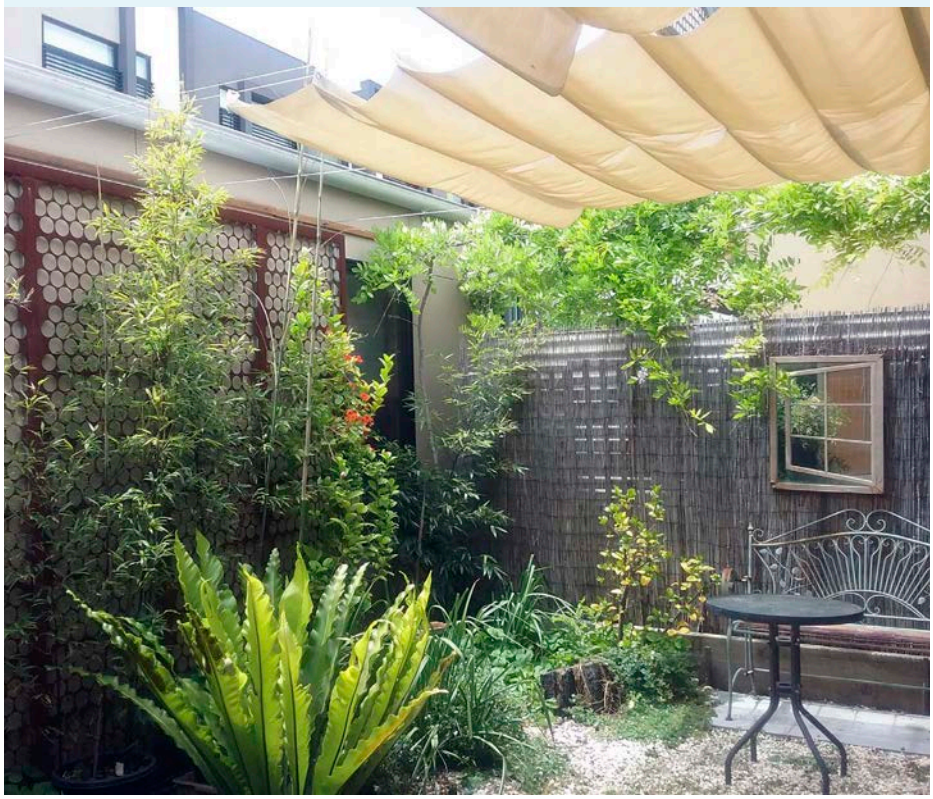


Photo: Jenny Backholer and Ed Smart

Case study: Beyond House

Tim and Karen's Melbourne terrace has a narrow north-facing street frontage. To bring natural light in and achieve passive solar performance on the challenging site, architect Ben Callery designed a two-storey extension around a central void. A roof deck sets the extension back from the pitched roof of the retained front part of the house, and a wall of louvre windows and glazed bifold doors admits northern sunlight deep into the home. Ben also opted for a large west window above the void, to provide more natural light to the kitchen and living area, as solar access from the east was blocked by the neighbouring house.

To cope with the unwanted heat load in the hotter months, he specified automated external metal louvre blinds from Warema for both north (pictured) and west windows. "We put big money into them, but without them the west window in particular would be a big problem."

Homeowner Tim says the blinds work well. "Up to about 30 °C it's fine having the external blinds down and fans going; over 30 °C the blinds start radiating heat in and we need to use the internal blinds too." He points out that being able to control the blinds remotely via a smartphone app—for example, to regulate temperature before they get home—is very handy.

The Beyond House is profiled in *Sanctuary 36*.

↓ Automated external louvre blinds from Warema protect the extension's north-facing upstairs glazing from unwanted summer heat gain. Similar blinds are fitted on the high west window (not pictured).

Photos: Peter Bennetts

so that the outer edges are raised, allowing daylight to be bounced into the room while providing complete privacy from below.

Colour: *Your Home* notes that lighter-coloured shading devices reflect more heat, and those with light-coloured undersides make better use of daylight than those with dark-coloured undersides. If you're looking to retain some of your view through your shading, "fabric colour makes a difference," says Joe Turner. "The darker the colour, the more heat gets in, but the better the view through the blinds; the lighter colours reflect heat better but don't give quite as clear a view."

DIY suitability, and ease of removal: If being able to install your shading yourself is important, check that it's possible for your chosen product. For example, Joe Turner says that while the folding arm awning has "taken the market in Australia by storm", it consists of two tensioned arms that are attached to the wall with very strong fixings to enable it to extend up to four metres from the wall with no support poles; it definitely needs to be installed by professionals. Other products like roller blinds are easier to DIY.

You might also like to opt for shading that is easy to remove and take with you to your next house, especially if you are a renter. Shadecloth on a freestanding frame or small shade sails are good options here.

At the end of the day

As the climate warms and as cooling becomes a bigger proportion of many homes' energy load, the importance of well-chosen external shading to keep the heat out before it hits the glass (or walls or roof) is only going to increase. Shaila Divakarla offers this advice for the most sustainable approach to choosing: "Spend time planning before making the choice; give it some thought with respect to your own particular situation. Don't be swayed by fashion or what your neighbours are doing. Don't just go for what's cheapest or looks nice—think about the long-term cost." ✱

A list of suppliers is available online at www.renew.org.au/energy-efficiency/shading

↑ Custom-made shutters blend into the external cladding of Baber Studio's Shutter House in Brisbane, allowing the narrow deck to be opened up to breezes and views or closed off for shading, weather protection and privacy. Both cladding and shutters are made from FSC-certified western red cedar with Danpalon multicell polycarbonate inserts. The Shutter House is profiled in *Sanctuary 33*.

Photo: Christopher Frederick Jones

"The WincovER simulation provides both the U-value (the level of heat transfer through the material) as well as the solar heat gain coefficient (how readily radiant heat from sunlight passes through a window covering or sun shade system)."

↓ Shading your walls, particularly western walls, is important too. Extending awnings or blinds along an entire wall can be pretty expensive, so consider shading with deciduous greenery or something as simple as a length of shadecloth attached to the gutter with bulldog clips.

Photo: Alan Cotterill

WincovER energy rating scheme

We have ratings schemes for many parts of a building, including the entire building itself with the Home Energy Rating Scheme, so why not a ratings system for shading options?

Well, the Blind Manufacturers' Association of Australia has been working on just such a rating scheme for window coverings and sun control systems, developed for the BMAA by the technical experts behind the Window Energy Rating Scheme (WERS) together with consulting scientist Dr Peter Lyons.

The new WincovER scheme will provide a simple star rating for many different types of internal and external shading products, with each product being rated separately for both heating and cooling performance out of a maximum possible 10 stars (in half star increments).

To become star rated, materials are tested for their basic solar-optical properties. This data is then used by WincovER to simulate a complete window/shade system, using the data for the material in its most commonly used format on a standard, basic window unit. The simulation provides both the U-value (the level of heat transfer through the material) as well as the solar heat gain coefficient (how readily radiant heat from sunlight passes through a window covering or sun shade system).

Those figures are then used to simulate a whole-of-house scenario to produce energy values for heating and cooling effect, which are then run through the WincovER star rating algorithm to obtain the number of stars for each product.

Rated products will be listed in a publicly accessible database so that homeowners can compare products on a simple star rating basis. At present, there are many different types of internal blind types that can be rated, while exterior products are limited to those that sit parallel to the window. It is expected the range will be broadened in the future as simulation technology allows.

Note that the star rating for the proposed shading system is independent from the WERS (Window Energy Rating Scheme, www.wers.net) rating, which rates the energy impact of the selected window system (not the external shading) on the whole house. However, ultimately a WincovER module will be added to WERS which will allow calculation of the effect of adding a shading layer to a window, quantifying the composite performance, whether the shading system is external, internal, or even between two panes of glass.

WincovER is set to be launched in the second half of 2017. For updates, keep an eye on the BMAA website: www.bmaa.net.au.

WINCOVER
WINDOW COVERINGS
ENERGY RATING

→ For homes in high-BAL bushfire-rated zones, Sonnenschutz's BAL-FZ (Flame Zone) Shade&Shield shutters are an option; they provide shading and can be retrofitted to existing windows. If you're building, however, Bryce Hedditch from Sonnenschutz suggests you "consider going with appropriate BAL-rated windows [rather than standard windows plus bushfire shutters]—then you get a much wider range of choice for window coverings and shading and can choose an option that will have a bigger impact on your house's day-to-day energy efficiency." In lower BAL zones, closely fitted hinged or sliding screens made from perforated steel or steel mesh can provide protection from ember attack and also offer less drastic shading than flame shutters.

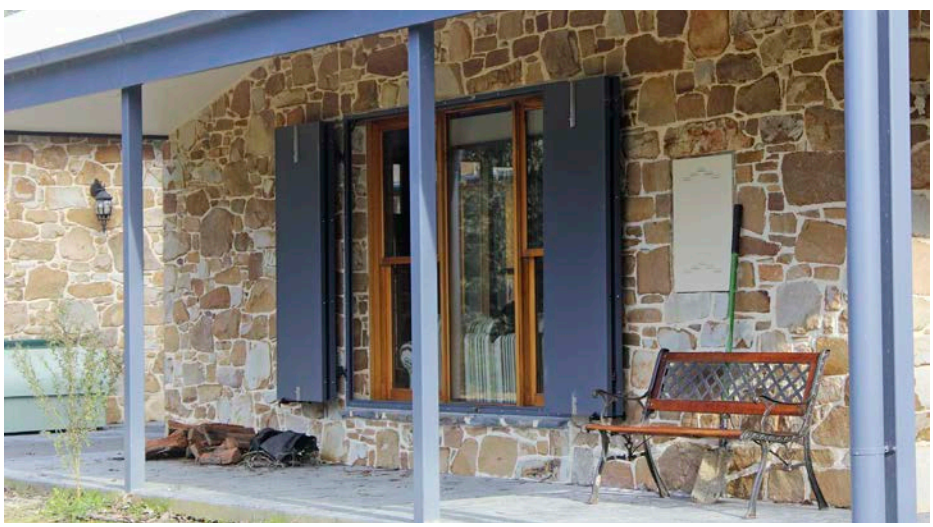
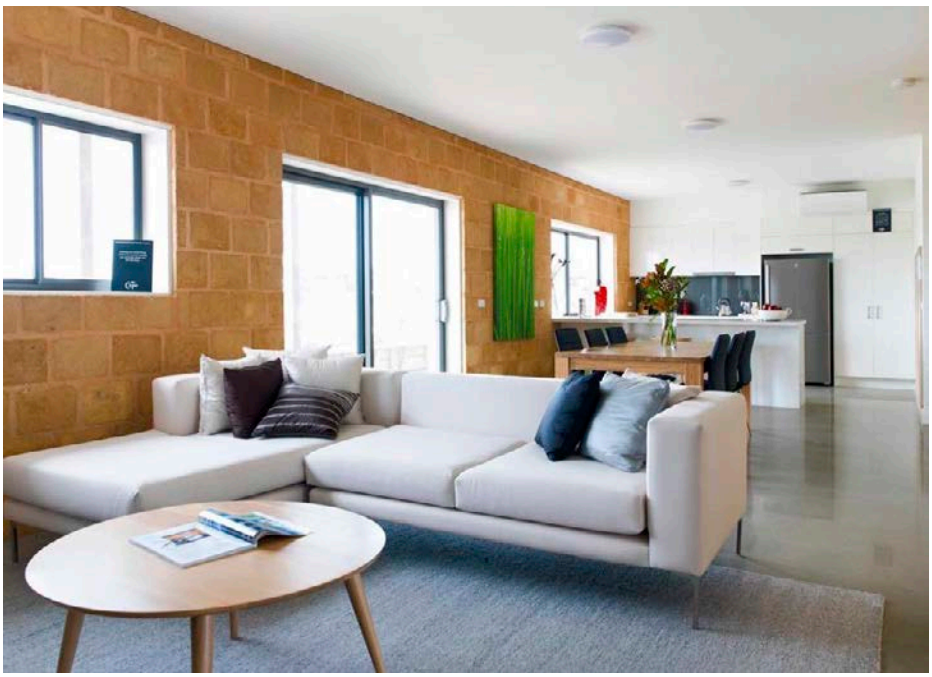


Photo: Sonnenschutz

DIFFICULTY RATING: ★★★★☆

Pressed into service
DIY earth bricks

Creating pressed earth bricks isn't hard when you have a machine and willing helpers. John Hermans describes the process and advantages of this low embodied energy approach to construction.



↑ A decorative use of the pressed bricks in the display home at the ecovillage at Cape Paterson.

THIS article aims to inspire owner-builders to minimise the carbon footprint of their new sustainable dwellings by using pressed earth bricks. By explaining the many virtues of this building material, I hope to spark interest in my offer to share the amazing machine that I use to make them.

I started making and using pressed earth bricks in 1988, shortly after commencing excavation for our house site. I had seen a hydraulic brick press working very effectively around this time and, with the intent of making a copy, I took several photographs of it in operation. I then found four aspiring owner-builder friends who were willing to become 'shareholders' and finance the brick press fabrication; my input was to build it.

The machine I built back then is still going strong today. To date, this press has made in excess of 70,000 bricks and has been responsible for some very creative, cost-efficient and low embodied energy housing.

What's in a pressed earth brick?

A pressed earth brick is simply a brick made by compacting soil that has a high percentage of clay. The machine compacts the soil by 50% using the power of a hydraulic press. The result is an attractive and easy-to-use brick that needs no firing and can often be made from subsoil excavated from the house site—and thus has much lower embodied energy than the average house brick.

My machine makes bricks that are 300mm long by 220mm wide by approximately 130mm high, so quite a bit larger than the average house brick (dimensions 230 x 110 x 76mm). The height of the brick depends on the amount of clay mix put into the press, but averages around 130mm. At that size, the brick ends up weighing around 15kg.

It is important to seal the bricks to prevent surface erosion. There are many earth brick sealing products available now (e.g. *Your Home* suggests linseed oil and turpentine; or you can use one of the Bondall products).

Quality bricks are achieved by using a clay-based subsoil that will bind well and dry hard. This is often an excavation waste product, with little commercial value. Using a press to make several test bricks is a sensible idea.

An addition of 5% to 10% cement will form a brick that will handle days of total water submergence, although this is a condition rarely encountered! No cement is needed in the mix if the bricks are used indoors. If used in exterior walls that are likely to be impacted by rain, then the use of cement is recommended.

The pressing process

In preparing to make these bricks, there are a few additional items that are essential to ensure a smooth operation;

- a medium-sized 5HP rotary hoe
- at least a dozen 15L plastic buckets
- two shovels
- water
- a team of four enthusiastic and fit workers
- several old wooden pallets.

The first step is to break up the clumps of earth using the rotary hoe to create a smaller

↓ Filling buckets with freshly hoed clay mixture.

↓ One bucket of material fills the press.

↓ The team working at Cape Paterson.

↑ The ram ejects the brick from the mould.

↑ The 15 kg brick is firm and easily handled.

⚠ Warning

Hydraulic machines such as this brick press have the potential to cause serious injury if used incorrectly. Extreme care should be taken when operating such machines, with a full understanding of the machine's operation.

particle size mix that has the correct moisture content and facilitates easy shovelling. Adding water from a trigger-jet hose to the earth pile while hoeing gets this job done easily. The amount of water added is low, to make the mix more like plasticine than wet mud.

The next step is to shovel the finished hoed mix into 15 L plastic buckets ready for the brick press; each bucket will create one brick. The brick press operator empties one bucket of hoed earth into the mould cavity of the press, then closes the lid and operates the hydraulic lever to compress the loose mix. With practice, this takes less than 30 seconds per brick.

To achieve uniformity in the height of bricks, you need to get a consistent amount of mix in each bucket. This is not too difficult, with small adjustments able to be made by the brick press operator as a bucket is poured into the mould.

The bricks are quite firm as they are taken from the press, and can be stacked on pallets to over six layers high.

As the amount of water used in the mix is so low, the time taken for the bricks to dry is quite quick, in summer perhaps a few weeks. And as the compression force is around 20 tonnes, there is little, if any, shrinkage of the finished brick. I have never seen evidence of shrinkage.

The ideal number in a team is four: one on the press, one carrying the finished pressed bricks away to the stack and two people on shovels, filling the 15 L buckets with equal amounts of earth mix. In this way 120 bricks per hour can be produced.

Laying the bricks

The bricks can be laid flat, 220 mm wide, or on their edges to create a double wall, which minimises the wall thickness and allows for a cavity for inclusion of a good R-value insulation. A double cavity wall like this can also have concrete poured in the centre gap, making a wall which will take a significant load. Pouring concrete in between the bricks is so easy to do. I have made some very strong curved 3 m high walls using this method to create wildfire/ember shielding walls.

For the mortar between the bricks, a traditional sand, cement and lime mix is recommended. This mortar uses minimal cement and is the fastest way to do the job.

"To date, this press has made in excess of 70,000 bricks and has been responsible for some very creative, cost-efficient and low embodied energy housing."

↑ The drive motor is connected to the hydraulic pump and reservoir.

Advantages of pressed earth bricks

I believe that using these bricks in internal and external walls has several advantages over traditional building materials.

1. Less cost. The material is often part of the site excavations or can be bought at a low rate per cubic metre.
2. Low embodied energy cost. There is no brick firing and little transport required.
3. Owner-builder layable bricks. The large-format bricks make it easier to create a flat, straight wall.
4. The bricks can be used to provide highly effective thermal mass if used internally or in a cavity wall. This gives the living space a narrower internal air temperature range.
5. Individual rooms are quiet due to the sound deadening of the heavy earthen walls.
6. You end up with a home that is more 'earthy'.

Copying the machine

A few years ago, an owner-builder wanted to hire my brick press, but as he wanted to make a large quantity of bricks I suggested that he take the machine and have it copied. A local engineer did a great job of this for around $4000. You could reduce this cost by doing as I did and sharing the cost with others who would also use it, or perhaps you could sell it when you are finished with it.

I am certainly no salesperson, telling a virtual stranger to take my machine to have it copied, although I did receive a lovely selection of homemade wines. Nothing is for nothing!

Since having made the brick press, I have not seen another like it apart from the copy made from mine. I would love to encourage more owner-builders to consider pressed earth bricks as a great option—please contact me through *ReNew* (renew@ata.org.au) if you would like to take up my offer to copy the design of the earth brick press. ✱

John Hermans has been living off-grid for 35 years on a highly sustainable property, He holds a BSc in forest ecology and is president of Gippsland Environment Group.

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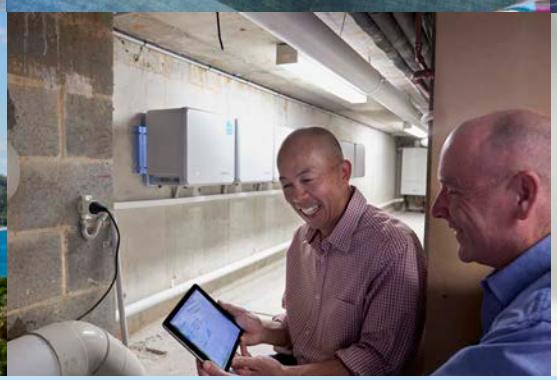


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As simple as IBC
DIY wicking beds

If your soil is so poor that nothing will grow, a raised bed could be the solution. Rob Phillips describes his DIY wicking 'IBC' pods which are proving very effective—and are made from a waste material.

A COUPLE of years ago my wife and I decided to make a raised vegie garden on our rural property in Wanneroo, WA. Attempts to grow vegies directly in the poor and sandy Perth soils had not been successful in the past. We levelled off an area of about 5 x 5m with a small retaining wall and drew a plan of where the beds would go.

Our initial plan was to build the beds from recycled plastic-wood composite. We'd decided that standard timber wasn't suitable because we have termites and we didn't want to risk chemicals leaching from treated pine. However, it was difficult to source wood composite in WA and the project went into the 'too hard basket' for a couple of years, particularly as we were travelling extensively during that time.

When we recently returned from a three-month trip around Australia, it was time to revisit the vegie garden. It was then that we read the article about wicking beds in *ReNew 135*. What a fantastic idea, we thought! The water savings features were particularly important to us as our primary source of water is a 110,000 litre rainwater tank. So we started looking at composite wood prices again.

However, there was a problem. The space for the garden contained a large pile of sand and a barrelful of biochar that I had made—thanks again, *ReNew*! We needed to move this, but wanted to store it permanently in a small bay, like they have at garden centres. How to do this cheaply?

Many uses for IBCs

After much looking around, I came upon the idea of using an IBC (intermediate bulk container) pod cut diagonally to store bulk materials. Empty pods seemed to cost around $90, but I found out there were some available for just $40 each on the other side of the city.

At this point, we only wanted to use the pods to clear space for the wicking beds—we were still intending to use wood composite for the beds themselves. Then the business selling the pods mentioned they were planning to use them to make wicking beds. We thought about it and decided the pods would be cheaper than wood composite, and we wouldn't have to worry about leaks in the waterproof membrane at the bottom.

So, after several trips with a trailer, we had nine pods: two for bulk storage, and seven to make fourteen 1.2m x 1m wicking beds, 500mm high—cutting each in half (horizontally) to make two wicking beds per pod.

↑ Intermediate bulk containers are very useful and quite cheap.

↑ The IBCs are simply cut in half to make the wicking beds. Water is fed into the bed via slotted pipe. Note the 300mm wide strip of geofabric used to improve wicking.

Cleaning and cutting the pods

The pods had been used to transport latex, but all but one had been quite well flushed so there was not much residual latex in them. I scrubbed them out carefully before use.

I used a 235mm angle grinder to cut the metal frame in half to create two pods, and this also cut nicely through the plastic as well. After being cut, the plastic was a bit floppy in the frame, so I secured the plastic with a few pop rivets. Then I levelled the site and laid out the pods. Because the base of the pods isn't even, I had to pad out beneath the base with loose sand. I then Tek-screwed each of the pods together so their top edges would remain lined up and level.

↑ The various stages of assembly of the wicking beds.

↑ Two months in, the completed wicking beds are working well!

Adapting the pods

The height of the halved pods is 500 mm. The plan was to have 200 mm of water, 250 mm of soil and 50 mm of spare space at the top.

The mechanism for getting water into the wicking beds in *ReNew 135* seemed a bit complex. I simply used a single length (approximately 2.5 m) of Vinidex 65 mm slotted drain coil with filter sock in each pod.

The bottom half of the pods have their own outlet valve, making it easy to flush out the wicking bed if the water becomes stale. Unfortunately, the metal frame prevented us from installing an overflow flange at 200 mm. We had to install this at approximately 220 mm, but we don't think this will be a problem.

The tops of the pods needed a different approach to drain them, because there was no bottom drain. I wanted to avoid the cost of having two outlets, so I used only one, as close to the bottom of the pod as the curves would allow. I managed this with a horizontal length of poly tube with a valve at the end and a T-piece with a riser tube extending to the height of the desired water level (the level of the geofabric layer).

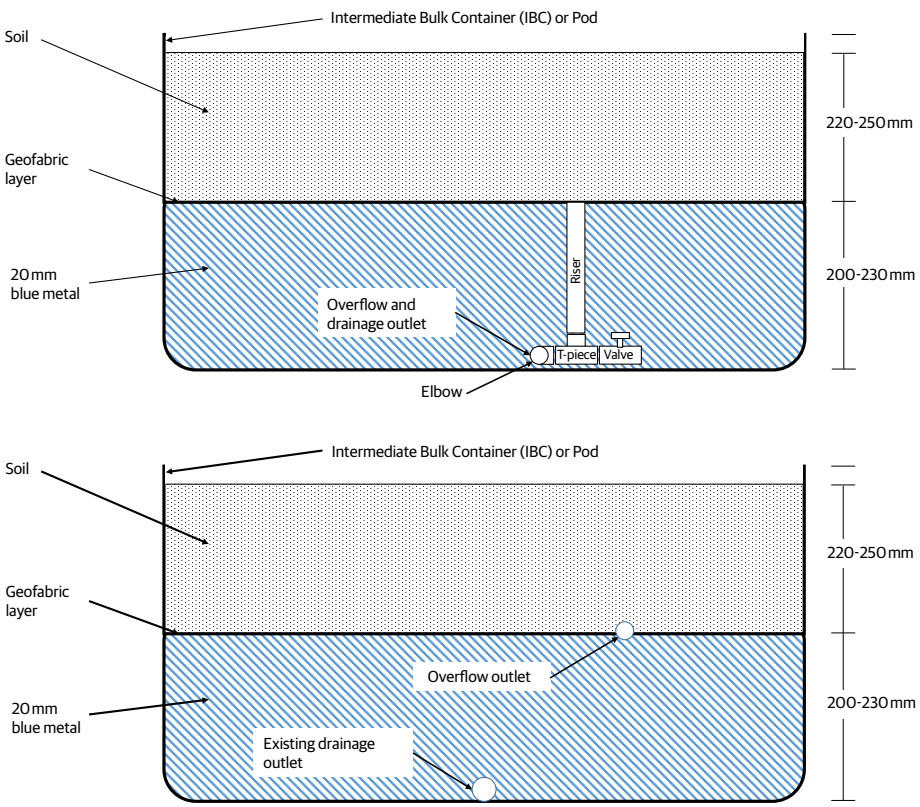
One thing I've learnt subsequently is that the riser is a great way to see how full the pods are. With the beds made from the bottom half of the pods, you have to fill them until they overflow, which wastes water.

We also needed to make sure that the large lid which was at the top of the pod was securely tightened. Luckily I thought of this before I shovelled in a cubic metre of fill and soil!

Filling the pods

Once the pods were set up, it was shovelling time! I sourced the blue metal (a type of gravel) fill material from local garden suppliers—five and a half trailer loads. I first laid a 300 mm wide piece of geofabric from the bottom up the side of the IBC. This acts as a wick to bring water to the growing medium when the water is not at its highest level. While shovelling in the blue metal, I added water at the same time so I could finish the fill level just where the water started overflowing. I then laid a larger piece of geofabric across the blue metal, and folded the end of the 300 mm wide piece over the top of the larger piece. Water wicked up by the 300 mm wide 'wick' flows into the larger piece, spreading the water.

I then started adding soil. I mixed most of the soil myself, in a concrete mixer, starting with the sandy soil which had come from our former chook run. I enriched this with



↑ Cut-away diagram showing how the wicking beds were assembled. The top unit is made from the top half of the IBC, the lower unit is made from the bottom half. Note the existing drain plug in the lower unit. All pipe and fittings are fixed outside of the containers.

→ The water outlet in the pod made from the top half of the IBC (right) has a vertical riser that sets the water level inside the wicking bed, as well as a drain tap. The bed made from the lower half of the IBC (left) has its outlet set at the height of the required water level and a separate drain using the IBC's original drain plug.

"We thought about it and decided the pods would be cheaper than wood composite, and we wouldn't have to worry about leaks in the waterproof membrane at the bottom."

homemade biochar, homemade compost, sheep manure, shredded office paper, trace elements and wetting agents. More shovelling! I had to supplement the soil with one trailer load of organic vegie soil mix.

Planting out

Things are growing well: in just a month, we've been able to harvest our first herbs, and the cos lettuce is just about ready. Even better, a lot of tomato and cucurbit plants have emerged from the compost, which I've been planting out in other pods. Time will tell how well the pods perform, but it's looking very good at the moment.

My wife suggested that the pods should have cladding to look nice. This is a good idea and indeed is a requirement as it will cool the pods, but more importantly will prevent the plastic biodegrading as it isn't UV stable—no part of it should be exposed to the sun. The cheapest option was zincalume corrugated miniorb sheeting. We ordered the sheets cut to size from a national metal products retailer and you can see the finished result in the photo on the previous page.

How to economically cover the top edge of the cladded pods was another challenge. Commercial products of the right size were not available. I plan to buy rectangular PVC downpipes and cut them into C-sections.

Because we travel a lot, it is important to ensure the pods are kept moist. We plan to connect them to our existing watering system, but, based on experience with manual watering, we believe we will only need to run the watering system for a few minutes twice a week. ✸

Rob Phillips is a semi-retired academic who has been improving the sustainability of his passive-solar designed house over the last 25+ years.

Costs

The costs and the materials we used were influenced by the closing down sales of the Masters hardware chain. A summary is below.

Component	Amount	Cost
IBCs	7	$280
Geofabric 1m wide	2 x 10m	$68
Drain coil 65mm	2 x 20m	$196
Plumbing	various	$227
Bluemetal	5.5 trailers	$433
Soil	1 trailer	$70
Soil conditioners	various	$49
Cladding	19.4 m^2	$641
Total		$1965
Price per bed		$140

⚠ Warning

The metal frames on the IBCs described in this article can have sharp edges when cut. Angle grinders are also a potentially dangerous tool if used by the inexperienced and should only be used by an experienced operator.

Shop with the ATA

The ATA shop stocks books, kits and energy-efficient devices. Below are just some of the products available in the ATA Shop. To browse the full range and place an order, go to shop.ata.org.au or call the ATA office on 03 9639 1500. **ATA members receive a 15% discount on ATA products, except where noted.**

Luci solar-powered camping lantern

Price: $22.35

Lightweight and collapsible, the Luci Outdoor leaves plenty of room for the rest of your outdoor gear. Great for anything from outdoor lighting, to travel, to patios. Includes 10 LED lights, 50 lumens. Charges in 8 hours direct sunlight and lasts up to 12 hours.

4000 mAh solar rechargeable power bank

Price: $55.88

This portable power bank with built-in solar panel can keep your phone, tablet and GPS powered when camping, hiking or out and about. It can also be recharged via USB when the sun isn't shining.

Kiri low-flow showerheads

Price: $152.35 (handset)/$132.35 (rose)

The revolutionary Kiri low-flow showerheads provide a great shower at a flow rate of just 5 litres per minute. This saves both water and the energy used to heat it! It comes in either a handset or rose mount. NB: suitable for mains-pressure water only.

LED strip light

Price: $24

An aluminium LED strip light kit with diffuser. Suitable for caravan, marine and domestic applications. 34cm long, runs from any 12 VDC power supply with over 0.5 A output.

Gift of Light

Give the gift of light to families in East Timor. A $500 donation allows the ATA to install a solar system and train one village technician to maintain it. Or $300 covers a full village lighting solar system, $50 a single solar panel.

Power-Mate Lite

Price: $123.53

The essential tool for measuring energy use. As well as instantaneous power, it displays energy used and the cost per hour, quarter and year, greenhouse gas production and some more technical figures such as power factor, frequency and VA (volt-amperes).

Sanctuary: modern green homes issue 37

Price: $11.95

In *Sanctuary 37*, you'll find a modular and prefab coastal home that's also off-grid, clever storage and shelving ideas, a guide to concrete floors, eco display homes, a tropical Tiny House and much more!

Your Home 5th edition

Price: $38.50

Written by experts across the residential building sector, *Your Home* is the definitive 'how-to' tool for creating a home that is great to live in, affordable and efficient. No member discount.

Shipping in Australia: booklets and magazines $4.50, all other items (books and electronics) $11. See online for overseas rates.

The ATA branches continue to share practical solutions and information on sustainability, renewable energy, building design and energy efficiency. This issue we put the spotlight on two of the 13 branches around Australia.

Canberra branch

The Canberra branch is led by an active local team and has a long-standing association with the Canberra chapter of the Australian Solar Council. Many of its members work in the sustainability arena, and the interesting and relevant events run by the branch reflect this level of expertise. Recently, the members ran an ATA stall in support of the Australian Institute of Architects Solar House Day and also held a guided tour of a local sustainable house by architect Peter Overton. Recent meeting topics have covered Beyond Zero Emissions's Zero Carbon Australia project, the Passive House Planning Package, next generation energy storage program, long-term performance testing of batteries and using electric heat pumps for water and space heating.

Meetings: 7.30pm, last Wednesday of the month, Ian Ross building at ANU.

community.ata.org.au/branches/canberra-branch

Melbourne branch

The Melbourne branch includes an exceptionally talented crew of people in the Melbourne region motivated to share their interest in and knowledge of sustainability. Topics over the past year have included renewable energy, conserving energy, good building design and water conservation. These topics often have a practical slant and include members' hands-on experience. The Melbourne branch has a FLIR thermal imaging camera for hire to local members. The branch has spent the last few months looking at big picture issues such as battery storage, post-election energy policy and what's in the offing for electric vehicle technology.

Meetings: usually 7pm, third Wednesday of the month, February to November, Swinburne University, Hawthorn.

community.ata.org.au/branches/melbourne-branch, community.ata.org.au/flir

For all questions about ATA branch activities, contact Doug Rolfe, ATA Branch Coordinator, on 03 9631 5407 or doug@ata.org.au or visit the branch webpages at community.ata.org.au/branches.

There are branches in Adelaide, Brisbane, Cairns, Canberra, Geelong (EV focus), Melbourne (EV focus and general), Perth, Sunraysia, Sydney (Central and West), Tasmania (North) and Toowoomba. Two new branches are starting up in Wollongong and southern Tasmania.

The Pears Report
Reflections on reflections

Two decades on and 75+ *ReNew* columns later, Alan Pears is still positive about our clean energy future. How does he do it? Alan reflects on the clean energy facts we all need to know.

IT WAS a real thrill to launch the eBook of my first 75 *ReNew* columns at the recent All-Energy conference in Melbourne. The ATA team did a great job in production and organising the launch. And I really appreciated former Greens leader Christine Milne's contribution through writing the foreword.

One thought-provoking question from the audience at the launch was: "Don't you get bored because we just keep going round in circles on energy policy?" Indeed, this question set me thinking: how do I remain so enthusiastic and positive about energy transformation, when progress is so much slower than it should be?

I'm lucky. I work across a wide range of issues and with a lot of different people. So there is always something positive happening—somewhere. Even when things look stuck or are going backwards on the surface, it is usually possible to find some underlying positive innovation or a subtle shift in the fine print. I also have a tendency to look for the fundamentals, whether it is the underlying physics that shows how inefficient we are, or why and how people react the ways they do. I am always learning.

I also feel pleased that, over almost 20 years, I have provided *ReNew* readers with an insider's perspective—from an independent, sometimes practical, sometimes naively idealistic person—on events, trends and possibilities on energy and climate issues.

I also recognise that those of us who drive change have to make a strong case and present it well. People need good reasons to change. And they need to feel confident that change won't have adverse consequences for them, their families and friends. Of course, powerful vested interests manipulate the situation to highlight the risks of change and overstate the benefits of sticking with the status quo. The blockers have slowed (and sometimes reversed) change, cost Australia many billions of dollars and amplified the cost and pain from climate change, but their effectiveness does force change agents like me to do our homework—over and over again! And to become more creative and effective in communicating and influencing.

At the same time, I have felt my share of despair and anger as sensible policy has been blocked, reversed and abused. I have been frustrated as I have seen exciting technological and social developments squashed, and abuse of power run rampant. A few issues have caused me serious distress.

The appalling story of Australia's energy market reform process is almost beyond belief, even for me at my most cynical. The naivety, arrogance and ruthlessness of key players and the failure of our leaders to pull them into line stand out. The unnecessary cost and pain of this process is beyond calculation.

The fact that, over 40 years after we realised that people want services, not energy, we still have an industry focused on providing more energy and trying to perpetuate the myth that we need more energy to build a better economy is truly devastating. The failure to integrate climate and energy policy, when fossil fuels produce three-quarters of Australia's climate impact, will go down as one of the most tragic leadership failures of our time. Maybe that is belatedly beginning to change.

I am also struggling to understand how, 25 years after I helped introduce Australia's first building energy regulations, some powerful building industry groups oppose sensible energy regulation even more aggressively and more righteously than they did then. Something is really wrong.

As we debate how to manage the closure of old coal-fired power stations, and the problems faced recently by South Australia with volatile energy prices and blackouts, I am completely bemused by the ensuing debate—and the level of ignorance, vitriol and blatant lying shown among the debaters. I am also (yet again) puzzled that the debate makes little or no reference to the major roles energy efficiency improvement and smart demand management could play in delivering solutions.

The election of Donald Trump as US president reinforces the need to focus on what we can do. I'm reminded of the old saying that smart people learn from the mistakes of others, while the not-so-smart have to make their own mistakes. Unfortunately, the education of Mr Trump on climate and basic energy trends will be very costly. But I hope it inspires many to do more, just as Tony Abbott's war against climate and clean energy policy has had some surprisingly positive outcomes in Australia.

Some clean energy facts

So we don't have to waste even more time debating our energy future, I thought it might be useful if I listed a few things we really know about energy.

1. LEAVE IT IN THE GROUND

Two-thirds of global greenhouse gas emissions and three-quarters of Australia's emissions result from fossil fuel extraction and burning. Most of the world's existing 'profitable' fossil fuel reserves must be left in the ground to avoid dangerous climate change. Spending money on exploration and building extra fossil fuel supply capacity is money down the drain.

2. WE KNOW IT CREATES MORE JOBS

An energy-efficient renewable energy future creates more jobs than conventional energy, because most of the new jobs are in light manufacturing and services sectors, which are much more employment-intensive and much less capital-intensive than traditional energy supply industries. We have known this for decades.

"Much of our existing energy supply infrastructure will have to be replaced over the next few decades anyway, so comparison of the cost of a clean energy future with existing energy costs is invalid—the real choice is between different investments."

3. AND IT'S CHEAPER

An energy-efficient, renewable energy future will be cheaper than a 'conventional' energy future, even if we don't introduce a carbon price. Much of our existing energy supply infrastructure will have to be replaced over the next few decades anyway, so comparison of the cost of a clean energy future with existing energy costs is invalid—the real choice is between different investments, and should include a science-based carbon price. A lot of energy efficiency potential is profitable (the 'lunch you are paid to eat' as pointed out by Amory Lovins decades ago). While renewable energy has been expensive in the past, costs are declining rapidly (and performance is improving), and it already seems to be cheaper or similar in cost to building new traditional energy plants. Interestingly, a clean energy future will also be mostly privatised—in a democratic way.

4. PLUS MORE RELIABLE AND RESILIENT

A well-designed, efficient renewable energy system should be more reliable and resilient than a centralised system, as local energy storage, smart management and generation reduce reliance on networks (where most disruptions occur) and transmission lines. Debate about supply of base load power can only be described as outdated and misinformed.

5. DEVELOPING COUNTRIES BENEFIT TOO

An efficient, clean energy future offers many developing countries multiple benefits including lower energy import costs, better services to the rural poor and lower pollution.

6. TRANSPORT IS NOT JUST ABOUT EVS

Transport is a very challenging energy problem, not because it can't be fixed, but because very few countries and cities even understand the fundamental problems. A car-based society is not practical, equitable or economic. Electric cars are only a small part of the solution. Virtual service delivery and workplaces, coordinated planning, comprehensive public transport, low-speed electric vehicles (with suitable infrastructure, speed limits and rules to ensure safety for all, including pedestrians), and better-organised walkable cities are needed.

7. FLY LOWER AND LESS

Air travel is a much bigger climate problem than most people realise. The overall warming effect of air travel is two to five times the value calculated using Kyoto carbon accounting. And most of this impact is due to the release of emissions at high altitude, not CO_2—so switching to renewable aircraft fuel doesn't fix the problem. Flying lower and less, and transitioning to electric aircraft, will be necessary.

8. NEW BUILDINGS REMAIN A PROBLEM

We are constructing buildings and urban infrastructure that will be future liabilities, not assets. And we are not providing the necessary infrastructure to support a successful economy and equitable, enjoyable lifestyles. The failures are deep and systemic. I really don't know how we fix this one.

9. ADD MONITORING TO APPLIANCES

Our appliances and equipment are 'dumb', as well as inefficient. They must all have built-in real-time monitoring, benchmarking and feedback systems so faults are detected, operation is optimised and inefficient products are exposed.

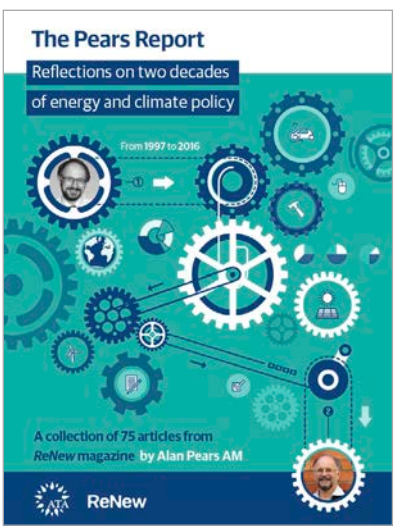
10. SKILLS CURRENTLY IN SHORT SUPPLY

We have very limited numbers of designers, tradespeople, professionals and customers who are competent to deliver energy-efficient low-carbon solutions. We have poor supply chains to deliver what is needed. Training capacity is limited and certification weak. We have few incentives and many disincentives regarding sensible decision-making and action.

Overall, it's a miracle we have progressed as far as we have! Based on our track record, it will also be a miracle if humanity gets out of the hole we've dug without a lot of pain, misery and conflict. But we have the tools and some smart people. The problems are our leadership, short-sightedness, the misguided fear we will be worse off in a clean energy future, and lack of vision and practical focus.

Merry Christmas and Happy New Year! ✱

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.



↑ Alan's first 75 columns are now collected in one place in an eBook, along with a substantial series of articles by Alan reviewing the major topics and themes—providing a history of energy and climate policy through his columns! It's $5, or free for ATA members, at the ATA webshop: shop.ata.org.au

Q&A

Do you need to know the best water heater for a holiday home, whether your insurance company will cover your solar power system, what's required to change from fluoros to LEDs, or how to pump water a long way from the electricity supply? Ask *ReNew* your question via renew@ata.org.au.

Solar system insurance

Q —

I was wondering how insurance companies deal with solar energy systems. Are they generally covered, do you have to add the system as an extra, or is there a limit that they will pay out?

—Jodie

A —

This question has come up a number of times in various forums (such as forums.whirlpool.net.au/archive/2044733 and forums.whirlpool.net.au/archive/1637451 and www.ata.org.au/forums/topic/1466) and responses vary. What level of cover you have depends entirely on your insurance company; it varies somewhat between companies and policies.

Some companies seem to cover all system costs, as they are attached to, and therefore considered part of, the house; thus they are part of the house insurance, not contents, as they are a fixture. Other companies consider them external infrastructure, like water tanks and the like, and will only pay out to a maximum value, say $5000, for all infrastructure (not $5000 for each item, $5000 in total).

So the only real answer to this is to contact your insurance company and ask them, or check your policy which should include such details. Your insurance company may make a mention of the solar system on your policy, and most likely the policy premium increase will be modest, if any. Make sure that the total insured cost for the home is enough to cover both a rebuild as well as the new solar system. Also ensure that the system is covered for accidental damage, such as falling tree limbs, not just for house fires and the like.

—Lance Turner

The end of gross metering

Q —

I am a long-term member of the ATA and I wonder if you could advise me. Did ATA promote an electricity supplier last year as an alternative to the main ones which are so coal-dependent, and if so which one?

I am with Energy Australia and 10 years ago I put in solar cells and they paid me what I paid them. A few years back when the feed-in-tariff (FiT) was introduced I was given a time-of-day meter for free and have been on a 60c/kWh FiT and gross metering ever since.

Now from 1 January 2017 they offer two plans: buy a smart meter and get 6c FiT and pay $120 per annum or buy a smart meter and get 12c FiT and pay $240 per annum plus a panel wash once a year! I also understand that the smart meter they propose cannot be read remotely from my living room. Would you have more information? I am actively looking for alternatives (I live in Artarmon, NSW).

—David Bruce-Steer

A —

In 2015, we worked with Total Environment Centre to produce the following online green retailer's guide available at www.greenelectricityguide.org.au.

However, the end of the NSW gross FiT and the need for net metering to be established has changed the ball game somewhat. While the greenest and dirtiest retailers won't have changed much, who is offering the best deal to transition you to a net metering arrangement with the most competitive feed-in and consumption tariffs can only really be ascertained by shopping around. We have prepared general advice on what to look for; find the report at www.ata.org.au/ata-research/life-after-feed-in-tariffs-report. Retail offers are changing regularly so the Australian Energy Regulator's tariff comparator site may be the best place to compare them, as it's location/network specific: www.energymadeeasy.gov.au

—Damien Moyse, ATA

Long cable losses

Q —

I would appreciate your advice. We live on the Mongarlowe River in the Braidwood district, NSW. I installed a Glockemann hydraulic ram pump in the river which pumps to a 50,000 litre tank about 15 metres above the house. This provides excellent water pressure for house, garden and stock watering. I often use a Honda fire-fighting pump to supplement if the flow in the river is too low or the ram is out of commission.

However, I have to move the pipes and pump if we have heavy rain. As I get older this is a bit of a drag. My solution would be a submersible pump using solar power. The problem is the panels and battery would need to be 100 m to 120 m away from the river as shade and flooding are a problem.

My question is: will the power drop in the cable be too great and will the cost of the cable be excessive? Our water usage would rarely exceed 2000 litres per day so the pump would not need to be too big. The head is about 20 to 30 metres I believe.

I would appreciate your advice as to whether this idea is feasible. Congratulations on your marvellous magazine, a radiant beacon in a sea of ignorance, vested interest and denial.

—Bill Chalmers

A —

You could use a 240 volt pump and that would give you allowable cable losses with standard 2.5 mm² builder's cable or similar.

For example, a 500 W pump draws around two amps. Assuming a worst case 200 metre cable run, which is 400 metres round trip, then 2.5 mm² cable, which has a resistance of 7.41 milliohms per metre, would give a total resistance of just under 3 ohms over that 400 metre run. That might sound like a lot, but at two amps the voltage drop along the cable is a total of just six volts, or 2.5%, which isn't much.

There are pumps designed to run on wide voltage ranges, such as the Grundfos SQflex, which can handle up to 300 VDC. This might be the sort of solution you require, see www.bit.ly/2gfflyi and a similar unit from SunPumps at www.bit.ly/2f39Pfz

"You can compare specific model numbers of star-rated appliances on the Energy Rating website at www.energyrating.gov.au (click the Registration Database button)."

There are other possibilities as well, such as using a MPPT pump controller to run a lower voltage pump (higher voltage goes in and the controller steps the voltage down and the current up to match the pump). It all depends on your budget and which system you are comfortable with.
—Lance Turner

Which indoor unit?

Q —
I have just been re-reading the article Efficient Heating Buyers Guide in *ReNew 135*. While there is a heap of useful information in the article, it seems to skip rather lightly over the merits of the various types of heat pump indoor units.

We are about to install heating in a new transportable house with under-floor insulation and space for more insulation if required. Here in our part of NZ we rarely get the chance to use it for air conditioning, which is probably why almost everybody refers to them as heat pumps. We have been offered floor-mounted or cassette units as alternatives to the more common wall-mounted units. The article does not really deal with the merits of each. Have you any information on the relative efficiency of each?
—Ian Verrall

A —
If you need predominantly heating then cassette units (normally fitted in the ceiling) are not ideal as they heat the room from the ceiling down, so it can take a while to feel the warmth.

Floor-mounted units are best in this case as you feel the warmth immediately as they flow the air across the floor. As you have under-floor insulation then heat losses through the floor will be quite low.

Most people go for wall-mounted as it is a good compromise for both heating and cooling, and when in heating mode many wall-mounted units will direct the airflow down towards the floor anyway. But you do tend to feel the air movement (and its cooling effect) somewhat more than a floor-mounted unit. Given your needs are mainly heating, I would suggest floor-mounted units would suit.

The actual efficiency of the air handling units, whether floor, wall or cassette type, varies between models and brands, so you need to compare datasheets for each type for the brand you are looking at. You can also look up and compare specific model numbers on the Energy Rating website at www.energyrating.gov.au (click the Registration Database button).
—Lance Turner

Hot water system for second house

Q —
We have just had our very old electric hot water service fail us after 34 years. Our house is a secondary dwelling, which at the moment is only occupied for about three months of each year (we live in Adelaide for most of the year). It is an electric-only house in rural Tasmania, in a hamlet called Liena.

We can still legally buy an electric hot water service in Tasmania, but I would like to get something a bit more energy efficient. We don't have a lot of money to spend on this, especially since it is a holiday house and I am retired on a modest income.

What do you think the best system would be for us? Would a heat pump system fit the bill? Do you have any recommendations?
—Lindsay Dent

A —
As you are budget-constrained and are not there most of the time, a simple high efficiency electric storage unit mounted indoors in an insulated cupboard is likely to be the best option. Solar will be too expensive and won't do much for most of the year so the cost can't be justified, while a heat pump, the only more efficient option, will also be expensive up front and won't really pay for itself over its lifetime due to the low level of use. If you have solar panels, you may be able to setup the system to heat during the day from excess solar as well.

One other option is instantaneous electric, but for a whole-of-house system you need a three-phase connection, something you probably don't have. There are single phase units capable of providing reasonable heating levels for single usage points, such as the Stiebel units at www.bit.ly/2ffnCgp but even the most powerful unit there will only add 33°C to the incoming water at 4L/min flow rate, which is not really enough for Tasmania much of the time. However, if you do have a three-phase connection, an instantaneous water heater might be the most cost-effective and least wasteful. If the Stiebel units are out of the budget range, Gleamous Hot Water also have three-phase models that would do it.
—Lance Turner

Fluoro retrofits

Q —
I'm recommending some improvements to lighting for a not-for-profit who are renting in a small office in Blackburn North. Their office uses T8 fluoro tubes. How easy/expensive is it to start using LED lighting instead of the old fluoros? Will they need to change their fixtures? They are on a long-term lease but are unsure on where they stand with things like light fixtures.
—Nicholas Carrazzo

A —
They are pretty easy to change: you just remove the starter on the fittings and put in the LED tubes. Some require that you also bypass the ballast, some don't; it depends on the tube design. Some also come with a starter that replaces the original but doesn't do anything.

This is assuming, of course, that the units use ferromagnetic (iron core inductor) ballasts. If they use electronic ballasts then those have to be bypassed or removed; although I have seen one or two LED tubes that can supposedly handle output from electronic ballasts.

A typical example is the Philips CorePro tubes, which cost less than $20. See www.bit.ly/2fWlFcv; there is some fitting information there as well.
—Lance Turner

Write to us

We welcome questions on any subject, whether it be something you have read in *ReNew*, a problem you have experienced, or a great idea you have had. Please limit questions to 200 words.
Send questions to: renew@ata.org.au

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ATA member profile
Ripples in the community

Long-time ATA member Ali Campbell has no qualms about buying secondhand instead of new and looks at all purchases through a "green lens." She talks to Jodie Lea Martire about how community is critical to sustainability.

ALI Campbell couldn't bear to see her old piano go to waste, so it stands in the chook shed as a piece of art. It's a good demonstration of her creative commitment to sustainability, which has led from high eco-living standards at home to diverse community involvement. As Ali says, being part of an active community "helps sustain you and recharges you for staying in the sustainability field."

Bushwalking and camping gave Ali a connection with nature, but her real evolution towards environmental action came with her first child. She and husband Bruce had been "unwise, unwary consumers until that point", but they realised that every other parent had also needed clothes, cots and change tables so they could use "secondhand everything." From there, the Campbells took a good look at their "consumption and stuff." They reduced purchases, packaging and waste, considered where their food and goods came from, and boosted their home chook-and-vegie garden.

The garden led to conversations about sustainability with others, and builder Duncan Hall put Ali and Bruce on to the ATA. Soon, the family was experimenting with solar stoves, and now "everything we do has that green lens."

They have worked to reduce their home's environmental impact, including greywater systems, water tanks, double-glazed windows, reorienting for better lighting and using Australian-made materials. Ali used ATA-sourced information to explain her decisions to both their builder and plumber during renovations, and emphasises that it's crucial to hire workers who 'get it' and aren't just greenwashing their work.

Photo: Jack Campbell

← ATA member Ali Campbell with her new VW Caddy, which she and husband Bruce have signed up to Car Next Door. "We're happy to be getting involved…if it stops people getting a second car"—or even a first car!

Ali says, "The community thing is critical. It goes without saying, but it needs to be said." She spent six or so years volunteering as an organiser with Melbourne's Sustainable Living Festival (SLF), and gardened with the Stephanie Alexander Kitchen Gardens in Altona Meadows for a time. She is also active on the Inner West Buy Swap Sell and Freecycle Facebook groups.

Ali participates in Transition Hobsons Bay (THB), and she and Virginia Millard run the Give Take Stand: an unstaffed booth where people share quality, unwanted items (like a free op shop). Ali says the autonomous setup has strengthened community involvement without forcing obligation or onus on anyone. It has been hosted in venues around Hobsons Bay and the council is providing funds to boost the work and establish the stand as a waterproof outdoor shed.

Another project Ali organises through SLF and the transitions group is Bunches of Lunches. Now in its third year, Ali and Transitions Hobsons Bay member Tarius McArthur run three-hour sessions which teach participants to cook five healthy, freezable dishes suitable for school lunches—and promote local food, low packaging and low energy use.

Ali and Bruce have also combined their home and community efforts by signing up their new seven-seater VW Caddy to Car Next Door, allowing locals to rent their vehicle. This let the Campbells balance their need for a second car every now and then, while knowing they're "not just sitting on this asset."

Reading *ReNew* gives Ali great ideas, a sense that she's not alone in her activism, and—most importantly—hope. The magazine's coverage of policy developments, news analysis and innovations provides "positivity and support, and that's what keeps her doing this."

To end with Ali's own assessment of her environmental contribution: "I can feel frustrated because I'm not creating seismic change, but I hear frequently, most weeks, 'You'd love this, Ali!', so I know I'm having a ripple effect around me and I just hope that keeps rippling on and on." ✱

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